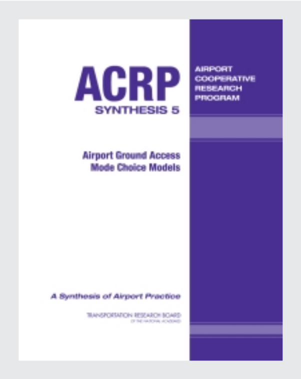

Airport Ground Access Mode Choice Models

DETAILS

104 pages | | PAPERBACK
ISBN 978-0-309-42034-1 | DOI 10.17226/23106

AUTHORS

AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 5

Airport Ground Access Mode Choice Models

A Synthesis of Airport Practice

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SUBJECT AREAS

Aviation and Planning

Research Sponsored by the Federal Aviation Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.

2008

www.TRB.org

AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

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Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

ACRP SYNTHESIS 5

Project 11-03, Topic 03-02
ISSN 1935-9187
ISBN 978-0-309-09798-7
Library of Congress Control Number 2007910441

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Transportation Research Board
Business Office
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Washington, DC 20001

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Printed in the United States of America

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ACKNOWLEDGMENTS

The preparation of this report benefited greatly from the extensive comments, suggestions, and help by the members of the Project Panel, as well as the input and assistance from a large number of organizations and individuals involved in airport ground access studies and planning. The respondents to the survey, who provided the information described in the report, although too numerous to mention individually, are gratefully acknowledged. The case studies documented in the report would not have been possible without the help of many individuals in obtaining copies of reports or other documents. Particular appreciation is extended to Gary Donn of the Florida Department of Transportation; Scott Drumm of the Port of Portland; Stacey Falzarano of Resource Systems Group, Inc.; Ricardo Fernandez of Earth Tech; Cary Greene of San José International Airport; Ian Harrington of the Central Transportation Planning Staff, Boston; Richard Hazlett of the city of Chicago; Craig Leiner of the Massachusetts Port Authority; Lloyd McCoomb of the Greater Toronto Airport Authority; Guy Rousseau of the Atlanta Regional Commission; Peter Smith of Halcrow Group, Ltd., London; and Richard Walker of Portland Metro. Finally, the help and support of Gail Staba, the Senior Program Officer for Airport Synthesis Studies, proved invaluable in bringing the study to completion.

FOREWORD

By Staff
Transportation
Research Board

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, Synthesis of Airport Practice.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis extends previous efforts to document the state of practice for airport ground access mode choice models. It examines the characteristics of existing models and discusses the issues involved in the development and use of such models to improve the understanding and acceptance of their role in airport planning and management. Information presented in this report may be of interest to a range of airport managers, airport and regional transportation planners, consultants and transportation modeling specialists, and researchers interested in issues involving airport ground access mode choice.

For this synthesis, a comprehensive review of the relevant literature was undertaken. To document the extent of the recent use of airport ground access mode choice models and to identify sources of technical documentation on existing models, this literature review was supplemented by a survey of airport authorities, metropolitan planning organizations, consulting firms and research organizations, and other government agencies and industry organizations. Follow-up communications by telephone and e-mail were made where necessary.

Geoffrey D. Gosling, Aviation System Consulting, LLC, Berkeley, California, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

AIRPORT GROUND ACCESS MODE CHOICE MODELS

SUMMARY

The prediction of air passenger and airport employee mode choice decisions for travel to and from the airport forms a key analytical component of airport landside planning, as well as airport system planning. However, there is currently no generally accepted and validated approach to modeling how airport users will change their access or egress mode in response to changes in the airport ground transportation system. The factors affecting airport travel are recognized as being significantly different from those affecting typical trips accounted for in regional transportation models. Therefore, it is difficult to determine the economic feasibility of proposed projects to improve airport ground transportation or effectively manage the existing airport ground transportation system using traditional regional models.

Travel forecasting models, particularly those developed to address airport ground access and egress trips, are highly specialized and not well understood by most airport managers and planners. With increasing emphasis on intermodal connections, there is a pressing need for more widely accepted and accessible reference material and information on such models. This report has been undertaken to update and extend previous efforts to document the state of practice for airport ground access mode choice models. It examines the characteristics of existing models and discusses the issues involved in the development and use of such models, as well as research and development efforts that are needed to improve the state of the art of modeling airport ground access mode choice and address technical issues that are not currently well handled.

The synthesis project has undertaken a comprehensive review of the relevant literature in the field. This was supplemented by an extensive survey of airport authorities, metropolitan planning organizations (MPOs), consulting firms and research organizations, and other relevant government agencies to document the extent of the recent use of airport ground access mode choice models and to identify sources of technical information on existing models. Based on the findings of the literature review and survey, the report summarizes the current state of practice of both air passenger and airport employee ground access mode choice models and discusses the type of planning issues to which the models have been applied, the technical approach adopted, the ground access modes included in the models, and the explanatory variables and market segmentation used to account for air passenger ground access behavior. The report also addresses the extent to which air passenger ground access mode choice models may be transferable to situations different from the one for which they have been originally developed and issues that arise in integrating air passenger and airport employee ground access mode choice models into more general regional transportation planning models.

The development of air passenger ground access mode choice models has been the subject of ongoing research for more than 30 years, during which time the state of practice has evolved from relatively simple multinomial logit (MNL) models to more complex nested logit (NL) models involving several levels of nesting and four or more market segments. However, no clear consensus has yet emerged as to what explanatory variables should be included or how the various modes and sub-modes should be nested and a number of problematic issues have not yet been addressed in a meaningful way, including how to treat rental

car use by non-residents of a region and how best to account for the role of traveler income in the mode choice process. In addition, there has been almost no attention given to how reliably existing models predict air passenger access mode use when circumstances change from those from which the model was developed.

In contrast to air passenger mode choice models, there has been very little effort directed at developing mode choice models for airport-based employees, including airline personnel and employees of the many other organizations that are involved in airport operations. The majority of MPOs model airport employee trips the same way as they model any other journey-to-work trips, although the characteristics of airport employee trips are often very different from regular journey-to-work trips because major airports operate 24 hours a day, 7 days a week. Thus, many airport-based employees work shift patterns outside the usual commute periods and airline flight and cabin crews may be away from their crew base for several days at a time.

Airport access mode choice decisions by air passengers and airport employees affect a wide range of airport planning and operational management decisions, including the development of landside facilities, airport revenue from parking and other ground transportation services, and programs to reduce the growth in vehicle trips generated by the airport and the associated emissions. Potential uses of models that can predict the effect on access mode use of proposed changes to the system include sizing new planned facilities, evaluating the financial implications of proposed changes in parking rates or other ground transportation fees, determining the expected air quality impacts of planned new facilities or proposed mitigation measures, and assessing the feasibility of proposed projects to improve airport access. Airport accessibility is also a significant factor in airport choice in multi-airport regions or situations where air service competition exists between local and more distant airports. Airport access mode choice is often embedded within models of airport choice and improved representation of airport access mode choice behavior should benefit those applications as well.

This report has been prepared to meet the needs of a wide range of airport managers and planners, transportation planning professionals, researchers, and others interested in modeling airport ground access mode choice, some of whom are primarily interested in a brief overview of the topic, whereas others are more interested in technical details of specific models. This executive summary provides a nontechnical introduction to the issues involved in airport access mode choice modeling and summarizes the current state of practice that is described in more detail in the remainder of the report. Airport planners involved in landside planning and regional transportation planners involved in travel demand modeling who are interested in the airport access mode choice modeling process in general, the details of specific models, or the way in which airport access travel can be integrated into the regional travel demand model will find a more thorough discussion in the relevant chapters of the report. Consultants and transportation modeling specialists may be more interested in the detailed case studies of a number of recent airport access mode choice models that are contained in an appendix to the report. Finally, members of the aviation or transportation research community who are interested in airport access mode use modeling may be interested in the potential areas for future research suggested in the report.

- **Airport Ground Access Mode Choice Modeling Process**

In broad terms, the general approach to developing a mode choice model is no different from the development of any other mathematical model of a physical or behavioral process. A set of data is assembled that describes the process being modeled. Next, a suitable functional form for the mathematical model is defined that expresses the value of the variable that the model is intended to predict in terms of some number of explanatory variables and model coefficients (sometimes referred to as parameters), the values of which are to be determined from the data. Statistical model estimation software is then used to estimate the values of model coefficients that best explain the observed values of the variable that the model is intended to predict, termed the *dependent variable*, using the observed values of the explanatory variables, termed the *independent variables*. The extent to which the model is able to reproduce the observed values of the dependent variable for any given set of values of the independent variables is referred to as the *goodness-of-fit* of the model and is an important measure of its usefulness.

In the case of airport access mode choice models, there are two types of data that are required to estimate a model. The first consists of the access mode choices made by a representative sample of airport users, together with explanatory data about their characteristics (such as their household income) or the characteristics of their trip (such as where they commenced their journey to the airport or the purpose of their air trip). These data are typically obtained from surveys of air passengers or airport employees. The second type of data consists of the transportation characteristics (such as travel time and cost) of the various access modes between which the mode choice decisions were made.

Because of the wide range of factors that affect airport access mode choice and the number of alternative modes that are typically available to a decision maker, airport access mode choice models are usually *disaggregate* models that attempt to predict how an *individual* decision maker with a given set of characteristics will behave. These models attempt to predict the *probability* that a given airport user will choose a particular mode, because two airport users with apparently identical characteristics may well choose different access modes. Because a disaggregate mode choice model predicts the probability of a decision maker choosing a given mode from among a defined set of alternatives, these models are also referred to as *discrete choice* models. If the probability of choosing each access mode is estimated for each airport user in a given sample of users, then the percentage of any group of such users choosing a given mode can be calculated.

There are two different approaches to assembling the necessary data on airport access mode choice behavior to develop mode choice models: revealed preference and stated preference surveys. Revealed preference surveys identify the travel choices actually made by airport travelers as well as collect information on other traveler characteristics and details of the trip that are believed to influence the choice. The model estimation process attempts to develop a model that explains the mode choice decisions in terms of the traveler characteristics and the service characteristics of the different airport ground access modes available to the traveler. Stated preference surveys follow a similar process, except that the respondent is presented with a set of hypothetical choices and asked to select from them. For realism, the stated preference experiment is usually structured so that the choices presented to the respondent correspond to their current trip or a recent actual trip, but change the characteristics of the ground transportation options available. This allows the model to incorporate ground access options that do not currently exist or to explore the effect of changing factors that do not exhibit much variation in the real world.

Once an estimation dataset has been assembled, *model specification* involves selecting an appropriate functional form and market segmentation for the model and defining relevant explanatory variables. *Model estimation* software is then used to obtain the estimated values of the model coefficients. The statistical significance of these estimated values and the overall goodness-of-fit of the model are examined and the model specification revised as necessary to address any problems with the model coefficients or statistical fit. Once a satisfactory model has been estimated, *model calibration* involves making any necessary adjustments to the model so that the model predictions agree with the observed pattern of mode use. *Model validation* is the final step in model development and involves comparing the predictions of the model with actual values of the phenomena being modeled, ground access mode use in this case, under different conditions from those under which the model was developed, usually after some change has occurred in the system being modeled.

The overall process of developing an airport access mode choice model is summarized in Figure 1 and discussed in more detail in chapter two of this report.

The basic concept underlying most disaggregate discrete choice analysis is that each alternative in the choice set provides the decision maker with some *utility* that can be expressed in terms of measurable or observable characteristics of both the decision maker and the alternative (e.g., the travel time involved or the income level of the decision maker). The larger the difference in the utility between two alternatives, the more likely the decision maker is to choose the alternative with the higher utility. Because the probability of choosing a particular alternative cannot be greater than one or less than zero, this results in an S-shaped relationship between the difference in utility between two alternatives and the probability of choosing the alternative with the greater utility for that decision maker. A common mathematical form for this relationship is the *logistic function*, which for more than two alternatives results in the MNL model that has been widely used for airport access mode choice studies. This model can be expressed as:

$$P(i) = \frac{e^{U_i}}{\sum_{j \in J} e^{U_j}}$$

where $P(i)$ is the probability of a decision maker choosing alternative i, U_i and U_j are the utilities of alternatives i and j, and J is the number of alternatives. The *utility function* for a given alternative is assumed to comprise a *deterministic* part that consists of a function of measured and observed variables and an *error* term that accounts for unobserved characteristics and variability in the perceived utility of a given set of characteristics across different individuals. In logit choice models, the error term is assumed to be a random variable and the variance of the error term reflects the goodness-of-fit of the model. The deterministic part of the utility function typically consists of a linear combination of explanatory variables with their associated model coefficients, the values of which are determined in the model estimation process. Therefore, a utility function can be expressed as:

$$U_i = a_i + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n + \varepsilon$$

where a_i and the b's are the model coefficients, the x's are the values of the explanatory variables such as travel time and cost, and ε is the error term. In general, the utility function for each alternative will have a constant term a_i, known as the *alternative-specific constant,* which reflects attributes of the alternative that are not accounted for by the other variables. Therefore, a fairly simple utility function for a mode choice model might comprise:

$$V_i = a_i + b_1(\text{travel time}) + b_2(\text{waiting time}) + b_3(\text{walk distance}) + b_4(\text{cost/income})$$

where V_i is the deterministic part of the utility function (it is common to omit the error term in presenting the components of a utility function). In this example, travel cost is divided by income in the fourth explanatory variable so that the choice process becomes less sensitive to cost for higher-income travelers.

Although the MNL model has been widely used, it is vulnerable to problems that arise from a property of the model termed the Independence from Irrelevant Alternatives. This states that including a new alternative in the choice set (or changing the perceived value of one of the alternatives) should not affect the relative probabilities of choosing any of the other alternatives. However, in many situations in airport access mode choice it is quite unlikely that changing the characteristics of one mode or sub-mode will leave the relative probabilities of choosing all the other modes and sub-modes unchanged. For example, changes in one public transportation service are likely to affect the use of other public transportation services to a greater extent than the use of private vehicles. These limitations can be addressed by grouping similar modes or sub-modes into separate groups or *nests* in a choice structure referred to as a NL model, as illustrated by Figure 4 in chapter three.

This figure (from a ridership study for a proposed airport express train in Chicago) shows that private transport modes have been grouped together in one nest, whereas public transport modes have been grouped in a different nest. It also shows another feature of NL models, that it is possible to define lower-level nests that contain sub-modes of a particular mode, in this case the access mode by which travelers reach the airport express train. The grouping of modes in the NL model requires some changes to the mathematical form of the model, which are not discussed here but are described in chapter two.

Once a calibrated or validated model is available, the process of applying the model is technically fairly straightforward, although there are a number of aspects that need to be carefully considered in developing the required input data and interpreting the results. One is that although a relatively small survey sample size (a few thousand respondents in the case of air passengers and perhaps even fewer for airport employees) may be adequate to estimate an airport access mode choice model, a much larger sample may be required for a given application of the model, depending on the issues of interest and the desired level of geographic resolution of the results. Two other considerations involve how to adjust the model to be able to predict behavior in future years, as is typically needed for planning studies. The first of these is how to adjust travel times and, particularly, costs to correspond to future conditions. These adjustments will need to consider expected changes in highway congestion as well as anticipated changes in real costs (in constant dollars) over time. The second consideration involves adjustments for the effect of changes in the levels of real household incomes over time. Implicit in the calibrated coefficients of a mode choice model are assumptions about how travelers trade off time and cost. If real incomes change, these tradeoffs can be expected to change as well. These issues are discussed in more detail in chapter two.

- **Review of Literature**

Given the importance of understanding air passenger airport ground access mode use it is not surprising that there have been a number of studies over the years that have developed air passenger ground access mode choice models. One of the earliest efforts to develop a formal model of air passenger airport ground access mode choice was undertaken by Ellis et al. in the early 1970s. This study used a MNL model, as did several other studies that developed air passenger ground access mode choice models over the next ten years. However, by the mid-1980s, it was becoming recognized that some of the limitations of the MNL model could be addressed through the use of NL models. One of the first applications of NL models to airport ground access mode choice was undertaken as part of a study of surface access to London Heathrow Airport, followed shortly thereafter by another study that used a NL structure to develop an integrated model of airport choice and ground access mode choice for the San Francisco Bay Area. Subsequent air passenger ground access mode choice models developed for Boston, Massachusetts; Portland, Oregon; and airports in the southeast and east of England used a nested structure, whereas other studies continued to use MNL models to represent air passenger ground access mode choice. In addition to models that have exclusively addressed airport access mode choice, a number of recent studies have used NL models to represent air passenger airport choice, with airport ground access mode choice as a lower level nest. However, these models generally only include a single-level nest for the airport ground access mode choice process and thus are equivalent to MNL models from the perspective of ground access mode choice.

In addition to papers in the open literature, the synthesis project identified several studies that had developed airport access mode choice models, the details of which had not been widely reported, in several cases because the models had been documented in technical reports that had restricted distribution or did not obviously involve airport access mode choice. These included the regional travel demand model for the Atlanta region, a ridership forecasting study for a proposed airport express train serving the two Chicago airports, a travel demand forecast study for the planned Miami Intermodal Center, a ridership analysis of a planned automated people mover connection between Oakland International Airport and the nearby Coliseum station of the Bay Area Rapid Transit system, and a revenue and ridership forecasting study for a proposed Air Rail Link between Toronto Union Station and Lester B. Pearson International Airport.

- **Use of Airport Ground Access Models in Airport Planning**

To better understand the current state of practice with airport access mode choice models, as well as to identify models that may have been developed for specific studies but not reported in the published literature, a web-based survey was undertaken of airport authorities, regional and state planning agencies, federal agencies involved in airport or surface transportation planning, airport consulting firms, selected universities and other research organizations, and relevant industry associations. The survey inquired about recent airport ground transportation studies undertaken by the responding organization and whether these involved the use of formal models of airport ground access mode choice. The survey also inquired about respondents' perceptions of the usability of such a model, as well as their awareness of other organizations that have experience with the use of these models.

Survey responses were obtained from 105 different organizations. These responses identified 85 specific studies completed in the past ten years that had included some analysis for airport access mode choice, of which 52 had involved the use of mode choice models. However, only four of these studies were available on the organization's website. The survey also asked about prior experience with airport access mode choice models, and from these responses it does not appear that there has been a significant increase in the use of analytical models in recent years. Respondents who reported the use of analytical models of airport access mode choice were asked to characterize the current state of practice with these models. Approximately 55% indicated that current models were adequate for their needs, 35% reported that current models are not reliable enough, 30% noted that they are too costly to use, and 10% indicated that they are too complex to use. However, it is worth noting that only 5 of the 13 consulting firms reporting involvement in studies using such models indicated that current models are adequate, whereas 7 of the 8 airport authorities and all 5 of the MPOs reporting the use of such models indicated that current models are adequate for their needs. Because in many cases the actual modeling is done by consultants rather than by airport authority or MPO staff, the limitations of the current models may not be fully appreciated by the organization sponsoring the studies.

The survey also explored how airport trips were modeled in the regional travel modeling process. Of the 23 MPOs responding to the survey, 15 (65%) reported using a special-generator sub-model for air passenger trips, whereas about 50% reported using a special-generator sub-model for airport employee trips. The other MPOs either treated airport trips the same way as other regional trips or did not consider airport trips at all.

- **Air Passenger Mode Choice Models**

Although the details of the different air passenger airport access mode choice models identified in the literature review vary widely, it is clear that a standard of best practice has evolved, although by no means is it always followed. This standard of best practice uses NL choice models with separate coefficients (and possibly including different variables) for at least four market segments:

- Resident business trips,
- Resident non-business trips,
- Non-resident business trips, and
- Non-resident non-business trips.

The modes available for resident and non-resident trips will generally be different because non-residents do not have the option of parking a private vehicle at the airport (indeed this would make no sense because their visit to the region begins at the airport and they return to the airport at the end of their stay). On the other hand, many non-residents rent a car on their arrival at the airport to provide local transportation during their stay in the region.

Although no generally accepted practice has yet emerged for how to structure the nests of a NL model, this should largely be determined by the characteristics of the different modes because the primary purpose of using a NL model is to allow higher rates of substitution between modes that have similar characteristics. Therefore, it would appear logical to group private vehicle modes in one nest, with different parking options as a second-level nest, group exclusive ride on-demand modes (taxi and limousine) together in a second first-level nest, and group shared-ride scheduled modes (public transit and scheduled airport bus) together in a third first-level nest, possibly with different transit options (e.g., rail and bus) as a second-level nest. It is not clear where door-to-door shared-ride van should best fit in this structure, as a separate mode at the top level, in the on-demand nest with taxi and limousine, or in the shared-ride nest with the scheduled modes. This may be an issue to resolve empirically by exploring which option gives the best fit to the data. Alternative access modes to scheduled services can also be included as lower-level nests to each mode.

Rental car and hotel shuttle use by non-residents is best modeled outside this choice process, because use of both modes is determined by factors that are largely independent of the service levels of other modes. Rental car use is often determined by local travel needs other than the airport egress and access trips. Therefore, visitors to the region may rent a car even if they are staying at a nearby hotel that has a free shuttle to and from the airport.

The form of the utility functions for each choice alternative will generally be a linear combination of explanatory variables with their associated coefficients. However, some variables are best entered in the utility function as an inverse or ratio. For example, the service headway of scheduled modes, which is a direct measure of average waiting time, is the inverse of the service frequency. The effect of household income may best be entered in the utility function by expressing direct travel costs as a ratio of the cost to some function of the per capita or total household income. Thus, higher-income travelers will be less influenced by cost than lower-income travelers.

- **Airport Employee Mode Choice**

Airport employee ground access and egress mode choice has received much less attention in the literature than that of air passengers, and only three studies were identified that describe an airport access mode choice model developed to account for airport employee access mode choice behavior. These three models each adapted other journey-to-work mode choice models to predict airport employee mode use rather than developing an entirely new model from airport employee travel data.

A special-purpose airport employee mode choice model was developed for the Greater London region as part of the U.K. South East and South of England Regional Air Service (SERAS) Study. This model was a fairly simple binary (two-mode) logit model that predicted the percentage use of private vehicle and public transport and was based directly on one developed for the South and West London Transport Conference for a study covering the area to the south and west of London Heathrow Airport that was felt to provide a good basis for the SERAS work. A study of the potential ridership on a proposed automated people mover link between Oakland International Airport and a nearby rail transit station and a second study of a similar link between San Jose International Airport and a nearby light-rail stop) both used a similar approach of adopting model coefficients from regional travel demand models for home-based work trips and then estimating alternative specific constants to calibrate the model predictions to survey data on airport employee travel.

The most common way to model employee travel to and from airports is to treat the airport in exactly the same way as any other transportation analysis zone in the regional travel demand model and use the trip generation, trip distribution, and mode choice sub-models for home-based work trips to generate the number of person and vehicle trips associated with airport employee travel. Those MPOs using special-generator models for airport employee travel tailor this process to better fit the number of airport employee trips, typically through the use of airport employment data and surveys of airport employee travel.

- **Transferability of Airport Ground Access Mode Choice Models**

Given the considerable cost and effort required to develop models of airport ground access mode choice, it is natural to ask whether separate models need to be developed for every airport or whether it would be possible to adapt or apply a model developed for one airport for use at another. Indeed, several of the existing models described in this report did just that. In general, experience in applying models of transportation behavior in situations that are different from the one for which they were developed has not been very encouraging. However, this experience has largely focused on models of general urban travel behavior, and airport ground access travel behavior may be more consistent.

In principle, one would expect that air travelers would behave similarly when faced with a similar choice situation, controlling for differences in ground access service characteristics (e.g., fares or travel times) and differences in traveler characteristics (e.g., trip purpose and duration, household composition, and income). Therefore, to the extent that a model accurately reflects the effect of these variables, it should explain the behavior of air parties in other geographical regions. However, this is a significant caveat, because many models are heavily dependent on alternative specific constants that at best reflect a range of local factors that are not explicitly included in the model and at worst correct for problems in the model specification. In particular, there may be regional differences in attitudes toward the service characteristics of different modes as well as differences in the nature of the services offered.

One important consideration is the way in which different modes are included in NL models. Because the nesting structure of the limited number of models that have used a NL structure is very dependent on the particular modes that exist in the region being modeled, it is difficult to generalize about how the various models have grouped the modes. It is unclear whether differences in the nesting structure of different modes reflects fundamental differences in choice behavior across different regions is a consequence of the modes included in the models or the explanatory variables used, or merely reflects different modeling philosophies by different developers. The way in which household income is included (or not included) in the models will also affect how well they can be expected to explain behavior in other regions where the distribution of household incomes is different.

Given the current lack of consensus over model specification and typical coefficient values between different airport access mode choice models, it can be assumed that the transferability of these models is highly suspect. Although it seems plausible that the underlying airport traveler behavior may not differ that much from region to region, after taking into account differences in air passenger or airport employee characteristics and transportation system service levels, it appears unlikely that current airport access mode choice models do this in a way that is transferable to other regions, based on the significant differences between the different models. There is an urgent need to better understand how well current models reflect the factors influencing the underlying travel behavior and how they can be improved to better reflect this behavior, both because of the obvious value of being able to apply airport access mode choice models in different situations from those for which they were originally developed, as well as the concerns about the reliability of even applying them to different situations at the airports for which they were developed.

- **Airport Ground Access Models in the Regional Planning Process**

Although modeling airport access mode choice by air passengers and, to a lesser extent, airport employees, has largely been restricted to specialized studies addressing airport landside and system planning issues, there is a growing interest in explicitly modeling such trips in the regional transportation planning process. A number of MPOs have begun to address air passenger trips using a special-purpose mode choice model or special-generator sub-model and a somewhat smaller number of MPOs have begun to do the same for airport employee trips. However, the majority continues to model trips to and from airports as regular regional travel using a standard trip classification such as home-based non-work trips. Because these standard trip classifications encompass a very wide range of activities, most of which have very little in common with airport travel, it would be surprising if the model components did a very good job of predicting airport access mode choice.

This is compounded by the concept that air passengers in particular typically have access to a much larger number of alternative modes for airport access and egress trips than are usually modeled in regional travel demand models, including taxi and limousine services, shared-ride door-to-door van services, and scheduled airport express bus services. Furthermore, a significant fraction of all airport access and egress trips is made by visitors to the region. Most current regional travel models are only designed to model travel by residents of the region and largely ignore travel by visitors. Therefore, modes such as rental car and hotel courtesy shuttle are typically not included in the models. Finally, the largest single air passenger access or egress mode at many airports, for both visitors and residents, is being dropped off or picked up by private vehicle. This option is also typically not explicitly modeled in regional travel models. Models predicting private vehicle use that are based on the assumption that the vehicle will be parked at the destination until the return trip will thus underestimate the vehicle-miles of travel involved by a factor of two.

These concerns may not be particularly important in terms of total regional travel, because airport trips comprise a fairly small fraction of all regional trips. However, these issues become of much greater concern when the regional travel models are used to predict trips on parts of the transportation network in the vicinity of the airport or are used for airport access and egress studies, including predictions of airport access and egress trips for use in environmental impact studies. Therefore, a fairly strong case can be made that airport access and egress trips need to be modeled separately from general regional travel patterns (or at least as a special-generator sub-model within the overall modeling framework) and then integrated with other trips in the traffic assignment process.

This synthesis project examined some of the technical issues involved in modeling airport trips within the context of regional travel demand models and identified a range of approaches that has been followed by different MPOs that have explicitly modeled airport trips in their regional travel modeling process. These approaches vary from a special-purpose sub-model within the travel modeling process of the Atlanta Regional Commission, through the external generation of airport trip tables that are combined with the trip tables generated by the regular travel modeling process of the Metropolitan Washington Council of Governments, to two examples of the use of external airport access mode choice models. In the case of the Boston Central Transportation Planning Staff, an air passenger mode choice model was developed in-house in cooperation with the airport authority. In contrast, the Southern California Association of Governments uses a proprietary air passenger mode choice model, the output of which is then used as input to the regular regional travel modeling process. Further information on these four approaches is provided in chapter eight of this report.

- **Conclusions and Further Research**

Airport ground access and egress mode choice models play a critical role in airport landside planning studies and modeling traffic on the regional transportation system in the vicinity of airports. The ability to predict how air passenger and airport employee access and egress mode use will change in response to changes in the airport landside access system or other anticipated changes in the regional transportation system is essential to the proper evaluation of proposed measures and projects. However, these decisions are influenced by very different factors from those affecting general regional travel patterns and the transportation options available to airport travelers are often quite different from those for other types of regional trip. Therefore, there is a need for specialized models that can represent these mode choice decisions as well as the means to integrate these models or their output into the regional traveling modeling process.

The development of air passenger ground access mode choice models has been the subject of ongoing research for more than 30 years. Over this period, the state of practice has slowly evolved from relatively simple MNL models to more complex NL models involving several levels of nesting and four or more market segments. However, no clear consensus has yet emerged as to what explanatory variables should be included or how the various modes and sub-modes should be nested. In addition, even the most recent models have still not addressed a number of problematic issues in a meaningful way. These include how to treat rental car use by non-residents of a region and how best to account for the role of traveler income in the mode choice process. Aside from these technical considerations, there has been almost no attention given to how reliably existing models predict air passenger access mode use when they are used to predict mode use under very different conditions from those prevailing when they were developed, including changes in the physical infrastructure, ground transportation services, and household income levels. There is an urgent need for more research into these specific aspects, as well as continuing research directed at improving the current state of practice.

In contrast to air passenger mode choice models, there has been very little effort directed at developing airport employee mode choice models. The majority of MPOs model airport employee trips the same way as they model any other journey-to-work trips. The development of better airport employee access models is a promising research opportunity.

Finally, many existing regional travel models do not explicitly model airport trips, but treat them as general regional travel. Because of the unique characteristics of airport travel and the range of transportation options typically available at airports, this is likely to give fairly poor predictions of airport mode use and the resulting vehicle trips. Further research is needed to explore how well existing regional travel models account for airport trips and to provide guidance on how best to implement explicit modeling of airport access mode choice in the regional travel modeling process.

CHAPTER ONE

INTRODUCTION

BACKGROUND

The prediction of air passenger and airport employee mode choice decisions for their travel to and from the airport forms a key analytical component of airport landside planning, as well as airport system planning. There is currently however no well-accepted and validated process for modeling how airport users will change their access or egress mode in response to changes in the airport ground transportation system (such as changes in fares, rates, or service levels) or the introduction of new modes (such as the extension of a light rail system to the airport). The factors affecting airport travel are recognized as being significantly different from those affecting typical trips accounted for in regional transportation models, as a result of both the characteristics of the travel party and the timing and duration of the trip, as well as the differences in available modes and services. Therefore, it is difficult to determine the economic feasibility of proposed projects to improve airport ground transportation or effectively manage the existing airport ground transportation system using traditional regional models.

Travel forecasting models, particularly those developed to address airport ground access and egress trips, are highly specialized and not well understood by most airport managers and planners. With increasing emphasis on intermodal connections, there is a pressing need for more widely accepted and accessible reference material and information on such models. This synthesis project was undertaken to update and extend previous efforts to document the state of practice for airport ground access mode choice models. It also examines the characteristics of existing models and discusses the issues involved in the development and use of such models to improve the understanding and acceptance of their role in airport planning and management. It is hoped that the report will also serve to focus research and development efforts on improving the state of the art of modeling airport ground access mode choice by assembling a detailed database of comparative information on recent model development efforts and identifying technical issues that are not currently well handled.

In contrast to the current state of practice of urban transportation modeling, which has been the subject of study and improvement by a large body of practitioners and researchers for many decades, airport ground access mode choice modeling has received only limited attention and relatively little funding. As a result, no clearly recognized body or practice has emerged and relatively few people have worked in this area long enough to develop significant expertise. Typically, airport access mode choice models have been developed by transportation modeling specialists, airport planners, or academic researchers who are mainly concerned with other issues. Part of the reason for this is that opportunities to develop such models occur relatively infrequently. At the same time, modeling airport ground access mode choice is arguably more complicated and challenging than general urban travel. First, airport ground access usually involves more transportation modes than are typically considered in general urban travel demand models, which are commonly restricted to single-occupant automobiles, carpools and vanpools with varying occupancy levels, and conventional transit services. The airport ground access system includes all of these, as well as other modes that are rarely considered in general urban travel models, such as rental car, taxi, shared-ride van, dedicated express bus services, and hotel courtesy shuttles, all of which can have a significant mode share at large airports. Indeed, at many airports the rental car is the largest single mode after private vehicles, and the other shared-ride transportation modes typically carry more passengers than transit.

Second, the circumstances surrounding airport access trips by air passengers are very different from other types of urban travel. A high proportion of travel is by visitors to the region; passengers travel in groups more often than for other urban trips, they make airport access trips far less frequently than other urban trips, they commonly have luggage, and they are often away for several days or even several weeks, which affects the cost and feasibility of parking a car at the airport while they are away. Picking up and dropping off air passengers at the airport with a private vehicle is one of the most common access and egress modes. This generates twice as many vehicle trips to and from the airport as air party trips owing to the round trip involved in either dropping off or picking up air travelers. These factors greatly complicate the issues that need to be considered in developing airport access mode choice models.

METHODOLOGY

A comprehensive review of the relevant literature in the field was undertaken. This was supplemented by an extensive survey of airport authorities, metropolitan planning organizations (MPOs), consulting firms and research organizations, and other government agencies and industry organizations to document the extent of the recent use of airport ground access mode choice models and to identify sources of technical information on existing models. Based on the responses to the survey, technical documentation on existing models has been assembled and reviewed, supplemented with follow-up communication by telephone and e-mail where necessary. The findings of this review were then assembled into a project database that was used to prepare summary descriptions of each model in a standard format.

The survey of airport authorities and other organizations was undertaken to complement the review of published literature as well as to obtain information on the extent to which each organization makes use of formal models of airport access travel and perceives the ease of use or reliability of such models. The survey was undertaken using Internet survey software hosted on the TRB website. E-mails were sent to survey recipients requesting their participation and providing a link to the appropriate survey. Four somewhat different survey questionnaires were developed reflecting the different concerns and needs of the various types of organizations included in the survey. Survey recipients were given the option of responding using a form that could be completed off-line and returned by e-mail, fax, or mail.

POTENTIAL USES OF AIRPORT ACCESS MODE CHOICE MODELS

Airport access mode choice decisions by airport travelers, including both air passengers and airport employees, impact a wide range of airport planning and operational management decisions, including the development of landside facilities, airport revenue from parking and other ground transportation services, and programs to reduce the growth in vehicle trips generated by the airport and the associated emissions. Potential uses of models that can predict the effect on access mode use of proposed changes to the system include sizing new planned facilities, evaluating the financial implications of proposed changes in parking rates or other ground transportation fees, determining the expected air quality impacts of either planned new facilities or proposed mitigation measures, and assessing the feasibility of proposed projects to improve airport access. Airport accessibility is also a major determinant of airport choice in multi-airport regions or situations where air service competition exists between local and more distant airports. Airport access mode choice is often embedded within models of airport choice, because the availability and use of different access modes affects the perceived accessibility of different airports, and improved representation of airport access mode choice behavior should benefit those applications as well. Several of these potential applications are discussed in more detail in chapter two.

REPORT AUDIENCE

The information presented in this report may be of interest to a range of airport managers and planners, transportation planning professionals, researchers, and others interested in modeling airport ground access mode choice. *Airport managers* may be interested in obtaining a fairly high-level understanding of the current state of practice and an appreciation of where and how such models can be used, as well as what is involved in using them. Such readers may find the executive summary sufficient or they may prefer to go into more detail in selected sections of the report, particularly the description of the mode choice modeling process in chapter two. *Airport planners* and *regional transportation planners* who are more directly involved in airport landside planning or regional travel demand modeling but do not have extensive experience with airport access mode choice modeling may find the description of the mode choice modeling process in chapter two of interest, as well as the technical details of existing models in the following chapters. Regional transportation planners may find the discussion of the role of airport ground access mode choice modeling in the regional travel demand modeling process in chapter eight of particular interest. *Consultants* and *transportation modeling specialists* who have prior experience with airport access mode choice models may find the comparative discussion of the various existing models of interest, together with the review of their strengths and weaknesses contained in the detailed case studies in Appendix D (which is found in the online version only). Finally, *researchers* interested in issues involving airport ground access mode choice may be interested in the discussion of the aspects of the current state of practice that are not well understood and the associated suggestions for future research in this topic that appear throughout the report.

REPORT ORGANIZATION

The remainder of this report consists of eight chapters and four appendixes. Chapter two describes the airport access mode choice modeling process and discusses a range of issues that arise in modeling airport access mode choice. Chapter three reviews the published literature on air passenger airport access mode choice models and addresses airport employee mode choice for journey-to-work trips. Chapter four reviews the use of airport ground access mode choice models in airport planning based on the findings of the survey of airport authorities, regional and state planning agencies, and other organizations. The chapter examines the extent to which formal models of air passenger or airport employee ground access mode choice have been used in airport planning studies, as well as how airport access trips are addressed in regional transportation planning models.

Chapter five presents the current state of practice of air passenger ground access mode choice models and forms the core of this synthesis review. The chapter discusses the type of planning issues to which the models have been applied, the technical approach adopted to represent air passenger choice behavior, the ground access modes included in the models, the explanatory variables used to model the transportation system and air passenger characteristics, and the market segmentation that has been used to improve the ability of the models to account for air passenger ground access behavior. It also discusses a number of considerations that arise in developing and applying these models, as well as issues of model performance.

Chapter six reviews the corresponding state of practice with the analysis of airport employee journey-to-work travel. In contrast to air passenger ground access, the literature review and survey of airport authorities and other organizations identified relatively few formal mode choice models explicitly developed to represent airport employee journey-to-work travel. Rather, analysis of airport employee travel in airport planning studies tends to be based on extrapolation from survey data of existing travel patterns, although regional planning studies typically use models designed for general urban travel.

The next two chapters explore two issues that arise from the review of current practice described in the previous chapters. Chapter seven addresses the extent to which air passenger ground access mode choice models may be transferable to situations different from the one for which they have been originally developed, or whether it is necessary to custom build ground access mode choice models for every airport. Chapter eight discusses the issues that arise in integrating air passenger and airport employee ground access mode choice models into more general regional transportation planning models.

Finally, chapter nine presents the conclusions of the synthesis of current practice and recommendations for further research. These address needed improvements in the current state of practice for air passenger ground access mode choice models as well as the development of appropriate models for airport employee mode choice for journey-to-work trips.

The four appendixes provide more detailed information as background to the discussion in the body of the report. Appendix A presents the questionnaires used in the surveys of airport authorities, planning agencies, and other organizations; Appendix B contains a detailed summary of the survey findings; Appendix C lists the organizations that responded to the survey; and Appendix D (provided only online) contains detailed technical summaries of nine of the mode choice models identified in the project.

CHAPTER TWO

AIRPORT GROUND ACCESS MODE CHOICE MODELING PROCESS

This chapter provides a short introduction to the motivation and methodology for modeling airport ground access mode choice. It is primarily intended to give airport management and planning staff some background on how these models can be used in the planning and decision-making process, and provide an overview of the technical issues involved in developing and applying these models so that they can interact with more technical specialists in an informed way and properly supervise contracts for the development and use of such models. It is also hoped that it will be helpful to airport planning consultants and other planning specialists, including transportation planners working for MPOs and other planning agencies, who do not have particular expertise in airport ground access modeling, but become involved in airport ground access modeling issues.

As will be apparent from the detailed discussion in this report, airport ground access mode choice modeling is a highly specialized field, with many complex aspects that make this a particularly challenging problem. This has two implications. The first is that the development of these models typically requires the use of specialists with prior experience in modeling airport ground access mode choice. The second is that it is therefore helpful if other planners and managers involved in the larger planning process have some idea of what is involved in developing and using these models, so that they have appropriate expectations of both the resources required and what it is reasonable to be able to accomplish with a given level of resources.

MOTIVATION FOR MODELING AIRPORT GROUND ACCESS MODE CHOICE

Airport travelers make use of a wide variety of different modes for their ground access trips to and from the airport, including private vehicles, rental vehicles, taxis, and multiple private and public transportation services. Large airports in particular are served by a large number of different ground transportation modes and services. Planning landside and airport ground access facilities, as well as accounting for the environmental impacts of airport ground transportation activities, requires the ability to predict how airport users will change their ground access and egress decisions in response to changes in the array of options that they face. It would be impractical to imagine that the proportion of airport users choosing a particular mode will remain constant when the factors influencing their choices are continuously changing.

In some cases, an airport may want to understand the consequence of decisions that are largely outside its control, such as changes in the price or service pattern of ground transportation services operated by other entities or changing congestion levels on the regional transportation system. In other cases, it may want to understand how decisions that it is considering will affect the airport ground transportation system or be affected by it. Examples of such decisions could include proposed changes in parking rates for airport-operated parking lots, the introduction of a shuttle bus link to a nearby rail station, or the construction of a consolidated rental car facility some distance from the airport terminal. Each of these decisions is likely to result in changes in the relative attractiveness of the different access and egress modes (including the different on-airport and off-airport parking facilities) and resulting shifts in the proportion of airport travelers using each mode, as well as the effect of this on the revenue generated by each facility or service. Finally, the requirement to predict the environmental impacts of decisions that change or affect the airport ground transportation system, particularly the need to predict air quality impacts, demands an ability to assess how those decisions will affect the use of the various modes (Gosling 2005). This can be a particularly critical issue for airports in regions that are not in attainment of the National Ambient Air Quality Standards, where it may be necessary to be able to demonstrate that a proposed project will not increase total emissions or that appropriate mitigation measures will offset any increase in emissions from the project. Indeed, it may be necessary to be able to demonstrate a reduction in total emissions.

Prediction of how changes in the airport ground transportation system will influence the mode choice decisions of airport travelers is complicated because those decisions depend not only on the price and level of service of the alternative modes but also on the characteristics of the individual travelers. In the case of air passengers, these characteristics include their trip purpose, whether they are residents of the region or visitors to it, how long residents of the region will be away from home on their trip, and whether visitors to the region will need a rental car for local travel during their visit. The distribution of these characteristics across the population of airport travelers not only varies seasonally but also in response to external influences, such as currency exchange rates and the state of the regional economy, and changes in the air services offered at the airport.

Given the many different factors influencing the proportion of airport travelers using each mode, it is unrealistic to expect planners and decision makers to be able to make quantitative estimates of the effect on mode use of any given change in the system without the use of formal analytical tools that model how airport users respond to changes in the available airport ground transportation services. Thus, airport ground access mode choice models provide the basic input to other analysis tools that are used to support airport landside and ground access planning and decision making, such as traffic flow models, simulation models, or financial planning tools.

Representative Applications

To illustrate the type of decision that can benefit from the availability of an airport access mode choice model, this section describes three representative situations where such a model could be applied.

Airport A is experiencing steady growth in air traffic and is planning to construct a new passenger terminal alongside the existing terminal. The existing surface parking lot in front of the current terminal is already reaching capacity at peak periods and there is no space between the terminal roadways and the site of the new terminal to significantly expand the parking lot. The terminal redevelopment plan envisages constructing a multi-level parking structure on the site of the existing surface lot. To pay for the parking structure, the airport authority is considering raising the daily parking rate once the new structure is in operation. However, it is concerned that this will reduce the parking demand for the new structure and divert air passengers to the surface long-term parking lot some distance away, privately operated off-airport parking facilities, or even convince some air passengers who might otherwise park at the airport to be dropped off and picked up instead, or make use of other modes such as a shared-ride van. It recognizes that the extent of any such diversion will depend on the new rate charged for the parking structure, any change in the rate for the use of the long-term lot, and whether the off-airport parking lot operators also adjust their rates. To study the effect of different rate structures on the demand for parking at both the new parking structure and the long-term lot, and the implications for the financial feasibility of the new parking structure, the airport retains a consultant to develop an airport access mode choice model that can be used to analyze the impact of different rate structures on parking demand and identify the optimal pricing strategy and resulting parking demand in both facilities.

Airport B is in a non-attainment region for several ambient air quality standards and is under pressure from the local Air Resources Board to reduce the emissions from airport ground access and egress travel. The airport authority recognizes that unless it can show significant progress at reducing emissions, it is unlikely to be able to undertake a much-needed terminal modernization and expansion program. The airport planning staff has suggested that as part of the terminal modernization program the airport construct an automated people mover (APM) link to the nearest station on the regional light-rail system, located approximately one mile from the airport, to replace the existing infrequent transit bus service between the airport and the light rail system. However, there are concerns about the capital and operating cost of the proposed people mover link and the likely use it will attract. As part of the landside planning for the modernization program, the airport decides to undertake a feasibility study of the APM link in cooperation with the regional transit authority. The scope of work for the feasibility study includes the development of a ground access mode choice model that can be used to evaluate the likely increase in the use of the light rail system for airport trips if the APM is constructed, as well as explore alternatives such as an enhanced shuttle bus connection to the light rail system or an express bus service to several off-airport terminals with remote parking.

The MPO for the region served by Airport C has recognized for some time that its regional travel demand model significantly underestimates vehicle trips to and from the airport when compared with the vehicle traffic volumes projected in landside planning studies undertaken by the airport authority and environmental documentation prepared for airport projects. A detailed review of the travel demand model and discussions with airport planning staff reveal that the underestimate is the result of two factors. The first is that the standard trip generation and attraction relationships in the model substantially underestimate the number of air passenger trips to and from the airport owing to the absence of relevant variables in the model and that the modeling process does not explicitly consider visitor trips to the region. Second, the mode choice model in the overall modeling process underestimates vehicle trips and produces poor estimates of the traffic composition by not accounting for several key characteristics of airport ground access and egress travel. These issues include not accounting for the two-way trips by private vehicles picking up or dropping off air passengers, underestimating the proportion of shared-ride automobile trips by ignoring that many air travel parties have more than one person, and those dropped off or picked up by private vehicles necessarily involve a shared-ride trip in one direction, not considering taxi and limousine trips, and treating vehicle trips by public modes such as a shared-ride van as part of regular public transit use.

To improve the ability of the regional travel demand model to estimate airport trips the MPO decides to develop a special-generator sub-model for airport access and egress trips. This sub-model combines a trip generation module and a mode choice module and generates vehicle trip tables for each category of vehicle trips included in the regional model that are combined with the trip tables for general regional travel before the traffic assignment stage of the regional model. The trip generation module converts airport passenger traffic forecasts into estimates of person-trips between the airport and each regional travel analysis zone, whereas the mode choice module converts these estimated person-trips into the corresponding vehicle trips for use in the regional travel demand model.

Airport Choice

The need to model air traveler choice of airport in multi-airport regions or situations where air service competition exists between local and more distant airports is becoming increasingly prevalent in airport system planning studies, particularly as low-fare carriers introduce service at secondary airports often some distance from congested major hubs. It is recognized that airport accessibility is a major determinant of airport choice, because the availability and use of different access modes affects the perceived accessibility of different airports. In consequence, the airport access mode choice process is often embedded within models of airport choice and improved representation of airport access mode choice behavior should benefit those applications as well.

OVERALL MODE CHOICE MODEL DEVELOPMENT PROCESS

This section presents an overview of the process of developing an airport access mode choice model. The application of such a model to support planning or decision-making activities is discussed in a subsequent section. In broad terms, the general approach to developing a mode choice model is no different from the development of any other mathematical model of a physical or behavioral process. A set of data is assembled that describes the process being modeled. Then, a suitable functional form for the mathematical model is defined that expresses the value of the variable that the model is intended to predict in terms of some other explanatory variables and model coefficients (sometimes referred to as parameters), the values of which are to be determined from the data. Statistical model estimation software is then used to estimate the values of model coefficients that best explain the observed values of the variable that the model is intended to predict, termed the *dependent variable*, using the observed values of the explanatory variables, termed the *independent variables*. The extent to which the model is able to reproduce the observed values of the dependent variable for any given set of values of the independent variables is referred to as the *goodness-of-fit* of the model and is an important measure of the usefulness of the model.

As with most model development efforts, the process is usually iterative. An initial functional form for the model is proposed. The values of the model coefficients are estimated and the fit of the model to the data examined. Then, based on how well the model appears to fit the estimation dataset and the reasonableness of the estimated coefficient values, the functional form is modified and new coefficients are estimated, hopefully improving the fit of the model. The process continues until a satisfactory model is obtained. Changes to the functional form of the model that are typically explored include adding or dropping independent variables, changing the way that an independent variable is defined or appears in the model, or segmenting the data so that different coefficient values are obtained for different subsets of the data, or different independent variables or model functional forms are used for different subsets of the data (e.g., developing separate models for business and non-business travel).

In the case of airport access mode choice models, there are two types of data that are required to estimate a model. The first type of data consists of the access mode choices made by a representative sample of airport users, together with explanatory data about their characteristics (such as their household income) or the characteristics of their trip (such as where they commenced their journey to the airport or the purpose of their air trip). These data are typically obtained from surveys of air passengers or airport employees, as the case may be. The second type of data consists of the transportation characteristics (such as travel time and cost) of the various access modes between which the mode choice decision was made. Because the mode choice decision depends not only on the transportation characteristics of the mode actually chosen, but also on the characteristics of the modes that were not chosen, it is generally necessary to obtain the transportation characteristics for all the modes included in the model corresponding to each airport user included in the estimation dataset. This can be a significant amount of work and is discussed further later.

The overall process of developing an airport access mode choice model is summarized in Figure 1 and discussed in more detail in the following sections.

Aggregate Versus Disaggregate Models

There are two broad types of behavioral models such as a transportation mode choice model. An *aggregate* model attempts to predict the value of an attribute of a group of decision makers, such as the percentage of air passengers from a given origin zone choosing a particular mode. In contrast, a *disaggregate* model attempts to predict how an *individual* decision maker with a given set of characteristics will behave. In the context of airport access mode choice, such a model typically attempts to predict the *probability* that a given airport user will choose a particular mode, because two airport users with apparently identical characteristics may well choose different access modes. If the probability of choosing each access mode is estimated for each airport user in a given sample of users, then the percentage of any group of such users choosing a given mode can be calculated. Because a disaggregate mode choice model predicts the probability of a decision maker choosing a given mode from

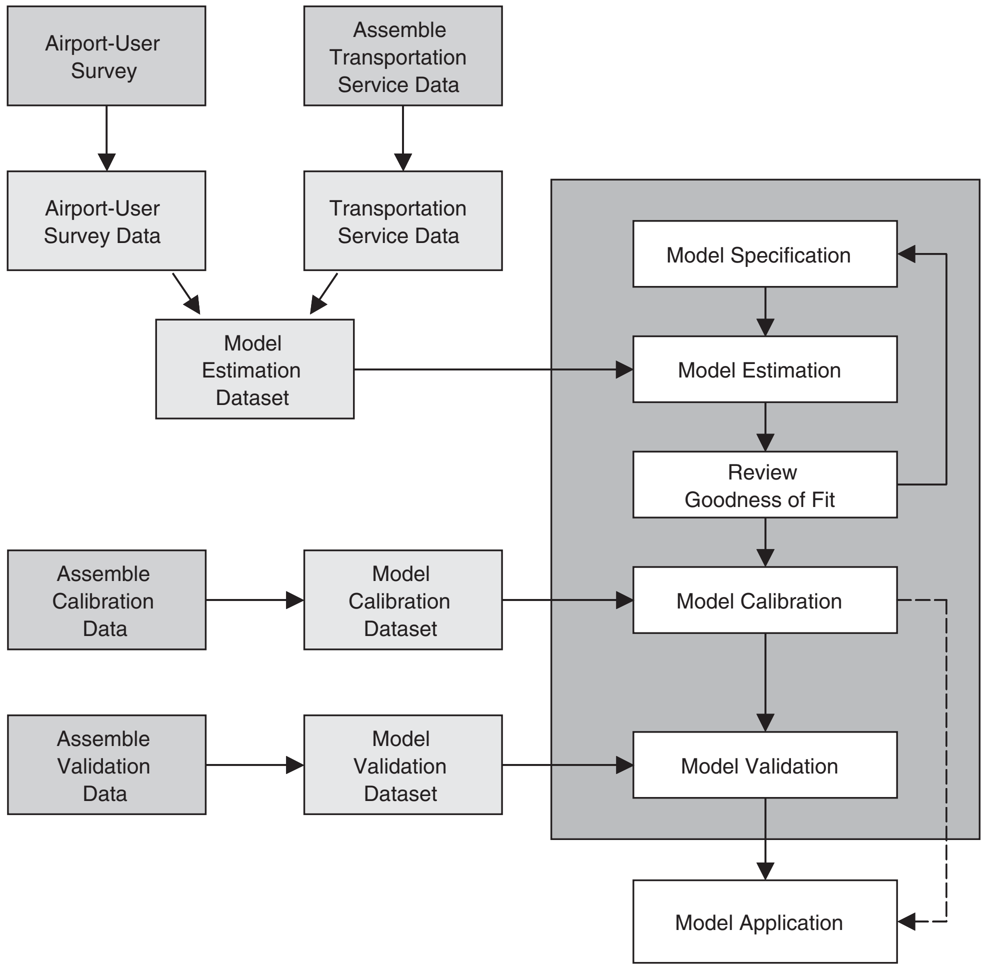

FIGURE 1 Mode choice model development process.

among a defined set of alternatives, these models are also referred to as *discrete choice* models.

Because the airport access mode choice decision depends on the characteristics of each individual travel party as well as the transportation characteristics of the different modes faced by that travel party, which in turn vary with the travel party characteristics (e.g., the travel costs typically vary with the access trip origin and the travel party size), most airport access mode choice models take a disaggregate approach. Indeed, it arguably impossible to develop a reasonable aggregate airport access mode choice model that adequately reflects all the relevant variables.

However, the decision to develop a disaggregate model imposes a number of constraints on the form of the model and the approach used to estimate the model coefficients. A mathematical form must be chosen for the model that predicts the probability of a given air travel party or airport employee choosing a given access mode. Suitable mathematical forms for the model are discussed in the next section. Because the model predicts the *probability* of a given decision maker choosing each of the available access modes but the estimation data give the access mode *actually chosen*, the statistical approach to estimating the model coefficients typically uses a *maximum* likelihood method rather than the more common statistical regression methods. The maximum likelihood method determines the value of the model coefficients that maximize the likelihood that the model will predict the mode actually chosen by each decision maker in the sample, where this likelihood is defined as the overall probability that the model predicts the actual mode choices (this is simply the product of the predicted probabilities of choosing the mode actually chosen across all the decision makers in the sample). Readers interested in more background on the mathematical details of estimating disaggregate choice models are referred to standard texts on the subject, such as Ben-Akiva and Lerman (1985) or Train (2003).

It should be noted that each data point (or record) in a dataset used to estimate a disaggregate choice model represents a single choice decision. In the case of airport access mode choice, air passengers often travel as a party of more than one person and the data point is the travel party, whether composed of one or more air passengers. Each travel party is considered to make the mode choice decision as a single unit, whether or not the decision is made jointly by the members of the party or by one individual within the party. In contrast, airport employees are usually assumed to make airport access mode choice decisions individually, even if they decide to travel to the airport in a group (e.g., a car pool).

A further complication with airport ground access travel by air passengers that is commonly ignored in developing mode choice models is that the ground access travel party and the air travel party may be different. For example, two colleagues making a business trip together may travel separately to the airport and then meet up at the airport and fly together to their destination. Conversely, situations may arise in which the members of a ground access travel party take different flights after they reach the airport, such as attendees at a conference who decide to share a taxi to the airport. In these cases the unit of decision is the ground travel party, not the air travel party. Therefore, the access mode choice model should strictly predict the mode choice decision of each ground travel party, rather than each air travel party. Shared-ride modes such as a door-to-door van will typically combine more than one ground travel party in a single vehicle, although each ground travel party is considered to make a separate decision, because its members could have chosen a different access mode without affecting the decisions of the others on the vehicle. In practice, any error that would be introduced in an airport access mode choice model by ignoring the distinction between the ground access travel party and the air travel party is likely to be very small, because the distinction is only relevant for a small proportion of air travelers. However, it is a point that should be borne in mind when designing air passenger surveys that will collect data for use in developing airport access mode choice models, because it can affect the way that questions are worded.

Model Estimation Data

As noted earlier, model estimation data are obtained in two different ways:

1. Surveys of air passengers or airport employees, as the case may be; and
2. Assembly of transportation service data for each mode from operator and agency records and data files, published information, and other sources.

Survey Data

The air passenger or airport employee surveys obtain information on the access mode used for a specific trip, typically the most recent one. In the case of air passengers who are surveyed at the airport, this will usually be the access trip that they have just completed. In the case of airport employees, the survey may ask about access trips over a recent period, such as the previous week, to identify variation in access mode use from day to day or to reduce the effect of some special circumstance on the day of the survey. In addition, the survey will obtain information on respondent characteristics that may be used as independent variables in the mode choice model or to segment the data for model estimation.

The survey will also need to identify where the access trip began to determine the transportation service characteristics of the different modes that were faced by the respondent. The more accurately the trip origin location can be determined, the more precisely the corresponding transportation service levels for the various modes can be estimated. Because the data on transportation service levels are typically assembled on a zonal basis, the trip origin locations need to be expressed in terms of the system of analysis zones used for the transportation service data. The issues involved in selecting an appropriate system of analysis zones are discussed further later. However, with the possible exception of U.S. Postal Service zip code areas, most practical systems of analysis zones will not be such that respondents can be expected to know which zone their trip began in. Some respondents may even have difficulty with zip codes. Therefore, the usual approach is to attempt to obtain the street address of the trip origin or the name of a specific origin location, such as a hotel, for which the address can be obtained later. For privacy reasons, the exact street address is not required and typically the block number or a nearby street intersection is considered adequate. These addresses can then be geocoded and later assigned to the appropriate analysis zone.

The respondent characteristics that are used as independent variables or to segment the data will depend on the functional form of the model. Because this is typically not known at the time that the survey is conducted, but evolves during the model estimation process, the survey should attempt to collect information on those respondent characteristics that are believed to influence the mode choice process, even if some end up not being used in the model. Although there is a small cost to collecting data that are not used, if the information is not collected, one will never know how important it might have been in the model. The following is list of air passenger or airport employee characteristics that have either been shown to influence airport access mode choice or might reasonably be expected to do so.

- Air Passengers
  - Essential
    - △ Trip purpose (business vs. personal)
    - △ Resident of region or visitor
    - △ Primary ground access mode
    - △ How accessed primary mode (where relevant)
    - △ Where parked (if relevant)
    - △ Trip origin location (address, hotel name, etc.)
    - △ Trip origin type (residence, hotel, etc.)
    - △ Number of air passengers in travel party
    - △ Air trip duration (nights away on trip)
    - △ Household income
    - △ Household size.

