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Opportunities for Improved Intermodal Connectivity at California Airports

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This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department Transportation, Federal Highway Administration.

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

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**Opportunities for Improved Intermodal Connectivity
at California Airports**

(PATH WORKING PAPER)

Project Number: TO 5406

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

Xiao-Yun Lu, Geoffrey D. Gosling and Jing Xiong

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Abstract

This working paper has been prepared as part of research to develop a combined quantitative and qualitative approach to planning for improved intermodal connectivity at California airports. The quantitative approach involves the development of an Intermodal Airport Ground Access Planning Tool that combines an air passenger model choice model, a model of transportation provider behavior and a traffic network analysis model. The qualitative approach will be used to enhance the quantitative analysis to account for those factors which are difficult to quantify and to provide recommended policy and planning guidelines.

Keywords

Intermodal connectivity, airport ground access planning, air passenger, air freight, modes, transportation providers, modeling

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This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation (Caltrans); and the United States Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

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Executive Summary

The motivation to improve intermodal connectivity at airports results from a growing interest in reducing the volume of highway traffic generated by airport access and egress trips and facilitating the ability of airport travelers to use high-occupancy modes. Continuing growth in air travel and air freight is generating ever increasing volumes of surface traffic traveling to and from airports, particularly major airports. This traffic arises primarily from air passenger trips, but airport employees and air cargo movement also contribute significant volumes of traffic at large airports. These vehicle trips contribute to congestion on the regional highway network and the local street system in the vicinity of the airport, as well as adversely impacting air quality through increased vehicle emissions. The goal of enhanced intermodal connectivity is to encourage greater use of high-occupancy modes, particularly rail modes that do not involve use of the highway system (other than for access and egress trips to the rail stations) and in many cases use electrical power. Improving the connectivity to rail modes leverages the public investments that have been made in these modes, and to the extent that these modes are operated below capacity (as is commonly the case) makes use of excess capacity that would otherwise remain unused.

This Working Paper summarizes our preliminary work on a combined quantitative and qualitative approach to planning for ground access improvements at California airports. Work that has been conducted so far can be divided into the following categories: (1) refinement of the scope of the project; (2) literature review; (3) preliminary consideration of a combined qualitative and quantitative approach and relevant data collection; (4) preliminary considerations for air cargo issues; and (5) identification of needs, challenges and possible alternatives for thirteen representative airports in California.

(1) Refinement of the scope of the project: As with any transportation system planning, airport ground access planning has multiple levels determined by the levels and purposes of the decision makers. Previous work in the *California Ground Access to Airports Study* (Landrum & Brown, 2001) has covered a wide range of topics including relevant institutional issues for both passenger and air cargo, identified problems and needs, and developed recommendations for future steps to address these needs from a strategic viewpoint at California airports. Starting from that basis, the current research is addressing how to practically improve the ground access at California airports, comparing possible alternatives using a combined quantitative and

qualitative approach. Because this project is focusing on ground access planning for specific given airports, its scope and detail are defined as the given airport and the connectivity within its influence area. The interactions between airports will not be considered here. Compared to the strategic planning by in Landrum & Brown (2001), this project is for implementation- related planning.

(2) Literature review: A review of previous work has been conducted, including government agency and consultant reports and academic papers published in journals and conferences, both national and international. It has covered the following topics (Chapters 2 and 3):

(a) Intermodal Transportation: Airport ground access is an example of intermodal transportation, thus its planning should follow the general principles of intermodal transportation;

(b) Special work on California airports, which emphasizes the work by the Landrum & Brown team on strategic planning for California airports and the work by Tsao and Rizwan (2000), which investigated intermodal air cargo transportation activities and needs in California airports;

(c) Passenger mode choice modeling: Mainstream work on this topic uses discrete choice models for estimating the passenger (ridership) probability distribution based on factors such as the available modes and their service characteristics (price and/or operating frequencies), air party survey data, and airport demand etc. This is a static approach in the sense that the model captures the mode choice behavior for a given airport in the time period when data are obtained. One also needs to consider transportation providers' behavior, which can be used jointly with passenger mode choice to understand the dynamic economic interactions between passengers and transportation providers.

(d) Transportation provider behavior: It is tightly coupled with the passenger mode choice behavior, the interaction reflecting the market economics of airport ground access. Little work has been done until now to address these interactions in transportation and particularly in airport ground access activities.

(3) Preliminary considerations for combined qualitative and quantitative approach: The quantitative approach includes the modeling of air passenger mode choice behavior and the

transportation provider's service behavior at selected representative airports. The qualitative approach includes consideration of some other factors that directly affect one or both of the passenger mode choice behavior and transportation provider behavior. Examples of those factors are the policies and regulations at/near airports by airport authorities/local governments, and household income and auto ownership of air passengers. It is hoped that the two parallel modeling approaches will reveal, to some extent, the dynamic ridership shift behavior driven by the transportation providers' competition in price and service. For the purpose of modeling, relevant data from the three main Bay Area airports, i.e. SFO, OAK and SJC, have been collected, including passenger survey data, airport revenue control (curb access) data, and public and private transportation provider service data such as schedules and fares.

(4) Preliminary considerations for air cargo: Air cargo is mainly dominated by four integrated carriers: UPS, FedEx, DHL and CNF. As indicated in the research results of the MTC Regional Goods Movement Study (2004), the air cargo business in the Bay Area will double in 2010 and triple in 2020 compared to 1998. Trucks are the primary ground mode for air freight door-to-door service delivery for all the carriers connecting airport/sorting facilities and customers. Regional traffic congestion in the vicinity of the major hub airports has significant impacts on the service quality of the integrated carriers, who have tight schedule constraints. It will be useful to identify effective alternatives that can avoid congested road traffic, while providing reliable and frequent service. Using a qualitative analysis approach, recommendations are provided, including using Bay Area transit systems, such as BART which have extra capacity, for freight delivery. (Chapter 4)

(5) Identification of needs, challenges and possible alternatives for thirteen representative airports in California: This study has identified practical needs and challenges and investigated possible alternatives for thirteen California airports, including large and small, hub and local airports. Some preliminary quantitative analyses have been conducted, identifying information such as yearly ridership distribution characteristics by mode, and ridership features by month for those airports between 2000- 2004. (Chapter 5 & 6)

Finally, work plans for further modeling and analysis work have been provided (Chapter 7).

Chapter 1. Introduction

This working paper identifies opportunities for improving intermodal connectivity at California airports and presents a preliminary analysis of a sample of representative projects at selected airports. It has been prepared as part of a research project undertaken for the California Department of Transportation by the Partnership for Advanced Transit and Highways (PATH) and titled *A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports*.

The objective of the project is to use a combined qualitative and quantitative approach to analyze the effectiveness of alternative strategies for improving intermodal connectivity at airports. The qualitative approach will involve a case study analysis of a selection of representative airports to identify and evaluate the potential effectiveness of alternative projects to improve the connectivity between the airports and the rest of the intermodal transportation system. This will be supplemented by a more detailed quantitative analysis of selected case study airports utilizing a mathematical model, termed the Intermodal Airport Ground Access Planning Tool (IAPT), which will be developed in the course of the research. The IAPT will be designed to provide an analytical environment that integrates existing data sources and transportation network analysis software with improved models of air passenger and airport employee travel choice behavior, as well as goods transport decisions that involve airport trips, to evaluate the costs and benefits of proposed projects to improve intermodal connectivity at airports. Based on the results of this case study analysis, policy recommendations and planning guidelines will be developed and reviewed with Caltrans and other stakeholders. The goal of developing the IAPT is to ensure a consistent approach to analyzing alternative projects and simplify the complicated modeling and computational aspects by providing decision makers and planners with a user-friendly interface to a standard set of analysis modules.

1.1 Scope of this Working Paper

As the first deliverable of the project, this working paper presents the findings of a set of initial case studies that explore airport access issues, data availability, and potential intermodal transportation facilities at selected airports in each of the six California regions considered in the analysis. The working paper also reviews the recent literature on intermodal access to airports

and the findings of a recent study on ground access to airports in California performed for the California Department of Transportation by a consultant team led by Landrum & Brown, identifies potential challenges and opportunities to improve connectivity between airports and other intermodal transportation nodes, and discusses plans for more detailed case study analysis using the modeling framework being developed as part of the research.

The motivation to improve intermodal connectivity at airports results from a growing interest in reducing the volume of highway traffic generated by airport access and egress trips and facilitating the ability of airport travelers to use high-occupancy modes. Continuing growth in air travel and air freight is generating ever increasing volumes of surface traffic traveling to and from airports, particularly major airports. This traffic arises primarily from air passenger trips, but airport employees and air cargo movement also contribute significant volumes of traffic at large airports. These vehicle trips contribute to congestion on the regional highway network and the local street system in the vicinity of the airport, as well as adversely impact air quality through increased vehicle emissions. The goal of enhanced intermodal connectivity is to encourage greater use of high-occupancy modes, particularly rail modes that do not involve use of the highway system (other than for access and egress trips to the rail stations) and in many cases use electrical power. Improving the connectivity to rail modes leverages the public investments that have been made in these modes, and to the extent that these modes are operated below capacity (as is commonly the case) makes use of excess capacity that would otherwise remain unused.

Although airport access and egress traffic is generated by air passengers, airport employees, and air cargo activities, as well as airport support functions and other ancillary activities that occur on the airport, both this working paper and the current research project are primarily focused on air passenger trips. However, this working paper does include a discussion of air cargo operations and it is envisaged that future work will extend the focus of the analysis to address airport employee and air cargo trips.

The case studies presented in this working paper examine a range of strategies to improve intermodal connectivity at airports, including the provision of direct rail service to the airport, the creation of improved links to nearby rail stations, and the development of express bus services to off-airport terminals or regional intermodal terminals. They discuss the likely ridership levels

and economic feasibility of the different strategies, and identify airport traffic levels and other factors that are likely to influence the viability of potential projects.

1.2 The Roles of Qualitative and Quantitative Analysis

Since the objective of the research project is to utilize a combined qualitative and quantitative approach to analyze the effectiveness of alternative strategies to improve intermodal connectivity at airports, it may be helpful to articulate the respective roles of qualitative and quantitative analysis.

1.2.1 Qualitative Approach

There are two different ways in which qualitative considerations arise in enhancing intermodal access to airports. The first aspect is how to effectively account for qualitative factors that affect ground access mode choice decisions by airport users. These include such factors as perceptions of comfort and convenience, concerns for personal security and the security of any baggage being carried, and the availability of information about alternative transportation options. While these are all reflected to some extent in the models used for quantitative analysis, they are typically accounted for through alternative-specific terms that take constant values. This makes it difficult to analyze the likely effect of changes in these factors, or to identify strategies that could be pursued to change how they affect mode use decisions. At one level, it is recognized that these qualitative factors may be much more important in determining the use of intermodal airport access options than relatively small differences in travel time and cost but at another level there is a very limited understanding of how to change the influence of these factors in a positive direction. Developing better ways to address these qualitative aspects is a critical need.

The second aspect is the application of descriptive analysis to characterize the behavior of transportation providers or to perform comparative case studies. The former is a key input to the development of an effective quantitative analysis framework, since changes in any airport ground access service is likely to stimulate a response from other transportation providers. If this response is not taken into consideration in the analysis, this is likely to result in an erroneous estimate of the likely use of the particular service. Descriptive case studies can shed useful light on the factors that influence the success of intermodal services for airport trips as well as the

potential costs of implementing or enhancing those services. These case studies may well include quantitative information, but do not typically involve mathematical models. One important application of such case studies is to examine the political dynamics involved in previous decisions to develop enhanced intermodal connections at airports in order to help identify ways to generate the necessary political support for future projects and define projects that are likely to attract support from transportation decision makers.

1.2.2 Quantitative Analysis

The approach of quantitative analysis is more straightforward. It incorporates mathematical modeling to predict the usage of any proposed project to improve intermodal connectivity at airports, and to assess the associated costs and any revenue generated by the project. It would also contain a quantitative evaluation of the impacts of a proposed project on the environment and the remainder of the transportation system, including such considerations as air quality emissions and highway congestion. The level of sophistication of the models involved can vary, but the complexity of the factors that influence the ground access and egress mode choice decisions of air passengers in particular require fairly specialized models.

1.2.3 Need for a Combined Approach

A combined qualitative and quantitative approach is increasingly necessary as intermodal transportation systems serving airports become more complicated. These systems involve passengers with different income levels, mode use preference, travel purpose, availability of ground transportation modes, travel time constraints, etc. They also involve multiple transportation service providers across modes and even for the same mode. These transportation providers may operate cooperatively, semi-competitively, or fully competitively, within a mode or between modes. The transportation providers can be divided into public sector agencies and private sector firms. The behavior and operation of both types of organization are affected by the policies and guidelines of the airport, which in turn result from multi-level planning processes. There are naturally dynamic interactions between transportation providers' services and travelers' decisions regarding their access and egress trips. All these factors directly affect the surface transportation network traffic near the airport or in the corridors that lead to it. Decision making based only on a qualitative approach is unlikely to enable the overall system to achieve the desired performance or maximize its capacity. However, many factors are difficult

to quantify in a modeling approach, and need to be addressed through a more qualitative approach, based on policy decisions and recommended guidelines for project development.

1.3 Airport Ground Access Planning Problems

Issues that arise in planning ground access to airports can be divided into those related to the ground transportation of people traveling to and from the airport (including air passengers and airport employees) and those related to the movement of air cargo and other goods. Although the decision needs of operations and planning are different, these decisions affect each other. Planning and operations may involve decision making at different levels, with operational decisions subject to the constraints provided by the policies and guidelines recommended by the planning process. The operational performance will provide feedback to the decision making in the planning process to lead to further improvement of the ground access system.

The decision-making process can be viewed as being applied at different geographic scales or levels, as well as at different stages of the planning and operational process. The lowest geographic level consists of the airport itself and its immediate influence area. The next higher level consists of the metropolitan region within which the airport is located and which may include several other airports. A higher level again consists of the state or larger geographical region that contains several metropolitan regions. While California is a large enough state to contain a large number of metropolitan regions, other regions at this level of planning may include several smaller states. The planning issues at this level begin to address inter-regional flows. Finally, a fourth level of planning considers interstate and international transportation flows.

At each stage of planning and operation, in order to optimize the performance of the overall system it is desirable to have coordination between the parties involved at that level as well as between those at higher or lower geographic levels. However, at the operational stage coordination often only happens within a single transportation provider or alliance instead of between all the transportation providers unless higher-level decision makers or government agencies intervene in parallel to the way that coordination occurs in the planning process.

1.3.1 Stages in the Planning Process

The planning process involved in improving intermodal connectivity in the airport system, or indeed implementing any transportation system improvement, can be viewed as being divided into three stages:

- Strategic planning
- Implementation planning
- Operational planning.

Stage 1 - Strategic planning: Strategic planning addresses long run and higher level planning issues. It is often conducted using primarily qualitative methods with possibly the assistance of some quantitative methods such as analysis of aggregated data. It attempts to identify problems, deficiencies and needs from the perspective of institutional issues, political relationships, funding strategies, and planning principles. It develops recommended policies and planning guidelines to solve the problems and needs that have been identified and to address existing gaps in the system. However, strategic planning generally does not attempt to evaluate specific projects. In particular, it does not address the best way to plan a given project under site-specific circumstances.

Stage 2 - Implementation planning: This stage of planning is where specific projects are identified and evaluated to implement the policies and strategies that have been identified in the strategic planning stage. To conduct planning in this stage, a quantitative analysis approach is necessarily given greater emphasis than in strategic planning. It is in order to answer the questions about how best to solve problems, address gaps in the system, and to remedy identified deficiencies. The ideal outcome is to identify and implement an optimal solution to a given problem in each specific circumstance. Since the end result of implementation planning is to provide recommendations for specific actions that can be taken to address the specific situation, it is necessary to combine the quantitative analysis with a consideration of qualitative aspects such that the recommended solution conforms to established policies and guidelines. Researchers and practitioners often have different perspectives on the necessary features of the quantitative approach. In fact, this difference typically revolves around the extent to which the quantitative analysis is conducted. A relatively simple quantitative approach may just involve some statistical analysis of aggregated data about the parties involved in the intermodal transportation system. A more extensive quantitative analysis may involve static modeling of the

relationships inherent in the dynamics of the intermodal transportation system. A more advanced quantitative approach may involve dynamic modeling of the system that can capture the interaction between the decisions and behavior of the major parties in the intermodal transportation system.

The function of the qualitative approach at this stage is to identify those factors in the project implementation planning which are difficult to take into consideration in the quantitative modeling, to study how those factors could affect the feasibility of the proposed solution and the resulting performance of the system, and to combine those factors with the results from quantitative analysis. Such qualitative factors can include political relationships, institutional issues, and the effect of the information available to passengers and transportation providers, all of which are often difficult to incorporate in quantitative modeling. The combination of quantitative and qualitative approaches is necessary for the effective application of broader policies and planning guidelines to practically situations and to evaluate their effect on the performance of the system. At present, this is the weakest aspect of current approaches to intermodal airport ground access planning.

Stage 3 - Operational Planning: Once a decision has been made to develop a specific project or service, it is necessary to determine how the service will be provided or the facility operated. In practice, these decisions take place on a continuous basis over the life of the project as circumstances evolve. However, for planning purposes it is necessary to make assumptions about how the system will be operated and thus it is often necessary to undertake some operational planning as part of implementation planning.

In practice the operation of an intermodal transportation ground access activity can be conducted in several ways. Two extreme cases are (a) completely competitive, in which each transportation provider independently establishes the service that it offers (service frequency and fares), resulting in a competitive situation between transportation providers within and between modes, ; and (b) fully cooperative, in which there is coordination between all the transportation providers within each mode and between different modes. The first situation is an example of an entirely free market. The second represents a fully managed or regulated system that could be designed to ensure that the overall system operates in an optimal way to satisfy social welfare goals, such as efficient land use, reduced traffic congestion and air pollution, increased transportation efficiency (reduced overall travel time), and to meet the needs of local and global

economic development. This ideal model, however, is difficult to implement in a free market economic system, even if it were clear how to implement it. In practice a feasible solution lies somewhere in between, i.e. a combined competitive and cooperative operation with some providers operating completely independently and others cooperating through alliances with similar providers. Within each alliance, providers may cooperate within the framework of established regulations, while different alliances may compete with each other under other regulations. However, the formation of such alliances for cooperation and coordination may need some government intervention as well as legal, jurisdictional or institutional changes at various levels.

1.3.2 Role of Coordination

Coordination plays a critical role in both quantitative and qualitative approaches to optimal planning and operation for a large scale system like the intermodal airport ground access system. It may involve the coordination in the same level and across different levels. However, coordination has different meanings in the qualitative approach from the quantitative approach. In a qualitative approach, coordination refers to institutional and political relationships among all the relevant government and planning agencies. A higher level government agency, such as a state department of transportation or a metropolitan planning organization, typically performs the role of conducting such a coordination process. In a quantitative approach, coordination refers to the analytical process, such as a computerized mathematical algorithm, which coordinates the dynamic behavior of the various subsystems, within the overall system, in order to ensure that the overall system performance is optimal in some sense.

The differing role of coordination in the three stages of the planning process described above is shown in Table 1-1.

1.3.3 Typical Planning Problems at Different Geographical Levels

For each of the planning stages described above, there are a typical set of planning problems that correspond to the geographic level of the decision making.

Airport level: Planning problems at this level deal with the design and operation of the ground transportation system at a single airport –trip generation, mode choice, operator regulation (policies and regulations towards transportation providers), airport revenue

considerations, service changes, etc. It is assumed that the total volume of air passenger traffic or air cargo activity at the airport is known or can be forecast.

Table 1-1: Role of Coordination in Airport Ground Access Planning

<i>Stage of the Planning Process</i>	<i>Potential Role of Coordination</i>
Strategic Planning	Consultation between planning and operating agencies in defining problems, issues and needs, and developing potential solution strategies, as illustrated by the California <i>Ground Access to Airports Study</i> and other related studies.
Implementation Planning	Development of a combined qualitative and quantitative planning approach to project identification and development with coordination among agencies and government at different geographical levels
Operational Planning	Service coordination and synchronization of schedules among the different transportation providers at the airport level

Intra-regional level: Planning problems at this level needs address multiple airports in a region. In general, competition exists between airports in the region, and in particular between airlines serving those airports, and thus airport users make choices about which airport to use based on the services available at each and their relative accessibility. It is no longer reasonable for planning at this level to assume that the demand for each airport can be forecast without considering these competitive interactions. Air travelers will choose among the available flights at different airports based on such considerations as the available air fare, the quality of the air service, airport parking rates, and access travel time and convenience. Such choices will directly affect the airport demand and ground access system use, resulting in a dynamic interaction between the available air service and performance of the ground access system at airports in the region. Compared to a single airport, analysis is more challenging, since the system is not closed

and airline decisions, such as flight schedules and fare changes, have to be taken into consideration.

Inter-regional level: Planning problems at this level involve the coordination between several regions. For passenger travel, it is recognized that competition between airports in different regions is relatively small, although the development of high-speed rail systems could potentially change this. However, for movement of air freight, such interaction can be significant due to the increasing integration of air cargo flights with long distance ground haul using trucks. Transportation systems at this level are more open than at the intra-regional level.

Interstate and international level: Intermodal transportation flows depend directly on the underlying patterns of economic activity and cannot be treated as an entirely closed system, although transportation system modeling often tries to separate the issues in some way. The market economy is experiencing increasing globalization. This globalization naturally leads to increased demand for interstate and international travel and trade flows, and corresponding demands on the intermodal transportation system at all levels. In particular these trends have led to a continuing growth in interstate and international goods movement by air freight. Continued growth in the national and global economy will bring more challenges and opportunities for intermodal airport ground access planning and practice, particularly for air freight.

1.4 Structure of this Document

The remainder of this working paper is organized as follows. Chapter 2 presents a review of recent literature on intermodal access to airports. The following chapter discusses the findings of the recent *Ground Access to Airport Study* performed for the California Department of Transportation. Chapter 4 supplements the findings of this study with a discussion of air cargo operations and the potential contribution of improved intermodal connectivity. Chapter 5 examines the challenges and opportunities for improving intermodal connectivity at airports in California, with a focus on air passenger travel. Chapter 6 presents the results of an initial case study analysis of a range of intermodal opportunities at selected California airports. The following chapter describes plans for more detailed analysis of selected case studies that will be performed as part of subsequent work. Finally, Chapter 8 presents the conclusions and recommendations from the initial analysis performed to date.

Supporting information is presented in two appendices. Appendix A contains an annotated bibliography of recent literature on intermodal access to airports that has been identified in the course of the project to date. Appendix B contains supporting data for future extension of the case study analysis described in Chapter 6.

Chapter 2. Review of Recent Literature on Intermodal Access to Airports

This chapter presents a review of recent literature relevant to intermodal airport ground access planning. The objective of this project is to improve intermodal connectivity in airport ground access using a combined qualitative and quantitative approach. This involves a number of different aspects of airport ground access planning. On the qualitative side, it involves institutional issues, political relationships and coordination between planners in different types of organization, as well as the role of air passenger information systems in air traveler mode choice behavior and understanding and accounting for the relevant decision making behavior of ground transportation providers. On the quantitative side, it involves how to measure the performance of an intermodal transportation system so that those performance measures can be used to guide decision making at different planning levels. This in turn requires the ability to model the air passenger mode choice and transportation provider decision making behavior, their interactions and the resulting effects on the number of vehicle trips generated by the airport, as well as the impact of these trips on traffic conditions on the street and highway network and air pollution. The review examines recent literature addressing these aspects of airport ground access planning as well as some principles, viewpoints, analysis methods, and recommendations from the literature on general intermodal transportation that are relevant to the particular case of airport ground access travel. The review also gives particular attention to the distinction between qualitative and quantitative analysis approaches, and includes the application to airport ground access issues of relevant modeling and analysis methods from general urban intermodal transportation.

2.1 Airport Ground Access Planning

There is an extensive literature on the many different aspects of airport ground access planning, particularly the planning and design of specific airport ground access facilities. This section summarizes some of the more recent key documents and studies that are particularly relevant to intermodal aspects of airport ground access planning. All of these documents and reports contain extensive bibliographies, from which the interested reader can obtain more detailed information.

In 1994 the Federal Aviation Administration (FAA) sponsored two workshops on ground access to airports that were organized by the Institute of Transportation Studies at the University of California at Berkeley. These examined the role of off-airport terminals and institutional and funding issues in developing improved airport ground access services and systems (Gosling, 1994). Subsequently, a contract was let by the FAA in association with the Federal Highway Administration to develop a planning guide for intermodal access to airports (Shapiro, *et al.*, 1996). The importance of viewing the airport ground access system as an intermodal interface and the role of such airport ground access systems as rail links and off-airport terminals was further developed in a paper by Gosling (1997).

The growing interest in improving public transportation access to large airports, and in particular proposals to develop very expensive rail links at an increasing number of airports, began to become of concern to the FAA and other Federal transportation agencies. Together with the Federal Transit Administration and the Federal Highway Administration, in 1998 the FAA requested the Transit Cooperative Research Program to undertake a comprehensive study of strategies for improving public transport access to large airports (Leigh Fisher Associates, 2000, 2002).

At about the same time, as part of the growing interest in developing intermodal strategies to address airport ground access, the Texas Department of Transportation sponsored an extensive study on the topic that undertook a comprehensive review of the literature, identified best practices and developed case studies, and performed an assessment of alternative strategies (Mahmassani *et al.*, 2000, 2001, 2002a, 2002b). While this study was primarily interested in methodology, another comprehensive study in California (Landrum & Brown, 2001) assembled information on the ground access conditions and needs at a large number of airports in the state, and examined the roles and responsibilities of different agencies. The findings of the latter study are discussed in more detail in the following chapter.

2.2 Intermodal Transportation Planning Principles

Since airport ground transportation can be considered as a particular subset of the more general intermodal ground transportation system, airport ground access planning should be guided by generally accepted principles for intermodal transportation planning. The National

Center for Intermodal Transportation (NCIT) has proposed the following four principles for the development of the intermodal transportation system (NCIT, 2001):

Connection: All modes should be well connected with one another to accomplish the convenient, expeditious, and efficient movement of commodities and people. Connecting points should be conveniently located and connections timed to facilitate movements from one mode to another.

Choices: The intermodal network should offer choices, allowing its users to select the mode that can most efficiently satisfy their transportation needs.

Coordination: The transportation infrastructure should be planned, designed, and built in a way that brings the modal networks sufficiently close together so that connections can be made relatively effortlessly. In addition, transportation providers must coordinate their schedules to reduce dwell time between intermodal movements.

Cooperation: There should be cooperation and collaboration among transportation providers and governmental agencies at the federal, state, and local levels to ensure that the needs of the users for seamless service are realized.

One definition of good intermodal connectivity is as follows: *Advanced and attractive systems that operate reliably, and relatively rapidly, and form part of the passenger and freight door-to door chain with smooth and synchronized transfers.*

However, in order to apply these principles effectively, it is necessary to understand the similarities and differences between planning for intermodal urban transportation in general and airport ground access in particular.

Similarities:

- As an example of intermodal transportation, the principles guiding airport ground access planning are similar to those for intermodal transportation in general;
- Basic requirements for facilities and service follow those identified by Homburger *et al.* (1996): adequacy to handle expected demand, compatibility with existing master plans, environmental compatibility, acceptability to decision makers and the public, and financial feasibility;

- Planning processes in both cases involve institutional issues, political relationships, identification of needs for enhanced facilities and services, and development of recommended changes to policy guidelines;
- Many of the factors influencing passenger mode choice decisions are similar;
- Public and private transportation providers operate in a similar way in serving airport ground access and general urban transportation trips.

Differences:

- Compared to general urban travel, airport ground access travel typically involves many more distinct modes and services;
- Airport ground access and egress trips by air passengers involve considerations not typically addressed in general urban travel, such as the need to carry luggage, round trips involving travel duration of many days, and a significant proportion of trips by visitors to the region;
- Many airport employees have shift patterns involving travel outside the usual commute times and the regular work week;
- Travel purposes for airport ground access trips are limited to airport related activities, which are not as diversified as those involved in general urban transportation;
- The total demand for airport ground access travel can be estimated from the air passenger traffic level at the airport and airport employee counts;
- Airport authorities typically maintain information on available airport ground access services at their airport(s), providing a current and consistent source of information;
- Airport access and egress trips involve travel to or from a single location, which reduces the complexity of travel patterns compared to general urban intermodal transportation;

- Transportation providers are generally subject to airport regulation which makes their behavior more predictable and can provide a source of statistics on operational traffic and activity levels, which is not always the case for more general urban intermodal transportation;
- Surveys of air passenger and airport employee travel patterns can be performed relatively easily at the airport, since these trips involve a common location.