- Potentially useful (used in some models)
  - △ Amount of checked baggage
  - △ Number of air trips from airport in past year
  - △ Whether trip costs paid by employer or client
  - △ Time arrived at airport
  - △ Gender of respondent.
- Airport Employees
  - Essential
    - △ Primary ground access mode
    - △ How accessed primary mode (where relevant)
    - △ Where parked (if relevant)
    - △ Monthly parking cost (if any)
    - △ Whether any travel costs paid by employer
    - △ Trip origin location (home address)
    - △ Work location on airport
    - △ Times shift starts and ends
    - △ Variability of shift times
    - △ Household income
    - △ Household size.
  - Potentially useful
    - △ Job type/classification
    - △ Employer
    - △ Number of automobiles owned by household.

Some of the characteristics may appear directly in the mode choice model, whereas others are needed to determine the appropriate travel costs of the various modes. In the case of air passengers, the number of air passengers in the ground access travel party affects the relative cost of different modes, whereas the duration of the air trip affects the cost of parking for residents of the area. For those modes (such as rail transit or express airport bus) where a secondary access mode is needed to reach the primary mode, the access mode used will affect the cost and time of the trip. Some mode choice models may even model this access mode choice.

Accounting for income effects in mode choice models is problematic, as discussed elsewhere in this report, and many past models have ignored the issue entirely. However, clearly income must have some effect on airport access mode choice. Household income may be a more appropriate measure than individual income, because this reflects the contribution of other members of the household in covering basic household costs; however, at the same time the discretionary income for a given level of household income will also depend on the size of the household.

As important as deciding what information should be collected in the survey is deciding how to word the questions. Poorly worded questions will produce unreliable data, because respondents may misunderstand the question and give an incorrect answer. In the case of self-completed surveys, this applies not only to the questions themselves, but also to any predefined response options that are provided. The design of survey questionnaires and question wording is a topic in its own right and beyond the scope of this report. However, an ACRP study currently underway (Project ACRP 03-04) is developing a "Guidebook for Airport-User Surveys," which will provide detailed guidance on these and other related issues.

Stratified Sampling

Because the use of different transportation modes for airport access varies widely, and in particular at many airports public transportation has a fairly small market share, surveying a random sample of air travelers (e.g., in airport terminal departure lounges) will result in relatively few respondents who used the less common modes. This will in turn adversely affect the ability of a model estimated on that data to explain the choice behavior of the respondents using those modes. One approach to overcoming this problem is to perform *stratified sampling*, in which the survey is done in a way that obtains a greater number of responses from a particular subset of travelers than would be expected from a truly random sample. For example, surveys could be performed where passengers alight from transit vehicles. Alternatively, the survey could be done in a location where respondents selected at random will intercept all types of travelers, but a screening question asked at the start of the survey will identify respondents in the subset of interest and the survey of those respondents will be performed in more depth.

Estimating mode choice models on the basis of data obtained from a stratified sample requires some adjustments to the standard model estimation techniques to weight the response data in the estimation process; however, these adjustments are discussed in most standard textbooks on discrete choice modeling. Similarly, in presenting the results of a stratified sample, it is important to weight the responses appropriately to reflect the correct distribution of respondent characteristics across the population of airport users as a whole. Developing appropriate response weights for both model estimation and presenting survey results requires data on the frequency of occurrence of the different categories of respondent. These weights can be obtained from actual traffic counts of the different respondent categories where these are available or by comparing the results of the stratified sample with that of a random sample of the larger population of air passengers or airport employees as the case may be.

Transportation Service Data

To calculate the travel times and costs faced by each travel party in using the different airport ground transportation services, it is necessary to assemble the transportation service data for each mode on the basis of a defined system of analysis zones so that the appropriate value of any particular service characteristic for a given travel party can be determined from the trip origin zone for that party. Some data, such as the highway travel time to the airport, will vary across the zones. Other data, such as daily airport parking rates, are independent of the trip origin zone and thus constant for every zone, although the cost for parking will depend on how long the vehicle is parked. Some costs, such as fares for some public transportation services will depend on both the origin zone and the number of people in the travel party.

Highway travel times, highway distances, and transit travel times and fares are typically available from the regional transportation planning agency. However, modes such as taxi, shared-ride van, and scheduled airport bus, which are not usually included in the regional travel demand model, will require some work to assemble the necessary data. The ground transportation information pages of the airport website may have current information on many of the ground transportation services and parking rates. Otherwise, it may be necessary to contact the individual operators to obtain fare and schedule information. In the case of scheduled services with defined stops or stations, the schedule will generally provide headways and travel times from each stop or station. It will be necessary to determine the analysis zone for each stop, as well as the analysis zones served by that stop and the transportation service characteristics (travel times and costs) for the secondary access trip to reach the stop from each zone served by the stop. Because there may be several alternative secondary access modes (such as walk, drop off by private vehicle, taxi, or public transit), the transportation services characteristics will have to be determined for each mode and each analysis zone.

The result of this process is a large data table with a row (or record) for each analysis zone and the transportation service variables for each mode and sub-mode forming the columns (or position in the record). The appropriate transportation service values can then be assigned to each travel party in the model estimation dataset by looking up the relevant data for the trip origin analysis zone for that party and computing the values where necessary to account for the travel party size, air trip duration, or other travel party characteristics that affect the value of the transportation service variable for that party.

Analysis Zones

Selection of a suitable system of analysis zones involves a tradeoff between the precision of the transportation service data used for each travel party in the sample and the work involved in assembling the necessary data. Some of the data may already be available in a particular system of analysis zones. For example, regional transportation planning agencies will generally have computer files with highway travel times between each transportation analysis zone (TAZ) used in their regional travel demand model and the TAZ containing the airport. Indeed it may be desirable or even required that an airport access mode choice model is based on the regional travel demand model TAZ system so that the results of the modeling can be integrated with the regional travel demand modeling process.

However, a large metropolitan region may easily have more than 1,000 TAZs, and some larger regions have significantly more than that. The current regional travel demand model for the San Francisco Bay Area utilizes 1,454 TAZs, whereas that for the Washington metropolitan area utilizes 2,191. For those travel variables that can be obtained directly from the regional transportation modeling datasets, such as highway times or transit fares, this is not a particular problem. However, for other modes, such as shared-ride van, where fares are not typically available from the regional datasets, or are usually expressed in terms of the TAZs, obtaining the relevant data and converting it to the TAZs can be a major task.

It might appear that the data management problem can be reduced somewhat by using larger zones, such as U.S. Postal Service zip code areas. However, apart from the loss of precision involved in using larger zones, most transportation service data are not available on a zip code basis anyway, so the work involved in converting the data to a zip code-based system may not be significantly less than using TAZs. Where data are available by zip code (e.g., some shared-ride van operators base their fares on zip codes), it is fairly easy to develop a mapping from zip code areas to the corresponding TAZs and convert the data to a TAZ basis. Most geographical information systems have functions that can do this automatically provided that the TAZ boundaries are available as a geographical information systems file.

Revealed Versus Stated Preference

There are two different approaches to assembling the necessary data on airport access mode choice behavior to develop mode choice models: revealed preference and stated preference surveys. Revealed preference surveys identify the travel choices actually made by airport travelers, as well as collect information on other traveler characteristics and details of the trip that are believed to influence the choice. The model estimation process attempts to develop a model that explains the mode choice decisions in terms of the traveler characteristics and the service characteristics of the different airport ground access modes available to the traveler.

Stated preference surveys follow a similar process, except that the respondent is presented with a set of hypothetical choices and asked to select from them. For realism, the stated preference experiment is usually structured so that the choices presented to the respondent correspond to their current trip or a recent actual trip but change the characteristics of the ground transportation options available, such as different prices or travel times or the introduction of a new service or mode. Estimating a mode choice model on such data allows the model to incorporate ground access options that do not currently exist or to explore the effect of changing factors that do not exhibit much variation in the real world. Although this is a powerful capability, there are concerns about how well travelers' expressed choices between hypothetical situations that they have not actually encountered correspond to how they would really behave if faced with those situations in practice. To attempt to address this concern, stated preference studies are often combined with analysis of revealed preference to at least ensure that the stated choice behavior is consistent with the actual behavior when applied to situations that have actually been experienced.

Even so, there remains the concern that survey respondents may overstate their willingness to use new alternatives that do not yet exist, whether out of a desire to appear responsive to the survey or because they misinterpret how attractive the new service will be relative to their current choices. There is a limit to how detailed the description of a new service can be in the context of a stated preference survey that has to be completed in a fairly short time period, and respondents may not fully consider all the factors that would arise in using the new service, such as how they would get to it at the time that they need to travel. A related factor is that a stated preference survey necessarily informs the respondents about the options that are hypothetically available so that they can make a choice. However, in practice many travelers may not be aware of the existence of the service or may have a misperception of the nature of the service offered.

Habit and Information

An important aspect of air passenger airport access mode choice is the role of travel habits and the awareness of travel alternatives. In contrast to most urban trips, such as the journey-to-work or shopping trips, most air passengers do not make air trips that often, and many visitors to a region may be visiting for the first time. It is self-evident that travelers will not choose to use modes that they do not know exist, or even if they have significant misperceptions about the nature of the service offered, such as the travel time involved or the cost. However, most air passenger surveys ignore questions of travelers' awareness of difference services and their perceptions of the service offered by modes that they did not use. As a result, the estimation process of most mode choice models has implicitly assumed that travelers have full information about each mode. The issue of how to address habit and information in airport access mode choice models (or any models of travel behavior for that matter) is not well understood and is one that could benefit from further research.

This is an important consideration because it directly addresses the role of marketing in the provision of airport access services. Airport authorities or transportation operators can choose to spend resources improving services or more intensively marketing the services that they already provide. It would be extremely helpful if airport access mode choice models could help shed some light on how best to allocate resources between service improvements and marketing. However, for this to happen it will be necessary to incorporate traveler information more explicitly in the models.

Model Specification, Estimation, Calibration, and Validation

The terms model estimation and model calibration are often loosely used interchangeably. However, strictly speaking they are two different steps in developing an airport access mode choice model (or indeed any model). *Model estimation* refers to the use of statistical procedures to determine the values of the model coefficients that best fit the data from which the model is being developed. Typically, this will be derived from a sample of air passenger or airport employee trips obtained from a survey.

Once an estimation dataset has been assembled, the first step in model estimation is *model specification*. This involves selecting an appropriate functional form and market segmentation for the model, and defining relevant explanatory variables. Model estimation software is then used to obtain estimated values of the model coefficients. The statistical significance of these estimated values and the overall goodness-of-fit of the model is examined and the model specification revised as necessary to address problems with the resulting model coefficients or statistical fit. Model development typically proceeds iteratively. A fairly simple functional form with relatively few explanatory variables is initially estimated. Then the model is improved progressively by adding variables or modifying the functional form, such as changing the structure of the way that modes are grouped within the model to improve the statistical fit of the model to the estimation data. However, statistical fit is not everything. A model must also make sound behavioral sense. A model that reflects a plausible structure of behavioral causality is generally preferred to one that contains counterintuitive features, even if the latter has a better statistical fit.

Once a satisfactory model has been estimated, model calibration should be undertaken to make any necessary adjustments to the model so that the model predictions agree with observations. If the model estimation has been done correctly, the model predictions will agree with the observed data in the model estimation dataset. However, because these data may not be a truly representative sample of the larger population being modeled, the model may need to be adjusted to produce satisfactory predictions. In the case of an airport access mode choice model, where the composition of the air travel market will vary seasonally or even from day to day and assumptions will need to be made about average vehicle occupancy of some modes to convert the number of person-trips using those modes to the equivalent number of vehicle trips, the total volume of vehicle trips by each mode predicted by the model using the estimated coefficients may differ from the observed volume of vehicle trips for any given period. This is particularly the case when a model has been estimated on survey data collected at one point in time, typically a few weeks or less, but is being used to predict mode use for a different time period, such as a year.

Even if the survey data used for model estimation is an accurate representation of the larger population, the conversion of model predictions from travel party trips to vehicle trips generally will require some model calibration. Because access mode choice models are estimated on data for a sample of air passenger travel parties or airport employees, they generate predictions of travel party or employee trips using each mode, which typically need to be converted to vehicle trips for use in planning studies or other applications. For most private vehicle modes the conversion is straightforward, because each travel party generates one vehicle trip in each direction (or two in the case of drop off or pick up by private vehicle). However, for most other modes the ratio of vehicle trips to travel party or employee trips depends on assumptions about average vehicle occupancy or (in the case of modes such as taxi or limousine) the proportion of deadhead trips to revenue trips. For scheduled modes, the number of vehicle trips is determined by the schedule rather than the mode use. Where observed counts of vehicle trips are available, it will generally be necessary to adjust the assumptions about average vehicle occupancy or proportion of deadhead trips to match the predicted values of vehicle trips to the observed values.

Model validation is the final step in model development and involves comparing the predictions of the model under different conditions from those under which it was estimated and calibrated, usually after some change has occurred in the system being modeled, with the actual values of the phenomena being modeled. In the case of an airport access mode choice model, this could involve comparing projections of mode use in subsequent years or after changes have occurred in the ground transportation services available at the airport with the observed mode use under those different conditions. Although limited model validation can be done using partial data on the use of certain modes, such as comparing the number of private vehicles parked at the airport with the number projected by the model, a more thorough model validation will require an extensive effort to collect comprehensive data on mode use for the validation period.

Because the pattern of access mode use at an airport will depend on the composition of the air travel market or of the employee workforce, as well as the transportation services available, a true validation of an access mode choice model should include a new air passenger or airport employee survey to ensure that the market composition assumptions being used in the modeling are correct. Otherwise, it is unclear whether differences between the predicted mode use and the observed mode use are the result of problems with the model or invalid assumptions about the market composition. Similarly, it is important that the transportation service assumptions for the various modes that are used in the modeling are updated to reflect changes in costs and service levels since the model was originally developed.

Because of the effort and resources required to assemble the necessary data to perform a proper validation of an airport ground access mode choice model, such validations are rarely if ever done and it is simply assumed that a calibrated model that has been developed from data on mode use patterns at one point in time will remain valid when used to model airport access mode use at other points in time or under different conditions. Also, because model validation involves comparing model predictions with observed conditions under different conditions from those from which it has been calibrated, this often cannot be done until some time after the initial model estimation effort, by which time it may already have been used for the application for which it was developed. However, airport access mode choice model development should not be viewed as a one-time effort, any more than any other aspect of travel demand analysis. Rather, opportunities to validate a model should be sought and pursued following its initial development, and the model refined and improved over time. In this way the model will be available for subsequent applications with a growing level of confidence in its predictive reliability.

MATHEMATICAL FORM OF TYPICAL MODE CHOICE MODELS

The challenge of developing mathematical models of discrete choice behavior has attracted the interest of statisticians, economists, social scientists, and transportation planners over a long period of time and thus not surprisingly there is an extensive literature on the subject that is beyond the scope of this report to summarize. Some of the earliest applications of discrete choice behavior models to transportation travel demand were undertaken by Daniel McFadden and colleagues (described in Domencich and McFadden 1996), as part of work for which McFadden was awarded the Nobel Prize in economics. Readers interested in the theoretical background and evolution of the current state of practice of transportation mode choice models can refer to standard texts such as Ben-Akiva and Lerman (1985) or Hensher et al. (2005). However, to help readers who have limited or no prior familiarity with these techniques understand the general approach; this section will attempt to provide a simplified introduction to the current state of practice. Those with some familiarity with transportation mode choice modeling may choose to skip this discussion.

The basic concept underlying most disaggregate discrete choice analysis is that each alternative in the choice set provides the decision maker with some *utility* that can be expressed in terms of measurable or observable characteristics of both the decision maker and the alternative (e.g., the travel time involved or the income level of the decision maker). The larger the difference in the utility between two alternatives, the more likely the decision maker is to choose the alternative with the higher utility. This can be illustrated by the relationship shown in Figure 2, which shows the probability of choosing alternative 1, $P(1)$, as a function of the

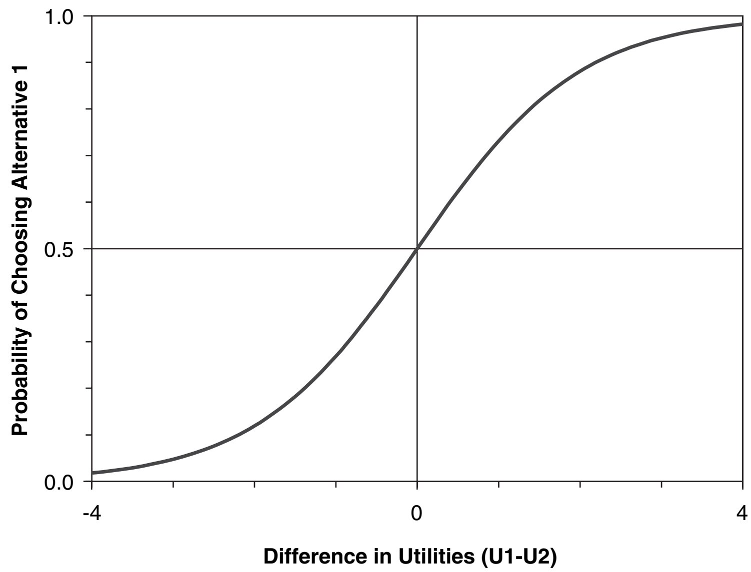

FIGURE 2 Illustrative binary choice relationship.

difference between the utility of alternative 1, $U1$, and that of some other alternative 2, $U2$, (termed a binary choice because it involves only two alternatives). As this difference becomes large and positive (i.e., the utility of alternative 1 is much greater than that of alternative 2), the probability of choosing alternative 1 approaches one (a probability by definition must lie between zero and one). Conversely, if the difference in utility is large and negative (i.e., the utility of alternative 2 is much greater than that of alternative 1), the probability of choosing alternative 1 approaches zero. If the difference in the utilities is zero, the two alternative are equally attractive and the probability of choosing either is equal to 0.5 (50%).

Multinomial Logit Model

As shown in Figure 2, the functional relationship between the difference in utility and the probability of choosing a particular alternative will be an S-curve, because it must be asymptotic to one and zero as the utility difference becomes very large in either the positive or negative direction. Early work on choice modeling identified the *logistic function*, defined as:

$$f(x) = e^x/(1+e^x) = 1/(1+e^{-x})$$

as providing a suitable S-shaped curve, where e^x is the exponential function of x. It can be seen that as x becomes very large and positive, $f(x)$ approaches one and as x becomes very large and negative, $f(x)$ approaches zero.

In the context of a choice model between two alternatives (termed a binary or binomial choice) the logistic function can be restated as:

$$P(i) = 1/\left(1+e^{-(U_i-U_j)}\right)$$

where U_i and U_j are the utilities of alternatives i and j, respectively, and $P(i)$ is the probability of choosing alternative i. This in turn can be reexpressed as:

$$P(i) = e^{U_i}/\left(e^{U_i}+e^{U_j}\right)$$

which became known as the *logit* model (strictly the *binomial logit* model). It can be shown fairly easily that with more than two alternatives the model can be extended as follows:

$$P(i) = \frac{e^{U_i}}{\sum_{j \in J} e^{U_j}}$$

where J is the number of alternatives. This is termed the *multinomial logit* (MNL) model and has been widely used for airport access mode choice models, because most airport access mode choice situations involve more than two alternatives.

Although the logit model was initially simply a convenient way of generating the required S-shaped relationship, later work showed that under certain assumptions regarding the form of the utility terms the logit model can be derived from theoretical principles of utility maximization, whereby the decision maker chooses the alternative that offers the highest utility, and the probability of choosing a given alternative is thus given by the probability that that alternative offers the highest utility of all the alternatives.

Utility Function

In developing discrete choice models, the utility of a given alternative is assumed to comprise two parts; a *deterministic* part that consists of a function of measured and observed variables and an *error* term that accounts for unobserved characteristics and variability in the perceived utility of a given set of characteristics across different individuals, therefore:

$$U_i = V_i + \varepsilon$$

where V_i is the deterministic part of the utility and ε is the error term. In logit choice models, the error term is assumed to be a random variable with values that are independent and identically distributed with a Gumbel (double exponential) distribution with a zero mean. (This assumption allows the logit model to be derived from utility maximization theory.) The variance of the error term reflects the goodness-of-fit of the model.

The deterministic part of the utility function typically consists of a linear combination of explanatory variables with their associated model coefficients, the values of which are determined in the model estimation process, therefore:

$$V_i = a_i + b_1x_1 + b_2x_2 + \cdot\cdot\cdot + b_nx_n$$

where a_i and the b's are the model coefficients and the x's are the values of the explanatory variables, such as travel time and cost. In general, the utility function for each alternative will have a constant term a_i, known as the alternative-specific constant (ASC), which reflects attributes of the alternative that are not accounted for by the other variables. Therefore, a fairly simple utility function might comprise:

$$V_i = a_i + b_1(\text{travel time}) + b_2(\text{waiting time}) + b_3(\text{walk distance}) + b_4(\text{cost/income})$$

Note that in this example travel cost is divided by household income in the fourth explanatory variable so that the choice process becomes less sensitive to cost for higher income travelers. This is included as an illustration that all explanatory variables do not have to enter the utility function as separate terms and may not be the best way to reflect the effect of household income.

It should also be noted that changing the utility functions of each alternative in a logit choice model by the same amount will not affect the resulting probabilities (because the change will factor the numerator and denominator of the logit expression for each alternative up or down by a constant amount that will cancel out). Therefore, it is usual practice to set the ASC for one of the alternatives to zero, so that the ASCs for the other alternatives then reflect the differences in the constant part of the utility for those alternatives relative to the alternative without an ASC.

The estimated coefficients of the utility function can be thought of as weighting factors that convert the units of the explanatory variable (e.g., minutes of travel time) to a measure of perceived utility. Because perceived utility is an abstract concept that has no intrinsic units of measurement, the estimated values of the coefficients have no direct interpretation. However, the ratio of the coefficients for two variables (or the ratio of the ASC to a coefficient of an explanatory variable) is another matter. This ratio expresses how an increase in one variable (or the ASC) will offset a decrease in the other variable and thus can be expressed as implied values. The ratio of a given coefficient or ASC to the coefficient for the cost term gives the implied value of that variable or constant in the units of the cost term. With appropriate adjustments for the units of two variables, this can give implied values of time in dollars per hour. Where the travel cost variable incorporates some function of household or other income the resulting implied values will be expressed in terms of this income measure.

This has an important implication for the specification of the utility function. Although different components of travel time can (and often should) be expressed with separate variables, cost terms should be combined into a single variable. This will avoid problems with the model giving different implied values of a given variable depending on which cost term coefficient is used. This is also conceptually sound. Although travelers may (and usually do) perceive different components of travel time as having a different disutility per unit time (i.e., different implied values), it would be surprising if they view a dollar spent on one aspect of the airport access journey any differently from a dollar spent on another aspect, because the money involved is completely interchangeable. (The one exception to this principle would be if some travel costs are reimbursable and others not. In this case, it would make sense to use separate variables for the two types of cost so that the ratio of the two cost coefficients reflect the relative importance of reimbursable to nonreimbursable costs. This would still allow values of time to be expressed consistently in terms of nonreimbursable costs.)

Limitations of Multinominal Logit Model

Although the MNL model has been widely used, it is vulnerable to problems that arise from a property of the model termed the "Independence from Irrelevant Alternatives." This states that including a new alternative in the choice set (or changing the perceived value of one of the alternatives) should not affect the relative probabilities of choosing any of the other alternatives. It can be seen from the previous equation for the MNL model that the ratio of the probability of choosing any two alternatives is determined only by the perceived utilities of those alternatives.

However, in many situations in airport access mode choice it is quite unlikely that changing the characteristics of one mode or sub-mode will leave the relative probabilities of choosing all the other modes and sub-modes unchanged. For example, increasing the parking rates in the short-term parking lot is likely to have a greater effect on the probability of an air party choosing to park in the long-term parking lot than on the probability of choosing to use a shared-ride van, because those who would have parked in the short-term lot at the former rates are much more likely to choose to park in the long-term lot instead than to decide to use a shared-ride van. Similarly, changes in one public transportation service are likely to affect the use of other public transportation services to a greater extent than the use of private vehicles.

This is not usually a significant problem with a model that only includes a limited number of well-differentiated modes, but becomes increasing problematical with models that attempt to distinguish between the use of similar modes (such as taxi and limousine) or to account for sub-modes (such as different parking facilities).

Nested Logit Model

The limitations of the MNL model can be addressed by grouping similar modes or sub-modes into separate groups or *nests* in a choice structure referred to as a *nested logit* (NL) model, as illustrated by Figure 3. In the nested model shown in the figure, alternative *b* consists of a second-level nest of two sub-alternatives, *b*1 and *b*2, the second of which consists of a third-level nest of two further sub-alternatives, *b*21 and *b*22. For example, alternative *b* might represent the use of a private vehicle, with alternative *b*1 representing the air party being dropped off at the airport and *b*2 the use a private vehicle that is parked at the airport for the duration of the air trip, where *b*21 represents the use of the short-term parking lot and *b*22 the use of the long-term parking lot.

The general form of the NL model is similar to the MNL model, with the addition of a scaling parameter μ_m for each nest *m*, as follows:

$$P(i|m) = \frac{\left(e^{U(i)}\right)^{\frac{1}{\mu_m}}}{\sum_{j \in N_m} \left(e^{U(j)}\right)^{\frac{1}{\mu_m}}}$$

$$P(m) = \frac{\left(\sum_{j \in N_m} \left(e^{U(j)}\right)^{\frac{1}{\mu_m}}\right)^{\mu_m}}{\sum_{l \in S} \left(\sum_{k \in N_l} \left(e^{U(k)}\right)^{\frac{1}{\mu_l}}\right)^{\mu_l}}$$

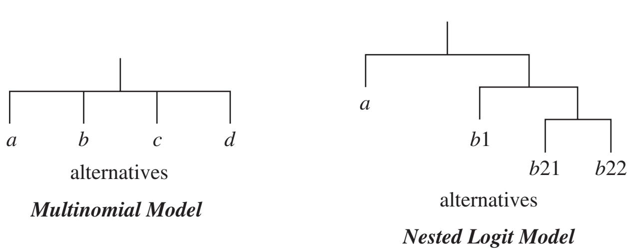

FIGURE 3 Multinomial and nested logit models.

where $P(i|m)$ is the probability of choosing mode *i* in nest *m* from among the set N_m of modes in nest *m*, given that nest *m* is chosen (strictly that a mode in nest *m* is chosen) and $P(m)$ is the probability of choosing nest *m* from the set *S* of nests at the same level as nest *m*. If one branch of a nest consists of a discrete mode m^* rather than a lower-level nest, the value for the scaling parameter for that mode $\mu_{m^*} = 1$. Therefore, if there is only one nest, the previous equations reduce to the MNL model.

Estimation of NL models involves estimating values for the scaling parameters as well as the utility function coefficients.

Other Model Specifications

Although the NL model overcomes some of the inherent limitations of the MNL model, there remain a number of other limitations to the use of NL models for modeling airport access mode choice. Perhaps the most significant of these is the assumption that the variance of the error term in the utility function is the same for all air parties and all alternatives. Another limitation can arise where the same alternative appears in different nests; for example, if several public transportation alternatives have station or stop access sub-mode nests, because these will typically involve the same sub-modes. Efforts to explore alternative model formulations to NL models for transportation mode choice applications have taken two approaches. One is to use more advanced logit model formulations that address some of the limitations in the standard model. The other is to use an entirely different conceptual approach to representing the mode choice process.

However, to date neither of these approaches has been applied to stand-alone airport ground access mode choice models, although some work has been done on modeling airport choice in which ground access mode choice forms part of the choice process (Hess and Polak 2005, 2006). Although these alternative approaches may be a promising area for future research, given the limited experience applying approaches other than MNL and NL models to airport ground access, the details of these approaches are not discussed further here. Readers interested in more information will find a discussion of the potential application of alternative mode choice model approaches to airport access travel in Lu et al. (2006).

MODEL ESTIMATION CONSIDERATIONS

Apart from questions of selecting an appropriate functional form and market segmentation for the model and defining relevant explanatory variables, careful consideration needs to be given to developing the necessary estimation dataset. The reliability of the resulting model is critically dependent on the accuracy of the data on which it is estimated. If the data contains errors or biased values of explanatory variables, the model will attempt to explain the traveler behavior in terms of those values rather than the real values. This may not be a problem in obtaining a good fit to the data, but will produce biased predictions when the model is later applied to other datasets that do not have the errors or biases.

Model Estimation Software

The process of estimating airport access mode choice models, such as mode choice models for other transportation applications, requires specialized software that is designed to perform maximum likelihood estimation with fairly complex model specifications. This software falls into three broad categories:

1. Special-purpose commercial software that has been developed specifically to estimate logit-type choice models or the mode choice component of transportation planning models.
2. General purpose commercial statistical packages that include modules for performing maximum likelihood estimation of discrete choice models.
3. Software developed by academic researchers to estimate a fairly broad class of econometric models that includes discrete choice models.

As might be expected, there is typically a tradeoff between the ease of use and cost of the different categories of software. Special-purpose commercial software for estimating logit choice models or transportation mode choice models is often the easiest to use, because considerable attention has been given to the design of the user interface and the software has been specifically developed for this purpose. However, the software is often more expensive than the other options, although the cost of acquiring software is usually small compared with the overall cost of the model development process.

A number of general purpose statistical software packages provide the capability to estimate discrete choice models using maximum likelihood techniques. Sometimes this requires the purchase of an additional software module. Although the cost of this additional capability (if required) is usually less than acquiring special-purpose software, estimating a model with this software may require somewhat more effort than using special-purpose software, although the interface between the model estimation function and the data management capabilities of the package is usually straightforward. This may be an attractive option for organizations that already are using one of these software packages for general statistical analysis.

Software developed by academic researchers to estimate various types of econometric models, often in support of their research or teaching activities, is often available at little or no cost. Depending on the scope of the software, this may require some customization to use to estimate a particular model specification. Documentation, user interface, and data management features are often fairly basic, and user support may be limited or nonexistent. On the other hand, the software may contain features or provide capabilities that are not available in commercial packages. A good example of this class of software is BIOGEME, developed by Michel Bierlaire at the Ecole Polytechnique Fédéral de Lausanne, Switzerland (Bierlaire 2003), and available on the Internet at http://biogeme.epfl.ch.

Unfortunately, obtaining comparative information on different software options is not as easy as might be thought. With some persistence, Internet searches can generally locate information on the principal software packages. However, some creativity is required in defining the search expressions to avoid being swamped by links to articles about choice model estimation methodology rather than the software involved or econometric software in general.

Market Segmentation

The air passenger market is not homogeneous and different market segments have different airport access needs and available options. The most obvious distinction is between residents of the local area and visitors. Residents typically have access to a private vehicle and often someone who can take them to the airport or pick them up. Visitors on the other hand may need to rent a car to meet their transportation needs while in the area or may be staying at a hotel that does not provide a courtesy shuttle service to the airport. Another important distinction is between those traveling on business trips, whose travel costs may be reimbursed by their employer or client, and those making trips for non-business purposes. These distinctions are typically addressed by defining different air passenger market segments and estimating a separate sub-model for each segment. The market segment sub-models may include different modes, may use different explanatory variables, and will generally have different estimated coefficients for a given variable.

Although a common market segmentation approach, discussed in more detail in subsequent chapters, is a four-way division into resident business trips, resident non-business trips, visitor business trips, and visitor non-business trips, other market segments may be worth considering. One is to differentiate visitors staying in a hotel from those staying with relatives or friends, because the latter may have access to private vehicles owned by the people they are staying with as well as people who can pick them up or drop them off at the airport.

Changes in the Airline Industry

The terrorist attacks of September 11, 2001 (9/11) have led to dramatic changes in the airline industry, in particular passenger security processing at airports. No longer can greeters and well-wishers enter the secure side of airport terminals, and passengers need to arrive at the airport earlier than before to ensure being able to clear security in time to make their flight. In addition, airports rigorously enforce the prohibition on leaving vehicles unattended at the terminal curb front or even waiting when not actively loading or unloading passengers. The combined effect of these measures has been a significant change in airport ground access mode use. Fewer well-wishers accompanying passengers to the airport (or drivers dropping passengers off at the airport) park for a short time to accompany the passengers into the terminal, because the passengers are usually anxious to get through security as quickly as possible and the well-wishers cannot accompany them. Similarly, greeters can no longer meet arriving passengers at the gate, and the increased use in cell phones over the past five years has simplified the process of picking up arriving passengers at the terminal curb front. As a result, many airports have introduced cell phone lots where drivers picking up air passengers can wait until the passengers are ready to be picked up.

Another significant change in the airline industry since 9/11 is a reduction in the percentage of short-haul trips. This is widely believed to be at least in part a result of the need to arrive at the airport for a flight earlier than before, which increases the time required to make an air trip and in turn makes driving or other surface transportation modes relatively more attractive. There may also be a heightened concern over aviation security that leads some who do have a surface transportation alternative to take this option even if it involves more time than flying. A third consideration is the increasing market share of low-fare airlines and the competitive response of the network carriers. This has led to a much higher proportion of air travelers using low-fare or heavily discounted tickets. It would seem likely that passengers attracted to air travel by cheaper fares would also be more cost-sensitive when making their airport access decisions. It is also likely that a higher proportion of air travelers are flying for personal rather than business reasons, although that has also been affected by cyclical changes in the economy.

Although these changes in the airline industry do not fundamentally affect the basic approach to modeling airport access mode use, they do affect the relative attractiveness of the different transportation services represented in the model and hence the estimated model coefficients, as well as the market composition. Any airport access mode choice model estimated on data from before 9/11 is likely to produce biased predictions of current or future air passenger access behavior. Similarly, current data on air passenger market composition, particularly the split between business and non-business travelers and the distribution of trip durations, is likely to have changed significantly from data collected before 9/11.

Level of Effort Required

It is clear from the foregoing discussion that developing an airport ground access mode choice model is not a simple or inexpensive matter. This raises the questions of how large an airport needs to be to justify the effort and what such an effort might cost, not easy questions to answer. For most large airports, with complex ground access systems to plan and manage, it is very difficult to conceive how this can be done well without such a model (although many airports try to make do without one). For smaller airports, perhaps with traffic levels in the range of 5 to 10 million annual passengers, the need may depend on the type of planning issue being faced.

The resources needed to develop an airport access mode choice model depend in part on the availability of air passenger survey data (or airport employee survey data in the case of employee access mode choice models). As discussed earlier, good air passenger survey data are critical to model development. Experience suggests that for adequate model development such a survey should have at least 3,000 responses, although models have been developed with smaller sample sizes. Stated preference surveys have been conducted with fewer respondents, approximately 800 and 1,100 in two recent cases; however, each respondent typically answers several choice experiments, each of which provides a data point, and such surveys cost more to perform per respondent than a revealed preference survey. Although the cost per completed survey of a revealed preference survey can vary significantly with local circumstances as well as the number of questions asked, typical costs identified in an on-going ACRP study of airport-user survey methodology (Project ACRP 03-04: "Guidebook for Airport-User Survey Methodology") are in the range of approximately $30 to $50 per completed response.

This suggests that developing the necessary survey data might cost somewhere in the range of $90,000 to $150,000. Assembling the corresponding transportation service data is also not trivial, although the local MPO may be able to provide some of these data in electronic format from the regional travel demand model network data. The amount of work involved in assembling the remaining data required will depend in part on how much information the airport authority already has available on the ground transportation pages of its website or in other files. Overall, this task might require between one and two person-months of effort and cost somewhere between $20,000 and $50,000 at typical consultant rates. Once the necessary data have been assembled, estimating, calibrating, and validating the model might require two to three person-months of effort, or perhaps between $40,000 and $75,000. Therefore, a complete study, including an air passenger survey, might cost between $150,000 and $275,000. However, the largest part of this cost is performing the air passenger survey, which has other value for airport planning purposes and should be done periodically anyway.

Whether such an investment is worthwhile depends on what the resulting model would be used for and the likely cost of making a bad decision. Certainly, in the case of evaluating the feasibility of a major infrastructure investment such as an airport rail link or even an automated people-mover link to a nearby rail station that might cost several hundred million dollars or more, the cost of having a good modeling capability is trivial and would easily be justified by avoiding a poor decision that results in an increase in the cost of the project by even 1%. Indeed, having such a modeling capability is probably a necessary requirement for obtaining environmental approval and funding. In the case of a smaller airport where the issues being addressed involve less money, the justification for such a modeling capability is less clear. Even so, an airport handing 5 million annual passengers, 20% of whom park at the airport for their trip duration, could be generating as much as $10 million per year in parking revenue. An increase in revenue of only 3% as a result of better pricing decisions could pay for the cost of developing the modeling capability in less than year.

MODEL APPLICATION

Once a mode choice model has been developed, to apply it to support planning and decision making it is necessary to have the ability to use it to analyze specific scenarios. This typically involves a significant amount of data management and model configuration to define the scenarios to be analyzed. One approach is to use the model in conjunction with standard transportation planning software or proprietary airport landside modeling software. These software tools are designed to facilitate the data management involved in modeling transportation network flows and typically provide users with the flexibility to define the structure and coefficients of the mode choice model incorporated in the analysis. If such models are not available, or the models that are available do not have the necessary capabilities, it will then be necessary to develop custom software to apply the model to analyze any given scenario.

Many discrete choice model estimation tools also provide the capability to apply a defined choice model to any suitably configured dataset of decision-maker characteristics and associated properties of the choice alternatives to estimate the resulting choice probabilities. The result of this process is typically a table of the probability of choosing each alternative for each decision maker (air passenger travel party or airport employee) in the dataset. Converting this table to a projection of passenger trips or vehicle trips by mode is then a matter of factoring up the results to correspond to the total airport activity for the period in question and applying the appropriate ratios of vehicle trips to travel party or employee trips. These estimated vehicle trips can in turn be allocated to the transportation network by segmenting the results by the trip origin zone and creating a zonal trip table. Although conceptually this is not difficult and the required calculations can generally be performed fairly easily using spreadsheet or database management software, because the process typically has to be repeated multiple times to analyze a number of scenarios it may be helpful to develop utility routines to perform the various steps.

Model Application Considerations

Although the process of applying an airport access mode choice model is technically fairly straightforward, there are a number of aspects that need to be carefully considered in developing the required input data and interpreting the results.

The first is that whereas a relatively small survey sample size (a few thousand respondents in the case of air passengers and perhaps even fewer for airport employees) may be adequate to estimate an airport access mode choice model, a much larger sample may be required for a given application of the model, depending on the issues of interest and the desired level of geographic resolution of the results. For example, a study to estimate the likely use of a proposed off-airport terminal in a particular location in the region served by the airport needs to have enough data points in the application dataset in the vicinity of the proposed terminal that the resulting estimate of the likely use of the facility is sufficiently accurate. To create a large enough application dataset, it may be necessary to develop a synthetic sample using Monte Carlo simulation methods based on the distribution of travel party characteristics in the original survey. This is more accurate than simply duplicating the survey records, because that cannot create a record with different characteristics from those that appear in the survey. Therefore, record duplication will simply create multiple records with identical characteristics, and combinations of traveler characteristics that do not appear in the original survey sample will never appear in the expanded sample no matter how large it is, whereas a synthetic sample will create records with characteristics that do not appear in the original sample. This will ensure that analysis zones that were thinly populated with survey respondents in the original sample will have a much more representative mix of traveler characteristics in the expanded sample and not be biased toward the characteristics of those travelers that happened to appear in the original survey sample.

Two other considerations relate to the application of a model estimated on data at one point in time to predict behavior in future years, as is typically done in planning studies. The first consideration is how to adjust travel times and costs for the various modes to correspond to future conditions. Highway travel times for future years should reflect any anticipated changes in highway congestion. Future costs are more problematical, because their effect on traveler decision making will depend on their value relative to the overall cost of living as well as changes in the income level of travelers over time. Typical practice is to consider that the cost and income variables in the model are expressed in real dollars (i.e., do not need to be increased to account for inflation). However, that is not to say that the cost of different modes will not change over time in real dollars. If general income levels rise or fuel prices increase in real terms, then transportation operators will need to raise their prices to cover their higher costs of doing business and the cost of operating private vehicles will rise. Conversely, if transportation operators are able to achieve productivity gains or rising levels of air travel increase the traffic that they carry, allowing them to be more efficient, then they may be able to reduce their prices in real terms. Although these effects may tend to offset each other, the net effect is likely to vary by mode. Therefore, some thought should be given to assumptions about future travel costs and not simply assume that they will remain unchanged in real terms.

Historically, household incomes have increased in real terms over time, although over the past 30 years the distribution of household incomes has also changed, with the incomes of higher-income households increasing faster than that of lower-income households (U.S. Census Bureau 2006, Table A-3). Whether the effect of household income is explicitly included in the mode choice model or implicitly included in the coefficients of cost terms, some thought should be given to how to incorporate future growth in household income in the application of the model for future years. This is not a trivial matter. From 1995 to 2005 the average household income in the United States increased by almost 11% in real terms (U.S. Census Bureau 2006, Table A-1). This is equivalent to a reduction in the relative costs of different modes by at least that amount, which could easily have a greater effect on mode use than the type of transportation system enhancement that mode choice models are used to evaluate. Because higher income households use air travel more than lower income households, the real increase in the average household income of air travelers and the corresponding effect on airport access mode choice is probably even greater.

Pivot Point Analysis

Rather than use a disaggregate mode choice model directly to predict the change in mode shares as a result of some change in transportation service levels, it is possible to use the relevant model coefficients and the existing mode shares to predict the *change* in mode share for a given *change* in the explanatory variables. This has come to be known as the *incremental logit model* or *pivot point analysis* (the predicted mode shares are considered to pivot about the existing mode shares) (Kumar 1980). Another way to think about this type of analysis is to use the model coefficients and existing mode shares to determine the slope of the demand curve at the current values of the transportation service variables and mode use, and then calculate the change in mode share for a given movement along the demand curve corresponding to the change in the value of the transportation service variable (Meyer and Miller 1984).

In the case of MNL models (or binary logit models), the incremental logit equations are fairly straightforward and are given by Kumar (1980). The derivation of the corresponding equations for a NL model is somewhat more involved, owing to the existence of the scaling parameters and the more complex structural form of the model, but the same approach can be applied.

The advantages of this approach are two-fold. The first is that it eliminates any error in the predictions resulting from differences between the mode use predicted by the model at current values of the transportation service variables and the actual mode use. The second is that it only requires values for the model coefficients of the variables that change in value and not for the other variables or the ASCs. However, this is also a potential weakness of the approach. If the ASCs reflect some of the contribution of the transportation service variables to the predicted mode shares (perhaps owing to specification errors in the model or errors in measuring the transportation service levels), then those effects will be ignored in the analysis. Therefore, an alternative approach would use the full model, but apply the predicted change in mode use to the existing observed mode use.

Demand Elasticity

The concept of demand elasticity refers to the percent change in demand for a 1% change in some variable. Therefore, the demand elasticity with respect to the price for taxi use at an airport would express the percent change in taxi use for each percent change in fare levels. In the case of a MNL model with a linear utility function, it can be shown that the elasticity of the probability of choosing a particular mode with respect to a given variable in the utility function is given by:

$$\varepsilon_{ik} = \alpha_{ki} \cdot X_{ki} \cdot (1 - P_i)$$

where ε_{ik} is the elasticity of the probability of choosing mode i with respect to changes in the value of the explanatory variable X_k for mode i (X_{ki}), α_{ki} is the coefficient of X_k in the utility function for mode i, and P_i is the current probability of choosing mode i. In simple terms, this is saying that the elasticity is given by the product of the coefficient of the variable, the current value of the variable, and the probability of not choosing the mode. As the probability of choosing a particular mode increases, the elasticity of the probability of choosing that mode with respect to any variable becomes less.

However, this is of limited use because it is clear from the previous equation that the elasticity of demand varies with the value of the variable in question for every air party and with the probability of each air party selecting the mode in question at current values of all the explanatory variables. Therefore, elasticity is not a constant property of a given mode or a given situation, but varies with the values of the transportation service variables and with the market shares of the different modes. Nonetheless, for any given situation the elasticity of demand for a given mode with respect to a given service variable can be calculated numerically, and this may be a useful thing to do to give planners and managers an easily understood tool to make quick assessments of the likely effect of any proposed change. The important caveat to ensure this is clearly understood is that any given elasticity value is only valid for the particular situation for which it has been calculated and will change as the situation changes. In particular, if changes occur in other modes the elasticity for the mode in question will change because changes in other modes will change the probability of choosing the mode for which the elasticity has been calculated.

CHAPTER THREE

REVIEW OF THE LITERATURE

AIR PASSENGER MODE CHOICE MODELS

The ability to predict how airport users will respond to changes in the service characteristics of the ground access modes serving the airport or the addition of new ground access services is clearly an essential part of any effective analysis of proposals to enhance the airport ground transportation system. In addition, airport ground access models play an important role in studies addressing how future air travel demand will be distributed among airports in a multi-airport region. The relative accessibility of airports serving a region is recognized as one of the key determinants of air passenger airport choice (in addition to the air service offered at the airports). Whereas early airport choice models simply used highway travel times as a measure of airport accessibility, later models have recognized that appropriate measures of airport accessibility need to account for the range of ground transportation services available and the proportion of airport users who choose different ground transportation modes for their travel to and from the airport.

Because airport ground transportation involves trips both to and from the airport, ideally what are required are airport ground access *and egress* models. However, in practice, most modeling efforts to date have only addressed airport access, and it has been assumed (often implicitly) that the reverse trip reflects a symmetrical pattern of mode use. Personal experience and a growing body of evidence suggests that this is not the case, at least on the basis of the behavior of individual air parties, but this report focuses primarily on airport ground access mode choice models, because those are the models that are generally available. The review of the literature undertaken as part of this study found no examples of prior studies that explicitly modeled airport ground egress travel behavior. The focus on ground access trips no doubt results primarily from the use of air passenger surveys as the source of data on which to base the development of airport ground travel mode choice models. Because it is much easier to survey departing passengers rather than arriving passengers, air passenger surveys have generally addressed the ground access trip that the respondent has just completed, rather than the egress trip that a respondent beginning their air trip will make on their return or the egress trip that a visiting air traveler made on their arrival in the area some time before. The issue of the difference between airport ground access and egress travel behavior is discussed later in this report.

Therefore, given the importance of understanding air passenger airport ground access mode use it is not surprising that there have been a number of studies over the years that have developed air passenger ground access mode choice models. One of the earliest efforts to develop a formal model of air passenger airport ground access mode choice was undertaken in the early 1970s (Ellis et al. 1974). This study used a MNL model, as did several other studies that developed air passenger ground access mode choice models over the next ten years (Leake and Underwood 1977; Sobieniak et al. 1979; Gosling 1984; Spear 1984; Harvey 1986). However, by the mid-1980s it was becoming recognized that some of the limitations of the MNL model could be addressed through the use of NL models (Ben-Akiva and Lerman 1985). One of the first applications of NL models to airport ground access mode choice was undertaken as part of a study of surface access to London Heathrow Airport (Howard Humphreys and Partners 1987), followed shortly thereafter by a study by Harvey (1988) that used a NL structure to develop an integrated model of airport choice and ground access mode choice for the San Francisco Bay Area. Subsequent air passenger ground access mode choice models developed for Boston, Massachusetts (Harrington et al. 1996; Harrington 2003); Portland, Oregon (*PDX Ground Access* . . . 1998); and airports in the southeast and east of England (Halcrow Group Ltd. 2002b) used a nested structure, whereas other studies continued to use MNL models to represent air passenger ground access mode choice (Tambi and Falcocchio 1991; Dowling Associates, Inc. 2002; Psaraki and Abacoumkin 2002). In addition to models that have exclusively addressed airport access mode choice, a number of recent studies have used NL models to represent air passenger airport choice, with airport ground access mode choice as a lower-level nest (Bondzio 1996; Monteiro and Hansen 1996; Mandel 1999; Pels et al. 2003). However, these models generally only include a single-level nest for the airport ground access mode choice process and thus are equivalent to MNL models from the perspective of ground access mode choice.

The technical details of many of these models have been reviewed by Lunsford and Gosling (1994) and later by Gosling et al. (2003). However, the level of detail reported in the literature for each of the models varies, with some authors only providing partial information on estimated parameter values or even on the independent variables included in the model. It is common to estimate separate sets of model parameters, or even different model specifications, for different market segments, such as residents of the area versus visitors, or air travelers on business trips versus those on leisure trips. Some published articles describing these models only present the estimated values of the model coefficients for some of the market segments. This makes comparison of the different models difficult. However, detailed results are available for a number of recent models. The principal features of these models are briefly described in the following sections. More detailed documentation of each of these models is provided in Appendix D included in the web version only.

Atlanta Regional Commission Model

The Atlanta Regional Commission (ARC), the MPO for the Atlanta region, has developed an Airport Passenger Model (APM) to model air passenger trips to and from Hartsfield–Jackson Atlanta International Airport (H-JAIA) as a component of the overall regional travel demand modeling process (*Model Documentation* . . . 2005). The model was originally developed in 2003 using data from the H-JAIA Peak Week Air Passenger Survey performed in 2000 and was updated in 2006 for new income groups for 2000 (*Travel Demand* . . . 2006). The ARC Airport Passenger Model (ARC/APM) consists of two components: a trip generation/distribution model that assigns the total originating air passenger traffic at H-JAIA to regional TAZs and a mode choice model that predicts the ground access mode use of those air passenger trips. A subsequent step converts air passenger trips to vehicle trips for inclusion on the traffic assignment step of the regional transportation demand model. The model is one of the few examples (and the only one documented in this study) of a special-generator airport access mode choice model fully integrated into a regional travel demand modeling process.

The ARC/APM predicts air passenger and vehicle trips using four market segments: resident business, resident non-business, non-resident business, and non-resident non-business. The mode choice model considers five modes: air passengers dropped off by private vehicle, private vehicle parked at the airport for the duration of the air trip (termed drive self), rental car, transit, and taxi. Although not explicitly stated in the model documentation, it appears from the documentation that the transit mode includes the Metropolitan Atlanta Rapid Transit Authority rail and bus services, commercial shared-ride shuttle van services, and other high-occupancy shared-ride modes such as charter bus, whereas the taxi mode includes exclusive ride limousine services and hotel and motel courtesy vehicles, as well as conventional taxi use.

The basic form of the mode choice model is a NL model with a separate structure for trips by residents of the region from that for non-residents. The model does not take the type of ground access trip origin into account. Therefore, all visitors to the region are considered to include drop off by private vehicle and rental car in their choice set, whether or not they are staying with residents of the region and thus have someone who could drop them off at the airport or the need for a rental car during their visit. The explanatory variables consist of the travel times and costs for each mode. Separate variables are defined for in-vehicle, walk, and wait times. The transit in-vehicle times use the total in-vehicle time for the trip from the origin zone to the airport zone, transit walk times combine access, egress, and sidewalk times from the transit network, and the transit wait times combine the initial wait with any transfer wait times.

Boston Logan International Airport Model

This model was developed by the Central Transportation Planning Staff (CTPS) in Boston using a 1993 air passenger survey done at Boston Logan International Airport (Harrington et al. 1996; Harrington 2003). Separate sub-models were developed for resident business trips, resident non-business trips, non-resident business trips, and non-resident non-business trips. The two resident sub-models consist of a NL model, with separate nests for door-to-door modes (taxi and limousine) and automobile modes (drop off, short-term parking, long-term parking, and off-airport parking). There are four shared-ride public modes at the top level (regular transit, scheduled airport bus, the Logan Express service to off-airport terminals in the region, and the Water Shuttle between the airport and the downtown Boston waterfront). The visitor sub-models are MNL models and omit the long-term parking alternatives but add a hotel shuttle mode.

This model is particularly relevant to studies involving improved public transportation access to airports because it includes both a rail access mode, the Massachusetts Bay Transportation Authority (MBTA) regional rail transit system, and off-airport terminals, the Logan Express service operated by the Massachusetts Port Authority (Massport), the airport authority for Logan Airport. The MBTA Airport Station is adjacent to the airport and linked to the passenger terminals by a free shuttle bus service operated by Massport. Unlike many other airport access mode choice models, the CTPS model is also interesting in that it treats rental car use as an independent decision and excludes it from the mode choice decision process.

Chicago Airport Express Ridership Forecasting Study

In 2003, the Chicago Department of Transportation retained Resource Systems Group, Inc. and Wilbur Smith Associates to undertake a ridership and revenue forecasting study of a proposed Airport Express train service between downtown Chicago and O'Hare International and Midway Airports (Wilbur Smith Associates 2004). To identify the pattern of air passenger trip ends, travel party characteristics, and existing access mode use, and to understand how airport travelers might change their access mode choice if the Airport Express train were available, two surveys of air travelers were undertaken by Resource Systems Group, Inc. at O'Hare and Midway Airports, an origin–destination survey and a stated preference survey (Resource Systems Group Inc. 2004). The origin–destination survey results were used to develop a profile of existing originating air passenger characteristics, including trip purpose, trip origin, and ground access mode use, as well as current and future trip tables that predicted the number of trips by market segment originating in each of 145 TAZs within the study area.

The stated preference survey interviewed 1,110 air travelers in the two airports, who were asked about details of their trip to the airport, and then asked to complete eight stated preference choice experiments in which they were presented with a choice between three trip modes, including the mode they had just used and the Airport Express train. The results of the stated preference survey were used to estimate a mode choice model that defined nine airport access modes: private vehicle parked at the airport for the duration of the air trip, drop off at airport by private vehicle, rental car, taxi, other private mode, Airport Express train, Airport Bus, Chicago Transit Authority train, and other public mode. The "other private mode" included limousine, hotel/motel courtesy shuttle, and shared-ride airport van service, whereas the "other public mode" included local bus, region train and bus service, and charter bus. The mode choice model used a NL form with a somewhat different nest structure for travelers on business and non-business trips, as shown in Figure 4.

The utility functions for each airport access mode included two continuous variables, total travel time and travel cost, in addition to alternative specific constants. The estimated coefficients for each of the two continuous variables within a given market segment were constrained to have the same value for each mode. Traveler income was not explicitly included in the model, but travelers were divided into two income categories on the basis of household income and separate travel cost coefficients estimated for each category. Although a single travel time variable was used in each utility function, weights were applied to various components of the total travel time that was used in the model estimation to account for different disutility of access, transfer, and waiting

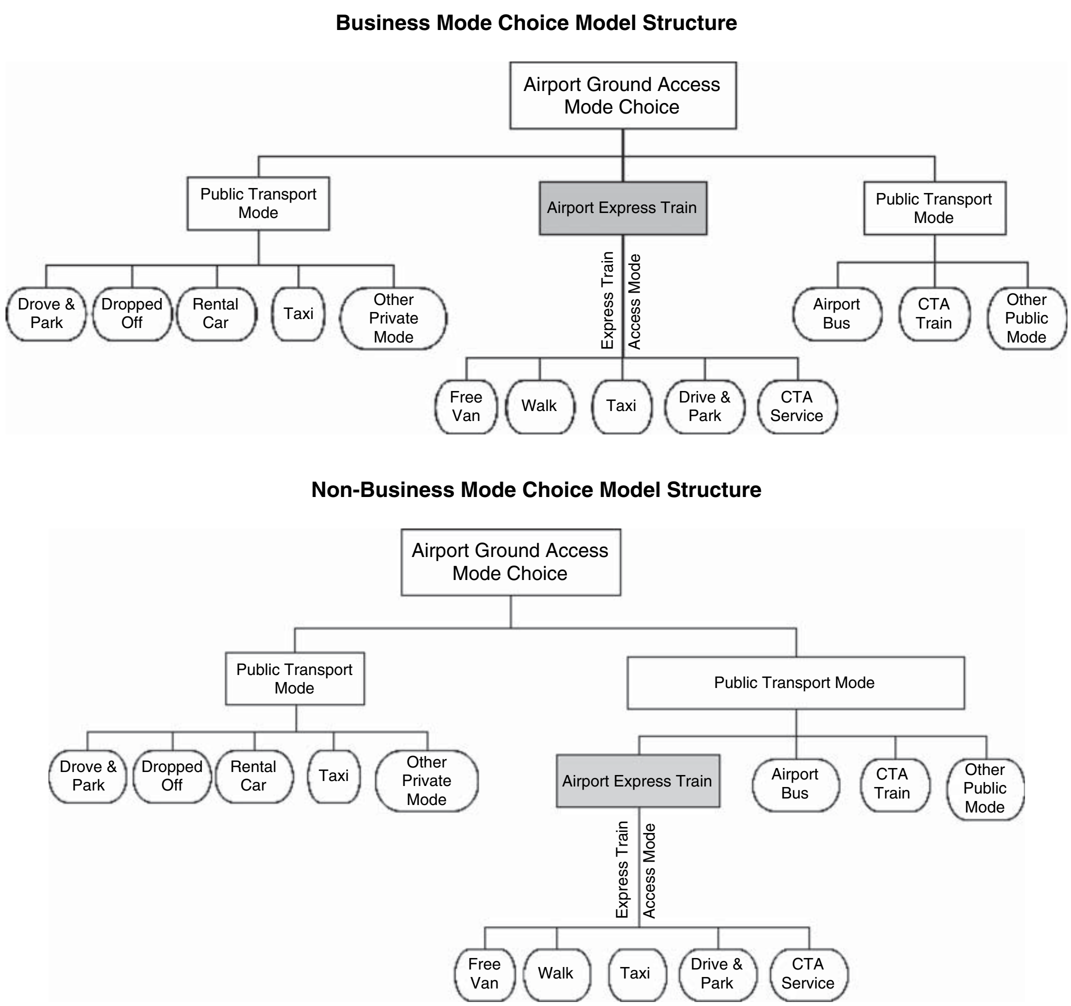

FIGURE 4 Chicago Airport Express mode choice model nesting structure (*Source:* Wilbur Smith Associates 2004).

time (as applicable) for each mode. The weights were determined by iteratively adjusting their value to obtain the best overall model estimation result. In addition to the two continuous variables, a dummy variable for the availability of baggage check-in at the downtown terminal was included in the Airport Express and Airport Bus modes, and a second dummy variable was included in the Airport Express mode for those passengers boarding at an intermediate station.

Separate model coefficients were estimated for business and non-business travelers. The same model coefficients were used for residents and non-residents of the Chicago region, although the available modes for these two market segments were different. After the model coefficients were estimated using the stated preference data, the model was calibrated to correspond to the mode shares for the study area obtained from the origin–destination survey data by adjusting several of the ASCs until the model predicted the observed mode shares from the study area.

The calibrated mode choice model was applied to forecast ridership and revenue for the Airport Express train for various service scenarios for 2009 and 2020, including two different fare levels, several different travel time assumptions for the service to O'Hare Airport, two different growth rates for off-peak highway travel time, and whether or not a free downtown shuttle or baggage check at the downtown terminal would be provided (Wilbur Smith Associates 2004).

Miami Intermodal Center Travel Demand Forecast Study

The Miami Intermodal Center (MIC) is being planned as a major transportation interchange facility located immediately to the east of the Miami International Airport (MIA) to provide an integrated terminal for several intercity transportation services, including Amtrak, Tri-Rail commuter rail, and Greyhound buses, as well as Metrobus and Metrorail transit services (*Miami Intermodal Center* . . . 1997). An APM (the MIC/MIA Connector) will link the MIC to the airport. Provision has also been made in the planning for future High Speed Rail and East–West Corridor rail lines as well as an Airport/Seaport Connector rail link. The MIC will also help accommodate growth of MIA by providing expanded airport landside facilities, including rental car and long-term parking facilities. As part of the planning for the MIC, a travel demand forecast was prepared by ICF Kaiser Engineers (1995) that incorporated an airport access mode choice model that was used to forecast ridership on the MIC/MIA Connector. The mode choice model was based on a model originally developed by KPMG Peat Marwick for a study for Newark International Airport in New Jersey.

Because of the large number of modes available at MIA and the complexity of the choices available as a result of the MIC project, the mode choice model was expanded to include the following nine modes: drop off by private vehicle, private vehicle parked for the air trip duration, rental car, taxi, limousine, premium transit, local transit, shared-ride van, and hotel courtesy shuttle. The model used a NL structure with the first five modes grouped into a nest called Non-Group modes and the other four modes grouped into a nest called Group modes. The model defined four market segments: resident business trips, resident non-business trips, non-resident business trips, and non-resident non-business trips.

The model has only three explanatory variables, apart from the ASCs: in-vehicle travel time, out-of-vehicle travel time (including waiting time and terminal time, such as walking from the parking lot to the airport terminal or returning a rental car), and travel cost. There is no consideration given to the effect of income differences in the model. The values for the coefficients for the continuous variables were not estimated from the air passenger survey data, but rather adopted from the values estimated for Newark International Airport in the original model with the same coefficient values being used for each market segment. Values for ASCs for each mode were estimated from air passenger survey data to fit the model predictions of mode use to the observed data.

Bay Area Rapid Transit–Oakland International Airport Connector Study

Since the 1970s, a number of studies have been undertaken by the Port of Oakland (the operator of Oakland International Airport), Bay Area Rapid Transit (BART), and other agencies to explore the feasibility of developing an APM connection to replace the current AirBART shuttle bus link between the airport and the Coliseum BART station located approximately 2.5 miles from the airport (*BART–Oakland* . . . 2002, Executive Summary). As part of on-going efforts to implement the Oakland Airport Connector, a Final Environmental Impact Report/Environmental Impact Statement (EIR/EIS) was completed and approved in March 2002. The analysis for the EIR/EIS included the development of an airport access mode choice model by CCS Planning and Engineering, Inc., that was applied to generate ridership projections for the Connector (*BART–Oakland* . . . 2002, Appendix B: Transit Ridership Procedures and Inputs). The mode choice model addressed both air passenger trips and airport employee trips, with the employee trips treated as a separate market segment. The general form of the model is a MNL logit model with air passenger trips divided into four market segments: resident business trips, resident personal trips, visitor business trips, and visitor personal trips.

Data on the air party characteristics for each market segment were obtained from the 1995 Air Passenger Survey undertaken for the Metropolitan Transportation Commission (MTC) at the three Bay Area airports (including Oakland International Airport), supplemented by surveys of AirBART passengers performed by CCS Planning and Engineering, Inc., in December 1999 and May 2000 as part of the study.

The model assigns airport trips among the following eight modes: private vehicle, rental car, scheduled airport bus, public transit, shared-ride van, hotel courtesy shuttle, taxi or limousine, and other. Public transit included both the use of BART by means of the AirBART shuttle (or the Connector in the future), as well as local transit bus service directly to the airport. The transit alternative for travelers with trip origins in zones near the airport was assumed to be local bus, whereas the transit alternative for those from more distant zones was assumed to be BART. The use of "other" modes was not explicitly modeled, but rather the use of those modes was assumed to remain constant from the mode share observed in the 1995 Air Passenger Survey.

The model utility functions included the following six variables: highway travel time, travel time by rail transit, travel time by bus transit, walking distances, waiting times, and travel costs, although not all variables applied to each mode. The distinction between rail transit travel time and bus transit travel time allowed the analysis to consider the effect of replacing the AirBART shuttle bus with the planned APM, as well as the different level of service between BART and local bus. Household income was included in the model by dividing the costs for personal trips by the household income in thousands of dollars raised to the power 1.5. This adjustment was not applied to business trips as it was considered that business travel decisions are unaffected by income because business travelers are usually reimbursed for travel expenses. The model coefficients for the continuous variables were adopted directly from an earlier airport ground access mode choice model for the Bay Area developed by Harvey (1988). The values of the ASCs were then estimated to fit the model to the mode use data from the 1995 MTC Air Passenger Survey.

The mode choice model market segment for airport employees included only two modes, private vehicle and public transit, and is discussed further in the following section on airport employee travel choice.

Portland International Airport Alternative Mode Study

Soon after the Boston Logan model was developed, a similar modeling effort was undertaken in Portland, Oregon, as part of a ground access study for Portland International Airport, jointly undertaken by the Port of Portland and Metro, the regional MPO, with the assistance of Cambridge Systematics, Inc. (Bowman 1997; Cambridge Systematics 1998; *PDX Ground Access* . . . 1998). The primary purpose of the model was to forecast the potential ridership on potential ground access enhancements, including a planned extension of the Portland MAX (Metropolitan Area Express) light rail system to the airport. An air passenger survey was done at the airport that combined a revealed preference survey that examined air passengers' actual mode use and a stated preference survey that was designed to determine travelers' preferences for modes that were not then available, namely light rail, express bus, and shared-ride transit (it is unclear from the documentation how this was defined).

An initial model estimation was done by Cambridge Systematics (Bowman 1997; Cambridge Systematics 1998) that jointly estimated MNL models using both the revealed preference and stated preference data for the same four market segments as the Boston Logan model. Separate ASCs were estimated for each mode for trips originating within the Portland metropolitan area (termed internal trips) and those originating outside the metropolitan area (termed external trips). Two different sets of model parameters were estimated for each market segment, reflecting different assumptions for the ASCs for the light rail and express bus modes. The models were subsequently revised by Metro staff to combine some of the choice alternatives and recalibrate the models by adjusting the ASCs (*PDX Ground Access* . . . 1998).

In addition to the development of a mode choice model, a review of the experiences of other U.S. airports with a range of airport ground access strategies was undertaken as part of the overall study of alternative airport access modes (Coogan 1997). This report included statistics on the ground access mode shares of various airports that had implemented ground transportation services similar to those being considered for Portland, as well as a discussion of the operational experience of those airports with the ground transportation services and the lessons that might be applicable to the Portland situation. Although there was no explicit comparison of the results of the mode choice analysis with the experience at other airports, this study put the results of the mode choice modeling into a larger context and served to provide some assurance of the likely validity of the modeling results.

San José International Airport Model

This model was developed by Dowling Associates (2002) and was designed to estimate the ridership on a planned APM to connect the airport to a nearby Santa Clara Valley Transportation Authority light rail line. The model was estimated using data from an air passenger survey performed at the airport for the Bay Area Metropolitan Transportation Commission in 1995 and supplemented with the results of stated preference surveys that were conducted as part of the study to determine how air passenger mode choice might be influenced by the availability of the APM and to compensate for the limited number of users of the light rail line in the 1995 survey sample. The model used a MNL form with separate coefficients for the same four market segments used in the Oakland International Airport–BART Connector model, as well as an airport employee segment. Each air passenger market segment included six modes: private vehicle, rental car, scheduled airport bus, shared-ride door-to-door van, taxi, and public transit. In addition, the visitor market segments included hotel shuttle. The model implementation allowed for up to four different public transit routes from any given analysis zone, and the model used separate coefficients for bus travel time and rail travel time. In addition, a separate ASC was used for those routes that included the use of the APM to reflect the greater attractiveness of this link as determined from the stated preference survey. The model is very similar in structure and form to the model used for the Oakland International Airport–BART Connector analysis and used the same approach of adopting the model coefficients from Harvey (1988) and estimating ASCs.

The mode choice model market segment for airport employees included only two modes, private vehicle and public transit, and is discussed further in the following section on airport employee travel choice.

Toronto Air Rail Link Revenue and Ridership Study

In May 2003, Transport Canada issued a Request for Business Case for a public–private partnership to develop an Air Rail Link between the Toronto Lester B. Pearson International Airport and Toronto Union Station (*Request for Business Case* . . . 2003). In preparation for the Request for Business Case, a revenue and ridership forecasting study was undertaken in 2002 (Halcrow Group 2002a). The study included the conduct of a stated preference air passenger survey and the development of a mode choice model to predict the diversion of airport access trips from existing modes to the proposed new rail link. The stated preference survey was carried out in February 2002 in the terminal departure lounges and collected data on the air party characteristics, ground trip origin, and ground access mode for the current trip. Some 807 respondents were identified as potential air rail link users and completed a stated preference questionnaire, the results of which were then used to estimate a set of binomial logit mode choice models, each of which models the choice between an existing mode and the planned rail link.

Air travelers using hotel bus or rental car to access the airport were excluded from the diversion analysis, because users of a hotel bus were assumed to have a door-to-door service that was effectively free, whereas those using a rental car were assumed to require the car for other purposes during their visit and thus not consider the use of other modes. The mode choice model relationships use three continuous variables: the in-vehicle travel time on each mode, the service headway for the mode, and the travel cost involved in using the mode. In addition, the utility function for the rail link includes two dummy variables: one that indicated whether the air traveler was accompanied (whether by other members of the air travel party or by well-wishers) or traveling alone and one indicating whether the air traveler(s) intended to check any bags. The model structure does not directly consider the type of trip origin. However, the approach of developing separate diversion models for each existing access mode indirectly addresses some of these effects, because air passengers being dropped off by private vehicle would largely have begun their trip from a private residence, whereas those using taxi or airport bus would be more likely to have begun their trip from a hotel or place of business. The model utility functions also do not consider the household income of the air travelers.

ASCs were initially included in the model utility functions; however, these were found to be not statistically significant and were dropped from the model. This is surprising given the relatively simple form of the utility functions and the absence from the model of such factors as household income and the access time involved in reaching the rail link station. Separate model coefficients were estimated for four market segments: resident business, resident non-business, non-resident business, and non-resident non-business.

In addition to estimating a formal mode choice model, the study included a benchmark comparison analysis that examined the mode share of existing airport rail links in 24 cities in the United States, Europe, and Australia. This analysis developed cross-sectional regression relationships that expressed the rail mode share in terms of a series of market and geographical characteristics, such as the percentage of air passengers with central city origins, the distance of the airport from the central city, and the ratio of rail travel time to taxi travel time from the city center. These relationships were then used to predict the corresponding rail mode share for Toronto using the same regional characteristics. The resulting range of rail mode shares (which varied with the characteristic chosen) was compared with the results of the formal mode choice modeling process, to provide a reality check on the modeling analysis.

United Kingdom South East and East of England Regional Air Service Study Air Passenger Surface Access Model

As part of the South East and East of England Regional Air Service (SERAS) study undertaken for the U.K. Department of Transport, Local Government and the Regions, a set of surface access models was developed that included an air passenger mode choice model, an airport employee trip distribution model, and an airport employee mode choice model (Halcrow Group 2002b). The air passenger mode choice model is a NL model that covers 12 defined ground access modes and has separate coefficients and model structures for the following six market segments:

- U.K. business passengers on domestic trips,
- U.K. business passengers on international trips,
- U.K. leisure passengers on domestic trips,
- U.K. leisure passengers on international trips,
- Non-U.K. passengers on business trips, and
- Non-U.K. passengers on leisure trips.

The 12 ground access modes consist of several different types of rail links, including a dedicated express rail service (such as the Heathrow Express service from Central London to Heathrow Airport), London Underground, and coach connections to nearby mainline rail stations, as well as private automobile (both drop off and park), rental car, taxi, local bus, and charter and intercity coach. The mode choice structure uses a multi-level tree to account for the complex pattern of public modes and alternative rail services, with the modes grouped in a different tree structure for each market segment. A representative choice structure for one of the market segments is shown in Figure 5, and details of the choice structure for the other market segments are included in Appendix D, which can be found in the web version of this report. The utility functions for each mode use a generalized cost approach that considers travel time, out-of-pocket costs, and time penalties for interchanges, with all costs converted to equivalent minutes of travel time.

The airport employee mode choice model is discussed further in the following section on airport employee travel choice.

Other Recent Studies

In addition to the foregoing nine models, the survey of airport authorities, MPOs, and consultants discussed in the next chapter identified several other recent airport access modeling studies that are not discussed in any detail in this report owing to limited technical documentation.

In 2002, the North Central Texas Council of Governments (NCTCOG), together with the Dallas/Fort Worth International Airport, Dallas Area Rapid Transit, and Fort Worth Transportation Authority completed a Major Investment Study to evaluate potential rail links to the Dallas/Fort Worth International Airport (DMJM Aviation, Inc. 2002). As part of the study, ridership estimates were prepared for a range of project alternatives that included shuttle bus links to existing commuter rail lines near the airport as well as direct commuter rail service to the airport and extension of a regional light rail system to the airport. The demand modeling was undertaken by the NCTCOG using its regional travel demand

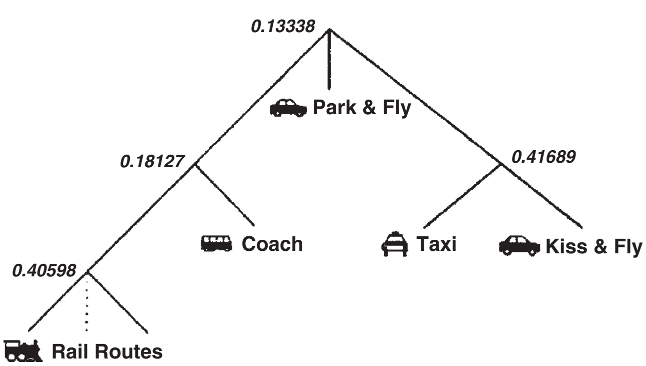

FIGURE 5 SERAS model—Representative mode choice structure: U.K. Business Passengers on International Trips (*Source:* Halcrow Group 2002b).

model that incorporates an airport trip special-generator model (*Dallas–Fort Worth Regional* . . . 2007). This model generates home-based non-work and non-home-based trips corresponding to the forecast air passenger traffic at the airport. These trips are then added to other regional trips in each category to determine the overall distribution of regional trips before mode choice analysis and trip assignment to the regional transportation network. Airport employment is handled through the regular home-based work trip generation process. The mode choice models do not treat airport trips differently from other trips in each trip category (Cambridge Systematics 2005).

Following the 9-11 attacks on the World Trade Center in New York, the Lower Manhattan Development Corporation was established to rebuild Lower Manhattan and create a sense of place that would revitalize the economy of the area. To improve the transportation links to Lower Manhattan, the Lower Manhattan Development Corporation, in cooperation with the Metropolitan Transportation Authority, the Port Authority of New York & New Jersey, and the New York City Economic Development Corporation, undertook a feasibility study of alternative ways to provide a new rail link between Lower Manhattan and suburban commuter markets in Long Island and John F. Kennedy International Airport (Parsons/SYSTRA Engineering 2004). Following an identification and screening process of potential project alternatives, two alternatives were selected for further analysis: a new tunnel under the East River between Lower Manhattan and Brooklyn and the use of the existing Montague Street tunnel and realignment of existing subway services. Both alternatives have a number of potential variants. As part of the on-going environmental analysis of these alternatives, a more detailed ridership analysis is being undertaken to evaluate the likely use of the proposed service by airport travelers under the various project alternatives being considered.

In 2005, the Aéroports de Montréal undertook a feasibility study for establishing a rail shuttle between the city center of Montréal and Montréal–Trudeau International Airport (Guilbault et Associés 2005). The rail link would operate largely over existing tracks of the Canadian National Railway from the Central Station in Montréal to the vicinity of the airport. The study involved a stated preference survey of 1,000 air passengers at Montréal–Trudeau International Airport and a further 200 air passengers at Montréal–Mirabel International Airport, the results of which were used to develop a mode choice model to predict the likely ridership on the rail shuttle at varying train frequencies and fare levels.

In July 2000, the Sacramento Area Council of Governments published the findings of a study of transit access to the Sacramento International Airport (*Sacramento International* . . . 2000). This study reviewed the findings of prior studies addressing the feasibility of extending the Sacramento light rail system to the airport through a developing area to the north of the city known as the Natomas Basin. The study recommended that the Sacramento Regional Transit District pursue more detailed analysis of the feasibility of an extension of the light rail system to North Natomas and the airport and to preserve the right-of-way identified in prior studies. In October 2001, the Regional Transit District initiated the Downtown/Natomas/Airport Transit Alternatives Analysis/Draft Environmental Impact Statement and Report project. This included the development of a travel demand forecasting methodology (DKS Associates 2002), the conduct of a combined revealed preference and stated preference survey, and the development of an air passenger mode choice model (DKS Associates 2004).

AIRPORT EMPLOYEE TRAVEL CHOICE

In contrast to air passenger ground access mode choice, there has been very little attention paid to airport employee ground access mode use in the literature. In one of the earliest studies to explicitly address airport employee access trip patterns, Dunlay (1978) developed a model of airport employee vehicle trips based on information on employee shifts from a survey of airport employees at Dallas/Fort Worth International Airport. However, the model did not address mode choice and assumed that the mode split found in the survey (which was almost exclusively private vehicle use anyway) would remain constant, or at least could be adjusted from exogenous data if the model were to be applied in another situation. Instead, the objective of the model was to predict access and egress vehicle traffic flows by time of day, reflecting that airport employees do not enter or leave the airport exactly at the start and end of their shift.

A later study by Boyle and Gawkowski (1992) examined the changes in ridership on the Q3 bus in Queens, New York, when the bus route was extended to better serve employment areas at John F. Kennedy International Airport, and service was subsequently improved to provide higher frequency and earlier and later hours. Because a large part of the increase in ridership was comprised of employees at the airport, it follows that this improvement in service resulted in a change of journey-to-work mode split. However, the study did not attempt to collect data on what other modes airport employees were using either before or after the improvement in service and did not develop a formal model of airport employee access mode choice.

A subsequent paper by Riccard (1995) described an airport employee commute program at Boston Logan International Airport that was instituted to encourage employees to use alternatives to single-occupant vehicles for their journey to work. The paper contains an extensive discussion on factors that affect airport employee decisions on how to get to and from work as well as a large amount of data on airport employee commute patterns at the airport, but no formal modeling of the mode choice process.

In general, it appears that most studies addressing airport employee mode choice have simply used the journey-to-work component of the regional travel demand model for the area, considering the airport as no different from any other employment center. However, three specific models of airport employee travel have been identified in the literature. A special-purpose airport employee mode choice model was developed for the Greater London region as part of the U.K. SERAS study (Halcrow Group 2002b) and airport employee market segments were included in two mode choice models that were developed to analyze planned APM connections, one between the Oakland International Airport and the Coliseum station of the BART system (*BART–Oakland* . . . , Appendix B: Transit Ridership Procedures and Inputs 2002) and one between the San José International Airport and a nearby light rail station of the Santa Clara Valley Transportation Authority (Dowling Associates 2002). However, none of these models was estimated directly on airport employee travel data. The SERAS model was based on one developed for a different study covering the area to the south and west of London Heathrow Airport that included all journey-to-work travel, not just airport employees. The Oakland International Airport and San José International Airport models adapted regional travel demand models for home-based work trips, but calibrated these to airport employee mode use data. All three models are discussed in more detail in chapter six and the relevant sections of Appendix D (web version only).

CHAPTER FOUR

USE OF AIRPORT GROUND ACCESS MODELS IN AIRPORT PLANNING

SURVEYS OF AIRPORTS, PLANNING AGENCIES, AND OTHER ORGANIZATIONS

To better characterize the current state of practice with airport access mode choice models, as well as to identify models that may been developed for specific studies but not reported in the published literature, a survey was undertaken of airport authorities, regional and state planning agencies, federal agencies involved in airport or surface transportation planning, airport consulting firms, selected universities and other research organizations, and relevant industry associations. The survey enquired about recent airport ground transportation studies undertaken by the responding organization and whether these involved the use of formal models of airport ground access mode choice. The survey also enquired about respondents' perceptions of the usability of such models, as well as their awareness of other organizations that have experience with the use of these models.

A list of potential survey recipients was developed and reviewed with the Project Panel. This list was comprised of all U.S. large hub and medium hub airports in 2005 (defined by the FAA as those enplaning more than 1% and 0.25% of total U.S. enplaned passengers, respectively), as well as the eight largest Canadian airports, together with a sample of 47 MPOs and the aeronautics or aviation agencies for each state. Three of the state aviation agencies (Hawaii, Maryland, and Rhode Island) are also responsible for operating large or medium hub airports included in the sample and were not surveyed separately as state agencies. The sample of MPOs comprised all of those responsible for regions with a Metropolitan Statistical Area population in 2003 of one million or more, because those were felt to be the most likely to become involved in airport ground transportation planning. Although the hub size definition used by the FAA is based on enplaned passengers rather than originating passengers (who use the ground access system), those airports with a high proportion of connecting passengers are generally the larger airports that also generate a large amount of ground access trips.

In addition, the survey recipients included 42 consulting firms involved in airport planning studies and 17 academic and other researchers who were known to have an interest in airport ground transportation studies, as well as selected key staff in four federal agencies involved in airport ground transportation issues: the FAA, FHWA, FTA, and Volpe National Transportation Systems Center. The survey was also sent to three industry organizations representing airport operators, airport consultants, and airport ground transportation operators.

In addition to the survey recipients on the mailing list, an e-mail request was sent to the chairs of several TRB committees with a scope relevant to airport ground transportation or transportation modeling issues. The e-mail described the scope of the study and asked them to forward the information to the members and friends of their committees and invite any with relevant experience to participate in the survey. This generated a number of additional survey responses.

Four slightly different survey questionnaires were developed reflecting the different concerns and needs of the various types of organizations included in the survey. In addition to the online versions of the survey, the four questionnaires were prepared as Microsoft Word documents that could be downloaded from the TRB website and completed off-line. Survey recipients were given the option of responding to the survey by downloading the appropriate version of the questionnaire and returning it by e-mail, fax, or mail. The four questionnaires are found in Appendix A.

A memorandum from the ACRP staff officer responsible for the project was sent by e-mail to each survey recipient requesting their assistance with the project by participating in the survey and providing a link to the online survey and the Word version of the questionnaire. The memorandum requested survey recipients to respond within approximately 3 weeks of the initial requests. A reminder e-mail message was sent at the end of this period to those survey recipients who had not responded and several follow-up messages were sent over the subsequent weeks.

Survey Response

As of July 2, 2007, 107 responses representing 105 different organizations were received. The composition of the responses is shown in Table 1.

The overall response rate to the survey was approximately 43%. The response rate varied across the different types of organizations, from a response rate for large hub airport authorities, MPOs, and airport planning consultants of around 50% to a response rate for research organizations of approximately 30%. The response rate for state aviation agencies

TABLE 1
SURVEY RESPONSE

Type of Organization	Sample Size	Sample Responses	Other Responses	Total Responses
Airport Authorities	26	13		
Large hubs	35	15		
Medium hubs	8	3	1	
Other (Canadian)				
Subtotal	69	31	1	32
Metropolitan Planning Organizations	47	23	2	25
State Aviation Agencies	47	16		16
Federal Transportation Agencies	7	3		3
Airport Planning Consultants	42	21	3	24
Research Organizations	17	5	2	7
Industry Organizations	3	0		0
Total	232	99	8	107

was approximately 35%, whereas that for medium hub airports and federal agencies was approximately 43%. One MPO forwarded the survey request to its state DOT, which does the transportation modeling for the MPO. The resulting response has been included with the MPO responses.

The overall response to the survey was believed to be reasonable, given the specialized nature of the topic and the diverse composition of the sample. It is likely that those organizations with the most experience with airport ground access modeling would have been more inclined to respond, and indeed many respondents provided valuable information. However, the relatively small number of responses in any category limits the ability to draw any statistically robust conclusions from the survey results for different types of organizations. Nevertheless, it is believed that the survey provides a reasonable profile of the extent to which airport ground access mode choice models are used in airport landside planning and some indication of how this varies across different types and sizes of organizations.

SURVEY FINDINGS

In view of the limited number of survey responses for each type of organization, the survey findings are presented for all respondents combined, although the role of each type of organization is somewhat different. Where there appear to be significant differences between the responses to a given question across the different types of organizations this is discussed in terms of the actual count responses.

Number of Airport Ground Access and Airport Choice Studies

Of the 105 organizations responding to the survey, 57 (53%) reported that they had sponsored, undertaken, or participated in studies over the past ten years that included some analysis of airport ground access mode choice. The proportion of different types of organizations that reported some involvement in ground access studies varied considerably. Perhaps not surprisingly, most large hub and equivalent Canadian airports (13 of the 14 responding), airport consulting firms (20 of 23 responding), and researchers (6 of the 7 responding) reported involvement in studies of this nature. In the case of airport consulting firms and researchers, this may reflect that those organizations with experience of this type of study would be more likely to respond to the survey. MPOs and state aviation agencies reported a much lower level of involvement in such studies, with only 8 of the 24 MPOs that responded to the survey and only one of the 16 state aviation agencies reporting any involvement.

The survey responses identified 103 specific studies, together with some references to other studies that were too vague to identify the specific studies in question. Some responses mentioned air passenger surveys. However, these are not considered analytical studies in the sense intended by the question and are not included in the count. Several of the respondents appeared to be referring to the same study and after eliminating duplicate references the responses identified 85 separate studies, ranging from airport master planning studies through feasibility studies for improved airport ground transportation services to academic studies of air passenger ground access mode choice.

A significant number of these studies have not previously been reported in the literature, at least in a way that would allow a typical literature search to identify them as being relevant to airport ground access mode choice analysis. Therefore, the survey has been very valuable in identifying a broader range of airport ground access studies than is generally reported in existing bibliographic reviews of airport ground access issues.

The survey also asked respondents whether their organization has undertaken or participated in studies over the past ten years that have included some analysis of air passenger airport choice. Of the 105 organizations responding to the survey, 37 (35%) reported some involvement in such studies. Respondents identified 32 separate studies. Although it appears from the titles of the studies that several may not be airport choice studies in the sense intended by the question, the responses identified a number of studies that have not been previously reported in the literature.

Use of Analytical Models

Respondents were asked to state whether any of the studies involving some analysis of airport ground access mode choice made use of formal analytical mode choice models. Of the 57 respondents reporting such studies, 34 (60%) indicated that the studies involved such models and specifically identified 52 of the 85 separate studies previously reported. Thus, it appears that the use of formal mode choice models in airport ground access studies is quite widespread.

The survey also asked whether any of the studies involving analysis of airport choice made use of formal analytical models of airport ground access mode choice as a factor in airport choice decisions. Of the 37 respondents reporting such studies, 15 (41%) indicated that the studies included the use of such models and specifically identified 16 separate studies. However, three of these studies were updates of a regional transportation planning process by the same organization using the same model.

Respondents who indicated that airport ground access studies included the use of formal analytical models of mode choice were asked about the source of air passenger survey data used in the development of the models. Of the 34 respondents reporting studies involving the use of such models, 23 (68%) indicated that the models utilized data from surveys performed specifically for model development and an equal number indicated that the models used data from surveys performed for other purposes. Multiple responses were possible from a given respondent, because their responses could cover more than one study or a given study could use data from more than one survey.

The survey asked those who reported involvement in airport ground access studies that made use of formal analytical models of mode choice whether reports from any of these studies are available on their organization's website. Only five respondents indicated that this was the case, one airport authority, two MPOs, and two universities. Further investigation established that the airport authority website was an intranet site that is not accessible to the general public. The survey also asked whether reports on the air passenger survey data used in the development of the mode choice models are available on the responding organization's or another organization's website. Only five respondents (not the same five) indicated that this was the case. Thus, it appears that the majority of the studies identified in the survey are not readily available from the Internet and direct follow-up with the sponsoring organizations would generally be necessary to obtain documentation on these studies.

To determine if the use of analytical mode choice models may have increased in recent years, as well as to identify experience that may not have been reported because it occurred before the ten-year period mentioned in the earlier questions, respondents from airport authorities and MPOs were also asked if their organization had undertaken or commissioned studies prior to the last ten years that made use of formal analytical models of airport ground access mode choice. Of the 55 organizations responding to this question, 9 (16%) indicated that they had and 29 (51%) indicated that they had not. A further 17 were not sure whether they had or not. Therefore, of the 38 respondents who knew whether such studies had been done, only approximately 24% reported the use of such models in earlier studies. This is not significantly different from the percentage reporting the use of such models in studies undertaken during the past ten years (13 respondents out of 56 organizations, or approximately 23%), particularly because those who were not sure or did not answer the question may well be less likely to have undertaken such studies than those who knew either way. Therefore, there does not appear to have been a significant increase in the use of analytical models in recent years.

Satisfaction with Existing Models

The survey asked those respondents who reported the use of formal analytical models of airport access mode choice how they would characterize the current state of practice with such models based on their organization's experience. Of the 34 organizations that reported experience with the use of such models, 19 (55%) indicated that current models were adequate for their needs, 12 (35%) indicated that current models are not reliable enough, 3 (10%) indicated that current models are too complex to use, and 10 (30%) indicated that they are too costly to use (multiple responses were allowed).

Although on its face this suggests a generally high level of satisfaction with the current state of practice, it is noteworthy that seven of the eight airport authorities and all five of the MPOs reporting the use of such models indicated that current models are adequate for their needs, whereas only 5 of the 13 consulting firms reporting involvement in studies using such models indicated that current models are adequate. Because in many cases the studies using such models are performed by consultants rather than the airport authority or MPO staff, and the consultants may well be reluctant to share any concerns about the adequacy of the analysis with their clients, this may suggest that the apparent confidence in the current models by the airport authorities and MPOs could be misplaced. It is also possible that the definition of what is considered adequate varies among the different organizations.

Those respondents that reported undertaking or being involved in airport ground transportation studies that included some analysis of airport ground access mode choice but did not make use of formal analytical models of mode choice were asked for the reasons that the studies did not include the use of such modeling. Of the 22 organizations in this category that answered the question, 15 (70%) indicated that the scope of the studies did not require it, 4 (20%) indicated that there is inadequate information and guidance on the use of such models, and 3 (15%) indicated that available models are not reliable enough or too difficult to use. An additional five respondents indicated that the decision on which analytical techniques to use either was made by those performing the study or they did not know the reason.

Modeling Airport Trips in Regional Transportation Planning Process

Of the 23 MPOs that responded to the question about how they modeled airport trips in their general regional travel modeling process, 15 (65%) reported that they modeled air passenger trips using a special-generator sub-model, 5 (20%) reported that they treated air passenger trips the same way as other home-based non-work trips, and another 5 reported that they treated air passenger trips the same way as other non-home-based non-work trips. Six MPOs (25%) reported that they modeled airport employee trips using a special-generator sub-model, whereas 12 (50%) reported that they treated airport employee trips the same way as other journey-to-work trips. Three MPOs reported that they modeled air passenger trips in the regional travel modeling process but not airport employee trips, whereas four other MPOs reported that they modeled airport employee trips but not air passenger trips.

One MPO reported that airport automobile driver trips were modeled using exogenous trip tables that are developed from air passenger survey data. Future year trip tables are developed using a Fratar-type extrapolation technique (Fratar et al. 1954; Papacostas 1987) based on future year household and employment forecasts. In summary, this technique extrapolates a base year trip table to a future year by initially applying growth factors to each zonal interchange flow based on the forecast change in the characteristics of each zone and then iteratively calculating adjustment factors and applying them to the zonal interchange flows so that the flows into and out of each zone balance.

CHAPTER FIVE

STATE OF PRACTICE OF AIR PASSENGER MODE CHOICE MODELS

Although the details of the different air passenger airport access mode choice models discussed in the literature review in chapter three vary widely, it is clear that a standard of best practice has evolved, although by no means is it always followed. This chapter summarizes that standard and identifies aspects where further improvement is needed.

MODEL APPLICATION

The airport access mode choice models reported in the literature fall into four broad categories. The first category consists of academic studies where the primary objective is to develop a model that explains air passenger access travel behavior. These studies address such issues as the appropriate functional form of the model to use, variables to include, and market segmentation issues. Some recent studies have also explored alternative approaches to the traditional MNL and NL choice models.

The second category consists of models that have been developed in support of specific airport ground access planning studies, such as an evaluation of the feasibility of constructing an APM link between the airport and a nearby rail station or of extending an urban or intercity rail system to an airport. These models are often less detailed than the first category of models, possibly because the primary focus of the study is not on model development, and the time and resources available for model development are limited.

The third category consists of airport access mode choice components of models developed to explain or predict air passenger airport choice. These too often tend to be fairly simple in terms of the number of modes included in the model, the variables used, and the structure of the choice process, in part because the primary focus of the study is on airport choice rather than ground access mode choice, and many of the more detailed aspects affecting ground access mode choice (such as differences in fare and travel time for different public transportation services) have only a second-order effect on airport choice.

Finally, the fourth category of airport access mode choice models consists of the components of regional transportation planning models that are used to generate estimates of vehicle trips to and from the airports in the region. In many cases these are not true airport access models, in that they are the result of a specific effort to model these trips, but rather are simply the application of models that have been developed to predict urban travel behavior in general to account for airport trips. Given the differences between the characteristics of airport trips and other types of regional travel, it can be expected that the application of general regional travel models to predict airport trips will not produce very good results, and indeed there is a growing interest in developing airport-specific sub-models to account for these trips within the overall regional transportation modeling framework.

TECHNICAL APPROACH

Current best practice uses NL choice models with separate coefficients (and possibly including different variables) for at least four market segments:

- Resident business trips,
- Resident non-business trips,
- Non-resident business trips, and
- Non-resident non-business trips.

The modes available for resident and non-resident trips will generally be different, because non-residents do not have the option of parking a private vehicle at the airport (indeed this would make no sense because their visit to the region begins at the airport and they return to the airport at the end of their stay). On the other hand, many non-residents rent a car on their arrival at the airport to provide local transportation during their stay in the region, whereas most residents already have a car that they can use for airport trips and do not consider renting a car for their airport access or egress trip.

Revealed or Stated Preference

As discussed in chapter two, there are two different approaches to assembling the necessary data to develop airport ground access mode choice models: revealed preference and stated preference surveys. The majority of past airport access mode choice models have been developed using revealed preference techniques. However, in a number of recent studies, including ridership studies for proposed airport rail links in Chicago and Toronto, demand analysis for the planned Airport MAX Red Line extension to Portland International Airport, and a feasibility evaluation of a proposed APM link to a light rail stop at San José International Airport, stated preference studies have been done to develop model coefficients for the planned modes or services that do not yet exist, and thus are not reflected in surveys of actual mode choice.

Functional Form of the Model

Although the MNL model continues to be used in airport access mode choice models, it is becoming accepted that the NL model is generally a more appropriate formulation. The airport ground transportation system consists of a large number of different modes and sub-modes, which are likely to be viewed by a traveler as having very different substitutability. Therefore, a traveler trying to decide between parking in a close-in parking lot or a remote parking lot with a shuttle bus connection to the airport terminal is not likely to care very much about differences between bus fares and taxi rates. Conversely, a traveler trying to decide between the lower cost but longer travel time of taking transit to the airport and the higher cost but greater convenience of a taxi or shared-ride van is unlikely to care very much about differences in parking rates between on-airport and off-airport lots. It is precisely the effect of these different substitution rates that the NL model is designed to reflect. Because the private vehicle generally accounts for the majority of airport ground access trips at most airports, at a minimum an air passenger mode choice model should nest the private vehicle choice alternatives for residents of the region (drop off and park for the duration of the trip).

Although no generally accepted practice has yet emerged for how to structure the nests of a NL model, this is largely determined by the characteristics of the different modes because the primary purpose of using a NL model is to allow higher rates of substitution between modes that have similar characteristics. Therefore, it would appear logical to group private vehicle modes in one nest, with different parking options as a second-level nest, group exclusive ride on-demand modes (taxi and limousine) together in a second first-level nest, and group shared-ride scheduled modes (public transit, scheduled airport bus) together in a third first-level nest, possibly with different transit options (e.g., rail and bus) as a second-level nest. It is not clear where the door-to-door shared-ride van would best fit in this structure, as a separate mode at the top level, in the on-demand nest with taxi and limousine, or in the shared-ride nest with the scheduled modes. This may be an issue to resolve empirically by exploring which option gives the best fit to the data. Alternative access modes to scheduled services can also be included as lower-level nests to each mode.

Rental car and hotel shuttle use by non-residents is best modeled outside this choice process, because use of both modes is determined by factors that are largely independent of the service levels of other modes. Rental car use is often determined by local travel needs other than the airport egress and access trip. Therefore, visitors to the region may rent a car even if they are staying at a nearby hotel that has a free shuttle to and from the airport.

The form of the utility functions for each choice alternative will generally be a linear combination of explanatory variables with their associated coefficients. However, some variables are best entered in the utility function as an inverse or ratio. For example, the service headway of scheduled modes, which is a direct measure of average waiting time, is the inverse of the service frequency. The effect of household income may best be entered in the utility function by expressing direct travel costs as a ratio of the cost to some function of the per capita or total household income. Therefore, higher-income travelers will be less influenced by cost than lower-income travelers.

Some model developers have attempted to reflect nonlinearity in the effect of some variables (such as service frequency or income) through the use of the logarithm of the variable value in the utility function. However, there are theoretical problems with this approach and great care is needed when introducing logarithms into the specification of terms in the utility function. Although a logarithmic transformation may approximate some other function (such as the inverse) over part of the data range (with appropriate coefficients), it can differ significantly at lower and higher values. However, it can be precisely at these values that the effect of the variable on traveler behavior is most important. Therefore, it is critical to consider whether the logarithmic transformation of the variable best reflects the nonlinear effect that is desired compared with some other function.

Survey Data Used in Model Development

Although air passenger or airport employee surveys are sometimes performed primarily (or entirely) to support development of airport access mode choice models, more commonly model development makes use of surveys conducted for other purposes. However, because such models, particularly air passenger models, require detailed information on air traveler characteristics and factors likely to influence their choice of access mode, it is highly desirable that if a survey will be (or even might be) used later to support development of an airport access mode choice model, the survey questions are reviewed by modeling specialists before the survey is performed to ensure that key questions are not omitted that would later compromise the ability to develop a reasonable model.

Among the factors that are often omitted from air passenger and employee surveys, but are critical for model development, is information on household income and household composition. It is self-evident that traveler decisions between alternative access modes that offer a trade-off between travel time and cost will be influenced by their perceived value of time (even if they do not think of the decision in those terms). Because one cannot meaningfully ask survey respondents to state their value of time, the functional form of the model needs to include some measure of household income so that the values of time implied by the model coefficients will vary by income. However, as noted elsewhere in this report, willingness to pay to save time is influenced not only by the total household income, but also by how many people that income has to support. Although these questions are often omitted as intrusive or even of little relevance for other purposes to which the survey data will be put, experience has indicated that reasonable responses can be obtained if the questions are asked in the right way.

Another factor that affects airport access travel decisions is the time that a traveler begins a trip to or from the airport, both in terms of the time of day and (in the case of departing air passengers) the time remaining before their scheduled flight departure. This information can also be useful in the case of shared-ride van services to determine how much lead time the operator required to schedule other pickups, because this can affect the overall access time experienced by the traveler. Similarly, with scheduled modes, this information can provide an indication of how much margin of error travelers allow in their travel plans to avoid missing scheduled services.

Transportation Service Data

In addition to data on the characteristics of the airport travelers, mode choice model development and application requires data on the transportation service levels of the different modes. These will include travel times, fares or costs, service frequencies of scheduled modes, any walking distances involved, and network connectivity issues such as the number and type of anticipated transfers required between different services. The extent to which different explanatory variables have been included in various existing models is discussed later in this chapter.

Generally, these data are obtained from transportation network models or from published information by transportation providers, rather than by asking survey respondents. There are two reasons for this. The first is that transportation service-level data are required for all the modes included in the model and it would be too cumbersome to ask each survey respondent for their perception of the value of these service levels for every mode, and indeed they may have no idea of the details of those modes that they did not use. The second reason is that for any application of the models, different values of at least some of the transportation service levels are typically assumed, whether to reflect expected future values or to model the effect of changing the ground access system in some way, and therefore the values used in the model application can be established in a consistent way to those used in the model development.

To the extent that the traveler perception of the service levels of the various modes differs from the values used in model estimation, it is implicitly assumed in the modeling that the estimated values of the model coefficients convert the values of the service levels used in the modeling to the values perceived by the travelers. Therefore, the model coefficients serve two purposes: to adjust the values of the service levels used in the modeling to the values perceived by the travelers and to express those perceived values in terms of their contribution to the overall perceived utility of each alternative. Because it is highly likely that many airport travelers have only limited information about many of the alternatives included in the modeling, and the perception of the transportation service levels relative to the values used in the modeling may vary widely across the respondents to surveys used to develop the models, this is likely to have a significant impact on the overall ability of the model to explain the observed choices. Unfortunately, the question of how well airport traveler perceptions of the service levels of the different modes conform to the values used in modeling is one that has been largely ignored in the literature on modeling practice.

Because it is necessary to determine the transportation service levels faced by each travel party included in the modeling process, it is normal practice to define a system of analysis zones and assign the ground access trip origin of each respondent in an airport traveler survey to the appropriate analysis zone. To provide a reasonable level of precision for the ground access service levels, in particular travel times, these analysis zones cannot be too large. A fairly common practice is to use the TAZs defined for the regional travel demand model developed for general transportation planning in the region.

The relevant regional transportation planning agency will generally be able to provide the highway travel times and transit service levels (travel times and fares) from each TAZ to the airport from the regional transportation network model. The extent to which these travel times can be expressed in terms of their components (e.g., walking time, waiting time, and in-vehicle time) or different values can be provided for different times of day or different days of the week is likely to vary from agency to agency. In general, regional travel demand modeling tends to be based on average weekday conditions and distinguish between peak and off-peak travel times. However, it is not uncommon to only model one peak period (typically the morning peak).

To develop the appropriate transportation service data for the other airport access modes, such as shared-ride van services, taxis, and any scheduled airport bus services, it will be necessary to obtain the relevant service information (travel times, fares, and schedules) from the transportation providers and convert these to the analysis zone system being used. Given the number of analysis zones typically used, this can be a significant task. This task can become more complicated if some time has passed since the airport traveler survey that is being used to develop the model was performed, because transportation providers may have changed their service levels in the interval and do not always maintain good records of past service levels. One potentially useful source of information on transportation provider service levels may be the ground transportation section of the airport website, where this provides the relevant level of detail, or websites of the transportation providers. Ideally, this information would be archived whenever an airport traveler survey is done, so that it can be referred to later if the data changes; however, unfortunately this is not often done. An historical archive of some website content is available through the Internet Archive, a nonprofit organization that maintains an online web archive called the Wayback Machine (http://www.archive.org). However, this only provides the content of web pages and cannot recover information in underlying databases that may have been accessed by web pages.

Travel times by services such as taxi and limousine will generally be the same as other highway modes. Taxi fares that are distance-based can be calculated from the meter rates and highway distances obtained from the regional travel demand model network data. Shared-ride van travel times will typically depend on the number of other parties that have to be picked up after picking up the party in question and the additional travel involved. Because this will vary from air party to air party, it will be necessary to make some assumptions about the average travel times experienced from a given analysis zone. In the case of fixed-route services, such as scheduled airport bus or rail modes, consideration needs to be given to how airport travelers will access the relevant stop or station where they will board the service. In the case of nested mode choice models, the access mode to the fixed-route service may be treated as part of the choice process and will require separate travel times and costs for the different access alternatives (e.g., walk, drop off by private vehicle, taxi, and public transit). Where this secondary access choice process is not explicitly modeled, assumptions will need to be made about the access time and cost to be included in the utility function of the primary mode.

MODES INCLUDED IN MODEL

The modes to be included in an airport access model are largely determined by the modes available at the airport, although not all the modes available at an airport may be included in a given model. In particular, some modes may be combined in the model or excluded from the analysis with users assumed to be captive to the mode. The modes included in nine recent airport access mode choice models described in chapter three are shown in Table 2, together with the type of model used and the nature of the data from which the model was estimated.

Rental car and taxi are generally available at all airports. Most of the larger airports will also have some form of limousine (black car) service and some door-to-door shared-ride van service. Public transit service is likely to be very location-specific. Representation of the use of private vehicles needs to distinguish between air passengers who are dropped off at the airport and those who park the vehicle at or near the airport for the duration of the air trip, because there are significantly different costs involved and being dropped off at the airport generates additional vehicle travel for the return trip. Whether or not those dropping off or picking up air passengers park the vehicle for a time at the airport is less important and generally not addressed in mode choice models. In any event, the decision of whether or not to park is likely to be determined by factors not typically included in ground access mode choice models, such as whether the vehicle driver arrives at the airport earlier than intended.

Whether or not to model the choice of parking location by those parking for the duration of their air trip is a more difficult question. Most airports offer a choice of parking facilities, with less expensive options often involving a shuttle bus ride to reach the terminal. In many cases there are also privately operated off-airport parking lots that provide a shuttle bus service to the airport. These various facilities typically charge different daily rates. Thus, the choice of which facility to use affects the cost of the ground access trip as well as the travel time involved in the access trip. Where these choices are not explicitly included in the model, the travel time and cost assumed for parking for the duration of the air trip needs to reflect the proportional use of the different parking options, which will vary with the air trip duration.

The degree to which it is necessary to identify specific public transportation services depends to an extent on the purpose of the model. Because in general public transit tends to attract a fairly small mode share at most U.S. airports, except at those with an extensive fixed-rail system serving the airport (e.g., the Washington Metro at Ronald Reagan National Airport), it may be sufficient to consider this a single mode and assume that travelers will use the best path through the network. However, where the model will be used to evaluate specific services or analyze the market for the introduction of a new mode, it will then be necessary to identify the alternative services in more detail so that ridership on specific services can be calculated. The model developed for Boston Logan International Airport discussed earlier included rail transit, the Logan Express scheduled airport bus service from off-airport terminals in the region, and a Water Shuttle ferry that ran between the airport and downtown Boston. However, the model does not distinguish between the different Logan Express terminals. In contrast, the model developed for the SERAS study in the United Kingdom includes an explicit representation of several different types of rail services to be able to model how changes in specific rail services affect not only the overall mode share of rail but how those using rail would choose between the different services.

Two important issues to be addressed are how to incorporate rental car use and the use of a courtesy shuttle bus service

TABLE 2
MODEL TYPE AND MODES INCLUDED IN RECENT AIRPORT ACCESS MODE CHOICE MODELS

	Airport or Study								
	ATL	BOS	CHI	MIA	OAK	PDX	SJC	YYZ	UK
Year Model Developed	2002	1996	2004	1995	2001	1997	2002	2002	2002
Model Structure									
Binomial logit								*	
Multinomial logit		*			*	*	*		
Nested logit	*	*	*	*					*
Estimation Data	RP	RP	RP/SP	RP	RP	RP/SP	RP/SP	RP/SP	RP
Modes in Model									
Private vehicle—drop off	*	*	*	*		*		*	*
Private vehicle—park	*		*	*		*		*	*
Private vehicle—park ST		*							
Private vehicle—park LT		*							
Private vehicle—park OA		*							
Private vehicle—combined					*		*		
Rental car	*		*	*	*	*	*		*
Taxi	*	*	*	*	*	*	*	*	*
Limousine		*		*					
Shared-ride van				*	*	*	*		
Scheduled airport bus		*			*		*	*	
Express bus from OAT		*	*			*			*
Transit (all services)	*				*			*	
Transit (rail)		*	*	*		*	*		*
Transit (bus)				*			*		*
Intercity coach									
Airport express train			*						*
Intercity rail/coach links									*
Ferry (water shuttle)		*							
Hotel shuttle bus/van		*		*		*	*		*
Charter coach									
Other private modes			*						
Other public modes			*						

Model: ATL = Hartsfield–Jackson Atlanta International Airport (*Travel Demand* . . . 2005).
BOS = Boston Logan International Airport (Harrington 2003).
CHI = Chicago O'Hare International Airport, Chicago Midway Airport (Resource Systems Group 2004).
MIA = Miami International Airport (ICF Kaiser Engineers 1995).
OAK = Oakland International Airport (*BART–Oakland* . . . 2002).
PDX = Portland International Airport (*PDX Ground Access* . . . 1998).
SJC = San José International Airport (Dowling Associates 2002).
YYZ = Toronto Lester B. Pearson International Airport (Halcrow Group 2002a).
UK = United Kingdom SERAS study (Halcrow Group 2002b).

Notes: RP = revealed preference data; SP = stated preference data; ST = short-term (i.e., associated with air passenger drop off); LT = long-term (i.e., park on airport for duration of air trip); OA = off-airport; OAT = off-airport terminal (e.g., Logan Express service at Boston)—includes inter-airport transfer coach (London).

from nearby hotels in the model. Visitors to the region may rent a car for local travel quite independently of their airport egress and access travel decisions. Those staying at hotels with courtesy shuttle bus service are likely to use that service, because it is usually free, unless they rent a car for other reasons. Therefore, it would appear appropriate to model rental car use by visitors first and then assign visitors staying at hotels with courtesy bus service to that mode if they are not assigned to a rental car.

In some cases residents of the region may also rent cars for their airport access trip, particularly if they live some distance from the airport and will be away for some time on their air trip. Local rental car agencies may not charge a drop-off penalty for returning the car to the airport, and two one-way rentals may be much less expensive than parking their own car at the airport for the duration of their trip or using other modes. Therefore, a rental car can be included in the regular choice set for resident travelers. In general, it will have a very low probability of being chosen owing to the high fixed cost, but will become more attractive for the type of trip described earlier.

EXPLANATORY VARIABLES

Existing models differ widely in terms of the explanatory variables used in the utility functions, as well as how those variables are defined. The variables included in the nine airport access mode choice models discussed in the previous section are shown in Table 3.

All existing models include some measures of travel time and cost. However, the extent to which travel time is separated into its components (walk time, waiting time, in-vehicle travel time, and time involved in private vehicle access to public transportation services) varies. The model developed for Boston Logan International Airport estimated separate coefficients for in-vehicle time, walk and wait time (combined as out-of-vehicle travel time), and automobile access time to public transportation. The models developed for Oakland International Airport and San José International Airport to evaluate proposed APM links (*BART–Oakland* . . . 2002; Dowling Associates 2002) used separate coefficients for walk distance, waiting time, and in-vehicle time in private vehicles, buses, and light rail, although these were adopted directly from Harvey (1988). The use of separate coefficients for in-vehicle time in the different modes was intended to capture differences in the perceived comfort and convenience of rail compared with bus, as well as between private vehicle and transit. The models developed to estimate ridership on the proposed Chicago Airport Express train (Resource Systems Group 2004) used a weighted travel time, with the weight for access time, waiting time, and transfer time adjusted incrementally to obtain the best model fit. Both the Boston Logan model and the U.K. SERAS model included fixed penalties for transfers on the public transit system. The coefficient of the variable for the number of transfers in both models can be thought of as measuring the perceived disutility of a transfer in terms of the equivalent additional riding time on a non-stop service. The SERAS model distinguished between different types of transfer, such as cross-platform or those involving a level change.

In contrast, the model developed for the Portland ground access study (Bowman 1997; Cambridge Systematics 1998; *PDX Ground Access* . . . 1998) combined the different components of travel time into a single variable for total travel time without weighting any of the components. The model developed by the Atlanta Regional Commission included separate coefficients for highway travel time, transit in-vehicle time, waiting time, and walk time, although the values of these coefficients were adopted from other models and not estimated for the Atlanta region. Similarly, the model developed for the Miami Intermodal Connector project distinguished between in-vehicle time on all modes and the combination of waiting and terminal time (the time required to access the zone centroid in the transportation network), although this model also adopted coefficients from another model for a different region.

Cost and Income

Not unreasonably, most models combine costs into a single variable, although the Boston Logan model defined different cost variables depending on the income of the traveler and whether the employer was paying the cost of a business trip. However, this was simply a way to obtain different cost coefficients for each case. Several models have divided the cost by a function of the household income, although there is no consistency in what function was used.

The Boston Logan model (Harrington et al. 1996; Harrington 2003) divided respondents who paid their own travel expenses into two income categories (low and high) and estimated separate travel cost coefficients for each income category as well as for a third category of respondents whose travel expenses were paid by their employer. The Portland ground access study model (Bowman 1997; Cambridge Systematics 1998; *PDX Ground Access* . . . 1998) divided the travel costs incurred by air passengers by the natural logarithm of the household income, although this was not done for the automobile operating cost for drop-off trips.

The Oakland Airport Connector model (*BART–Oakland* . . . 2002) and the San José International Airport Model (Dowling Associates 2002) divided the travel costs for personal trips by the household income raised to the power 1.5, but did not do this for business trips.

Although each of these approaches will ensure that higher-income travelers (at least those paying their own expenses in the case of the Boston Logan model and those

TABLE 3
EXPLANATORY VARIABLES INCLUDED IN RECENT AIRPORT ACCESS MODE CHOICE MODELS

	Airport or Study								
	ATL	BOS	CHI	MIA	OAK	PDX	SJC	YYZ	UK
Continuous Variables									
Off-peak highway time	*								
Travel time (private vehicle)					*		*		
In-vehicle time (all modes)		*		*				*	
In-vehicle time (transit)	*								
In-vehicle time (rail transit)					*		*		
In-vehicle time (bus transit)					*		*		
In-vehicle time + walk time									*
Out-of-vehicle time[a]		*							
Total travel time (all modes)						*			
Weighted travel time[b]			*						
Wait time + terminal time[c]				*					
Wait time/headway	*				*		*	*	*
Walk time	*								
Walk distance					*		*		
Auto access time to transit		*							
Number of transfers		*							
Interchange penalties									*
Drop-off driver time						*			
Driving distance									*
Travel cost (all modes)		*	*	*	*	*	*	*	*
Private vehicle cost	*								
Drop off vehicle operating cost						*			
Transit fare	*								
Taxi fare	*								
Household income					*	*	*		
Dummy variables									
Air party size		*							
Baggage check-in			*						
Employer pays cost		*							
Flights/year		*							
Household income		*							
Luggage/checked bags		*						*	
Non-residence trip origin		*							
One-person travel party								*	
Use of intermediate station			*						

Model: ATL = Hartsfield–Jackson Atlanta International Airport (*Travel Demand* . . . 2005).
BOS = Boston Logan International Airport (Harrington 2003).
CHI = Chicago O'Hare International Airport, Chicago Midway Airport (Resource Systems Group 2004).
MIA = Miami International Airport (ICF Kaiser Engineers 1995).
OAK = Oakland International Airport (*BART–Oakland* . . . 2002).
PDX = Portland International Airport (*PDX Ground Access* . . . 1998).
SJC = San José International Airport (Dowling Associates 2002).
YYZ = Toronto Lester B. Pearson International Airport (Halcrow Group 2002a).
UK = United Kingdom SERAS study (Halcrow Group 2002b).

[a] Out-of-vehicle time on Boston model combined waiting time and walking time (access, transfer, and egress) as appropriate for the mode.

[b] Weighted travel time in Chicago model combined in-vehicle time and egress time with a weighted sum of access time, transfer time, and waiting time.

[c] Terminal time in Miami model used the regional travel demand model zonal terminal times that represent the additional travel time required to reach the TAZ centroid from the actual trip origin.

making personal trips in the case of the San José International Airport model) will be less sensitive to travel cost than lower-income travelers, clearly the effect on travelers of a given income level varies significantly. It is most unlikely that they all correctly reflect sensitivity to income, and those that simply classify travelers into two income categories obviously can only approximate the effect. Indeed, common sense suggests that total household income is only part of the story and the effect of household income must depend in part on the size of the household. There is clearly a huge difference between a single person making $100,000 per year and a family of six making the same annual income.

A related issue that is generally ignored is the difference of purchasing power of a given income level between residents of the area in question and visitors. Perceived values of time are likely to depend on the level of discretionary income of individual travelers, which in turn is affected by the cost of living in their home region rather than that of the region where the airport is located. Therefore, it can be expected that visitors to a region from another region where the cost of living is significantly different are likely to have different perceived values of time for a given level of per capita household income than residents of the region where the airport is located. This issue has important implications for the transferability of mode choice models from one region to another, as discussed further in chapter seven.

In view of the lack of any well-established practice regarding how best to incorporate traveler income into airport ground access mode choice models, this would seem to be a useful topic for future research.

Travel Time Components

As discussed earlier, it is widely recognized that the different components of travel time are likely to have a different disutility per minute. This is particularly true for waiting time and walking time (although this may be measured by distance rather than time). There are two approaches to addressing this. The first is to weight the various components of travel time differently before combining them into a single travel time variable for the purpose of model estimation. The second is to estimate separate coefficients for each component. The latter is preferable, because assumptions for the relative weights of different travel time components based on the experience of other models may not be appropriate for the particular situation being modeled. Some models estimate separate coefficients for travel time on different modes. This has the advantage over the use of a single travel time variable for all modes that if the relative perceived disutility of different modes varies by length of trip, this will be reflected in the estimated values of the coefficients. Only relying on ASCs to reflect differences in the perceived disutility of different modes implicitly assumes that any differences are independent of the length of the trip, which is highly unlikely.

One issue that arises with scheduled modes is how to handle the waiting time involved. There is an extensive literature on how travelers value the disutility of waiting time relative to travel time, particularly in the context of transfers between different transportation modes or services (e.g., Mohring et al. 1987; Moreau 1992; Small 1992; Chang and Hsu 2001; Hensher 2001; Lam and Small 2001). The general consensus is that waiting time has a higher disutility (higher perceived value of time savings) than in-vehicle travel time, although the ratio between the two appears to vary with circumstances, typically in the range between 1.5 and 2.5.