These differences make some aspects of the modeling and analysis of airport ground access more challenging than that for general urban intermodal transportation while making other aspects easier.

2.3 Quantitative and Qualitative Approaches in Airport Planning

To develop a combined quantitative and qualitative approach for intermodal airport ground access planning, it is necessary to look at quantitative, qualitative and combined approaches used for planning in previous work. This requires a way to distinguish between quantitative and qualitative approaches. For the purpose of this discussion, a quantitative approach is considered to be one that involves modeling for analysis, however simple or complicated the model. Most previous work used either a qualitative or a quantitative approach. Few studies tried to combine them for intermodal transportation planning.

Cunningham and Gerlach (1998) discuss the use of decision support systems for airport ground access planning using both quantitative and qualitative approaches. The approach used in this work included: (1) a literature review to obtain background information concerning the airport ground access problem and analysis of various proposed ground access solutions; (2) telephone interviews with airport and regional transportation officials to clarify issues and identify key transportation officials familiar with airport ground access planning; and (3) focus group meetings with airport ground transportation managers, local metropolitan planning organization (MPO) staff directly involved in airport ground transportation planning, and relevant staff from local transit authorities at a selected number of case study locations. Participants were encouraged to provide their opinions as well as factual information regarding the planning process and the extent to which decision makers relied on quantitative models and qualitative information to reach a decision.

However, this study does not discuss how the quantitative approach was conducted in the locations examined. Instead, the main part of the study discusses some practical problems encountered in (or controversial attitudes towards) the use of quantitative analysis in intermodal airport ground access planning. The main findings are the following: (1) on the one hand, decision makers need a decision support system to provide numerical results as references for decision making; (2) on the other hand, using quantitative modeling for strategic decision support is very difficult. This difficulty arises because (a) modelers are not confident about the accuracy of their models and transportation officials believe that the information supplied is flawed by a number of defects that minimize the value for the decision maker, which in turn leads to the situation that decision makers lose confidence in the quantitative method; and (b) modeling is generally believed to be very costly and difficult – human behavior is not sufficiently understood to accurately predict how travelers make individual transportation decisions. To avoid these difficulties, the authors propose the following solution: (i) improve quantitative modeling such that the model can actually reflect passenger mode choice behavior; (ii) use a combined quantitative and qualitative approach for decision making, where the qualitative approach involves the use of such techniques as community or airport user focus groups to identify attitudes toward airport ground access issues and likely use of proposed new services, the use of expert opinion to supplement analytical modeling, comparative analysis with airport ground access systems in other regions, and consideration of the potential implications of longer-term visions for land use development in the areas around the airport or the evolution of the regional transportation system.

They point out that planning, designing and building a transportation system involves multiple constituencies, as well as multiple decision variables and criteria. This suggests that decision making at different levels of government needs to consider the interests of the different constituencies at the local, regional, and state level.

Cunningham and Gerlach suggest that decision makers, particularly higher level officials, tend to rely on a qualitative analysis based on a subjective assessment that draws on their background, beliefs, and experience. They might never make use of model results or cost-benefit numbers generated from models, in part because such models do not generate the type of information that they need. In practice, decision makers often base their strategic planning on their “vision” of how they think the transportation system should evolve based on their intuition and experience.

Reliance on a vision of how an organization, community or region should evolve is also a widely used tool for decision making in the business and political community. Quantitative information is then often developed to support that vision. In this case, the main information used by the decision makers in practice is derived from the vision with only minor information from quantitative analysis. In consequence, decision makers often choose to rely on models that are consistent with their visions. Where the results of analysis are in conflict with their vision, decision makers often choose to base their decisions on their vision rather than the analysis. This can often arise from a large gap between the quality of the analysis tools and how the decision makers perceive those tools.

The authors also identify a number of concerns and limitations with existing approaches to quantitative analysis:

- (a) Small amounts of data often only allow models to provide a general representation of complex phenomena, such as the use of average daily traffic levels;
- (b) Models are often too sensitive to key inputs and too easily manipulated;
- (c) Models sometimes do not predict what is really happening;
- (d) There is often difficulty modeling the effect of new modes or services using models that have been calibrated on data for the existing pattern of services.

The authors propose a number of ways to remedy these modeling limitations in order to win the confidence of decision makers:

- (a) Involve the transportation agency decision makers in the modeling process by organizing a committee to oversee the design and use of transportation models;
- (b) Ensure that the modelers make clear to decision makers the following aspects:
 - What assumptions have been made
 - What data are to be used and why

- The methodology to be used, which should be documented in a form that decision makers can understand;

(c) Encourage the decision makers to use the results of model analysis as prudently and conservatively as possible.

Ceder (2004) discusses the major elements and challenges surrounding the introduction of new or improved public transportation (PT) systems or services. The choice between public and private transport is an individual decision that is influenced by government and community decisions. These decisions often send mixed signals to the public transport passengers and potential users while failing to recognize system-wide considerations and integration implications. This paper attempts to summarize the current state of PT practice and to cover issues affecting the use of PT including the willingness of users to pay for improved service, assessment and projection of economic viability, the effectiveness of new initiatives mostly in Europe and North America, and strategies to achieve multi-modal service integration.

Ceder discusses the use of a qualitative analysis approach to address factors which affect the quality of service offered by the intermodal system but are difficult to quantify. These factors could include the introduction of the following intelligent transportation systems (ITS) technologies and other measures to improve user comfort and convenience:

- Automatic vehicle monitoring (AVM)
- Signal priority for public transportation vehicles
- Traveler information systems
- Stability of perception of service
- Ticketing integration
- Improved terminal, interchange and park and ride facilities
- Coordination between different modes to reduce total travel time
- Increased passenger comfort
- Introduction of different modes to increase system capability.

2.4 Policy and Institutional Issues

Lacombe (1994) suggests that inadequate ground access facilities may limit airport capacity. This paper examines the requirements in the Clear Air Act Amendments (CAAA) and Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) as they affect airport ground access planning. The paper examines the effect of institutional constraints and funding limitations that hinder intermodal approaches to improving airport ground access, and points out the necessity and opportunity for cooperation between airport authorities and urban transportation planners.

Yevdokimov (2000) examines the use of cost benefit analysis and related techniques to analyze the effect of transportation investment on economic growth. Microeconomic and macroeconomic simulations are used to support the benefit measurement.

2.5 Mode Choice Modeling and Analysis

To date the quantitative approach to air passenger ground access model choice analysis has almost exclusively used a form of logit model (multinomial logit or nested logit). Past model development efforts have been summarized in a recent review of the relevant literature by Gosling *et al.* (2003). A number of subsequent studies and alternative approaches are discussed below.

Tam and Lam (2005) studied the mode choice pattern for ground access travel to Hong Kong International Airport using a survey of air passengers. Their results show that due to very low car ownership and relatively short travel distances to and from the airport, access is mainly by public transport such as bus and train or light-rail. Passengers are divided according to arrival, departure and transit/transfer. The authors conclude that business travelers are less concerned with the cost of service than with travel time and convenience. This paper is primarily focused on the design of the survey and explanation of the results rather than their use for model development.

Arentze and Timmermans (2005) discuss the application of formal decision rules, such as *parametric action decision trees*, to explain travelers' mode choices. According to the authors, using discrete choice models (such as the logit model) could limit the sensitivity of the model to travel time and travel cost. This paper uses a hybrid model to reduce such defects. It is claimed that the hybrid model can reproduce realistic price elasticities of travel demand. The authors assert that decision trees have the advantage of being consistent, exclusive, and complete compared to other methods for formal representation of decision making, such as *belief networks*, *association*

rules and *production systems*. However, this paper does not specifically address airport ground access travel.

Two recent papers by Outwater *et al.* (2003, 2004) describe a market segmentation modeling approach to predicting the effect on mode choice of introducing a new mode, in this particular case the introduction of ferry service in markets not currently served by ferries. Two types of models were considered: multinomial logit and nested logit. The authors found that the later did not give any improvement and thus based their analysis on the former. Stated-preference survey data were used to calibrate the model. The calibrated model was then used to analyze three future year alternatives and to test sensitivities to pricing, service changes and alternative modes. According the author, previous mode choice modeling work has tended to emphasize the following factors: trip purpose, geographical location, and travel time. However, the focus of the current paper was to extend this mode choice modeling approach to reflect the effect of passengers' attitudes toward improvement in ferry service and apply this to the forecasting ferry ridership in the San Francisco Bay Area. Six attitudinal factors were identified: desire to help the environment, desire for time saving, need for flexibility, sensitivity to travel stress, insensitivity to transport cost, and sensitivity to personal travel experience. Three of these were used to partition the potential ferry-riding market into eight segments and develop demand estimates for each segment.

Lo, Yip and Wan (2004) incorporated the competitive behavior of transit services in an intermodal planning model using a nested logit approach. However, the competitive behavior between transit providers was considered in a static manner rather than a dynamic interaction between the transportation provider decisions and the passenger travel choices. The effect of the transportation provider behavior on passenger mode choice was reflected through the relationship between fare changes and ridership. Using their model, the authors studied the effect of fare changes on overall network congestion. A case study of travel between Hong Kong International Airport and the Downtown Area was used to illustrate the method.

2.6 Airport Ground Access Travel Information

A key aspect of air passenger choice of travel mode for airport trips is the information available to them about travel options. It is self-evident that travelers will not use transportation options that they are not aware of, but an equally important consideration is whether they can readily obtain the necessary information to decide whether to use a particular service. In the

absence of accurate information, their perceptions of travel times or costs may be sufficiently biased to cause them to reject options that in fact might work very well for them. In spite of the importance of this issue, it has received relatively little attention in the literature.

In the early 1990s the California Department of Transportation (Caltrans) funded a research project to examine how advanced technology might be used to improve information available to air passengers to help their airport ground access decisions (Du & Gosling, 1994). Subsequently, Caltrans funded a demonstration project at several airports in the state in which automated ground transportation information kiosks were installed in the airport terminals. These kiosks used a touch-screen display to provide information on alternative travel options and contained a database for all the airports in the demonstration program. Thus air passengers waiting for their flight at one airport could obtain information about ground transportation options at their destination airport. As part of the demonstration program, a series of surveys were conducted of air traveler and airport user information needs and the effectiveness of the kiosks at meeting those needs (Gosling & Lau, 1995). The survey results found that kiosk users generally found the information provided by the kiosks helpful and that they liked being able to obtain information about their destination airport in advance to arriving there.

A similar survey was undertaken a few years later at George Bush Intercontinental Airport in Houston (Burdette & Hickman, 2001). The latter survey only addressed the needs of departing air passengers and included information related to the flight (such as gate information and flight delays) as well as ground access information. It focused on traditional highway travel information issues, such as traffic delays and road conditions, rather than the type of information needed to make an informed access mode choice.

More recently, Lo and Szeto (2004) studied how to model traveler response to advanced travel information systems using both static and dynamic paradigms. Although not directly applied to air passenger travel decisions, their approach may offer some insights as to how to better understand the role of travel information systems in airport ground access travel decisions.

Chapter 3. California Ground Access to Airports Study

In 2001 the California Department of Transportation (Caltrans) released the findings of an extensive study of airport ground access issues in the state that had been undertaken by a consulting team led by Landrum & Brown (2001). The study report consisted of an Executive Summary and three working papers. Working Paper One addressed roles and responsibilities of the different agencies and organizations involved in airport ground access in the state. Working Paper Two examined issues and problems at 47 airports in California and one in Tijuana, Mexico near the U.S. border. Working Paper Three presented recommendations from the study.

This chapter reviews the general findings of the study and discusses in more detail those aspects that relate more specifically to intermodal airport ground access problems, approaches, and potential solutions. A significant part of the study addressed institutional issues involved in airport ground access planning, particularly at a policy or strategic planning level, such as project potential funding sources for airport ground access projects and the roles, responsibilities and political relationships of government agencies at different levels (airport, local, regional, state and Federal) involved in airport ground access planning. These issues are briefly discussed in this chapter as they relate to improving intermodal connectivity in airport ground access. The issues and needs at specific airports identified in Working Paper Two of the study are discussed in more detail, particularly those relevant to the current project. The recommendations contained in Working Paper Three are also discussed, particularly the principles underlying the recommendations, since they may form a basis for the recommendations addressing policies and guidelines that will be developed at the end of the current research project based on the results of the case study analysis that will be undertaken for selected California airports.

3.1 Institutional Issues

The first working paper produced by the study, *Working Paper One: Roles and Responsibilities*, examines the institutional setting within which airport ground access planning is conducted and the respective roles and responsibilities of the airport operator and tenants, transportation providers, and local, state and Federal government. The working paper reviews existing funding sources that are available to support airport ground access projects, and the planning and programming process used to prioritize and allocate those funds. The working

paper also presents a number of case studies of funding strategies that have been used to finance airport ground access projects in California and other states.

The working paper includes several appendices that provide a detailed description of the institutional setting for each of the 47 airports included in the study (a 48th airport was included in the study after the working paper was prepared), as well as a summary of various local, state and federal programs that provide funds that could potentially be used to support airport ground access projects and the type of project that might be eligible for those programs.

The study included interviews with state, regional, and local agency officials and staff to identify their perceptions regarding their agency's approach to addressing airport ground access issues. In general these discussions suggested that there was a lack of a clear strategic approach to funding and implementing airport ground access projects. Many of those interviewed did not feel that there was a specific state, regional or local process for addressing airport ground access needs, and suggested that both the state and Federal government should play a larger role in addressing policy and funding issues. In particular, there was widespread support for greater flexibility in the use of Federal airport development funds for airport ground access projects outside the airport boundary. Concern was expressed by many of those interviewed that airport ground access funding needs are relatively minor compared to overall statewide surface transportation infrastructure needs, and that without a specific statewide airport ground access funding and implementation policy and associated funding sources, development of airport ground access projects will not keep pace with growth in aviation passenger and cargo activity.

3.2 California Airport Ground Access Needs

A major focus of the work by the Landrum and Brown Team was to identify airport ground access needs and specific problems at a wide range of California airports. This information was then used to develop recommended policies and guidelines to address these problems and needs. These policies and guidelines provide a strategic or high level approach but do not get into the details of how this could be accomplished in practice. For example, they suggest that improved coordination between airport authorities and ground transportation agencies is needed but it do not address how this coordination could be facilitated. The report recommended that the next step for improving the various planning, programming and

implementation processes for California airport ground access is for Caltrans to develop a specific improvement plan.

3.2.1 Airport-Identified Issues and Problems

In order to identify the ground access issues and problems at each airport, the study undertook a survey of airport managers throughout the state. The predominant issues identified by the survey respondents are summarized as follows:

- Large and medium sized commercial airports are primarily concerned with major regional mobility issues.
- Small and non-hub commercial airports tend to have more localized problems associated with roadway geometry and immediate terminal area requirements of curbside and parking.
- Issues and needs at general aviation and business airports are also more localized in nature, and are generally related to parking, roadway geometry and roadway conditions.
- Cargo airports are often served by an infrastructure of local roads that are inadequately constructed to meet the truck traffic demands generated by the airports.

3.2.2 Performance Based Needs

The study asked each airport to identify the most significant ground access system deficiencies that they faced and to assess how severe the inadequacy was currently and was expected to be in the future. The specific deficiencies identified by each airport were grouped into the following categories:

- adequacy of alternative modes
- auto access
- curbside
- goods movement
- airport parking.

The study findings presented only those airport needs for which the existing or future conditions were deemed to be moderately to severely inadequate. The specific deficiencies at each airport were listed in the report and then summarized for each airport in terms of the occurrence of deficiencies in each of the five aspects of the airport ground access system described above.

Table 3-1 presents these summary findings for the large and medium hub commercial service airports in California, since it is these airports where intermodal connectivity issues are likely to be most relevant.

Table 3-1: Most Significant Ground Access System Deficiencies at Major California Airports

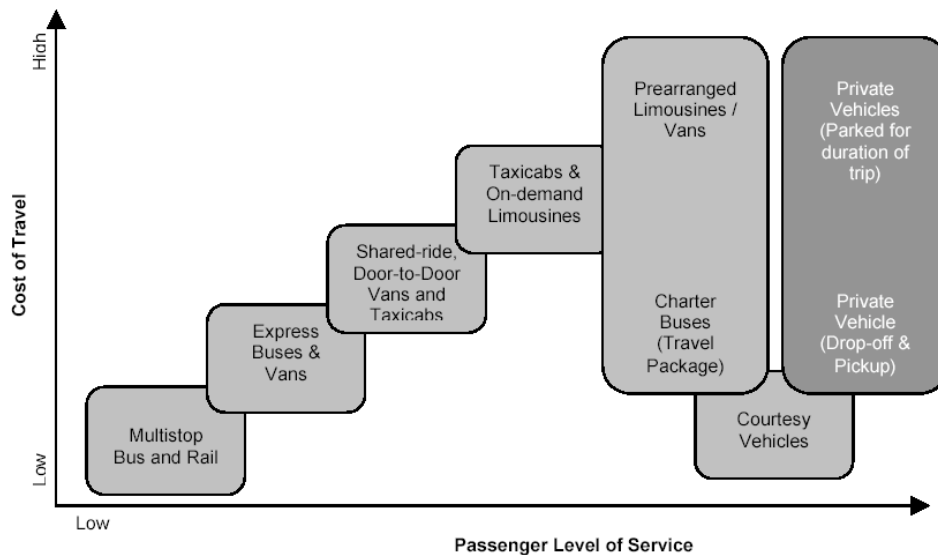
Airport	Adequacy of alternatives		Auto access		Terminal/ curbside		Airport parking		Goods movement	
	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020
Burbank		(a)	●							(a)
John Wayne		(a)		●	●	●	●	●		(a)
Los Angeles	●	(a)	●	●	●	●	●	●		(a)
Oakland	●	(a)		●	●		●	●	●	(a)
Ontario		(a)	●	●			●	●	●	(a)
Sacramento		(a)			●		●			(a)
San Diego		(a)	●	●			●			(a)
San Francisco		(a)		●	●		●	●	●	(a)
San Jose		(a)	●				●		●	(a)

Source: *California Ground Access to Airports Study*, Working Paper Two: Issues and Problems (Landrum & Brown, 2001), Table 2-4.

Note: (a) Deficiencies not assessed for 2020.

3.2.3 Availability and Use of Public Transportation Modes

Working Paper Two also discussed the tradeoff between the cost of travel and the level of service offered by different modes, as illustrated in Figure 3-1 and percent market share of different public transportation modes at major California airports shown in Table 3-2. Appropriately reflecting the tradeoff between cost and level of service provided to the users by different modes is obviously critical to accurately modeling of air passenger mode choice and transportation provider behavior in the current project. The data shown in Table 3-2 demonstrate the relatively low market share that has historically been achieved by conventional transit services at California airports, although it should be noted that since the table was prepared the Bay Area Rapid Transit (BART) system has been extended to San Francisco International Airport and use of that service has significantly increased. In addition, use of BART for trips to and from Oakland International Airport has also increased since the data shown in Table 3-2 was assembled by the Transit Cooperative Research Program study from which the data was obtained.



Source: *California Ground Access to Airports Study*, Working Paper Two: Issues and Problems (Landrum & Brown, 2001). Original source: Transit Cooperative Research Program, Report 62, Improving Public Transportation Access to Large Airports, Transportation Research Board, 2000.

Figure 3-1: Comparison of Ground Transportation Options

Table 3-2: Transit Percent Market Share by Mode

	Rail	Bus		Shared-Ride Vans	Chartered Buses & Pre-Arranged Limousines	Hotel/Motel Courtesy Vehicles	Total All Forms
		Multi-Stop	Express				
San Francisco International	-	4.0	5.0	12.0	4.0	7.0	32.0
Los Angeles International	0.5	-	7.4	5.2	8.9	5.0	27.0
San Diego International	-	-	-	9.0	-	10.0	19.0
Metropolitan Oakland International	4.1	1.2	1.3	1.5	1.1	1.5	10.7
San Jose International	-	0.7	1.4	1.6	0.1	2.8	6.6
Sacramento International	-	-	-	5.0	-	1.0	6.0

Source: Reformulated from 1999 data developed under the Transit Cooperative Research Program, Report 62, Improving Public Transportation Access to Large Airports, Transportation Research Board, 2000.

Source: *California Ground Access to Airports Study*, Working Paper Two: Issues and Problems (Landrum & Brown, 2001)

3.3 Recommendations

The Landrum and Brown study also provided recommendations as how to improve the planning, programming and implementation of airport ground access at a strategic level. In particular, recommended criteria are provided for the selection of ground access projects at different types of airport: commercial (large, medium and small), general aviation, cargo and military. They can be summarized as the following five points:

- Choose cost effective projects;
- Maintain or improve passenger/cargo ground accessibility to airports including road quality and signage and minimize delays at curbside including providing adequate curbside space;
- Maintain or improve passenger accessibility to local, regional, intra-state, or international air service;
- Mitigate neighborhood, local, regional highway traffic by maximizing the use of the transit network to decrease vehicle miles of travel and reduce traffic;
- Promote safety.

These criteria can be considered as addressing four different concerns: cost effectiveness, accessibility, environmental impacts, and safety. The recommendations suggested that the project

selection should be performance-based and that the performance should be quantifiable, although they did not provide any specific guidance on how to achieve this.

The recommendations of the Landrum & Brown study can be viewed as based on the principle that, since each airport is neither isolated from the larger concerns of society nor from the surface transportation network, it should be viewed as an integral part of the overall transportation system. Thus decisions by each party involved in airport ground access issues affect others directly or indirectly. This requires the decision making in the planning process to consider the problem as a whole and will involve different levels of government. Thus there needs to be effective coordination among decision makers in government agencies and other organizations for addressing airport ground access planning issues at different levels: airport, regional, state, and Federal. There should also be coordination between decision makers involved in planning the aviation system and those involved in planning the ground transportation system.

3.3.1 Need for Planning Guidelines

According to the Landrum & Brown study, many airport managers are frustrated by the lack of guidance from local, regional, state and Federal agencies to help them implement ground access projects. To develop planning guidelines based on a combined qualitative and quantitative approach is one of the objectives for the current project. The quantitative approach will be reflected in the development of an Intermodal Airport Ground Access Planning Tool (IAPT) which will involve systematic modeling of airport traveler and transportation provider behavior in order to support airport ground access planning and project implementation. The IAPT will generate measures of system performance, which can be used to guide decision making by planning agencies or decision makers at different levels of government.

Chapter 4. Intermodal Air Cargo Considerations

The California Ground Access to Airport Study (Landrum & Brown, 2001) gave only limited attention to air cargo needs. However, at large airports, truck traffic generated by air cargo activities can have a significant impact on traffic levels on airport access and egress routes. The efficiency of air cargo operations is reduced when trucks are delayed by highway and roadway congestion in the vicinity of the airport. Although air cargo movements at airports are inherently intermodal, there is a growing interest in exploring the potential application of improved connections between different surface modes in order to facilitate the movement of air cargo and to reduce the impact of air cargo related truck trips on the local street and highway system since they involve a transfer between aircraft and surface modes (typically truck).

This chapter provides an overview of the air cargo industry and an introduction to intermodal planning issues in handling air cargo. It also discusses opportunities for improving intermodal connections to better serve air cargo activity.

The air cargo industry is generally considered to comprise three components: air express, air freight, and air mail. Traditionally air express consisted of high priority shipments that were carried on passenger flights, while air freight consisted of heavier shipments that were moved using a combination of dedicated cargo aircraft and the belly holds of passenger aircraft. The evolution of the integrated carriers, such as Federal Express and UPS, which provide door-to-door shipment services using fleets of ground vehicles and aircraft, has blurred the distinctions between the different types of cargo. Indeed, the integrated carriers have recently begun to carry air mail for the Post Office as well as packages and freight that they pick up and deliver themselves. They have also developed second- and third-day delivery services that have allowed them to attract larger amounts of heavier freight and have moved into the provision of contract logistics services in which they operate warehouses or other functions on behalf of their customers and handle the distribution through their intermodal network of trucks and aircraft.

The development of second- and third-day products has also allowed the integrated carriers to operate their fleets of trucks and aircraft as an intermodal network, with some shipments moving long distances by truck and some not even being put on an aircraft at all. Since sorting facilities are often located at or near airports, this can result in an increase in truck traffic to and from the airport

carrying freight that is not moved by aircraft at all and has begun to also blur the distinction between air freight and surface freight.

4.1 Intermodal Air Freight Planning

Intermodal freight transportation has evolved in two stages. In the first stage, the introduction of containerization greatly increased the ease of loading and unloading for delivery and mode changes, and has been widely adopted for many years. The second stage, which is still evolving, involves the development of a seamless transportation chain to provide intermodal door-to-door service. The structure and composition of the intermodal freight industry has been documented by Muller (1995) and Wegmann *et al.* (1995).

These general intermodal freight transportation trends also apply to air cargo although the latter has some distinct characteristics (Hall, 2002). In recent years, air cargo has been the fastest growing segment of the goods movement industry in the United States, placing increasing demands both on airports and ground transportation to and from airports. Air cargo shipments are inherently intermodal, as few shippers and receivers are located at airports.

Hall (2002) undertook a study of ground access trips handling air cargo in Southern California. More trucks need to be on the road during peak periods to meet start-of-day delivery commitments, particularly in the evenings in the West Coast according to FedEx. Truck movements experience significant roadway congestion on the way to or from, and in the vicinity of, major airports. However, it should be mentioned that although air cargo is a fast growing segment of the freight transportation sector, it accounts for only a relatively small proportion of truck movements in any given region.

The so-called integrated carriers, such as Federal Express (FedEx) and UPS (formerly United Parcel Service), provide an integrated door-to-door service, merging four principal elements: (1) a ground fleet of pickup/delivery trucks, (2) terminals for sorting and processing freight, (3) a long-haul truck fleet for moving freight between terminals, and (4) an aircraft fleet for moving freight between airports. UPS and Federal Express dominate the integrated air cargo market in the U.S., as indicated in the following table.

Table 4-1: Integrated Air Freight Carriers

Revenues for American Integrated Carriers	
United Parcel Service	\$29,771 (2000)
Federal Express	\$19,629 (2001)
DHL	\$ 5,100 (1999)
Airborne	\$ 3,276 (2000)
CNF (Emery Parent)	\$ 5,572 (2000)
BAX Global	\$ 2,097 (2000)

Source: Hoovers Online for all financial statistics in report.

Source: Hall (2002). (Revenues shown in millions)

Both carriers have extensive ground freight transportation networks, particularly UPS, and the revenue data shown in Table 4-1 covers both their air and ground operations. Federal Express has been steadily increasing the proportion of its cargo which is moved by truck.

In addition to serving passengers, most airlines also provide freight and mail services. International passenger airlines carry well over half of the world's air freight. To handle this freight, airlines typically form partnering arrangements with freight forwarders, trucking companies, postal services and couriers.

A key aspect of airport access/egress requirements for air cargo is the location of consolidation and sorting facilities relative to the airport. Currently there are two approaches to consolidation and sorting. One is to fill aircraft containers at the local pickup/delivery terminals and move these on tractor-trailers to the airport. The containers are typically pre-sorted, so that they can be moved directly to the aircraft. The alternative approach is to use smaller shuttle trucks, which are bulk loaded during the pick-up cycle and then proceed directly to the airport where their contents are sorted and loaded into containers for loading on to the aircraft.

In common with all freight transportation planning, there are two major problems that need to be addressed in planning intermodal air cargo operations: vehicle routing and facility/terminal locations. Vehicle routing has been extensively studied and algorithms developed to optimize the routing of pick-up and delivery vehicles (see for example Magnanti, 1984). Arnold (2004) studied the problem of optimal location of intermodal terminals involving transfer

of freight between rail and road. For this special case, a combined quantitative and qualitative approach was adopted to develop a planning decision making tool, the ITLSS (Intermodal Terminals Location Simulation System), and planning decisions based on the use of the tool have been implemented. This approach could potentially be adapted for intermodal facility location planning for airport ground access by considering the airport as a node on the regional intermodal transportation network.