Some authors have argued that because the schedule is published and people will arrive a certain amount of time before departure, waiting time is effectively independent of service headway. Others have used half the service headway as the average waiting time. This is commonly referred to as schedule delay, and it is argued that although the traveler may only wait at the bus stop or station for few minutes, they have a time that they would prefer to have departed and the difference between that time and the time that they actually depart is part of the disutility of travel, even if they are actually doing something else. In the case of airport access and egress trips, this argument is quite persuasive. Airport travelers will generally take an earlier bus or train if one is not leaving at the time they would prefer to have departed, because taking a later service may cause them to miss their flight or, in the case of airport employees, be late for work. However, arriving early at the airport has relatively little value, because they are likely to just spend longer waiting in the gate lounge or for their shift to start. Similarly, in the reverse direction, any time spent waiting at the airport for the next departure from the airport is generally not usable for other activities apart perhaps from reading.

The changes in the amount of time that air travelers have to allow for airport security screening since the events of 9/11 adds a further complication to how passengers may perceive the disutility of arriving at the airport earlier than they would prefer. On the one hand, any additional time provides something of a buffer against unexpected delays in clearing security. On the other hand, if passengers are already concerned about the amount of time that they have to spend at the airport because of the need to allow enough time for security delays, they may be even more intolerant of having to arrive at the airport earlier than they would prefer owing to the waiting time while traveling to the airport.

A related issue arises from the schedule dependability when a connection is involved. If the trip to the airport involves connecting between two (or more) scheduled services, then the traveler needs to consider the possibility that if one service runs late, they may miss their planned connection and have to wait for the next departure on the subsequent segments of the trip. Therefore, the perceived schedule reliability may play an even more important role than the actual waiting time involved according to the schedule. Ironically, the less the waiting time involved in making connections according to the published schedule, the higher the probability that the traveler may miss the connection, unless the outbound services at the connecting point wait for the inbound services to arrive. This issue is not unique to airport ground access trips and arises with all scheduled transportation services.

The issue of travel time dependability is not restricted to waiting time. One advantage of rail access modes is that the travel times involved are not subject to the variability that can affect highway travel times resulting from accidents or unexpected congestion. Thus, it might be expected that the perceived disutility of each minute of travel time on a rail mode might be different from that of each minute of travel time on highway modes. Because the disutility of time spent on different modes is also affected by the level of comfort offered by the mode and other factors, such as perceptions of personal safety, it is not obvious whether on balance the higher reliability of rail modes could be offset by other factors. The use of separate coefficients for travel time on each mode allows the model estimation process to determine the relative perceived disutility. However, the more model coefficients that have to be estimated, the larger the dataset needs to be to obtain statistically significant estimates of the coefficients.

Other Variables

In addition to travel time and cost, several models have attempted to include other variables believed to influence air passenger ground access mode choice, including the amount of luggage that an air party has, familiarity with the airport, and whether the traveler or someone else is paying for the trip. Some models, such as the Boston Logan model (Harrington et al. 1996; Harrington 2003), have also included air party size as a separate variable. However, to the extent that some costs, such as transit fares, vary with the number of people in the travel party, it is generally better to address the effect of air party size through the calculation of the travel costs of the different modes, rather than try to handle this through a separate variable, which simply adds a fixed amount to the disutility of the affected modes irrespective of the actual value of the travel costs involved.

Those models that have included variables reflecting the amount of checked baggage, such as the Boston Logan model (Harrington et al. 1996; Harrington 2003), the Toronto Air Rail Link model (Halcrow Group 2002a), and the earlier work by Harvey (1988) on which the models for Oakland International Airport and San José International Airport were based, have generally found this to be a significant factor in explaining model choice. It would therefore seem desirable to include this in any airport access mode choice model, particularly if the model is to be used to study proposed services that include off-airport baggage check-in, where the attractiveness of that capability will depend on the amount of baggage that an air party has. However, some thought needs to be given to the appropriate specification of a baggage variable in the post-9/11 environment, in which there are strict limits on carry-on bags. As a result, passengers may well check a bag, even though it is not large enough to present any limitation to their use of public transportation. The widespread adoption of wheeled bags over the past decade has also reduced the difficulty of carrying bags on public transportation services.

Not surprisingly, the issue of whether any of the travel costs will be paid by someone other than the traveler was found to be a significant factor in mode choice in the Boston Logan model (Harrington et al. 1996; Harrington 2003), the only model where this has been included. Although this is not a factor that can be independently forecast and simply applies to a particular subset of respondents in a given survey sample (generally those on business trips), its inclusion in a model improves the model fit to the data and helps reduce any bias in the coefficients of other variables that might result from not considering this issue. Similarly, the Boston Logan model found that familiarity with the airport and available ground transportation services, as measured by the number of flights from the airport in the past year by the survey respondents, was a significant factor in explaining mode choice of residents of the region. Although frequency of use of an airport may be a useful indicator of familiarity with alternative ground transportation services, it is likely to be a fairly inaccurate one. Some frequent travelers may make no effort to learn about the alternative transportation options, whereas some infrequent (or even first-time) users of the airport may have researched their different options or sought advice from more frequent users. Therefore, ideally, air passenger surveys would attempt to obtain a better indication of the familiarity of respondents with alternative ground transportation services. However, it is far from clear how to do this effectively and this is an important aspect for further research, because it is self-evident that travelers will not choose services that they do not know exist.

Implied Values of Time

The ratio of the travel time coefficient to the cost coefficient can be interpreted as the implied value of time (strictly of travel time savings). These values for eight of the mode choice models described in Tables 2 and 3 and discussed in more detail in Appendix D (web only version) are summarized in Table 4. The implied travel time values for the U.K. SERAS model are not included in the table because they are expressed in pounds and were derived using a different methodology; therefore, they are not directly comparable to the U.S. experience. Because separate coefficients were estimated for the two Chicago airports in the Chicago Airport Express study, Table 4 presents the implied values of time for each airport separately.

TABLE 4
IMPLIED VALUES OF TIME FROM RECENT AIRPORT ACCESS MODE CHOICE MODELS

	Airport or Study								
	ATL	BOS	ORD	MDW	MIA	OAK	PDX	SJC	YYZ
Year of Cost Data	a	1993	2003	2003	b	c	1996	c	2002
Travel Times ($/hour)						d		e	f
Highway time		g	h	h			i		
Resident business trips	15	11	33	63	78	15	19	15	53
Resident non-business trips	13	17	25	22	78	16	29	10	29
Non-resident business trips	16	40	33	63	78	15	19	15	71
Non-resident non-business trips	12	13	25	22	78	16	30	10	34
Transit in-vehicle time		j				k		k	
Resident business trips	11	26	33	63	78	11	19	11	53
Resident non-business trips	9	7	25	22	78	12	29	7	29
Non-resident business trips	12	15	33	63	78	11	19	11	71
Non-resident non-business trips	9	9	25	22	78	12	30	7	34
Travel time (other cases)		l	m	m		n	o	n	
Resident business trips		22	92	82		20	24	20	
Resident non-business trips		38	55	57		19	37	12	
Non-resident business trips		40	92	82		20	24	19	
Non-resident non-business trips		13	55	57		19	39	11	

Model: ATL = Hartsfield–Jackson Atlanta International Airport (*Travel Demand* . . . 2005).

BOS = Boston Logan International Airport (Harrington 2003).

ORD = Chicago O'Hare International Airport (Resource Systems Group 2004).

MDW = Chicago Midway Airport (Resource Systems Group 2004).

MIA = Miami International Airport (ICF Kaiser Engineers 1995).

OAK = Oakland International Airport (*BART–Oakland* . . . 2002).

PDX = Portland International Airport (*PDX Ground Access* . . . 1998).

SJC = San José International Airport (Dowling Associates 2002).

YYZ = Toronto Lester B. Pearson International Airport (Halcrow Group 2002a).

[a]Coefficients for time and cost adopted from other models (date unspecified).

[b]Coefficients for time and cost adopted from another model (date unspecified).

[c]Coefficients for time and cost adopted from Harvey (1988), 1995 cost data.

[d]For household income (only applies to non-business trips) of $75,000/year.

[e]For household income (only applies to non-business trips) of $55,000/year.

[f]Canadian dollars.

[g]Private vehicle drop off, costs not reimbursed, low income (undefined).

[h]Weighted travel time, low household income (less than $100,000/year).

[i]For household income of $50,000/year.

[j]Costs not reimbursed.

[k]Rail transit.

[l]Private vehicle drop off, costs not reimbursed, high income (undefined).

[m]Weighted travel time, all modes, high household income ($100,000/year or more).

[n]Bus transit.

[o]For household income of $150,000/year, all modes.

In addition to the implied values of time, Table 4 shows the year for which the cost data were obtained where this is known. Because the implied value of time is obtained from the ratio of the travel time coefficient to the cost coefficient, it is expressed in dollars of the year for which the cost data were assembled from which the model was estimated. In cases where the travel time and cost coefficients were adopted directly from other models, the value of time is expressed in dollars of the year for which the cost data used in estimating those models were assembled.

For those models where household income was included in the cost term of the utility function or different cost coefficients were estimated for different income categories, the implied value of travel time is a function of income (or varies by income category). In those cases where the values of time vary with income the values shown in Table 4 have been calculated for specific household income levels.

Because the different models were estimated using cost data for different years, the values of time are not directly comparable. Furthermore, for those models where the implied value of time is a function of household income, the values shown in Table 4 have not been calculated for comparable household income levels. Even so, it is clear from Table 4 that the variation in implied value of time across the different models is much greater than can be explained by either the different year for which the cost data were obtained or differences in the household income used to calculate the implied value of time. Given the differences in model structure and explanatory variables included in the model, this is hardly surprising. Including other terms than travel time and cost in the utility functions, or changing the way that travel time is defined in the model, will change the estimated values of the travel time and cost coefficients and hence the implied values of time. However, this has important implications for the ability of the models to predict how airport travelers will respond to changes in travel time and cost of airport access modes. If other terms in the model utility functions (such as dummy variables or ASCs) are accounting for part of the perceived disutility of travel time or cost for a particular mode, the contribution of those terms to the overall disutility of the mode will not change when the values of travel time or cost are changed in a given application of the model, resulting in an incorrect prediction of the impact of the change on perceived disutility and hence on predicted mode use.

MARKET SEGMENTATION

As noted earlier, although some early models considered more limited market segmentation, it is now widely recognized that at a minimum separate airport access mode choice models should be developed for at least four market segments corresponding to residents of the region being modeled versus visitors to the region, with each segment further split into business and non-business (or personal) trips. Almost all of the recent models developed in the United States have used this approach, although the model developed for the United Kingdom the SERAS Study (Halcrow Group 2002b) to analyze surface access to airports in the London region included two additional market segments to distinguish between domestic and international trips by U.K. residents. Although this model distinguished between U.K. residents and non-U.K. residents, rather than residents of the London region and visitors to the region, the distinction is less critical than it might at first appear. Distances in the United Kingdom are such that many U.K. residents will travel to the London airports by surface modes for international trips, whereas visitors to the United Kingdom will fly in to the London airports, even if their final destination is elsewhere in the country. The inclusion of a U.K. domestic market segment accounts for travel between London and the rest of the United Kingdom. Even so, this segmentation is problematical on a number of counts, and if the distinction between domestic and international travel is considered to be important (as it might well be in the United States as well as the United Kingdom), then it would probably be desirable to distinguish between international and domestic visitors to a region as well as international and domestic travel by residents of the region, giving eight market segments rather than the six used in the SERAS study.

Although the distinction between business and personal trip purposes is widely followed, air travel forecasting practice often also makes a distinction between what is usually termed vacation travel and visiting friends and relatives travel. The factors that influence the choice of where to stay (a hotel versus a local residence) as well as the airport egress and access travel options are quite different for visitors in the two categories. This distinction is less important for residents of the region, because their airport access trip is generally unaffected by what they are going to do at the other end of their trip.

The distinction between business and personal trips is largely a reflection that travelers on business are typically not paying their own travel costs. However, it does not always follow that business travelers are less concerned about cost than non-business travelers. The airport access mode choice model developed for Boston Logan International Airport by the CTPS (Harrington et al. 1996; Harrington 2003) distinguished between business travelers paying their own out-of-pocket costs from those whose travel costs were paid by their employer. This was handled by including a separate variable in the model utility function, but it could equally well (perhaps better) be handled by defining a separate market segment.

One important consideration in choosing the number of market segments to include in a model is the implications for the number of survey responses required to obtain reliable estimates of the model coefficients. Somewhat oversimplified, the more market segments that are defined the larger the sample size needed to estimate the model. This is not always true, because a poorly specified model may need a larger data sample size to achieve a desired level of confidence for the model coefficients; therefore, adding another market segment may actually improve the model fit with a given data sample size if indeed that better reflects differences in the underlying behavior of the travelers. However, consideration also has to be given to the number of travelers in each market segment. A market segment with very few travelers will be difficult to model with any degree of confidence without a very large data sample, unless a stratified sample is somehow obtained that ensures an adequate number of responses in the data sample for each defined market segment.

MODEL PERFORMANCE

The issue of model performance is one that has largely been ignored in the literature, apart from the simplistic approach of reporting the level of significance (*t*-statistics) of the model coefficients and the overall goodness-of-fit of the model. The latter is usually expressed by the likelihood ratio, a statistical measure of overall fit of the model to the data that is quite meaningless to most users of the models. However, as suggested by Gosling (2006), what really matters is not how well the model fits the data from which it has been estimated, because the nature of the model estimation process largely forces this to be fairly good (that after all is the whole point of model estimation). Rather, what matters is how well the model predicts the airport ground access mode choice behavior when conditions change, such as the transportation services levels are improved (or degraded) or a new service is introduced. Even the stability of the model coefficients over time is an important concern if the model is to be used for forecasting (as they almost always are).

Unfortunately, there is very little discussion of these aspects in either the general literature on airport access mode choice modeling or the technical documentation of existing models. Some academic studies have selected a holdout subset of the data that they can then use to test how well the estimated model explains this subset. However, although this is better than no test at all, it still does not address many of the concerns identified previously, such as the effect of changing the transportation system or the stability of the model coefficients over time.

This issue is not unique to airport access mode choice models and there is very little literature on how well most travel demand models perform over time or when conditions change. There is a growing interest in this issue by the FTA in the context of the modeling used to support the Federal New Starts capital grant program (U.S. Federal Transit Administration 2006) and the term "reference-class forecasting" has started to come into use to describe a forecasting method that is based on the development of a so-called "outside view" of a particular project on the basis of information from a class of similar projects (Flyvberg 2005, 2007; Flyvberg et al. 2005). This approach involves placing the project in a statistical distribution of outcomes from a class of similar projects. Although the concerns that have motivated the development of reference-class forecasting are broader than simply the performance of travel demand models themselves and have as much to do with how those models are used, including the input assumptions on which forecasts are based, the approach is directly applicable to airport ground access mode choice modeling, particularly where the motivation for the development of these models is to forecast ridership on proposed new airport access links or services. The benchmark comparison analysis that was undertaken as part of the modeling for the Toronto Air Rail Link described in chapter three represents an example of this approach.

This suggests that monitoring the performance of the airport ground access system after the introduction of new services or transportation links should be a part of the project funding, so that adequate resources are available to do the necessary ongoing data collection and analysis after the project is complete, and indeed that the requirement to undertake this monitoring should be a condition of the project funding. Only by collecting data on the use of all of the ground access modes on an ongoing basis after a new service or link is opened can the changes in mode use be compared with the predictions of the mode choice models during the project planning stage and the performance of the models assessed.

However, although improved models are clearly desirable, as is a better understanding of the likely reliability of existing models; even an inaccurate model may be better than no model at all. The range of transportation alternatives that comprise the airport ground access system at most airports and the myriad traveler decisions that result in the observed pattern of access mode use are sufficiently complex that it is highly unrealistic to attempt to determine the likely effect of any significant change in the system by intuition alone. A well-constructed model is better than a guess. Even so, it is important to give appropriate consideration to likely sources of forecast error in any model application and undertake sensitive analysis to explore the possible effect of potential error in both the modeling and forecast assumptions on the model predictions. Potential sources of error include omission or incorrect representation of important explanatory variables, incorrect representation of the mode choice process implicit in the model structure, and optimism bias in selecting future values of explanatory variables. One useful approach to assessing the likely reliability of a model is to undertake a back-casting analysis that applies the model to explain observed behavior in the period before that for which the model was developed. This is particularly useful if significant changes occurred in the airport ground transportation system during that period, but may also shed light on the ability of the model to reflect the effect of changes in real costs and income levels over time.

CHAPTER SIX

AIRPORT EMPLOYEE MODE CHOICE

As discussed in the literature review in chapter two, the topic of airport employee ground access and egress mode choice has received much less attention in the literature than that of air passengers, and only one study was identified that described an airport access mode choice model developed to account for airport employee access mode choice behavior. In the case of airport employees, airport access trips are more commonly referred to as journey-to-work trips. However, these trips will be referred to as airport access trips in the following discussion for consistency with the treatment of airport access travel by air passengers.

As with air passengers, discussion of airport employee access mode choice behavior should really address both access and egress travel. However, unlike air passengers, airport employee egress mode use is likely to be the same as their access mode use. If they drive to work by private vehicle, then that constrains their choice mode for the return trip. Similarly, if they use public transportation for the journey to work, they do not generally have a private vehicle available for the return trip. Although situations may arise on an individual basis from time to time in which airport employees travel to work one way and return home another (e.g., they may come to work by public transportation but get a ride home from a co-worker), it can be expected that the effects of these irregular commute patterns will generally cancel each other out in the overall mode split.

Airport employee trips can account for a large share of the ground access trips generated by an airport, particularly for large airports that have a wide range of support activities, including air cargo handling, aircraft maintenance, and airline crew bases. An earlier TCRP study (Leigh Fisher Associates 2000) assembled data for a sample of airports on air passenger traffic and the estimated average number of daily employees working at the airport. These data are shown in Table 5, together with the ratios of average daily employees to average daily enplaned passengers and average daily originating passengers. The first ratio indicates the relationship between the number of airport employees and the overall level of airport activity, whereas the second ratio indicates the relationship between the number of airport employee airport access person-trips per day and the number of air passenger ground access person-trips per day, assuming that each employee makes one access trip per day.

The data in Table 5 show that the ratio of daily employees to enplaned passengers varies widely, from 0.13 to 0.83, with the values for major airline hub airports in the range from 0.3 to 0.6; whereas airports with predominantly origin and destination traffic generally fall in the range from 0.2 to 0.3. The high value for Oakland International is most likely the result of the presence of an on-site major sorting facility for Federal Express, which had relatively low passenger traffic compared with the other airports in the sample. The very low value for San Diego International could be the result of part of the very constrained site, which limits the opportunities for ancillary activities at the airport. The higher values for the major airline hub airports reflect the additional airline activities that occur at those airports, including maintenance activities and crew bases.

The more interesting statistics from the perspective of airport ground access are the ratios of average daily employees to average daily originating passengers. Apart from San Diego International, these range from about 0.25 in the case of predominantly origin and destination airports to a high of 1.55 for Dallas/Fort Worth International. Most of the major airline hub airports have values between 0.7 and 1.0, with Lambert–St. Louis International (which at the time was the main hub for TWA) having a ratio of 1.27. Although person-trips do not translate directly to vehicle trips owing to differing use of high-occupancy vehicles (HOV) and the additional vehicle trips resulting from air passenger drop-off and pick-up trips by private vehicle, this suggests that daily employee vehicle trips at major airline hub airports are of the same order of magnitude as vehicle trips generated by air passengers, and could be significantly higher.

The statistics given in Table 5 also provide a perspective on the relative importance of airport employee trips in the overall pattern of regional travel. A flow of 10,000 to 40,000 trips per day each way clearly has a significant impact on the regional transportation system in the vicinity of the airport, even though it may be only about 1% of the total regional journey-to-work travel (the number of average daily employee trips shown in Table 5 averages approximately 1.1% of the corresponding metropolitan area average weekday journey-to-work trips, although the ratios vary from 0.2% to 2.1% across the different metropolitan areas).

Airport employee travel to and from work differs in a number of ways from typical journey-to-work travel. Major

TABLE 5
AIRPORT EMPLOYEE ACCESS TRIP GENERATION

Airport	Enplaning Passengers 1998	Originating Passengers 1998	Average Daily Employees	Avg. Daily Employees to Avg. Pax per Day	
				Enplaned	Originating
Los Angeles International	30,826,859	18,313,990	40,000	0.47	0.80
Chicago O'Hare International	35,841,551	16,127,120	40,000	0.41	0.91
San Francisco International	19,658,626	12,531,590	31,000	0.58	0.90
Dallas/Fort Worth International	30,121,523	11,279,510	48,000	0.58	1.55
Las Vegas McCarran International	15,132,220	11,114,050	7,500	0.18	0.25
Boston Logan International	13,250,754	10,364,870	14,500	0.40	0.51
Phoenix Sky Harbor International	15,984,620	10,323,330	23,655	0.54	0.84
Seattle–Tacoma International	12,867,830	9,592,000	11,375	0.32	0.43
Denver International	18,444,540	8,956,900	17,400	0.34	0.71
San Diego International	7,453,186	6,980,960	2,600	0.13	0.14
Houston Bush Intercontinental	15,492,252	6,356,870	14,406	0.34	0.83
Tampa International	6,955,805	6,289,530	8,219	0.43	0.48
Lambert–St. Louis International	14,334,844	5,442,800	19,000	0.48	1.27
Portland International	6,487,226	5,353,170	5,000	0.28	0.34
San Jose International	5,202,502	4,861,650	3,500	0.25	0.26
Salt Lake City International	10,097,036	4,762,760	13,026	0.47	1.00
Metropolitan Oakland International	4,612,614	4,183,300	10,500	0.83	0.92
Sacramento International	3,593,647	3,521,200	2,300	0.23	0.24

Source: Leigh Fisher Associates (2000, Table 1-1). Average daily employees estimated for 1998 based on data reported by airport operators. Passenger ratios calculated by author.

Notes: Avg. = average; Pax = passengers.

airports operate 24 hours a day, 7 days a week, and as a result many employees work shifts that are significantly different from the conventional workday. In addition, airline flight and cabin crews often have multi-day duty cycles during which they are away from their crew base. It is unclear how these characteristics cause employee access mode use patterns to be different from more general journey-to-work trips represented in regional travel demand models. Although there may be other trip generators in a region that have similar work shift patterns to those at the airport, these trips are probably not well handled by standard regional travel demand models either.

The survey of MPOs described in chapter three examined how airport employee access travel is handled in regional travel demand models. Although no MPOs reported the use of a special-purpose airport employee mode choice model, six reported the use of a special-generator sub-model for airport employee trips, with the majority treating airport employees the same way as other regional journey-to-work trips. This chapter therefore examines the use of special-generator sub-models for airport travel, as well as a selection of general urban journey-to-work mode choice models, to give an indication of the typical structure of such models.

MODEL APPLICATION

The application of airport employee mode choice models, whether special-purpose models, adapted special-generator sub-models, or general-purpose journey-to-work models, falls into two broad categories. The first is to predict airport employee travel patterns for airport planning studies, whether specifically oriented to employee travel or more general airport ground transportation issues. Airport employee travel accounts for a significant proportion of the vehicle trips generated by airports, particularly large airports, as well as of the ridership on transit services to and from airports. Therefore, modeling these trips forms an important part of feasibility studies for improved airport ground transportation services or infrastructure, as well as studies directed at reducing the environmental impacts of airport activities. In particular, environmental impact documentation for airport projects needs to address airport employee travel as part of considering transportation impacts. Although this can be (and often is) addressed by simply using existing mode split data from employee surveys or similar sources, to the extent that proposed projects will change the factors affecting employee choices or that proposed mitigation measures have the goal of modifying employee access mode use, it becomes necessary to have tools that can predict the resulting changes in airport employee access mode behavior.

The second category of model application is the representation of airport employee travel in general urban or regional travel modeling. Where airport employee travel is simply treated the same as any other journey-to-work trip then the only question becomes the number of employee trip ends that are assigned to the airport TAZs in the trip generation process. However, where special-purpose airport employee mode choice models or adapted special-generator sub-models for airport employee trips are used, then in addition to the models themselves consideration needs to be given to how the resulting airport employee trip patterns are integrated into the overall trip assignment process.

TECHNICAL APPROACH

In general, the airport ground access modes available to airport employees are the same as those available to air passengers, although some modes, such as rental car and drop off by private vehicle, are not likely to be used by airport employees on a regular basis, whereas other modes that may be available to airport employees, such as car pool and van pool, are not applicable to air passenger travel. This suggests that a similar modeling approach would be appropriate. Given the number of alternative modes that would need to be included in the model, as will be discussed later in this chapter, it would seem likely that a NL model would be the most appropriate structural form (at least at the current state of practice of airport access mode choice modeling). This also corresponds to the current state of best practice for general regional travel mode choice models. Because different factors influence air passenger and airport employee mode choice decisions, the explanatory variables included in the modal utility functions and the market segmentation (if any) used in airport employee mode choice models will be different from that used in models of air passenger mode choice. Pivot-point analysis, as discussed in chapter two, may be an appropriate approach for modeling employee travel where data on existing employee mode use are available.

Airport Employee Access Mode Choice Models

The literature review only identified three studies in which mode choice models were specifically developed to predict airport employee access mode use. All three studies adapted other journey-to-work mode choice models to predict airport employee mode use rather than developing an entirely new model from airport employee travel data.

SERAS Model

A special-purpose airport employee mode choice model was developed for the Greater London region as part of the U.K. SERAS study (Halcrow Group 2002b). This model was a fairly simple binary (two-mode) logit model that predicted the percentage use of private vehicle and public transport. The model used an incremental logit formulation, sometimes described as a pivot-point analysis. Rather than directly predicting the percentage of employees using private vehicles, it predicted the change in the percentage use in terms of the change in the explanatory variables. This change was then applied to the observed mode split in the base case. Mathematically there is no difference between this approach and the use of a regular logit choice model as long as the utility functions in the regular logit model have ASCs to ensure that the mode splits in the base case correspond to the observed data.

The SERAS employee mode choice model was based directly on one developed for the South and West London Transport Conference for a study covering the area to the south and west of London Heathrow Airport. It was therefore felt that this provided a good basis for the SERAS work. However, the Conference study covered all journey-to-work travel, not just airport employees, and thus the model does not include factors specific to airport employee travel (such as irregular shift times or multi-day duty cycles). The parameters used in the SERAS model were derived from an earlier revealed preference study of multi-modal travel, the details of which were not reported. It is unclear whether this earlier study comprised (or even included) airport employee travel.

Because the SERAS model included only two modes, private vehicle and public transport, no account was taken of factors influencing shared-ride behavior. However, the costs and travel times involved in using public transport were obtained from a public transport network model that took into account interchanges between different services (such as mainline rail, London Underground, and local bus). Therefore, the use of different public transport modes is included in the model by implication. The model used a generalized cost approach with separate travel time coefficients for access and egress time, waiting time, and in-vehicle time. In addition, public transport travel times included a constant for travel on each mode, termed a boarding penalty, which reflected relative preferences for different modes. Each bus journey incurred a boarding penalty of 7.5 min, whereas each journey by rail, light rail transit, or guided bus incurred a boarding penalty of 2.5 min. The boarding penalties were added together if a trip involved a change of mode. However, there were no penalties for an interchange within a mode, apart from any waiting time involved. Costs were combined into a single variable. Costs and times were converted to a generalized cost by multiplying travel times by an assumed average value of time. The same value was used for all employees, because the model was applied at the level of an analysis zone rather than individual employee.

Oakland Airport Connector Model

As part of the analysis for the preparation of an Environmental Impact Report/Environmental Impact Statement for a planned APM connection between the Oakland International Airport and the Coliseum station of the BART system, located approximately 2.5 miles from the airport, an airport access mode choice model was developed and applied to generate ridership projections for the APM connection, termed the Oakland Airport Connector (*BART–Oakland* . . . 2002, Appendix B: Transit Ridership Procedures and Inputs). The mode choice model comprised five market segments covering four air passenger market segments and an airport employee segment.

The airport employee segment of the mode choice model considered only two modes, private vehicle and transit, and used the same coefficient value for both highway and transit travel time, including rail and bus. In addition to travel time, the utility functions included walking distance, waiting time, and cost. The coefficient values were not estimated from employee survey data, but were adapted from the regional travel demand model developed by the MTC, using the mode choice model coefficients for home-based work trips. The ASC for transit does not correspond to the MTC model coefficients and appears to have been estimated to make the transit mode share match observed data for airport employees.

However, the MTC model includes seven modes and several other explanatory variables, including household income and vehicle ownership. It could be expected that excluding these variables from the model would change the appropriate values of the other coefficients, because the behavioral explanation that they provide in the MTC model would now have to be accounted for by the remaining variables. The likely impact of this on the performance of the model is unclear. Furthermore, the MTC mode choice model was estimated using constant 1990 dollars for travel costs. Applying these model coefficients to costs in 1999 dollars, as appears to have been done in the analysis, without making any adjustments for inflation would overstate the effect of cost in mode choice decisions.

A more detailed discussion of this model is provided in Appendix D (web version only) and additional information on the MTC home-based work mode choice model is given later in this chapter.

San José International Airport Model

A very similar approach to that used to model airport employee travel in the Oakland Airport Connector study was followed in a similar model that was developed about a year later for a study of the potential ridership on a planned APM that would connect San José International Airport with a nearby station of the Santa Clara Valley Transportation Authority light rail system (Dowling Associates 2002). As with the Oakland Airport Connector model, coefficients for travel time and cost were adopted from those for home-based work trips in a regional travel demand model, in this case the Santa Clara countywide transportation model, and the ASC for transit was estimated to fit the model predictions of mode use to airport employee survey data. Although details of the Santa Clara countywide model were not reviewed, it appears from the values of the coefficients that the inconsistency in the years in which the cost data was expressed in the two models may be even greater than for the Oakland Airport Connector model.

The application of the model allowed for up to four different connecting transit routes between any given analysis zone and the airport. For those routes involving the use of the APM, the ASC for transit was adjusted on the basis of the results of a stated preference survey performed as part of the study to reflect the greater reported likelihood of using transit if the APM link was available. However, the adjustment was not particularly large and the difference would be offset by a difference in fare of only 20 cents. A more detailed discussion of this model is provided in Appendix D (web version only).

Special-Generator Models

Special-generator models form part of the regional travel demand model and make use of customized techniques to predict travel to zones such as a sports stadium or airport that is not likely to be properly represented by the regular modeling process. Six of the MPOs responding to the survey described in chapter three indicated that they used a special-generator model for airport employee trips, although only one of these, the Houston–Galveston Area Council, provides any relevant information on its website. The Council commissioned a travel survey at Houston Intercontinental Airport in November 1995 to support the development of a special-generator model. This survey assembled data on air passenger ground access travel, airport employee travel, and commercial vehicle trips to and from the airport. In addition to surveys of air passengers, airport employees, and commercial vehicle drivers, traffic counts were undertaken on airport access roadways to develop expansion factors to convert the survey results to daily trips.

The airport employee survey obtained data on household and travel characteristics for 193 employees, including the number of people and workers in the household, the number and age of vehicles available, and the household income. The survey respondents reported an average of 2.4 trips to and from the airport on the travel survey day. The majority were by private vehicle, with 88% auto driver, 10% auto passenger, and 1% each transit and other. These trips were expressed in terms of the trip types used in the regional travel demand model and factored up on the basis of total airport employment to give average weekday trips by trip type.

General Regional Travel Models

The most common way to model employee travel to and from airports is to treat the airport in exactly the same way as any other TAZ in a regional travel demand model and use the trip generation, trip distribution, and mode choice sub-models to generate the number of person and vehicle trips associated with airport employee travel. Typically, an airport will be represented as single TAZ within the regional travel analysis zone system. Most regional travel demand models include separate sub-models for different types of trips, such as travel to and from work or for shopping or recreation. Most models consider journey-to-work, commonly termed home-based work (HBW), trips and assume that the reverse trip is symmetrical (although at a different time of day).

Because the focus of this report is on airport access mode choice, this section provides a brief review of current practice with HBW mode choice models in regional travel demand modeling. However, it should be noted in passing that the total number of employee trips and the resulting travel patterns on the regional transportation network depend on the trip generation and trip distribution components of the regional models as much as on the mode choice component. The extent to which the trip generation relationships incorporated in the regional model are representative of the employment at an airport is an issue that should be considered in interpreting the predictions of airport employee travel produced by a regional model. There are two aspects that may need to be addressed. The first is how well the base year employment levels implicit in the model correspond to actual employment at the airport, whereas the second is how well the model predicts the expected growth in employment at the airport in the future. The first aspect is primarily a question of how well the regional model is calibrated to the airport employment data at the TAZ level. The second aspect relates to how well the way that the regional model predicts future growth in employment corresponds to the expected growth in airport activity and employment. Where there are exogenous forecasts of future airport employment levels, such as forecasts produced by the airport authority, it may be possible to improve the predictions of future airport employee travel produced by the regional travel model by factoring the airport employee trips predicted by the regional model for future years so that the number of employee trip ends in the airport TAZ corresponds to the exogenous forecast of airport employment.

Although trip distribution issues will generally be of lesser concern than trip generation and mode choice, the airport authority will typically have data on the distribution of employee residences that can be compared with the distribution of employee trip origins predicted by the regional model trip distribution process. If the differences are significant, and this is important for a particular application such as predicting the likely demand for a new airport access service, then further adjustments to the employee travel pattern predicted by the regional model may be necessary.

A survey of MPOs recently completed by Vanasse Hangen Brustlin for TRB explored the state of practice in metropolitan area travel forecasting (Vanasse Hangen Brustlin 2007). The survey found that the great majority of the 228 MPOs responding use a trip-based four-step or similar travel forecasting process. However, although approximately 95% of the large MPOs reported that they used a mode choice model for HBW trips, overall slightly less than 50% of the MPOs modeled HBW mode choice. About three-quarters of the large MPOs use a NL models for HBW trips. The study presented data on the frequency of use of different modes in the mode choice models, but did not indicate which of these were used for HBW trips or provide any information on the explanatory variables used or how the modes were nested.

Home-Based Work Mode Choice

To illustrate the variety of model structures and explanatory variables included in typical HBW mode choice models, this section presents some technical details on five representative models for the following regions: Atlanta, Dallas/Fort Worth, the San Francisco Bay Area, Seattle, and Metropolitan Washington (the Baltimore–Washington region). Each of these models differed in a number of ways, including the modes represented, the structural form of the model, and the explanatory variables. Because of the complexity of the models, their need to reflect the different transportation facilities and geographical aspects of each region, and differences in the underlying transportation system data used to apply the models, this discussion does not cover all the details of the models, for which the interested reader is referred to the technical documentation referenced in the discussion, but rather attempts to provide a comparative overview to give a broad sense of how these models function and differ.

The principal characteristics of the five models are summarized in Table 6, which shows the model structure, the modes included in the model, and the explanatory variables used in each of the models. Four of the models were true NL models with two or more levels, whereas the fifth consisted of two linked MNL models that were estimated sequentially. The terminology varied in the documentation for the different models (e.g., some models refer to shared-ride auto trips, whereas others use the term group ride), but consistent terminology has been used in the following discussion for clarity. Therefore, the terminology in the discussion of a specific model may differ slightly from that used in the model documentation.

TABLE 6
CHARACTERISTICS OF SELECTED HOME-BASED WORK MODE CHOICE MODELS

	Regional Model				
	ARC	MTC	MWCOG	NCTCOG	PSRC
Model Structure					
Sequential multinomial logit			*		
Nested logit	*	*		*	*
Modes Included					
Drive alone	*	*	*	*	*
Shared ride 2	*	*	*	*	*
Shared ride 3	*		*		
Shared ride 3+		*		*	*
Shared ride 4+	*		*		
Transit auto access	*	*	*	*	*
Transit walk access		*	*	*	*
Bus transit walk access	*				
Rail transit walk access	*				
Bicycle		*			*
Walk		*			*
Nests					
Motorized (auto, transit)		*			
Drive alone/shared ride	*			*	
Drive alone/drive to transit					*
Shared ride			◆[a]		
Transit access	*	*			
Bus vs. rail transit	*				
Variables					
In-vehicle travel time	*	*	*	*	*
Waiting time	◆[b]	*	*	*	*
Walking time	◆[b]	*	*	*	*
Bicycle time					*
Trip cost	◆[b]	*	*	*	*
Persons/household		*		*	
Workers/household		*			
Vehicles/household		*	*		
Vehicles/worker					*
Households w/ vehicles < people				*	
Bus miles in peak hour	*				
Household income	*	*		*	
Employment density		*			
Land use mix index			*		
Sub-area dummy variables	*	*		*	*

Model: ARC = Atlanta Regional Commission (*Travel Demand* . . . 2005).
MTC = Metropolitan Transportation Commission (Purvis 1997).
MWCOG = Metropolitan Washington Council of Governments (*COG/TPB Travel* . . . 2007).
NCTCOG = North Central Texas Council of Governments (*Dallas–Fort Worth Regional Travel Model* . . . 2007).
PSRC = Puget Sound Regional Council (Cambridge Systematics 2003).

[a]Estimated as separate multinomial logit model.
[b]Coefficients adopted from other models.

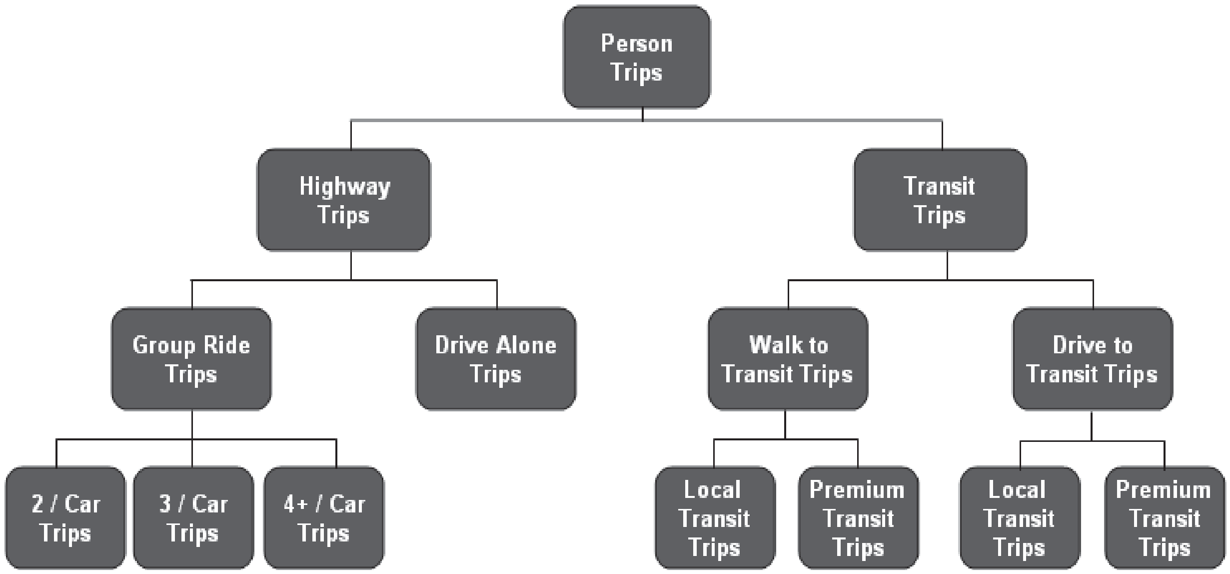

FIGURE 6 Home-based work mode choice structure—Atlanta region. (*Source: Travel Demand* . . . 2005).

All five models distinguish between single-occupant auto trips (drive alone) and at least two categories of shared-ride auto trips. Three models have three vehicle occupancy categories (drive alone, two people, and three or more people), whereas two of the models add a fourth category and distinguish between three people and four or more. The representation of transit in the models is more varied. All the models distinguish between walk access and automobile access to transit in some way; however, the details differ. Some models represent the access mode as a secondary choice, whereas others treat walk access to transit and auto access to transit as separate modes. The Metropolitan Washington model (*FY-2003 Models* . . . 2007) assumes either walk access or automobile access to transit based on the distance from the trip origin to the nearest bus stop or rail station. Transit trips beyond the assumed maximum walking distance from the nearest rail station but within walking distance of a bus stop are assumed to walk to the bus stop. Use of rail or bus then depends on the quickest path through the transit network. Two of the models included bicycle and walk the entire trip as alternatives in the choice set for some trips.

Not only did the models differ in which modes they included but the way in which the modes were nested differed across every model. The Atlanta HBW regional model (*Travel Demand* . . . 2005) divides person-trips into highway trips and transit trips at the top level and then at the second level splits highway trips into drive alone and shared-ride and transit trips into walk access and automobile access. Shared-ride auto trips are split into three vehicle occupancy categories at the third level, whereas walk access transit trips are split into local bus and rail rapid transit service (termed premium transit) trips, as shown in Figure 6. This structure implicitly assumes that the disutility involved in choosing to walk to transit depends on a lower-level choice of whether to walk to a local bus stop or walk directly to a rail station. Although some travelers indeed face this choice, most do not and have a trip end far enough from the nearest rail station that their options are to drive to the station or walk to a local bus stop. Those who choose to walk to a local bus stop may subsequently use the rail rapid transit system depending on their route through the transit network.

In contrast, the HBW mode choice model for the Seattle region (Cambridge Systematics 2003) has five modes and one composite alternative at the top level: auto, two-person shared-ride, three or more person shared-ride, walk access to transit, walk to destination, and bicycle, as shown in Figure 7. The auto composite alternative is split into drive alone and auto access to transit at the second level. This structure implicitly assumes that the disutility involved in choosing to make an auto trip depends on a lower-level choice of whether to drive alone to the destination or to an intermediate transit stop or station. In the case of automobile access to transit, the perceived disutility of the alternative will include the effect of the travel time and cost involved in riding transit.

The HBW mode choice model for the San Francisco Bay Area (Purvis 1997) lies somewhere between the Atlanta and Seattle models, as shown in Figure 8. At the top level there is a choice between motorized modes (both automobile and transit), bicycle, and walking to the destination. The motorized modes are then split into three auto modes (drive alone,

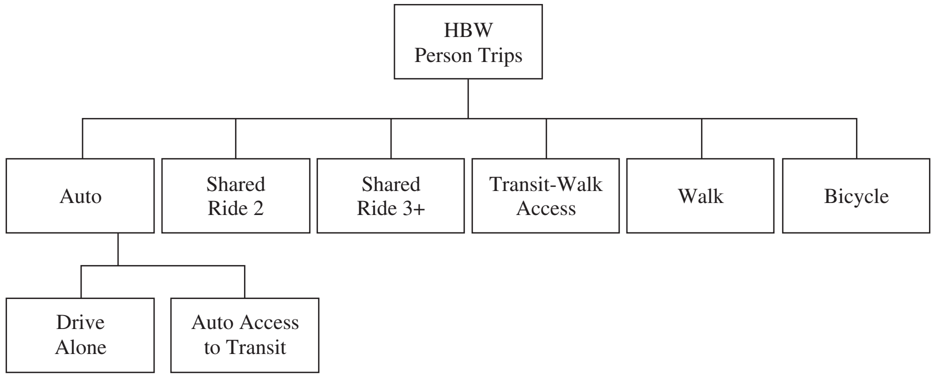

FIGURE 7 Home-based work mode choice structure—Seattle region. (*Source:* Cambridge Systematics 2003.)

two-person shared-ride, and three or more person shared-ride) and transit. At the third level, transit trips are split into automobile access and walk access. There is no explicit distinction between the use of local bus or regional rail services (BART or commuter rail); however, the use of rail depends on the path taken through the transit network.

The HBW models for the Dallas/Fort Worth region (Cambridge Systematics n.d.; *Dallas–Fort Worth* . . . 2007) and for the Metropolitan Washington region (*COG/TPB* . . . 2007) both have a somewhat simpler structure than the other three models, with only three alternatives at the top level, one of which is split into three modes at the second level. However, the modes at each level are different. The NCTCOG model has an auto composite alternative at the top level, together with walk access to transit and auto access to transit as separate modes. The auto composite alternative is then split into three modes at the second level: drive alone, two-person shared-ride, and three or more person shared-ride. The Metropolitan Washington Council of Governments (MWCOG) model has the following three alternatives at the top level: transit, drive alone, and shared-ride auto (termed group ride). As described previously, access to transit is not explicitly modeled as a mode choice, but transit trips are assumed to involve either walk access or automobile access depending on the distance to the nearest bus stop or station. The shared-ride alternative is then split into three carpool/vanpool modes at the second level for different vehicle occupancy: two-person shared-ride, three-person shared ride, and four or more person shared-ride. The split into three carpool/vanpool modes is done with a separate carpool occupancy model that is estimated independently from the top-level model. The resulting vehicle occupancy information is then used in the main model to determine the average costs for the shared-ride mode for each person.

Variables Used in Models

The range of explanatory variables included in the utility functions of the HBW models varies from region to region, as indicated by Table 6. Furthermore, not all variables used in a given model are used in the utility function for each mode because many of the variables, such as waiting time or bicycle travel time, are only relevant for some modes. Other variables that are not mode-specific, such as measures of vehicle ownership, have been found to provide a statistically significant contribution to the explanatory power of the model when included in the utility function for some modes but not others.

All five models include measures of in-vehicle travel time, waiting time, walking time (or walking distance), and travel cost, although the coefficients for travel time and cost in the Atlanta model were adopted from other regional models rather than being estimated from local data. Some models used the same travel time or travel cost coefficients for each mode, whereas others estimated different coefficient values

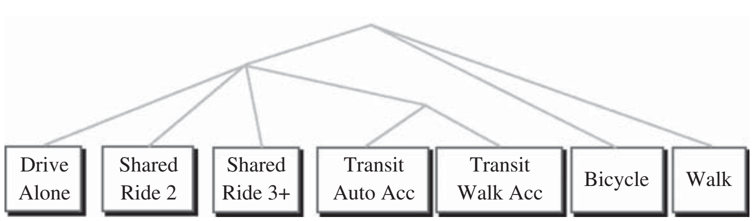

FIGURE 8 Home-based work mode choice structure—San Francisco Bay area. (*Source:* Purvis 1997.)

for different modes, typically distinguishing between transit and automobile use. Similarly, some models estimated separate model coefficients for different travel time components, such as waiting or walking, whereas others assumed that these coefficients were a fixed multiple of the in-vehicle travel time coefficient and only estimated a single coefficient for the weighted travel time. If the assumed weighting factor for the out-of-vehicle time components is incorrect, this will bias the estimated values of the coefficients for each of the travel time components.

Only three of the regional models included household income in the model in some form, and the approach varied across the models. The Bay Area model used a continuous variable for household income up to a maximum value of $25,000 in 1989 dollars. The NCTCOG model used dummy variables for low- and high-income households, defined as those with incomes of less than $30,000 or more than $75,000 in 1996 (when the household travel survey used to estimate the model was performed). Separate values of the dummy variable coefficients were estimated for each mode. The Atlanta model stratified the model estimation sample into four household income groups, with household incomes in 2000 dollars of less than $20,000, $20,000 to $49,999, $50,000 to $99,999, or $100,000 or more. Separate ASCs were estimated for each income group for each mode apart from local bus and rail rapid transit. Estimating separate ASCs is effectively the same as using a dummy variable for those income groups.

Two of the models considered employment density in the destination zone, whereas a third model used an index of land-use mix in both the origin and destination zone to explain differences in mode use behavior in different areas of the region. Four of the models used dummy variables for certain sub-areas within the region, although the way that these were defined and how extensively they were applied varied widely. The use of sub-area dummy variables provides a way to adjust the model predictions to better match observed mode shares in specific areas. Although this improves the fit of the model to the estimation data, it also implies that the other variables in the model are not adequately explaining the observed choice behavior for those areas. This could in turn lead to forecasting errors when the model is used to predict travel patterns in future years when the conditions or influences reflected by the other variables are expected to change.

Because of the differences in the way that the variables are defined in each model and of the differences in functional form, the specific values of the coefficients are not directly comparable. Similarly, differences in the years when the data were collected from which the models were estimated, as well as differences in the way that household income was (or was not) included in the models, means that implied values of travel time are also not directly comparable. The work required to reexpress this information on a consistent basis is beyond the scope of the current study.

Summary

Although the current state of practice of regional travel demand modeling is fairly consistent in broad terms among large metropolitan planning agencies, the details of how the components of this process are implemented vary widely from region to region. Therefore, the use of these models to study airport employee mode choice in a specific region should be approached with caution. There is a need for significantly more work to determine how the differences in the models could affect their ability to predict journey-to-work travel behavior of specific sub-groups of the larger regional population, such as airport employees.

MODES INCLUDED IN MODEL

Generally, the modes included in airport employee mode choice models are more limited than those for air passenger mode choice models, because many of the modes used by air passengers are not relevant to airport employee journey-to-work trips. Airport employees will not usually consider renting a car to get to work (except perhaps in the rare case where their own car is not available), whereas modes such as taxi and limousine are too expensive for use on a regular basis. Although modes such as scheduled airport bus or shared-ride door-to-door van will often be too expensive to be a viable option, the cost of using these modes may be affordable if discounted fares are available to airport employees.

On the other hand, airport employees may have access services available to them that are not available to air passengers, such as dedicated employee buses or van pools. Unlike air passengers, who generally cannot arrange to share a ride to the airport with another air party other than by the use of commercial shared-ride services, airports or airport employers often establish ride-matching services to arrange car or van pools, or airport employees may be able to make use of local ride-sharing organizations.

Given the interest of many regional transportation planning agencies in modeling shared-ride trips, as well as that in many regions the number of vehicle occupants affects the ability to use HOV lanes or avoid paying tolls, it is desirable that airport employee mode choice models identify the number of occupants in car or van pools. This is necessary anyway to be able to convert from employee trips to vehicle trips. However, where the number of occupants that are required to use HOV lanes varies for different facilities in the region, then determining an average vehicle occupancy for shared-ride trips is not sufficient and it will be necessary to distinguish between the occupancy categories that allow the use of each facility (typically shared-ride occupancy criteria are either two or more people or three or more). Although there may be no reason to distinguish between formal van pools and car pools with three or more people from the perspective of HOV lane use, it may be desirable for other reasons, such as evaluating the effectiveness of ride-sharing programs or because van pool vehicles are provided by the airport or employer.

Although airports are typically located sufficiently far from residential areas that walking is not usually a feasible access mode for the entire journey to work (as distinct from the access or egress trip from other modes), some employees may cycle to work, particularly if the airport provides facilities to encourage this. Indeed, the provision of such facilities may form part of airport ground access trip reduction or mitigation programs. Therefore, a fairly comprehensive airport employee mode choice model might include the following modes:

- Single-occupant private vehicle
- Shared-ride private vehicle—two occupants
- Shared-ride private vehicle—three or more occupants
- Van pool
- Charter bus or van
- Public transit
- Scheduled airport bus service
- Bicycle.

Depending on the application, it may also be desirable (or even necessary to estimate the model coefficients adequately) to include sub-modes such as different parking locations, different transit services, and different access or egress modes to or from the stations or stops used for public transit or other fixed-route services, as with air passenger mode choice models. Although mode choice models developed for general urban travel are increasingly incorporating a wider range of modes and many explicitly considering how transit users will access transit services, very few current models include the range of modes that are typically available to employees at a large airport. Even so, as a wider range of modes is included in the more sophisticated regional travel demand models, including different types of shared-ride trip and nonmotorized modes such as cycling, these may have an adequate degree of resolution to model airport employee trips.

As the number of different modes and sub-modes included in the model increases, so the structure of the model becomes an important issue. The MNL model is predicated on the assumption that the utility of each mode is independent of that of other modes, which is clearly not the case with many of the modes discussed earlier. This difficulty can be overcome with the use of a NL model. However, this raises the question of how best to group the modes into different nests. This is an issue that deserves further research, as evidenced by the widely different model structures used in different regional travel demand models, which is discussed later in this chapter.

Because of the timing of shift start and end times, airport employee travel may well occur at times when some modes, particularly public transportation services, are not available. This will need to be reflected in the mode choice model through constraints on mode availability. Shift times will also constrain the ability of employees to find a car or van pool at the appropriate time, and this needs to be reflected in how these modes are represented in the model.

EXPLANATORY VARIABLES

As with air passenger airport access mode choice models, airport employee mode choice models will need to include travel time and cost variables. Although costs can be aggregated into a single variable, the different components of travel time (walking, waiting, and in-vehicle time) should be expressed as separate variables to allow for the possibility of different perceived disutility of each component.

An important consideration in determining the values of explanatory variables is how to represent travel constraints arising from the timing of shifts. Where highway travel times or transit travel times, service frequency, or fares vary significantly by time of day, it will be necessary to ensure that the appropriate values are used for each employee. It may be desirable to have separate travel time variables for use of public transportation late at night to reflect differences in perceived disutility owing to concerns for personal security, in addition to greater travel time as a result of infrequent service. However, the majority of regional travel demand models provide limited resolution for differences in travel times by time of day. It is not uncommon to only model the morning commute peak and average off-peak conditions, which will not distinguish between mid-day and late night conditions. In this situation, it will not be possible to obtain the appropriate travel times directly from the regional travel demand model data files and significant adjustments may be needed to appropriately represent late night travel times on public transportation.

Where employees pay for parking (or a transit pass) through a payroll deduction, it may be desirable to use a separate variable for this cost component to allow for the possibility that employees may perceive this cost differently from a regular out-of-pocket expense. In the case of a transit pass, there is also the benefit that the pass can usually be used for other transit trips in addition to the journey to work.

Employee income level is likely to be a significant factor in mode choice and an appropriate variable should be included in the model. Employee wage rate is likely to be a more relevant measure than household income, because the latter may be unduly influenced by the income of other workers in the household.

MODELING CONSIDERATIONS

Development of airport employee access mode choice models requires both survey data on existing employee mode use patterns and service data on the costs and travel times involved in using the alternative modes available. Much of the modal service data, such as highway travel times and transit travel times and frequencies, are the same as that required for developing air passenger airport access mode choice models. However, additional data will have to be collected on employee-specific costs, such as parking fees, transit passes, and employee discounts on scheduled airport bus services, as well as information on employer-provided services such as free parking or employee charter buses.

As with air passenger airport access mode choice, the range of factors that influence the mode choice decisions of a given employee are sufficiently individual-specific that any reasonable model will have to be disaggregate in nature and predict the probability of a given employee choosing a particular mode. This implies that such a model can only be developed from fairly detailed survey data of a large enough sample of employees. In addition to information on the existing mode use, the survey needs to collect data on all the factors that might reasonably influence that choice, including the respondent's shift patterns, type of work, residence location, wage or salary level, and eligibility for any special benefits, such as free parking or transit passes, even if the respondent is not actually using that benefit.

It will also be necessary to determine the respondent's employer (or at least the type of employer), because this is important in expanding the model to predict airport access mode use patterns for all airport employees, not just the respondents to the survey. Because the survey response rate is likely to vary across employers or even departments within an organization, reflecting different managerial support for performing the survey or even willingness to participate, it will be necessary to develop expansion factors for each respondent based on the total employment within each organization or unit. Fortunately, the requirement for most airport employees to have security badges means that the airport authority usually has good data on the number of employees in each category.

Given the very limited experience developing employee access mode choice models, it is unclear how large a sample size would be necessary to estimate a reasonably accurate model. This is yet another aspect that would benefit from further research. Until this issue is better understood, based on experience with air passenger access mode choice models, an airport undertaking an employee survey for use in developing such a model should attempt to obtain as large a sample as possible, in the range of 1,000 to 3,000 responses.

Although not strictly an airport employee mode choice modeling issue, the application of an airport employee mode choice model requires an airport employee trip generation model that predicts the number of airport employees living in each TAZ and generates a representative sample of airport employee trips with their associated characteristics. Unless the employee survey responses are a very large sample of total employment, simply factoring up the employee characteristics from the survey by the ratio of the total airport employment to the survey responses will result in a trip generation pattern that has a large number of employees with identical characteristics from some TAZs and no employee trips from other zones. This will tend to overstate the potential for ridesharing, as well as bias the predicted mode use from any given zone.

This issue is not that different from regional travel demand models, which typically include a trip generation model component. However, the journey-to-work trip generation models in regional travel demand models cover all types of employment and typically do not generate individual traveler characteristics, much less those appropriate to airport employees (such as shift start and end times). Therefore, it may be desirable to generate a synthetic sample of trips using Monte Carlo simulation methods based on the distribution of airport employee characteristics obtained from an employee travel survey.

It is common practice in regional travel demand modeling to treat the airport as a single TAZ. This is reasonable within the context of the overall regional travel demand, but may not be adequate for airport planning studies, particularly where different areas of the airport may be served by different access roads. Therefore, it may be desirable to subdivide the airport into different zones and identify the level of airport employment in each zone as well as use a more refined representation of the transportation network in the vicinity of the airport. Although this will not significantly change travel times to trip origin TAZs at some distance from the airport, it may affect travel times for those employees who live closer to the airport and will be necessary to properly assign to trips to the different access routes.

MODEL PERFORMANCE

Given the limited experience with special-purpose airport employee mode choice models, there is no basis for assessing the likely performance of such models. Assessments of the overall performance of general regional travel models shed little light on their performance at predicting airport employee mode choice, because airport employees form such a small percentage of the total regional journey-to-work travel. It would of course be possible to compare the regional travel model predictions of journey-to-work mode use for the airport TAZs with data from airport employee surveys. However, no such studies have been identified. This would appear to be a promising area for further research, because it is fairly simple to do and would provide valuable information on the extent to which existing regional travel models can be used to predict airport employee mode use.

As with air passenger airport access mode choice models, assessment of the performance of existing models is critical to understanding how much reliance can be placed on their predictions and identifying the need for further improvement in these models. However, before the performance of special-purpose airport employee mode choice models can be assessed, it is first necessary to develop the models to assess. This is another area that could benefit from further research.

CHAPTER SEVEN

TRANSFERABILITY OF AIRPORT GROUND ACCESS MODE CHOICE MODELS

Given the considerable cost and effort required to develop models of airport ground access mode choice, it is natural to ask whether separate models need to be developed for every airport or whether it would be possible to adapt or apply a model developed for one airport at another. This would depend on how transferable such models are. In general, experience applying models of transportation behavior in situations that are different from the one for which they were developed has been mixed. An early study of the transferability of work-trip mode choice models (Atherton and Ben-Akiva 1976) suggested that these models might transfer fairly well. However, further work that examined model transferability issues in more detail (McFadden et al. 1977) found that whereas the evidence for transferability of work-trip mode choice model coefficients between different market segments within a region was mixed, their transferability between regions did not appear very encouraging. Subsequent work (Pas and Koppelman 1984; Badoe and Miller 1995) showed that although mode choice models appeared reasonably transferable within the same metropolitan region, the model parameters were not temporally stable. McCoomb (1986) estimated journey-to-work models for the ten largest Canadian cities using the same mode choice model specification and consistent travel data that was collected for each city using the same survey for the same day. Although the model coefficients were found to differ across the cities, some models were similar enough to lead the author to conclude that they could be transferred when the cities are reasonably similar in size, urban structure, and transportation system. The importance of consistent data as a requirement for model transferability has also been noted by Galbraith and Hensher (1982).

More recently, Rossi and Outwater (1999) undertook a comparative analysis of mode choice model parameters for home-based work, home-based non-work, and non-home-based segments of regional travel demand models for 11 U.S. metropolitan areas. The values of the parameters for a given variable were found to vary quite widely, particularly for home-based non-work and non-home-based trips. The authors undertook a simple experiment of applying the parameters for each of the regional models to a hypothetical origin-destination zone pair in some other region after obtaining ASCs for transit for the other region by fitting each model to an assumed transit share in a different origin-destination zone pair. The results showed that the estimated transit share in the test market varied from 10.2% to 19.8%, or by a factor of almost two. The authors concluded that whereas transferring mode choice model parameters may sometimes be necessary where adequate data are not available to estimate a model on local conditions, the results should be used with caution. They also stress that the complete model should always be used and not just selected coefficients, because variables may be correlated with each other.

For readers interested in more details on past work on model transferability, there is a good summary of the literature on the transferability of regional travel demand models by Karasmaa (2003).

Past studies of travel demand model transferability have focused on models of general urban travel behavior, which includes a wide range of trip purposes that are likely to be heavily influenced by the local characteristics of the transportation system, and airport ground access travel behavior may be more consistent. In principle, one would expect that air travelers would behave similarly when faced with a similar choice situation, controlling for differences in ground access service characteristics (e.g., fares or travel times) and differences in traveler characteristics (e.g., trip purpose and duration, household composition, and income). Airport access mode choice models attempt to account for the effect of these variables on the choices made by a given air party. Therefore, to the extent that a model accurately reflects the effect of these variables, it should explain the behavior of air parties in other geographic regions. However, this is a significant caveat that may well not hold for reasons discussed here.

In particular, there may be regional differences in attitudes toward the service characteristics of different modes, as well as differences in the nature of the services offered. This is likely to be a significant consideration with the use of public transit services. Air travelers living in large metropolitan areas with well-developed transit systems are more likely to consider using public transportation for a trip to the airport than those from areas with less extensive transit services and less use of transit, partly owing to familiarity and comfort with using public transportation and partly the result of differences in automobile availability. Whereas differences in service characteristics of different modes should in principle be accounted for by the explanatory variables in the model, in practice this is not necessarily the case. Misspecification of utility functions or inaccuracies in the values of service characteristics used for model estimation can result in biased values of the ASCs or coefficients of other variables that will result in biased estimates of the utilities of each mode when these coefficients are applied in different situations.

ISSUES IN MODEL TRANSFERABILITY

Because the mix of air passenger or airport employee characteristics and the details of the airport ground transportation services that are available differ widely from airport to airport, for an airport access mode choice model to be transferable it must correctly reflect the influence of the different factors that determine airport traveler ground access mode choice. If model coefficients are partly accounting for factors that are not directly associated with the variable in question (or are inherent to the mode in the case of the ASCs), then differences in these factors when the model is applied in other situations will result in biased estimates of the modal utilities and errors in the predicted probabilities of using each mode.

Although this applies to the transferability of a model from one region to another, it also applies when a model is used to analyze a significant change in the ground transportation system serving the airport for which it was developed, such as the addition of a new mode or service, as well as the application of a model to forecast future mode use, as discussed by Gosling (2006). Therefore, ensuring that models correctly reflect the factors that influence mode choice decisions not only improves their transferability to other regions, but also their use in planning studies at the airport or airports for which they were developed. This is a lot easier said than done.

In particular, model transferability is likely to be influenced by the following factors:

- Incorrect or incomplete model specification,
- Missing explanatory variables,
- Incorrect market segmentation, and
- Problems with the data used to estimate the model coefficients.

VARIABILITY IN MODEL SPECIFICATION

Although there are a fairly limited number of different airport access mode choice models that have been documented in the review of recent literature and professional practice, it is relevant to ask how consistent these models are in terms of their functional specification and use of explanatory variables. Wide variation in model specification would suggest that either the underlying behavior that they are attempting to explain varies widely from region to region or the models do not correctly reflect that behavior in their technical specification. Either way, this would suggest that they are not likely to be reliably transferable to other situations.

Functional Form

Although a number of recent models have continued to use a MNL structure, the more advanced models have used a NL structure. There are sound theoretical reasons why the NL structure should be superior to the MNL, particularly if the model attempts to include modes that are likely to be perceived as having a stronger substitutability with some alternative modes than others or to distinguish between different secondary modes that are used to access a primary mode, such as parking at an off-airport terminal compared with being dropped off by private vehicle.

Because the nesting structure of the limited number of models that have used a NL structure is very dependent on the particular modes that exist in the region being modeled, it is difficult to generalize about how the various models have grouped the modes. The model for Boston Logan International Airport developed by the Central Transportation Planning Staff (Harrington et al. 1996; Harrington 2003) adopted a hybrid structure, in which the resident models were nested but the nonresident models were not. The resident models included an automobile nest (drop off, short-term parking, and long-term parking on and off airport) and a door-to-door nest (taxi and limousine). The public transport modes (MBTA transit, scheduled bus/limousine, Logan Express, and Water Shuttle) were not nested, although that would have been redundant because there were no other modes at the top level of the tree. In contrast, the nesting structure of the SERAS Air Passenger Surface Access Model (Halcrow Group 2002b) involves up to six levels of nest, including a three-level nest of different rail options. The decision of which modes are nested together appears to have been made on the basis of what gave the model the best fit. For some market segments the use of taxi and drop off by private vehicle (termed kiss and fly) are grouped in the same second-level nest, with private vehicle parked for the trip duration (termed park and fly) at the top level, whereas for other market segments all three modes are at the top level or are grouped differently at lower levels.

However, the discussion of household income brings up an interesting issue with respect to model transferability, namely how to reflect differences in the cost of living in different regions. Although including household income in an airport access mode choice model in some way is clearly necessary if the model is to correctly reflect traveler behavior, a given income level may provide more disposable income in one region than in another. The extent to which this will influence traveler sensitivity to time and cost tradeoffs in airport access trips is unclear.

Explanatory Variables

Differences in the explanatory variables included in different airport access mode choice models, although not necessarily a problem for model transferability, do raise questions about the extent to which the model coefficients may be explaining factors not directly measured by the variables in question. The absence of studies that have taken a model estimated in one region and applied in another to compare the model predictions with the observed mode choices in the second region makes it difficult to assess how sensitive the model predictions might be in such a situation to the choice of variables included in the model. In particular, the absence of a household income variable (or equivalent measure of the perceived value of time) in many models means that such models would most likely not work well at all if applied in a situation where the distribution of household income is very different.

An ideal model would not have ASCs in the utility function because these imply that the mode will have some probability of being selected even if the values of all the continuous variables are zero. Rather, the intrinsic attributes of the mode would be expressed through appropriate continuous variables that could be adjusted for different situations. However, in practice the ASCs account for missing variables and other data problems and frequently take values that are quite large compared with the effect of the continuous variables. This is likely to be a significant problem for the transferability of these models, because the factors represented (at least in part) by the values of the ASCs are not likely to occur in the same way in another situation.

Market Segmentation

This is the aspect in which there is the most consistency in recent airport access mode choice models. It has become general practice to develop separate sub-models for four market segments (although terminology may vary slightly) comprising:

- Resident business trips,
- Resident non-business trips,
- Non-resident business trips, and
- Non-resident non-business trips.

This market segmentation recognizes that residents of the area have different airport access mode options than visitors to the region (non-residents) and that travelers on business trips may value their time differently from those on personal trips. There is also the consideration that many business travelers are able to charge their travel expenses to their employer or client. The need of some visitors to rent a car for their local travel while in the area is another important difference between residents and visitors. Once a decision is made to rent a car for other reasons, then that typically predetermines the airport access mode choice.

However, examination of recent airport access mode choice models suggests that this four-way market segmentation may be too simplistic to fully reflect the factors that shape airport access mode choice behavior. Visitors staying with friends or relatives often have access to a private vehicle for local travel (indeed, the local travel may be undertaken together with those they are visiting) as well as people who can pick them up from the airport and drop them off, whereas those staying in a hotel or visiting a business typically do not. Similarly, travelers on business who can charge their travel expenses to an employer or client may behave very differently from those who have to meet their travel expenses out of their own pocket or out of a limited travel budget. Thus, there may be significantly different behavior by someone traveling to a professional conference at their own (or their organization's) expense compared with someone attending a meeting the costs of which they can charge to a client. Although these issues have typically been handled (if at all) through the specification of the utility functions, this imposes limitations on the ability of the model to reflect the relevant behavior and it may be better to address these issues through more detailed market segmentation.

COMPARATIVE ANALYSIS OF MODEL PARAMETERS

Although the numerical value of the model coefficients in a nested or MNL model have no direct significance because they depend in part on the variance in the dataset from which they have been estimated, the ratio of two coefficients does have an interpretable meaning that can be compared across different models. The ratio of the travel time coefficient to the cost coefficient represents the implied value of travel time. Similarly, the ratio of coefficients of other variables to the travel time coefficient can be interpreted as a factor that converts the values of the other variable to equivalent minutes of travel time.

Even if the implied value of travel and other continuous variables is reasonably consistent between two models, the values of the ASCs are likely to be problematic from the perspective of the transferability of a given model. If indeed these coefficients represent intrinsic characteristics of the mode that will be similar in other situations, then using them in another situation should produce reasonable results. However, in practice they are likely to account for missing variables, model specification errors, inaccuracies in the estimation dataset, and other issues. To the extent that these are likely to be different in different situations, the use of the ASCs in the second situation would most likely generate incorrect results.

DATA CONSIDERATIONS

It is a truism that a model is only as good as the data from which it was developed and with which it is applied. This is particularly relevant to airport access mode choice models owing to the extensive amount of data that are needed to develop and apply them and because much of these data are not readily available. Errors in the data used for model estimation will result in biased model coefficients, as those coefficients attempt to explain behavior in terms of data that are incorrect. Errors in the estimation data will not typically be detected by the usual tests of model goodness-of-fit. Similarly, even if the model is estimated on valid data and the model coefficients are not biased by data problems, applying the model with incorrect data will produce incorrect results.

Potential data problems arise in both of the two broad categories of data required for their development: survey data of air passenger or airport employee characteristics and data on the transportation service levels in the airport ground access system.

Air passenger and airport employee surveys are rarely truly random samples of the underlying population, although this is often overlooked in their analysis. In particular, the logistics of performing air passenger surveys necessarily restricts the sample to a subset of the total population. Surveys are typically performed for a limited time period and often for only part of each day on which the survey takes place, owing to staffing considerations. Air passenger surveys are often done in airline gate lounges, because that is a location in which passengers are most likely to be willing to take the time to answer a survey. However, this limits the sample to passengers on specific flights traveling to a specific destination. Although an effort is typically made to survey a reasonably representative sample of flights, budget limitations on the number of flights that can be surveyed will usually result in a biased sample. This can be partly corrected by appropriate weighting techniques; however, careful thought needs to be given to how this is done. Weighting responses to correct for one issue such as the distribution of responses by flight destination can exacerbate any bias in the responses with respect to a different issue, such as the distribution of responses by time of day.

The second set of problems that can arise with air passenger and airport employee surveys relates to question wording or which questions are asked. Omitting a topic in the survey, such as the household income of the respondents, necessarily precludes including that factor in the specification of a mode choice model estimated from the data. Poorly worded questions can also introduce errors in the data. Air passengers in particular may not use the same terms to describe their trip characteristics or ground access modes used as the designers of the survey expected. For example, an air passenger may refer to a shared-ride van as a limousine (indeed some shared-ride van operators use the word limousine in the name of the service). Although these errors in individual responses may not be too serious in presenting the aggregate results of the survey, particularly where there may be offsetting errors by other respondents that reduce the overall error in the results, they can have a significant impact on the use of survey results to estimate disaggregate mode choice models that attempt to explain why individual survey respondents chose the access mode that they did.

Whereas in principle it should be fairly easy to determine the travel times and costs of using different access modes from existing data sources, such as the regional transportation planning process or airport ground transportation information systems, in practice this is often problematic and prone to error. Highway travel times vary by time of day and day of the week. Although regional transportation planning agencies are increasingly developing datasets that better reflect this variation, it is still common for planning agencies to divide the day into a limited number of time periods (e.g., the a.m. peak period, p.m. peak period, and off-peak period) and determine average weekday travel times for each period. However, airport travelers will base their ground access decisions on how long they think their trip will take at a particular time of day, which may be quite different from the travel times given by the regional transportation network datasets. Airports, particularly large airports, are typically served by a large number of private transportation providers, such as shared-ride van or limousine (black car) services, that may charge a wide range of fares that vary by the location of the trip origin as well as from provider to provider. The travel time involved in taking a shared-ride van is also influenced by how many other travel parties have to be picked up or dropped off. Basing the mode choice model estimation on travel time and cost assumptions for each mode that is different from what the travelers perceived those values to be when they made their decision will inevitably bias the model.

SUMMARY

Given the current lack of consensus over model specification and typical coefficient values between different airport access mode choice models, it can be assumed that the transferability of these models is highly suspect. Although it seems plausible that the underlying airport traveler behavior may not differ that much from region to region, after taking into account differences in air passenger or airport employee characteristics and transportation system service levels, it appears unlikely that current airport access mode choice models do this correctly, based on the significant differences between the different models.

Both because of the obvious value of being able to apply airport access mode choice models in different situations from those for which they were originally developed, as well as the concerns about the reliability of even applying them to different situations at the airports for which they were developed, there is a pressing need to better understand how well current models reflect the factors influencing the underlying travel behavior and how they can be improved to better reflect this behavior. It is not sufficient to simply say that existing models are unlikely to be transferable and that a new model must be developed for every application. This is to admit that the existing models do not properly reflect the causal structure of the underlying traveler behavior and by implication calls into question the reliability of the predictions generated by these models.

In the event that a study sponsor does not have the resources or time to develop a new mode choice model for a particular planning study where an existing model is not available and wishes to try using an existing model that was developed for another situation elsewhere, at a minimum it would be prudent to conduct validation tests of a number of candidate models by examining how well they predict recent travel behavior in the new location. Although the predictions from these models can usually be improved by adjusting the ASCs, it should be recognized that this may well be creating a false sense of confidence. What is more important is to ensure that the effects of differences in the continuous variables are properly reflected in the model predictions. If the prediction errors are reasonably consistent for each mode across all subsets of the data (e.g., by distance from the airport or across different income levels or air trip duration), then it is more likely that the model is reflecting the underlying behavior. On the other hand, even if the model correctly predicts the total number of trips using each mode but predictions for subsets of the data are wildly off, then it is very unlikely that the model will produce reasonable predictions of the likely effect of changes in the system.

CHAPTER EIGHT

INTEGRATION OF AIRPORT GROUND ACCESS MODELS IN REGIONAL PLANNING PROCESS

Although modeling airport access mode choice by air passengers and, to a lesser extent airport employees, has largely been restricted to specialized studies addressing airport landside and system planning issues, there is a growing interest in explicitly modeling such trips in the regional transportation planning process. As indicated in the survey responses discussed in chapter three, a number of MPOs have begun to address air passenger trips using a special-purpose mode choice model or special-generator sub-model and a somewhat smaller number of MPOs have begun to do the same for airport employee trips. However, a significant number continue to model trips to and from airports as regular regional travel using a standard trip classification, such as home-based non-work trips. Because these standard trip classifications encompass a very wide range of activities, most of which have very little in common with airport travel, it would be surprising if the model components did a very good job of predicting airport access mode choice. This is likely to be compounded because airport access and egress trips, by both air passengers and airport employees, typically have access to a much larger number of alternative modes than are usually modeled in regional travel demand models, such as shared-ride door-to-door van services and in some cases scheduled airport express bus services. Even taxi and limousine services, which account for a significant proportion of ground access trips at many airports, are typically not included as a separate mode in most regional travel models.

Furthermore, a significant fraction of all airport access and egress trips (as much as half or even greater at some tourist destinations) is made by visitors to the region. Most current regional travel models are only designed to model travel by residents of the region and largely ignore travel by visitors. Therefore, modes such as rental car and hotel courtesy shuttle are typically not included in the models. Although visitor trips have been considered in some activity-based microsimulation models (Bradley et al. 2001; Waddell et al. 2002) as well as in travel demand models for areas with a significant number of visitor trips, such as the Visitor Intra-CBD Model developed for the Central Area Loop Study for Cincinnati (Parsons Brinckerhoff 2001), the focus tends to be on the travel of visitors within the region rather than their travel to and from the airport. However, to the extent that intercity travel is increasing faster than intraregional travel, visitor trips will become a larger component of regional travel patterns, particularly in those areas that attract a large amount of tourist activity, and can be expected to attract greater interest in regional travel demand modeling.

Finally, the largest single air passenger access or egress mode at many airports, for both visitors and residents, is drop off and pick up by private vehicle. This option is also typically not explicitly modeled in regional travel models. Models predicting private vehicle use that are based on the assumption that the vehicle will be parked at the destination until the return trip will thus underestimate the vehicle-miles of travel involved by a factor of two.

These concerns may not be particularly important in terms of the total regional travel, because airport trips comprise a fairly small fraction of all regional trips, although it is unclear to what extent the errors tend to cancel each other out or are all in one direction. However, these issues become of much greater concern when the regional travel models are used to predict trips on parts of the transportation network in the vicinity of the airport or are used for airport access and egress studies, including predictions of airport access and egress trips for use in environmental documents.

Therefore, a fairly strong case can be made that airport access and egress trips need to be modeled separately from general regional travel patterns (or at least as a special-generator sub-model within the overall modeling framework) and then integrated with other trips in the traffic assignment process. This chapter discusses some of the issues that arise in integrating specialized airport access mode choice models into the general modeling framework and describes how these have been addressed by selected MPOs that have incorporated special-purpose airport access mode choice models or special-generator sub-models into their regional travel modeling process.

TECHNICAL CONSIDERATIONS

Most regional travel demand models are based on the well-established four-step approach of trip generation, trip distribution, mode choice, and traffic assignment, although not all regional models include all four components and implementation details differ widely (Vanasse Hangen Brustlin 2006). However, the regional travel demand models for most large metropolitan areas include all four components. Most models distinguish between home-based trips and non-home-based trips and between work trips and non-work trips. For example, the regional travel demand model for the San Francisco Bay Area (*Baycast-90 Users Guide* . . . 2004) considers the following seven types of trip for intraregional personal travel:

- Home-based work
- Home-based shop/other
- Home-based social/recreational
- Home-based school (grade school)
- Home-based school (high school)
- Home-based school (college school)
- Non-home-based.

In addition, the model considers interregional personal trips and commercial (truck) trips, although projections of each of these two types of trip are generated by a separate analysis from that used to model intraregional personal travel.

Home-based work trips are synonymous with journey-to-work trips and cover travel in both directions to the extent that the modeling process considers travel outside the morning peak period. These trips would include the journey to work by airport employees. Air passenger travel would generally be included in home-based shop/other for airport access trips by area residents from their home and in non-home-based for airport access trips by area residents from other locations (e.g., their workplace) or visitor trips. Airport access trips by visitors to the area that start from the home of a relative or friend in the area should strictly also be included in home-based shop/other. However, the trip generation relationships for home-based trips do not typically consider trips by visitors to the household.

Given the very diverse trip purposes that will be included in home-based shop/other or non-home-based trips, any consideration of air passenger trips in the trip generation models is likely to be swamped by other types of trips. Perhaps of even greater concern, the distribution of those trips to destination zones in the trip distribution step of the modeling process is likely to be driven by measures of zonal attraction that take no account of the nature of airport trips. Thus, the number of airport trips generated by the normal modeling process will probably bear little or no relationship to the actual number of air party trips. Although the number of trips attracted to the airport zone can be adjusted to correspond to the actual level of airport traffic by using artificial values of the trip attraction variables (e.g., adjusting the amount of retail space assigned to the zone), this is obviously not a very satisfactory solution because the trips attracted to the airport zone are drawn away from the other zones and there is no guarantee that the resulting distribution of airport trip ends in the region will bear any relationship to reality. Indeed, because shopping trips are generally much shorter than airport access trips, this approach is likely to bias the distribution of airport access trip ends in favor of zones closer to the airport.

This suggests that airport access trips (at least air passenger trips) need to be modeled outside the general travel modeling process and the resulting vehicle trip tables between the access trip origin or the egress trip destination zones and the airport zones added in to the trip tables for other types of trips before the traffic assignment step. This will allow an appropriate mode choice model to be used for air passenger trips. Although air passenger survey data can provide the distribution of air passenger trip ends across the region, the fairly small sample sizes typically used in such surveys will produce a relatively "lumpy" distribution of air passenger trip ends and air party characteristics, with some analysis zones having no trip ends and others having air party trips with certain combinations of characteristics but not others. Therefore, it may be desirable to generate a much larger synthetic sample using Monte Carlo simulation techniques based on the distribution of air party characteristics in the survey results and measures of zonal socio-economic characteristics. This would require the development of an air passenger trip generation model that predicts the number of air passenger trip ends in each zone based on the zonal socio-economic characteristics (such as population, household income, commercial space, and hotel rooms). The Monte Carlo simulation would then generate a synthetic sample of trips of any desired size, assigning each trip to an analysis zone based on the distribution of trip ends from the trip generation model and assigning it air party characteristics by drawing randomly from an appropriate subset of the sample of air parties in the original survey.

The extent to which existing models of home-based work trip generation, distribution, and mode choice adequately account for airport employee travel is unclear and a potential subject for future research. However, it seems likely that any inaccuracy in the application of these models to airport employee travel will be much less significant than for air passenger travel.

CASE STUDIES

The following four case studies present a range of approaches that has been followed by different MPOs that have explicitly modeled airport trips in their regional travel modeling process. They have been chosen to illustrate a number of different ways in which airport trips can be integrated within the general regional travel modeling process. These approaches vary from a special-purpose sub-model within the travel modeling process of the ARC, through the external generation of airport trip tables that are combined with the trip tables generated by the regular travel modeling process of the MWCOG, to two examples of the use of external airport access mode choice models. In the case of the Boston CTPS, an air passenger mode choice model that has been described earlier in this report was developed in-house in cooperation with the airport authority. In contrast, the Southern California Association of Governments (SCAG) utilizes a proprietary air passenger mode choice model, the output of which is then used as input to the regular regional travel modeling process.

Atlanta Regional Commission

The ARC is the MPO for the Atlanta region. The ARC has developed an APM as a component of its regional travel demand model (*Model Documentation* . . . 2005; *Travel Demand* . . . 2006). The ARC/APM enables air passenger travel to and from Atlanta Hartsfield–Jackson International Airport to be included in the overall regional travel modeling process. The details of the model are summarized in chapter three and presented in more detail in Appendix D (web version only) of this report.

The model is programmed in Fortran and can be called by the software used by the ARC to implement its regional travel demand model. This was originally programmed using Tranplan software, but has recently been converted to TP+/Cube Voyager software. The program reads highway and transit travel times and costs from standard TP+/Cube skim files and generates binary trip tables of transit passenger and vehicle trips in TP+/Cube Voyager format that can be combined with trip tables generated by the regional travel demand model for other types of trips before assigning passenger trips to the transit network and vehicle trips to the highway network in the final step of the regional travel demand modeling process.

Boston Central Transportation Planning Staff

CTPS is the MPO for the Boston metropolitan area. With support from Massport, CTPS developed an air passenger airport access mode choice model for use in a range of airport ground transportation planning studies at Boston Logan Airport. The details of the model are summarized in chapter three and presented in more detail in Appendix D (web version only) of this report.

The model is run separately from the regional travel demand model to generate estimates of air passenger and vehicle trips by regional TAZ. These trip tables are then used to include the air passenger trips in the regional transit assignment model and the vehicle trips in the regional highway assignment model as the last pre-assignment step in the CTPS Regional Travel Forecasting Model Set for Eastern Massachusetts (Harrington 2003).

Metropolitan Washington Council of Governments

MWCOG is the MPO for the Baltimore–Washington metropolitan area, which includes three large commercial service airports: Ronald Reagan Washington National Airport, Washington Dulles International Airport, and Baltimore–Washington International Airport. MWCOG conducts periodic air passenger surveys at the three airports to obtain information for use in its aviation system planning and regional travel demand modeling activities. The most recent survey was undertaken in 2005 (*2005 Washington–Baltimore* . . . 2006a).

The MWCOG travel demand modeling process distinguishes between "modeled" trips and "non-modeled" trips (*FY-2003 Models* . . . 2003). Modeled trips are those estimated from the traditional four-step transportation planning process and are based on travel data obtained from household travel surveys. Although these trips may include some air passenger trips, to the extent that households may have recorded air travel trips in the household travel survey, most air passenger trips will not be reflected in the modeled trips. Non-modeled trips are those types of trips that will not be reflected in the household travel surveys, such as trips by visitors to the region or many air passenger trips. Therefore, MWCOG estimates air passenger trip tables from the air passenger survey data outside the travel demand modeling process, converts air passenger trips to vehicle trips, divides these trip tables into the three time-of-day periods used in the regional travel demand model (a.m. peak, p.m. peak, and off-peak), and then combines the resulting vehicle trip tables with those for modeled trips and other types of non-modeled trips (such as taxi trips or trips passing through the region) before the traffic assignment step of the modeling process.

Because the MWCOG regional travel modeling process is based on an average weekday, the results of the air passenger survey are first converted into average weekday enplanements. The resulting pattern of access trips is then transposed to give the pattern of egress trips and the two trip tables are added together to give the flow in both directions. These are then divided into the time-of-day trip tables by assuming that 10% of the air passenger trips occur in the a.m. peak period and another 10% in the p.m. peak period. The projection of these trip tables to future years uses a Fratar-based approach that initially applies growth factors at the airport end of the trip based on forecasts of airport enplanements and growth factors at the other ends of the trip based on regional forecasts of households and employment and then iteratively balances the resulting flows (*FY-2006 Development* . . . 2006).

MWCOG has established the goal of improving the representation of special traffic generators, including airports, and has begun the process of developing a more formal model of airport access demand, including potentially an airport choice component (*FY-2003 Models* . . . 2003; *FY-2005 Development* . . . 2005; *FY-2006 Development* . . . 2006). As part of this effort, MWCOG staff undertook a review of airport access and airport choice modeling in eight large metropolitan regions (*FY-2003 Models* . . . 2003). The findings of this review largely parallel the information presented in this report, although some additional detail is provided on the modeling approach in some of the metropolitan areas. In particular, the review addresses airport choice modeling, which is outside the scope of this report.

Southern California Association of Governments

SCAG is the MPO for the six-county Southern California region that includes the Los Angeles basin and contains six primary commercial service airports with significant levels of airline service and several secondary commercial service airports that have some regional airline service or support air cargo activity. Since the early 1990s, SCAG has made use of a proprietary air travel demand forecasting model called the Regional Airport Demand Allocation Model (RADAM) to support its aviation planning activities (Southern California Association of Governments 2002). Although the model is primarily designed to allocate regional air travel demand to airports, it contains an airport access mode choice component and can predict vehicle trips by different modes from each analysis zone to each airport in the region. The model has undergone a number of extensions and enhancements over the years and, in addition to air passenger travel, the current version has the capability of modeling the distribution of air cargo demand among airports in the region and can consider the effect of airport capacity constraints on the allocation of demand among airports. It can also estimate vehicle-miles of highway travel resulting from airport access and egress trips and the associated vehicle emissions. However, the published documentation on RADAM is fairly limited and does not include many technical details on the model form or structure. In particular, there is very little information on the ground access mode choice component of the model.

The analysis zones used in the model (called RADAM zones) consist of aggregations of SCAG TAZs, with approximately 3,000 SCAG TAZs grouped into approximately 100 RADAM zones. This would make it difficult to directly integrate the results of the RADAM analysis into the regional travel demand model trip assignment process and that does not appear to be how the model is used. Rather, the model is run as an entirely separate activity and the aggregate results (e.g., vehicle-miles of travel and vehicle emissions) are added to the regional travel demand model results for other types of trips.

CHAPTER NINE

CONCLUSIONS AND FURTHER RESEARCH

Airport ground access and egress mode choice models play a critical role in airport landside planning studies and modeling traffic on the regional transportation system in the vicinity of airports. The ability to predict how air passenger and airport employee access and egress mode use will change in response to changes in the airport landside access system or other anticipated changes in the regional transportation system is essential to the proper evaluation of proposed measures and projects. However, these decisions are influenced by very different factors from those affecting general regional travel patterns and the range of transportation options available to airport travelers are often quite different from those for other types of regional trips. Therefore, there is a need for specialized models that can represent these mode choice decisions as well as the means to integrate these models or their output into the regional traveling modeling process.

Aside from the need to predict ground access mode use at a given airport, air passenger ground access mode choice also affects airport choice in regions served by multiple commercial airports. The relative accessibility of each airport is one of the key determinants in air passenger choice of airport (together with the air service offered at each airport) and for any given traveler the accessibility of an airport is influenced not only by the driving time needed to reach it, but also by the alternative ground transportation options that are available. In those cases where regional planners or local airport authorities wish to encourage the use of secondary airports serving the region, or to explore the feasibility of constructing a new airport, improvements to the ground access system may be one way to influence air passenger choice of airports and in turn the willingness of airlines to provide or expand air service at those airports.

As a result, the development of air passenger ground access mode choice models has been the subject of ongoing research for more than 30 years. Over this period, the state of practice has slowly evolved from relatively simple multinomial logit models to more complex nested logit models involving several levels of nesting and four or more market segments. However, no clear consensus has yet emerged as to what explanatory variables should be included or how the various modes and sub-modes should be nested. In addition, even the most recent models still have not addressed a number of problematic issues in a meaningful way. These include how to treat rental car use by non-residents of a region who often rent a car to meet local travel needs other than the airport egress and later return access trip, and how best to account for the role of household income in the mode choice process.

In addition to these technical considerations, there has been almost no attention given to how reliably existing models predict air passenger access mode use when circumstance change from those prevailing when the model development data were collected. However, because the models are typically used to predict mode use under very different conditions, including changes in the physical infrastructure or ground transportation services, there is a pressing need for more research into this aspect, as well as continuing research directed at improving the current state of practice.

In contrast to air passenger mode choice models, there has been very little effort directed at developing airport employee mode choice models. The majority of metropolitan planning organizations model airport employee trips the same way as they model any other journey-to-work trips, if indeed they model them at all. The development of better airport employee access models is a promising research opportunity.

Finally, many existing regional travel models do not explicitly model airport trips, but treat them as general regional travel. Because of the unique characteristics of airport travel and the range of transportation options typically available at airports, this is likely to give fairly poor predictions of airport mode use and the resulting vehicle trips. However, the likely magnitude of the error is not clear. Further research is needed to explore how well existing regional travel models account for airport trips and to provide guidance on how best to implement explicit modeling of airport access mode choice in the regional travel modeling process.

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GLOSSARY

Air party—group of air passengers traveling together.

Airport access trip—travel by air passengers, airport employees, or others to an airport from their home or other local trip origin.

Airport egress trip—travel by air passengers, airport employees, or others from an airport to their home or other destination.

Alternative-specific constant (ASC)—constant term in the utility function for a specific mode in a mode choice model that reflects the attributes of the mode that are not accounted for by the other variables in the utility function.

Calibration—see model calibration.

Causal variable—factor that is believed to influence the outcome of some process, such as a characteristic of a decision maker or a measure of the situation faced by that decision maker that influences the decision that is made.

Coefficient—terms in a model that assume fixed values and interact with the independent variables to predict the value of the dependent variable.

Composite alternative—an alternative in a choice model (typically a nested choice model) that represents the combined effect of several discrete sub-choices.

Continuous variable—variable in the utility function for a specific mode in a mode choice model (or indeed a variable in any model) that can assume any appropriate value.

Dependent variable—term in a model the values for which are predicted by the model based on the values of the independent variables.

Deplanements—number of passengers getting off aircraft at an airport.

Disaggregate choice model—model explaining the choice made by an individual (or group of individuals) in terms of the characteristics of that individual or group and the prevailing conditions under which the choice was made.

Dummy variable—variable that can only take the value zero or one.

Enplanements—number of passengers boarding aircraft at an airport.

Estimation—see model estimation.

Explanatory variable—independent variable describing some external factor or attribute of the process being modeled that is believed to influence or has been shown to influence the outcome of the process being modeled.

Independent variable—term in a model that can take values that can be varied independently of the values of other terms in the model.

Logarithmic transformation—conversion of a variable to the logarithm (usually the natural logarithm) of its value.

Logit model—particular form of mathematical model describing the probability of choosing an alternative from among a set of possible choices, in which the natural logarithm of the ratio of the probability of choosing one alternative to that of choosing a second alternative is equal to the difference in the value of the utility functions of the two alternatives.

Mode choice—process by which a traveler chooses the mode of transportation to use for a trip.

Mode of transportation—specific form of transportation (e.g., automobile, taxi, and public transit).

Model calibration—process of adjusting the formulation or parameters of a model so that the predictions of the model correspond to an observed outcome of the process being modeled.

Model estimation—process of determining the values of the parameters of a model that result in the model giving the best fit to a given set of data describing the process being modeled.

Monte Carlo simulation—an analysis technique in which a series of pseudo-random numbers are generated by a computer program (pseudo-random because numbers generated by a computer program cannot be truly random) and then used to select values from one or more defined statistical distributions to generate a new dataset that conforms to the statistical distribution(s).

Multinomial logit (MNL) model—form of logit model with more than two choice alternatives in which all the alternatives enter into the choice process at the same level.

Nested logit (NL) model—form of logit model in which some choice alternatives are considered to enter into the choice process as sub-choices of a higher-level choice alternative.

Originations—number of passengers boarding aircraft at an airport who have traveled to the airport by ground and are starting their directional air trip.

Pivot-point analysis—a technique in which the coefficients of a mode choice model are used to predict the proportional change in mode share from a change in some transportation service variable and then this proportional change is applied to the existing mode share to predict the new mode share.

Revealed preference model—model of behavioral choice process estimated from data on choices actually made by subjects together with data on factors believed to influence their choice process and descriptive data on alternatives available to subjects from which they made their choices.

Stated preference model—model of behavioral choice process estimated from data in which subjects select options from among hypothetical sets of alternatives for which they have been provided with comparative descriptive data.

Utility function—mathematical expression combining the effect of several causal variables into a single measure of the perceived attractiveness of a given alternative within a set of possible choices.

APPENDIX A

Survey Questionnaires

Four versions of the survey questionnaire were prepared to tailor the questions to the four types of organizations that become involved in airport ground access modeling:

- Airport Authorities
- Metropolitan Planning Organizations
- Airport Planning Consultants and Research Organizations
- State and Federal Government and Industry Organizations

Each of these questionnaires is shown in turn on the following pages.

TRB

ACRP SYNTHESIS SURVEY

Airport Ground Access Mode Choice Models

Airport Authority Survey

Survey purpose: This survey is being performed as part of a study by the Airport Cooperative Research Program (ACRP) to document the state-of-the-practice in airport ground access mode choice models. Formal models of airport ground access mode choice form a key analytical component of airport landside planning, as well as airport system planning, and are used to predict how airport users will change their access or egress mode in response to changes in the airport ground transportation system (such as changes in fares, rates, or service levels) or the introduction of new modes (such as the extension of a light rail system to the airport). Airport access trips are different from the typical trip accounted for in regional transportation planning models. Therefore, it is difficult to determine the economic feasibility of proposed projects to improve airport ground transportation or effectively manage the existing airport ground transportation system using traditional regional travel forecasting models. However, models designed to address airport ground access travel decisions are highly specialized and their technical details are often not well understood by airport managers and planners. The purpose of this survey is to gather information on the use of such models by airports and other organizations.

The final report, to be published by the Transportation Research Board, will document the technical details of existing airport ground access mode choice models together with agency assessments of their effectiveness and reliability. This report will be extremely useful to all airports and other agencies involved in airport ground transportation planning as they consider how best to analyze the effect of changing conditions and circumstances on how air passengers, airport employees, and other airport users decide to travel to and from the airport. All survey responses will be confidential.

Thank you for taking the time to participate. Instructions on returning the survey are included on the last page.

This form can be completed by typing information in the fill-in text fields and clicking the check boxes to check them. Save the file when done and return by e-mail. Alternatively, the form can be printed, filled in by hand, and returned by fax or mail.

RESPONDENT INFORMATION

Date: ____________________

Name and Title of Respondent: ____________________

Agency Name: ____________________

Respondent Telephone Number: ____________________

Respondent e-Mail Address: ____________________

AIRPORT GROUND ACCESS STUDIES

1. Has your airport undertaken or commissioned any studies in **the past 10 years** that have included some analysis of airport **ground access mode choice**?
   - ☐ Yes. *Please provide title of study or studies* (*add lines as necessary*).
     1. ____________________
     2. ____________________
     3. ____________________
   - ☐ No (*Skip to Q.8*)

2. Did any of these studies make use of formal **analytical models** of airport ground access mode choice?
   - ☐ Yes. *Please indicate which* (*using numbers from Q.1*): ____________________
   - ☐ No (*Skip to Q.7*)

3. Are reports from any of these studies available on your organization's website?
   - ☐ Yes. *Please provide website address:* ____________________
   - ☐ No

4. What was the source of air passenger survey data used in the development of these airport ground access mode choice models? (*Please check all that apply.*)
   - ☐ Surveys performed specifically for the model development
   - ☐ Surveys performed for other purposes
   - ☐ Don't know

5. Are reports on any of these surveys available on your organization's website?
   - ☐ Yes. *Please provide website address:* ______________________________
   - ☐ No

6. Based on your agency's past experience with airport ground access mode choice models, how would you characterize the current state-of-practice? (*Please check all that apply*.)
   - ☐ Adequate for our needs
   - ☐ Predictions from existing models are not reliable enough
   - ☐ Available models are too complex to use
   - ☐ Models are too costly to use except for very large studies

   Please skip to Q.8

7. What was the reason that these studies did not include any analytical modeling of airport ground access mode choice? (*Please check all that apply*.)
   - ☐ Scope of studies did not require it
   - ☐ Available models are not reliable enough
   - ☐ Available models are too difficult to use
   - ☐ There is a lack of information and guidance on the use of such models
   - ☐ Decision on analytical techniques to use was made by those performing the studies
   - ☐ Don't know

8. Has your airport undertaken or commissioned any studies **prior to** the last 10 years that made use of formal analytical models of airport ground access?
   - ☐ Yes
   - ☐ No
   - ☐ Not sure

AIRPORT CHOICE STUDIES

9. Has your airport undertaken or commissioned any studies **in the past 10 years** that have included some analysis of air passenger **airport choice**?
   - ☐ Yes. *Please provide title of study or studies* (*add lines as necessary*).
     1. ______________________________
     2. ______________________________
     3. ______________________________
   - ☐ No (*Skip to Q.11*)

10. Did any of these studies make use of analytical techniques that took **airport ground access mode choice** into consideration as a factor in airport choice?
    - ☐ Yes. *Please indicate which* (*using numbers from Q.9*): ______________________________
    - ☐ No

STUDIES BY OTHER ORGANIZATIONS

11. Are you aware of any other airports or organizations that have made use of formal analytical models of airport ground access mode choice in the course of studies or analysis addressing airport ground transportation or airport choice?
    - ☐ Yes. *Please provide name of organization*(*s*) (*list up to three*).
      1. ______________________________
      2. ______________________________
      3. ______________________________
    - ☐ No

GENERAL COMMENTS

12. Please feel free to add any comments about airport ground access mode choice models in general or the scope of this ACRP study in particular:
____
____
____
____
____

Please return by **February 23, 2007** to:

Geoffrey Gosling
Principal
Aviation System Consulting, LLC
805 Colusa Avenue
Berkeley, CA 94707
phone: (510) 528-8741
fax: (510) 528-8745
e-mail gdgosling@aol.com

We encourage you to return your completed survey via e-mail. If you have any questions on the survey or the project, feel free to contact Geoff Gosling by e-mail or phone.

THANK YOU FOR YOUR HELP

ACRP SYNTHESIS SURVEY

Airport Ground Access Mode Choice Models

Metropolitan Planning Organization Survey

Survey purpose: This survey is being performed as part of a study by the Airport Cooperative Research Program (ACRP) to document the state-of-the-practice in airport ground access mode choice models. Formal models of airport ground access mode choice form a key analytical component of airport landside planning, as well as airport system planning, and are used to predict how airport users will change their access or egress mode in response to changes in the airport ground transportation system (such as changes in fares, rates, or service levels) or the introduction of new modes (such as the extension of a light rail system to the airport). Airport access trips are different from the typical trip accounted for in regional transportation planning models. Therefore, it is difficult to determine the economic feasibility of proposed projects to improve airport ground transportation or effectively manage the existing airport ground transportation system using traditional regional travel forecasting models. However, models designed to address airport ground access travel decisions are highly specialized and their technical details are often not well understood by airport managers and planners. The purpose of this survey is to gather information on the use of such models by airports and other organizations.

The final report, to be published by the Transportation Research Board, will document the technical details of existing airport ground access mode choice models together with agency assessments of their effectiveness and reliability. This report will be extremely useful to all airports and other agencies involved in airport ground transportation planning as they consider how best to analyze the effect of changing conditions and circumstances on how air passengers, airport employees, and other airport users decide to travel to and from the airport. All survey responses will be confidential.

Thank you for taking the time to participate. Instructions on returning the survey are included on the last page.

This form can be completed by typing information in the fill-in text fields and clicking the check boxes to check them. Save the file when done and return by e-mail. Alternatively, the form can be printed, filled in by hand, and returned by fax or mail.

RESPONDENT INFORMATION

Date: ____________________

Name and Title of Respondent: ____________________

Agency Name: ____________________

Respondent Telephone Number: ____________________

Respondent e-Mail Address: ____________________

AIRPORT GROUND ACCESS STUDIES

1. Has your agency undertaken or commissioned any studies in **the past 10 years** that have included some analysis of airport **ground access mode choice**, apart from your normal travel demand modeling activities?
   - ☐ Yes. *Please provide title of study or studies* (*add lines as necessary*).
     4. ____________________
     5. ____________________
     6. ____________________
   - ☐ No (*Skip to Q.9*)

2. Did any of these studies make use of formal **analytical mode choice models** for airport ground access trips?
   - ☐ Yes. *Please indicate which* (*using numbers from Q.1*): ____________________
   - ☐ No (*Skip to Q.8*)

3. Were these mode choice models specifically developed for airport ground access travel or did you use or adapt mode choice models for general urban travel behavior? (*Please check all that apply.*)
   - ☐ Studies used special-purpose airport ground access mode choice models
   - ☐ Studies adapted special-generator sub-models designed for other types of trips
   - ☐ Studies adapted mode choice models for general urban travel to airport trips
   - ☐ Studies used mode choice models for general urban travel for airport trips

4. Are reports from any of these studies available on your organization's website?
   - ☐ Yes. *Please provide website address:* ______________________________
   - ☐ No

5. What was the source of air passenger survey data (if any) used in the development of the mode choice models for airport ground access travel? (*Please check all that apply.*)
   - ☐ Surveys performed specifically for the model development
   - ☐ Surveys performed for other purposes by this agency
   - ☐ Surveys performed for other purposes by another agency
   - ☐ No survey data used in the development of the models
   - ☐ Don't know

6. Are reports on any of these surveys available on your organization's website?
   - ☐ Yes. *Please provide website address:* ______________________________
   - ☐ No

7. Based on your agency's past experience with airport ground access mode choice models, how would you characterize the current state-of-practice? (*Please check all that apply.*)
   - ☐ Adequate for our needs
   - ☐ Predictions from existing models are not reliable enough
   - ☐ Available models are too complex to use
   - ☐ Models are too costly to use except for very large studies

   Please skip to Q.9

8. What was the reason that these studies did not include any analytical modeling of airport ground access mode choice? (*Please check all that apply.*)
   - ☐ Scope of studies did not require it
   - ☐ Available models are not reliable enough
   - ☐ Available models are too difficult to use
   - ☐ There is a lack of information and guidance on the use of such models
   - ☐ Decision on analytical techniques to use was made by those performing the studies
   - ☐ Don't know

9. Has your agency undertaken or commissioned any studies **prior to** the last 10 years that made use of formal analytical models of airport ground access?
   - ☐ Yes
   - ☐ No
   - ☐ Not sure

10. How do you model airport trips in your general regional travel modeling process? (*Please check all that apply.*)
    - ☐ Use a special-generator sub-model for air passenger trips
    - ☐ Use a special-generator sub-model for airport employee trips
    - ☐ Treat air passenger trips the same way as other home-based non-work trips
    - ☐ Treat air passenger trips the same way other non-home-based non-work trips
    - ☐ Treat airport employee trips the same way as other journey-to-work trips
    - ☐ Do not consider airport trips in regional travel modeling process
    - ☐ Other (*Please describe*): ______________________________

      ____

AIRPORT CHOICE STUDIES

11. Has your agency undertaken or commissioned any studies **in the past 10 years** that have included some analysis of air passenger **airport choice**?
    - ☐ Yes. *Please provide title of study or studies* (*add lines as necessary*).
      1. ____________________
      2. ____________________
      3. ____________________
    - ☐ No (*Skip to Q.13*)

12. Did any of these studies make use of analytical techniques that took **airport ground access mode choice** into consideration as a factor in airport choice?
    - ☐ Yes. *Please indicate which* (*using numbers from Q.11*): ____________________
    - ☐ No

STUDIES BY OTHER ORGANIZATIONS

13. Are you aware of any **other** planning agencies, airports, or organizations that have made use of formal analytical models of airport ground access mode choice in the course of studies or analysis addressing airport ground transportation or airport choice?
    - ☐ Yes. *Please provide name of organization* (*list up to three*).
      1. ____________________
      2. ____________________
      3. ____________________
    - ☐ No

GENERAL COMMENTS

14. Please feel free to add any comments about airport ground access mode choice modes in general or the scope of this ACRP study in particular.

    ____
    ____
    ____
    ____
    ____

Please return by **February 23, 2007** to:

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Principal
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Berkeley, CA 94707
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e-mail gdgosling@aol.com

We encourage you to return your completed survey via e-mail. If you have any questions on the survey or the project, feel free to contact Geoff Gosling by e-mail or phone.

THANK YOU FOR YOUR HELP

ACRP SYNTHESIS SURVEY

Airport Ground Access Mode Choice Models

Consulting Firm and Research Organization Survey

Survey purpose: This survey is being performed as part of a study by the Airport Cooperative Research Program (ACRP) to document the state-of-the-practice in airport ground access mode choice models. Formal models of airport ground access mode choice form a key analytical component of airport landside planning, as well as airport system planning, and are used to predict how airport users will change their access or egress mode in response to changes in the airport ground transportation system (such as changes in fares, rates, or service levels) or the introduction of new modes (such as the extension of a light rail system to the airport). Airport access trips are different from the typical trip accounted for in regional transportation planning models. Therefore, it is difficult to determine the economic feasibility of proposed projects to improve airport ground transportation or effectively manage the existing airport ground transportation system using traditional regional travel forecasting models. However, models designed to address airport ground access travel decisions are highly specialized and their technical details are often not well understood by airport managers and planners. The purpose of this survey is to gather information on the use of such models by airports and other organizations.

The final report, to be published by the Transportation Research Board, will document the technical details of existing airport ground access mode choice models together with agency assessments of their effectiveness and reliability. This report will be extremely useful to all airports and other agencies involved in airport ground transportation planning as they consider how best to analyze the effect of changing conditions and circumstances on how air passengers, airport employees, and other airport users decide to travel to and from the airport. All survey responses will be confidential.

Thank you for taking the time to participate. Instructions on returning the survey are included on the last page.

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RESPONDENT INFORMATION

Date: ______________________

Name and Title of Respondent: ______________________

Organization: ______________________

Respondent Telephone Number: ______________________

Respondent e-Mail Address: ______________________

AIRPORT GROUND ACCESS STUDIES

1. Have you or your organization undertaken or participated in any studies in **the past 10 years** that have included some analysis of airport **ground access mode choice**?

☐ Yes. How many? _____

Please provide name of study sponsor and title of the most recent study or studies (*list up to six*).

1. Sponsor: ______________________
   Study: ______________________
2. Sponsor: ______________________
   Study: ______________________
3. Sponsor: ______________________
   Study: ______________________
4. Sponsor: ______________________
   Study: ______________________
5. Sponsor: ______________________
   Study: ______________________
6. Sponsor: ______________________
   Study: ______________________

☐ No (*Skip to Q.8*)

2. Did any of these studies make use of formal **analytical models** of airport ground access mode choice?
   - ☐ Yes. *Please indicate which* (*using numbers from Q.1*): ______
   - ☐ No (*Skip to Q.7*)

3. Are reports from any of these studies available on your or another organization's website?
   - ☐ Yes. *Please provide website address:* ______
   - ☐ No

4. What was the source of **air passenger survey data** used in the development of these airport ground access mode choice models? (*Please check all that apply*.)
   - ☐ Surveys performed specifically for the model development
   - ☐ Surveys performed for other purposes
   - ☐ Don't know

5. Are reports on any of these surveys available on your or another organization's website?
   - ☐ Yes. *Please provide website address:* ______
   - ☐ No

6. Based on your organization's past experience with airport ground access mode choice models, how would you characterize the current state-of-practice? (*Please check all that apply*.)
   - ☐ Adequate for our needs
   - ☐ Predictions from existing models are not reliable enough
   - ☐ Available models are too complex to use
   - ☐ Models are too costly to use except for very large studies

   Please skip to Q.8

7. What was the reason that these studies did not include any analytical modeling of airport ground access mode choice? (*Please check all that apply*.)
   - ☐ Scope of studies did not require it
   - ☐ Available models are not reliable enough
   - ☐ Available models are too difficult to use
   - ☐ There is a lack of information and guidance on the use of such models
   - ☐ Decision on analytical techniques to use was made by those performing the studies
   - ☐ Don't know

AIRPORT CHOICE STUDIES

8. Have you or your organization undertaken or participated in any studies **in the past 10 years** that have included some analysis of air passenger **airport choice**?
   - ☐ Yes. How many? ______

     Please provide name of study sponsor and title of the most recent study or studies (*list up to three*).

     1. Sponsor: ______
        Study: ______
     2. Sponsor: ______
        Study: ______
     3. Sponsor: ______
        Study: ______
   - ☐ No (*Skip to Q.11*)

9. Did any of these studies make use of analytical techniques that took **airport ground access mode choice** into consideration as a factor in airport choice?
   - ☐ Yes. *Please indicate which* (*using numbers from Q.8*): ______
   - ☐ No

STUDIES BY OTHER ORGANIZATIONS

10. Are you aware of any **other** organizations that have made use of formal analytical models of airport ground access mode choice in the course of studies or analysis addressing airport ground transportation or airport choice?

☐ Yes. *Please provide name of organization(s) (list up to three).*

4. ____________________
5. ____________________
6. ____________________

☐ No

GENERAL COMMENTS

11. Please feel free to add any comments about airport ground access mode choice models in general or the scope of this ACRP study in particular:

____
____
____
____
____

Please return by **February 23, 2007** to:

Geoffrey Gosling
Principal
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805 Colusa Avenue
Berkeley, CA 94707
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THANK YOU FOR YOUR HELP

TRB

ACRP SYNTHESIS SURVEY

Airport Ground Access Mode Choice Models

Government and Industry Organization Survey

Survey purpose: This survey is being performed as part of a study by the Airport Cooperative Research Program (ACRP) to document the state-of-the-practice in airport ground access mode choice models. Formal models of airport ground access mode choice form a key analytical component of airport landside planning, as well as airport system planning, and are used to predict how airport users will change their access or egress mode in response to changes in the airport ground transportation system (such as changes in fares, rates, or service levels) or the introduction of new modes (such as the extension of a light rail system to the airport). Airport access trips are different from the typical trip accounted for in regional transportation planning models. Therefore, it is difficult to determine the economic feasibility of proposed projects to improve airport ground transportation or effectively manage the existing airport ground transportation system using traditional regional travel forecasting models. However, models designed to address airport ground access travel decisions are highly specialized and their technical details are often not well understood by airport managers and planners. The purpose of this survey is to gather information on the use of such models by airports and other organizations.

The final report, to be published by the Transportation Research Board, will document the technical details of existing airport ground access mode choice models together with agency assessments of their effectiveness and reliability. This report will be extremely useful to all airports and other agencies involved in airport ground transportation planning as they consider how best to analyze the effect of changing conditions and circumstances on how air passengers, airport employees, and other airport users decide to travel to and from the airport. All survey responses will be confidential.

Thank you for taking the time to participate. Instructions on returning the survey are included on the last page.

This form can be completed by typing information in the fill-in text fields and clicking the check boxes to check them. Save the file when done and return by e-mail. Alternatively, the form can be printed, filled in by hand, and returned by fax or mail.

RESPONDENT INFORMATION

Date: __________

Name and Title of Respondent: __________

Agency Name: __________

Respondent Telephone Number: __________

Respondent e-Mail Address: __________

AIRPORT GROUND ACCESS STUDIES

1. Has your organization undertaken or commissioned any studies in **the past 10 years** that have included some analysis of airport **ground access mode choice**?

☐ Yes. *Please provide title of study or studies* (*add lines as necessary*).

7. __________

8. __________

9. __________

☐ No (*Skip to Q.8*)

2. Did any of these studies make use of formal **analytical models** of airport ground access mode choice?

☐ Yes. *Please indicate which* (*using numbers from Q.1*): __________

☐ No (*Skip to Q.7*)

3. Are reports from any of these studies available on your organization's website?

☐ Yes. *Please provide website address:* __________

☐ No

4. What was the source of **air passenger survey data** used in the development of these airport ground access mode choice models? (*Please check all that apply*.)
   - ☐ Surveys performed specifically for the model development
   - ☐ Surveys performed for other purposes
   - ☐ Don't know

5. Are reports on any of these surveys available on your organization's website?
   - ☐ Yes. *Please provide website address:* ______________________________
   - ☐ No

6. Based on your organization's past experience with airport ground access mode choice models, how would you characterize the current state-of-practice? (*Please check all that apply*.)
   - ☐ Adequate for our needs
   - ☐ Predictions from existing models are not reliable enough
   - ☐ Available models are too complex to use
   - ☐ Models are too costly to use except for very large studies

   Please skip to Q.8

7. What was the reason that these studies did not include any analytical modeling of airport ground access mode choice? (*Please check all that apply*.)
   - ☐ Scope of studies did not require it
   - ☐ Available models are not reliable enough
   - ☐ Available models are too difficult to use
   - ☐ There is a lack of information and guidance on the use of such models
   - ☐ Decision on analytical techniques to use was made by those performing the studies
   - ☐ Don't know

AIRPORT CHOICE STUDIES

8. Has your organization undertaken or commissioned any studies **in the past 10 years** that have included some analysis of air passenger **airport choice**?
   - ☐ Yes. *Please provide title of study or studies* (*add lines as necessary*).
     4. ______________________________
     5. ______________________________
   - ☐ No (*Skip to Q.10*)

9. Did any of these studies make use of analytical techniques that took **airport ground access mode choice** into consideration as a factor in airport choice?
   - ☐ Yes. *Please indicate which* (*using numbers from Q.8*): ______________________________
   - ☐ No

STUDIES BY OTHER ORGANIZATIONS

10. Are you aware of any airports or other organizations that have made use of formal analytical models of airport ground access mode choice in the course of studies or analysis addressing airport ground transportation or airport choice?
   - ☐ Yes. *Please provide name of study sponsor and title of study* (*list up to five*).
     7. Sponsor: ______________________________
        Study: ______________________________
     8. Sponsor: ______________________________
        Study: ______________________________
     9. Sponsor: ______________________________
        Study: ______________________________

10. Sponsor: ____

    Study: ____

11. Sponsor: ____

    Study: ____

☐ No

GENERAL COMMENTS

11. Please feel free to add any comments about airport ground access mode choice models in general or the scope of this ACRP study in particular:

    ____

    ____

    ____

    ____

    ____

Please return by **February 23, 2007** to:

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THANK YOU FOR YOUR HELP

APPENDIX B

Summary of Survey Results

The following tables (B1–B6) summarize the responses to the survey questions by type of responding organization. Where more than one individual responded from a given organization, their responses have generally been combined in the following statistics. For ease of reference, the question numbers in the tables generally follow the numbering in the Airport Authority survey questionnaire. The corresponding questions may have different numbers in the questionnaires for other types of organizations owing to the addition of questions specific to each type of organization. The two questions that were specific to metropolitan planning organizations are numbered with their original number in the relevant questionnaire.