For air freight ground access planning, it is necessary to understand the characteristics of the system, including how it is operated.

(1) The characteristics of air freight (in contrast to air passenger) intermodal connectivity can be summarized as:

- Customer mode choice criteria: delivery time and affordable price
- Time definite nature of intermodal service results in a major concern with *traffic congestion*
- End-to-end delivery chain increasingly operated by single integrated carriers that perform pickup and delivery, forwarding and transportation functions: allowing them to optimize the flow over their network.

(2) Characteristics of the door-to-door service chain are:

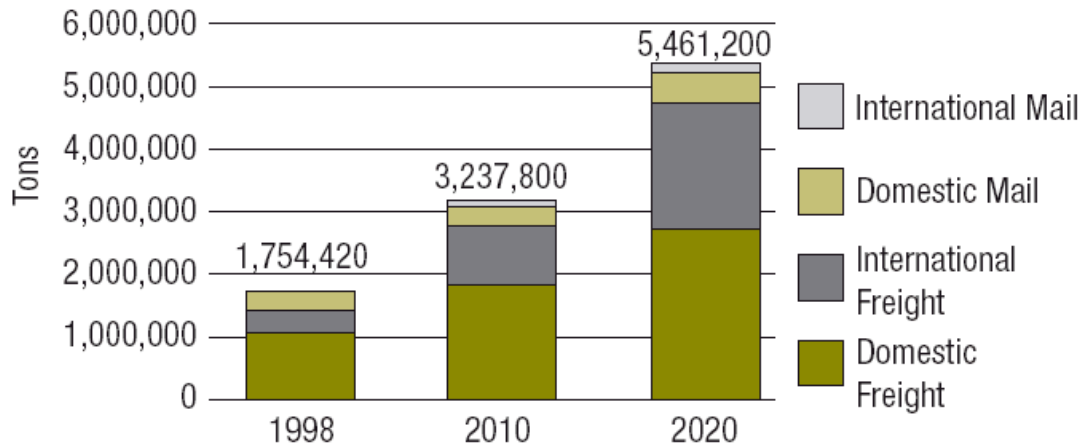
- National and regional sorting sites that allow the integrated carriers to route shipments between their local dispatching centers throughout their service network
- Local dispatching centers for shipment consolidation and breakdown for transportation to and from the nearest airport or sorting site
- Hub-and-spoke network configuration: related to the locations of sorting sites and dispatch centers
- Centralized control of dispatching through real-time tracking of the location of each truck or van, allowing monitoring of system performance and traffic conditions
- An aircraft fleet for moving freight between airports with extensive use of night-time flights
- A long-haul truck fleet for moving freight between terminals

- Terminals for sorting and processing freight
 - A ground fleet of local pickup/delivery trucks.
- (3) The evolution of time-definite intermodal services progressed through the following stages:
- Conventional independent modal services including end-to-end forwarding (connecting multiple services to achieve end-to-end transportation)
 - Integrated (or single-control) forwarding (coordinating multiple services to achieve time-definite deliveries at an economical cost)
 - Single company (or single alliance) integrated forwarding, allowing optimized network flows.
- (4) There are dynamic interactions between the integrated air-cargo industry and customer needs. The economics of the overall system is affected by many factors:
- Characteristics of the demand and supply chain
 - Origins and destinations of the packages determined by customer and producer locations
 - Time definite delivery commitments
 - Traffic conditions on the highway network
 - Relationship between demand and capacity of the integrated and non-integrated air freight services
 - Routing and scheduling as one of the main strategies in competition
 - Independent or cooperative operations.

4.2 Air Freight Development in California

As indicated in the recent summary report of the Regional Goods Movement Study for the San Francisco Bay Area undertaken by the Metropolitan Transportation Commission (MTC, 2004), air cargo activity will increase dramatically in the next 10 to 20 years with the growth of the U.S. and global economy, as shown in Figure 4-1. The current traffic situation is already severe in some corridors which are particularly affected by trucks involved in air cargo movement. With the projected increase in the Bay Area air cargo traffic, trucks activity related to air cargo will have an increasing impact on the traffic network and contribute to increased levels of traffic congestion and air pollution.

Bay Area Air Cargo Forecasts — Total Cargo Tonnage Will Triple by 2020 to 5.5 Million Tons Annually



Source: Bay Area Seaport Plan 2003, reported in MTC Regional Goods Movement Study, Final Summary Report, 2004

Figure 4-1: Bay Area Air Cargo Forecast

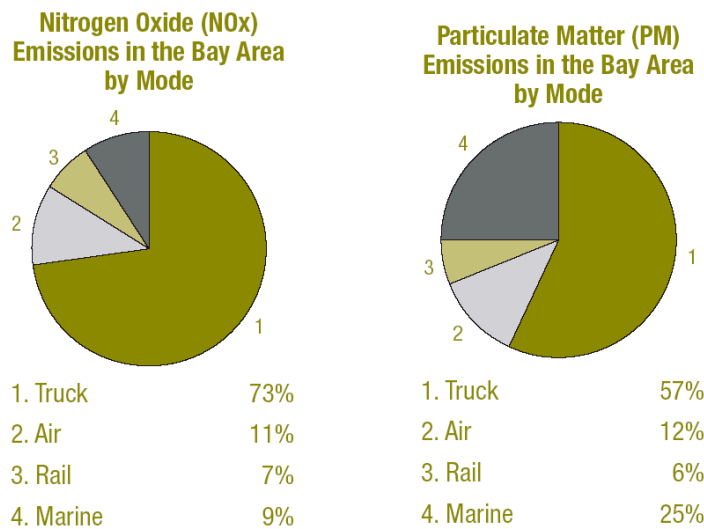
Traffic Congestion: Traffic congestion presents two difficulties for time definite intermodal service:

- Overall time limit to meet delivery commitments – if trucks spend longer getting to their local delivery areas, it may be necessary to dispatch additional vehicles in order to reduce the number of deliveries that each truck has to make.
- Limited time window at each step of the whole delivery chain – missing one time window may cause shipments to miss the following time windows in the chain, leading to what may be viewed as a “domino effect.”

Air Pollution: Goods movement has a great impact on air quality. Truck emissions contribute to ground level ozone, the main ingredient of smog, through the complex chemical reactions between Volatile organic compounds (VOC) and nitrogen oxides (NOx) in the presence of heat and sunlight. Particulate matter (PM), a significant emission from diesel engines, is easily inhaled and remains in the lungs where it can be carcinogenic. Goods

movement generates emissions both during on-road activity (truck driving) and off-road activity (truck idling and cargo loading and unloading), as well as from aircraft, rail and marine operations, as shown in Figure 4-2.

In order to facilitate the continued expansion of air cargo activity, it may become necessary to develop alternative pickup and distribution modes that generate less air pollution and have less impact on street and highway traffic congestion to replace or at least partly replace trucks in the door-to-door service delivery chain.



Source: Bay Area Air Quality Management District, reported in MTC Regional Goods Movement Study, Final Summary Report, 2004

Figure 4-2: Air Pollution Caused by Goods Movement Activities

4.3 Opportunities for Improved Intermodal Connections for Handling Air Cargo

Alternative strategies that have been proposed to improve intermodal connectivity to handle air cargo include dedicated truck lanes, accommodating freight on maglev or high-speed rail systems providing access to airports, and conventional rail transportation. Some of these potential strategies would present significant operational problems that would have to overcome, quite apart from the cost of the necessary infrastructure. However, it may be useful to perform a

preliminary evaluation of selected concepts in order to better understand the issues involved.

Possible ways to improve intermodal air freight transportation include the following:

- Expanding the capacity of existing facilities or introducing new services or modes
 - Freeway capacity expansion
 - Dedicated truck lanes
 - Introducing other modes in the delivery chain: e.g. rail, hovercraft, or ferries;
- Deployment of new technology or other operational improvements to make more efficient use of existing facilities
 - Real-time network traffic information for dispatching and routing
 - Advanced traveler information systems for traffic prediction
 - Use of high occupancy vehicle lanes for freight delivery
 - Truck flow management systems near airports or sorting sites.

4.4 Possible Intermodal Air Freight Delivery System in the Bay Area

In order to address the impact of highway congestion on the timely movement of air freight within the San Francisco Bay Area, planning staff at the Bay Area Rapid Transit (BART) District have expressed an interest in exploring the feasibility of moving air freight on BART trains. The potential advantages of such a system from the perspective of air freight carriers are a reduction in travel time and improvement in reliability through reducing the use of congested highways in transporting freight to and from the airports. There may also be cost savings to the air freight carriers, depending on the fees that BART would charge for this service. The reduced level of truck movement on the regional highway system would also reduce highway congestion, particularly at peak times, and provide air quality benefits. The proposed system could also financially benefit BART if the revenues from moving air freight exceeded the additional costs of doing so.

However, there are a number of operational and economic aspects that would need to be explored further before it can be determined whether such a service is even remotely feasible. These include how the freight would be transported on the BART system, the likely magnitude of any time savings, given the time required to transfer the freight to and from the BART trains, and the capital and operating costs involved. Two different approaches have been suggested. The first would use dedicated trains to move freight between dedicated facilities located at off-

line yards, either existing maintenance and storage yards or new yards constructed specifically to handle freight. This would of course require running additional trains, which would have to be interleaved with regular passenger trains and might encounter track capacity problems at critical points in the system. The second approach would involve adding dedicated freight cars to regular passenger trains. This would require modifying stations to accommodate freight containers and would limit the volume of freight that could be carried on a single train without unduly increasing station dwell times. As a practical matter, only one or two containers could be loaded or unloaded at each door of a freight car per stop and the process of loading and unloading the containers could be very labor intensive. During peak travel periods, when the advantage of such a system would be greatest, many trains already operate at their maximum length and so adding cars to the trains would not be feasible without lengthening the station platforms or reducing the passenger carrying capacity of the trains.

Although these problems may not be technically insuperable, they could be very costly to overcome. Without further analysis, it is unclear whether the travel time savings for the air freight carriers (if any) would be sufficient to justify the rates that BART would need to charge to cover its costs of providing the service. This analysis would need to address the following issues:

- (1) Design and size of cargo containers to be used on the BART cars;
- (2) Feasibility of loading and unloading containers at BART stations or yards:
 - (a) Design of the necessary facilities
 - (b) Impact of loading and unloading times on BART schedules
 - (c) Staffing levels and responsibilities for loading and unloading the containers;
- (3) Potential freight capacity of the system;
- (4) Total time required to move containers to BART, load, transport, and unload containers on BART, and move containers to their destination, in comparison with the time required to transport the freight directly by highway;
- (5) Rate structure required to cover BART capital and operating costs;
- (6) Impact of dedicated freight trains on passenger train schedules;
- (7) Safety, liability and insurance considerations.

Chapter 5. Challenges and Opportunities for Improving Airport Intermodal Connectivity

This chapter discusses potential strategies for improving intermodal connectivity at California airports, and reviews existing services at various airports in the state that provide examples of these strategies. The chapter also examines some of the challenges to the successful implementation of projects designed to improve intermodal connectivity at airports.

5.1 Motivation for Improving Intermodal Connectivity

In the broadest sense all airport ground transportation services are intermodal, in that they provide the connectivity between the air transport and surface transportation system. However, for the purposes of the current project, intermodal connectivity is defined more narrowly to address strategies to increase the use of high occupancy public transport modes. These include regional and intercity rail systems as well as dedicated express bus services, whether operated by the public or private sector.

The motivation for increased intermodal connectivity in this sense arises from the importance of reducing the use of single-party occupancy vehicles for airport access and egress trips. Continuing growth in air travel and air freight has tended to result in ever increasing volumes of surface traffic generated by airports, particularly major airports. This traffic arises primarily from air passenger trips, but airport employees and air cargo movement also contribute significant volumes of traffic at large airports. These vehicle trips contribute to congestion on the regional highway network and the local street system in the vicinity of the airport, as well as adversely impact air quality through increased vehicle emissions. The goal of enhanced intermodal connectivity is to encourage greater use of high-occupancy modes, particularly rail modes that do not involve use of the highway system (other than for access and egress trips to the rail stations) and in many cases use electrical power. Improving the connectivity to rail modes leverages the public investments that have been made in these modes, and to the extent that these modes are operating below capacity (as is commonly the case) makes use of excess capacity that would otherwise remain unused.

5.1.1 Potential Strategies to Enhance Intermodal Connectivity

With this broad context, there are three principal strategies to improve intermodal connectivity at airports:

- Direct rail service to the airport
- Improved links to nearby rail stations
- Express bus service to off-airport terminals or regional intermodal terminals.

Although direct rail service to an airport station has been proposed or implemented at an increasing number of large airports worldwide, it is typically a very expensive solution. Except in rare cases where an existing rail line runs within close proximity to an airport terminal, the engineering required to bring a rail line into a station in the airport terminal complex requires substantial capital investment. There is also the question of train frequency. Operating a dedicated line at high frequency can incur significant operating costs. While such an approach may be justified at the very largest airports, where the volume of air passengers and airport employees may be enough to make such a service economically viable, in general this is not an appropriate strategy for most airports.

Improving links to nearby rail stations is generally a much less expensive strategy and more appropriate for smaller airports. These links may take the form of a dedicated shuttle bus service or an automated people-mover. The latter may provide a higher level of service to the user, and eliminates the vehicle trips associated with a shuttle bus service, but is generally more expensive to construct and operate. The attractiveness of such links will depend on the frequency of service of both the link itself and the rail service to which it connects, as well as the fares charged for the use of the link and by the rail service. While there is no need to operate the link at a higher frequency than the rail service that it serves, it is important for less frequent rail services that the connecting link schedule is coordinated with the rail service schedule, so that the users do not incur a long wait twice.

The provision of express bus services to off-airport terminals located close to the trip ends of airport users provides another strategy to reduce the volume of vehicle trips to and from the airport. Such off-airport terminals typically provide parking at lower rates than at the airport, as well as waiting facilities for bus passengers or those waiting to pick up bus passengers. Larger facilities may also provide ancillary services, such as a newsstand or food and beverage, and some have provided airline ticketing or check-in. While the ability to check baggage at a

remote location has often been proposed as a feature of off-airport terminals, it is unclear whether this is a significant factor in the attraction of such a facility and justifies the logistical complexities involved. The principal advantages of an off-airport terminal to the users are the reduction in the driving time and distance, particularly for passengers being dropped off or picked up, compared to driving to and from the airport, and any saving in parking costs. For those using taxi to get to or from the off-airport terminal, there are also typically significant cost savings compared to taking a taxi all the way to or from the airport. Locating an off-airport terminal at a major transit hub also allows airport travelers to use transit to get to and from the terminal, which may provide better service than taking transit all the way to or from the airport.

Similarly, providing express bus links between the airport and regional intermodal terminals, such as central rail stations or transit hubs, can allow airport travelers to utilize the better rail or transit service at those locations to travel to and from their ultimate trip end, while increasing the ease of travel between the airport and those facilities.

5.2 Examples of Existing Services

Services representing each of the foregoing strategies currently have been implemented at various California airports.

The extension of the Bay Area Rapid Transit (BART) system to San Francisco International Airport (SFO) that opened in June 2003 provides direct rail service to the second largest airport in the state. The BART system provides an extensive and frequent region-wide network with 43 stations serving Alameda, Contra Costa, San Francisco, and northern San Mateo counties. In addition, the Millbrae BART station provides an interchange with the Caltrain rail line that serves the Bayshore corridor of eastern San Mateo County and northern Santa Clara County.

There is also direct rail service at Burbank Airport, where the Burbank Airport Station is located adjacent to the airport within an easy walk of the airport terminal. This station is served by both Metrolink and Amtrak trains that provide service between Los Angeles Union Station and communities in the San Fernando Valley and along the coast in Ventura and Santa Barbara counties. However, trains are relatively infrequent outside of weekday commute hours (Metrolink is primarily a commuter rail service) and to and from points north of Moorpark in the San Fernando Valley. As of November 2004, there were 9 Metrolink trains in each direction on

weekdays, and 5 Amtrak Pacific Surfliner trains in each direction daily. The Metrolink schedule was heavily oriented to the commute direction, with 7 of the 9 southbound trains in the morning and 6 of the 9 northbound trains in the afternoon. Only three of the Metrolink trains in each direction served communities between Moorpark and Montalvo Station in Ventura, southbound in the early morning and northbound in the late afternoon and evening. All five of the Amtrak trains in each direction served communities as far as Goleta, north of Santa Barbara, with two trains in each direction starting from or continuing on to San Luis Obispo. There was a connecting Amtrak Thruway bus service to and from San Luis Obispo for those trains that start or end in Goleta.

Several California airports have dedicated shuttle bus service to nearby stations. At Los Angeles International Airport (LAX) there is a shuttle bus operated by Los Angeles World Airports to the nearby Green Line Metro station. In the Bay Area, the AirBART bus operated by the Port of Oakland connects Oakland International Airport (OAK) with the Coliseum BART station and at San Jose International Airport the Route 10 Airport Flyer bus operated by the Santa Clara Valley Transportation Authority (VTA) connects the airport terminals with the Metro/Airport station on the Alum Rock-Santa Teresa Light Rail line and the Santa Clara Caltrain station. The AirBART bus also serves a new station near the Oakland Coliseum that opened on June 6, 2005 and serves the Amtrak Capitol Corridor route between San Jose and Sacramento. The Port of Oakland and BART are currently pursuing a joint project to construct an automated people-mover to link Oakland International Airport to the Coliseum BART and Amtrak stations.

Two California airports currently have express bus service to off-airport terminals. The Los Angeles World Airports (LAWA) operates the Van Nuys FlyAway service between LAX and an off-airport terminal adjacent to the Van Nuys airport in the San Fernando Valley. This terminal provides long-term parking and waiting facilities. LAWA has recently modernized the terminal building and provided additional parking in an adjacent structure. In the past, a number of airlines maintained ticket offices at the terminal, although there was no provision for baggage check-in. Buses provide 24-hour service every 30 minutes in each direction for most of the day (every 15 minutes for trips to the airport from 4:45 am to 8 am and a variable headway to the airport between 1 am and 4:45 am and from the airport between midnight and 5:30 am). A second off-airport terminal was operated briefly in West Los Angeles by the then Los Angeles

Department of Airports in the 1970's but did not attract significant patronage and was discontinued. The Los Angeles World Airports has since undertaken studies to explore the feasibility of additional off-airport terminals in the region, but has not so far taken any actions to establish any new terminals.

In the Bay Area, Marin Airporter operates a scheduled bus service between SFO and two off-airport terminals in Marin County, at Larkspur and Ignacio near Novato (North Hamilton Parkway). Both terminals provide long-term parking and waiting facilities. Buses operate in each direction between the Larkspur terminal and SFO every 30 minutes from 4 am to 11 pm to the airport and from 5 am to midnight from the airport. Hourly service is provided from the Hamilton terminal to SFO via the Larkspur terminal from 4 am to 10 pm. Northbound service to the Hamilton terminal from the Larkspur terminal is also provided hourly, departing Larkspur on the half-hour.

Scheduled airport bus service is also available to regional transit centers at a number of airports. Marin Airporter buses to and from the Hamilton terminal stop at the Central San Rafael Transit Center, as do Sonoma Airport Express buses serving both SFO and OAK. In Southern California, Airport Bus of Anaheim provides scheduled bus service between the Anaheim Bus Terminal and LAX and John Wayne Orange County Airport.

5.3 Potential Opportunities at California Airports

Although a number of intermodal connections already exist at many of the larger California airports, there are clearly additional opportunities to improve intermodal connectivity both at these airports as well as others. However, for such potential connections to be economically viable, they need to be able to attract a reasonable level of ridership. This imposes several constraints:

1. The activity level at the airport has to be large enough that a realistic proportion of airport trips likely to be attracted to the proposed service translates into a sufficient number of riders;
2. In the case of an intermodal connection to a rail system, that system offers a good enough service to be attractive to air passengers and airport employees and forms

part of a network that is reasonably accessible from a large enough proportion of trip ends;

3. In the case of a link to a regional intermodal facility or transit hub, there is a large enough proportion of regional trip ends that are reasonably well served by that facility.

Obviously, these constraints interact. At a very large airport, such as LAX the percentage of regional airport trips that a given service will need to attract to generate a viable level of patronage will be smaller than would be required for a viable service at a smaller airport. Similarly, an intermodal connection that is relatively inexpensive to implement could be viable at a much lower level of market penetration than one that involves large capital and operating costs. None the less, it is likely that economically viable intermodal connection opportunities will occur only at the larger airports.

Chapter 6. Analysis of Intermodal Opportunities at Selected California Airports

This chapter presents a preliminary analysis of additional opportunities that appear to exist to improve intermodal connectivity at California airports beyond the existing examples of intermodal services described in the previous chapter. The chapter first presents a case study analysis of two existing examples of intermodal connections at airports in the San Francisco Bay Area. These are particularly interesting because they involve airports of different size, with one providing the only current example in the state of an airport with direct service by a regional rail transit system to a station within the airport terminal complex while the other provides a good example of a dedicated shuttle bus connection to a regional rail transit system. Thus they provide an indication of the potential utilization that can be expected of good intermodal connections at airports. The chapter then identifies a range of potential projects at thirteen of the larger airports in the state and presents the results of a preliminary assessment of the feasibility of the more promising of these potential opportunities and their likely contribution to increasing the use of intermodal access services at airports in the state. The chapter concludes with a description of a simplified spreadsheet model that has been designed to perform a preliminary quantitative analysis of the potential use of these intermodal opportunities in the next stage of the research.

6.1 Case Study Analysis of Intermodal Connections at Bay Area Airports

The Bay Area Rapid Transit (BART) system provides rail rapid transit service on four lines linking the East Bay counties of Alameda and Contra Costa with the City and County of San Francisco and more recently the northern part of San Mateo County as far south as the City of Millbrae, as shown on Figure 6-1. The Millbrae Station provides a connection with the Caltrain commuter railroad service that links San Francisco with the City of San Jose and communities in San Mateo and Santa Clara Counties. BART also provides connections at the Richmond Station with the Capital Corridor and San Joaquin Amtrak trains serving communities between the Bay Area and Sacramento and in the Central Valley as far south as Bakersfield, as well as other communities throughout the state via connecting bus services. Therefore intermodal

connections between Bay Area airports and the BART system allow airport travelers to make use of this extensive network of public transportation services for their trip to and from the airport.



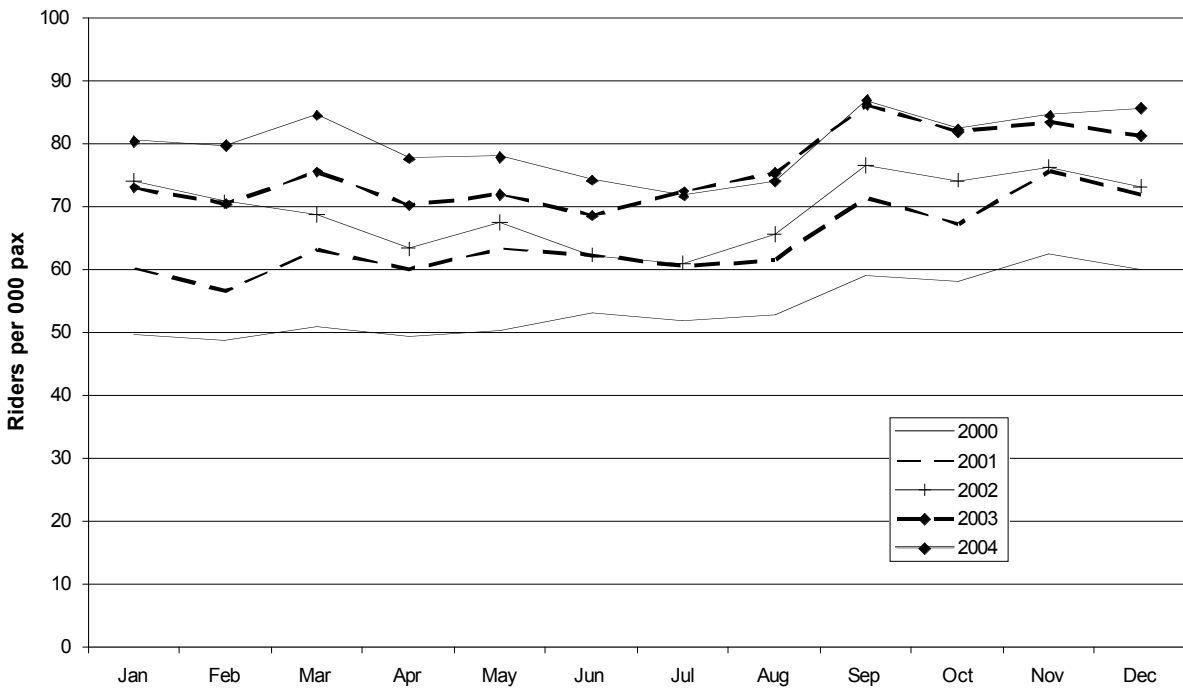
Figure 6-1: BART System Map

At present, two Bay Area airports are easily accessible from the BART system: Oakland International Airport and San Francisco International Airport. This section presents a case study analysis of recent trends in the use of BART for ground access trips to these two airports.

6.1.1 Oakland International Airport

The Oakland International Airport is located approximately three miles from the Coliseum BART station, which is served by trains on the Richmond-Fremont line, the Daly City-

Fremont line and the Daly City-Dublin/Pleasanton Line. The Port of Oakland, which operates the Oakland International Airport, has operated a shuttle bus service, called AirBART, between the airport and the Coliseum Station for many years. The buses operate on a 10 to 20 minute headway and a fare of \$2 is charged in each direction. Ridership on the AirBART service has been steadily increasing in recent years, as shown in Figure 6-2, which shows the number of AirBART riders per thousand air passengers at the airport each month over the past five years, adjusting for the effect of changes in air passenger traffic at the airport. It can be seen that the monthly use of the AirBART service over the past three years has tended to be somewhat higher in the spring and fall and lower in the summer, possibly reflecting a higher proportion of vacation travel during the summer months with larger air travel parties and more baggage, both of which would tend to discourage the use of BART to access the airport.

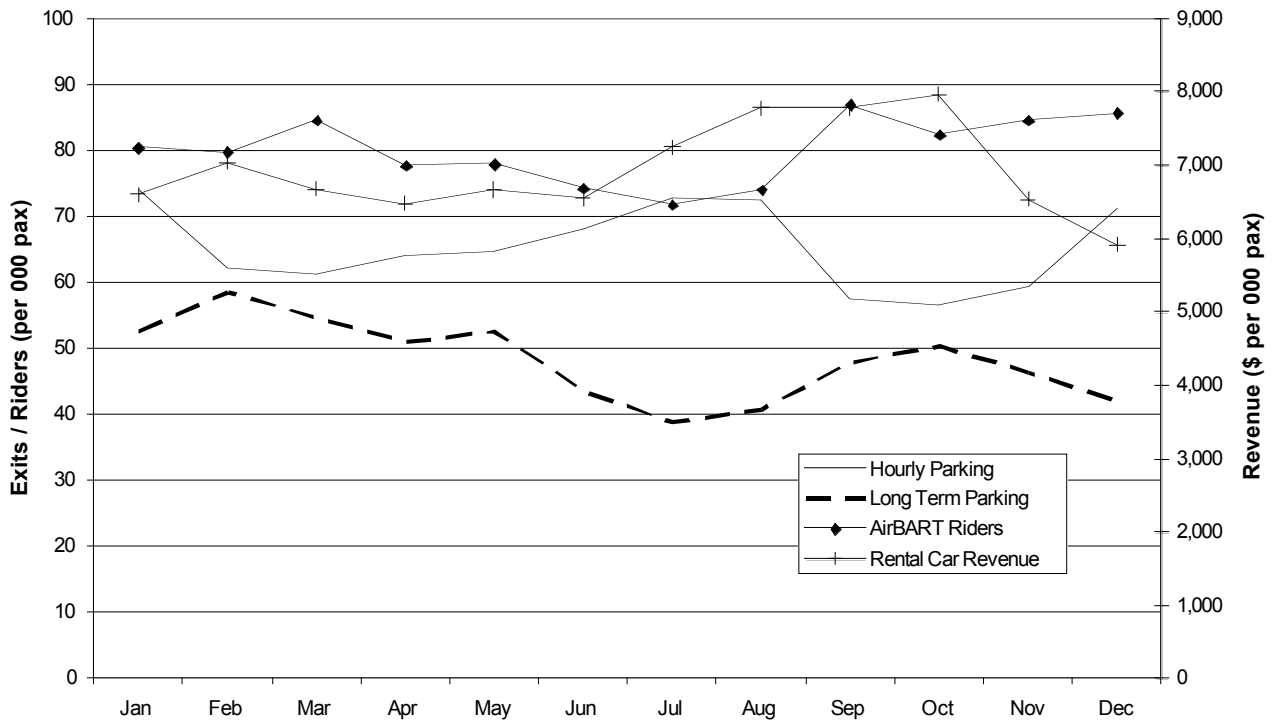


Source: Port of Oakland, Monthly Activity Reports

Figure 6-2: Monthly Pattern of AirBART Use at Oakland International Airport

Figure 6-3 compares the monthly AirBART ridership for the most recent year with the use of other ground access modes. Long-term parking represents air passengers who park at the

airport for the duration of their trip, while hourly parking generally represents those who park for a short time while dropping off or picking up air passengers. Since the data is based on the exits from the long-term and hourly parking lots, rather than an analysis of parking duration in each lot, the hourly parking exits include a small number of air passengers who park in the hourly lot for the duration of their air trip, whether for the convenience of being closer to the terminal building or by mistake. Similarly, the long-term parking exits include a small number of users who only park for a short time, presumably while dropping off or picking up air passengers, possibly under the mistaken impression that the parking rate is less (in fact both lots charge the same rate for the first few hours).