TABLE B1
AIRPORT GROUND ACCESS STUDIES

	Airport Authorities	MPOs	State/Fed Government	Consulting Firms	Research	**Total**	Percent
Survey Responses (organizations)	32	24	19	23	7	**105**	
Q.1: Number reporting ground access studies	21	8	2	20	6	**57**	54%
Number of studies identified	24	11	7	43	10	**95**	
Unduplicated						85	
Q2: Number reporting mode choice model use	8	5	2	13	6	**34**	*60%*[a]
Number of studies identified	12	7	7	23	9	**58**	
Unduplicated						52	
Q3: Study reports available on web	1	2	0	0	2	**5**	*15%*[b]

Notes: a) Percent of organizations reporting ground access studies
b) Percent of organizations reporting use of mode choice models

TABLE B2
AIRPORT ACCESS MODE CHOICE MODEL DEVELOPMENT AND USE

	Airport Authorities	MPOs	State/Fed Government	Consulting Firms	Research	**Total**	Percent
Number reporting mode choice model use	8	5	2	13	6	**34**	
Q.4: Source of air passenger survey data							*Of those using models*
Model development	6	2	1	9	5	**23**	*68%*
Other purposes	4	3	2	10	4	**23**	*68%*
Don't know	0	0	0	0	0	**0**	
Q.5: Survey reports available on web	1	0	0	2	2	**5**	*15%*
Q.7: Reasons modeling not used (where not)							*Of those not using models*
Number reporting	12	3		7		**22**	
Not required	8	1	*all reported model use*	6	*all reported model use*	**15**	*68%*
Not reliable enough	-	2		-		**2**	*9%*
Too difficult to use	-	1		-		**1**	*5%*
Lack of guidance	-	2		2		**4**	*18%*
Decided by others	2	-		-		**2**	*9%*
Don't know	2	-		1		**3**	*14%*

TABLE B3
CURRENT STATE OF PRACTICE WITH AIRPORT ACCESS MODE CHOICE MODELS

	Airport Authorities	MPOs	State/Fed Government	Consulting Firms	Research	**Total**	Percent
Number reporting mode choice model use	8	5	2	13	6	**34**	
Q.6 Assessment of current state of practice							
Adequate for needs	7	5	-	5	2	**19**	*56%*
Not reliable enough	1	-	1	6	4	**12**	*35%*
Too complex to use	-	-	1	2	-	**3**	*9%*
Too costly to use	2	-	1	5	2	**10**	*29%*

TABLE B4
STUDIES INVOLVING AIRPORT ACCESS MODE CHOICE MODELS PRIOR TO LAST TEN YEARS

	Airport Authorities	MPOs	**Total**	Percent
Survey responses to question	31	24	**55**	
Q.8 Prior studies using mode choice modeling				
Yes	4	5	**9**	*16%*
No	15	14	**29**	*53%*
Not sure	12	5	**17**	*31%*

TABLE B5
STUDIES OF AIR PASSENGER AIRPORT CHOICE

	Airport Authorities	MPOs	State/Fed Government	Consulting Firms	Research	**Total**	Percent
Survey responses (organizations)	32	24	19	23	7	**105**	
Q.9: Number reporting airport choice studies	13	2	6	14	2	**37**	35%
Number of studies identified	11	4	3	13	3	**34**	
Unduplicated						32	
Q10: Number reporting mode choice model use	5	1	1	6	2	**15**	*41%*
Number of studies identified	4	3	1	5	3	**16**	
Unduplicated						16	

Note: Some respondents reported involvement in airport choice studies or use of mode choice models but did not identify specific studies

TABLE B6
MODELING AIRPORT ACCESS TRIPS IN REGIONAL TRANSPORTATION PLANNING

	MPOs	Percent
Number responding to Question 3 (MPO performed study using airport access mode choice model)	5	
Q.3 (MPO) Type of model used		*(a)*
Special purpose airport access model	4	*80%*
Adapted special-generator model	1	*20%*
Adapted general urban travel model	—	
Used general urban travel model	1	*20%*
Number responding to Question 10 (all MPO respondents)	24	
Q.10 (MPO) How airport trips are modeled in general regional travel modeling process		*(b)*
Special-generator sub-model for air passengers	15	*65%*
Model air passengers as home-based non-work trips	6	*26%*
Model air passengers as non-home-based non-work trips	5	*22%*
Special-generator sub-model for airport employees	5	*22%*
Model airport employees as regular journey-to-work trips	12	*52%*
Do not consider airport trips in modeling process	—	
Other	2	*9%*
Don't know	1	

Notes: a) Multiple responses allowed
b) Percent excludes "Don't know" response

AIRPORT GROUND ACCESS STUDIES IDENTIFIED BY SURVEY RESPONDENTS

Studies Involving Airport Access Mode Choice Modeling

Sponsor	Study
Atlanta Regional Commission	Regional Travel Demand Model Update
Bay Area Rapid Transit District	Oakland Airport Connector EIR/EIS
Chicago DOT/Chicago Transit Authority	Chicago Airport Express Study
Dallas/Fort Worth International Airport	Curbside Assignment Study
Dallas/Fort Worth International Airport	DFW Zonal Activity Forecasts
Federal Aviation Administration	New England Regional Airport System Plan
Federal Transit Administration	Rail Access to Honolulu International Airport
Federal Transit Administration	Rail Access to Minn.–St. Paul Int'l Airport
Federal Transit Administration	Rail Access to New York Kennedy Int'l. Airport
Federal Transit Administration	Washington–Dulles Access Study
Greater Orlando Aviation Authority	Analysis of Terminal Curbside Roadways
Hartsfield–Jackson Atlanta Int'l. Airport	Terminal Planning—Phases I–III
Lower Manhattan Development Corp.	JFK to Lower Manhattan Transit Access Study
Massachusetts Port Authority	Boston Logan AITC Environmental Assessment
Massachusetts Port Authority	Logan Express Analysis
Massachusetts Port Authority	Logan Airport Environmental Status and Planning Report
Massachusetts Port Authority	Surface Access Study of Boston Area Airports
Metro–Portland, Oregon	Airport Max (Red Line) Analysis
Miami–Dade County Transit	Airport Access Study
New York MTA/NYC Transit	LaGuardia Access Study
North Central Texas Council of Govts.	DFW Rail Access Implementation Plan
Port Authority of NY & NJ	Regional Air Service Demand Study
Port of Seattle	SEA-TAC Comprehensive Development Plan Joint Transportation Study
Sacramento Regional Transit District	Sacramento Airport Light Rail Extension Study
San José International Airport	Airport Transit Connector
Southern California Assoc. of Govts.	1998 Regional Transportation Plan
Southern California Assoc. of Govts.	2001 Regional Transportation Plan
Southern California Assoc. of Govts.	2004 Regional Transportation Plan
Southern California Assoc. of Govts.	Regional Airport Demand Model
Unspecified	O'Hare Commuter Rail Market Assessment
Privately Funded Studies	
Denver East Corridor Rail Group, LLC	Denver Airtrain Study
Resource Systems Group, Inc.	Biannual Syndicated Air Traveler Surveys
Canada	
Aéroports de Montréal	Navette du Centre-ville à l'Aéroport Montréal–Trudeau/Volet: Passagers
Greater Toronto Airports Authority	Toronto Pearson International Airport Air Rail Link Revenue and Ridership Study
United Kingdom	
BAA, Plc	Heathrow Airport Surface Access Model (2003)
BAA, Plc	Heathrow Airport Surface Access Model (2004–current)
Scottish Executive	Rail Links to Glasgow and Edinburgh Airports

High Speed Rail and Maglev Studies Involving Mode Choice Modeling

Sponsor	Study
California High-Speed Rail Authority	Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study
Florida Department of Transportation	Florida High Speed Rail Study
Maryland Department of Transportation	Baltimore to Washington Maglev Study
Pennsylvania Dept. of Transportation	Pittsburgh Maglev Study

University Research Involving Airport Access Mode Choice Modeling

University	Study
University of California, Berkeley	Planning for Improved Intermodal Connectivity at California Airports
University of Virginia	Feasibility of Offsite Terminals in Landside Access
International	
City University of Hong Kong	Ground Access Mode Choices at Hong Kong International Airport
Imperial College, London	Airport, Airline, and Access Choice in SF Bay Area
Imperial College, London	Airport, Airline, and Access Choice in Greater London
National Technical University of Athens	Access Mode Choice for Relocated Airports
National Technical University of Athens	Demand and Mode Choice in Access to Airports
National Technical University of Athens	Parking Capacity Requirements for Relocated Airports

University Research Involving Airport Ground Access Analysis

University	Study
Virginia Transportation Research Council	Evaluating Improvements in Landside Access for Airports

Other Airport Ground Access Studies

Sponsor	Study
Anchorage International Airport	Airport Roadway Traffic Analysis
E-470 Public Highway Authority	Denver E-470 (Tollroad) Airport Forecasts
Dallas Area Rapid Transit	Application of the North Central Texas Council of Governments Regional Travel Demand Model to the planning for the Northwest Corridor light rail transit line
National Aeronautics and Space Administration	Civil tilt rotor studies
Hartsfield–Jackson Atlanta Int'l. Airport	CONRAC Study
Houston Intercontinental Airport	Master Plan
I-95 Corridor Coalition	Airport Ground Access Study
Indianapolis Metropolitan Planning Organization	Intermodal Freight Study
Jacksonville Aviation Authority	Jacksonville International Airport Master Plan 2002
Los Angeles World Airports	LAX Advanced Planning
Los Angeles World Airports	LAX Master Plan EIS/EIR
Los Angeles World Airports	Ontario International Airport Master Plan—Phase 2
Metropolitan Washington Airports Authority	North Area Road Landside VISSIM Simulation
Metropolitan Washington Council of Governments	Washington/Baltimore Region Access Forecast Update
Puget Sound Regional Council	Regional Airport Ground Access Plan (2004)
Raleigh–Durham Airport Authority (with Triangle Transit Authority)	Airport Rail Link Study
Reno–Tahoe Airport Authority	Terminal Area Master Plan
Reno–Tahoe Airport Authority	Terminal Programming Study (underway)
Sacramento County Airport System	Sacramento International Airport Master Plan Update
San Diego Regional Airport Authority	San Diego International Airport Master Plan
San Diego Regional Airport Authority	San Diego Int'l. Airport Terminal 2 Expansion
San José International Airport	Terminal Area Improvement Program

Sponsor	Study
Southern California Assoc. of Govts.	2007 Regional Transportation Plan (underway)
Tampa International Airport	Airport Master Plan Updates
West Virginia Public Port Authority	Western West Virginia Regional Airport Feasibility Study
Canada	
Greater Toronto Airports Authority	Toronto Pearson International Airport New Terminal Groundside Design
Ottawa Macdonald–Cartier International Airport Authority	2006 survey of key attributes of modal choice

AIRPORT CHOICE STUDIES IDENTIFIED BY SURVEY RESPONDENTS

Studies Involving Airport Access Mode Choice Modeling

Sponsor	Study
Federal Aviation Administration	New England Regional Airport System Plan
Federal Transit Administration	Washington–Dulles Access Study
New York State Dept. of Transportation	Stewart Airport Access Analysis
Port Authority of NY & NJ	Regional Air Service Demand Study
Resource Systems Group, Inc.	Biannual Syndicated Air Traveler Surveys
Sacramento County Airport System	Sacramento International Airport Master Plan Update
San Diego Association of Governments	Maglev Study, Phase 1
Southern California Assoc. of Govts.	1998 Regional Transportation Plan
Southern California Assoc. of Govts.	2001 Regional Transportation Plan
Southern California Assoc. of Govts.	2004 Regional Transportation Plan
Southern California Assoc. of Govts.	Regional Airport Demand Model
Unspecified	High Speed Rail Access to Third Chicago Airport
Canada	
Greater Toronto Airports Authority	Air Traveller Choice in Southern Ontario

University Research Involving Airport Choice and Access Mode Modeling

University	Study
Imperial College, London	Airport, airline, and access choice in SF Bay Area
Imperial College, London	Airport, airline, and access choice in Greater London
Imperial College, London	Stated preference studies of airport choice

Other Airport Choice Studies

Sponsor	Study
Anchorage International Airport	Airport Master Plan Update 2002
Hartsfield–Jackson Atlanta Int'l. Airport	CONRAC Study
Jacksonville Aviation Authority	Jacksonville International Airport Master Plan 2002
Los Angeles World Airports	LAX Advanced Planning
Los Angeles World Airports	LAX Master Plan
Los Angeles World Airports	Remote Terminal Market Analysis for LAX
Massachusetts Port Authority	Hanscom Airport Environmental Status and Planning Report
Minnesota DOT Office of Aeronautics	State of Minnesota Leakage Study
North Central Texas Council of Govts.	DFW Rail Access Implementation Plan
Reno–Tahoe Airport Authority	2005 Catchment Area Survey
Southern California Assoc. of Govts.	2007 Regional Transportation Plan (underway)
Tampa International Airport	Air service development market studies
Tampa International Airport	International Market Study, March 2006

APPENDIX C

List of Participating Agencies

AIRPORT AUTHORITIES

State	Agency
AK	Alaska Dept. of Transportation & Public Works (Anchorage International Airport)
AR	Fort Smith Regional Airport
AZ	Albuquerque International Sunport
CA	City of San José Airport Dept. (Norman Y. Mineta San Jose International Airport)
CA	County of Orange (John Wayne Airport)
CA	Los Angeles World Airports
CA	Reno–Tahoe Airport Authority
CA	Sacramento County Airport System (Sacramento International Airport)
CA	San Francisco International Airport
CO	Denver International Airport
DC	Metropolitan Washington Airports Authority
FL	Greater Orlando Aviation Authority
FL	Jacksonville Aviation Authority
FL	Lee County Port Authority (Southwest Florida Regional Airport)
FL	Tampa International Airport
GA	Hartsfield–Jackson Atlanta International Airport
LA	Louis Armstrong New Orleans International Airport
MA	Massachusetts Port Authority (Boston Logan International Airport)
MN	Metropolitan Airports Commission (Minneapolis–St. Paul International Airport)
MO	Lambert–St. Louis International Airport
NC	Raleigh–Durham Airport Authority
NY/NJ	Port Authority of New York and New Jersey
PA	Allegheny County Airport Authority (Pittsburgh International Airport)
PA	Philadelphia International Airport
TN	Memphis–Shelby County Airport Authority (Memphis International Airport)—State Agency
TX	City of Dallas Department of Aviation (Dallas Love Field Airport)
TX	Dallas/Fort Worth International Airport
WA	Port of Seattle (Seattle–Tacoma International Airport)
WI	General Mitchell International Airport (Milwaukee)
Canada	
Quebec	Aéroports de Montréal
Ontario	Greater Toronto Airports Authority
Ontario	Ottawa Macdonald–Cartier International Airport

METROPOLITAN PLANNING ORGANIZATIONS

State	Agency
CA	Sacramento Area Council of Governments
CA	Southern California Association of Governments (Los Angeles region)
CT	Capitol Region Council of Governments (Hartford)
DC	Metropolitan Washington Council of Governments
FL	First Coast Metropolitan Planning Organization (Jacksonville)

State	Agency
FL	Hillsborough County Metropolitan Planning Organization (Tampa)
FL	Metroplan Orlando
GA	Atlanta Regional Commission
HI	Oahu Metropolitan Planning Organization (Honolulu)
IL	Chicago Metropolitan Agency for Planning
IN	Indianapolis Metropolitan Planning Organization
KY	Kentuckiana Regional Planning and Development Agency (Louisville)
MA	Central Transportation Planning Staff (Boston)
MD	Baltimore Metropolitan Council
MN	Metropolitan Council of the Twin Cities (Minneapolis–St. Paul)
NV	Regional Transportation Commission of Southern Nevada (Las Vegas)
NY	New York Metropolitan Transportation Council
OH	Northeast Ohio Areawide Coordinating Agency (Cleveland)—State Agency
OH	Ohio–Kentucky–Indiana Regional Council of Governments (Cincinnati)
OR	Metro (Portland)
TX	Houston–Galveston Area Council
TX	North Central Texas Council of Governments (Dallas/Fort Worth)
VA	Virginia Department of Transportation (travel modeling for MPOs in Virginia)
WA	Puget Sound Regional Council (Seattle)

AIRPORT/TRANSPORTATION CONSULTING FIRMS

State	Organization
CA	Dowling Associates, Inc. (Oakland)
CA	Mark Bradley Research and Consulting (Santa Barbara)
CA	PB Consult (San Francisco)
CA	Velocity Group (San Francisco)
CO	PRT Consulting, Inc. (Franktown)
MA	Cambridge Systematics, Inc. (Cambridge)
MA	MarketSense Consulting, LLC (Charlestown)
MA	SH&E, Inc. (Cambridge)
MD	Vanesse Hangen Brustlin (Silver Spring)
NY	Aviation Consulting (New York)
NY	Earth Tech (New York)
PA	GRA, Incorporated (Jenkintown)
SC	Wilber Smith Associates (Columbia)
TX	DMJM Aviation (Fort Worth)
TX	TransSolutions, LLC (Fort Worth)
VA	AECOM Consult, Inc. (Arlington)
VA	HNTB Corporation (Alexandria)
VA	Larry Kiernan, Consultant (Reston)
VA	Ricondo & Associates (Alexandria)
VT	Resource Systems Group, Inc. (White River Junction)—State Organization
WA	HDR Engineering, Inc. (Bellevue)
WA	URS Corporation (Seattle)

International

Australia	Sinclair Knight Merz (Armadale, Victoria)

RESEARCH ORGANIZATIONS

State	Organization
CA	University of California at Berkeley
MI	Michigan Tech University (Houghton)
VA	University of Virginia (Charlottesville)
VA	Virginia Transportation Research Council (Charlottesville)
International	
Greece	National Technical University of Athens
H.K.	City University of Hong Kong
U.K.	Imperial College (London)

STATE AND FEDERAL GOVERNMENT

State	Agency
AZ	Arizona Department of Transportation, Aeronautics Division (Phoenix)
CA	California Department of Transportation, Division of Aeronautics (Sacramento)
FL	Florida Department of Transportation, Aviation Office (Tallahassee)
IA	Iowa Department of Transportation, Office of Aviation (Ames)
KY	Kentucky Department of Aviation (Frankfort)
MN	Minnesota Department of Transportation, Office of Aeronautics (St. Paul)
MS	Mississippi Department of Transportation, Aeronautics Division (Jackson)
ND	North Dakota Aeronautics Commission (Bismarck)
NE	Nebraska Department of Aeronautics (Lincoln)
NJ	New Jersey Department of Transportation, Division of Aeronautics (Trenton)—State Agency
NY	New York State Department of Transportation, Aviation Services Bureau (Albany)
OH	Ohio Department of Transportation, Office of Aviation (Columbus)
OK	Oklahoma Aeronautics Commission
OR	Oregon Department of Aviation (Salem)
TX	Texas Department of Transportation, Aviation Division (Austin)
WA	Washington State Department of Transportation (Arlington)
Federal	
DC	Federal Aviation Administration
DC	Federal Transit Administration
MA	U.S. Department of Transportation, Volpe National Transportation Systems Center

APPENDIX D

Mode Choice Model Technical Summaries

This appendix contains detailed technical summaries of selected airport ground access mode choice models discussed in the body of the report. The summaries document the technical details of the models, including the functional form adopted, market segmentation, causal variables included in the model, estimated parameter values, and goodness-of-fit measures where these have been reported in the literature or model documentation. The summaries also include statistical information on the airports for which the models have been developed.

The total annual passengers for each U.S. airport shown in the summary table for each technical summary are obtained from FAA statistics for primary and nonprimary commercial service airports for the calendar year 2005. These statistics typically differ slightly from those published by each airport on their websites. The percentage of passengers at each airport for whom the airport is their origin or destination was estimated from data reported to the U.S. Department of Transportation by U.S. airlines in the Airline Origin and Destination (O&D) Survey and published by the Bureau of Transportation Statistics (BTS) on their TranStats website (http://www.transtats.bts.gov). Because the origin-destination (O-D) data on the BTS website is restricted to U.S. domestic itineraries, the calculated O&D percentages were adjusted to account for passengers connecting between domestic and international flights. The sources for passenger statistics for non-U.S. airports are noted on the summary tables.

LIST OF TECHNICAL SUMMARIES

D1 Atlanta Regional Commission Model
D2 Boston Logan International Airport Model
D3 Chicago Airport Express Ridership Forecasting Study
D4 Miami Intermodal Center Travel Demand Forecast Study
D5 Oakland International Airport BART Connector Study
D6 Portland International Airport Alternative Mode Study
D7 San José International Airport Model
D8 Toronto Air Rail Link Revenue and Ridership Study
D9 United Kingdom SERAS Study Air Passenger Surface Access Model

D1 ATLANTA REGIONAL COMMISSION MODEL

Summary

Airport	Hartsfield–Jackson Atlanta International Airport (H-JAIA)	
Model Developer	Atlanta Regional Commission	
Date Developed	2003 (updated 2006)	
Market Addressed	Air passengers	
Model Type	Revealed preference data	
Model Structure	Nested logit	
Survey Data Used	2000 H-JAIA Peak Week Survey	
Airport Profile	Total annual passengers (2005): 84.8 million	
	Percentage O&D: 35%	
	Ground access mode split (2005 H-JAIA Peak Week Survey):	
	Private vehicle—drop off	25%
	Private vehicle—parked	31%
	Rental car	16%
	Taxi	8%
	Limousine	2%
	Public transit	10%
	Commercial shuttle/van	4%
	Hotel/motel courtesy vehicle	4%
	Other	<1%
Market Segmentation	Residents—Business trips	
	Residents—Non-business trips	
	Non-residents—Business trips	
	Non-residents—Non-business trips	
Explanatory Variables	Off-peak highway travel time	
	Private vehicle cost (operating, parking)	
	Walk time (transit)	
	Wait time (transit)	
	In-vehicle time (transit)	
	Transit fare	
	Taxi fare	

Description

The Atlanta Regional Commission (ARC) Airport Passenger Model (APM) comprises a component of the overall regional travel demand model that models air passenger trips to and from Hartsfield–Jackson Atlanta International Airport (H-JAIA) (*Model Documentation . . .* 2005). The model was originally developed in 2003 using data from the H-JAIA Peak Week Air Passenger Survey performed in 2000 and was updated in 2006 for new income groups for 2000 (*Travel Demand . . .* 2006). The reestimation of the mode choice model only changed the alternative-specific constants (ASCs) for three of the modes and did not affect the coefficients for the continuous variables, as explained here.

The ARC/APM consists of two components: a trip generation/distribution model that assigns the total originating air passenger traffic at H-JAIA to regional transportation analysis zones (TAZs) and a mode choice model that predicts the ground access mode use of those air passenger trips. A subsequent step converts air passenger trips to vehicle trips for inclusion on the traffic assignment step of the regional transportation demand model. The trip generation model (and subsequent prediction of air passenger trips by mode and resulting vehicle trips) is based on the airport passenger traffic for an average day of the year, which is assumed to be the same as the average weekday, and is discussed in more detail here.

The ARC/APM predicts air passenger and vehicle trips by four market segments that distinguish between residents of the Atlanta region and visitors to the region (non-residents) and between business and non-business (personal) trips, giving the following market segments: resident business, resident non-business, non-resident business, and non-resident non-business.

The mode choice model considers five modes: air passengers dropped off by private vehicle, private vehicle parked at the airport for the duration of the air trip (termed drive self), rental car, transit, and taxi. Although not explicitly stated in the model documentation, it appears from the existing mode use data given in the documentation that the transit mode includes the Metropolitan Atlanta Rapid Transit Authority (MARTA) rail and bus services, commercial shared-ride shuttle van services, and other high-occupancy shared-ride modes such as charter bus. The taxi mode appears to include exclusive ride limousine services and hotel and motel courtesy vehicles, as well as conventional taxi use. This grouping of modes is likely to have a significant effect on the estimated model coefficients, because it implies that the modes grouped together for the purpose of model estimation have similar service characteristics. However, in reality this is clearly far from the case. Shared-ride shuttle van services provide a door-to-door service for a significantly higher fare than regular transit, whereas hotel/motel courtesy vehicles provide a free service by definition, although their use is typically restricted to guests at the hotel or motel providing the service.

The basic form of the mode choice model is a nested logit (NL) model with a separate structure for trips by residents of the region from that for non-residents, as shown in Figure D1. The resident model divides the modes into private vehicle trips and public modes (termed non-auto modes). The private vehicle nest distinguishes between drop-off trips and those where the vehicle was parked for the duration of the air trip. The public mode nest distinguishes between use of transit and taxi. The non-resident model contains three modes at the top level: drop off by private vehicle, rental car, and public modes. As with the resident model, the public mode nest distinguishes between use of transit and taxi.

The model does not take the type of ground access trip origin into account. Thus, all visitors to the region are considered to include drop-off by private vehicle and rental car in their choice set, whether or not they are staying with residents of the region and thus have someone who could drop them off at the airport or the need for a rental car during their visit.

Explanatory Variables

The explanatory variables consist of the travel times and costs for each mode. The travel times for the private vehicle and taxi modes use the off-peak travel time from the highway network in the regional travel demand model. Transit travel times are obtained from the a.m. peak transit network in the regional travel demand model. Separate variables are defined for in-vehicle, walk, and wait times. The transit in-vehicle times use the total in-vehicle time for the trip from the origin zone to the airport zone. Transit walk times consist of the combined access, egress, and sidewalk times from the transit network, whereas the transit wait times consist of the initial wait plus any transfer wait times from the network.

Private vehicle operating costs are assumed at 8.74 cents per mile, based on the off-peak highway distance from the regional network. Parking costs for vehicles parked for the duration of the air trip are based on half the daily long-term parking cost at H-JAIA multiplied by the average trip duration in days, assumed as 4 days for business trips and 7 days for non-business trips. Thus, all air parties with a given trip purpose are assumed to incur the same parking cost if they choose to park at the airport during their trip, irrespective of their actual air trip duration. Transit fares are obtained from the transit network (the fares are unaffected by the time of day). Taxi fares were estimated from the off-peak highway distance assuming a flag drop of $1.75 and a rate of $1.75 per mile.

There are no explanatory variables in the utility function for the rental car mode, only an ASC. Thus, the model implicitly assumes that the rental car alternative is perceived as providing the same utility to all non-resident air parties, irrespective of their air party characteristics.

Apart from estimating different model coefficients for the four market segments and any differences in travel time and cost owing to the different trip origin locations, the model does not consider any air party characteristics, such as household income or air party size. Based on the model documentation, the treatment of air party size appears to be inconsistent, with costs for private vehicle and taxi modes being calculated on an air party basis, but transit fares being calculated on an air passenger basis.

Model Coefficients

The adopted and estimated model coefficients for each of the market segments are shown in Table D1, and the corresponding implied values are shown in Table D2.

The coefficients for the continuous variables were *not* estimated from the data but rather adopted from other models. The

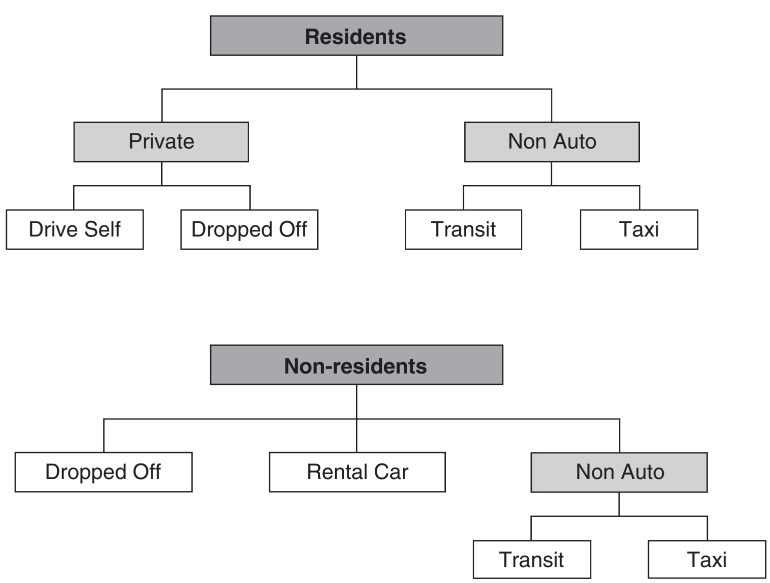

FIGURE D1 ARC/APM model choice model nesting structure.
[*Source: Model Documentation: Mobility 2030 Regional Transportation Plan,* Atlanta Regional Commission (2005).]

TABLE D1
ATLANTA AIRPORT PASSENGER MODEL COEFFICIENTS

Coefficient	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Variables				
Highway time (minutes)	–0.071	–0.044	–0.068	–0.039
Transit in-vehicle time (min)	–0.053	–0.031	–0.050	–0.029
Walk time (minutes)	–0.093	–0.051	–0.089	–0.045
Wait time (minutes)	–0.107	–0.077	–0.096	–0.071
Cost (cents)	–0.00277	–0.002105	–0.00256	–0.001969
Constants				
Private vehicle parked for trip	5.427	4.517	N/A	N/A
Rental car	N/A	N/A	–4.061	–3.153
Transit[a]	–0.738	0.159	0.720	–1.853
Taxi[a]	8.366	2.876	7.753	3.408
Nest Coefficients				
Private auto nest	0.3	0.3	N/A	N/A
Public mode nest	0.3	0.3	0.3	0.3

Note: N/A = not applicable.

[a]Includes nest constant term.

ASCs (termed model bias coefficients in the documentation) were then estimated to ensure that the model predicted the observed mode shares. Therefore, the model bias coefficients not only account for intrinsic attributes of the different modes not explained by the continuous variables but also any differences that would have existed between the continuous variable coefficients that were adopted for the model and the values that would have been obtained had these coefficients been estimated from the data.

The adopted coefficients for the continuous variables all have the expected signs. The implied value of highway travel time varies between $12/h and $16/h, which is significantly less than values of time typically found for air travelers in air travel demand models. Although the implied values of time for non-business trips are lower than those for business trips, as is normally expected, the differences are surprisingly small. The implied values of time for residents of the region on business trips is slightly lower than for non-residents on business trips, which is not unreasonable given the general income levels in the Atlanta region compared with many other parts of the United States. However, because these coefficients were apparently not estimated from the Atlanta data, this appears coincidental. The implied values of transit in-vehicle time are lower than for highway travel time, as expected because those with a higher value of time will tend to use other modes than transit. The implied values of walk and wait time involved in transit trips are significantly higher than for in-vehicle time, as is generally found in other mode choice models.

The constant term for private vehicle parked for the duration of the air trip suggests that this alternative has a lower disutility than being dropped off by private vehicle after allowing for the travel time and cost involved in the two alternatives, equivalent to about $20 per air party. Because the utility functions for the

TABLE D2
IMPLIED VALUES OF ATLANTA AIRPORT PASSENGER MODEL COEFFICIENTS

Parameter	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Travel Time ($/hour)				
Highway time	15	13	16	12
Transit in-vehicle time	11	9	12	9
Walk time	20	15	21	14
Wait time	23	22	23	22
Constants ($)				
Private vehicle parked for trip	20	21	N/A	N/A
Rental car	N/A	N/A	–16	–16
Transit	–3	1	3	–9
Taxi	30	14	30	17

drop-off alternative do not consider the operating cost of the vehicle for the return trip or assign any disutility to the time of the driver, this does not seem unreasonable, although in reality these effects are not likely to be constant across all air parties. Because the utility functions for the rental car alternative do not include any continuous variables (travel time or cost), the estimated values of the constant terms ensure that the model predicts the observed use of rental car in the estimation dataset and have no intrinsic interpretation.

Model Fit

The documentation on the model provided no information on the overall fit of the model.

Model Application

The ARC/APM has been designed to be used as an integral part of the regional travel demand modeling process and generates trip tables for air passenger trips and the associated vehicle trips that are subsequently combined with other types of trips in the regional travel demand model (*Travel Demand* . . . 2006). However, the results of the APM are saved as separate tables and can be presented or exported independently of the regional travel demand model results for use in airport planning or related studies.

The ARC/APM is programmed in Fortran and can be called as part of running the regional travel demand modeling software. This was originally programmed using Tranplan software but has recently been converted to TP+/Cube Voyager software. The model can read regional travel demand model skim tree tables of highway and transit travel times, highway distances, and transit costs directly for use in modeling air passenger trips.

Trip Generation/Distribution Model

The first steps in the ARC/APM generate a sample of air passenger trips with their associated air party characteristics, including the trip origin TAZ, for use in modeling the air passenger ground access mode choice. Although strictly not part of the access mode choice model, these steps are sufficiently important to generating the overall pattern of air passenger and associated vehicle trips that they deserve a fairly detailed explanation.

The first step in the trip generation/distribution process is to obtain an estimate of the total air passenger enplanements at H-JAIA for the year in question. This is then adjusted to exclude connecting passengers and divided into the four market segments. In the case of historical data, the percentage of originating air passengers in each market segment can be obtained from air passenger survey information and the proportion of connecting passengers can be obtained from airline data reported to the U.S.DOT. For the purposes of developing the APM, the ARC used an estimate of connecting passengers from the H-JAIA Master Plan. When applying the APM to future years, it will be necessary to adjust the proportion of connecting passengers and the percentage of originating passengers in each market segment to reflect any forecast changes in the traffic composition at H-JAIA.

The second step in the trip generation/distribution process allocates these trips to TAZs. Analysis of the 2000 H-JAIA air passenger survey showed that there were significant differences between resident business trips that started from a residence and those that started from another type of origin, typically the place of work. Almost all resident non-business trips originated from a private residence. Similarly, there was a significant difference between non-resident non-business trips that originated from a private residence and those that originated from some other type of trip origin (primarily hotels or motels), whereas relatively few non-resident business trips originated from a private residence. Therefore, the four market segments were further divided into six trip types based on the type of origin, as follows:

- Resident business trips from private residences
- Resident business trips from other types of trip origin
- Resident non-business trips
- Non-resident business trips
- Non-resident non-business trips from private residences
- Non-resident non-business trips from other types of trip origin.

The division into these six categories was made on the basis of the proportions in the 2000 H-JAIA air passenger survey. These trips were then allocated to TAZs on the basis of either households (for trips from a private residence) or total employment in a zone (for trips from other origin types). The household allocation equations divided households into four income categories on the basis of the 2000 census. The coefficients of the allocation equations were estimated using linear regression from the results of the 2000 H-JAIA air passenger survey. The form of each equation estimates the number of trips in the survey data in each category from a given zone in terms of the number of households in each income category in a zone or the total employment in the zone. These estimates must then be converted to a percentage of all trips in that category from the zone in question to allocate any other estimate of total trips by category.

However, because the survey only gave the trip origin information by zip code, rather than TAZ, the allocation equations were estimated on a zip code basis. When these equations were applied to TAZs, it was found that the trips from some parts of the region were over-estimated while those from other parts of the region were under-estimated. Therefore the region was divided into three different groups of zones and different adjustment factors were applied to each group of zones. Details of the allocation equations and adjustment factors are provided in the model documentation (*Model Documentation* . . . 2005), but are not presented here because they do directly affect the mode choice model.

Integration with Regional Planning Process

The mode choice model within the APM generates a table of air passenger trips using each of the five defined modes from each TAZ. These tables of air passenger trips are then converted to associated vehicle trips using assumed values of average vehicle occupancy for each mode. The number of vehicle trips for the private vehicle drop-off mode is doubled to allow for the return trip by the driver dropping off the air party and the total number of vehicle trips doubled again to allow for the traffic generated by egress trips, which are assumed to be symmetrical to the pattern of access trips.

The resulting tables of air passenger trips using transit and highway vehicle trips are then added to the trip tables for other types of regional trips generated by the other components of the regional travel demand model before the highway traffic assignment and transit trip assignment steps of the overall modeling process.

Although this approach provides a reasonable representation of vehicle trips by private vehicles and rental cars, the combination of several distinct modes in the transit and taxi modes of the APM is more problematical. Trips on public modes other than MARTA do not contribute to MARTA ridership, as implied by including these in the transit assignment step, but rather generate additional highway vehicle trips. Although the various modes included in the APM taxi mode each generate highway vehicle trips, the average vehicle occupancy for hotel/motel courtesy vehicles is likely to be greater than that for conventional taxi and limousine, owing to the shared-ride nature of hotel/motel courtesy vehicles, resulting in an overestimate of vehicle trips for the taxi mode. However, the geographic pattern of this error is likely to be very uneven, because most hotel/motel courtesy vehicle trips are from areas fairly close to the airport, whereas taxi and limousine use is more widely distributed throughout the region.

Documentation

Model Documentation: Mobility 2030 Regional Transportation Plan, Atlanta Regional Commission, Atlanta, Ga., Feb. 11, 2005.

Travel Demand Model Documentation, Atlanta Regional Commission, Atlanta, Ga., May 2006.

D2 BOSTON LOGAN INTERNATIONAL AIRPORT MODEL

Summary

Airport	Boston Logan International Airport	
Model Developer	Central Transportation Planning Staff, Boston	
Date Developed	1996	
Market Addressed	Air passengers	
Model Type	Revealed preference data	
Model Structure	Nested logit (resident), multinomial logit (visitor)	
Survey Data Used	1993 Boston Logan Air Passenger Survey	
Airport Profile	Total annual passengers (2005): 26.4 million	
	Percentage O&D: 90%	
	Ground access mode split (2003 Logan Air Passenger Survey):	
	Private vehicle—drop-off	21%
	Private vehicle—parked	11%
	Rental car	17%
	Taxi	19%
	Limousine	7%
	Logan Express	5%
	Scheduled bus/limo	4%
	Public transit—MBTA subway	6%
	Water shuttle	1%
	Hotel courtesy shuttle	6%
	Charter bus	3%
	Other (including MBTA bus)	<1%
Market Segmentation	Residents—Business trips	
	Residents—Non-business trips	
	Non-residents—Business trips	
	Non-residents—Non-business trips	
Explanatory Variables	In-vehicle time	
	Out-of-vehicle time (walk, wait, transfer)	
	Automobile access time	
	Travel cost (parking, tolls, automobile operating cost, fares)	
	Dummy variables (employer pays cost, luggage, air party size, non-residence trip origin, household income, flights/year from Logan)	

Description

This model was developed by the Central Transportation Planning Staff (CTPS) in Boston using a 1993 air passenger survey performed at Boston Logan International Airport. Separate sub-models were developed for resident business trips, resident non-business trips, non-resident business trips, and non-resident non-business trips. The two resident sub-models consist of a two-level NL model, with separate second-level nests for door-to-door modes (taxi and limousine) and automobile modes (drop-off, short-term parking, long-term parking, and off-airport parking). There are four shared-ride public modes at the top level (regular transit, scheduled airport bus, the Logan Express service to off-airport terminals in the region, and the Water Shuttle between the airport and the downtown Boston waterfront). The visitor sub-models are multinomial logit (MNL) models and omit the long-term parking alternatives, but add a hotel shuttle mode.

This model includes a rail access mode, the Massachusetts Bay Transportation Authority (MBTA) regional rail transit system, and off-airport terminals, the Logan Express service operated by the Massachusetts Port Authority (Massport), the airport authority for Logan Airport. The MBTA Airport Station is adjacent to the airport and linked to the passenger terminals by a free shuttle bus service operated by Massport. Unlike many other airport access mode choice models, the CTPS model treats rental car use as an independent decision and excludes it from the mode choice decision process.

Explanatory Variables

Independent variables include both in-vehicle and out-of-vehicle travel time, automobile access time to the public modes, the number of transfers, travel costs, and dummy variables for the type of trip origin (residence or not), the amount of luggage, air party size, number of air trips in past year, and whether an employer was paying travel expenses. Not all variables are included in all models, and various combinations of the independent variables were estimated. For some model variations, separate travel cost coefficients were estimated for low-income and high-income travelers or for those for whom their travel costs were paid by their employer. However, the definition of low-income and high-income travelers was not included in the model documentation. Travel times were measured in minutes and costs in dollars, based on 1993 rates.

Model Coefficients

Tables D3 to D6 show the estimated model coefficients for the four market segment models. Values in parentheses are the *t*-statistics of the estimates. With a few exceptions, most of the estimated coefficients are statistically significant at the 95% level or better. The *t*-statistics for the ASCs for the non-resident non-business model (Table D6) are as reported in the model documentation, but appear to be incorrect. They are identical to those shown for the non-resident business model (Table D5), which would be surprising, and three have incorrect signs (*t*-statistics are generally reported with the same sign as the coefficient), suggesting that the wrong values were reported in the model documentation.

As can be seen from Tables D3 to D6, separate travel time and cost coefficients were estimated from groups of modes. This has the effect of giving different implied values of travel time for different modes, as shown in Table D7. Whereas it can be expected that travelers choosing different modes will on average tend to have different values of time (e.g., travelers choosing a taxi will tend to have a higher value of time than those using the MBTA) that is an entirely different issue from assuming that a *given* traveler will have a different implied value of travel time when considering alternative modes (as implied by the models).

TABLE D3
BOSTON LOGAN RESIDENT BUSINESS MODEL COEFFICIENTS

	Travel Time Coefficients					Travel Cost Coefficients			Dummy Variable Coefficients			
Mode	Const.	Tree Coeff.	IVTT	OVTT	Auto Access	Self-Pay Low Income	Self-Pay High Income	Empl. Pays	Non-Resident Origin	Empl. Pays	Luggage >2 bags	>6 Flights in Year
MBTA Rail	1.471 (−1.7)		0.034 (−4.9)	−0.034	0.072 (−5.7)	0.080 (−0.8)	0.080	0.080			−1.175 (−2.2)	
Scheduled Bus/Limo	0.437 (0.8)		−0.034	−0.034	−0.072	−0.080	0.080	0.080				
Logan Express	−0.126 (0.4)		−0.034	−0.034	−0.072	−0.080	0.080	0.080				
Water Shuttle	−2.851 (−2.6)		−0.034	−0.034	−0.072	−0.080	0.080	0.080				
Door-to-Door Nest		0.361 (2.9)							–0.503 (−2.5)	1.337 (4.3)		
Taxi	−1.279 (−3.4)		−0.173 (−2.0)	−0.173		−0.295 (−2.2)	0.101 (−7.5)	0.101				
Limousine			−0.173	−0.173		−0.295	−0.101	0.101				
Automobile Nest	−0.290 (−0.9)	0.72 (5.6)										
Long-term park on airport	0.897 (2.4)		−0.036 (−2.2)	−0.171 (−2.9)		−0.370 (−3.4)	−0.193 (−6.1)	0.102 (−6.1)				0.850 (3.7)
Long-term park off airport	0.527 (0.8)		−0.036	−0.171		−0.370	−0.193	−0.102				0.850
Short-term park at airport	−1.491 (−4.0)		−0.070 (−3.8)	−0.171		−0.370	−0.193	−0.102	−0.794 (−2.6)			
Drop off			−0.070	−0.171		−0.370	−0.193	−0.102	−0.794			

Note: *t*-statistics shown in parentheses (omitted for repeated values). IVTT = in-vehicle travel time; OVTT = out-of-vehicle travel time.

TABLE D4
BOSTON LOGAN RESIDENT NON-BUSINESS MODEL COEFFICIENTS

	Travel Time Coefficients						Travel Cost Coefficients			Dummy Variable Coefficients			
Mode	Const.	Tree Coeff.	IVTT	OVTT	Auto Access	No. of Transfers	Self-Pay Low Income	Self-Pay High Income	Empl. Pays	Non-Resident Origin	Luggage >2 Bags	>2 Flights in Year	Party Size >1
MBTA Rail	0.926 (2.9)		–0.027 (–4.7)	–0.027	–0.092 (–8.1)	–0.150 (–0.9)	–0.232 (–2.9)	–0.232	–0.232		–1.805 (–5.2)		
Scheduled Bus/Limo	3.799 (4.4)		–0.027	–0.027	–0.092	–0.150	–0.232	–0.232	–0.232				
Logan Express	2.781 (5.1)		–0.027	–0.027	–0.092	–0.150	–0.232	–0.232	–0.232				
Water Shuttle	–0.213 (–0.0)		–0.027	–0.027	–0.092	–0.150	–0.232	–0.232	–0.232				
Door-to-Door Nest	–0.401 (–0.4)	0.470 (3.2)											
Taxi	–0.957 (0.3)		–0.057 (–1.7)	–0.057			–0.093 (–4.6)	–0.073 (–4.1)	–0.073	1.118 (2.2)			
Limousine			–0.057	–0.057			–0.093	–0.073	–0.073				2.452 (4.3)
Automobile Nest		0.631 (4.7)											
Long-term park on airport	0.115 (1.4)		–0.036 (–1.8)	–0.066 (–1.0)			–0.259 (–6.5)	–0.118 (–5.4)	–0.118			1.139 (4.0)	
Long-term park off airport	–0.075 (0.1)		–0.036	–0.066			–0.259	–0.118	–0.118			1.139	
Short-term park at airport			–0.074 (–3.6)	–0.066			–0.259	–0.118	–0.118	–1.153 (–3.5)			
Drop off	0.604 (3.4)		–0.074	–0.066			–0.259	–0.118	–0.118	–1.153			1.109 (4.1)

Note: *t*-statistics shown in parentheses (omitted for repeated values). IVTT = in-vehicle travel time; OVTT = out-of-vehicle travel time.

TABLE D5
BOSTON LOGAN NON-RESIDENT BUSINESS MODEL COEFFICIENTS

		Travel Time Coefficients				Travel Cost Coefficients			Dummy Coefficients		
Mode	Const.	IVTT	OVTT	Auto Access	No. of Transfers	Self- Pay Low Income	Self-Pay High Income	Empl. Pays	Non-Resident Origin	Luggage >2 Bags	Party Size >1
MBTA Rail	1.855	0.022	0.022	–0.039	–0.286	–0.091	–0.091	0.058		–0.508	
	(–3.7)	(–4.2)		(–4.3)	(–1.8)	(–7.9)		(–6.9)		(–1.9)	
Scheduled Bus/Limo	1.564	0.022	0.022	–0.039	–0.286	–0.091	–0.091	0.058			
	(–3.8)										
Logan Express	2.856	0.022	0.022	–0.039	–0.286	–0.091	–0.091	0.058			
	(–4.7)										
Water Shuttle	1.620	0.022	0.022	–0.039	–0.286	–0.091	–0.091	0.058			
	(–4.8)										
Taxi		0.039	0.039			0.091	–0.091	0.058			
		(–4.3)									
Limousine	0.275	0.039	0.039			–0.091	–0.091	0.058			
	(–1.4)										
Hotel Shuttle	2.187	0.039	0.039								
	(–11.4)										
Short-Term Park at Airport	1.586	0.039	0.152			–0.058	–0.058	0.058	–2.105		
	(–2.1)		(–2.4)			(–6.9)			(–9.6)		
Drop Off	0.376	0.039	0.152			–0.058	–0.058	0.058	–2.105		0.377
	(–1.2)										(1.6)

Note: *t*-statistics shown in parentheses (omitted for repeated values). IVTT = in-vehicle travel time; OVTT = out-of-vehicle travel time.

TABLE D6
BOSTON LOGAN NON-RESIDENT NON-BUSINESS MODEL COEFFICIENTS

		Travel Time Coefficients				Travel Cost Coefficients			Dummy Coefficients		
Mode	Const.	IVTT	OVTT	Auto Access	No. of Transfers	Self-Pay Low-Income	Self-Pay High-Income	Empl. Pays	Non-Resident Origin	Luggage >2 Bags	Party Size >1
MBTA Rail	–1.066	–0.013	–0.013	–0.013	–0.213	–0.091	–0.091	–0.058		–0.508	
	(–3.7)	(–2.5)	(–2.5)	(–2.2)	(–1.2)	(–7.9)		(–6.9)		(–1.9)	
Scheduled Bus/Limo	0.155	–0.013	–0.013	–0.013	–0.213	–0.091	–0.091	–0.058			
	(–3.8)										
Logan Express	–2.020	–0.013	–0.013	–0.013	–0.213	–0.091	–0.091	–0.058			
	(–4.7)										
Water Shuttle	–2.352	–0.013	–0.013	–0.013	–0.213	–0.091	–0.091	–0.058			
	(–4.8)										
Taxi		–0.013	–0.013			–0.091	–0.091	–0.058			
		(–2.2)	(–2.2)								
Limousine	0.812	–0.013	–0.013			–0.091	–0.091	–0.058			
	(–1.4)										
Hotel Shuttle	–0.021	–0.013	–0.013								
	(–11.4)										
Short-Term Park at Airport	–0.229	–0.013	–0.152			–0.058	–0.058	–0.058	–2.105		
	(–2.1)		(–2.4)			(–6.9)			(–9.6)		
Drop Off	0.376	–0.013	–0.152			–0.058	–0.058	–0.058	–2.105		0.377
	(–1.2)										(1.6)

Note: *t*-statistics shown in parentheses (omitted for repeated values). IVTT = in-vehicle travel time; OVTT = out-of-vehicle travel time.

TABLE D7
IMPLIED VALUES OF BOSTON LOGAN MODEL COEFFICIENTS

Parameter	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Travel Time ($/hour)				
In-vehicle				
Shared-ride modes[a]				
Self-pay/employer pays	26	7	15/23	9/13
Taxi/limousine				
Low-income	35	37	26	9
High-income/employer pays	103	47	26/40	9/13
Auto park				
Low-income	6	8	N/A	N/A
High-income/employer pays	11/21	18	N/A	N/A
Auto drop or park short-term				
Low-income	11	17	40	13
High-income/employer pays	22/41	38	40	13
Auto access (shared-ride modes)				
Self-pay/employer pays	54	24	26/40	9/13
Constants (minutes of IVT)[b]				
MBTA	43	–34	84	82
Scheduled bus/limo	–13	–141	71	–12
Logan Express	4	–103	130	155
Water Shuttle	84	8	74	181
Taxi	7	24	—	—
Limousine	—	7	7	–62
Hotel shuttle	N/A	N/A	56	2
Automobile				
Park long-term on airport	–17	–3	N/A	N/A
Park long-term off airport	–7	2	N/A	N/A
Park short-term at airport	25	—	41	–29
Drop off	4	–8	–10	18

[a]MBTA, scheduled bus/limo, Logan Express, Water Shuttle.
[b]Equivalent minutes of in-vehicle time.
N/A = mode is not available for this market segment; — = no alternative-specific constant estimated for this mode; IVT = in-vehicle travel.

It makes no sense that given travelers will value their time at one amount when considering a high-priced mode and a different amount when considering a less expensive, but more time-consuming mode. Because the CTPS modelers were able to obtain a statistically significant difference in the model coefficients for different modes suggests that this is a result of specification problems with the models or problems with the model estimation data. In particular, the omission of any air party size information in the utility functions for most modes would ignore the distinction between costs that are incurred on a per person basis from those costs that are incurred once per air party. Similarly, the use of the same travel cost coefficient for all air parties irrespective of income is likely to lead to differences in the estimated coefficients for modes with widely different costs.

Given these problems with the data and the conceptual difficulty with having different implied values of time for different modes, there is no reason to expect any particular relationship between the implied values of time for different market segments or different income levels. However, the implied values of time for higher income travelers or those for whom their employer is paying their travel costs are generally higher than those for lower income travelers, as could be expected. Similarly, for non-resident travelers the implied values of time for business travelers are higher than the corresponding values of time for non-business travelers. Although this is also true for some modes for resident travelers, business travelers have a lower implied value of time than non-business travelers for automobile users paying their own travel expenses.

The implied value of the ASCs, expressed as equivalent minutes of in-vehicle time where a positive value indicates that the mode has a relative perceived disutility that would be offset by reducing the travel time by that amount, show no obvious pattern and no consistent relationship across the different market segments. For some market segments a given mode is significantly more attractive than another mode, whereas for other market segments the reverse is true. It is quite likely that these values are so distorted by the model specification problems that they have no intrinsic interpretation.

Model Fit

The documentation on the model provided no information on the overall fit of the model.

Model Application

The model has been used as part of the regional transportation planning process for the Boston metropolitan area to forecast vehicle trips to and from Boston Logan International Airport, as well as for specific planning studies by the Massachusetts Port Authority (the operator of Logan Airport), including an evaluation of a people-mover link between the MBTA Airport Station and an assessment of strategies to address an anticipated future parking shortfall in the on-airport parking facilities.

Integration with Regional Planning Process

The direct output of the model consists of the number of air passengers in 1993 air passenger survey using each mode by TAZ. These air passenger flows are then expanded to correspond to the desired period of analysis (e.g., average weekday or annual demand) using a survey expansion factor that relates the number of air passengers in the survey sample to the O&D passenger traffic at the airport for the period of analysis (accounting for forecast traffic growth for future years where necessary). Air passenger flows are then converted into vehicle trips for exclusive ride modes using the number of people in each travel party reported in each survey record.

The resulting passenger and vehicle trip tables are incorporated in the CTPS regional highway and transit assignment models. The following five trip tables are created for each of the four weekday time periods (a.m. peak, midday, p.m. peak, and night time):

- MBTA passenger trips
- Scheduled bus and limousine passenger trips
- Logan Express passenger trips
- Water Shuttle passenger trips
- Highway vehicle trips.

The highway vehicle trips include automobile access and egress trips to and from the MBTA origin or destination stations, the scheduled bus and limousine stops, and the Logan Express terminals for those air passengers using private vehicles to access those services, as well as taxi, exclusive-use limousine, and rental car trips. The calculation of vehicle trips includes two-way trips for passengers dropped off or picked up at the airport, MBTA stations, bus stops, or Logan Express terminals.

Documentation

Harrington, I.E., J. McClennen, E. Pereira and C.-Y. Wang, *Summary of People Mover Study Passenger Mode Choice Models*, draft memorandum, Central Transportation Planning Staff, Boston, Mass., May 17, 1996.

Harrington, I.E., *The Logan Airport Passenger Ground Access Mode Choice Model*, draft memorandum, Central Transportation Planning Staff, Boston, Mass., Feb. 28, 2003.

D3 CHICAGO AIRPORT EXPRESS RIDERSHIP FORECASTING STUDY

Summary

Airport	Chicago O'Hare International Airport; Chicago Midway Airport		
Model Developer	Resource Systems Group, Inc.		
Date Developed	2004		
Market Addressed	Air passengers		
Model Type	Combined revealed preference and stated preference data		
Model Structure	Nested logit		
Survey Data Used	2003 Chicago Air Traveler Stated Preference Survey		
Airport Profile		O'Hare	Midway
	Total annual passengers (2005):	73.4 million	16.8 million
	Percentage O&D:	45%	73%
	Ground access mode split (2003 O-D survey):		
	Private vehicle—drop off	22%	27%
	Private vehicle—parked	15%	22%
	Rental car	12%	13%
	Taxi	18%	15%
	Limousine	14%	10%
	Hotel/airport van	9%	4%
	CTA train	4%	6%
	Other	5%	4%
Market Segmentation	Residents—Business trips Residents—Non-business trips Non-residents—Business trips Non-residents—Non-business trips		
Explanatory Variables	Total travel time (weighted access, transfer, and waiting time) Travel cost Availability of baggage check-in at downtown terminal Use of intermediate station on Airport Express rail link		

Description

The Chicago Transit Authority (CTA) in partnership with the city of Chicago has been pursuing the feasibility of establishing an express train service between downtown Chicago and O'Hare International and Midway Airports (PB Consult 2006). The proposed service would utilize the tracks of the existing Blue Line of the CTA rapid transit system between downtown Chicago and O'Hare Airport and the existing CTA Orange Line tracks between downtown Chicago and Midway Airport, although some additional passing sections could be provided to reduce travel times. In 2003, the Chicago Department of Transportation (CDOT) retained Resource Systems Group, Inc. (RSG) and Wilbur Smith Associates (WSA) to undertake a ridership and revenue forecasting study of the proposed Airport Express train service (WSA 2004). The study examined the potential use of the Airport Express by air travelers with ground origins in a study area that extended approximately 9 miles north and south of the planned Airport Express terminal in downtown Chicago, as shown in Figure D2.

To identify the pattern of air passenger trip ends, travel party characteristics, and existing access mode use, and to understand how airport travelers might change their access mode choice if the Airport Express train was available, two surveys of air travelers were undertaken by Resource Systems Group, Inc., at O'Hare and Midway Airports in September 2003, an O-D survey and a stated preference survey (RSG 2004). Both surveys were undertaken in the secure area of the airport terminals after passengers had cleared security screening. The O-D survey intercepted 6,789 air travelers, of whom 3,348 were originating passengers and completed the survey. The O-D survey results were used to develop a profile of existing originating air passenger characteristics, including trip purpose, trip origin, and ground access mode use, as well as current and future trip tables that predicted the number of trips by market segment originating in each of 145 TAZs within the study area.

The stated preference survey interviewed 1,110 air travelers in the two airports that a screening question had identified as having a ground access trip origin in the study area. Respondents were asked about details of their trip to the airport, including their trip origin, mode used, and travel times and costs, as well as their trip purpose and whether they were residents of the Chicago region. They were then asked to complete eight stated preference choice experiments in which they were presented with a choice between three modes: the mode they had just used, the Airport Express train, and a third mode. The characteristics of the Airport Express and third mode were varied in the experiments and the respondents were asked which option they would have chosen for their current trip had these been available. The experiments varied the travel time on the main mode and service headway, the access mode used, the access and egress time, travel cost, and availability of baggage check-in at the Airport Express terminal.

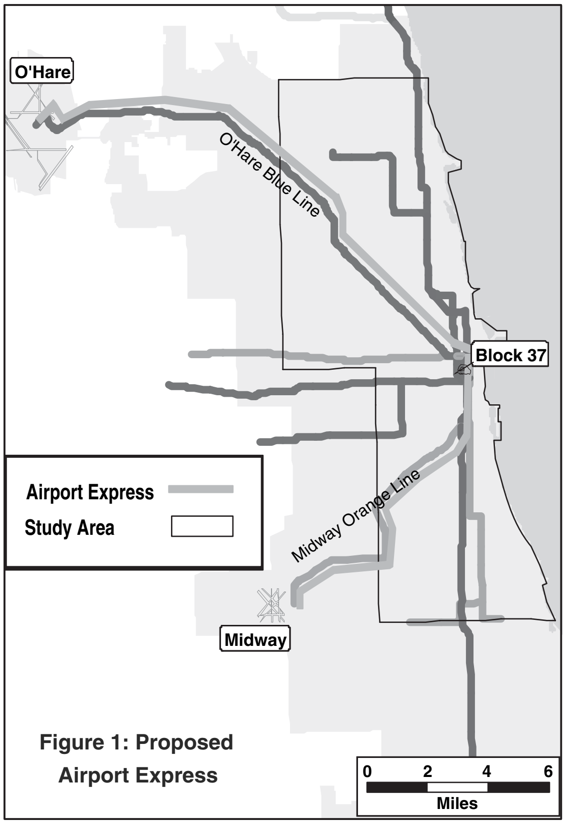

FIGURE D2 Proposed Airport Express routes and study area. (*Source:* WSA 2004.)

The results of the stated preference survey were used to estimate a mode choice model that defined nine airport access modes, as follows:

- Private vehicle parked at the airport for the duration of the air trip (drive and park)
- Dropped off at airport by private vehicle (dropped off)
- Rental car
- Taxi
- Other private mode
- Airport Express train
- Airport Bus
- CTA train
- Other public mode.

The "Other private mode" included limousine, hotel/motel courtesy shuttle, and shared-ride airport van service, whereas the "Other public mode" included PACE bus, METRA train service, regional bus and charter bus. This grouping of modes has the effect of combining modes with very different service characteristics, particularly limousine, shared-ride van, and hotel/motel courtesy shuttle. Similarly, charter bus is not usually a feasible option for most air travelers, and those using this mode (such as tour groups) typically have the mode choice decision made for them, in contrast to users of regional bus and rail services. The Airport Bus alternative is not currently available, but was included in the stated preference experiments as a proposed new service from downtown Chicago as an alternative to the Airport Express train.

The mode choice model used a NL form with a somewhat different nest structure for travelers on business and non-business trips, as shown in Figure D3. Generally, modes are grouped into two nests, one for private modes and one for public modes, where taxi and rental car were considered private modes. The nest structure differed between business and non-business trips in the treatment of the Airport Express train. In the business trip model structure, the Airport Express was treated as a separate alternative at the same level as the private and public mode nests, whereas in the non-business trip model it was considered one of the public modes in the public mode nest.

In both cases the model defined a lower level nest of five access sub-modes below the Airport Express mode. These included a free van service in addition to walk, taxi, drive and park, and CTA transit. The free van alternative was assumed to only be available in certain downtown zones, principally those with a concentration of hotels along Michigan Avenue, whereas the walk alternative was restricted to zones within about a one-half mile of the downtown terminal. The drive and park access alternative was excluded from the available access modes at the downtown terminal, but was assumed to be available at intermediate stations where these were included in the Airport Express service scenarios.

Explanatory Variables

The utility functions for each airport access mode included two continuous variables in addition to ASCs: total travel time and travel cost. The estimated coefficients for each of these two variables within a given market segment were constrained to have the same value for each mode. Traveler income was not explicitly included in the model but travelers were divided into two income categories on the basis of household income and separate travel cost coefficients estimated for each category, where low-income travelers were defined as those with a household income under $100,000 and high-income travelers were defined as those with a household income of $100,000 or more.

Although a single travel time variable was used in each utility function, weights were applied to various components of the total travel time that was used in the model estimation to account for different disutility of access, transfer, and waiting time (as applicable) for each mode. Egress time at the airport was considered to have the same disutility per minute as in-vehicle time on the primary mode. The other travel time components were assumed to have the same weight with different values of this weight for business and non-business trips. These values were determined by iteratively adjusting the weights in steps of 0.25 to find the value that gave the best overall model estimation result. This turned out to be 1.25 for business trips and 1.50 for non-business trips. It is surprising that travelers on business trips appear to be slightly less sensitive to access and waiting time compared with in-vehicle time than travelers on non-business trips.

In addition to the two continuous variables, a dummy variable for the availability of baggage check-in at the downtown terminal was included in the Airport Express and Airport Bus modes. A second dummy variable was included in the Airport Express mode for those passengers boarding at an intermediate station.

Estimation of the mode choice model coefficients used the travel times and costs reported by the survey respondents for the mode they had actually used and the values for the alternative modes provided in the stated preference experiments.

Model Coefficients

Separate model coefficients were estimated for business and non-business travelers. Separate model coefficients were not estimated

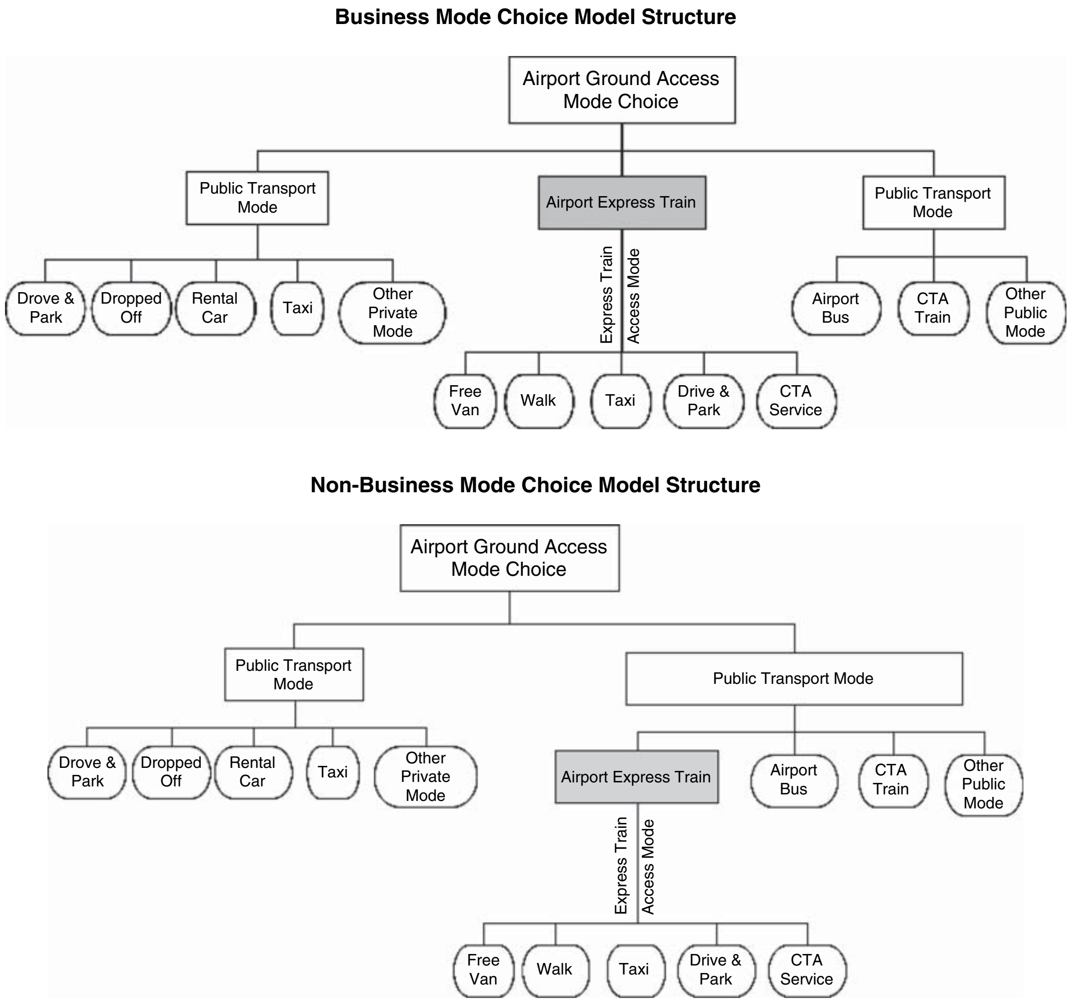

FIGURE D3 Chicago Airport Express mode choice model nesting structure. (*Source:* WSA 2004.)

for residents of the Chicago region and non-residents, although the available modes for these two market segments were different, as noted earlier. The estimated model coefficients for travel time and the dummy variables were constrained to be the same for O'Hare and Midway airports, whereas separate travel cost coefficients were estimated for each airport. The ASCs for taxi and Airport Bus, as well as those for the access modes to the Airport Express train, were constrained to be the same for both airports, whereas those for the other modes were allowed to vary by airport.

After the model coefficients were estimated using the stated preference data, the model was calibrated to correspond to the mode shares for the study area obtained from the O-D survey data by adjusting several of the ASCs until the model predicted the observed mode shares from the study area.

The initial estimated model coefficients for each trip purpose and each airport are shown in Table D8 (RSG 2004). The final calibrated model coefficients for each of the market segments at both airports are shown in Tables D9 and D10 (WSA 2004). It appears that further changes were made in all coefficient values between the estimated values reported in the results of the model estimation (RSG 2004) and the results of the model calibration (WSA 2004). The implied values corresponding to the calibrated model coefficients are shown in Tables D11 and D12. Because the implied values depend on the value of the travel cost coefficient, which varies between low-income and high-income respondents, two implied values are given for each coefficient, corresponding to the two income groups.

The implied values of travel time appear reasonable and broadly consistent with values of time for air passenger travel in other models. The values for business trips are higher than for non-business trips as expected, although the value for low-income respondents on business trips through O'Hare Airport appears surprisingly low compared with the value for high-income respondents at a little over one-third the value. Given the income category split at a household income of $100,000 per year and the general distribution of household incomes in the population at large, one might expect a ratio of about 2.0, as observed for non-business trips at both airports. Similarly, the value for low-income respondents on business trips through Midway Airport appears surprisingly close to that for high-income respondents. The latter may be partly explained by the location of Midway Airport to the south of the downtown and the dominance of low-fare carriers at the airport. Higher income individuals are more likely to live in the more affluent suburbs to the north and northwest of the downtown. These individuals would find O'Hare Airport more convenient and may be less concerned about using a low-fare carrier, resulting in a different income distribution for business travelers using O'Hare and Midway Airports. However, if this is the explanation, it does not appear to apply to non-business trips, where the implied value of travel time for high-income travelers using O'Hare is slightly lower than for those using Midway.

TABLE D8
CHICAGO AIRPORT EXPRESS MODEL ESTIMATED COEFFICIENTS

Coefficient	OHare Business	O'Hare Non-Business	Midway Business	Midway Non-Business
Continuous Variables				
Total travel time (minutes)	–0.098	–0.080	–0.098	–0.080
	(–4.5)	*(–5.0)*	*(–4.5)*	*(–5.0)*
Travel cost—low income ($)	–0.183	–0.212	–0.116	–0.239
	(–4.4)	*(–5.0)*	*(–4.1)*	*(–4.9)*
Travel cost—high income ($)	–0.069	–0.096	–0.056	–0.117
	(–3.8)	*(–4.0)*	*(–3.5)*	*(–3.8)*
Dummy Variables				
Downtown baggage check	0.566	1.788	0.566	1.788
	(2.1)	*(3.9)*	*(2.1)*	*(3.9)*
Use of intermediate station	–1.640	–0.723	–1.640	–0.723
	(–3.3)	*(–2.1)*	*(–3.3)*	*(–2.1)*
Constants				
Private vehicle parked for trip	–0.789	–1.270	–0.209	1.453
	(–1.3)	*(–1.7)*	*(–0.4)*	*(2.0)*
Private vehicle dropped off	–3.269	–3.236	–0.351	–1.482
	(–3.9)	*(–3.7)*	*(–0.6)*	*(–2.2)*
Rental car	–2.911	0.825	2.001	0
	(–2.7)	*(0.9)*	*(2.6)*	
Taxi	–2.730	–3.623	–2.730	–3.623
	(–4.3)	*(–4.1)*	*(–4.3)*	*(–4.1)*
Other private mode	–0.588	–0.605	–1.488	–1.964
	(–1.3)	*(–0.8)*	*(–2.8)*	*(–1.5)*
Airport Bus	–7.354	–4.669	–7.354	–7.087
	(–4.7)	*(–4.8)*	*(–4.7)*	*(–4.9)*
CTA train	–0.545	–0.943	0.002	0.267
	(–1.5)	*(–2.5)*	*(0.0)*	*(0.5)*
Other public mode	–4.426	0.028	–1.279	–0.524
	(–2.5)	*(0.0)*	*(–0.7)*	*(–0.7)*
Airport Express Access Modes				
Free van	0.683	–0.025	0.683	–0.025
	(2.1)	*(–0.1)*	*(2.1)*	*(–0.1)*
Walk	–0.573	–1.100	–0.573	–1.100
	(–1.7)	*(–2.3)*	*(–1.7)*	*(–2.3)*
Drive & park	2.261	2.431	2.261	2.431
	(2.3)	*(3.1)*	*(2.3)*	*(3.1)*
CTA bus or train	–1.019	–0.943	–1.019	–0.943
	(–2.9)	*(–2.5)*	*(–2.9)*	*(–2.5)*
Nest Coefficients				
Private mode nest	0.630	0.374	0.630	0.374
	(8.0)	*(5.5)*	*(8.0)*	*(5.5)*
Public mode nest	0.485	0.747	0.485	0.747
	(5.5)	*(10.0)*	*(5.5)*	*(10.0)*

These differences in the implied value of travel time across the market segments are troubling, because they directly affect the trade-off between travel times and cost, which is central to the evaluation of a new service that offers shorter travel times for a premium fare. Given the obvious importance of household income in explaining traveler behavior, both from the perspective of common sense and as demonstrated by the model estimation results, the classification of travelers into only two income categories must necessarily only provide a very approximate representation of the role of income in access mode choice. Although better than ignoring traveler income completely, it is likely to significantly reduce the ability of the model to explain observed mode choice behavior and could adversely affect predictions of the likely future use of new modes.

The implied values of the two dummy variables present some interesting implications. As might be expected, business travelers (who typically have less baggage than non-business travelers and may only have carry-on bags) appear to value the availability of downtown baggage check-in at about half the value of non-business travelers. However, the implied value for non-business travelers of between about $7 and $18, depending on income, is surprisingly high. With proposed fares on the Airport Express train of only $10 per passenger, this suggests that the provision of downtown check-in would have a similar effect in ridership to making the service free, at least for non-business travelers. Those travelers using an intermediate station appear to find the Airport Express service significantly less attractive than those using the downtown terminal, particularly travelers on business trips, who would require a fare difference of somewhere between $9 and $26 to make the attractiveness of the service similar to that of the downtown terminal, other things being equal. The upper end of this range is of course significantly higher than the planned fare and it is unclear why this should be so if the stated preference experiments had correctly reflected the access times and costs to both the downtown terminal and intermediate stations.

One possible explanation is that the access options were different between the downtown terminal and the intermediate station, with the drive and park access option only available at the intermediate station. It is noteworthy that the ASCs for drive and park access are of the opposite sign to the intermediate station coefficients and somewhat larger (slightly larger in the case of business trips and about twice as large in the case of non-business trips). If these ASC values were overestimated, as discussed further later, the estimated

TABLE D9
CHICAGO AIRPORT EXPRESS MODEL CALIBRATED COEFFICIENTS: O'HARE AIRPORT

Coefficient	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Continuous Variables				
Total travel time (minutes)	–0.092	–0.091	–0.092	–0.091
Travel cost—low income ($)	–0.166	–0.220	–0.166	–0.220
Travel cost—high income ($)	–0.060	–0.099	–0.060	–0.099
Dummy Variables				
Downtown baggage check	0.499	1.714	0.499	1.714
Use of intermediate station	–1.553	–1.051	–1.553	–1.051
Constants				
Private vehicle parked for trip	5.690	7.981	N/A	N/A
Private vehicle dropped off	–1.433	–2.311	–1.022	0.925
Rental car	N/A	N/A	4.081	2.159
Taxi	2.750	3.658	6.620	7.017
Other private mode	3.147	3.767	6.461	6.515
Airport Bus	–6.981	–5.556	–6.981	–5.556
CTA train	–0.639	–2.320	–0.639	–2.320
Other public mode	3.989	1.702	5.582	4.788
Airport Express Access Modes				
Free van	0.467	–0.092	0.467	–0.092
Walk	–0.620	–1.728	–0.620	–1.728
Drive and park	1.795	2.380	1.795	2.380
CTA bus or train	–0.963	–1.133	–0.963	–1.133
Nest Coefficients				
Private mode nest	0.647	0.335	0.647	0.335
Public mode nest	0.523	0.775	0.523	0.775

N/A = not applicable.

TABLE D10
CHICAGO AIRPORT EXPRESS MODEL CALIBRATED COEFFICIENTS: MIDWAY AIRPORT

Coefficient	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Continuous Variables				
Total travel time (minutes)	–0.092	–0.091	–0.092	–0.091
Travel cost—low income ($)	–0.088	–0.254	–0.088	–0.254
Travel cost—high income ($)	–0.067	–0.096	–0.067	–0.096
Dummy Variables				
Downtown baggage check	0.499	1.714	0.499	1.714
Use of intermediate station	–1.553	–1.051	–1.553	–1.051
Constants				
Private vehicle parked for trip	2.195	5.695	N/A	N/A
Private vehicle dropped off	–2.767	0.189	0.157	0.335
Rental car	N/A	N/A	3.349	1.899
Taxi	0.625	3.532	5.588	5.849
Other private mode	0.492	8.708	5.003	5.548
Airport Bus	–6.981	–8.768	–6.981	–8.768
CTA train	–0.150	–0.182	–0.150	–0.182
Other public mode	–2.242	–5.778	–2.506	–7.400
Airport Express Access Modes				
Free van	0.467	–0.092	0.467	–0.092
Walk	–0.620	–1.728	–0.620	–1.728
Drive and park	1.795	2.380	1.795	2.380
CTA bus or train	–0.963	–1.133	–0.963	–1.133
Nest Coefficients				
Private mode nest	0.647	0.335	0.647	0.335
Public mode nest	0.523	0.775	0.523	0.775

N/A = not applicable.

TABLE D11
IMPLIED VALUES OF CHICAGO AIRPORT EXPRESS MODEL COEFFICIENTS

Parameter	O'Hare Business	O'Hare Non-Business	Midway Business	Midway Non-Business
Travel Time ($/hour)				
Total travel time	33/92	25/55	63/82	22/57
Dummy Variables ($)				
Downtown baggage check	3/8	8/17	6/8	7/18
Use of intermediate station	–9/–26	–5/–11	–18/–23	–4/–11
Constants ($)				
Airport Express access modes				
Free van	3/8	0/–1	5/7	–0.5/–1
Walk	–4/–10	–10/–17	–7/–9	–7/–18
Drive and park	11/30	11/24	20/27	9/25
CTA bus or train	–6/–16	–5/–11	–11/–14	–4/–12

Notes: The two values shown for each coefficient are for low-income and high-income respondents, respectively.
The implied values of the dummy variables show the contribution of the attribute to the perceived utility of the Airport Express train alternative.
The table shows the implied values of the alternative-specific constants for the Airport Express train access modes relative to taxi (i.e., the perceived utility of the mode relative to taxi if travel times and costs are equal).

TABLE D12
IMPLIED MODAL CONSTANT VALUES FOR THE CHICAGO AIRPORT EXPRESS MODEL

Parameter	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Modal Constants ($)				
O'Hare Airport				
Private vehicle parked for trip	34/ 95	36/81	N/A	N/A
Private vehicle dropped off	–9/–24	–11/–23	–6/–17	4/9
Rental car	N/A	N/A	25/68	10/22
Taxi	17/46	17/37	40/110	32/71
Other private mode	19/52	17/38	39/108	30/66
Airport Bus	–42/–116	–25/–66	–42/–116	–25/–66
CTA train	–4/–11	–11/–23	–4/–11	–11/–23
Other public mode	24/66	8/17	34/93	22/48
Midway Airport				
Private vehicle parked for trip	25/33	22/59	N/A	N/A
Private vehicle dropped off	–31/–41	1/2	2/2	1/3
Rental car	N/A	N/A	38/50	7/20
Taxi	7/9	14/37	64/83	23/61
Other private mode	6/7	34/91	57/75	22/58
Airport Bus	–79/–104	–35/–91	–79/–104	–35/–91
CTA train	–2/–2	–1/–2	–2/–2	–1/–2
Other public mode	–25/–33	–23/–60	–28/–37	–29/–77

Notes: The two values shown for each coefficient are for low-income and high-income respondents, respectively.
The table shows the implied values of the alternative-specific constants relative to the Airport Express train (i.e., the perceived utility of the mode relative to the train if travel times and costs are equal).
N/A = not applicable.

value of the coefficient for the intermediate station dummy variable would attempt to correct for this.

Interpreting the implied values of the ASCs for the access modes to the Airport Express train requires some caution owing to the way that the associated costs and travel times were included in the stated preference experiments. Each experiment presented an access time for the Airport Express option to the respondent and indicated the associated access mode. The access times were derived from the trip origin that the respondent had indicated; however, it is unclear from the model documentation whether these access times varied by the access mode indicated. It is also unclear from the model documentation how the associated access costs were presented to the respondent, if indeed they were. The example scenario shown in the documentation for the stated preference survey (RSA 2004) gives the access time to the downtown terminal by CTA bus or train but makes no mention of the fare involved. In any event, the respondents were only presented with one access option for each Airport Express scenario and could not choose between other options to access the service. Given the need to vary several different parameters over the course of only eight stated preference experiments, it is doubtful that the experiments provided much opportunity to examine tradeoffs between time and cost of different access modes as distinct from those of the primary modes. Thus, it is likely that most respondents focused on the access time shown rather than the other attributes of the access modes.

This could explain some of the rather surprising implied values. It is counterintuitive that a free van service would be viewed as more attractive than a taxi if the taxi fare was already accounted for, given that the taxi provides a direct service with no waiting and does not have to be shared with other riders. It is not unreasonable that walking would have a higher disutility than the same time spent riding a taxi, although the travel time calculations apparently already include a weighting for this. The relatively high implied value of the ASCs for drive and park mentioned earlier, in the range of $9 to $30, could reflect that this access mode would have a much shorter travel time than access by CTA bus or train, whereas the higher cost involved may not have been fully apparent to the respondents. The model documentation does not provide any screen shots of stated preference scenarios involving the intermediate station or access options other than CTA bus or train; therefore, it is unclear how much information respondents had about the cost of different access alternatives.

The implied values for many of the ASCs for the primary access modes shown in Table D11 appear generally to have the expected sign, but many of the values are surprisingly high. It is unclear why the option of "other public mode" is viewed as inherently more attractive than the Airport Express in the case of O'Hare Airport, by an amount equivalent to a cost difference as high as $93 (in the case of non-resident business trips by high-income respondents), but inherently less attractive than Airport Express in the case of Midway Airport by an amount equivalent to a cost difference of $77 (in the case of non-resident non-business trips by high-income respondents). Similarly, it is unclear why Airport Bus would be viewed as inherently less attractive than the Airport Express by an amount equivalent to a cost difference that varies between $35 and $104. If travelers really valued the attributes of rail travel over bus travel by amounts of this magnitude, the challenge of financing rail transit systems would have been solved long ago.

These issues are a significant cause for concern because of the relative magnitude of the ASC values compared with the travel times and costs. Not only does this mean that the model predictions are relatively insensitive to changes in travel time and cost, but that errors in the estimation and calibration of the ASC values can easily swamp the effect of differences in travel times and costs between modes.

Model Fit

The model documentation presents *t*-statistics for each of the model coefficients, although it does not provide an overall measure of the fit of the model to the estimation data. Although the model calibration process ensured that the predicted mode shares from the study area corresponded to the observed mode shares, the model documentation does not discuss how different the predicted mode share using the estimated coefficients was from that given by the O-D survey data, nor how much the mode share using the calibrated model coefficients differed from the observed mode share at the level of each TAZ. Although differences are inevitable at the TAZ level, because the model is not a perfect predictor of individual behavior and the O-D data itself will contain some error at the zonal level owing to sample size issues, the issue of concern is whether these differences exhibit any geographical bias that could affect the predictions of the use of the Airport Express train.

The *t*-statistics for travel time and cost coefficients are all highly significant. The dummy variable coefficient for downtown baggage check is highly significant for non-business travelers and just statistically significant at the 95% confidence level for business travelers. The dummy variable coefficient for boarding at an intermediate station shows the reverse pattern, being highly significant for business travelers and just statistically significant at the 95% confidence level for non-business travelers. The statistical significance of the estimated ASCs varies, with several having *t*-statistics less than 1.0 and a few having *t*-statistics close to zero. However, it could be quite appropriate for an ASC to have a value close to zero, giving a very low *t*-statistic. What is of more concern is the absence of any consistent pattern in the relative values of the ASCs for each mode between the two airports and for each trip purpose.

Model Application

The calibrated mode choice model for each market segment was applied to forecast ridership and revenue for the Airport Express train for various service scenarios for two future years, 2009 and 2020. These service assumptions included two different fare levels, several different travel time assumptions for the service to O'Hare Airport (the travel time to Midway Airport was not varied), two different growth rates for off-peak highway travel time, and whether or not a free downtown shuttle or baggage check at the downtown terminal would be provided (WSA 2004).

To apply the mode choice models it was necessary to calculate travel times and costs on each mode from each TAZ. This issue did not arise in the model estimation, because the values were either provided by the respondents for their existing choice or generated hypothetically for the other options in the stated preference experiments. Highway travel times were obtained from highway network skims of the Chicago Area Transportation Study, whereas transit travel times were obtained from similar skims from a CDOT/WSA transit network model developed for the CDOT Mid-City Transitway Study (WSA 2004). Other travel cost and time assumptions were made for various components of the airport access time and cost by each mode. Because highway travel times vary by time of day, separate highway travel times were calculated for peak and off-peak conditions and the models applied separately to each time period, with the results weighted by the proportion of airport access and egress travel that occurs during each period based on the profile of flight arrivals and departures.

Because the air passenger trip tables that were developed for the study did not include detailed air party characteristics, but only counts of passengers from each TAZ by market segment, the model application was based on average air party size and average air trip duration for each market segment in calculating travel costs, as well as the average percentage of rental cars that were not needed for other purposes than travel to and from the airport. Because logit choice models tend to exhibit strong nonlinearity with respect to the values of the explanatory variables, it is unclear what effect this might have on the results. Modes such as the Airport Express train become less attractive to passengers traveling in larger parties, because the cost increases in proportion to the party size in contrast to modes such as taxi, limousine, or the use of private vehicles. The average air party size used in the analysis was based on the O-D survey results and varied by trip purpose between 1.57 and 1.96. Thus, the mode choice analysis included no single-person parties, even though these are by far the largest percentage of air travel parties (because the average air party size reflects a small number of quite large parties). Similarly, the average number of days away by Chicago area residents varied between 3.8 and 5.5, depending on the airport and trip purpose. The mode choice behavior of someone who is away for a period from 4 to 6 days is likely to be very different from someone who is only away for one or two days on the one hand or someone who is away for several weeks on the other, owing to the increasing cost of airport parking as the trip duration increases. Whether these effects cancel each other out, giving reasonable estimates of the likely use of the Airport Express train or result in biased estimates of ridership is unclear.

Documentation

PB Consult, Inc., in association with Mercer Management Consulting, Inc., Parsons Brinckerhoff Quade & Douglas, Inc., and Velma Butler & Company, Ltd., *Express Airport Train Service: Business Plan*, Prepared for Chicago Transit Authority, Chicago, Ill., Final Report, Sep. 22, 2006.

Resource Systems Group, Inc., *O'Hare and Midway Airport Express Train Ridership Forecasting Study: Chicago Air Traveler Stated Preference Survey Report*, Prepared for Chicago Department of Transportation, White River Junction, Vt., Jan. 2004.

Wilbur Smith Associates, in association with Resource Systems Group, Inc., *Airport Express Ridership and Revenue Forecast*, Prepared for Chicago Department of Transportation, Chicago, Ill., 2004.

D4 MIAMI INTERMODAL CENTER TRAVEL DEMAND FORECAST STUDY

Summary

Airport	Miami International Airport	
Model Developer	Gannett Fleming, Inc. with KPMG Peat Marwick	
Date Developed	1995	
Market Addressed	Air passengers	
Model Type	Revealed preference data	
Model Structure	Nested logit	
Survey Data Used	1991 Miami International Airport Air Passenger Survey	
Airport Profile	Total annual passengers (2005): 30.2 million	
	Percentage O&D: 55%	
	Ground access mode split (1991 survey):	
	Private vehicle—drop off	45%
	Private vehicle—parked	13%
	Rental car	28%
	Taxi	6%
	Limousine	2%
	Shared-ride van	3%
	Public transit	<1%
	Hotel van	3%
Market Segmentation	Residents—Business trips	
	Residents—Non-business trips	
	Non-residents—Business trips	
	Non-residents—Non-business trips	
Explanatory Variables	Travel cost	
	In-vehicle travel time	
	Waiting time plus terminal time (if any)	

Description

The Miami Intermodal Center (MIC) is being planned as major transportation interchange facility located immediately to the east of the Miami International Airport (MIA), as shown in Figure D4. The project is intended to provide an integrated terminal for several intercity transportation services, including Amtrak, Tri-Rail commuter rail, Greyhound buses, and future High Speed Rail and East–West Corridor rail lines, as well as Metrobus and Metrorail services (FHWA and Florida DOT 1997). An automated people mover (the MIC/MIA Connector) will link the MIC to the airport. Provision has also been made in the planning for a future Airport/Seaport Connector rail link. The MIC will also accommodate growth of MIA by providing expanded airport landside facilities, including rental car facilities and long-term parking facilities.

As part of the planning for the MIC, a travel demand forecast was prepared in 1995 (ICF Kaiser Engineers 1995). This incorporated an airport access mode choice model that was used to forecast ridership on the MIC/MIA Connector. The mode choice model was based on a model originally developed by KPMG Peat Marwick for a study for Newark International Airport in New Jersey. The Newark model was calibrated as a simple binomial logit choice model of the use of transit versus non-transit modes and was subsequently converted into a nested model by adding the choice between rail and bus to the transit nest. Because of the large number of modes available at MIA and the complexity of the choices available as a result of the MIC project, the mode choice model was expanded to include the following modes:

- Drop off by private vehicle (termed auto–kiss and ride)
- Private vehicle parked for the air trip duration (termed auto–park and ride)
- Rental car
- Taxi
- Limousine
- Premium transit
- Local transit
- Shared-ride van (termed Super Shuttle)
- Hotel courtesy shuttle (termed hotel van).

The first five modes were grouped into a nest called Non-Group modes and the other four modes were grouped into a nest called Group modes. The resulting structure of the model is shown in Figure D5.

The model adopted the four market segments used in the Newark model:

- Resident business trips
- Resident non-business trips
- Non-resident business trips
- Non-resident non-business trips.

Air passenger trip tables were developed for each market segment based on an air passenger survey of 3,002 respondents conducted at MIA by Landrum & Brown in 1990. This survey had coded the trip origins of survey respondents using a system of 19 zones. The number of air passenger trip origins in each zone was weighted

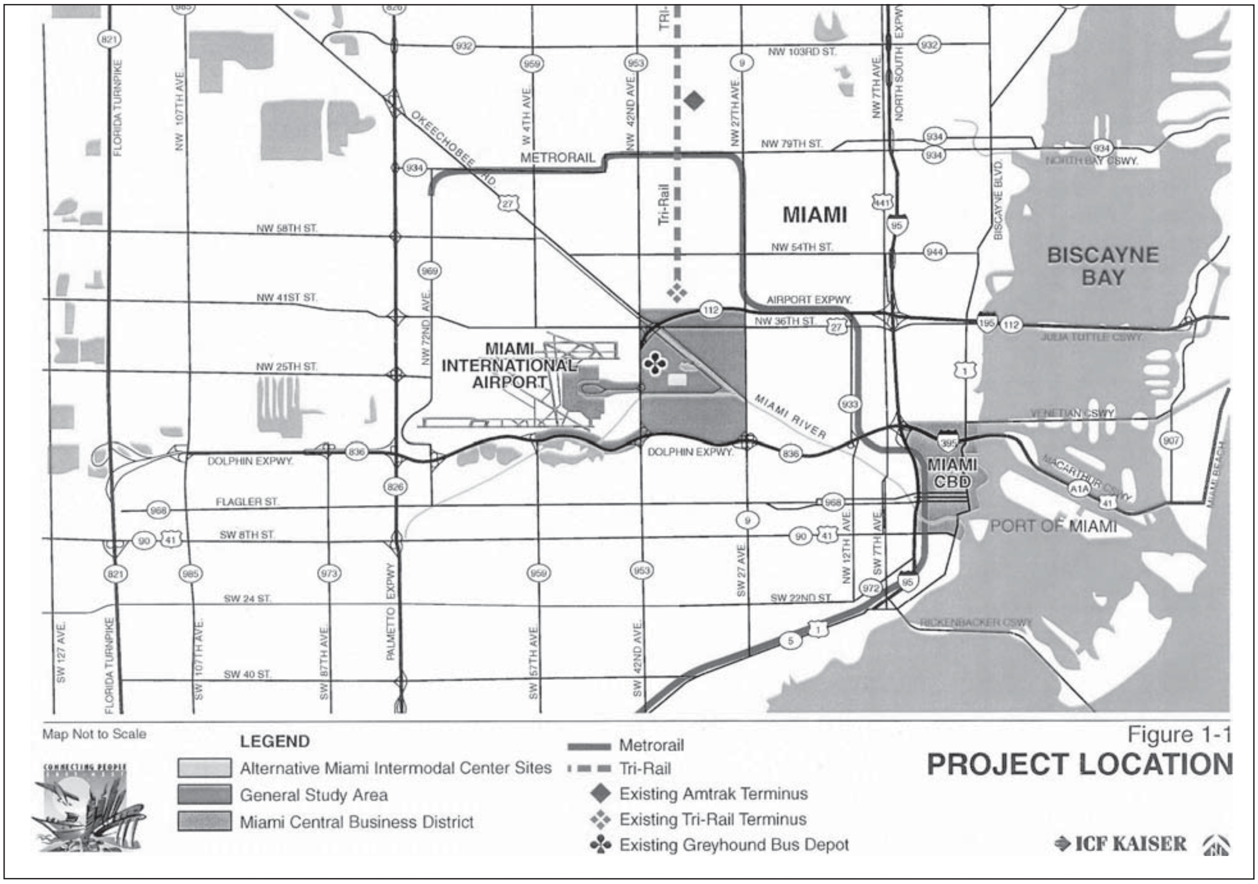

FIGURE D4 Miami intermodal center location.
(*Source:* ICF Kaiser 1995.)

to represent the number of originating average weekday passengers in 1991 and doubled to account for arriving passengers. These air passenger trips were then assigned to the much larger number of regional (TAZs) in the regional travel model using a simple prorating process based on the type of trip origin given by the air passenger survey. Trips with home origins were allocated on the basis of population, trips with a workplace origin were allocated on the basis of employment, trips from a hotel or motel were allocated on the basis of the number of hotels and motels in the zone, and trips with other types of trip origin were allocated on the basis of population. Air passenger trips from external zones in the regional model were allocated on the basis of the total internal–external trips for the external TAZ in the regional model.

Highway and transit travel times and highway distances from each TAZ to the airport or MIC were obtained from the travel time skim tables in the regional travel model. Transit travel times were divided into in-vehicle time and waiting time from the transit network skim tables. Constant values for waiting and other out-of-vehicle times were assumed for other modes. Transit fares were assumed constant at $1.25. Private vehicle operating costs were assumed to be 27.5 cents per mile and parking costs were assumed to be $3 for drop-off trips and $18 for vehicles parked for the duration of the air trip. Taxi costs were estimated from the highway distance and meter flag drop and rate per mile, with a flat fare for airport area hotels and the seaport. Limousine and shared-ride van fares varied by trip origin zone. The model documentation does not discuss how the size of

Miami International Airport (MIA)

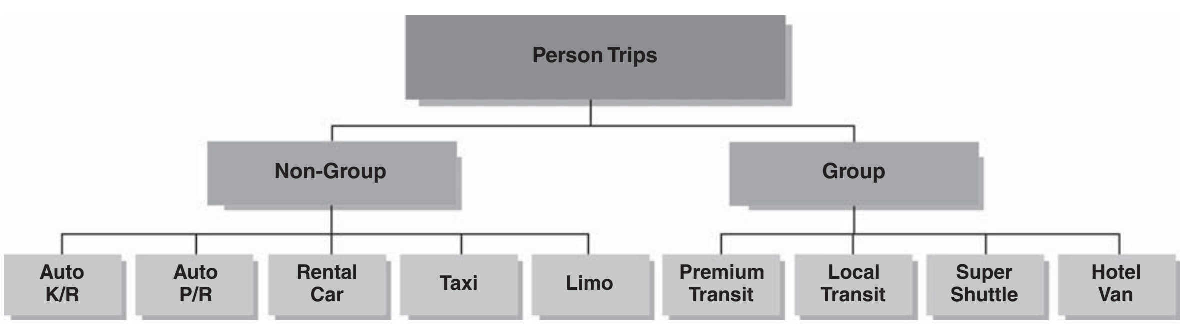

FIGURE D5 Miami air passenger ground access mode choice model structure.
(*Source:* ICF Kaiser 1995.)

the air party was addressed in calculating travel costs, if at all. The cost assumptions appear to have been made on the basis of the travel cost for each air party. If these costs were then applied in the model on the basis of each air passenger, this would significantly overstate the cost of some modes for travel parties with more than one air passenger. Similarly, the same cost for parking at the airport for the duration of the air trip appears to have been used for each passenger, irrespective of the actual trip duration. This would tend to overstate the cost of this alternative for passengers on shorter trips and understate the cost for those on longer trips.

Peak highway travel times were assumed for all air passengers, irrespective of their actual flight time. This would tend to overstate the travel times for highway-based modes during most of the day and to the extent that transit travel times are less subject to peak period congestion would bias the model in favor of transit use.

All modes were assumed to be available to each market segment, including parking a private vehicle for the duration of the trip, rental car, and hotel/motel courtesy shuttle. Because visitors do not have the option of parking a car at the airport during their trip (if they had access to a car during their visit they would not leave it at the airport), and residents typically do not rent cars to access the airport or start their trip to the airport from a hotel or motel that provides a courtesy shuttle, it is likely that the estimated ASCs for these modes are biased by the need to explain the low mode share by those market segments for which certain modes are not a viable option.

Explanatory Variables

The model has only three explanatory variables, apart from the ASCs: in-vehicle travel time, out-of-vehicle travel time (including waiting time and terminal time, such as walking from the parking lot to the airport terminal or returning a rental car), and travel cost. The same three variables are used for each mode, although the calculation of the variable values differs for each mode. There is no consideration given to the effect of income differences in the model. Therefore, all respondents are assumed (in effect) to have the same value of travel time.

Model Coefficients

The values for the coefficients for the continuous variables were not estimated from the air passenger survey data, but rather adopted (or "borrowed" to use the expression in the model documentation) from the values estimated for Newark International Airport in the original model. There is no discussion in the model documentation about whether any adjustments were made to reflect changes in income levels and price values during the period of time that had elapsed because the Newark model was estimated or there were differences in income levels between Miami and the New York/New Jersey region. The same coefficient values were used for all four market segments, implicitly implying the same value of time for business and non-business travelers and for residents of the Miami region and visitors.

Values for the ASCs were estimated from the air passenger survey data to fit the model predictions of mode use to the observed data. Estimated values were obtained for each mode, although usual practice is to set the ASC for one mode to zero and express the other ASCs relative to that. Because the premium transit service did not exist at the time of the air passenger survey, the values for that mode were based on the values of the ASCs for other modes and the ability of the model to predict transit ridership levels typically observed in other U.S. cities with premium transit services similar to that envisioned for Miami.

The assumed and estimated values of the model coefficients are shown in Table D13 and the implied values of the coefficients are shown in Table D14. The values of the ASCs have been adjusted so that the ASC for drop off by private vehicle is zero. These values

TABLE D13
MIAMI INTERMODAL CENTER TRAVEL DEMAND MODEL COEFFICIENTS

Coefficient	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Variables				
In-vehicle time (minutes)	–0.06383	–0.06383	–0.06383	–0.06383
Waiting/terminal time (min)	–0.16077	–0.16077	–0.16077	–0.16077
Cost (cents)	–0.00049	–0.00049	–0.00049	–0.00049
Constants				
Private vehicle—dropped off	1.67737	2.82737	2.22737	2.22737
Private vehicle parked for trip	2.22737	2.22737	0.89737	1.37737
Rental car	2.71737	4.41737	6.05737	6.07737
Taxi	0.47737	1.47737	2.76237	1.63737
Limousine	–4.27263	2.69737	3.80737	2.28737
Premium transit	–0.7	0.8	–0.2	2.8
Local transit	–5.9	–3.7	–8.2	–4.2
Shared-ride van	–6.2	–6.3	–7.66	–6.86
Hotel courtesy shuttle	–8.0	–7.0	–5.5	4.0
Nest Coefficients				
Non-group modes nest	0.3	0.3	0.3	0.3
Group mode nest	0.3	0.3	0.3	0.3

TABLE D14
IMPLIED VALUES OF MIAMI INTERMODAL CENTER TRAVEL MODEL COEFFICIENTS

Parameter	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Travel Time ($/hour)				
In-vehicle time	78	78	78	78
Waiting/terminal time	197	197	197	197
Constants ($)				
Private vehicle—dropped off	—	—	—	—
Private vehicle parked for trip	11	–12	–27	–17
Rental car	21	32	78	79
Taxi	–25	–28	11	–12
Limousine	–121	–3	32	1
Premium transit	–49	–41	–50	12
Local transit	–155	–133	–213	–131
Shared-ride van	–161	–166	–202	–185
Hotel courtesy shuttle	–198	–201	–158	36

vary across the four market segments, reflecting difference in mode use across the segments.

The implied value of in-vehicle time of $78/h appears reasonable for air passenger travel, particularly because it applies to both business and non-business travel. The implied value of waiting and terminal time is about two and one-half times the value of in-vehicle time, which is somewhat higher than is commonly found in urban travel models but not unreasonable, particularly given the time-sensitive nature of airport access travel, where an unexpected delay could result in a missed flight. The implied values of ASCs vary widely, with several implausibly large. The large negative values for the hotel courtesy shuttle are most likely an artifact of this mode being available to all air passengers, rather than those starting their access trip from hotels that provide a courtesy shuttle service to the airport. However, the large negative implied values for the shared-ride van is surprising, because the assumed fares were based on the prevailing fare structure for SuperShuttle and travel times are similar to other highway modes. The travel time assumptions did not consider the time involved in any circuitry to pickup or drop off other passengers or schedule delay resulting from the frequency with which pickups can be scheduled. However, the implied ASC values are equivalent to more than 2 h of travel time, which is far greater than the time involved in waiting for a pickup or picking up other passengers.

Although the difference in ASC between premium transit and local transit is in the expected direction, the magnitude of the difference, an implied value of between about $90 and $160, seems unrealistically high. The model documentation does not clearly define premium transit, but presumably this mode is used to distinguish between Metrorail and local bus service. Although air travelers may well prefer rail transit to bus service in situations in which the travel times on either mode are the same, it seems unlikely that this preference would be strong enough that the mode shares of the two services would be equal if travel times were the same, but the Metrorail fare was $160 more than the bus fare.

The implications of the large ASC values is that the continuous variables are not explaining the observed mode shares very well at all and the ASCs are having to adjust the model to enable it to predict the observed mode shares. This in turn suggests that the model is not going to do a very good job of predicting the use of new or improved modes, because changes in the values of the continuous variables will have a relatively small effect on the model predictions.

The values of the nest coefficients were presumably also taken from the Newark model. It is unclear that these would still be valid if the number of alternatives in each nest is increased to the extent that was done.

Model Fit

The model documentation provides no information on the statistical significance of the estimated values of the ASCs or the overall fit of the model.

Model Application

The mode choice model was used to predict ground access mode use to MIA in 2020 and resulting peak-hour passenger trips using the MIC/MIA Connector. The 2020 air passenger trip tables were obtained by factoring up the 1991 trip tables by the forecast growth in total airport traffic and the assumed proportion of locally originating air passengers in 2020 provided by MIA staff. The peak-hour demand on the MIC/MIA Connector was assumed to occur on a Friday afternoon between 3:30 and 4:30 p.m. and the air passenger component was assumed to comprise 14% of the average weekday air passengers other than cruise ship passengers. The forecast average weekday air passenger traffic was reduced to allow for cruise ship passengers using the Airport/Seaport Connector who would not use the MIC, with the balance of the cruise ship passengers using the MIC. It was assumed that 13% of the cruise ship passengers on an average Friday using the MIC would do so in the peak-hour, together with 20% of the average weekday employees at the airport estimated to use the MIC.

Documentation

ICF Kaiser Engineers, Inc., with Gannett Fleming, Inc., and KPMG Peat Marwick, *Miami Intermodal Center: Travel Demand Forecast Report*, Prepared for Florida Department of Transportation and Federal Highway Administration, Miami, Fla., Aug. 1995.

U.S. Federal Highway Administration and Florida Department of Transportation, *Miami Intermodal Center Final Environmental Impact Statement*, Report FHWA-FLA-EIS-95-01-F, Tallahassee, Fla., Dec. 23, 1997.

D5 OAKLAND INTERNATIONAL AIRPORT BART CONNECTOR STUDY

Summary

Airport	Oakland International Airport	
Model Developer	CCS Planning and Engineering, Inc.	
Date Developed	2001	
Market Addressed	Air passengers	
Model Type	Revealed preference data	
Model Structure	Multinomial logit	
Survey Data Used	1995 Metropolitan Transportation Commission Air Passenger Survey; 1999 Survey of AirBART Passengers	
Airport Profile	Total annual passengers (2005): 14.1 million	
	Percentage O&D: 95%	
	Ground access mode split (2002 MTC Air Passenger Survey):	
	Private vehicle—drop off	42%
	Private vehicle—parked	21%
	Rental car	15%
	Taxi	3%
	Limousine	2%
	Hotel courtesy shuttle	2%
	Shared-ride van	3%
	Scheduled airport bus	3%
	Shuttle bus from BART	8%
	Public transit bus	1%
	Other	<1%
Market Segmentation	Residents—Business trips	
	Residents—Personal trips	
	Visitors—Business trips	
	Visitors—Personal trips	
Explanatory Variables	Travel time (private vehicles)	
	Travel time (rail transit)	
	Travel time (bus transit)	
	Walk distance	
	Wait time	
	Travel cost	
	Household income	

Description

Oakland International Airport currently operates a shuttle bus link called AirBART between the airport and the Coliseum station of the Bay Area Rapid Transit (BART) system, located about 2.5 miles from the airport. Since the 1970s, a series of studies have been undertaken by the Port of Oakland (the operator of Oakland International Airport), BART, and other agencies to explore the feasibility of an automated people-mover connection between the airport and the Coliseum BART station (*BART–Oakland International Airport Connector* . . . 2002, Executive Summary). The most recent of these efforts commenced in 1999 with a public scoping meeting for the preparation of an Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for a planned Oakland Airport Connector. The Draft EIR/EIS was distributed in August 2001 and the Final EIR/EIS was approved in March 2002. As part of the analysis for the EIR/EIS, an airport access mode choice model was developed and applied to generate ridership projections for the Connector (*BART–Oakland International Airport Connector* . . . 2002, Appendix B: Transit Ridership Procedures and Inputs).

The planned Connector would include two stops between the airport and the Coliseum BART station and would reduce the current AirBART travel time of about 13 min to about 6 min. It was assumed that service frequency would also improve from the current AirBART frequency of every 10 min to a 3.2-min headway. The goal of the mode choice analysis was to evaluate the effect of this service improvement on ridership on the Connector compared with the AirBART service, as well as to examine an alternative improved bus service.

The mode choice model addressed both air passenger trips and airport employee trips. The employee trips were treated as a separate market segment and this aspect of the model is discussed further later. The general form of the model is a MNL model with air passenger trips divided into four market segments as follows:

- Resident business trips
- Resident personal trips
- Visitor business trips
- Visitor personal trips.

Data on the air party characteristics for each market segment were obtained from the 1995 Air Passenger Survey performed for the Metropolitan Transportation Commission (MTC) at the three Bay Area airports, including Oakland International Airport (Franz 1996). This information was supplemented by surveys of AirBART passengers performed by CCS Planning and Engineering, Inc., in December 1999 and May 2000 as part of the study. The mode choice analysis assigns airport trips among the following eight modes:

- Private vehicle (termed private auto)
- Rental car
- Scheduled airport bus (termed scheduled shuttle bus)
- Public transit
- Shared-ride van (termed door-to-door shuttle)
- Hotel courtesy shuttle
- Taxi and limousine
- Other.

Public transit included the use of BART through the AirBART shuttle (or the Connector in the future), as well as local transit bus service directly to the airport. However, these two modes were not separately identified in the model but rather the transit alternative for travelers with trip origins in zones near the airport was assumed to be local bus, whereas the transit alternative for those from more distant zones was assumed to be BART. The model did not distinguish between resident air passengers who were dropped off by private vehicle and those who parked at the airport for the duration of their air trip. Rather, all resident air passengers using private vehicles were assumed to park at the airport during their trip, whereas all visitors using private vehicles were assumed to be dropped off. The use of "Other" modes was not explicitly included in the model, but rather the use of those modes was assumed to remain constant from the mode share observed in the 1995 Air Passenger Survey.

The perceived operating cost of private vehicles was assumed to be 15 cents per mile in 1999 dollars, whereas airport parking costs were calculated assuming a parking rate of $8 per day. However, the parking cost was not calculated separately for each air party, but rather the average trip duration and average air party size for each market segment was used to calculate a fixed parking cost for each segment. The highway travel time for visitors dropped off at the airport (or picked up on their arrival) was increased by 50% to represent the inconvenience for the drivers dropping off or picking up air passengers. Appropriate costs and times were assigned to the other modes based on published fares and schedules and assumed walking distances and waiting times.

Rental car costs were calculated on the basis of $50 per day factored by the average trip duration and average air party size for each market segment. Apart from that this assigned the same cost to all air parties, irrespective of their actual trip duration, it also assumed that the full cost of renting the car was attributable to the airport access and egress trip. It is unclear from the model documentation whether this cost was divided between the access and egress trip or whether the costs and travel times for all modes were calculated on a round-trip basis (the same issue applies to parking costs at the airport).

Highway and transit travel times and highway distances were obtained from the MTC regional travel demand network model. However, the model was not run using the regional travel demand model TAZ system, but rather a system of 25 larger zones. A representative TAZ was chosen for each of the analysis zones to obtain travel times and distances. Access times to transit for each zone were estimated based on the size of the zone and assuming walk access for the smaller zones and driving for the larger zones.

Explanatory Variables

The model utility functions included the following six variables: highway travel time, travel time by rail transit, travel time by bus transit, walking distances, waiting times, and travel costs. Obviously, not all variables applied to each mode. The distinction between rail transit travel time and bus transit travel time allowed the analysis to consider the effect of replacing the AirBART shuttle bus with the planned automated people-mover as well as accounting for the different level of service between BART and local bus.

Household income was included in the model by dividing the costs for personal trips by the household income in thousands of dollars raised to the power 1.5. This adjustment was not applied to business trips as it was considered that business travel decisions are unaffected by income level because business travelers are usually reimbursed for travel expenses. However, rather than using the actual income level of each air party, the average income for all air passengers at Oakland International Airport found in the 1995 Air Passenger Survey appears to have been used. If this is the case, then this of course is a constant that applies to all air passengers and does not vary behavior by income level as implied by including this in the model formulation.

Model Coefficients

The model coefficients for the continuous variables were adopted directly from an earlier airport ground access mode choice model for Bay Area developed by Harvey (1988). The values of the ASCs were then estimated to fit the model to the mode use data from the 1995 MTC Air Passenger Survey. The resulting values of the assumed and estimated coefficients are shown in Table D15. The corresponding implied values of the coefficient values are shown in Table D16.

The implied values of travel times are fairly low compared with values typically found in air passenger travel models. The model documentation notes that the average household income of the respondents to the 1995 MTC Air Passenger Survey was $75,000. Assuming 1.7 wage earners per household (about the current U.S. average)—that translates to an average wage rate of about $22/h. However, the values of time implied by the model coefficients for the continuous variables derive directly from the coefficients estimated by Harvey (1988), with those for personal travel factored up by the change in income levels between 1985 (the base year used by Harvey to estimate his model) and 1995 (the year of the MTC air passenger survey data used to estimate the current model). This also explains why the implied values of time for business trips are approximately the same as for personal trips (or even slightly lower) rather than higher as would be expected. Because the coefficients for travel times and costs reflect the perceived value of time,

TABLE D15
OAKLAND AIRPORT CONNECTOR MODEL COEFFICIENTS

Coefficient	Resident Business	Resident Personal	Visitor Business	Visitor Personal
Variables				
Highway time (minutes)	–0.071	–0.044	–0.068	–0.039
Rail transit time (minutes)	–0.053	–0.031	–0.050	–0.029
Bus transit time (minutes)	–0.093	–0.051	–0.089	–0.045
Walk distance (miles)	–5.17	–3.28	–4.69	–2.94
Wait time (minutes)	–0.107	–0.077	–0.096	–0.071
Cost (cents)	–0.00277	$-1.04/(HHINC)^{1.5}$	–0.00256	$-0.973/(HHINC)^{1.5}$
Constants				
Private vehicle	—	—	—	—
Rental car	–0.8	–4.2	0.7	–1.2
Scheduled airport bus	–0.5	–1.4	0.0	–1.2
Public transit	–1.5	–1.2	–1.0	–1.8
Shared-ride van	0.0	–0.9	1.0	–0.9
Hotel courtesy shuttle	N/A	N/A	–3.2	–4.2
Taxi/limousine	–0.2	–1.6	0.8	–0.8

Notes: HHINC = annual household income in thousands of dollars; N/A = mode is not available for this market segment.

TABLE D16
IMPLIED VALUES OF OAKLAND AIRPORT CONNECTOR MODEL COEFFICIENTS

Parameter	Resident Business	Resident Personal	Visitor Business	Visitor Personal
Travel Time ($/hour)				
Highway travel time	15	16	15	16
Rail transit time	11	12	11	12
Bus transit time	20	19	19	18
Walk time	56	61	55	59
Wait time	23	29	21	28
Constants (dollars)				
Private vehicle	0.7	10.0	–3.1	5.3
Rental car	–13.0	–16.2	–0.4	–2.7
Scheduled airport bus	–1.1	1.2	–3.1	–2.7
Public transit	–4.7	2.5	–7.0	–6.7
Shared-ride van	0.7	4.4	0.8	–0.7
Hotel courtesy shuttle	N/A	N/A	–15.6	–22.7
Taxi/limousine	—	—	—	—

Notes: Implied values of personal trips calculated for an annual household income of $75,000 per year.
Implied value of walk time based on a walking speed of 3 mph.
N/A = mode is not available for this market segment.

coefficient values estimated on data for one year cannot simply be applied to data for another year without adjustment for changes in real income levels (and hence the perceived value of time) between the two years.

Given these problems with the values of the coefficients for the continuous variables, it follows that the estimated values for the ASCs are accounting for more than the differences in the perceived inherent attractiveness of the different modes. In addition, they have to correct for biases in the predicted mode use that result from the use of invalid coefficients for the continuous variables. Although the ASCs have been estimated relative to the private vehicle mode, expressing the implied values in this way would give misleading relative values of the coefficients across the different market segments because of the assumption that the private vehicle mode represents parking for the duration of the air trip in the case of resident trips but drop off in the case of visitor trips. Therefore, it would provide a better comparison to express the implied values of the constants relative to taxi, which offers the same service characteristics across each market segment, as shown in Table D16. The values shown in Table D16 indicate the amount by which the cost of a mode would have to be greater than that for taxi (or less than if negative) for travelers to consider the mode and taxi to be equally attractive if travel times were identical.

In addition to reflecting the inherent relative attractiveness of the different modes and any biases resulting from invalid coefficients of the continuous variables, the ASCs also have to correct for incorrectly specified mode availability. The large negative values for the rental car constant for resident trips undoubtedly reflects that most residents already have a private vehicle available and therefore do not need to rent one. Similarly, the large negative value for the hotel courtesy shuttle for visitor trips reflects that this alternative is only available for those beginning their trip from a hotel near the airport that offers a courtesy shuttle. Visitors staying in hotels elsewhere in the region or with family or friends do not have this option available. Less obviously perhaps, the negative value for the constant for private vehicle (i.e., drop off) for visitor business trips reflects that those visitors staying in a hotel or starting their trip to the airport from a business or similar location will generally not have access to someone who can take them to the airport by private vehicle.

Residents on business trips and visitors appear to find scheduled airport bus and transit less attractive than taxi (after accounting for differences in travel time and cost), as might be expected, with transit significantly less attractive than scheduled airport bus. Somewhat surprisingly, residents on personal trips appear to find transit and scheduled airport bus more inherently attractive than taxi after accounting for differences in travel time and cost, although the effect is not very large. Shared-ride van appears to be inherently more attractive than scheduled airport bus, as might be expected owing to the door-to-door service. However, the difference in the perceived value of the constant is not very large, equivalent to just two or three dollars. The relatively high implied value for the private vehicle constant for residents making personal trips could be a result of assuming that all residents using private vehicles park for the duration of their air trip. In practice many are dropped off and do not incur the parking cost assumed for this mode. Therefore, the constant will need to be large enough to offset the assumed parking cost.

Overall, whereas the implied values of the ASCs appear to be readily explainable from the way that the availability of the different modes has been assumed and the values of the service characteristics for each mode defined, it also appears likely that the resulting model, although replicating the observed mode shares for the base condition, will not correctly reflect the effect on mode share of the service improvements provided by the Oakland Airport Connector. In particular, the low implied values of travel time will tend to underestimate the effect on the attractiveness of using BART of the reduced waiting and travel times involved in traveling between the Coliseum station and the airport.

Model Fit

The model documentation did not provide any information on the statistical significance of the estimated values of the model coefficients or the overall fit of the model to the estimation data.

Model Application

The mode choice model was used to estimate transit ridership for two future years, 2005 and 2020, and three project alternatives: a continuation of the AirBART shuttle (no-project alternative), an improved shuttle bus alternative (termed Quality Bus), and the proposed automated people-mover (termed Automated Guideway Transit). Forecasts of future levels of air passenger traffic were interpolated from forecasts prepared as part of the Regional Airport System Plan and estimates of future airport employment levels were provided by the Port of Oakland. These forecasts were used to factor up the air passenger and airport employee trip tables before applying the mode choice model.

Airport Employee Mode Use

The mode choice model included a market segment for airport employees that considered only two modes, private vehicle and transit. The employee model used the same coefficient value for both highway and transit travel time, including rail and bus. In addition to travel time, the utility functions included walking distance, waiting time, and cost. The coefficient values were not estimated from employee survey data but were adapted from the MTC regional travel demand model for home-based work trips. The model documentation does not state what assumptions were made about the cost for employee parking.

The model coefficients and implied values are shown in Table D17. In this case, the implied value of the transit ASC is relative to private vehicle, because taxi was not considered in the employee mode choice model.

The coefficient values for the continuous variables were taken directly from the MTC mode choice model (Purvis 1997, Table 5.1), with the walk time coefficient converted to distance assuming a walking speed of 3 mph. However, the MTC model includes seven modes and several other explanatory variables, including household income and vehicle ownership. Excluding these variables from the model would change values of the other coefficients, because the behavioral explanation that they provide would now have to be accounted for by the remaining variables. The magnitude of this effect would depend on the distribution of the employee characteristics and is unclear without more detailed analysis. Furthermore, the MTC mode choice model was also estimated using constant 1990 dollars for travel costs. Applying these model coefficients to costs in 1999 current dollars without making any adjustments for inflation would overstate the effect of cost in mode choice decisions. The ASC for transit use does not correspond to the MTC model coefficients and appears to have been estimated to make the transit mode share match the observed data for airport employees. Although this will offset the effect of any bias in the model coefficients for the base year, the net effect on the model predictions for any future year is unclear.