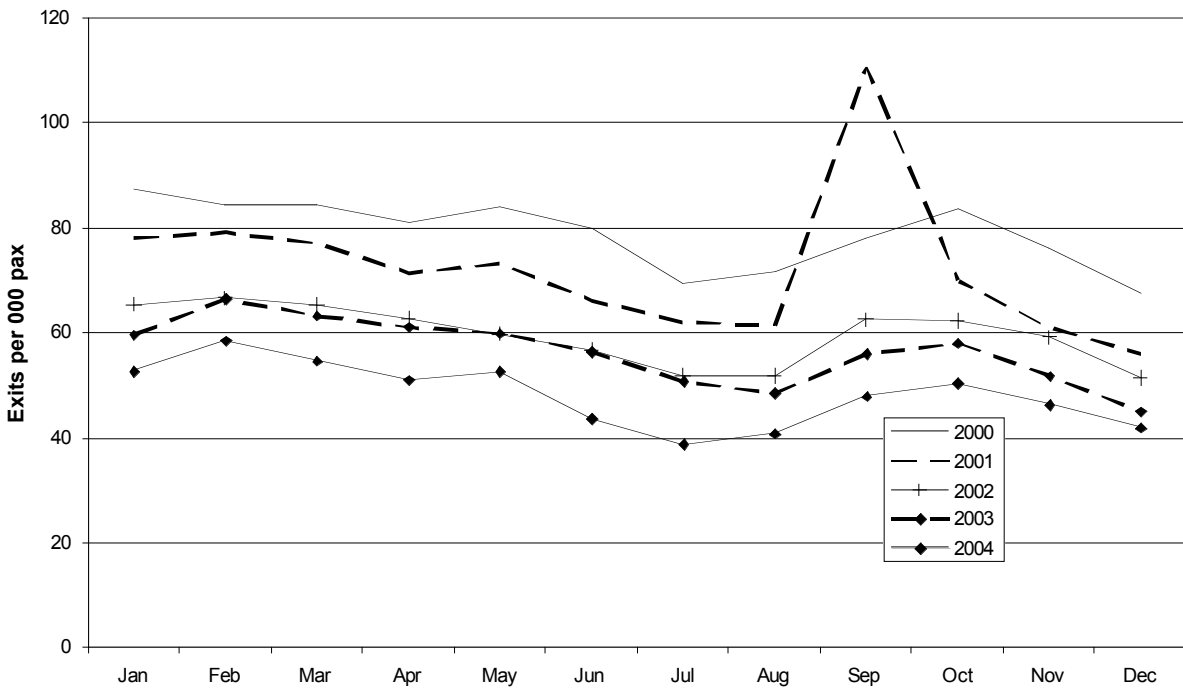
Source: Port of Oakland, Monthly Activity Reports

Figure 6-3: Ground Access Mode Use at Oakland International Airport in 2004

It can be seen from Figure 6-3 that the use of hourly parking varies inversely to the use of long-term parking through the year, with a greater use of hourly parking in the summer and over the Christmas and New Year holiday period than during the spring and fall. The pattern of rental

car revenue through the year indicates that there is a greater use of rental cars from July through October, suggesting that the ratio of visitors to Bay Area residents using the airport may be higher during those months.

The trend in the use of long-term parking over the past five years is shown in Figure 6-4. It can be seen that in contrast to the AirBART ridership, the use of long-term parking has steadily declined during this period, after adjusting for changes in air passenger traffic. The spike in the data for September 2001 is an anomaly due to the effects of the terrorist attacks on September 11 that year. In the immediate aftermath of the attacks, the Federal Government prohibited parking within 300 feet of a terminal building. This eliminated a large proportion of the hourly parking spaces until the Port of Oakland was able to reconfigure the lots, resulting in many short-term parkers having to use the long-term lot. The decline in the use of long-term parking could be partly due to parking rate increases that were implemented in July 2000, July 2001 and June 2003, but may also reflect changes in travel patterns over the period.



Source: Port of Oakland, Monthly Activity Reports

Figure 6-4: Use of Long-Term Parking at Oakland International Airport

The foregoing data suggest that at least some of the increase in AirBART ridership has come from air passengers who would otherwise have parked at the airport for the duration of their air trip. This makes sense, since those air passengers who have someone willing to take them to the airport or pick them up are unlikely to choose to use BART with its generally longer travel time and higher cost (assuming that they do not incur the cost of driving to and from the airport). However, those who would otherwise park at the airport for the duration of their air trip may find the lower cost of using BART more attractive. The cost advantage of BART would of course be increased by the series of parking rate increases in recent years.

However, some caution is warranted in interpreting these data, since changes in ground access mode use could also be due to changes in the composition of the air passenger traffic at the airport. The past five years has corresponded to a number of important changes in the pattern of air service at the airport. The introduction of low-cost transcontinental service by jetBlue Airways and the competitive response by the other airlines, particularly United Airlines, has resulted in much lower fares and more long-haul service. This in turn has drawn long-haul traffic away from San Francisco International Airport and changed the composition of the type of traffic being handled by Oakland Airport. It is likely that these changes have led to a lower proportion of business trips, an increase in the average trip duration, and an increase in the proportion of cost-sensitive travelers. Each of these effects would tend to favor the use of BART and reduce the use of long-term parking at the airport.

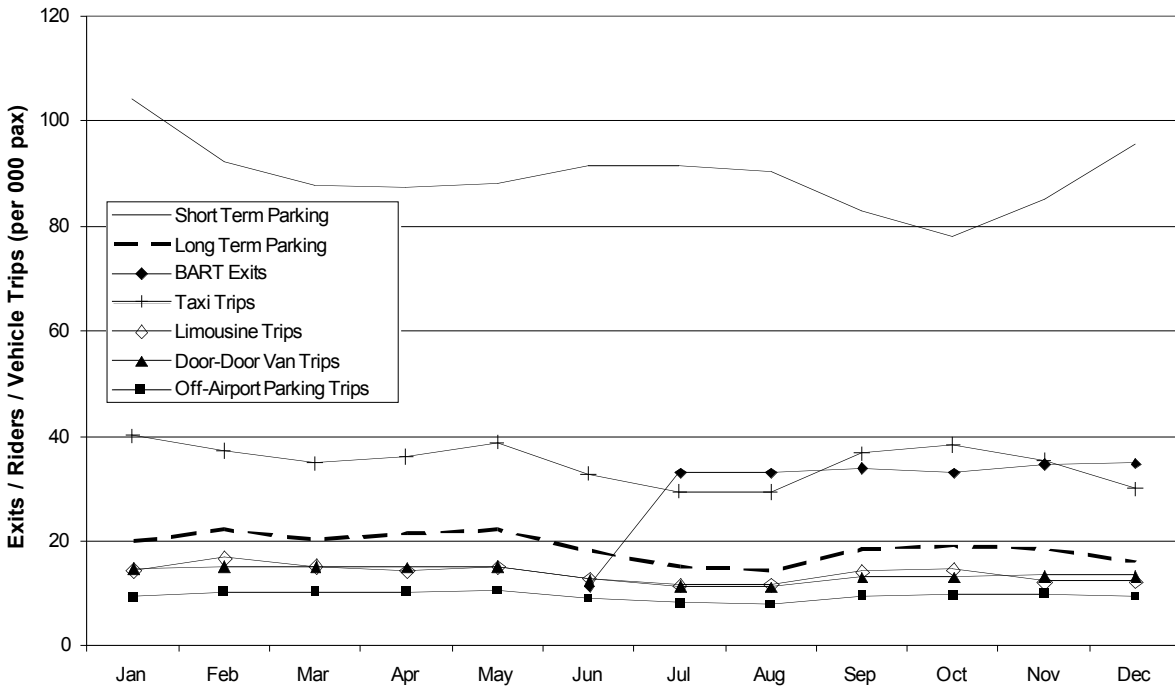
Assuming an average air party size of about 1.5 for air passengers using long-term parking, the number of air passengers in vehicles exiting the long-term parking lot in 2004 was somewhat less than the number of AirBART riders. Of course an air passenger using BART counts as one rider in each direction, whereas vehicles parked for the duration of the air trip only get counted once. Furthermore, the AirBART riders include airport employees, whereas there are separate airport employee parking lots so they are not counted in the long-term parking exits. This suggests that about half as many air passengers used BART as used airport long-term parking.

6.1.2 San Francisco International Airport

The BART extension to San Francisco International Airport (SFO) opened on June 22, 2003. Prior to that time the San Mateo County Transit District (Samtrans) provided bus service between SFO and the Colma BART station, about 9 miles from the airport. The airport station is

located at the end of a Y-branch off the line between the San Bruno and Millbrae stations. When the service first opened, some trains from the East Bay and San Francisco traveled to the SFO station and then on to Millbrae, while others went first to Millbrae and then returned via the SFO station. However, in September 2004 the service pattern was modified so that all trains to and from Millbrae travel via the SFO station.

Figures 6-5 and 6-6 shows the ground access mode use at SFO for BART and those modes that compete most directly with BART. The BART station exit counts were obtained from staff at the BART District (BARTD) and monthly use of each service is expressed per thousand air passengers using the airport to adjust for changes in air passenger traffic over the year.

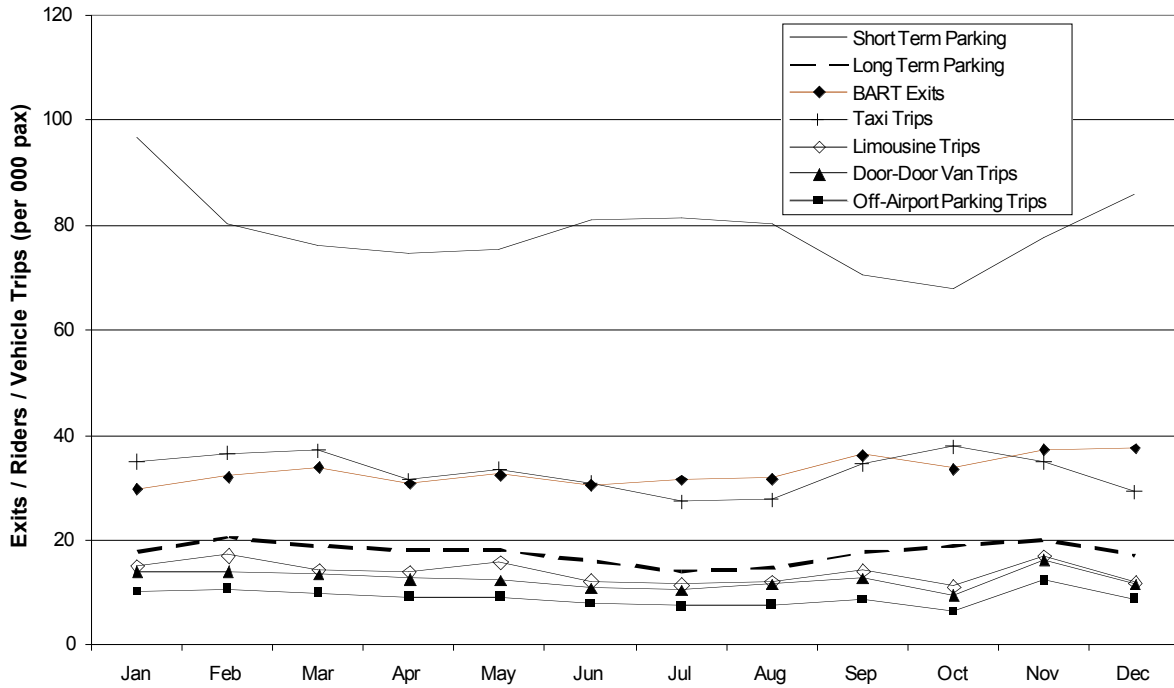


Sources: San Francisco International Airport, Internal reports; BARTD, Station exit counts.

Figure 6-5: Ground Access Mode Use at San Francisco International Airport in 2003

In contrast to the airport parking data for Oakland International Airport discussed in the previous section, the short-term parking exits are for vehicles parked for 6 hours or less, while the long-term parking exits are for vehicles parked for longer than 6 hours. Thus these data more

accurately distinguish between air passengers parking for the duration of their air trip and those dropping off or picking up air passengers (or visiting the airport for other reasons). However, the BART exit counts include all BART riders, and thus count airport employees and airport visitors as well as air passengers.



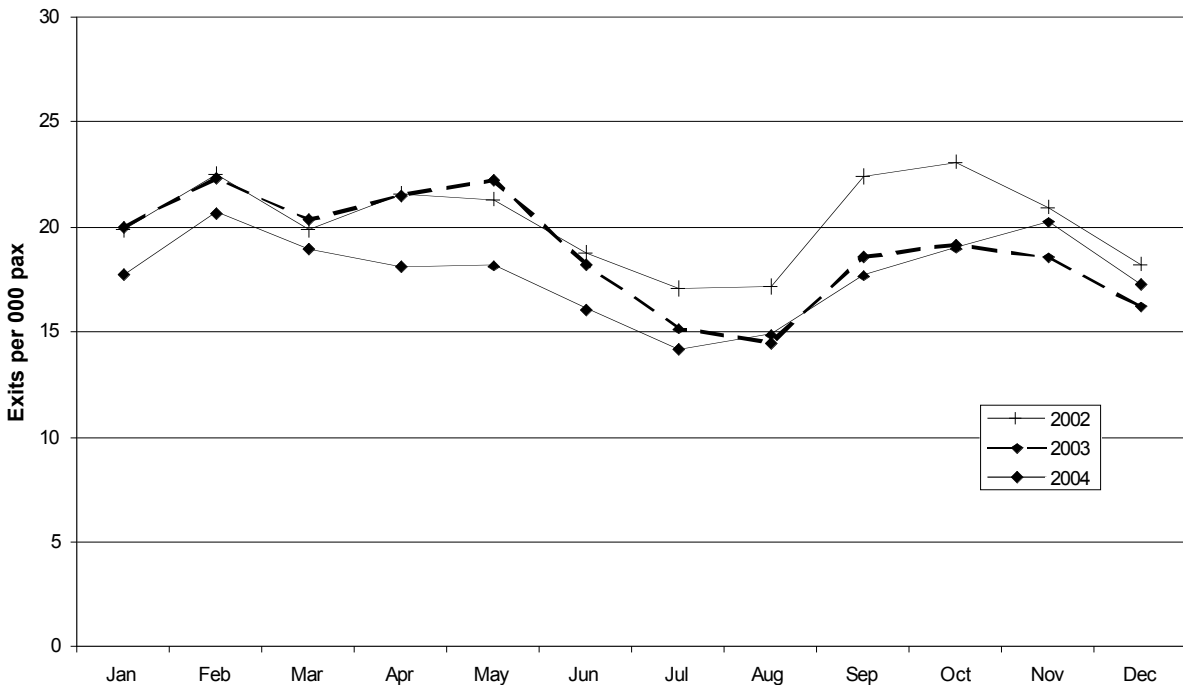
Sources: San Francisco International Airport, Internal reports; BARTD, Station exit counts.

Figure 6-6: Ground Access Mode Use at San Francisco International Airport in 2004

Figure 6-7 shows the use of airport long-term parking for the past three years. The opening of the BART station in June 2003 appears to have had a noticeable impact on the use of long-term parking, although the drop in parking use is fairly small compared to the BART ridership, with total use of airport long-term parking in 2004 being about 22 percent below the level in 2002.

The corresponding data for the use of short-term parking, shown in Figure 6-8, shows a steady reduction in short-term parking use over the past three years, but does not indicate any obvious effect of the opening of the BART station in 2003. The decline in use could be partly accounted for the changes in airport security since September 2001, which prevent greeters and

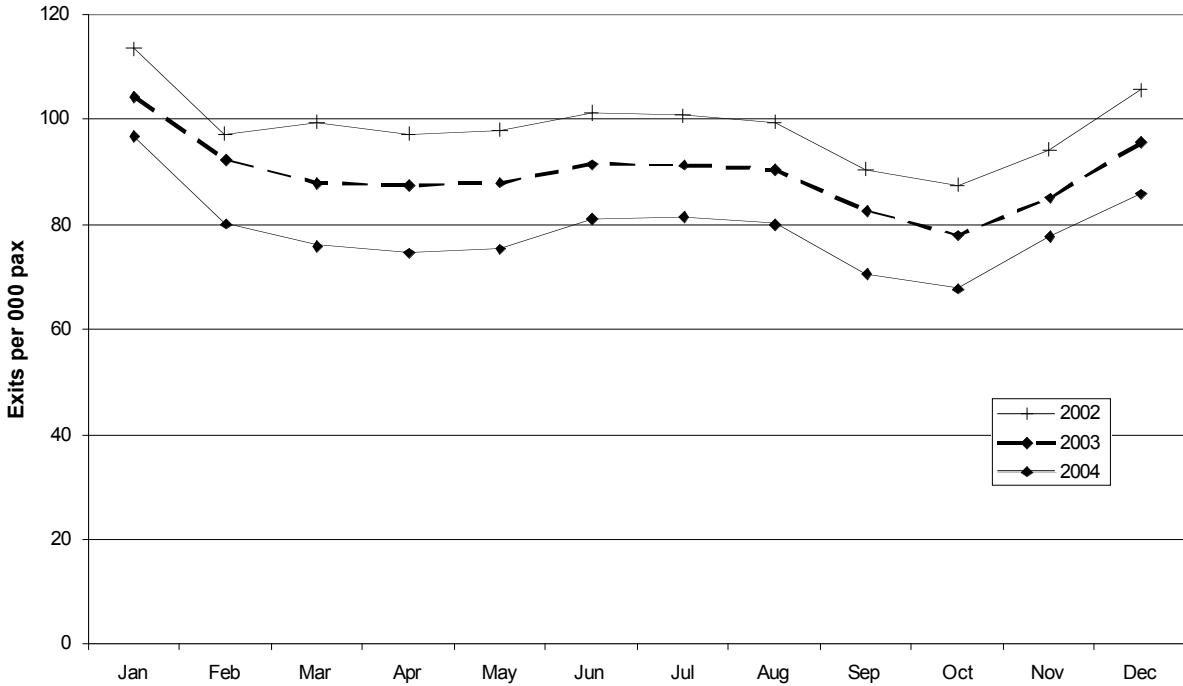
wellwishers from going to the terminal gate lounges to meet or see off air passengers, and the increasing use of cellular telephones to coordinate picking up air passengers. Both these effects reduce the value or need for parking at the airport when dropping off or picking up air passengers. It is also likely that many of those dropping off or picking up air passengers who park at the airport do so because they want to spend time in the airport terminal with the air passengers before their flight or to be in the airport terminal to meet arriving passengers. It is therefore less likely that these air passengers would consider making use of BART instead.



Source: San Francisco International Airport, Internal reports

Figure 6-7: Use of Long-Term Parking at San Francisco International Airport

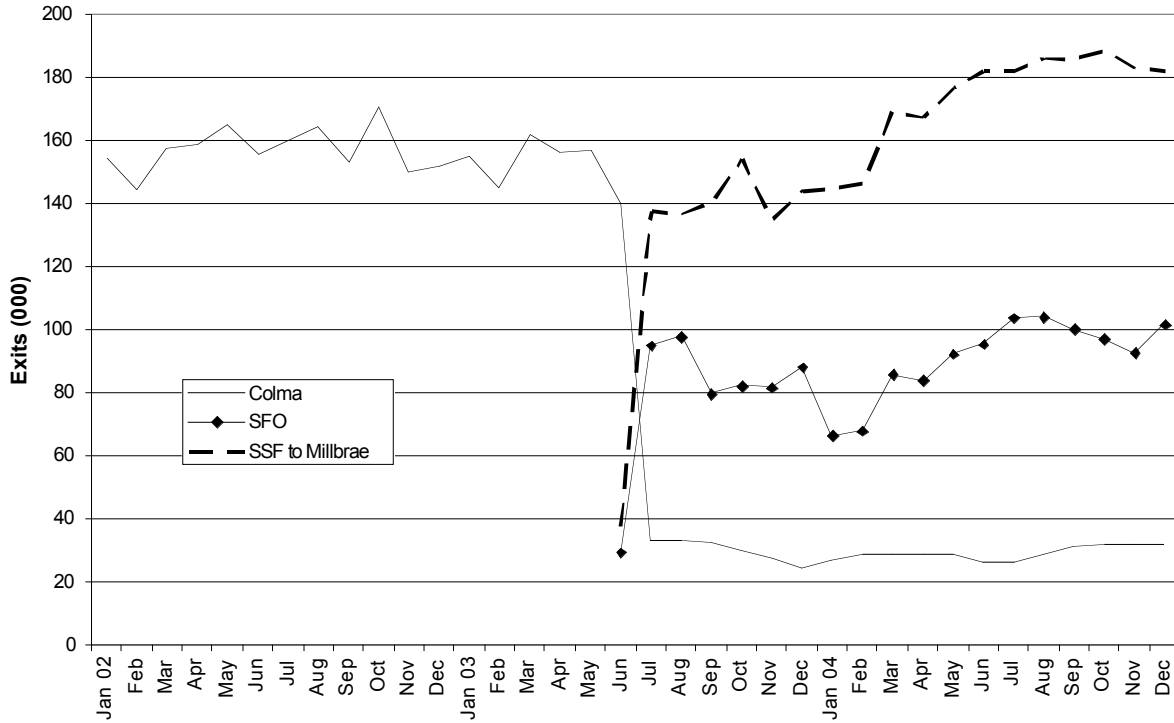
In combination, these data suggest that the majority of air passengers using BART have been drawn from those who would otherwise have been picked up or dropped off at the airport without using the airport parking facilities, and to a lesser extent those who would otherwise have parked at the airport for the duration of the air trip. While the latter represents a loss of parking revenue to the airport, the former generates no revenue for the airport and makes a much greater contribution to traffic congestion and vehicle emissions, due to the two-way trip involved.



Source: San Francisco International Airport, Internal reports

Figure 6-8 Use of Short-Term Parking at San Francisco International Airport

One final issue is the extent to which air passengers were already using BART to travel to or from the Colma station before the SFO station opened. Figure 6-9 shows the station exits at Colma, the SFO station, and the other stations on the extension from South San Francisco to Millbrae over the past three years. Although the Colma station showed a dramatic decline in use when the extension opened, total exits from all stations from Colma to Millbrae, excluding the SFO station, increased immediately and continued to increase through 2004. While it is of course to be expected that opening the extension would attract new riders to the system, apart from those using the airport station, and therefore one cannot tell from the data what proportion of the drop in use of the Colma station represents a shift of airport trips to the SFO station, the data do suggest that this effect was probably not very great and the majority of those using the SFO station would not have used BART prior to the SFO station opening.



Source: BARTD, Station exit counts

Figure 6-9: Trends in BART Station Exits on the SFO/Millbrae Extension

On balance, it appears that the BART extension to SFO has been successful at attracting a significant share of the airport ground access trips, comparable to those using long-term airport parking and about half as many as those using taxi. It also appears that BART has attracted a significant number of air passengers who would otherwise have been picked up and dropped off by private vehicles.

6.2 Identification of Potential Intermodal Opportunities

The *Ground Access to Airports Study* performed for the California Department of Transportation in 2001 by a consultant team led by Landrum & Brown prepared a list of airport ground access projects and “most pressing needs” at 26 commercial airports in California.¹ The information was derived from an earlier Ten-Year Funding Needs Study performed by the California Transportation Commission and airport surveys performed by the consultant team.

The information presented in the study identified nine intermodal connectivity projects at five of these airports, as follows:

Los Angeles International (LAX)

- FlyAway bus terminal expansion
- New remote FlyAway terminals
- Metro Green Line extension to the airport
- Airport people-mover (potential links to Metro Green Line)

Oakland International (OAK)

- BART connector to airport (people-mover)

Sacramento International (SMF)

- Remote terminal with light rail access

San Francisco International (SFO)

- Improve regional access system from the south and east
- Airport ferry service dock

San Jose International (SJC)

- Automated people-mover system (potential links to the VTA Light Rail system and Caltrain)

The foregoing list excludes two types of projects listed for a number of airports: additional transit services and on-airport ground transportation centers. While these projects may improve the service provided by existing public modes, they do not specifically enhance intermodal connectivity. The information provided on each project in the Landrum and Brown Team study was fairly minimal, and in some cases it is not clear what the identified project would involve, or whether it would enhance intermodal connectivity. The foregoing airports are all large or medium hub commercial airports. There were no intermodal connectivity projects identified at small hub or non-hub commercial airports.

In addition to the foregoing projects, the following sections identify a number of other potential opportunities for improved intermodal access at the larger California commercial service airports.

¹ Landrum & Brown Team, Ground Access to Airport Study - Working Paper Two: Issues and Problems, Prepared for the California Department of Transportation, Division of Aeronautics, August 24, 2001.

Bakersfield (Meadows Field) Airport

Bakersfield Airport is located about 4 miles to the north of the Amtrak station in downtown Bakersfield. There is currently no dedicated link between the airport and the station, which provides access to Central Valley communities via the Amtrak San Joaquin trains, although taxis are available at both the airport and station. Given the relatively low frequency of the trains, a shuttle bus link could be scheduled to meet each train. However, ridership on a shuttle is likely to be very low, given the level of air passenger traffic at the airport, which handled only about 200,000 passengers in 2003, and the relatively small proportion of those trips that are likely to find the train service an attractive way to access the airport.

Burbank (Bob Hope) Airport

Burbank Airport is currently served by an airport station that provides access to Metrolink and Amtrak trains. However, these trains are relatively infrequent, as noted in the previous chapter. The Red Line of the Los Angeles Metro terminates at North Hollywood station, about 4 miles to the southeast of the airport. A shuttle bus could be provided to link the airport to the Red Line station, which provides frequent service to downtown Los Angeles seven days a week and connections to other Metro lines that provide service to large parts of the Los Angeles basin.

Fresno Yosemite International Airport

Fresno Yosemite International Airport is located about 4 miles to the northeast of the Amtrak station in downtown Fresno. There is currently no dedicated link between the airport and the station, which provides access to Central Valley communities via the Amtrak San Joaquin trains, although taxis are available at both the airport and station. Given the relatively low frequency of the trains, a shuttle bus link could be scheduled to meet each train. However, ridership on a shuttle is likely to be quite low, given the level of air passenger traffic at the airport, which handled about 1 million passengers in 2003, and the relatively small proportion of those trips that are likely to find the train service an attractive way to access the airport.

John Wayne Orange County Airport

John Wayne Airport currently has no dedicated link to any regional rail system. However a shuttle bus link between the airport and the Tustin Metrolink and Amtrak station about 4 miles to the northeast of the airport would provide access to trains serving communities

between downtown Los Angeles and San Diego, as well as the Metrolink Inland Empire-Orange County line serving communities in Riverside County and connections to other Metrolink and Los Angeles Metro lines that provide service to large parts of the Los Angeles basin. Given the relatively low frequency of the trains, the shuttle bus link could be scheduled to meet each train.

In October 2001 the Orange County Transportation Authority (OCTA) Board of Directors approved an 18 mile rail transit alignment between the Irvine Transit Center and the Santa Ana Regional Transportation Center that included an intermediate stop at John Wayne Airport. This rail line was designated the CenterLine project and would have linked the airport to the Santa Ana Metrolink and Amtrak station to the northwest and the Irvine Metrolink and Amtrak station to the east. Both stations serve trains on the Metrolink Orange County Line and Inland Empire-Orange County Line, as well as Amtrak trains on the line between San Diego and Los Angeles Union Station. In July 2003 the OCTA Board reduced the scope of the project to an 8 mile line between John Wayne Airport and the Santa Ana Regional Transportation Center.

However, in response to anticipated shortfalls in Federal funding, the OCTA Board decided in February 2005 to pause work on the project. As of the date of this report, future plans for the CenterLine project are unclear. Since this project appears in the 2004 Regional Transportation Plan for Southern California as a designated Transportation Control Measure in the regional Air Quality Management Plan (AQMP), if the project is not implemented as planned, it will be subject to the substitution process defined in the AQMP. Projects proposed in place of the CenterLine project would not necessarily have to serve John Wayne Airport.

Long Beach Airport

Long Beach Airport currently has no dedicated link to any regional rail system. However the Blue Line of the Los Angeles Metro Rail system runs about a mile and a half to the west of the airport and connects downtown Long Beach with downtown Los Angeles. A shuttle bus link to the Willow station on the Blue Line would provide access to communities between Long Beach and downtown Los Angeles, as well as connections to other Metro lines that provide service to large parts of the Los Angeles basin.

Ontario International Airport

Ontario International Airport currently has no dedicated link to any regional rail system. However the Metrolink San Bernadino Line runs about 2 miles to the north of the airport, while

the Metrolink Riverside County Line runs about one mile to the south of the airport. A shuttle bus link serving the Rancho Cucamonga station on the San Bernadino Line and the East Ontario station on the Riverside Line would provide access to Inland Empire communities served by both lines, as well as connections to other Metrolink and Los Angeles Metro lines that provide service to large parts of the Los Angeles basin.

San Diego International Airport

The Blue Line of the San Diego Trolley light rail system runs to the north of the airport and links Mission Valley and the Old Town Transit Center to the north of the airport with downtown and communities to the south of downtown. The Blue Line connects in downtown with the Orange Line serving communities to the east. There is currently no dedicated shuttle bus service between the airport and the Trolley stations on the north side of the airport. The MTA transit bus Flyer Route 992 provides frequent (10 minute headway) service between the airport and downtown, including stops at the Amtrak Station and Blue Line and Orange Line Trolley stops. However, Trolley riders on the Blue Line traveling from stops to the north of the airport have to travel past the airport to the downtown in order to connect to the Route 992 bus to reach the airport. Potential connectivity enhancements include a dedicated shuttle between the airport terminals and the Blue Line Middletown station adjacent to the airport.

Santa Barbara Municipal Airport

Santa Barbara Municipal Airport is located about 6 miles to the west of the Amtrak station in downtown Santa Barbara. There is currently no dedicated link between the airport and the station, which provides access to Central Coast communities via the Amtrak Pacific Surfliner and long distance trains, although taxis are available at both the airport and station. There is also an Amtrak station in Goleta, immediately adjacent to the airport. However, providing a link to the station in downtown Santa Barbara would also serve other downtown origins and destinations. Given the relatively low frequency of the trains, a shuttle bus link could be scheduled to meet each train. The shuttle bus could stop at the Goleta station on the way to and from Santa Barbara, to serve passengers taking trains to or from communities to the north of the Goleta, as well as the University of California Santa Barbara campus immediately to the southwest of the airport. However, ridership on a shuttle is likely to be quite low, given the level of air passenger traffic at the airport, which handled about 750,000 passengers in 2003, and the

relatively small proportion of those trips that are likely to find the train service an attractive way to access the airport.

6.3 Preliminary Assessment of Potential Intermodal Opportunities

This section presents a preliminary qualitative assessment of the feasibility of the potential intermodal opportunities identified in the previous section. In a few cases, the intermodal opportunities have already been subject to more detailed quantitative analysis, and the results of this analysis are presented where they are known.

In the following discussion, the thirteen airports identified in the previous section have been grouped by major region of the state and presented alphabetically by airport.

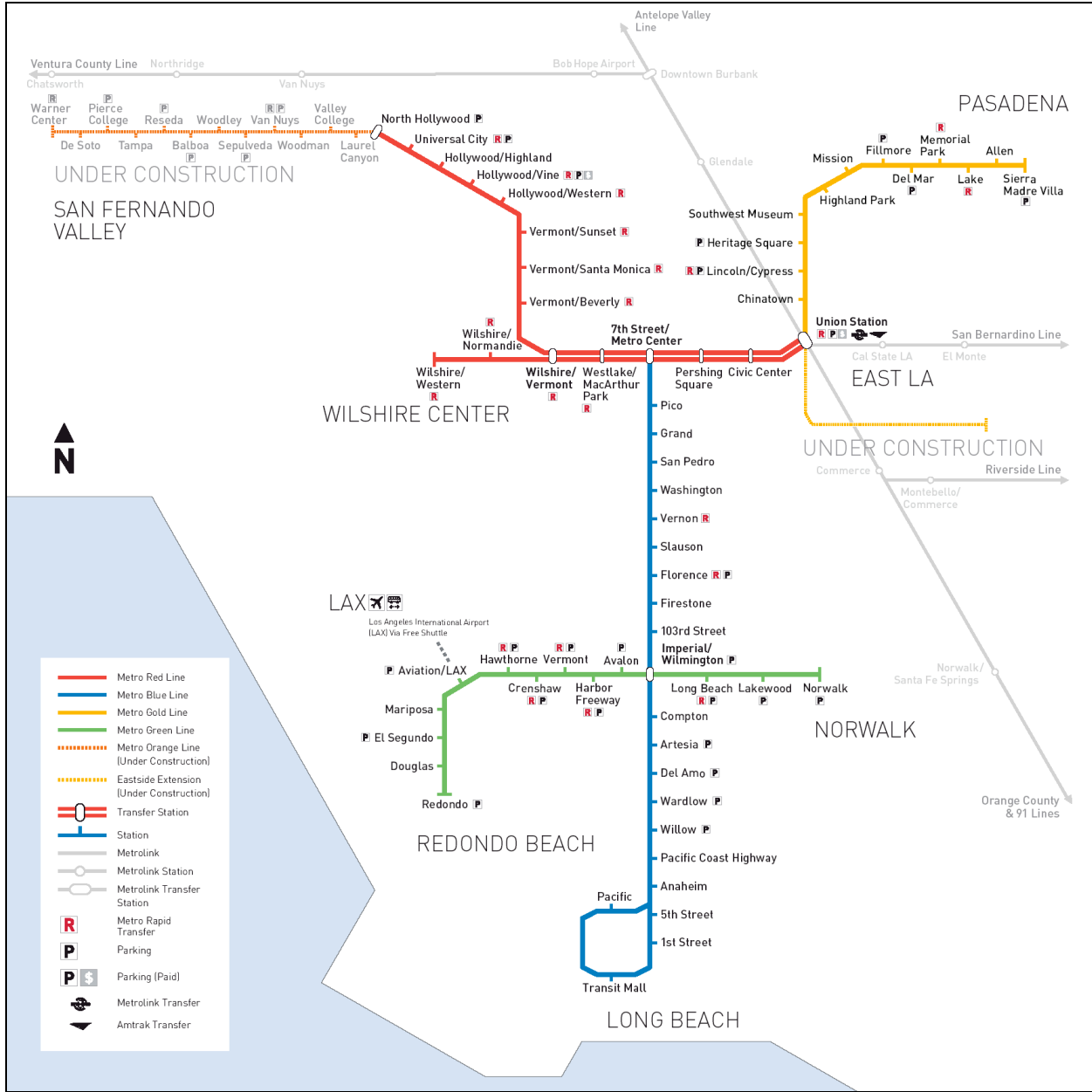
6.3.1 Southern California

Burbank (Bob Hope) Airport

A shuttle bus link between the airport and the North Hollywood Metro Rail station would provide airport travelers with an intermodal connection to a rail transit service linking Hollywood and communities along the Vermont Avenue and Wilshire Boulevard corridors to Downtown Los Angeles and Union Station. From Union Station, the Metro Rail Gold Line serves communities to Pasadena to the northeast, while from Downtown Los Angeles the Blue and Green Lines serve communities as far south as Long Beach and as far west as El Segundo and Redondo Beach, as shown in Figure 6-10. Union Station provides connections to the regional network of Metrolink commuter railroad trains that serve communities in Orange, Riverside and San Bernadino Counties, as shown in Figure 6-11. An extension of the system beyond North Hollywood to Van Nuys, Reseda and Chatsworth in the San Fernando Valley, termed the Orange Line, is under construction, as well as an extension of the Gold Line to the southeast of Downtown.

At present, the majority of Burbank air passengers come from the San Fernando Valley to the west of the airport or communities in the San Gabriel Valley to the east of the airport as far as Pasadena. Communities along the foothills further east are generally closer to Ontario International Airport, while those communities to the south of Downtown Los Angeles are closer to Los Angeles International Airport (LAX). A link to the North Hollywood station would serve communities between North Hollywood and Downtown Los Angeles served by the Red Line as

well as communities in the San Fernando Valley served by the Orange Line when it opens. Travelers using Metro Rail to access Burbank Airport from communities in the San Gabriel Valley would need to take the Gold Line into Downtown to connect to the Red Line. Since there are fairly direct freeway links between the San Gabriel Valley and Burbank Airport, it can be expected that relatively few airport travelers from the San Gabriel Valley would find Metro Rail an attractive way to reach the airport. This suggests that the primary market for a shuttle bus connection would be airport travelers with a trip end in the Red Line corridor between Downtown Los Angeles and North Hollywood and those with a trip end in the Orange Line corridor in the San Fernando Valley.



Source: www.mta.net

Figure 6-10: Metro Rail System Map



Source: www.metrolinktrains.com

Figure 6-11: Metrolink System Map

In addition to those air passengers with trip ends in the Red and Orange Line corridors already using Burbank Airport, an enhanced connection to the North Hollywood station might attract some passengers, particularly visitors to the region, who would otherwise travel through LAX. However, the number of such passengers would be limited by both the more restricted range of flight options at Burbank compared to LAX and more limited awareness of ground transport options by visitors to the region.

John Wayne Orange County Airport

A shuttle bus link to the Metrolink Orange County Line at Tustin station would provide access from communities in Orange County in the rail corridor from Buena Park to San Clemente, as shown in Figure 6-11, as well as more distant communities in the region through connections to the Inland Empire-Orange County Line at the City of Orange station and to the Los Angeles Metro Rail system at Union Station. However, relatively few air travelers using John Wayne Airport have trip ends outside Orange County due to the more extensive air service available at LAX to the northwest and Ontario International Airport to the north. It is therefore

unlikely that improved intermodal connections at John Wayne Airport would attract significant numbers of air passengers to use the airport who would otherwise use other airports in the region. While the communities served by the Orange County Line account for about 60 percent of the Orange County residents using John Wayne Airports based on an air passenger survey performed in 2000 (Applied Planning & Management Group, 2000), as shown in Table 6-1, for many of these trips the time involved in accessing the nearest station, riding the train, and then riding the shuttle bus to the airport would be significantly longer than driving to the airport. In particular, most trip origins in Irvine, which account for about 12 percent of the total, are closer to the airport than to the Irvine station. Therefore it is likely that the percent of air passengers who would use such a service is likely to be quite small.

Table 6-1: Trip Origins of Orange County Residents using John Wayne Airport

Metrolink Service	Percent	Outside Metrolink Corridor	Percent
Anaheim	3.7	Aliso Viejo	4.5
Brea/Placentia	1.6	Costa Mesa	4.1
Buena Park	0.8	Cypress	2.9
Coto de Caza	0.4	Fountain Valley	2.1
Dana Point/Capistrano Beach	2.9	Garden Grove	2.9
Foothill Ranch/Lake Forest	4.5	Huntington Beach	9.5
Fullerton	1.2	Laguna Beach	2.5
Irvine	11.5	Newport Beach/Corona Del Mar	8.6
Laguna Hills	1.2	Seal Beach	1.2
Laguna Niguel/Mission Viejo	10.7	Trabuco Canyon	1.6
Orange/Villa Park	5.7	Westminster	1.6
Rancho Santa Margarita	1.2		
San Clemente	1.6		
San Juan Capistrano	1.2		
Santa Ana	3.7		
Tustin	2.9		
Yorba Linda/Anaheim Hills	3.2		
Total	58.4	Total	41.6

Source: Applied Management and Planning Group, 2000.

Visitors to Orange County accounted for 61 percent of the air passenger survey respondents. The survey did not determine the location of their trip origin, but about 54 percent of those visiting the region stayed in a hotel or motel, while about 37 percent stayed in a private

residence. It is unlikely that visitors staying in a hotel would choose to use Metrolink trains, due to the lack of any convenient way to travel between the hotel and the nearest station, while those staying at private residences are likely to be picked up or dropped off the airport rather than a train station, except possibly from the more distant communities. In addition, many visitors to the region are likely to rent a car to meet their local travel needs during their visit.

Therefore the shuttle bus link is likely to attract a relatively small number of air passenger trips, at least initially until the connection is more widely known and there are future increases in train service frequency. However, it may attract a number of airport employees who are more likely to be familiar with the train schedules and can park a car at their nearest train station, take local bus service to the station, or be dropped off at the station by a family member.

Long Beach Airport

Long Beach Airport has recently experienced a significant growth in traffic as a result of the introduction of air service by jetBlue Airways and the competitive response by the other airlines serving the airport. In consequence, it is likely that the airport is now drawing air passengers from a wider area in the Southern California region. This suggests that an improved connection to the regional rail system might attract some of these air passengers. Unfortunately, there is very limited air passenger survey data for the airport. The airport has conducted a small sample survey of air passengers every month for the past few years, primarily to obtain information on passenger satisfaction with the airport facilities and services. This survey does provide a limited amount of information on the ground trip origin of the air party, but the sample is too small to develop a meaningful trip generation profile.

None the less, it is likely that many of the air passengers are drawn from communities served by the Blue and Green Lines of the Metro Rail system, shown in Figure 6-10. Also, since the air service at the airport is primarily targeting low-fare travelers, it is likely that many of those air passengers would be attracted to an improved transit connection. At present local bus service between the airport and stations on the Blue Line is relatively infrequent, particularly at weekends, and rather circuitous. Long Beach Transit Route 111 serves the airport and the downtown Long Beach transit mall, the terminus of the Blue Line. Travel time between the airport and the transit mall is about 45 minutes and the weekday service frequency is about every 30 minutes from 5:45 am until 6 pm and then every hour until 12:30 am. Saturday and Sunday service frequency varies from about every hour to 75 minutes from 7:25 am to 11:30 pm. While

the transit mall provides connections to a large number of other bus routes serving the City of Long Beach, its location at the end of the Blue Line means that air passengers using the Blue Line from stations north of Long Beach have to travel several stations past the airport and then spend 45 minutes on a bus going back in the opposite direction. It is possible to take buses from either the Willow or Pacific Coast Highway stations on the Blue Line and transfer to Route 111. However that may be intimidating to air passengers unfamiliar with the Long Beach Transit route system, and would require additional travel time to make the transfer.

A shuttle bus link to the Blue Line Willow station would take about 10 minutes in each direction, so it would be possible to provide service every 30 minutes with only one vehicle per shift. In view of the limited flight frequency at the airport, service every 30 minutes is probably adequate, particularly if the runs can be timed to coordinate with the Blue Line train schedules. This could reduce the ground access time for air passengers using the Blue Line by an hour or more compared to using Route 111 from the transit mall (30 minutes travel time difference plus as much as 30 minutes waiting time for the transfer to the local bus, or more at weekends).

In 2004 Long Beach Airport handled about 1.5 million air passengers. If a half of these had trip ends in communities served by the Blue and Green Lines, and 15 percent of those travelers used a shuttle bus connection to the Blue Line, that would translate into about 300 air passengers per day using the shuttle. If service is provided from 6 am to midnight at 30 minute headway, that would average about 4 riders per run.

A much less expensive way to provide equivalent service would be to persuade Long Beach Transit to modify the route of the Route 102 bus, which currently provides service on weekdays with stops at the Willow station and on Spring Street on the southern boundary of the airport, but does not serve the terminal, to include the airport terminal in the route and add evening and weekend service. Route 102 currently has about 30 minute service frequency from 6:00 am to 7:30 pm from Willow Street and Lakewood Boulevard near the airport to the Willow station, with a final run at 9:00 pm.

Los Angeles International Airport

The California *Ground Access to Airports Study* (Landrum & Brown, 2001) identified four potential intermodal connectivity projects at LAX: expansion of the current Van Nuys FlyAway bus terminal in the San Fernando Valley; development of new FlyAway terminal elsewhere in the region; an extension of the Metro Green Line to the Airport; and an airport

people-mover link to the Green Line. The expansion of the Van Nuys FlyAway bus terminal has been initiated by the Los Angeles World Airports (LAWA) and was almost complete by early June 2005. The Metro Green Line currently extends past LAX to a terminus in Redondo Beach, with a station (Aviation/LAX) adjacent to the airport and served by a free shuttle bus connection operated by LAWA. The LAX master plan update that is currently in progress envisages a major reconfiguration of the airport terminal area with an automated people-mover link to an intermodal facility located at the Aviation/LAX station.

Therefore expansion of the FlyAway bus system with additional terminals at new locations in the region would appear to be the only intermodal connectivity project identified in the Landrum & Brown airport ground access study that remains to be addressed. In 2001 Leigh Fisher Associates undertook a market analysis of a number of potential sites for new FlyAway facilities in the Los Angeles region (Leigh Fisher Associates, 2001). The analysis examined alternative sites in four corridors, as well as the feasibility of a terminal located at Union Station in downtown Los Angeles, and developed estimates of average daily ridership from each site for the peak month (August) in 2000, 2005 and 2010. The sites were then compared using a scoring system and the preferred site identified in each corridor.

Ontario International Airport

Detailed information on air passenger trip origins for Ontario International Airport are available from an air passenger survey performed for LAWA in 2001 (Applied Management and Planning Group, 2004). The report provides information on the zone of origin of both resident and visitor trips using the zone system adopted for the Regional Airport Demand Analysis Model (RADAM) developed for the Southern California Association of Governments. The distribution of these trip ends is shown in Table 6-2.

Table 6-2 also shows which zones are served by the Metrolink San Bernadino or Riverside lines, excluding the Ontario zone. Trip ends within the latter zone are considered too close to the airport to make using Metrolink a viable airport access option. Some 36 percent of resident trip ends and 31 percent of visitor trip ends are in zones served by the two Metrolink lines. While it would be possible for some air passengers with trip ends in zones served by other Metrolink lines (such as the Orange County Line) to use Metrolink to connect to the San Bernadino or Riverside lines, the circuitry involved would not make this an attractive option.

Table 6-2: Trip Origins of Air Passengers at Ontario International Airport

Community (RADAM zone)	Total %	Residents %	Visitors %	Metrolink Service
Ontario	17	13	22	
Pomona/Claremont	10	9	10	Y
Riverside	8	8	7	Y
San Bernadino	6	6	6	Y
Fullerton/Brea	4	5	3	
Corona	4	5	3	
Hemet/Idyllwild	4	5	3	
Fontana	3	3	3	Y
North San Bernadino County	3	3	2	
San Gabriel	3	3	2	Y
Walnut	3	3	3	Y
Chino	3	4	-	Y
Twenty-Nine Palms	2	3	2	
Anaheim/Disneyland	2	-	4	
Anaheim/Orange	2	-	2	
Other	26	30	28	
Total	100	100	100	

Source: Applied Management and Planning Group, 2004.

In 2004 Ontario International Airport handled about 6.9 million air passengers. According to the 2001 air passenger survey about 56 percent of air passengers were residents of the region. If 10 percent of resident air passengers in zones served by Metrolink and 5 percent of visitors were to use the trains to access the airport, this would translate into an average ridership of about 500 air passengers per day using the shuttle bus service between the Metrolink stations and the airport. Assuming the shuttle buses operate on a 30 minute headway from 5:00 am to 10:00 pm, this would require about 35 round trips per day, with an average ridership of 7 passengers per trip in each direction, plus any airport employees who would be attracted to the service.

This would appear to be a sufficient level of patronage to justify initiating the service. As airport passenger traffic increases, these numbers would grow.

6.3.2 San Francisco Bay Area

Oakland International Airport

The California *Ground Access to Airports Study* (Landrum & Brown, 2001) identified a proposed project to develop an automated people-mover link between the airport and the Coliseum BART station. This project has been studied extensively since the early 1970s. On August 28, 2003 the BART Board of Directors approved a list of six Prequalified Design Build Entities to prepare bids for the Oakland Airport Connector project. Procurement documents were scheduled to be completed in late 2004, and utility relocations and right-of-way acquisition were planned to take place in 2005 (<http://www.bart.gov/about/projects/airport.asp>, accessed 6/28/05). A contact award was expected in 2006 with revenue operation commencing in late 2010. The project is being developed as a collaborative partnership between BART, the Alameda County Transportation Improvement Authority, the Alameda County Congestion Management Agency, the California Transportation Commission, the California Department of Transportation, the City of Oakland, and the Port of Oakland. The BART Board of Directors certified the Final Environmental Impact Report on March 28, 2002.

The connector will be about 3.2 miles long and as currently planned will follow the Hegenberger Road corridor, with two intermediate stations, one at Edgewater Road between the Interstate 880 freeway and the airport and one at Doolittle Drive on the northeast boundary of the airport. The total project budget is reported as approximately \$232 million in 2001 dollars.

San Francisco International Airport

The California *Ground Access to Airports Study* (Landrum & Brown, 2001) identified two intermodal connection opportunities at San Francisco International Airport: improved regional access from the south and east; and an airport ferry service dock. It is unclear from the report what was envisaged by the first of these opportunities. The opening of the airport BART station with the connection to the Caltrain line at the Millbrae BART station provides good rail connections to the south, while BART itself provides extensive coverage of the East Bay. There are currently efforts underway to expand ferry service on the Bay, and if a ferry route was to be established from the Ferry Terminal in downtown San Francisco to Peninsula communities to the south of the airport, it could be useful to have the ferries stop at a dock at the airport. This would

require a shuttle bus connection to the airport terminals. Further analysis of this potential project is very dependent on the exact nature of the likely ferry service.

San Jose International Airport

The California *Ground Access to Airports Study* (Landrum & Brown, 2001) identified a proposed project to develop an automated people-mover link between the airport and the Valley Transit Authority (VTA) light rail system. This project has been fairly well defined (Lea+Elliott, 1999), ridership estimates have been prepared (Dowling Associates, 2002), and environmental documentation completed (San Jose International Airport, 2003). The project involves an elevated automated people-mover 0.6 miles in length between the airport terminal complex and a VTA light rail station on North First Street. The project has been estimated to cost \$110 million to construct and \$1.5 million per year to operate (San Jose International Airport, 2003, Appendix B, p. B-12). Average daily ridership in 2010 has been projected at about 2,500, or about 4.3 percent of total air passenger and employee airport trips (*ibid*, p. 17).

6.3.3 San Diego

San Diego International Airport

Assessment of the potential ridership on a shuttle bus connection between San Diego International Airport and the Middletown station on the Blue Line of the San Diego Trolley depends heavily on the distribution of air passenger trip ends in the region, since it will primarily serve air passengers with trip ends to the north of the airport. While it may well attract some riders from communities to the south of the airport, these can already use the MTA Flyer Route 992 from the Blue and Orange Line stops in downtown San Diego. One option would be to modify the route of the MTA Flyer to serve the Middletown station en route to and from the airport. While this would increase the travel time for passengers riding to or from downtown San Diego, that may be offset by the significant reduction in travel time for those with trips ends to the north of the airport.

6.3.4 Sacramento

Sacramento International Airport

The California *Ground Access to Airports Study* (Landrum & Brown, 2001) identified the possibility of a remote terminal with light rail access to the airport as a potential intermodal

connection opportunity. The area immediately to the east of the airport is currently being developed as a business park, termed the Metro AirPark, with residential development planned in the area further east of the airport and north of the existing urban boundary of Sacramento, known as the Natomas Basin. As part of this development, it is envisaged that the Sacramento light rail transit system will be extended to the Metro AirPark and the airport.

The optimal location for an off-airport terminal serving the airport via the light rail connection will require careful analysis. The principal purpose of such a terminal would be to provide remote parking closer to the trip ends of air passengers. If the terminal is simply to allow air passengers to be dropped off and picked up, it is not clear why this is any different from the existing light rail stations. The off-airport terminal could also provide airline check-in, although this has always been difficult to implement and keep in service, since the airlines are reluctant to bear the staffing costs involved. However, Interstate 80 passes to the north of Sacramento, crossing the Sacramento River about 12 miles to the southeast of the airport. While locating an off-airport terminal in the vicinity of the junction of Interstate 80 and Interstate 5, which provides the access to airport, would ensure the largest number of air passengers who could conveniently access the off-airport terminal, this location may be too close to the airport to attract many users. The travel time on the light rail service from this location would be significantly longer than continuing on to the airport. Locating the terminal closer to central Sacramento would mean that many air passengers would have to back-track to reach it. On the other hand, locating a terminal to the east or south of the city, while being more convenient to access by air passengers with trip ends in those areas, would require users to ride the light rail through downtown Sacramento, which would significantly increase the journey time.

6.3.5 Central Valley

Bakersfield (Meadows Field) Airport

Bakersfield Airport is currently served by Route 3 of the Golden Empire Transit District which runs between the airport and the downtown transit center. Hourly service is provided from the airport to downtown from Monday to Saturday from 6:42 am to 6:42 pm. Service to the airport from the downtown transit center is provided from 7:15 am to 6:15 pm. Travel time is approximately 30 minutes. In order to get to and from the Bakersfield Amtrak station, it is necessary to transfer at the downtown transit center to Route 5, which provides 20 minute service

frequency on weekdays from about 7 am until about 7 pm and then hourly service until about 10 pm. On weekends, a 30 minute service frequency is provided from about 7 am until about 7 pm.

Rather than run a separate shuttle bus, it would be more cost effective to extend the route of Route 3 beyond the transit center to terminate at the Amtrak station. This may require some modification of the route between downtown and the airport in order to free up the time for the additional distance and still be able to complete the round trip in an hour. It would also be desirable to increase the service frequency to 30 minutes, and add evening and weekend service. While it is unlikely that the utilization would justify the full costs of the additional runs, increasing the service frequency would also most likely increase ridership by other users of the route.

Fresno Yosemite International Airport

Fresno Yosemite International Airport is currently served by Route 26 of the Fresno Area Express transit system, which runs between the airport and the downtown transit center. It does not however pass the Fresno Amtrak station. Half-hourly service is provided on weekdays from about 6 am to about 10 pm and hourly service is provided on weekends from about 8 am to about 7 pm. Travel time is approximately 30 minutes. In order to travel to or from the Fresno Amtrak station, it is necessary to transfer to the Route 22 bus at the downtown transit center. This also operates at 30 minute intervals on weekdays from 5:20 am to 9:45 pm and at 50 minute intervals at weekends from 6:45 am to 6:20 pm. Waiting times for the transfer at the transit center vary between about 5 minutes and 15 minutes.

Intermodal connection between the airport and the Amtrak station would be greatly enhanced by changing the route of bus Route 26 to reach the downtown transit center via First Street and the Amtrak station on Tulare Street. While this would eliminate service to a small area to the southeast of the downtown that is currently served by Route 26, this could be resolved with a minor readjustment to one of the other routes in the area, several of which provide duplicate service on M Street and Van Ness Avenue. It would also be desirable to extend the weekend service hours to provide evening service and to increase the weekend service frequency to every half hour.

6.3.6 Central Coast

Santa Barbara Municipal Airport

Santa Barbara Municipal Airport is served by Route 11 of the Santa Barbara Metropolitan Transit District (MTD), which links the campus of the University of California Santa Barbara (UCSB) with the downtown transit center on State Street. Service is provided every 30 minutes from about 6 am to about 11:30 pm on weekdays, from about 6:30 am to about 10:30 pm on Saturdays, and from about 7 am to about 10 pm on Sundays. To reach the Santa Barbara Amtrak station, it is necessary to transfer to another route at the downtown transit center. Although the Goleta Amtrak station is immediately north of the airport, there is no bus service to the station itself although two bus routes pass within about 200 yards.

Intermodal connection between the airport and the Santa Barbara Amtrak station could be enhanced by extending the route of bus Route 11 down State Street beyond the transit center to terminate at the Amtrak station. Connection between the airport and the Goleta Amtrak station could be enhanced by modifying the route of bus Route 11 slightly to stop at the station when leaving the airport for downtown or before arriving at the airport from downtown. Since only a few Amtrak trains stop at the Goleta station each day, it would only be necessary for some runs of bus Route 11 to make this small detour (they could be designated with a suffix, such as Route 11G with appropriate schedule adjustments). As a side benefit, this would also provide a bus connection between the Goleta Amtrak station and the UCSB campus.

6.4 Quantitative Analysis of Potential Intermodal Opportunities

In order to expand the preliminary assessment of the feasibility of the potential intermodal opportunities described in the previous section, a more quantitative analysis will be undertaken in the next stage of the research using a simplified spreadsheet model. The objective of this analysis is to obtain an approximate estimate of the likely use of the proposed intermodal connectivity enhancement as well as an estimate of associated revenues and costs. Revenue estimates will be derived from the assumed fares and ridership estimates, while cost estimates will be derived from capital and operating cost experience for similar projects that have been implemented at other airports. This section describes the proposed analysis approach and structure of the spreadsheet model.

Estimating the use of any proposed intermodal access project requires some form of mode choice analysis, since the potential use will depend on the trip origins of air travelers using the airport, the distribution of air party characteristics, and the other airport ground access options available at the airport. Since many of the airports in question do not have extensive (or any) recent air passenger survey information available, it is also necessary in many cases to use a trip generation model to estimate the number of trips that originate in each zone in the region served by the airport. For the purposes of this preliminary analysis, the zonal system will be based on postal zip codes, rather than the more detailed traffic analysis zones used by regional planning agencies. Because of the potential application for marketing research, population and income data are readily available at the zip code level, and air passenger survey responses often give trip origin information in terms of zip codes. Highway distances and travel times from each zip code to an airport can be estimated from web-based trip planning services (e.g. maps.yahoo.com).

6.4.1 Trip Generation Model

The number of air passenger trips that originate in a given zip code depends on the demographics and other characteristics of the zone, such as the population and number of hotels or businesses. For those airports where reasonably detailed air passenger survey data is available, the composition of air party characteristics and the distribution of air passenger origins can be estimated from the survey data. In the case of airports for which air passenger survey data is not available, it will be necessary to develop estimates of both the air party characteristics and the distribution of trip origins. For the purpose of this preliminary case study analysis, it was decided to classify air travelers into five groups:

- Residents of the area making a business trip
- Residents of the area making a non-business trip
- Visitors to the area making a business trip
- Visitors to the area making a non-business trip and staying in a hotel
- Visitors to the area making a non-business trip and staying with residents.

Residents of the area are assumed to begin their trip to the airport from their home. While in practice a small proportion begin their trip from their place of work or other location,

they obviously reached that location from their home, and thus their ground access mode choice decisions are likely to be influenced by similar factors in both cases.

Visitors on business trips are assumed to stay in a hotel and begin their ground access trip to the airport from their hotel. In practice, some business visitors may begin their ground access trip from the business location that they are visiting, depending on the time of day of their flight. However, to the extent that they are likely to stay in a hotel near the business they are visiting, assuming that their ground access trip begins from their hotel will not introduce a significant bias in the assumed trip end distribution. It is further assumed that the trip origins of visitors staying in hotels are distributed according to the distribution of hotel rooms, while the distribution of trip origins of visitors staying with residents of the area are distributed according to the distribution of trip origins of resident non-business trips, on the grounds that residents who make more non-business air trips are more likely to have visiting air passengers stay with them than are residents who make fewer non-business air trips. This not only reflects differences in income level in different areas, but also more subtle issues of life-style, age distribution, occupation, and similar factors that influence both where people live and their use of air travel.

Although air passenger surveys have been widely used to develop airport ground access mode choice models and airport choice models, there has been very little attention given in the literature to developing models of air passenger trip generation at a zonal level (Gosling, *et al.*, 2003). Therefore for the purposes of the current analysis, a simplified trip generation model can be developed using data from an air passenger survey performed at Orange County John Wayne Airport in July 2000 (Applied Management & Planning Group, 2000). Although data from more extensive surveys at other airports are available, it was felt that the pattern of trip generation at John Wayne Airport would be more representative of smaller airports for which air passenger survey data is not available.

Separate models can be developed for resident business and resident non-business trips, as follows:

$$Pax_{RB} = Pop * (a_{0B} + a_{1B} * HHINC)$$

$$Pax_{RN} = Pop * (a_{0N} + a_{1N} * HHINC)$$

where Pax_{RB} = Annual resident business air passenger trips from zip code

Pax_{RN} = Annual resident non-business air passenger trips from zip code

Pop = Population of zip code (2000)

HHINC = Average household income in zip code (1999 in \$000)

Visitor trips can then be estimated from the proportions of air passengers who are visitors traveling on business, visitors making non-business trips and staying in a hotel or similar accommodation, and visitors staying with residents of the area. While these proportions are likely to be different for other airports, reflecting the nature of the region served by the airport, for the purposes of the current analysis in the absence of air passenger survey data for a given airport, the relative proportions of resident trips for business and non-business purposes and of visitor trips for business, vacation (staying in a hotel) or visiting friends or relatives (staying with residents) are assumed to be the same as at airports serving a similar market. The proportion of air trips by residents compared to visitors can be estimated from air passenger itinerary data reported by the airlines to the U.S. Department of Transportation and referred to as the 10 percent Airline Origin and Destination Survey (U.S. DOT, 2005).

The distribution of hotel rooms by zip code can be obtained from travel industry publications. For the purposes of the current analysis, data on the number of hotels in each zip code can be obtained from travel web sites such as maps.yahoo.com, while data on the number of rooms in each hotel can be obtained from the California Tour Books published by the American Automobile Association (AAA Publishing, 2004a,b).

6.4.2 Mode Choice Model

A number of airport ground access mode choice models have been reported in the literature over the years (Gosling *et al.*, 2003). However, they vary widely in functional form, the airports for which they have been developed, and the dataset from which they have been estimated. In consequence, the values of the estimated model coefficients vary widely and are not directly comparable. Two recent airport ground access models have been developed for airports in the San Francisco Bay Area by Pels *et al.* (2003) and Dowling Associates (2002). Both models were estimated using the same air passenger survey dataset, the 1995 air passenger survey performed for the Metropolitan Transportation Commission. However, the model developed by Dowling Associates is better documented and includes the values of the mode-specific constant terms that Pels *et al.* omit. Dowling Associates stated that their model was based on earlier work by Harvey (1988), and like Harvey they estimated separate model

coefficients for four types of air passenger trip: resident business trips, resident personal trips, visitor business trips, and visitor personal trips. However, they estimated a multinomial logit model rather than the nested logit model used by Harvey. Also, it is not clear from the description of the model how they distinguished between air passengers who were dropped off by private vehicle and those who parked for the duration of their air trip.

Since the Dowling Associates model was specifically developed to estimate the future ridership on a proposed automated people-mover to connect the San Jose International Airport to the Santa Clara Valley light rail system, their model has separate coefficients for travel times using rail and bus transit, and separate mode-specific constants for transit access using the people-mover and transit access without using the people-mover. The differences in the mode-specific constants for transit access with and without the people-mover were estimated from a survey of air passengers conducted at San Jose International Airport, in which passengers had been asked how likely they would be to make use of transit to access the airport on future trips, with and without the people-mover.

Since this model had been specifically designed to estimate the likely use of an improved intermodal connection (the proposed people-mover), it was judged to be an appropriate model to perform preliminary assessments of the use of improved intermodal connections at other airports. In the absence of models specifically estimated for those airports, it is of course unknown how well the model coefficients estimated for ground access trips to San Jose International Airport will explain air traveler behavior at other airports, and this is an issue to be explored further in future stages of the current research. However, for the purposes of the current application, an assessment of the likely accuracy of the model predictions can be made by comparing the use of other modes predicted by the model with data on the actual use of those modes, either from air passenger surveys (where they exist) or airport operational statistics such as the use of airport parking lots.

In order to distinguish between residents parking private vehicles at the airport for the duration of their air trip from those dropped off at the airport by others, the private vehicle mode included in the model has been split into two modes representing drop-off and park. Both of these modes are assigned the same mode-specific constant, but of course they have different travel times and costs. The airport access travel time and vehicle operating cost for the private vehicle drop-off mode should be increased to account for the return trip by the driver, while cost

for the private vehicle park mode included the cost of parking at the airport. No attempt is made to predict whether air parties used the short-term or long-term parking lots, and all air parties parking for the duration of their air trip are assumed to use the long-term parking lot where there is a different rate structure.

The assumed mode choice model coefficients based on the Dowling Associates model are documented in Appendix B.

Model Application

In addition to information on the travel times and costs by the different access modes from each zone, the mode choice model requires information on air party size, air trip duration (to estimate parking costs), and household income, as well as trip purpose and whether the air travelers are residents of the region or visitors (to determine which model coefficients to use). Therefore the model needs to be applied to a sample of air party trips that provide the necessary air party characteristics, including the location of the trip origin. In order to apply the model at a given airport, the ground access mode choices are calculated for a sample of 1,000 air parties developed to reflect the distribution of air passenger characteristics found in the most recent air passenger survey for the airport, where data from such a survey is available, or the John Wayne Airport survey data where air passenger survey data is not available. The distribution of ground access trip locations is determined from the estimated number of air party trips originating in each zip code given by the trip generation model. This approach assumes that the distribution of air party characteristics for a given market segment (e.g. resident business trips) is constant across all zip codes. However, the household income for each air party starting their trip from a residence (this only applies to non-business trips in the model) is assumed to be the average household income for that zip code. The household income for visitors on non-business trips staying in a hotel is assigned on the basis of the household income distribution for those trips found in the John Wayne Airport air passenger survey.

Assignment of air party characteristics to each party in the sample is performed by Monte Carlo simulation (a random number between zero and one is generated and used to select a value from the cumulative distribution of the relevant characteristic). Once the trip origin zip code has been assigned, the travel times and costs for each alternative mode for that air party can then be obtained from a table of travel times and distances to the airport from each zip code.

6.4.3 Structure of the Spreadsheet Model

The trip generation and mode choice models are combined into a spreadsheet model that estimates the annual number of air passengers using a proposed intermodal connection. Since the mode choice model also estimates the use of other modes in the course of estimating the use of the intermodal connection, the use of these modes are also presented by the model to assist in assessing the reasonableness of the mode use estimates. The model consists of a number of separate worksheets, some of which are common to each application of the model and some of which have to be developed for each airport for which the model is applied. In general, those data that vary by zip code require a specific table to be developed for each application, since obviously the zip codes representing the area served by the airport will be different in each case.

By designing the model in this way, a given application can be analyzed by copying the relevant airport-specific worksheets into the model and entering the appropriate data into the common worksheets. The model is then run by initiating a recalculation of the cell values on those worksheets that contain the random number functions for the Monte Carlo simulation. This configures the data for the sample of air parties to appropriate values for the airport in question and initiates the calculations of the mode choice model, which then calculates the use of the different modes at that airport.

Chapter 7. Plans for More Detailed Further Analysis

The previous chapter has presented an initial case study analysis for a range of potential opportunities to improve intermodal connectivity at selected California airports. The next stage of the research will involve the development of an analytical model for undertaking a more rigorous analysis of potential projects to improve intermodal connectivity and the application of this model to several selected case studies. The planned model has been termed the Intermodal Airport Ground Access Planning Tool (IAPT).

This chapter presents the proposed design for the IAPT and discusses some of the data requirements that will need to be addressed in order to apply it to a specific analysis. The proposed analysis approach will provide a formal representation of the interaction between the mode choice behavior of air passengers and the resulting decision-making by the transportation providers.

7.1 Analysis Approach

The development of IAPT will provide a tool to perform detailed analysis of potential projects or strategies to improve airport ground transportation in support of planning studies at different levels of government decision-making. Through the development of the research, it has been recognized that planning at these different levels will involve different aspects of analysis, although some aspects will cross all levels. Since this research is intended to address the impact of changes in state policy and planning guidelines on ground transportation at California airports, particularly at the selected airports in the next phase of the study, the analysis will be structured to examine how these changes will impact the performance of the airport ground transportation system. The next stage of the research will involve the following two aspects:

(1) Development of the analytical capabilities of the IATP:

- Airport passenger and airport employee model choice
- Transportation provider behavior in terms of the service changes (such as service frequency and fare) in response to changes in traffic levels, introduction of new services, or competitive actions by other providers

- Forecasting changes in ridership and mode use resulting from the introduction of new services or changes in the existing ground transportation services available at the airport
- Incorporation of ground traffic resulting from air freight activities

(2) Using the IAPT to analyze potential alternatives to improve intermodal connections identified for the selected airports, including the addition of a new mode at an airport.

For the four aspects listed in item (1) above is itself a significant research area. Subject to the resource limitations of this stage of the project, we will review the results of prior research in those areas, identify those that are most relevant for the needed analytic capabilities of the IAPT, and pursue additional research in those areas to support the development of the IAPT.

There are several elements that must be considered in planning for intermodal transportation: decision makers (at different levels), users of the system (air passengers, air cargo shippers and airport employees), transportation providers and operating agencies, and the relevant surface transportation networks. The relationships among these four elements is shown in Figure 7-1, together with potential modeling assumptions regarding the decisions being made by the various parties in the process.

Airport traveler access/egress mode choice behavior is central to any evaluation of proposed projects or policies to improve intermodal connectivity at airports. In order to develop projections of the increase in traffic using the intermodal facilities and services as the connectivity to the airport is improved, it is necessary to be able to predict how air passengers and airport employees change their travel patterns in response to changes in connectivity between the airport and the intermodal transportation nodes.

There has been extensive past research on modeling air passenger ground access mode choice, as discussed in Chapter 2. Yet the most existing air passenger mode choice models are not well configured to account for the effect of the quality of information provided about the travel options available. In urban transportation, travelers make their journey to work every day and many other types of trip (such as shopping or recreation) relatively frequently. So it is reasonable to assume that they are aware of the available alternatives. But air travelers make relatively few air trips (on average about one per year), and of course about half the air travelers are from outside the region and may be visiting for the first time in their life, so their knowledge

of the alternatives is very limited, or even non-existent. There is thus a significant challenge to reflect these effects appropriately in the mode choice analysis.

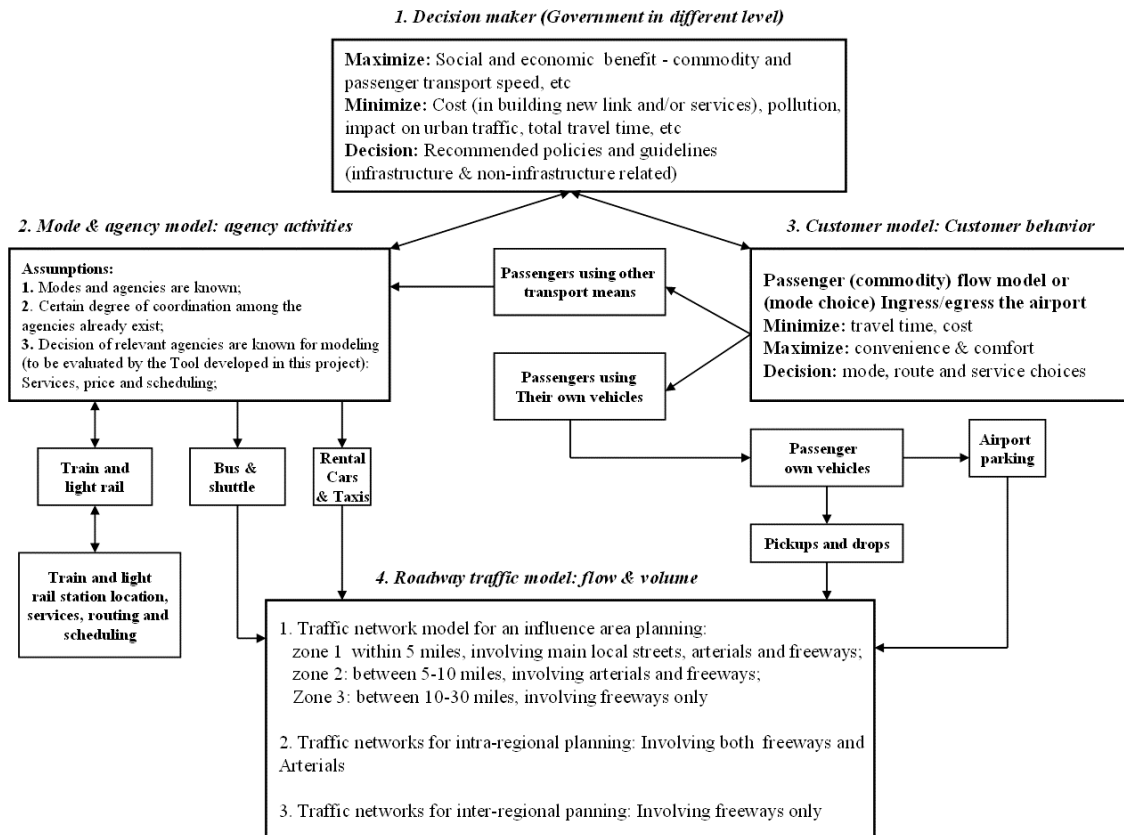


Figure 7-1: Conceptual Modeling Approach

A major component of the current research is the development of an air passenger ground access/egress mode choice model that is sensitive to the attributes of improved intermodal connections. This model will be developed on the basis of prior and on-going research into such models. Data from recent air passenger surveys at selected case study airports will be used to calibrate nested logit models and explore alternative functional forms and select and define appropriate explanatory variables. A major focus of this model development work will be on the accuracy of the models to predict the choice of fixed route public modes, particularly rail services. Many existing models have shown a fairly poor ability to capture the effect of changes

in the attributes of fixed route public modes although this has been tolerated due to the relatively small share of traffic using those modes. However, this is quite unacceptable for a model specifically designed to evaluate improvements in these modes.

While the mode choice of airport employees is often modeled using standard urban journey-to-work mode choice models, in fact airport employees have different work characteristics, such as shift work or multi-day duty cycles, that make such models inappropriate. Therefore the research will also address the development of more appropriate models through an analysis of employee travel mode surveys at selected airports, as well as a review of previous research on the topic. However, surveys of airport employee access travel mode are less common than for air passengers and further research will be necessary in order to obtain a reasonable model for employee travel.

A further aspect of air passenger travel behavior is the interaction between airport ground access mode choice and airport choice, particularly in regions served by multiple commercial airports, such as the San Francisco Bay Area and Southern California. Improving the accessibility of a particular airport through improvements in intermodal connectivity is likely to influence air traveler airport choice as well as ground access mode choice. Although this effect could be particularly significant from a policy perspective, it will not be addressed in the current phase of the research.

Given the limitations of the scope of the proposed research project and the current state of the art of modeling air passenger and airport employee mode choice, as well as likely data limitations, it is recognized that the development of the initial models may well identify aspects that could benefit from follow-on research. Therefore it is proposed to design the analytical framework in a modular way so that the component models can be swapped in and out as necessary (following a toolkit approach). As better models are developed, those components can be upgraded in future work.

In addition to modeling air passenger mode choice behavior, the modeling of the behavior of ground transportation service providers and agencies at an airport forms another challenging issue for this project. Some previous work has addressed the price elasticity for public transit in relation to mode choice modeling for urban travel, but extending these results to airport travel is problematical. The main difficulty is that the multiple transportation providers at airports may behave competitively, cooperatively or something in between, and they may operate

independently or in association with other providers. In addition, the available data for many of the transportation providers at airports are often very limited.

Thus there is a need for research into how best to model transportation provider behavior, based on the following considerations.

(a) There are dynamic interactions between transportation provider service decisions and airport traveler mode choice that determines the transportation provider's strategy for the service offered. These service decisions directly affect the airport traveler mode choice although in past static modeling the reverse interaction has been ignored. Some researchers in the past have noted this dynamic interaction although no previous work has actually tried to model it. This dynamic interaction can be viewed as an example of the relationship between producers and consumers in an economic system, in which consumers \Leftrightarrow airport travelers, products \Leftrightarrow ground transportation services, firms \Leftrightarrow transportation providers, and different types of product \Leftrightarrow different modes.

(b) Competition exists between transportation providers in different modes as well as within a mode. Such competition has the function of ensuring a range of fares and service levels, which meet the different needs of the customers. Private sector transportation providers can be viewed as attempting to maximize their profit through the adjustment of their level of service, frequencies and fares. It is well known in microeconomics that such relationships can be described with nonlinear dynamic models. However, how to solve these nonlinear dynamic models for multiple competitors is not yet clear. One potential approach is to use repetitive multiple-player game theory. There are two possibilities to model the dynamics of this process: (i) to ignore the temporal dimension of the sequence of decisions by each transportation provider and only consider the system characteristics when they reach equilibrium, as is typically done for traffic networks in transportation management and planning; (ii) to consider the time lags that occur in the process as each transportation provider adjusts their service levels in response to actions by their competitors and changes in their ridership or usage levels. Competition between transportation providers can also be addressed at two levels. The simplest is to consider competition between modes but treat the different providers in each mode as an aggregated entity. A more realistic, but more complex, representation would consider the competition between all transportation providers, both within and between modes.

7.2 IAPT Design and Software Development

The design and development of the IAPT can be divided into the following parts:

(1) Graphical user interface: The graphical user interface (GUI) is critical to the effective use of the software. It will be designed to manage the interfaces between the analytical components and the associated data flows, as well as to allow the user to define the problem to be analyzed and to view the results of the analysis. It is expected that many users of the IAPT will not be concerned with the underlying technical details of the modeling or the internal data flows. In particular, the model calibration process can be rather complex and not something that the average user will wish to modify. What the users will require is an easy way to enter the necessary data for a given airport and to define the characteristics of the project to be analyzed, such as consideration of alternative service changes (schedule, routing, frequencies, fare, etc.) or undertaking cost and benefit analysis for adding a new mode to improve connectivity. In the first phase of this project, it would be unrealistic to try to fully develop all these capabilities. However, the main model framework and the interface links will be developed so that the tool can be refined and further developed in the future.

(2) Database design and interface: The supporting database must be configured to meet the data needs of the analytical modules. In order to preserve the planned modularity and flexibility of the IAPT, these analytical modules will communicate with each other through the underlying database. Where common data resources are typically available in a fairly standard format, such as highway network travel time data, it may be helpful to develop utility routines to convert the data to the format used within the IAPT by the analytical modules. Except for model calibration which will typically be performed outside the IAPT, all the other processes will be designed to run automatically. Thus the interfaces between software modules and the database files need to be defined.

(3) Model calibration and software implementation: The general design of the IAPT shown in Figure 7-1 consists of four basic components. The air passenger mode choice model will be developed off-line using standard statistical analysis software for model estimation and calibration. The resulting model will then be incorporated in the IAPT to interface with the other components. The second module will interact iteratively with the mode choice model to predict the transportation provider response to changes in the ground access system and to feed the resulting changes in the transportation services available at the airport back to the mode choice

model. A transportation network model forms the third component of the IAPT and performs two functions. The first is to generate travel times on the regional highway and transit networks serving the airport for use by the mode choice model. The second function is to model the changes in traffic levels on the highway system links in the vicinity of the airport as a result of the changes in airport traveler mode use. It is envisaged that these functions will be performed using standard transportation network analysis software, such as TP+/Cube distributed by Citilabs (www.citilabs.com). The fourth module will utilize the outputs of the other three modules to generate performance measures for each defined project that can be used for evaluation and decision-making.

(4) Component Integration: Since the IAPT is composed of four distinct parts which necessarily will be developed separately, it will be necessary to integrate the different model components and databases to run together in the IAPT. These interfaces can be implemented as shared data files or direct dynamic links using data passing and process triggering techniques.

(5) Validation and testing: The modeling framework implemented in the IAPT will be validated and tested by analyzing alternative potential projects at selected California airports. Since each airport has very different characteristics, including differences in mode availability and service characteristics, the air markets served, air party characteristics, and the surface transportation networks serving the airport, the selected airports and projects will be chosen to provide a range of different conditions to analyze.

7.3 Data Collection

Data collection is one of the key steps in the development and application of the IAPT. For model development and validation (parameter determination, etc.) it is necessary to have adequate and representative data sets for appropriate time periods. The planned data collection needs to address the following issues:

- (a) What data are needed for model development, validation and case studies;
- (b) The required time period for the data being collected;
- (c) The level of detail required for each dataset;
- (d) Potential sources to obtain the required data.

For this project, we need data for the development and validation of three model blocks: air passenger and airport employee behavior, transportation provider (agency) behavior, and

representation of the surface transportation network serving the airport. Accordingly, the data required for this project are also divided into these three categories. In addition to passenger transport data, air freight data are also necessary for considering air freight ground transportation needs. The latter data have significantly different characteristics from data about passenger travel.

7.3.1 Representative Data for the San Francisco Bay Area

In order to support the development of the IAPT and perform the case study analysis planned for the next stage of the project, it is necessary to assemble a complete set of representative data for a specific region. It was decided to base this model development and testing activities on the San Francisco Bay Area. This decision was partly based on the availability of data on the Bay Area airport ground access system and regional transportation system, and partly on the availability of recent air passenger survey data for the entire region. The Metropolitan Transportation Commission (MTC) sponsored air passenger surveys at the three Bay Area commercial service airports in September 2001 and September 2002 (Charles River Associates, 2004).

For consistency with the MTC air passenger survey results and travel time and cost data from the MTC surface transportation network, it was decided to base the analysis of airport ground access trips and modeling of the resulting traffic flow on the MTC system of 1454 traffic analysis zones for the San Francisco Bay Area. This level of analysis resolution was selected because it provides an analysis zone system detailed enough for IAPT application and can readily provide highway and transit travel times from each zone to each airport or other relevant locations from existing MTC data files for use in the IAPT, which reduces the work involved in developing these data. In addition, the MTC surface transportation network analysis model uses the same software platform (TP+) that is proposed for the traffic flow analysis component of the IAPT. The availability of highway network files in a compatible format simplifies developing the analytical capability required to model the assignment of airport-related trips to the general highway network.

Since the air passenger survey data was collected in late August and early September 2001 and 2002, it is important to assemble data on airport ground transportation service characteristics for the same time period. In addition, the corresponding data has been assembled for current conditions in 2005. It is generally recognized that changes in air travel patterns and

airport security following the events of September 11, 2001 have caused significant changes in airport related ground traffic. Thus the air passenger survey data for 2001 and 2002 provide an indication of these changes in air travel characteristics and the airport ground transportation system after September 2001.

Chapter 8. Conclusions

Improving intermodal airport ground access will require coordinated strategic planning, implementation related planning and operational management at different levels of government (airport, local, regional, state-wide and national). Airport ground access studies will thus need to consider institutional issues, to identify problem and needs, to carry out analysis and to develop recommendations. The *California Ground Access to Airports Study* (Landrum & Brown, 2001) has discussed relevant institutional issues, identified problems and needs at California airport, and developed recommendations for future steps to address these needs. That study covers many aspects of strategic planning. Based on the findings of the Landrum & Brown team, the project described in this working paper addresses implementation planning. Whereas the Landrum & Brown study has identified the problems and what needs exist at California airports, specific strategies for ground access improvement will be studied in this project. This working paper has identified alternative strategies for improving intermodal connectivity and potential opportunities at selected California airports. To examine those opportunities in more detail, a combined quantitative and qualitative approach is proposed. The quantitative approach comprises modeling the air passenger mode choice decisions, transportation provider behavior, and traffic flows on the relevant street and highway networks, as well as the interactions between them. The qualitative approach will take into consideration other factors that are more difficult to quantify such as air passenger information and its effect on travel behavior. The combined quantitative and qualitative approach will be designed to provide performance measures to support decision makers at various levels of planning from airport authorities to regional and state agencies.

Due to the projected increase in demand for both air travel and air cargo, airport ground access systems will face a growing challenge in the coming years. Planning for air passenger ground access and egress travel will require greater emphasis on the use of high occupancy modes to reduce the growth in vehicle trips to and from the airport, including enhanced connectivity with regional and intercity rail systems as well as development of dedicated express bus services, whether operated by the public or private sector. Improving the efficiency of existing intermodal connections can contribute to this goal through the improvement of service levels (frequency, fare, comfort, and information) or the addition of new services and access

links. Three principal strategies to improve intermodal connectivity at airports are discussed in this working paper and comprise:

- Direct rail service to the airport
- Improved links to nearby rail stations
- Express bus service to off-airport terminals or regional intermodal terminals.

Although direct rail service to an airport station has been proposed or implemented at an increasing number of large airports worldwide, it is typically a very expensive solution. Improved links to nearby rail stations is generally a much less expensive strategy and more appropriate for smaller airports. These links may take the form of a dedicated shuttle bus service or an automated people-mover. Off-airport terminals located as separate facilities or at regional intermodal terminals can provide a link to the airport using express bus service as well as cheaper parking than at the airport and other services such as airline ticketing and check-in. The principal advantages of such facilities are the reduction in driving time, distance and parking costs for both air passengers and airport employees.

In discussing strategies for ground access improvement at a particular airport, it is necessary to consider what modes currently serve that airport. For potential connections to be economically viable, they need to be able to attract a reasonable level of ridership. It is likely that economically viable intermodal connection opportunities will occur only at the larger airports. Based on those considerations, some potential opportunities for improving ground access has been identified for thirteen California airports. In addition to describing these opportunities, this working paper has presented a preliminary assessment of their feasibility. The thirteen airports include the three major Bay Area airports (SFO, OAK, SJC) which will be used as case study airports for the evaluation of alternative strategies using an analysis model termed the Intermodal Access Planning Tool (IAPT), to be developed as part of future work. A rail transit link to SFO has recently opened, which presents a useful opportunity to compare predictions using the IAPT with the mode use changes that actually occurred. At both OAK and SJC automated people-movers have been proposed to link the airports with the regional rail system and have already been the subject of extensive study. This will present an opportunity to illustrate the potential application of the IAPT by comparing the results of analysis performed using the tool with those performed using other analysis approaches.

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Appendix A

ANNOTATED BIBLIOGRAPHY

Where noted, some abstracts in this annotated bibliography were obtained from the Transportation Research Information Service (TRIS).

Airport Ground Access Planning

Coogan, Matthew A., "Comparing Airport Ground Access: A Transatlantic Look at an Intermodal Issue," TR News, No. 181, November-December 1995.

Abstract by TRIS: This article examines airport ground access, with specific interest in the following areas: trends in U.S. ground access patterns; use of rail in Europe; components of successful European rail ground access services; users of successful rail services; comparison of airport ground access services in San Francisco and in Zurich; categorizing airport access systems; and a better way to look at airport access. In conclusion, it is stated that U.S. airport ground access planners should work to bring their systems to overall mode shares above 30%, to emulate the ridership levels attained by the most completely interconnected systems in Europe.

Coogan, Matthew A., "European and U.S. Airports push for better Ground Access," Mass Transit, Vol. 22, No. 3, May/June 1996.

Abstract by TRIS: In both Europe and the U.S., the problem of improving the quality of ground access to airports is receiving policy attention at the highest level. Recent research conducted for the Federal Aviation Administration suggests that when comparing travel behavior between the two continents, the nature of demand for ground services is similar, and the nature of consumer behavior is similar; but the nature of the ground transportation systems into which the airport has to be integrated are markedly different. Yet, improved intermodal connections for passengers in advanced airports like De Gaulle in Paris and San Francisco International show how the airport congestion is being tackled on both sides of the Atlantic.

Cunningham, Lawrence F., and James H. Gerlach, "Transportation Agencies' Experiences with Decision Support Systems for Airport Ground Access Planning," Transportation, Vol. 25, No. 1, February 1998.

The authors discuss the issues of decision support systems for airport ground access planning using both quantitative and qualitative approaches. The main findings are: (1) decision makers need a decision support system; (2) using quantitative modeling for strategic decision support is very difficult due to a lack of confidence in the model results by the decision makers; (3) modeling is very costly and difficult. Although modelers are confident about the accuracy of their models, transportation officials often believe that the information supplied is flawed by a number of defects that minimize the value to the decision maker, leading to the situation in which decision maker lose confidence in the use of quantitative analysis. A major concern is that human behavior is not sufficiently well understood to predict mathematically how travelers make individual transportation decisions. To avoid these difficulties, the paper recommends that efforts are undertaken to improve quantitative modeling and to use a combined quantitative and qualitative approach for decision making.

Landrum & Brown (with Booz Allen & Hamilton, Planning Company Associates, and Nelson/Nygaard), Ground Access to Airport Study, Prepared for the California Department of Transportation, Division of Aeronautics, Sacramento, August 2001. Executive Summary; Working Paper One: Roles and Responsibilities; Working Paper Two: Issues and Problems; Working Paper Three: Recommendations.

Abstract by TRIS: A study to assist Caltrans identify needs and provide tools to improve the planning, programming and implementing of ground access to airport projects in California. The study focused on 47 airports in California and one in Mexico (Aeropuerto de Tijuana S.A. de C.V.-Rodriguez). Tasks were identified and summarized. They include: 1) Task 1: Ground Access Needs Inventory; 2) Identification of Roles and Responsibilities; 3) Identification of Issues and Problems; 4) Recommended Strategies; and, 5) Project Coordination.

Madas, Michael A., and Konstantinos G. Zografos, "Practical Implementation of Airport Demand Management: From Instruments to Strategies," Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., January 2005.

Author abstract: Demand management has been long recognized as a principal instrument to deal with capacity shortfalls and delay phenomena in air transport. Transportation researchers have examined the potential for applying airport demand management in the form of administrative measures, as well as economic and hybrid instruments such as the implementation of congestion-based pricing, slot trading, and auctions. These measures and instruments have been extensively examined and critically assessed in the literature. Despite the comprehensive amount of research in the field, there seems to be a knowledge gap as to how these instruments can be integrated and operationalized to constitute a set of principal building components for the implementation of an overall demand management strategy. Based on the state-of-the-art and state-of-practice review of demand management instruments, a number of distinct strategies are identified and examined in this paper: i) status quo with recycling and centralized trading of the pool (*Enhanced Status Quo*), ii) grandfather rights with recycling, auctioning of the pool, and secondary trading (*Gradual*), iii) pure (congestion-based) pricing strategy (*Congestion Pricing*), iv) grandfather rights with full trading of all slots (*Controlled Trading*), and v) removal of grandfather rights accompanied by decentralized auctions and secondary trading (*Big Bang with auctions and secondary trading*). The objective of this paper is to capitalise on the existing research work in the field of airport demand management instruments to define a series of distinct strategies as the candidate strategic options for practical implementation.

Mundy, Ray A., "Evolution of Ground Transportation Management as a Major Airport Function," Transportation Research Record, No. 1373, 1992.

Author abstract: Airport organization is discussed, special attention being given to the structure of landside management. The past structures of airport management are surveyed, the origin of the structures of these organizations is explained, and ways the structures have evolved from 1940 to the present are discussed. With this background the results of a recent U.S. survey on current airport organizational structures are presented as they pertain to ground transportation management. Organizational literature and theory are discussed as they pertain to the potential development of airport organizational structure; specifically, four evolutionary stages of ground transportation management are proposed. It is suggested that airport ground transportation officials are represented inadequately in the management of U.S. airports as depicted by their representation in the organizational charts. However, this is changing as the management of landside activities receives more attention and resource prominence within the overall management of modern airport complexes.

Ndoh, N.N., and N.J. Ashford, "Evaluation of Airport Access Level of Service," Transportation Research Record, No. 1423, 1993.

Author abstract: Access to airports is a major influence on passenger distribution among competing airports, and the level of service of the available modes also affects the observed modal split at each airport. Access to the airport is an integral component of the passenger's trip from origin to final destination. Improvements at an airport therefore need to be matched by ensuring that the level of service of the airport's access system is also adequate. Evaluation of level of service for airport landside, in particular the terminal, has been given research attention. Little research has been done to measure the level of service of access to airports, yet these measurements are required by airport management to improve access or formulate policies to influence modal split. Research in level-of-service evaluation to airport access using psychometric techniques is discussed. The raison d'etre of the methodology is to provide scale values of level of service and use of the scales developed to investigate the effects of level of service on mode choice. The method was applied to a case study of access at a London airport. Results are presented in terms of passengers' satisfaction with various access attributes, and the scale deduced for access information indicates the need for better distribution of access information to air passengers.

Shapiro, Phillip S., and Marcy Katzman, "Relationships between Airport Activity and Ground Transportation Needs," Transportation Research Record, No. 1622, August 1998.

Author abstract: Shortly after the passage of the Intermodal Surface Transportation Efficiency Act of 1991, the Federal Highway Administration and the Federal Aviation Administration recognized that there was very little guidance available for airport operators and metropolitan planning organizations (MPOs) to use for planning intermodal access to airports in the United States. As a result, the "Intermodal Ground Access to Airports: A Planning Guide" was developed. This Guide is designed to provide guidance to states, MPOs, and airport operators on the types of analyses that should be performed when airport access is being planned. It describes the airport access planning process and procedures for performing analyses. During the development of the Guide, relationships were developed between the level of originating passengers at American airports and the characteristics of airport access and landside facilities. The types of characteristics that were related to originating passengers included public parking, vehicle trips, terminal curbside design, and mode of access. Some of the relationships that were developed, how they were derived, and their importance to airport access planning are now presented. In addition, some additional relationships that should be developed are suggested.

Thompson, Kelsey A., Michael S. Bomba and C. Michael Walton, The Trans-Texas Corridor and the Texas Airport System: Opportunities and Challenges, Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., January 2005.

Abstract by TRIS: The proposed Trans-Texas Corridor (TTC) is a series of multimodal transportation corridors traversing approximately 4,000 miles (6,440 km) in rural Texas that includes ten controlled-access toll lanes for passenger cars and commercial trucks, six rail lines for high-speed rail, commuter rail, and freight rail, and a 200 foot (61 m) wide utility zone. The TTC will allow for faster and safer movement of people and goods throughout Texas, relieve congestion on existing roadways, divert hazardous materials away from urban areas, and stimulate economic growth and development along its path. However, to become fully integrated with the Texas transportation network, the TTC must also consider connections with the state's extensive airport system. While the TTC could produce significant opportunities for commercial services and general aviation airports, many of its planners and engineers are not familiar with the special land use and connectivity needs of airports. The TTC also has the potential to limit airport safety, operations, and expansion if planned poorly. Possible airport benefits include increased usage due to improved

airport user access and indirectly to economic development along its path. Potential challenges include infringement on approaches and approach procedures, restriction of airport growth, limited accessibility or connectivity to the TTC, and competition with land-based modes for passenger and freight movement. Integrating Texas airports into the overall multimodal TTC design will leverage intermodal transportation for intercity travel and freight movement throughout Texas.

Airport Ground Access Facilities

Lott, J. Sam, and David D. Hathaway, "Ready to Roll: Following More than Three Decades of Development, Personal Rapid Transit and Group Rapid Transit Technology is Poised for Application in Demonstration Projects that could Establish its Benefits for the Nation's Airports," Civil Engineering, Vol. 75, No. 5, May 2005, p. 58-63.

The article reviews the development of technology for personal rapid transit (PRT) - also known as personal automated transport - and its derivative, group rapid transit (GRT). The concept of PRT emerged at the time when automated people mover (APM) systems were first beginning to be applied in major activity centers and a federally funded PRT system developed at West Virginia University has been in operation since the 1970s. However, no other applications have endured and only a few technologies have advanced to the test track stage. The article describes several new PRT/GRT designs that have been brought to the prototype stage in recent years and discusses a number of studies that have explored the application of these technologies to passenger transportation at airports. The article concludes that the U.S. airport industry needs to invest in demonstration-level projects to determine whether PRT and GRT can help meet the challenges that airports will face in the future.

Gomke, Russ S., Bruce Haldors, Peter Lindsay and Heather Bornhorst, "Port of Seattle Airport Access Study Microsimulation Modeling," Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., January 2005.

This paper describes the development and use of a microscopic traffic simulation model to evaluate the operation of the Seattle-Tacoma International Airport (SeaTac) landside roadway system. A total of 10 different users of the roadway network were identified and modeled. The simulation model was used to identify the bottleneck areas and operational features of the existing landside network, and revealed deficiencies with the current roadside system that would lead to severe access congestion with increased future airport activity. The paper discusses the use of the model to evaluate the effect of several proposed changes to the roadway network on the level of service of the landside roadway system.

Intermodal Planning

Gosling, Geoffrey D., "Airport Ground Access and Intermodal Interface," Transportation Research Record, No. 1600, September 1997.

Author abstract: The airport ground transportation system is receiving increasing attention from airport authorities and regional transportation planning agencies. The need to plan for facilities at the airport and concern about the impact of traffic on streets and highways surrounding the airport, and about emissions generated by this traffic are forcing airports to consider strategies to reduce or mitigate ground access traffic. The 1991 Intermodal Surface Transportation Efficiency Act has caused transportation agencies at all levels to address the integration of different transportation modes, including coordination between the air and surface components of the

transportation system. The range of ground access planning issues is reviewed, and three alternative strategies to improve intermodal connections at airports are discussed: new or upgraded rail links, off-airport terminals, and ground transportation centers at the airport. The planning and design issues that arise with each type of facility are addressed, as well as the analytical tools and data needed to evaluate the wide range of airport ground access projects and to plan the implementation of those selected. These include air passenger surveys, development of operational data on the ground access system, and use of access mode choice and traffic flow models. Research needs in the area of airport ground access are also discussed.

Kaper, G. A., "Airport Links by Public Transport," Public Transport International, Vol. 53, March 2004, p. 30-33.

Abstract by TRIS: The article examines the possibilities for public transit to provide airport links and it sets out some condition for their success. The focus of the article is on rail, because of its usually high capacity and speed. The first condition is sufficient market potential, to be divided in: air passengers; employees; and visitors. An equally vital condition is the creation of a dedicated system for short distance connections to the main urban area served by the airport. In addition, customer related and operator related conditions need to consider the following for the passenger: convenience, transparency, information, accessibility, safety, reliability, and image. And, for the operator: marketing, communication, income, and fulfilment.

Lacombe, Annalynn, "Ground Access to Airports: Prospects for Intermodalism," Transportation Quarterly, Vol 48, No. 4, Autumn 1994.

This paper examines the potential role for intermodal approaches to airport ground access problems in light of the requirements and goals of the Clear Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991. The paper explores the regulatory, funding and institutional constraints that hinder intermodal approaches to addressing airport ground access problems. It notes that officials at the Federal Highway Administration and Federal Aviation Administration had expressed different opinions on the extent to which airport planning must be incorporated into local transportation plans, and shows that practice varies widely across a sample of 11 metropolitan planning organizations (MPOs). It also examines how selected airport access projects in those regions have been funded. The paper discusses the limited Federal funds available for aviation planning at a regional level and the need to improve guidance to both MPOs and airport authorities on how to perform airport ground access planning, as well as the institutional conflicts that can arise over which agencies should fund airport ground access projects and the contribution of parking revenues to airport finance. It concludes by examining opportunities for cooperation between airport authorities and local planning agencies, but notes that the restrictions in Federal regulations on the uses of airport grants present obstacles to intermodal ground access solutions that would require Congressional action to remove.

Leigh Fisher Associates, in association with Matthew A. Coogan and MarketSense, Improving Public Transportation Access to Large Airports, Transit Cooperative Research Program Report 62, Transportation Research Board, National Academy Press, Washington, D.C., 2000.

Abstract by TRIS: This report will be of interest to individuals involved in planning and implementing improved public transportation access to large airports. The dramatic increases in air travel, congestion near airports, and interest in providing rail transit to airports make this a very timely research report. Chapter 1 defines large airports and public transportation services, as a subset of the ground transportation services providing access to airports. Chapter 2 describes travel mode choice patterns and other data for passengers and employees at selected large U.S. and international airports. Key factors affecting passenger and employee use of public transportation for

airport access are also presented. Market trends and factors affecting ridership at nine U.S. airports with direct rail service are presented as well as trends and factors at U.S. airports with rubber-tired access systems such as prearranged limousines, shared-ride vans, express buses, and multistop buses. Chapter 3 presents a market research approach to planning public transportation to airports. Chapter 4 describes 14 of the most successful airport access systems in the world. Chapter 5 assimilates the findings from Chapter 4 and presents lessons learned from the successful rail systems. Chapter 6 summarizes recent transit industry developments in the following six areas that could affect ground access to airports: advanced traveler information systems, technology for ridesharing, emerging bus technology, emerging rail technology, automated people mover technology, and alternative strategies for off-site airport check-in. Chapter 7 provides an overview of the key legal, financial, institutional, and jurisdictional factors affecting public transportation to airports. Chapter 8 examines implications for further research.

Leigh Fisher Associates, in association with Matthew A. Coogan and MarketSense, Strategies for Improving Public Transportation Access to Large Airports, Transit Cooperative Research Program Report 83, Transportation Research Board, National Academy Press, Washington, D.C., 2002.

Abstract by TRIS: This report will be of interest to individuals involved in planning and implementing improved public transportation access to large airports. The report presents the results of the second phase of a two-part research effort. The results of the first phase of the research were published as Transit Cooperative Research Program (TCRP) Report 62: "Improving Public Transportation Access to Large Airports." The two reports provide considerable information and practical guidance. In this report, Chapter 1 provides background on why this study is important at this time, which is because congestion at large airports continues to increase. Chapters 2, 3, and 4 present aspects of a market-based approach to planning ground access services to airports. Chapters 5, 6, and 7 examine management strategies for improving the quality of public transportation services to large airports. Chapter 8 integrates the entire report, summarizing key elements of the previous seven chapters and presenting a guidebook for a market-based strategy for improving public transportation access to large airports.

Lin, Kenneth, "Making New Connections: Airport Rail Links in the United States," Japan Railway & Transport Review, No. 39, July 2004, p. 26-33.

The article analyzes the factors that contribute to recent increasing interest in rail links to airports and lists all U.S. airports with rail links. The article focuses on four new airport rail links opened since 2001 and discusses the different technologies used at each airport: John F Kennedy International Airport (Airtrain), Newark Liberty International Airport (Airtrain), San Francisco International Airport: (BART), and Portland International Airport (MAX). The article points out the continuing interest in constructing new rail links to airports and stresses that to be successful the link should be high-quality, rapid, and reliable.

Lopez-Pita, Andres, and Francesc Robuste, "High-Speed Line Airport Connections in Europe: State-of-the-Art Study," Transportation Research Record, No. 1863, 2004, p. 9-18.

Author abstract: Throughout the history of the different modes of transport, the idea of intermodal competition has, until very recently, dominated viewpoints. In the past 10 years, however, recognition of the need for collaboration between rail and aviation transport has become increasingly evident, mainly as a result of increased mobility. Since the 1950s, in Europe, rail transport has been the prevailing method used to connect urban centers to their respective airports. With the introduction of high-speed rail service, however, a distinctly new type of collaboration between both transport modes has appeared, for through the use of high-speed rail connections, travelers from areas located as far as 300 to 400 km from the urban center can reach the airport with

ease. Presented are the current transport solutions that have been adopted by certain European airports in regard to high-speed rail. There is also an objective to reach some conclusions that could be of interest to the airports in Europe or around the world that are not currently using high-speed rail service.

Mahmassani, Hani S., Michael McNerny, Keisha Slaughter and Hussein Chebli, Synthesis of Literature and Application to Texas Airports, Research Report 1849-1, Center for Transportation Research, University of Texas at Austin, June 2000.

Author abstract: Air transportation plays a vital role in the Texas economy. Air passenger/cargo traffic is projected to continue to increase considerably at many of the state's large airports. Ground access to airports is an important function that must be provided for at the regional level as well as in the immediate vicinity of the facility itself. Congestion problems affecting airport access are in some instances reaching unacceptable proportions; there are also concerns regarding the negative impacts such congestion is having on air quality and other environmental considerations. Accordingly, these issues require concerted action to meet project needs. To address the above challenges and current gaps, this project takes a comprehensive look at the landside access issues associated with the major airports in the state. It seeks to improve on existing planning procedures and processes to meet the unique needs of airport traffic demand, for both people and goods. To be effective, planning for airport ground access must be multimodal and intermodal, consider operational, regulatory and capital-intensive infrastructure provision issues, consider multiple levels of scale/resolution, and recognize the unique dynamic aspects of air traffic demand, i.e., its temporal patterns. This report presents an overview and synthesis of the literature reviewed under the first task. The research team concludes that the motivation and the need for the ground access study is high and that existing approaches and documents are insufficient to meet the needs for strategic ground access planning of major airports in Texas.

Mahmassani, Hani S., Keisha Slaughter, Hussein Chebli and Michael McNerny, Domestic and International Best Practice Case Studies, Research Report 1849-2, Center for Transportation Research, University of Texas at Austin, February 2001.

Author abstract: Air transportation plays a vital role in the Texas economy. Air passenger/cargo traffic is projected to continue to increase considerably at many of the state's large airports. Ground access to airports is an important function that must be provided for at the regional level as well as in the immediate vicinity of the facility itself. Congestion problems affecting airport access are in some instances reaching unacceptable proportions; there are also concerns regarding the negative impacts such congestion is having on air quality and other environmental considerations. Accordingly, these issues require concerted action to meet project needs. To address the above challenges and current gaps, this project will take a comprehensive look at the landside access issues associated with major airports in the state. It will seek to improve on existing planning procedures and processes to meet the unique needs of airport traffic demand, for both people and goods. To be effective, planning for airport access must be multimodal and intermodal; consider operational, regulatory, and capital-intensive infrastructure provision issues; consider multiple levels of scale/resolution; and recognize the unique dynamic aspects of air traffic demand, i.e., its temporal patterns. This report documents domestic and international best practice case studies. The overall impact of the entire airport transportation network must be considered in order to address ground access issues. This study confirms the objectives and tasks laid out in the research proposal.

Mahmassani, Hani S., Hussein Chebli, Keisha Slaughter and F. Jordan Ludders, Assessment of Intermodal Strategies for Airport Access, Research Report 1849-3, Center for Transportation Research, University of Texas at Austin, April 2002.

This report forms the final report on a three-year comprehensive study that examined landside access issues associated with major airports in Texas. The report presents a review of the related literature, including reports and articles covering such topics as airport access, public transportation to airports, off-airport terminals, and dynamic traffic assignment. It summarizes current best practices for airport ground access planning as determined from a study of successful domestic and international airports and documented in more detail in an earlier report prepared as part of the overall study. The report describes an analysis methodology and framework that was developed to perform a stated preference analysis of airport access mode choice behavior in order to assess alternative intermodal airport access strategies. The report documents the design and administration of stated preference surveys that were undertaken of air travelers from three major Texas airports and presents the relevant findings. The report also presents results of an evaluation of alternative intermodal access strategies at Dallas-Fort Worth International Airport that was undertaken using a computer network simulation model. Finally, the report concludes by presenting a summary of findings and recommendations to the Texas Department of Transportation for further implementation and possible future steps in the area of airport access.

Mahmassani, Hani S., Hussein Chebli, Keisha Slaughter and F. Jordan Ludders, Strategies for Airport Accessibility, Project Summary Report 1849-S, Center for Transportation Research, University of Texas at Austin, December 2002.

This report provides a high-level summary of the methodology and findings of a multi-year study that examined short-term and long-term intermodal and multimodal strategies for effective management of landside access congestion at Texas airports. The study developed a stated preference mode choice model to understand traveler's behavior and incorporated this into a dynamic traffic assignment simulation tool to simulate traffic flows after the implementation of airport access improvement scenarios. This was used to evaluate alternative airport access strategies at Dallas-Fort Worth International Airport. The report recommended that airport ground access planning should be integrated with other transportation plans and programs and summarized the role of different state and local agencies in planning for airport access.

Shapiro, Phillip S., *et al.*, Intermodal Ground Access to Airports: A Planning Guide, Prepared for the Federal Highway Administration and the Federal Aviation Administration, Report No. DOT/FAA/PP/96-3, Bellomo-McGee, Inc., Vienna, Virginia, December 1996.

Abstract by TRIS: This guide is designed for use by airport, state, local, and metropolitan planners to manage and plan for intermodal ground access for all types of airports. It identifies key components of an airport access work program and contains detailed sections on airport groundside access planning methods, including data collection methods and analysis, survey strategies, identification of current travel patterns and emerging trends, forecasting techniques, estimating modal split, evaluation of alternatives, and implementation. The guide focuses on providing passengers access to commercial airports from primary origins or destinations. It deals with: off-airport roads, transit and HOV facilities up to airport boundary; and on-airport roads, parking circulation elements, transit and curb facilities up to the terminal entrance. Guidance for conducting passenger origin-destination surveys is included. Sample questionnaires for various types of surveys are included in the appendices. This guide compiles information from other sources and presents this information so that it can be used to systematically analyze airport access problems and alternative solutions.

Yevdokimov, Yuri V., "Measuring Economic Benefits of Intermodal Transportation," Transportation Law Journal, Vol. 27, No3, p.439-452.

This paper examines the limitations of cost benefit analysis and related techniques that are typically used to analyze the benefits of transportation investments when considering the contribution of intermodal transportation to the growth of the economy. The paper describes an approach using microeconomic and macroeconomic simulation to explore the increased productivity resulting from an expansion of the transportation system and discusses the major findings of the study. However, the details of the simulation analysis are not presented in the paper and therefore it is not possible to assess the reasonableness of the modeling approach adopted. Moreover, the analysis was based on modeling the effect of an assumed increase in the volume of transportation in a particular market or a one-time increase in the scale of the transportation system, including the volume of traffic moving on the network, rather than specific investment actions that would improve the performance of the intermodal transportation system.

Airport Bus and Van Services

Boyle, Daniel K., and Paul R. Gawkowski, "Public Transportation for Airport Employees: Q3 Extension into John F. Kennedy International Airport," Transportation Research Record, No. 1373, 1992.

Author abstract: Public transportation extensions to airports have often focused on the needs of air travelers; the employee market has generally received less attention in ground transportation planning at airports. An extension of a local New York City Transit Authority bus route, the Q3, into John F. Kennedy International Airport (JFK) is described, and the results of a survey of Q3 riders are presented. JFK employees form a stable ridership base, and those recently employed are especially dependent on Q3 service. The route extension has been successful in attracting new riders from alternative modes (primarily the automobile). Free transfer privileges with connecting bus routes have been instrumental in establishing a large service area for local bus service to JFK.

California Public Utilities Commission, The California Airport Shuttle Van Industry, A Report by the Transportation Division, San Francisco, December 1992.

Author abstract: This report examines the on-call airport shuttle van industry (centering efforts on LAX and SFO) and presents possible alternatives for changes in Commission rules and programs. Several parties including airport commissions throughout California, have called upon the Commission to investigate problems in the industry. Staff has identified two main policy issues in the Commission's regulatory program: strictness of entry regulation and clarity of independent contractor regulation.

Mohr, Eric, and Geoffrey D. Gosling, "The Role of Door-to-Door Vans in Airport Ground Transportation," Transportation Research Record, No. 1461, December 1994.

Author abstract: The characteristics of door-to-door van service in the airport ground transportation system are analyzed. The evolution of airport ground transport is traced; the market niche of door-to-door van service is delineated; and air passenger characteristics favoring door-to-door modes in general and door-to-door vans in particular are reviewed. A detailed intermodal comparison of vehicle kilometers (vehicle miles), person minutes, and user cost for air-traveling parties of various sizes using the six airport ground transport modes is presented. Management issues facing door-to-door van service managers are discussed, and information needs of the industry and future research needs are indicated.

Spear, Bruce D., An Analysis of the Demand for Airport Bus Services at Washington National and Dulles International Airports, Report No. DOT-TSC-FAA-84-2, Transportation Systems Center, Cambridge, Massachusetts, May 1984.

Author abstract: This report presents the findings and recommendations from a study of the demand for airport bus service at Washington National and Dulles International Airports. The purpose of the study was to provide FAA's Metropolitan Washington Airports with a better understanding of the existing and potential markets for airport bus services to assist them in planning bus service improvements and marketing strategies. Data from several recent surveys of Washington metropolitan air passenger and airport bus users were analyzed to develop a profile of the market and to gain an understanding of airport access mode choice behavior. Based on this knowledge a set of airport access mode choice models were developed and calibrated. The models were used to forecast the share of air passengers who would be attracted to airport bus service under various fare and service scenarios. The results of these model applications formed the basis for recommendations regarding improvements in airport bus service at the two airports.

Airport Rail Links

Cho, Aileen, "Growing Number of Flyers take the Train to the Plane," Engineering News Record, Vol. 251, No. 24, December 15, 2003, p. 61.

Abstract by TRIS: This article, part of a special report titled "Airports of the Future", looks at the ways that North American airports are finally achieving some of the connectivity long associated with their counterparts overseas. On December 17, 2003, Airtrain's debut will mark the first time Manhattan has had a light rail connection to an airport in the city. It does not have express service and it was delayed a year after the death of a train operator during testing, but its construction proceeded more smoothly than a similar system serving Newark, NJ. Minneapolis, San Francisco, Miami and Dallas-Ft. Worth are other places where intermodal links are completed or underway.

Foote, Peter J., Sarah J. LaBelle and Darwin G. Stuart, "Increasing Rail Transit Access to Airports in Chicago," Transportation Research Record, No. 1600, 1997.

Author abstract: The results of two surveys of arriving and departing air travelers at O'Hare and Midway airports in Chicago concerning their choice of ground access and egress modes are reported. The purpose of the surveys was to better understand the travelers' trip purpose, trip frequency, origin and destination location, and perception of rail rapid transit as an access mode, so that promotional programs can be developed to increase this transit use. For both airports, about 15% of all air travelers whose ground trip-ends fell within the Chicago Transit Authority's (CTA's) service area used rail transit for access and egress. Rail access has been provided to O'Hare (Northwest Corridor, Blue Line) since 1984 and to Midway (Southwest Corridor, Orange Line) since 1993. The CTA has undertaken targeted promotional campaigns to increase the overall diversion of automobile travelers in both corridors to rapid transit. Such improved access to the airport increases the potential for greater market penetration. Passenger characteristics and survey methods are summarized, and the two ground access surveys are compared. The importance of express transit service as a significant consideration for managers and designers of major airports is highlighted.

Sharp, Andrew, "Air Rail Links: Challenges and Benefits," International Airport Review, Vol. 7, Issue 3, 2003, p. 49-52.

The article lists some of the benefits of rail links to airports in European countries. It notes that airport employees are more likely to use the rail links than air passengers and that some airports are served by more than one type of rail system. It suggests that airport rail links could also be valuable for moving freight, such as building materials and air cargo. Also, air passengers who take rail run less risk of missing their flight than passengers who drive to the airport by car. The challenge is that it is difficult to generate support for new or improved rail links from all the stakeholders since some of them may lose business because of the rail links.

Sharp, Andrew, "Which Way to the Airport?: Do Airports Need Dedicated Express Shuttle Trains, or should Services be aimed at all Rail Users?" Railway Gazette International, Vol. 161, No. 4, April 2005, p. 217-219.

The article examines proposed changes to London's Gatwick Express. It notes that many air passengers prefer dedicated rail service to the airport because it can provide special equipment with adequate provision for luggage; The platform and train car floor should be at the same level so that luggage is easy to handle, while passengers with a large amount of luggage feel less stressed if it takes some time to board the train if it is a dedicated train. However, the argument against dedicated trains is that the expensive, uncrowded dedicated train can be viewed as a waste of resources while local commuters are required to use overcrowded trains. The article examines the market for both dedicated and non-dedicated trains and suggests that a busy airport can justify a dedicated train to the airport if most of the traffic uses a single corridor between the airport and the city, while a train system that serves both local and airport passengers is more appropriate if the air traffic catchment area is more dispersed. These principles are illustrated with four examples of airports rail service: Shanghai's maglev airport link, the O'Hare Express in Chicago, the CG Express in Paris, and Chubu's Centrair rail link.

Off-Airport Terminals

Cook, Chris, "Hands Free to the Airport?: In the U.S. and Canada, there's Potential for Rail Station Remote Luggage Check-in," Railway Age, January 2004.

Abstract by TRIS: Remote check-in is already available in Europe and Asia, where airline passengers can check in, both for their boarding passes and baggage, at airport/rail link stations. Today, that service is available in the United Kingdom, Hong Kong, Madrid and Kuala Lumpur. The U.S. Federal Aviation Administration has approved the operations for U.S. airlines, and in Canada, Rail Air International Limited is in discussion with a number of North American agencies to make remote check-in a reality.

Kaplan, Margorie, "Airport Access: Case Study of a Remote Terminal Operation," Transportation Research Record, No. 803, 1981.

Author abstract: Interest has developed in recent years in remote airport terminals as a means of reducing landside congestion at metropolitan airports. A prime consideration in assessing the suitability of the remote terminal concept for a particular airport lies in its economic feasibility (i.e., Can it attract sufficient patronage and be operated efficiently enough to be cost effective?). This paper analyzes the costs of operating the FlyAway bus system, an express bus service that links Los Angeles International Airport with a suburban area that contributes about 15 percent of the airport's passengers. Although it does not offer baggage check-in, other services, such as

ticketing, are offered on a limited basis and expansion to a full-service remote terminal is a distinct possibility in the future. The objective is to identify actual costs relative to all aspects of the operation to assist planners in determining the costs of such systems for other airports. Included are overviews of physical characteristics, operational problems, passenger market segment, airport and bus patronage growth rates, cost-revenue ratios of bus operation and terminal maintenance, bus fuel price impacts, foregone bus terminal site rental income, break-even patronage, facility replacement costs, and prognosis for future activity. After five years of operation, many of them beset with problems, FlyAway appears to be thriving. A recent passenger survey revealed that much of the system's attractiveness lies in its economical fare, frequent headways, low-cost parking, and dependable service. As passenger volumes rise and roadway capacity continues to be stretched beyond design standards, remote terminals offer the best hope for alleviating airport congestion on the ground. FlyAway demonstrates, that, not only do they work, but they work well and cost effectively.

Mansel, Douglas M., and Peter B. Mandle, "Off-Airport Passenger Check-in Facilities at Satellite Terminals – A Review," Transportation Research Record, No. 1703, 2000.

Author abstract: In many regions, satellite (i.e., remote, off-airport) terminals that provide baggage check-in and baggage claim would provide several advantages to air travelers, including the ability to avoid parking at the airport or asking a relative or friend to drive to the airport, once to drop off and once to pick up the passengers; congested airline ticket counters and long lines at the skycap podiums; and traffic congestion on the way to the airport and at the airport curbsides. In some regions, such as Boston and Los Angeles, the benefits of satellite terminals have already been demonstrated, even though these terminals currently do not provide baggage check-in or baggage claim. In the United States, satellite terminals that provide baggage check-in and baggage claim serve only passengers traveling on a single airline or a distinct group of airline passengers (e.g., only passengers disembarking a cruise ship). However, baggage check-in and baggage claim for the general public is provided at several satellite terminals that serve overseas airports. The two most significant challenges to be overcome are satisfying the Federal Aviation Administration security requirements and justifying to airlines that the benefits of providing baggage check-in and baggage claim at a satellite terminal outweigh the associated costs.

"Workshop 1: Implementation of Off-Airport Terminals," in Geoffrey D. Gosling (ed.), Ground Access to Airports, Proceedings of Two Workshops Sponsored by the Federal Aviation Administration, Berkeley, California, October 31 - November 2, 1994, Proceedings UCB-ITS-P-94-1, Institute of Transportation Studies, University of California, Berkeley, December 1994.

Author abstract: The two workshops described in these proceedings form part of an effort to promote increased dialogue between the Federal Aviation Administration (FAA) and the airport community on goals, constraints, and needs in the development of more effective airport access strategies. Because of the intermodal character of airport access, financial and institutional factors tend to be the dominant barriers to implantation. As a consequence, the workshops emphasized contrasting institutional perspectives, with participants being drawn from airports, airlines, ground transportation providers, planning organizations, government, and experts in the field. The program consisted of two workshops. The first was structured as an exercise in the practical application of one of the more promising intermodal approaches to airport access: off-airport terminals. Problems identified in the course of this exercise provided a useful basis for the more general analysis of the second workshop. This workshop examined a wider range of ground access solutions in order to identify critical gaps in knowledge which impede the development of effective investment strategies. The primary objective of the workshop was to formulate a long-range program of research and development capable of bridging these gaps.

Airport Access Mode Choice

Gosling, Geoffrey D., "Analysis of Changes in Airport Ground Access Mode Use," Rebuilding Inner City Airports, Proceedings of the 24th International Air Transportation Conference, Louisville, Kentucky, June 5-7, 1996, American Society of Civil Engineers, New York, 1996.

Author abstract: Increasing concern over the impacts of airport generated traffic on the surrounding street and highway system, as well as the emissions generated by those vehicle trips, is forcing airports to pay more attention to strategies to reduce or mitigate ground access traffic. However, airport ground access traffic covers many different types of trips, and few airports currently have effective systems to collect and integrate the information to effectively manage this system. The introduction of automated vehicle identification systems at a growing number of airports has created a significant data resource, which is largely used only for revenue accounting. This paper presents the results of a comprehensive analysis of ground access mode use patterns at seven California airports over a two-year period that integrated information from a wide range of sources at each airport. It was found that use of the different modes varied significantly throughout the year, even after allowing for changes in air traffic volumes. Since air passenger surveys are typically only conducted for short periods of time at infrequent intervals, this could lead to significant errors if these data are used to predict airport ground access traffic. The paper explores the factors that contribute to these fluctuations and discusses how a more comprehensive integration of existing data could greatly improve the ability of airports to predict short-term changes in demand for different modes and longer-term impacts of ground access management strategies.

Gosling, Geoffrey D., with Cambridge Systematics, Inc., and SH&E, Inc., SCAG Regional Airport Demand Model: Literature Review, Prepared for the Southern California Association of Governments, Los Angeles, California, June 2003.

This report presents an extensive literature review of past reports and papers on airport demand allocation models, airport ground access mode choice models, air passenger trip generation models, and air service forecasting models that was prepared as part of a study to develop a regional airport demand model for Southern California. The report discusses the differences in model formulations that have been adopted in prior studies that have developed airport choice and airport ground access mode choice models and discusses the explanatory variables that have been incorporated in various models, including access time and cost, income, luggage and gender. Based on the survey of the literature, the report discusses potential improvements that could be made in modeling airport choice and airport ground access mode choice as part of the planned regional airport demand model development.

Karlaftis, Matthew, "Predicting Mode Choice through Multivariate Recursive Partitioning," Journal of Transportation Engineering, Vol. 130, no. 2, Mar/Apr. 2004.

Author abstract: Understanding and predicting individual mode choice decisions can help address issues ranging from forecasting demand for new modes of transport to understanding the underlying traveler behavior and characteristics. Early research in mode choice modeling revolved, almost exclusively, around the family of logit models. But a number of researchers have recently argued that these models place restrictions on their parameters that compromise their performance and have thus experimented with a number of newly developed, flexible mathematical techniques. The present paper extends prior research by developing a methodology for predicting individual mode choice based on a nonparametric classification methodology that imposes very few constraining assumptions in yielding mode choice predictions. Preliminary results, using data from three vastly

different international settings, are promising, especially when considering that the models are successful while using only a limited number of independent variables to achieve these predictions.

Lo, Hong K., Chun-Wing Yip and Quentin K. Wan. "Modeling Competitive Multi-modal Transit Services: A Nested Logit Approach," Transportation Research, Part C, Emerging Technologies, Vol. 12C, No. 3-4, June-August 2004, p. 251-272.

This study presents a framework to model a State-Augmented Multi-modal (SAM) network.. Rules for probable transfers as well as nonlinear route fares or utilities are automatically captured in the SAM network, which provides a structure to model travelers' combined mode and route choices in a network of multi-modal transit services, given the fare and frequency characteristics of the services. The formulation of the SAM network is provided along with the fare competition formulation. To illustrate this approach, a case study of transit services between the Hong Kong International Airport and the downtown Kowloon West area is provided.

Lythgoe, W.F., and M. Wardman, "Demand for Rail Travel to and from Airports," Transportation, Vol. 29, No. 2, May 2002.

Abstract by TRIS: This paper presents an analysis of the number of air passengers who use rail for traveling to and from airports, and the sensitivity of this market segment to air traffic growth, as well as rail fare and service quality changes. Specifically, inter-urban rail demand to and from the Manchester and Stansted Airports in the U.K. is analyzed. The estimated demand parameters vary in an expected manner between outward and inward air travelers as well as between airport users and general rail travelers. These parameters can be entered into the demand forecasting framework widely used in the rail industry in Great Britain to provide an appropriate means of forecasting for this otherwise neglected market segment. This research provides the first British detailed analysis of aggregate rail flows to and from airports. The research is also unique in that it has disaggregated the traditional generalized time measure of rail service quality in order to estimate separate elasticities to journey time, service headway and interchange, and it also has successfully explored departures from the conventional constant elasticity position. In addition to enhancing the demand forecasting procedure used in the railway industry, findings can also be used by the airports and other bodies seeking to increase public transport's share of airport trips.

Outwater, Maren L., Steve Castleberry, Yoran Shifan, Moshe Ben-Akiva, Yu Shuang Zhou and Arun Kuppam "Attitudinal Market Segmentation Approach to Mode Choice and Ridership Forecasting: Structural Equation Modeling," Transportation Research Record, No.1854, 2003.

Author abstract: The San Francisco Bay Area Water Transit Authority is evaluating expanded ferry service, as required by the California Legislature. As part of this process, Cambridge Systematics developed forecasts using a combination of market research strategies and the addition of nontraditional variables into the mode choice modeling process. The focus of this work was on expanding the mode choice model to recognize travelers' attitudes and different market segments. Structural equation modeling was used to simultaneously identify the attitudes of travel behaviors and the causal relationships between traveler's socioeconomic profile and traveler attitudes. Six attitudinal factors were extracted, and three of these were used to partition the ferry-riding market into eight segments. These market segments were used to estimate stated preference mode choice models for 14 alternative modes, which separated the travelers' reactions to time savings by market segment and which recognized that mode choices are different for market segments that are sensitive to travel stress or the desire to help the environment. The new mode choice models were applied within the framework of the Metropolitan Transportation Commission's regional travel model and calibrated to match modal shares, modes of access to each ferry terminal, ridership by route and time period, and person trips by mode at screening line crossings. Additional validation

tests of significant changes in ferry service in recent years were used to confirm the reasonableness of the stated preference model. The model has been applied for three future year alternatives and to test the sensitivities of pricing, service changes, and alternative transit modes.

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Access to and Competition Between Airports: a Case Study for the San Francisco Bay Area," Transportation Research, Part A, Vol. 37A, No. 1, January 2003.

The paper presents a model of both airport choice and ground access mode choice for air passengers in the San Francisco Bay Area. There are two approaches in the paper: the first represents airport choice and access mode choice independent decisions using two separate models. The second approach assumes that air passengers choose the airport and access mode simultaneously, making the two decisions dependant. For this approach, the authors estimate a two-level nested logit model with the airport choice at the top and the mode choice as a second level. The model is calibrated using data from a 1995 air passenger survey performed by the Metropolitan Transportation Commission. The authors conclude that access time is a very important factor in air passenger choice of airport in a multi-airport region.

Tam, Mei Ling, and William H.K. Lam, "A Study of Airport Ground Access Mode Choice in Hong Kong," Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., January 2005.

Author abstract: This paper reports on an investigation of factors affecting air passenger ground access mode choice to the Hong Kong International Airport (HKIA). Data were collected from interview surveys conducted at the Departures Hall of the HKIA in 2004. Target respondents of the survey were departing air passengers whom orientated from Hong Kong. The survey results showed that public transport is the major mode for accessing to the HKIA, in which bus has the largest market share, followed by the rail transit. Those who traveled for business tend to select a mode that is more reliable and they are more willing to pay a higher travel cost than the non-business travelers. Compared with the results obtained from the old Hong Kong airport at Kai Tak, it was found that the share of taxi decreased dramatically. This is due to the longer travel distance going to the HKIA than to the Kai Tak Airport. The results of this survey are also compared with similar airport ground access surveys conducted in North America. It was revealed that in Hong Kong, due to the low car ownership rate, majority of the air passengers traveled by public transport while private car is the dominant mode in North America.

Airport Ground Access System Modeling

Monteiro, Ana B., and Mark Hansen, "Improvements to Airport Ground Access and Behavior of Multiple Airport System: BART Extension to San Francisco International Airport," Transportation Research Record, No. 1562, 1996.

Author abstract: Metropolitan regions with more than one major airport--multiple airport systems (MASs)--are important to the U.S. air transport system because of the large number of passengers they serve. Airport ground access factors strongly influence the allocation of traffic in MASs. The effects of improvements to airport ground access (by nonautomobile modes) on airport use in a MAS are analyzed. A case study of an extension of a Bay Area Rapid Transit rail link into the San Francisco International Airport (SFO) is presented. Two airport choice models were developed. One is a nested logit model in which the airport choice decision occurs at the higher level and the mode choice decision at the lower level, and the other is a multinomial logit model. The results indicated that improvements to SFO ground access would modestly strengthen SFO

as the dominant airport in the San Francisco Bay Area and that most of the diversion of passengers would be from Oakland Airport.

Airport Employee Travel Planning

Ricard, Diane M., "Challenges in Developing an Airport Employee Commute Program: Case Study of Boston Logan International Airport," Transportation Research Record, No. 1506, July 1995.

Author abstract: Boston Logan International Airport, a major trip generator, contributes to and is impacted upon by traffic congestion in the Greater Boston area. Located about 3 km from downtown Boston, Logan is the fifth largest airport in the United States in terms of origin-destination air passengers. Logan origin-destination passengers begin or end their air travel in the Boston region and affect the Boston regional transportation system. Because air passenger growth must be accommodated within the existing airport boundaries and regional roadways, restrictions imposed by the Logan Airport Parking Freeze, and by a responsibility to help reduce regional environmental impacts, it has become increasingly important to find feasible ways to reduce the vehicle trip generation rates of the various Logan Airport user groups. The commuting patterns of the 16,000 Logan employees, who account for about 20% of average annual weekday traffic, are characterized in this paper. Data presented in the paper are based on the results of an airport employee survey conducted in 1990. Commute profiles of both flight crews (who exhibit travel characteristics similar to those of air passengers) and non-flight crew employees are highlighted. Since the airport is staffed 24 hours a day with various types of workers, feasible solutions to reduce airport employee trips will be different from measures tailored to influence commute habits of the traditional office workers. In this paper available alternatives to the single-occupant private automobile are discussed, and their effectiveness relative to employee demand is assessed. There is a small employee market for most alternatives currently available, although each service was developed primarily for air passengers or downtown commuters. Finally, a summary is presented of the initiatives that the Massachusetts Port Authority (owner and operator of Logan International Airport) has taken in the past and is considering in the future to encourage employees to use higher-occupancy commute modes.

Ground Access Information

Du, Yafeng, and Geoffrey D. Gosling, Airport Ground Transportation Information Systems: State of the Art and Technology Opportunities, Research Report UCB-ITS-RR-94-13, Institute of Transportation Studies, University of California, Berkeley, December 1994.

Abstract by TRIS: Described are the results of an evaluation study of a demonstration program sponsored by the Division of Aeronautics of the California Department of Transportation, in which computer-based ground transportation information kiosks were installed in four California airports, in conjunction with a similar program undertaken by the Los Angeles Department of Airports. The study included an analysis of kiosk-use patterns derived from the logfiles of user keystrokes and various system actions, which are automatically maintained by the kiosks, and surveys of both kiosk users and airport users in general to determine traveler awareness of the new information kiosks, identify passenger ground transportation information needs, evaluate user satisfaction with the information provided, and determine general travel characteristics of kiosk users. Finally, the costs involved in routine operation and in maintenance of the kiosks are examined and a number of recommendations are made on the future use of the kiosks and on the need to preserve the information generated by the demonstration program.

Gosling, Geoffrey D., and Samuel W. Lau, Evaluation of a California Demonstration of an Automated Airport Ground Transportation Information System, Research Report UCB-ITS-RR-95-3, Institute of Transportation Studies, University of California, Berkeley, May 1995.

Abstract by TRIS: Described are the results of an evaluation study of a demonstration program sponsored by the Division of Aeronautics of the California Department of Transportation, in which computer-based ground transportation information kiosks were installed in four California airports, in conjunction with a similar program undertaken by the Los Angeles Department of Airports. The study included an analysis of kiosk-use patterns derived from the log-files of user keystrokes and various system actions, which are automatically maintained by the kiosks, and surveys of both kiosk users and airport users in general to determine traveler awareness of the new information kiosks, identify passenger ground transportation information needs, evaluate user satisfaction with the information provided, and determine general travel characteristics of kiosk users. Finally, the costs involved in routine operation and in maintenance of the kiosks are examined and a number of recommendations are made on the future use of the kiosks and on the need to preserve the information generated by the demonstration program.

Lo, Hong K., and W.Y. Szeto, "Modeling Advanced Traveler Information Services: Static versus Dynamic Paradigms," Transportation Research, Part B, Vol. 38, 2004, p.495–515.

Abstract by TRIS: This study compares and contrasts static versus dynamic paradigms for modeling the impact of advanced traveler information systems (ATIS) services. A cell-based variational inequality formulation of the dynamic traffic assignment problem was developed that considers two classes of drivers: those equipped with ATIS and those without. Both classes are modeled to follow the stochastic dynamic user optimal conditions, with the equipped drivers having a lower perception variation of the network travel time due to the availability of better information. The model represents traffic dynamics according to the cell-transmission model, including such physical effects as queue spillback and shockwaves. Two scenarios are set up to evaluate the two modeling paradigms while carefully controlling the scenario parameters. The results from the numerical study suggest that benefits estimated by the two models could be very different, with some aspects appearing directly opposite. The discrepancy is mainly attributed to the fundamental characteristics of how traffic is represented. A big difference results when traffic dynamic is modeled indirectly via a link performance function rather than represented realistically with physical queues. The findings suggest that simplifications from the physical queue representation are inadequate in producing correct results.

Public Transportation Planning

Ceder, A., "New Urban Public Transportation Systems: Initiatives, Effectiveness and Challenges," ASCE Journal of Urban Planning and Development, Vol. 130, No 1, March 2004, pp 56-65.

Author abstract: Growing traffic congestion, the need to preserve the environment, and the problems of road safety are the main reasons for many cities worldwide to consider new initiatives in public transport (PT) systems. This work discusses the major elements and challenges related to the introduction of a new or an improved PT system. The choice between public and private transport is an individual decision that is influenced by government/community decisions. These decisions are often sending mixed signals to the public transport passengers and potential users while failing to recognize system-wide and integration implications. The aim here is to provide the current state of the PT practice and to cover the issues of why or why not to use PT including the willingness to pay, viability and projection perspectives, the effectiveness of new initiatives mostly

in Europe and North America, and achieving multimodal service integration. A concluding example is provided with reference to the city of Auckland in New Zealand.

Zhou, Jing, William H.K. Lam, and Benjamin G. Heydecker, "The Generalized Nash Equilibrium Model for Oligopolistic Transit Market with Elastic Demand," Transportation Research, Part B, Vol. 39, 2005, p. 519-544.

Abstract by TRIS: In this article, a transit network is described by a set N of transfer stations (nodes) and a set S of route sections (links). The transit route is also referred to as a path. The authors present a bilevel transit fare equilibrium model for a deregulated transit system. The authors demonstrate that there is a generalized Nash game between transit operators, which is formulated as a quasi-variational inequality problem. The bilevel transit fare equilibrium problem is presented in the Stackelberg form and solved by a heuristic solution algorithm based on a sensitivity analysis approach. In the Stackelberg form, the transit operators dominate the decision-making process and the passengers' response is represented explicitly. The authors include a numerical example to show the competition mechanism on the transit network. The authors conclude that, according to their numerical analysis, the transit operators can achieve competitive advantages by improving their service quality, which is beneficial to passengers.

Air Cargo and Goods Movement

Tsao, H.-S. Jacob, The Role of Air Cargo in California's Goods Movement, NEXTOR Research Report RR-98-5, Institute of Transportation Studies, University of California, Berkeley, September 1998.

The purpose of this project was to (a) gain a broader understanding of the State's air cargo industry and the role of air cargo in California's goods movement; (b) assess the importance of air cargo to the state's economy; (c) begin identification of issues hindering efficient air cargo movement in the state, and (d) explore possible State roles for resolving issues. The authors examined the air cargo industry, California's air cargo market, air cargo and goods movement, and finally they raised major issues in California's air cargo movement and State role for resolving the issues. They also pointed out future study areas in air cargo.

Tsao, H.-S. Jacob, and Asim Rizwan, The Role of Intelligent Transportation Systems (ITS) in Intermodal Air Cargo Operation, Research Report UCB-ITS-RR-2000-5, Institute of Transportation Studies, University of California, Berkeley, 2000.

Author abstract: The air cargo industry is a vital part of the state's economy. The objectives of this research include (a) investigating and suggesting how the public sector in California can assist the air cargo industry in providing efficient services to businesses and the general public and (b) learning from the air cargo industry about intermodal transportation operations and ITS deployment in general. We focused on the industry of integrated air-express forwarding, i.e., the segment of freight industry offering overnight and other time-definite delivery services, and on the industry's operations in California. Our research included eight visits to air-freight operators in California. Through those visits and other research, we achieved a basic understanding of the industry and identified a number of salient features of its operations. Based on a small number of metrics quantifying the level of satisfaction of the customer, the industry developed a large number of performance measures for its internal operations. Through the tracking of the operational performance and service quality, efficiency problems are identified or anticipated, and solutions, including ITS and other advanced technologies, are proposed, evaluated with simulation and other industrial engineering techniques, and implemented. We identified many specific issues and public-sector innovation opportunities. The number-one concern of the industry is traffic congestion in

metropolitan areas. In fact, some managers we visited with requested special public-sector attention to some particular issues and opportunities. A vicious cycle regarding the interaction of traffic congestion and integrated air-express forwarding (and perhaps the general short-haul freight industry) is that, to counter traffic congestion in metropolitan areas, the operators send out more trucks and, as a result, the congestion worsens, particularly on freight corridors. We suggested many factors that would facilitate ITS deployment as well as steps that would improve intermodal transportation. Many public-sector roles have been recommended. Unlike people movement, for which HOV lanes and public transit provide a possible way out of the effect of traffic congestion, freight movement sees no relief in sight. This is clearly one of the most critical issues facing the industry of integrated air-express forwarding and perhaps the entire short-haul freight industry. A major question is what the public sector can do to help.

Appendix B
MODE CHOICE MODEL PARAMETERS
FOR CASE STUDY ANALYSIS

This appendix presents the model variables and estimated parameter values for a multinomial logit airport ground access mode choice model that was developed by Dowling Associates, Inc. as part of a study to prepare ridership projections for an automated people-mover link between San Jose International Airport and the Santa Clara Valley Transportation Authority light rail system.²

Table B-1 Model Coefficients and Constants

Variable	Resident Business	Resident Personal	Visitor Business	Visitor Personal
COEFFICIENTS				
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 Car	0.0	0.0	0.0	0.0
Rental Car	-2.9	-4.1	+3.9	+1.0
Scheduled Shuttle	-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
Door-to-Door Shuttle	-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

² Dowling Associates, Inc., San Jose International Airport Transit Connection Ridership, Final Report, Prepared for San Jose International Airport, Lea+Elliott and Walker Parking, Oakland, California, June 14, 2002. Appendix D: Ridership Forecast Methodology.