The implied values of travel time components correspond to the values in the MTC model (not surprisingly, because the coefficients are unchanged). The documentation of the MTC model (Purvis 1997) notes that the value of time for journey-to-work trips has typically been found to be in the range of 25% to 50% of the wage rate. Unlike air passenger business travel costs, journey-to-work travel costs are not generally reimbursed by employers and so ignoring income in the utility function will fail to reflect the effect of income on mode choice. This becomes a particularly important issue if the model is to be used to forecast travel behavior in future years. Without knowing what assumptions were made for employee parking costs it is difficult to assess the reasonableness of the value of the ASC for transit.

TABLE D17
OAKLAND AIRPORT CONNECTOR AIRPORT EMPLOYEE MODEL

Parameter	Model Coefficient	Implied Value
Variables		$/hour
Travel time (minutes)	–0.02683	11
Walk distance (miles)	–1.1552	24
Wait time (minutes)	–0.0418	17
Cost (cents)	–0.001468	
Constants		$
Private vehicle	—	—
Public transit	–2.0	–14

Notes: Coefficients derived from regional travel demand model.
Implied value of walk time based on a walking speed of 3 mph.

Documentation

Franz, J.D., *1995 Metropolitan Transportation Commission Airline Passenger Survey*, Final Report, Prepared by J.D. Franz Research for the Metropolitan Transportation Commission, Oakland, Calif., Feb. 1996.

Harvey, G., *ACCESS: Models of Airport Access and Airport Choice for the San Francisco Bay Region—Version 1.2*, Prepared for the Metropolitan Transportation Commission, Berkeley, Calif., Dec. 1988.

Purvis, C.L., *Travel Demand Models for the San Francisco Bay Area (BAYCAST-90): Technical Summary*, Metropolitan Transportation Commission, Oakland, Calif., June 1997.

U.S. Federal Transit Administration and San Francisco Bay Area Rapid Transit District, *BART—Oakland International Airport Connector, Final Environmental Impact Report/Environmental Impact Statement*, State Clearinghouse No. 99112009, Oakland, Calif., Mar. 2002.

D6 PORTLAND INTERNATIONAL AIRPORT ALTERNATIVE MODE STUDY

Summary

Airport	Portland International Airport
Model Developer	Cambridge Systematics, Inc. and Portland Metro
Date Developed	1997–1998
Market Addressed	Air passengers
Model Type	Combined revealed preference and stated preference data
Model Structure	Multinomial logit
Survey Data Used	Port of Portland Air Passenger Survey
Airport Profile	Total annual passengers (2005): 13.6 million Percentage O&D: 85% Ground access mode split (2006 Customer Satisfaction and Terminal User Survey):

	Private vehicle—drop off	36%
	Private vehicle—parked	24%
	Rental car	19%
	Taxi	4%
	Limousine	2%
	Shared-ride van	4%
	Light rail transit	6%
	Hotel shuttle	4%
	Charter/tour bus	1%
Market Segmentation	Residents—Business trips	
	Residents—Non-business trips	
	Non-residents—Business trips	
	Non-residents—Non-business trips	
Explanatory Variables	Travel time (in-vehicle time, wait, on-airport time)	
	Travel cost/ln(household income)	
	Drop-off driver time (as cost at assumed value of time)	
	Drop-off automobile operating cost (assumed)	

Description

Soon after the Boston Logan model discussed earlier was developed, a similar model was developed for Portland, Oregon, as part of a ground access study for Portland International Airport (PDX) that was jointly undertaken by the Port of Portland and Metro, the regional MPO, with the assistance of Cambridge Systematics, Inc. The primary purpose of the model was to forecast the potential ridership on a planned extension of the Portland MAX light rail system to the airport, as well as other ground access enhancements. An air passenger survey was performed at the airport that consisted of a revealed preference (RP) survey that examined air passengers' actual mode use and a stated preference (SP) survey that was designed to determine travelers' preferences for modes that were not then available, namely light rail, express bus, and shared-ride door-to-door vans (termed shared-ride transit).

An initial model estimation by Cambridge Systematics jointly estimated four MNL models using both the RP and SP data, with different modal alternative choice sets for residents and non-residents of the region and separate coefficients for business and non-business travelers (Bowman 1997; Cambridge Systematics 1998). These models were subsequently revised by the Metro staff to combine some of the choice alternatives and adjust the ASCs to recalibrate the models (Portland Metro 2001). The revised model coefficients reported by Metro staff also included one change to the cost coefficient for non-resident non-business trips.

The final model included eight modes: private vehicle parked at the airport for the trip duration, drop off at the airport by private vehicle, rental car, taxi and limousine (combined), hotel shuttle, shared-ride van and scheduled bus, light rail, and express bus. The use of private automobile parked at the airport for the trip duration (termed auto park) was restricted to residents of the region, whereas the use of a rental car was restricted to non-residents of the region. In the case of the light rail and express bus alternatives it was assumed that travelers would be dropped off at the station or stop by a private vehicle.

As part of the overall study of alternative airport access modes, a review of the experience of other U.S. airports with a range of airport ground access strategies was undertaken (Coogan 1997). This report included statistics on the ground access mode shares of various airports that had implemented ground transportation services similar to those being considered for Portland, as well as a discussion of the operational experience of those airports with the ground transportation services and the lessons that might be applicable to the Portland situation. Although there was no explicit comparison of the results of the mode choice analysis with the experience at other airports, this study nonetheless helped put the results of the mode choice modeling into a larger context and served to provide some assurance of the likely validity of the modeling results.

Explanatory Variables

The model included four explanatory variables: travel time, travel cost, household income, and the time and cost of the driver dropping off air passengers by private vehicle. Travel time combined in-vehicle time, waiting time, and any on-airport time (such as the time required to travel from a parking lot to the terminal). Travel costs were divided by the natural logarithm of the average household income for each origin zone.

The direct costs of each mode (but not the operating costs and value of driver time of automobiles dropping off air passengers) were divided by the logarithm of the average household income for the trip origin zone (in thousands of dollars per year) for each market segment, determined from the air passenger survey. This gives values of time that vary with household income, as is to be expected, but that have a nonlinear relationship that increases at a declining rate at higher income levels. The use of the average household income for the zone resulted from the way that the model was applied, although this obviously fails to account for the effect of variation in household income across survey respondents from a given zone.

For the drop off alternatives, including air passengers dropped off at the airport by private automobile (termed auto drop off), the time of the driver (termed the chauffeur in the model documentation) was assigned a value of $20/h for business travelers and $10/h for non-business travelers according to the model documentation (tables giving the final model coefficients indicate that $20/h was used for all trip purposes; however, this is assumed to be a typographic error). Automobile operating costs were assumed to be 12 cents per mile.

Model Coefficients

The final model coefficients are given in Tables D18 to D21 (the variation in the number of decimal places of the coefficient estimates reflect the model documentation prepared by Portland Metro). Separate coefficients were estimated for the same four market segments as the Boston Logan model. In addition, separate ASCs were estimated for each mode for trips originating within the Portland metropolitan area (termed internal trips) and those originating outside the metropolitan area (termed external trips). Two different sets of model coefficients were estimated for each market segment. The first set (termed Model 1) assumed that the ASCs for the light rail and express bus modes would be the same as those for shared-ride van and RAZ bus (a scheduled bus service between the airport and downtown Portland locations operated by RAZ Transportation, a Gray Line affiliate). The second set (termed Model 2) used the SP data to estimated separate ASCs for the light rail and express bus modes. The documentation on the initial model estimation by Cambridge Systematics provides *t*-statistics for the coefficient estimates, but the documentation of the final model does not.

The model documentation does not explain why ASCs were not determined for taxi and limousine use for resident business trips from external origins or for shared-ride van and RAZ bus use for non-resident business trips from external zones, but were determined for the other three market segments in each case. Indeed, it is

TABLE D18
PORTLAND GROUND ACCESS STUDY RESIDENT BUSINESS MODEL COEFFICIENTS

Coefficient	Model 1	Model 2
Variables		
Drop off cost ($)	–0.0195	–0.0195
Travel time (minutes)	–0.0176	–0.0176
Cost/ln(income) $/ln($K)	–0.2185	–0.2185
Constants (auto park base)		
Internal trips		
Auto drop off	0.85	0.85
Taxi and limousine	–1.162	–1.272
Van, RAZ bus, and hotel shuttle	–0.988	–1.258
Light rail (auto drop off)	–0.988	–1.258
Express bus (auto drop off)	–0.988	–1.258
External trips		
Auto drop off	–0.85	–0.85
Taxi and limousine	N/A	N/A
Van, RAZ bus, and hotel shuttle	2.312	0.742
Light rail (auto drop off)	2.312	0.742
Express bus (auto drop off)	2.312	0.742

N/A = not available.

TABLE D19
PORTLAND GROUND ACCESS STUDY RESIDENT NON-BUSINESS MODEL COEFFICIENTS

Coefficient	Model 1	Model 2
Variables		
Drop off cost ($)	–0.0235	–0.0235
Travel time (minutes)	–0.0264	–0.0264
Cost/ln(income) $/ln($K)	–0.2170	–0.2170
Constants (auto park base)		
Internal trips		
Auto drop off	–0.30	–0.30
Taxi and limousine	–2.068	–1.538
Van, RAZ bus, and hotel shuttle	–1.632	–1.362
Light rail (auto drop off)	–1.632	–0.3654
Express bus (auto drop off)	–1.632	–1.5281
External trips		
Auto drop off	–0.80	–0.80
Taxi and limousine	–2.188	–2.188
Van, RAZ bus, and hotel shuttle	2.368	–0.652
Light rail (auto drop off)	2.368	–2.3447
Express bus (auto drop off)	2.368	–3.8869

TABLE D20
PORTLAND GROUND ACCESS STUDY NON-RESIDENT BUSINESS MODEL COEFFICIENTS

Coefficient	Model 1	Model 2
Variables		
Drop off cost ($)	–0.0082	–0.0082
Travel time (minutes)	–0.0073	–0.0073
Cost/ln(income) $/ln($K)	–0.0913	–0.0913
Constants (rental car base)		
Internal trips		
Auto drop off	–0.50	–0.50
Taxi and limousine	–0.9135	–1.2335
Hotel shuttle	–0.8865	–0.9965
Van and RAZ bus	–0.9365	–1.3965
Light rail (auto drop off)	–0.9365	–0.8009
Express bus (auto drop off)	–0.9365	–0.9960
External trips		
Auto drop off	–0.30	–0.30
Taxi and limousine	–1.0635	–2.2135
Van and RAZ bus	N/A	N/A
Light rail (auto drop off)	–1.287	–1.4665
Express bus (auto drop off)	–1.287	–2.4165

N/A = not available.

TABLE D21
PORTLAND GROUND ACCESS STUDY NON-RESIDENT NON-BUSINESS MODEL COEFFICIENTS

Coefficient	Model 1	Model 2
Variables		
Drop off cost ($)	–0.0082	–0.0082
Travel time (minutes)	–0.0092	–0.0092
Cost/ln(income) $/ln($K)	–0.0716	–0.0716
Constants (rental car base)		
Internal trips		
Auto drop off	0.10	0.10
Taxi and limousine	–1.754	–1.574
Hotel shuttle	–0.246	–0.046
Van and RAZ bus	–0.596	–0.956
Light rail (auto drop off)	–0.596	–0.914
Express bus (auto drop off)	–0.596	–0.935
External trips		
Auto drop off	–0.50	–0.50
Taxi and limousine	–1.304	–2.054
Van and RAZ bus	–0.346	–1.206
Light rail (auto drop off)	–0.346	–1.206
Express bus (auto drop off)	–0.346	–0.6862

not clear why the RAZ bus was included as an option for external trips at all or why the hotel shuttle was considered as an option for resident trips.

There are a number of counterintuitive or surprising values for the ASCs. Because the ASCs for taxi and limousine have a generally higher disutility than auto drop off suggests that the perceived cost of taxi and limousine fares have been underestimated. Also, it is not clear why the perceived relative disutility of existing modes should change between Model 1 and Model 2 when the values for the light rail and express bus were adjusted using the SP data. The large positive value of the ASC for shared-ride van and RAZ bus for resident trips from external zones seems inconsistent with the values for internal trips.

The implied values of the model coefficients for Model 2 are shown in Table D22. Because the inclusion of household income in the cost term results in implied values of time that vary with average household income, these values have been calculated for average annual household incomes of $50,000 and $150,000. Although the resulting values of time seem consistent for resident and non-resident travelers for each trip purpose, this is a consequence of the way the model was estimated, and the lower value of time for business trips compared with non-business trips is counterintuitive.

The relatively small change in the value of time between a zone with an average annual household income of $50,000 and one with an average annual household income of $150,000 per year is a consequence of the use of the logarithmic transform. For comparison with the implied values shown in Table D22, a household with one worker and an annual income of $50,000 would have a wage rate of $25/h, whereas a household with two workers and an annual income of $150,000 would have an average wage rate of $37.50/h. Therefore, the implied values appear to be in the general range of the wage rate.

The implied values of the ASCs, expressed as equivalent minutes of travel time, appear implausibly large for many modes. For example, the relative disutility of most public modes for non-resident trips compared with auto drop off, apart from any differences in cost and travel time, is equivalent to well over an hour of travel time and more than 3 h of travel time in the case of taxi or limousine use for non-business trips from internal zones, or taxi, limousine, or express bus use for business trips from external zones. The large differences in the auto drop off constant compared with auto park (for resident trips) and rental car (for non-resident trips) between business and non-business trips suggests that these constants are accounting for more than just the inherent differences in the comfort and convenience of the various modes.

The ratio of the auto drop off cost coefficient to the cost coefficient for all other costs suggests that the auto drop off costs (primarily the time of the driver) are valued at between about one-third and one-half of the other costs. This is not unreasonable, because some air travelers may consider being taken to the airport by others as essentially without cost to them. However, it is worth noting that the assumed values of time for the drivers (twice as high for business trips as for non-business trips) are inconsistent with the estimated values of time for the air passengers, which are about half again higher for non-business trips than business trips.

TABLE D22
IMPLIED VALUES OF PORTLAND GROUND ACCESS STUDY COEFFICIENTS

Parameter	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Travel Time ($/hour)				
$50,000 avg. h/h income	19	29	19	30
$150,000 avg. h/h income	24	37	24	39
Auto Drop Off Cost Ratio				
$50,000 avg. h/h income	0.35	0.42	0.35	0.45
$150,000 avg. h/h income	0.45	0.54	0.45	0.57
Constants (minutes)				
Internal trips				
Auto drop off	–48	11	68	–11
Taxi and limousine	72	58	169	171
Hotel shuttle	71	52	137	5
Van and RAZ bus	71	52	191	104
Light rail (auto drop off)	71	14	110	99
Express bus (auto drop off)	71	58	136	102
External trips				
Auto drop off	48	30	41	54
Taxi and limousine	N/A	83	303	223
Van and RAZ bus	–42	25	N/A	131
Light rail (auto drop off)	–42	89	201	131
Express bus (auto drop off)	–42	147	331	75

Notes: avg. h/h income = average household income. N/A = not available.

Model Fit

The initial Cambridge Systematics model estimation results include *t*-statistics for the coefficients for each variable and measures of overall goodness-of-fit of the model, including the final value of the log likelihood and the improvement over the log likelihood with zero coefficients or constants only. The overall improvement in the goodness-of-fit of the model from the inclusion of the continuous variables is not particularly large.

Model Application

As noted, the model was primarily developed to predict ridership on the planned extension of the Portland MAX light rail system to serve the airport, as well as to examine alternative ground access measures, including development of an express bus service and charging private vehicles a fee to drop off or pick up air passengers at the airport.

The approach to applying the model follows the traditional four-step urban transportation planning approach, with the number of trips generated by the airport determined from the airport traffic forecasts. A trip distribution model (termed an origin location model in the documentation) calculates the number of air parties beginning their access trip in each zone. The mode choice model is then applied to these trips to calculate the number of vehicle and air passenger trips from each zone.

Documentation

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Coogan, M.A., *The Peer Airport Analysis Report*, prepared for the Port of Portland, Apr. 9, 1997. Included as Appendix D to Cambridge Systematics, Inc., *Portland International Airport Alternative Mode Study*, Prepared for the Port of Portland, Portland, Ore., Oct. 1998.

Portland Metro, *PDX Ground Access Study Model Summary*, Prepared by the Travel Forecasting Staff, Portland, Ore., undated (May 1998), revised June 2001.

D7 SAN JOSÉ INTERNATIONAL AIRPORT MODEL

Summary

Airport	Norman Y. Mineta San José International Airport	
Model Developer	Dowling Associates, Inc.	
Date Developed	2002	
Market Addressed	Air passengers	
Model Type	Combined revealed preference and stated preference data	
Model Structure	Multinomial logit	
Survey Data Used	1995 Metropolitan Transportation Commission Air Passenger Survey; Supplementary stated preference survey at San José International Airport	
Airport Profile	Total annual passengers (2005): 10.6 million	
	Percentage O&D: 91%	
	Ground access mode split (2002 MTC Air Passenger Survey):	
	Private vehicle—drop off	49%
	Private vehicle—parked	17%
	Rental car	19%
	Taxi	7%
	Limousine	1%
	Hotel courtesy shuttle	2%
	Shared-ride van	2%
	Shuttle bus from train	1%
	Public transit bus	<1%
	Other	<1%
Market Segmentation	Residents—Business trips	
	Residents—Personal trips	
	Visitors—Business trips	
	Visitors—Personal trips	
Explanatory Variables	Travel time (private vehicles)	
	Travel time (rail transit)	
	Travel time (bus transit)	
	Walk distance	
	Wait time	
	Travel cost	
	Household income	

Description

This model was developed by Dowling Associates to estimate the ridership on a planned automated people-mover (APM) to connect the airport to a nearby Santa Clara Valley Transportation Authority (VTA) light rail line (Dowling Associates 2002). The model was estimated using data from an air passenger survey performed at the airport for the Bay Area Metropolitan Transportation Commission (MTC) in 1995 (Franz 1996) and supplemented with the results of stated preference surveys that were conducted as part of the study to determine how air passenger mode choice might be influenced by the availability of the people-mover, as well as to overcome the problem that there were very few users of the light rail line in the 1995 survey sample. MNL models were estimated for the same four market segments used in the Oakland Airport BART Connector Study: resident business trips, resident personal trips, visitor business trips, and visitor personal trips. Each market segment model included six modes: private vehicle, rental car, scheduled airport bus, shared-ride van (termed door-to-door shuttle), taxi, and public transit. In addition, the visitor segment models included hotel shuttle.

The model also included an airport employee segment as discussed further here. This only considered two modes: private vehicle and public transit. Because the primary purpose of the model was to estimate ridership on the planned APM, the model allowed up to four connecting transit routes and developed separate fare and travel times for each. Those routes involving the use of the APM to access the VTA light rail line were given a separate ASC from other transit routes to reflect the greater attractiveness of the APM based on the stated preference survey.

Explanatory Variables

Independent variables consisted of the automobile travel time, transit travel time by rail, transit travel time by bus, waiting time, walking distance, and cost. The cost variable for personal trips was divided by the annual household income raised to the power 1.5. Only one set of ASCs for private car was presented in the report, making no distinction between air parties being dropped off and those parking for the duration of the air trip. This resulted from a limitation in the 1995 air passenger survey, which also did not make this distinction. It was assumed in the model estimation that residents using private vehicles parked at the airport, whereas visitors were dropped off. The parking cost was included in the parking utility function for resident trips, whereas a "drop-off" factor was included in the private vehicle utility function for visitor trips to account for the inconvenience for drivers dropping off air passengers (the details of this factor are not given in the report). It is possible to use the estimated model to predict the choice of resident air passengers being dropped off by including both modes in the model and assuming that the ASC is the same for both drop off and park.

Model Coefficients

The approach taken in estimating the model followed that used in the Oakland International Airport BART Connector Study with the model coefficients for the continuous variables adopted directly from an earlier airport ground access mode choice model for Bay Area developed by Harvey (1988). The values of the ASCs were then estimated to fit the model to the mode use data from the 1995 MTC Air Passenger Survey. The estimated model coefficients presented in the study report are shown in Table D23.

As discussed earlier in the description of the Oakland Airport Connector study model, the use of coefficients from a model that was estimated on much earlier data, without any adjustments for changes in the implied values of time, introduces significant distortions in the model that are compounded when the model is used to predict future mode use.

The implied values of the estimated coefficients are shown in Table D24. As with the Oakland Airport model, the implied values of the ASCs are expressed relative to taxi, because the private vehicle mode is different for residents and visitors. These implied values are expressed in dollars and represent the difference in cost between the mode and a taxi that would be required for travelers to be indifferent between use of the two modes if travel times were the same. Because the implied values for personal trips depend on the household income, the values have been calculated for a household income of $55,000, which is stated in the study report to be the average annual household income for potential transit users at San José International Airport based on data for Santa Clara County from the Association of Bay Area Governments (it is unclear what "potential transit users" means in this context or how the Association of Bay Area Governments could determine the household income of such users, but the value provides a reasonable point of comparison).

The implied values of the various components of travel time are quite low by comparison with the values typically found in air passenger ground access mode choice models (and air travel models generally). However, because these implied times came directly from the coefficients estimated by Harvey (1988) using 1985 data, this is hardly surprising. Because the implied value of rail transit travel time is lower than travel time by private auto is counterintuitive. Although the higher implied value for bus transit travel time is consistent with typical experience in urban travel models, the difference from travel time by private auto is surprisingly small, particularly for visitor personal trips. Similarly, the implied values of the ASCs are quite low compared with those typically found in air passenger ground access mode choice models and the differences between the values for different modes are surprisingly small and in several cases intuitively unreasonable. For example, it makes no sense that the implied value of the ASC for transit or shared-ride van for resident business trips would be greater than that for taxi, which provides significantly greater comfort and convenience. Similarly, it seems quite implausible that scheduled bus, transit, or shared-ride van would be viewed by visitors on business trips as more attractive than being dropped off at the airport by private automobile.

What is most likely distorting the values of the estimated coefficients is a failure to control for the need for and availability of different modes for different air parties. Visitors who are not staying with residents of the area may not have anyone who can take

TABLE D23
SAN JOSÉ INTERNATIONAL AIRPORT MODEL COEFFICIENTS

Coefficient	Resident Business	Resident Personal	Visitor Business	Visitor Personal
Variables				
Auto time (minutes)	–0.071	–0.044	–0.068	–0.039
Rail transit time (minutes)	–0.053	–0.031	–0.050	–0.029
Bus transit time (minutes)	–0.093	–0.051	–0.089	–0.045
Walk distance (miles)	–5.17	–3.28	–4.69	–2.94
Wait time (minutes)	–0.107	–0.077	–0.096	–0.071
Cost (cents)	–0.00277	$-1.04/(HHINC)^{1.5}$	–0.00256	$-0.973/(HHINC)^{1.5}$
Constants				
Private vehicle	—	—	—	—
Rental car	–2.9	–4.1	3.9	1.0
Scheduled bus	–2.3	–2.7	1.2	–0.8
Transit (does not use APM)	–1.3	–2.0	0.9	–0.4
Transit (uses APM)	–1.2	–1.8	0.8	–0.3
Shared-ride van	–1.2	–1.4	0.6	–0.1
Hotel shuttle	N/A	N/A	0.0	–3.1
Taxi	–1.4	–1.3	1.1	0.1

Notes: HHINC = annual household income in thousands of dollars; N/A = mode is not available for this market segment; APM = automated people-mover.

TABLE D24
IMPLIED VALUES OF SAN JOSÉ INTERNATIONAL AIRPORT MODEL COEFFICIENTS

Parameter	Resident Business	Resident Personal	Visitor Business	Visitor Personal
Travel Time ($/hour)				
Auto time	15	10	15	10
Rail transit time	11	7	11	7
Bus transit time	20	12	19	11
Walk time	56	39	55	37
Wait time	23	18	21	18
Constants (dollars)				
Private vehicle	5.1	5.1	–4.3	–0.4
Rental car	–5.4	–11.0	10.9	3.8
Scheduled bus	–3.3	–5.5	0.4	–3.8
Transit (does not use APM)	0.4	–2.8	–0.8	–2.1
Transit (uses APM)	0.7	–2.0	–1.2	–1.7
Shared-ride van	0.7	–0.4	–2.0	–0.8
Hotel shuttle	N/A	N/A	–4.3	–13.4
Taxi	—	—	—	—

Notes: Implied values of personal trips calculated for an annual household income of $55,000 per year.
Implied value of walk time based on a walking speed of 3 mph.

them to the airport and therefore either rent a car to meet their local transportation needs or use public modes. To explain these choices in a situation when the model has assumed that being dropped off by private vehicle is an option that is available, the values of the ASCs have to be increased. Similarly, residents of the region generally have access to a private vehicle and therefore do not need to rent a car.

Model Fit

No goodness-of-fit statistics for the estimated coefficients or the overall model were provided in the report.

Model Application

The model was developed as part of planning studies for a proposed APM that will connect the passenger terminal at San José International Airport to a nearby stop on the Santa Clara VTA light rail line that runs about a block to the east of the airport and connects in downtown San José with other lines on the light rail network serving the Santa Clara Valley. A possible future extension of the APM to the west side of the airport would also serve the nearest station on the Caltrain commuter rail line that serves the Peninsula corridor between San José and San Francisco.

Airport Employee Mode Use

The mode choice model included a market segment for airport employees that considered only two modes, private vehicle and transit, although separate ASCs were developed for transit trips using the APM and those without the APM being available. The employee model used the same coefficient value for both highway and transit travel time, including rail and bus. In addition to travel time, the utility functions included walking distance, waiting time, and cost. The coefficient values were not estimated from employee survey data, but were adapted from the Santa Clara County countywide travel model for home-based work trips. The employee model documentation does not state what assumptions were made about the cost for employee parking.

The model coefficients and implied values are shown in Table D25. In this case, the implied value of the transit ASC is relative to private vehicle, because a taxi was not considered in the employee mode choice model.

The implied values of travel time are extremely low, which is most likely the result of the adoption of the model coefficients from

TABLE D25
SAN JOSÉ INTERNATIONAL AIRPORT EMPLOYEE MODEL

Parameter	Model Coefficient	Implied Value
Variables		$/hour
Travel time (minutes)	–0.02545	4.2
Walk distance (miles)	–1.17	9.6
Wait time (minutes)	–0.05854	9.6
Cost (cents)	–0.00366	
Constants		$
Private vehicle	—	—
Transit (does not use APM)	–1.4	–3.8
Transit (uses APM)	–1.3	–3.6

Notes: Coefficients derived from countywide travel demand model.
Implied value of walk time based on a walking speed of 3 mph.

the Santa Clara countywide travel demand model. Although these have similar values for travel time components (and walking distance) to those for the MTC regional travel demand model discussed in the description of the Oakland Airport Connector model earlier, the coefficient for cost is significantly greater, suggesting that the countywide model is based on travel costs in even earlier constant year dollars than the MTC model. Without adjusting for changes in prices and income, the direct use of these coefficients and their implied value of time will tend to overstate the attractiveness of transit.

Documentation

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Harvey, G., *ACCESS: Models of Airport Access and Airport Choice for the San Francisco Bay Region—Version 1.2*, Prepared for the Metropolitan Transportation Commission, Berkeley, Calif., Dec. 1988.

D8 TORONTO AIR RAIL LINK REVENUE AND RIDERSHIP STUDY

Summary

Airport	Toronto Lester B. Pearson International Airport, Canada
Model Developer	Halcrow Group Limited
Date Developed	2002
Market Addressed	Air passengers
Model Type	Combined revealed preference and stated preference data
Model Structure	Binomial logit diversion
Survey Data Used	February 2002 Air Passenger Survey
Airport Profile	Total Annual Passengers (2005): 29.9 million[a] Percentage O&D: 75%[b] Ground access mode split (2005 air passenger survey):[c] Private vehicle—drop off 45% Private vehicle—parked 13% Rental car 9% Taxi and limousine 24% Courtesy vehicles 6% Scheduled airport bus 2% Public transit 1% *Source:* Greater Toronto Airports Authority [a]Passenger Statistics as of June 30, 2007. [b]Estimate quoted in Halcrow Group (2002). [c]Personal communication, Marc Turpin, 6/29/07.
Market Segmentation	Residents—Business trips Residents—Non-business trips Non-residents—Business trips Non-residents—Non-business trips
Explanatory Variables	In-vehicle travel time Service headway Travel cost Dummy variables: travel party size (accompanied/travel alone); checked baggage

Description

In May 2003, Transport Canada issued a Request for Business Case for a public–private partnership to develop an Air Rail Link between Toronto Lester B. Pearson International Airport (LBPIA) and Toronto Union Station (*Request for Business Case* . . . 2003). Subsequently, a private sector consortium, Union Pearson AirLink Group, was selected to finance, design, construct, and operate the rail link in association with eight public and three private stakeholders, including the Greater Toronto Airports Authority and several regional and national rail and transit agencies (Borges 2006). In preparation for the Request for Business Case, a revenue and ridership forecasting study was undertaken in 2002 (Halcrow Group 2002). This study included a stated preference air passenger survey and the development of a mode choice model to predict the diversion of airport access trips from existing modes to the proposed new rail link.

The stated preference survey was carried out in February 2002 in the terminal departure lounges, and interviewed 2,566 passengers of whom 1,927 (75%) were not connecting between flights. The survey collected data on the air party characteristics, ground trip origin, and the ground access mode for the current trip. Some 807 respondents were identified as potential air rail link users, based on their ground trip origins, and completed a stated preference questionnaire. The results of the survey were then used to estimate a set of mode choice models.

The Greater Toronto region was divided into a system of 34 zones, with the 2 downtown Toronto zones further subdivided into 10 zones. Peak period highway and transit travel times between each of these zones and the airport and potential Air Rail Link stations were extracted from the city of Toronto Greater Toronto Area transportation network model. Off-peak highway travel times were assumed to be 6% less than peak period travel times based on an analysis of the travel times reported in the stated preference survey. Travel costs were largely derived from actual costs reported in the stated preference survey. Taxi fares for zones with no reported data were derived from a distance-based regression using the reported fares from zones for which there were data. Private vehicle fuel costs were calculated on the basis of 4.6 cents per kilometer.

The mode choice model consists of a set of binomial logit models (described in the model documentation as logistic, probabilistic, diversion models), each of which models the choice between an existing mode and the planned rail link. If such models had been developed for every existing mode, they could have been combined into a MNL model. However, air travelers using a hotel bus or rental car to access the airport were excluded from the diversion analysis, because users of the hotel bus were assumed to have a door-to-door service that was effectively free, whereas those using a rental car were assumed to require the car for other purposes during their visit and thus not considering the use of other modes. The use of the binomial logit diversion models has another consequence, namely that the models only predict the diversion from existing modes to the rail link and do not allow for future shifts in use between existing modes owing to changes in future values of travel time and cost for the different modes or changes in travel patterns in the Toronto market. Although the purpose of the analysis was to predict the ridership on the rail link, because this is calculated on the basis of the diversion from existing modes, any errors in the predictions of the future use of existing modes without the rail link will in turn affect the ridership projections for the rail link.

The model documentation does not explicitly discuss the modes that were included in the analysis; however, based on the presentation of the survey results it would appear that the analysis was based on four modes: private vehicle parked at the airport for the trip duration (termed drive & park), drop off by private vehicle (termed driven in car), taxi/limousine, and transit/airport bus.

In addition to estimating a formal mode choice model, the study included a benchmark comparison analysis that examined the mode share of existing airport rail links in 24 cities in the U.S., Europe, and Australia. This analysis developed cross-sectional regression relationships that expressed the rail mode share in terms of a series of market and geographical characteristics, such as the percentage of air passengers with central city origins, the distance of the airport from the central city, and the ratio of the rail travel time to the taxi travel time from the city center. These relationships were then used to predict the corresponding rail mode share for Toronto using the same regional characteristics. The resulting range of rail mode shares (which varied with the characteristic chosen) was compared with the results of the formal mode choice modeling process, to provide a reality check on the modeling analysis. The details of this analysis are presented in the model documentation (Halcrow Group 2002). They are not presented here, because they are not directly relevant to the details of the mode choice model, but the results of the comparison are discussed below.

Explanatory Variables

The mode choice model relationships used three continuous variables: the in-vehicle travel time on each mode, the service headway for the mode, and the travel cost involved in using the mode. In addition, the utility function for the rail link included two dummy variables: one that indicated whether the air traveler was accompanied (whether by other members of the air travel party or by well-wishers) or traveling alone and one indicating whether the air traveler(s) intended to check any bags. These dummy variables were chosen based on survey results that indicated that air travelers who traveled to the airport alone or did not intend to check any bags were more likely to use the rail link. This seems reasonable, because larger travel parties or those with significant amounts of baggage are likely to find other modes more convenient or cost-effective. In particular, being accompanied to the airport by well-wishers will often mean that someone is available to take the air party to the airport by private vehicle.

The model structure did not directly consider the type of trip origin. However, the approach of developing separate diversion models for each existing access mode indirectly addressed some of these effects, because air passengers being dropped off by private vehicle would largely have begun their trip from a private residence, while those using taxi or airport bus would be more likely to have begun their trip from a hotel or place of business. The primary reason for including the type of trip origin in an airport access mode choice model is to account for the effect of this on available access modes (principally the availability of someone who can take the air party to the airport). By segmenting the mode choice analysis by the existing access mode, this effect is already considered in the data. However, this approach does have one drawback. Because the share of existing access modes in the absence of the rail link is required to perform the analysis, which is necessarily derived from existing conditions, the approach assumes that the distribution of air passenger trips across the different types of trip origin will remain unchanged in the future.

The model utility functions also do not consider the household income of the air travelers. Because the rail link will offer a different combination of cost and travel time from existing modes, the attractiveness of this service to air travelers from a given geographic zone is likely to vary depending on their income. This in turn is likely to have a significant effect when considering the impact on revenue of changing fare levels.

Model Coefficients

The estimated model coefficients are shown in Table D26, with the associated implied values of the travel time components and dummy variables shown in Table D27.

ASCs were initially included in the model utility functions; however, these were found to not be statistically significant and were dropped from the model. This is surprising given the relatively simple form of the utility functions and the absence from the model of such factors as household income and the access time involved in reaching the rail link station.

The implied values of in-vehicle time (strictly the implied values of reduced in-vehicle times) appear reasonable. The values for business trips are approximately twice those for non-business trips, which is not unreasonable, particularly given that income is not

TABLE D26
TORONTO AIR RAIL LINK MODEL COEFFICIENTS

Coefficient	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Continuous Variables				
In-vehicle time (minutes)	–0.0494	–0.0665	–0.0435	–0.0462
	(–4.2)	(–7.6)	(–2.8)	(–3.9)
Headway (minutes)	–0.1180	–0.0665	–0.1678	–0.0692
	(–4.5)	(–3.7)	(–7.0)	(–3.1)
Cost ($)	–0.0557	–0.1382	–0.0368	–0.0820
	(–5.9)	(–8.6)	(–7.3)	(–4.5)
Dummy Variables				
Accompanied to airport	N/S	–0.2736	N/S	–0.7951
		(–2.3)		(–4.8)
Checked baggage	N/S	–0.4284	N/S	–0.5120
		(–2.8)		(–2.5)
Number of cases	173	348	167	162

Notes: N/S = not statistically significant; *t*-statistics shown in parentheses.

TABLE D27
IMPLIED VALUES OF TORONTO AIR RAIL LINK MODEL COEFFICIENTS

Parameter	Resident Business	Resident Non-Business	Non-Resident Business	Non-Resident Non-Business
Travel Time ($/hour)				
In-vehicle time	53	29	71	34
Waiting time	254	58	547	101
Dummy Variables ($)				
Accompanied to airport	N/A	2	N/A	10
Checked baggage	N/A	3	N/A	6

N/A = not applicable.

explicitly included in the model. Business travelers will tend to have higher incomes on average than non-business travelers. The implied values of in-vehicle time for non-residents are somewhat higher than for residents (33% higher for business trips and 17% higher for non-business trips). Because it can be assumed that a fairly high proportion of non-residents are from the United States, this is also not unreasonable.

However, the implied values of waiting time appear surprisingly high except for resident non-business trips, for which waiting time is perceived as twice the inconvenience of in-vehicle time, which corresponds to typical experience in urban travel demand models. The implied value for non-resident non-business trips is three times the implied value of in-vehicle time, which is higher than would normally be expected. The implied values of waiting time for business trips are implausibly high, at almost five times the value of in-vehicle time for resident trips and almost eight times the value of in-vehicle time for non-resident trips. Because the non-resident business travelers already had a fairly high value of in-vehicle time, the resulting implied value of waiting time is more than $500/h. Although business travelers may be particularly averse to waiting, it would be surprising if they found waiting that onerous compared with travel time. Indeed, such a ratio implies that they would be willing to incur an additional hour of travel time to avoid a 10 minute wait, which makes no sense.

This is not a trivial issue, because overstating the disutility of waiting time in the model will result in underestimating the demand for the rail link if headways are increased and conversely overestimating the demand if headways are reduced. This will overestimate the willingness of travelers, particularly business travelers, to pay a higher fare to have a shorter headway and could result in an operating plan that runs too many trains at too high a fare.

In contrast to the implied values of waiting time, the implied values of the disutility of the rail link for travelers who are accompanied to the airport or have checked baggage are relatively low, varying between $2 and $10, and being higher for non-residents than residents. These values can be interpreted as the reduction in fare that would be needed to offset the disutility and result in the rail link being perceived to be as attractive as it is for those traveling alone with only carry-on bags. Thus, the fare reduction needed to offset the combined disutility of being accompanied to the airport and having checked bags is approximately $16 for non-residents and $5 for residents. This would represent a significant percentage of the proposed fare of $20.

Model Fit

The model documentation presents *t*-statistics for each of the explanatory variables, as shown in Table D26. However, there is no discussion of the overall fit of the model relationships to the survey data. The *t*-statistics for each of the variables included in the model utility functions are all statistically significant at the 95% confidence level; highly so in the case of the cost terms and most of the travel time terms.

Model Application

The binomial logit diversion models were used to predict the ridership on the Air Rail Link for future years following the introduction of service under a range of different service scenarios. These included potential intermediate stations between Union Station and the airport, as well as different fare and frequency assumptions. The predicted ridership on the Air Rail Link during the first two years after the start of service was adjusted to allow for an expected ramp-up in the diversion from other modes based on the experience following the start of service on the Heathrow Express rail link to London Heathrow Airport.

The models were applied to a range of different service scenarios, including a base case with an intermediate stop at the Dundas Station of the Toronto Transit Commission Bloor–Danforth subway line, as well as nonstop service from Union Station to LBPIA and a reduced headway for both the nonstop and one-stop service with trains departing every 20 min rather than every 15 min. Other sensitivity tests were performed to explore the effect of changes in rail service travel times, changes in access times for travelers to reach the rail link stations or egress times from the airport station to the passenger terminal, changes in highway travel times, changes in the value of time for air passengers, and the introduction of another intermediate station at a proposed entertainment complex located at the site of the Woodbine Racetrack adjacent to the planned rail route.

To understand the potential uncertainty in the prediction of ridership and revenues over the first 30 years of the project, a risk analysis was performed that took into account the confidence in the mode choice model relationships as well as the predicted future values of the airport traffic, changes in market segments, trip end distribution, and transportation system variables. This analysis generated distributions of predicted future levels of ridership and revenue that were used to present both 20% and 80% confidence values for both measures. This recognized that private investors in the planned Air Rail Link would want to adopt a conservative view of the likely return on investment, whereas design of the necessary facilities would need to consider a more aggressive forecast of possible ridership.

Comparison with Benchmarking Analysis

A particularly interesting aspect of the Air Rail Link Revenue and Ridership study is the comparison of the predictions of the mode choice model and the findings of the benchmarking analysis. In spite of both the very broad scope of the benchmarking analysis and the technical concerns with the mode choice model discussed earlier, the results of both approaches gave surprisingly consistent results. The benchmarking analysis suggested that the likely mode share of originating air passenger traffic at LBPIA using the rail link might varying between about 7% and 14%, with a central estimate of 9.3%. The forecasts of ridership applying the mode choice model to the base case service scenario gave a mode share of 9.3% for 2001 traffic levels, rising to 9.7% for 2021 traffic levels.

Documentation

Borges, H., *Air Rail Link: Pearson Airport–Union Station*, presented to the Chartered Institute of Logistics and Transport, Transport Canada, Ottawa, ON, Apr. 11, 2006

Halcrow Group Limited with Cansult Ltd., *Air Rail Link from Lester B. Pearson International Airport to Union Station: Revenue & Ridership Study*, Report T8080-01-1213, Final Report, Prepared for Transport Canada, Ottawa, ON, May 2002.

Request for Business Case: Air Rail Link from Toronto–Lester B. Pearson International Airport to Toronto Union Station, Transport Canada, Ottawa, ON, May 2003.

D9 UNITED KINGDOM SERAS STUDY AIR PASSENGER SURFACE ACCESS MODEL

Summary

Airports	London area airports [Heathrow (LHR), Gatwick (GTW), Stansted (STN), Luton (LTN)]
Model Developer	Halcrow Group Ltd.
Date Developed	2002
Market Addressed	Air passengers
Model Type	Revealed preference data
Model Structure	Nested logit
Survey Data Used	U.K. Civil Aviation Authority air passenger surveys 1992–1997

Airport Profile

Source: United Kingdom Civil Aviation Authority, CAA Passenger Survey Report 2005

	LHR	GTW	STN	LTN
Total annual passengers (2005):	66.8 m	31.8 m	21.7 m	8.9 m
Percentage O&D:	66%	84%	89%	94%

m = million.

Ground access mode split (2005):

	LHR	GTW	STN	LTN
Private vehicle	34%	51%	48%	56%
Rental car	3%	2%	4%	3%
Taxi/minicab	26%	14%	9%	13%
London Underground	13%	—	—	—
Rail	11%	26%	25%	18%
Bus/coach	13%	7%	14%	10%
Other	<1%	<1%	1%	<1%

Market Segmentation	U.K. business passengers on domestic trips U.K. business passengers on international trips U.K. leisure passengers on domestic trips U.K. leisure passengers on international trips Non-U.K. passengers on business trips Non-U.K. passengers on leisure trips
Explanatory Variables	Travel time (in-vehicle time, walk access time) Waiting time Travel cost (fares, parking, automobile operating cost) Driving distance Interchange penalties

Description

As part of the SERAS study undertaken for the U.K. Department of Transport, Local Government and the Regions, a set of surface access models were developed that included an air passenger mode choice model, as well as an airport employee trip distribution model and an airport employee mode choice model.

The structure of the air passenger mode choice model is stated to be the same as the Heathrow Surface Access Model (HSAM) developed by the MVA Consultancy for the British Airports Authority. This is a NL model that covers 12 defined ground access modes and has separate coefficients for six market segments:

- U.K. business passengers on domestic trips
- U.K. business passengers on international trips
- U.K. leisure passengers on domestic trips
- U.K. leisure passengers on international trips
- Non-U.K. passengers on business trips
- Non-U.K. passengers on leisure trips.

The 12 ground access modes consist of:

- Drop off by private automobile (termed Kiss & Fly)
- Private automobile parked at airport (termed Park & Fly)
- Rental car (termed Hire Car)
- Taxi
- Local bus and intercity coach
- London Underground
- Coach links to British Rail stations (BR Coach)
- Dedicated premium rail service (Heathrow Express)
- New standard British Rail services
- Alternative premium rail service
- Charter coach (including hotel bus)
- Inter-airport transfer coach.

Although the term British Rail is used in the model documentation, these services are now provided by private companies (e.g., Great Western Trains) and British Rail as such no longer exists. The Park & Fly mode was assumed to only be available to U.K. passengers and was substituted by the Hire Car mode for non-U.K. passengers. The Heathrow Express is a dedicated non-stop service between London Paddington Station and Heathrow Airport. The alternative premium rail service was assumed to be a similar service from another London station, whereas the new standard British Rail service would provide direct rail service to the airport using conventional rail equipment with intermediate stops. The hotel bus service refers to a system of shuttle buses that serve local hotels near Heathrow Airport. However, the use of charter coach, hotel bus, and interairport transfer coach was not explicitly represented in the model, but instead the use of these services was determined independently and the resulting vehicle trips added to those determined using the mode choice model. Thus, the mode choice model for each market segment consisted of nine modes.

The nesting structure of the model is shown in Figure D6. There are several levels of nest, particularly for the different rail modes. The utility functions for each mode use a generalized cost approach that considers the travel time and out-of-pocket costs (fares, parking, and private automobile operating costs), as well as time penalties for interchanges on public modes, and converts all costs to equivalent minutes of travel time. The utility function divides the

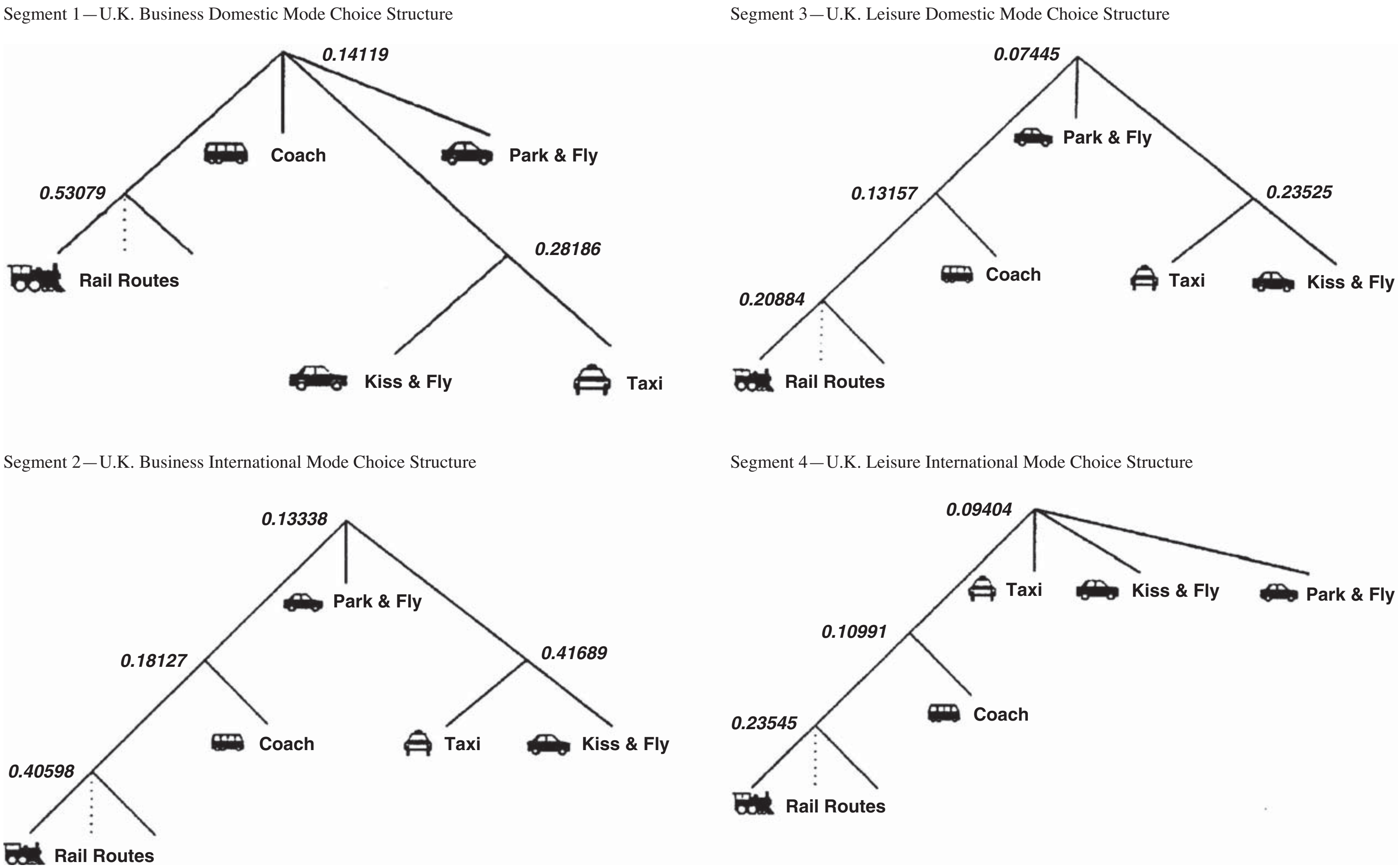
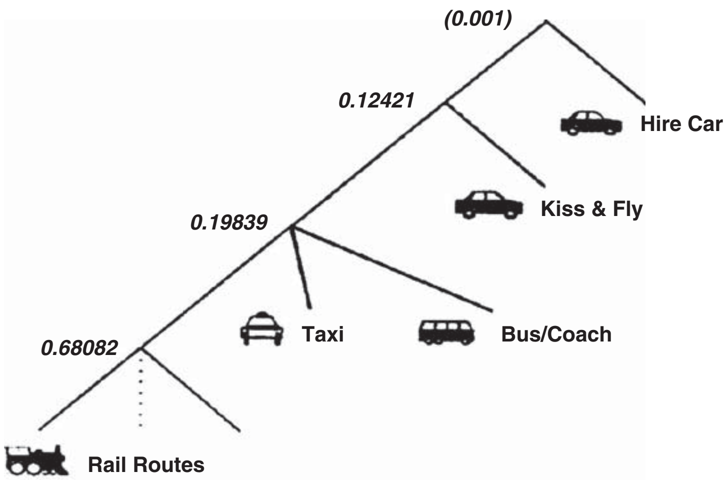
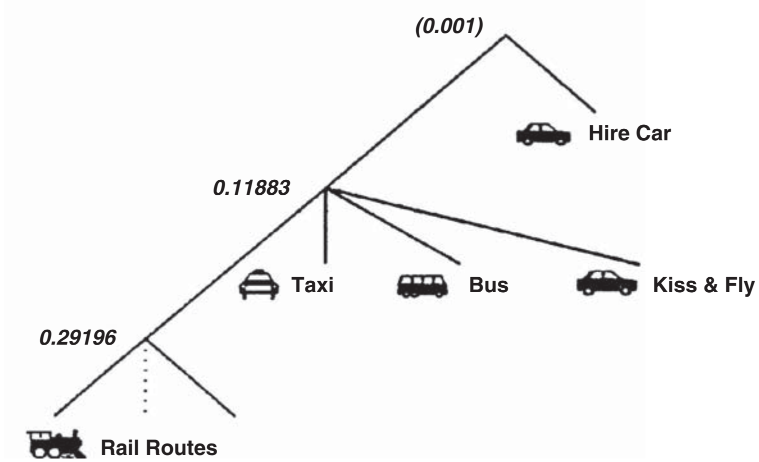


FIGURE D6 SERAS mode choice model nesting structure.

Segment 5—Non-U.K. Business Mode Choice Structure



Segment 6—Non-U.K. Leisure Mode Choice Structure



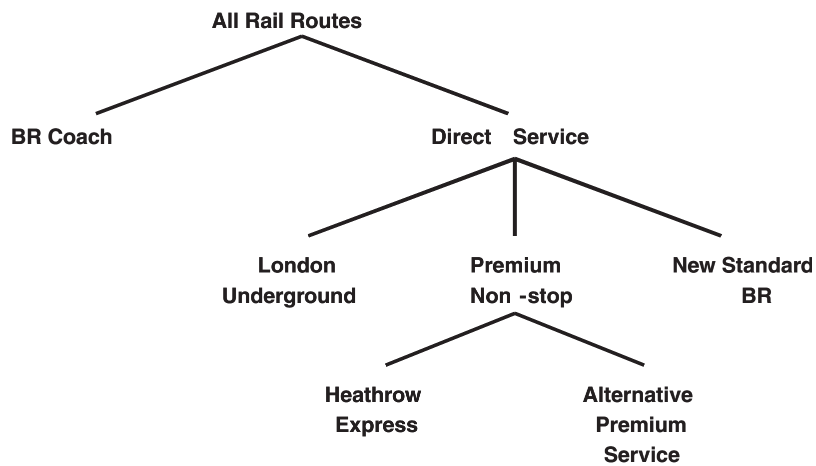


FIGURE D6 (*Continued*).

generalized cost for the mode by the square root of the direct driving distance to the airport. There are no calibration parameters as such, although different values of time are assumed for each market segment and different weights are applied to waiting time for some market segments. Different automobile operating costs (in pence per kilometer) are assumed for U.K. business and U.K. leisure passengers. Because the models are applied to estimates of air passenger trips that originate in each analysis zone, an average air party size and average trip duration are assumed for each market segment.

One of the most questionable aspects of the SERAS model is the use of an average value of time for each market segment. Although this is a consequence of the use of aggregate trip generation data rather than applying the model to disaggregate air passenger survey data, it will tend to under-predict the use of public transport modes by lower-income travelers and over-predict their use by higher-income travelers. To the extent that higher- and lower-income travelers are not uniformly distributed geographically, this will result in biased estimates of public transport mode use from any given zone, and hence for any particular service.

Another questionable feature of the SERAS model is the division of the computed generalized cost by the square root of the distance in computing the utilities. To the extent that the same distance is used in computing the utilities for each air party from a given origin zone, this simply scales the utility values, which implicitly assumes that the variance of the error term in the utility functions increases with distance from the airport, albeit at a declining rate. Although it is likely that the uncertainty in highway travel times increases with distance from the airport, this is not true for out-of-pocket costs (such as public transport fares and parking costs) or for travel times on rail or intercity bus modes, which operate to a published schedule (whereas intercity buses may get delayed in traffic congestion, passengers are likely to base their mode choice decisions on the published schedule). Therefore, the effect of travel time uncertainty should play a greater role for private car, rental car, and taxi modes than for public transport modes. Another concern with this approach is that the scaling effect changes most rapidly at short distances. However, it is precisely at these distances that travel times are most predictable. What would therefore provide a better reflection of uncertainty in travel times is an S-shaped distance function that is asymptotic to one at short distances and would only be applied to private car, rental car, and taxi modes.

The utility functions for each mode are as follows:

$$U_{\text{P\&F}} = \frac{T_{\text{car}} + \frac{c}{gv}D + \frac{pd}{gv}}{\sqrt{D}}$$

$$U_{\text{taxi}} = \frac{T_{\text{car}} + \frac{1}{gv}F_{\text{taxi}}}{\sqrt{D}}$$

$$U_{\text{bus}} = \frac{T_{\text{bus}} + \alpha W_{\text{bus}} + \frac{1}{v}F_{\text{bus}}}{\sqrt{D}} + \tau_1 I1$$

$$U_{rail} = \frac{T_{\text{rail}} + \alpha W_{\text{rail}} + \frac{1}{v}F_{\text{rail}}}{\sqrt{D}} + \tau_x X1 + \tau_1 I1 + \tau_2 I2 + \theta$$

where T_m = in-vehicle time plus access walk time for mode m (minutes),
D = direct driving distance to airport (kilometers),
c = perceived private car fuel cost (pence/kilometer),
v = value of travel time (pence per minute),
g = air party size,
p = parking rate (pence per day),
F_m = fare for mode m (pence),
W_m = wait time for mode m (minutes),
$X1$ = number of cross-platform interchanges,
$I1$ = number of full intra-modal interchanges,
$I2$ = number of intermodal interchanges,
α = weighting of wait time relative to in-vehicle time,
τ_x = cross platform transfer penalty (minutes),
τ_1 = intra-modal interchange penalty (minutes),
τ_2 = intermodal interchange penalty (minutes),
θ = direct rail constant (minutes).

TABLE D28
SERAS MODE CHOICE MODEL PARAMETERS

Parameters	U.K. Business Domestic	U.K. Business International	U.K. Leisure Domestic	U.K. Leisure International	Non-U.K. Business	Non-U.K. Leisure
Value of Time (£/hour)	28.5	46.3	4.7	6.6	47.8	5.6
Vehicle Operating Cost (p/km)	9.40	9.40	8.14	8.14	n/a	n/a
Average Air Party Size	1.36	1.36	1.99	1.99	1.56	2.08
Average Trip Duration (days)	2.57	8.50	6.43	18.66	N/A	N/A
Wait Time Weighting Factor	1.0	1.0	1.0	1.9	1.0	1.35
Parking Adjustments	2.0	2.5	2.5	4.0	N/A	N/A
Interchange Penalty (min)						
Cross-platform	0.43	0.50	0.77	0.90	0.30	0.69
Intra-modal	2.13	2.52	3.86	4.48	1.48	3.45
Intermodal	2.48	2.52	3.86	5.40	1.48	4.19
HEX Constant (min)						
Central London	6.70	9.10	17.93	15.54	5.88	16.90
Outer London	3.20	4.09	5.10	7.84	2.99	9.41

Notes: N/A = not applicable; p/km = pence/kilometer; HEX = Heathrow Express.

Model Coefficients

The values for the various model parameters that were used in the SERAS study are shown in Table D28. Air passenger value of time and vehicle operating costs are given in 1998 pence. Most of the parameter values were adopted unchanged from the 1991 version of the Heathrow Surface Access Model.

The values of time for business travelers appear reasonable, although those for leisure travelers appear surprisingly low (in 1998 the pound was worth approximately 1.66 dollars). The interchange penalties appear too low, particularly for cross-platform connections. In general, travelers will experience a wait of about half the headway of the outbound service at an interchange, in addition to any walking time involved. However, it is not clear from the documentation whether these penalties are in addition to any waiting time or are intended to account for it. The Heathrow Express constant (θ) reflects the higher quality of service relative to the London Underground. The difference in value between central and outer London presumably results from the need for a longer journey on the Underground to reach the Heathrow Express terminal at Paddington Station. However, because the ride on the Heathrow Express is the same duration for all travelers, any measure of the higher utility of the Heathrow Express service should be a constant for all travelers. Because these interchange penalties and direct rail constants have been estimated from air passenger survey data, this suggests that the model estimation has underestimated the perceived disutility of the access journey to Paddington Station, possibly owing to underestimated interchange penalties (from most parts of London, reaching Paddington Station by Underground involves several changes of line or even changes of mode).

Documentation

Halcrow Group Ltd., *SERAS Surface Access Modelling*, Prepared for the Department of Transport, Local Government and the Regions, South East and East of England Regional Air Services Study, London, England, July 2002.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation