Integrating Aviation and Passenger Rail Planning

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 118

Integrating Aviation and Passenger Rail Planning

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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

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The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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FOREWORD

By Theresia H. Schatz
Staff Officer
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ACRP Report 118: Integrating Aviation and Passenger Rail Planning identifies planning process options, funding challenges, and potential actions to improve integration of rail services with airports, particularly in congested corridors. The report identifies the challenges involved in a variety of institutional settings in different regions and develops ways to better integrate inter-agency planning processes. It identifies specific site planning and service coordination actions to promote air rail transfers, defines the data and analysis capabilities needed to determine the feasibility and effectiveness of improved integration of air and rail services, and demonstrates the application of methods and tools to support integrated planning for air and rail services and decision making. Key issues covered include rail and air in a competitive and complimentary mode.

The report has an accompanying CD-ROM that includes an Air/Rail Diversion model, a sketch planning tool capable of supporting the evaluation of a range of policy actions that affect choice of air or rail for long distance travel. A User Guide provides direction in applying the model to evaluate different scenarios and a Technical Appendix provides supplemental information for the model. The report and accompanying tool will be of interest to airport and rail operators, state and regional transportation planners, and other interested stakeholders.

Passenger rail systems interact with aviation systems in several ways. *ACRP Report 118* is structured to help the practitioner understand the manner in which rail makes a contribution to the intermodal system by helping air passengers gain access to airports, and the manner in which rail makes a contribution to the intermodal system by diverting traffic from congested airports. In both cases, the full system may become more efficient as airports become more focused on critical long-distance tripmaking, with rail efficiently transporting people in shorter distance contexts. In both cases, the data, tools, and methods may or may not be in place to support the analysis of multimodal and intermodal systems and strategies. This research has examined the market-based performance of these services, commenced the examination of the adequacy of the analytical tools available, and developed new tools in response to the gaps revealed.

The public and private sectors are analyzing the expenditure of billions of dollars on intercity and regional passenger rail projects and airport development projects. However, it is not clear that there is a solid set of standardized, agreed-on methodologies to use when complicated questions are asked about the impacts of passenger rail services on issues such as airport capacity. There is a lack of accepted tools to use in documenting the interrelationship between these modal investments. Most important, there is a lack of a discussion regarding the potential complementary investments in aviation and rail systems in North

America. In many parts of the world, rail and air investments are seen as complementary elements of a larger multimodal and intermodal public policy.

Under ACRP Project 03-23, research was led by Resources Systems Group, Inc. in association with Matthew Coogan, an independent consultant who served as Principal Investigator for the project. As part of the research, the team examined experience in the United States and Europe where rail systems interact with air systems in order to identify the quality of tools and methods and the benefits of effective modal combinations for services in an intermodal context.

CONTENTS

CHAPTER 1

Integrating Aviation and Passenger Rail Planning: Introduction and Setting

Introduction and Structure

Passenger rail systems interact with aviation systems in several ways. This Airport Cooperation Research Program (ACRP) report is structured to help the practitioner understand the manner in which rail makes a contribution to the intermodal system by helping air passengers gain access to airports, and the manner in which rail makes a contribution to the intermodal system by diverting traffic from congested airports. In both cases, the full system may become more efficient as airports become more focused on critical long-distance tripmaking; rail can efficiently transport people in shorter distance contexts. In both cases, the data, tools, and methods may or may not be in place to support the analysis of multimodal and intermodal systems and strategies. This project has examined the market-based performance of these services, commenced the examination of the adequacy of the analytical tools available, and developed new tools in response to the gaps revealed.

The Purpose of ACRP Project 03-23

The objectives of ACRP Project 03-23 described in this report were established by the project panel at the inception of the study.

Objectives:

> The objectives of this research are to (1) provide guidance to airport and rail operators, state and regional transportation planners, elected officials, and interested stakeholders that identifies planning process options, funding challenges, and potential actions; and (2) develop methods and tools necessary to improve integration of rail services with airports, particularly in congested corridors. As part of this process, it is important to (a) identify the challenges involved in a variety of institutional settings in different regions and develop ways to better integrate inter–agency planning processes; (b) identify specific site planning and service coordination actions to promote air/rail transfers; (c) define the data and analysis capabilities needed to determine the feasibility and effectiveness of improved integration of air and rail services; and (d) develop and demonstrate the application of methods and tools to support integrated planning for air and rail services and decision making.

The Content of the Report

This report summarizes the work undertaken in ACRP Project 03-23 and presents its major conclusions. A focal area of the project is the examination of data and tools to help policy makers make good decisions about the potential for air systems and rail systems to be planned and implemented together. The project has examined experiences in the United States and Europe in which rail systems interact with air systems in order to identify the quality of tools and methods. The Research Team is aware that excellent examples exist in Asia, including services/facilities in China and Japan, where long-distance rail is working in collaboration with major airports. However, the research team's scope has been limited to the documentation of case examples in the United States and Europe.

The ordering of the chapters in this report follows the arrangement of the research project:

- Chapter 1 now seeks to define the issues of rail in a complementary mode with air—and rail in a competitive mode—and establish the overall scale of their application in Europe, with reference to lesser levels of success in the United States. This Chapter introduces basic concepts and themes explored in later chapters.
- Chapters 2 and 3 explore the role of rail in a complementary mode, first in Europe and then in the United States.
- Chapters 4 and 5 explore the role of rail in a competitive mode to aviation, first in Europe and then in the United States.
- Chapters 6, 7, and 8 look at the planning issues being faced in the Midwest, the San Francisco Bay Area, and the San Diego region, looking both at how planners are dealing with

the integration of air and rail, and also the question of the adequacy of the data, methods, and tools available to them.

- Chapter 9 reviews what is known about funding sources to support the kind of analyses described herein, including two case studies on the role of non-federal agencies.
- Chapter 10 presents an analysis of what was learned in Europe and the United States about the availability of data and tools to apply to the issue of integrated air and rail planning. This Chapter presents a checklist of areas where resources exist, where research is presently underway, and where more research efforts are warranted.
- Chapter 11 presents the results of the model building effort designed to address the issues identified in the review. A new travel forecasting model for the diversion from air to rail has been created by the Research Team. This model is designed to be transparent, intuitive, and easily applied, while dealing with the important issue of the reaction of the aviation industry to change in passenger volumes resulting from diversion from rail.
- Chapter 12 recaps the major themes developed in the process described herein and provides suggestions for further research.

Interaction of Major Themes to Be Explored in this Report

This report examines the experience of practitioners in the United States and Europe to realize the benefits of effective modal combinations of services in an intermodal context. Rail is examined in terms of its impact on air, and air is examined in terms of its impact on rail. These relationships are reviewed in terms of the actual experience with markets and in terms of the experience of practitioners in several areas to plan and analyze these interconnected services. Figure 1-1 illustrates how the project is concerned with the two kinds of modal interaction in one dimension (rows) and with the adequacy of data, methods, and tools in a second dimension (columns.) Thus, the prime focus of the project has been on market-based experience, while a separate thread has examined the adequacy of data, tools, and methods of analysis to better understand how the two modes work together.

Central to this project structure is the examination of rail in two very different contexts, shown as the rows in Figure 1-1. This document examines the relationship between air and rail systems once in terms of complementarity and once in terms of competition. In general, in terms of complementarity, rail is seen as providing important services to gather passengers in their access to airports and to distribute passengers from airports. In terms of competition, rail makes a contribution to the full intermodal system by providing choices for travelers who may or may not want to use the already congested air system at a major airport. Figure 1-1 illustrates the concept that the data, tools, and analytical methods must be applied separately to the two categories of air/rail interaction. As will be explored in subsequent chapters, the two roles are not only different, but in some cases they may be in direct conflict; the rail manager asked to provide service to an extra airport rail stop may be seeking, simultaneously, to minimize travel times between center-city terminals. The research structure suggested in Figure 1-1 suggests the need for separate examination of all six cells of the matrix.

The Scale of Rail Services Relating to Aviation, by Categories

This research project is concerned with the integration of longer distance rail services with aviation systems, and airports in particular (e.g., while rail might influence the need for investment in the air traffic control system, that is not within the scope of this research). Beyond this Chapter, the report will focus on examples where long-distance rail has diverted passengers from air and where long-distance rail has brought passengers to airports to take even longer distance air journeys. Chapter 2 will briefly review the importance of long-distance rail relative to aviation, separately from the other roles of rail for airports, particularly in Europe. Chapter 3 documents that, with the exception of Newark Liberty International Airport and Baltimore/Washington International Thurgood Marshall

	Market based experience of the projects	*Existence of data, tools, and methods*	*Need for additional data, tools, or methods*
Rail and air in a competitive mode	✓	✓	✓
Rail and air in a complementary mode	✓	✓	✓

Figure 1-1. Coverage of key issue areas in this research.

Table 1.1. Estimates of long distance rail use, 2012.

Airport	*Total 2012 Annual Airport Passengers (in millions)*	*Estimated Long Distance Rail Users to Airport (in millions)*
Frankfurt (FRA)	57.5	6.0
Amsterdam (AMS)	51.0	4.5
Copenhagen (CPH)	23.3	4.3
Zurich (ZRH)	24.7	4.1
Paris CDG (CDG)	61.6	2.8
Geneva (GVA)	13.9	2.5
Manchester UK (MAN)	19.4	1.4
Dusseldorf (DUS)	20.8	1.0
Lyon (LYS)	8.4	0.1
Study Total	280.6	26.7

Airport, American air travelers simply do not access airports by Amtrak in any meaningful volumes.

Scale of Long-Distance Rail in the Complementary Mode: Access to Airports

This section of Chapter 1 presents some background context information to help understand the role of rail in bringing in passengers from beyond the immediate metropolitan context. Table 1-1 summarizes the volumes of long-distance rail passengers brought to European airports in this sample. Thus, while Paris's Charles de Gaulle Airport (CDG) has a high amount of air passenger accessing by all kinds of rail (Figure 1-2), higher volumes of long-distance rail use are reported in Frankfurt, Amsterdam, Copenhagen, and Zurich, ranging from 4 to 6 million annual rail riders.

Figure 1-2 shows the total number of air passengers accessing 16 major European airports by rail, broken out to show the number of trips from beyond the metropolitan area; these represent possible candidates for higher speed services. These calculations were made by the Research Team from data developed in Chapter 2 for airports with long-distance rail, and from metropolitan data presented in *ACRP Report 4: Ground Access to Major Airports by Public Transportation* (2008), as updated. The project calculations reveal, in Figure 1-2, that the high absolute volume of rail passengers to a European airport occur at London Heathrow, with Paris CDG, London Gatwick, Madrid Barajas and Amsterdam Schipol similar in overall scale of use by all rail riders.

From the outset, the reader can note that, while a significant portion of the Paris rail users came from the national rather than the metropolitan system, no users to either Heathrow or Madrid Barajas came directly from the national system—there are no such connections at either airport. More relevant to this research, long-distance rail does comprise a significant component at airports serving Amsterdam, Frankfurt, Zurich, and Copenhagen. Reading the chart from left to right, there are no long-distance trains serving airports in Munich, Vienna, and Hamburg. Thus, of the 16 airports in this sample, 12 of them are located on track that is part of a nationwide system; 4 of them are located along alignments that serve only metropolitan networks.

The data presented in Figure 1-2 show how most rail access to European airports is from the immediate metropolitan area, not from the longer distance national rail network. Specifically, of the 16 relevant airports included in Figure 1-2, 29 million annual air passengers are using long-distance rail to gain access to or from the airports, while 79 million are using metropolitan based systems, according to the calculations. In terms of overall environmental impact, it should be noted trip distances on the long-distance system are much longer than on the metropolitan systems.

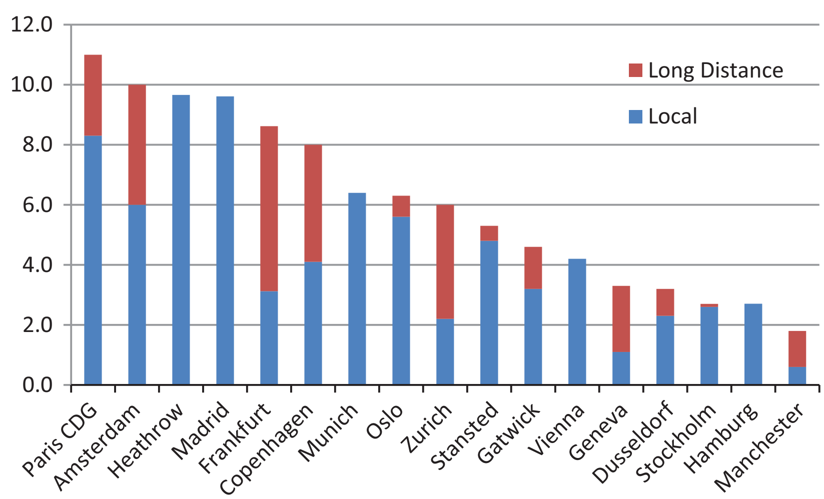

Figure 1-2. Air passengers accessing selected airports by long distance rail and local rail.

Scale of Long-Distance Rail in the Competitive Mode

It is instructive to review what is known about the scale of the role of rail in the competitive mode from the same perspective. Figure 1-3 shows the estimated number of rail passenger-kilometers for those diverted from air for 8 of the corridors described in Chapter 4.

What Does It Take to Make a Successful Air/Rail Station and Service?

It is clear from Table 1-1 and Figure 1-2 that rail service can play a significant role in providing service directly to an airport. The question then turns to how difficult it is to accomplish this, whether in Europe or in the United States. Nearly optimal conditions must exist for an air/rail transfer system to work well: this report reviews a series of attempts in the United States to add rail stations to existing long-distance lines in a manner that would allow the intercity (beyond metropolitan) rail service to serve as a feeder service to long-distance aviation services. As discussed in Chapter 3, only one of them (Newark) has attracted more than 1% of originating air passengers from such intercity rail services. This report will examine the service options that have been attempted at all of the existing transfer points between intercity rail and major airports in the United States.

From this research, one can observe that, in order for long-distance rail to have a successful presence at a major airport, all of the stakeholders must be motivated for the intermodal project to work. Using themes examined in later chapters of this report, success will require a truly rare combination of all the following roles:

- The airport must have some rationale for investing in capital and operating costs associated with the station, and the connections for persons and baggage between the rail station and the airport. Some airports in the United States are supportive of such a concept, while most are not.
- The airline must have some belief that cooperation with another mode will increase its competitive position in the market. One airline has entered into an agreement with Amtrak, while the rest have not.
- The rail operator must conclude that the additional travel times and costs associated with an additional stop make sense in a rational business model. The business case against high-speed rail (HSR) stops at several United States airports is presented in Chapter 3, as seen from the perspective of the long-distance rail company.
- The public must conclude that the investment in capital expenditure is worthy of their support, particularly in a political environment that discourages any activities "in my back yard." Arguably, it is difficult to expect the public to support projects with local impacts if the overall case has not been made at a higher level of government.

Importantly, even if buy-in were to occur from all four stakeholder groups, the experiences documented in this volume reveal that locally managed interventions, such as architectural quality and site planning details, are less important predictors of success than are the conditions of the product in the context of a competitive network. The case study of the Lyon Airport will be used as an example of exceptional site planning and architectural detail, where long-distance access to air failed because of the relative position of the intermodal service offering in the market of long-distance services; the services were not competitive, and no one bought them. A major observation concerning the successes or failures of airport rail stations is that the role of the station within complex markets and networks, rather than the quality of the local design or site planning, is determinant. This, of course, has major implica-

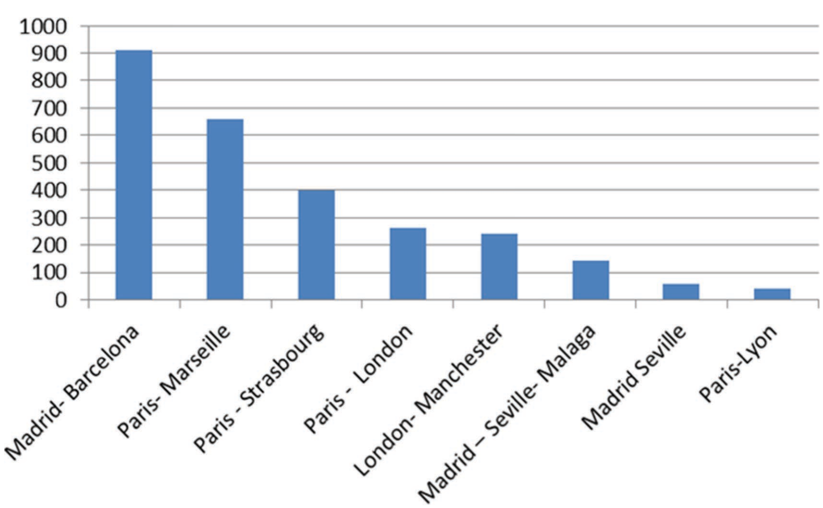

Figure 1-3. Estimated diversion from air to rail, in millions of passenger-kilometers per year. Source: Chapter 4.

tions for carrying out locally initiated station and site planning improvements.

Air Rail Competition: Where Would One Expect Rail to Do Well?

What are the characteristics of successful city-to-city rail investment, especially investment that is effective enough to divert passengers from air to rail? While the subject is explored in detail in Chapters 4 and 5, some context may be helpful. *ACRP Report 31: Innovative Approaches to Addressing Aviation Capacity Issues in Coastal Mega-regions* presented information that supports and re-enforces the observation long held in the rail industry that a rail service needs to attain terminal-to-terminal trip times of 3.5 hours in order to be competitive with air in any given corridor. This rule of thumb is further explored in Figure 4-2 of Chapter 4 (in which air markets are examined with the inclusion of passengers connecting to other flights) and Figure 5-2 of Chapter 5 (in which air markets are examined for only those with both origin and destination in the study corridor). Although such a shortcut rule of thumb is not favored for actual forecasting, the observation reported in *ACRP Report 31* that 3.5 hour travel times are necessary but not sufficient to attract the majority of this particular market is supported in the present research.

As part of the work program for this report, an analysis of the role of the rail system has been prepared by team members Thompson, Galenson and Associates, based on their work with Amtrak, FRA, and private clients. As part of this assignment, Figure 1-4 was created to quantify relationships observed in many years of studying the Northeast Corridor between Boston and Washington (the authors caution against too much geographic generalization from this site-specific data). The travel times are based on assumptions about access times to airports and downtown terminals, as well as the capability of the existing corridor to accommodate very high speeds (Table 1-2). The work shows the highest speed that a train can attain is only one factor out of many in determining a good overall total trip time. Particularly for the shorter distance trips, the relationship between speed and total trip time is not linear; for a 250 mile trip, a 220 mph technology might produce an overall trip time that is one 25% lower than produced by a 110 mph technology. Other considerations include a wider set of variables, including: frequency, access times, and the ability of the equipment to recover (re-accelerate) from unavoidable areas of lower speeds.

Figure 1-4 illustrates that there is a relatively well-defined market in which rail can be competitive with air. Rail's primary competitor for mode choice is the private auto across shorter distances. This analysis suggests that highway travel is generally faster than rail services with a top speed of 110 mph or less for distances of under 100 miles, with rail gaining the clear advantage by somewhat around 125 miles of distance. Thus, in examining the shorter distance trip, the rail manager must provide a travel time advantage in the line haul (in-rail-vehicle) portion of the trip that is sufficient to overcome the additional time for access to the terminal, wait time in the terminal, and distribution time from the terminal experienced in the full trip. For market segments

Table 1-2. Input assumptions used in Figure 1-4.

Line Haul Distance	200	miles
Time by air		
Airport access	40	minutes
Security + board	45	minutes
Airport egress	30	minutes
Air gate to gate time	65	minutes
Time by highway		
Access from starting point to highway	15	minutes
Egress from highway to destination	15	minutes
Average highway speed (MPH)	55	miles/hr
Time by rail		
Station access time	30	minutes
Boarding time	15	minutes
Station egress time	20	minutes

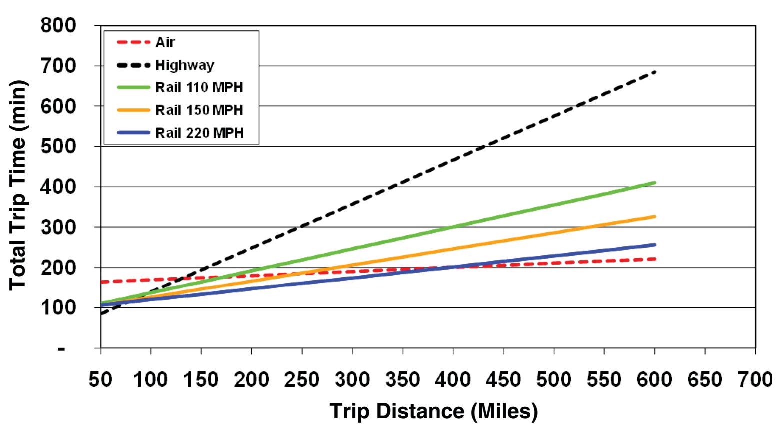

Figure 1-4. Relationship between distance and total time. Source: Thompson and Galenson, for ACRP.

with access to a car, this tends to limit the role of rail for the very-short-distance trip.

Concerning the upper geographical limits of rail's competitiveness with air, Figure 1-4 presents some interesting points of observation. The chart shows that rail with a peak speed capability of 150 mph could provide superior travel times for trips of roughly 275 miles in distance. Rails with a peak speed potential of 220 miles per hour could achieve such time parity in city pairs of 400 miles in distance.

The outcome of the North American analysis by Thompson is largely consistent with the examination of relative costs undertaken by Steer Davies Gleave (SDG 2006) for conditions in Europe. SDG concluded that, at distances of roughly 400 miles, the costs of providing rail service are higher than the costs experienced by the legacy air carriers for the same distance (with the low-cost air carriers considerably cheaper than either). These findings, based on cost characteristics from Europe, support the same basic conclusion observed from American data that HSR services are most relevant in a generalized trip distance range between 150 and 400 miles.

Major Questions to Be Explored in This Report

A wide variety of themes and conclusions were developed as part of this research effort. A summary of the major themes, and major conclusions based on those themes, is presented in Chapter 12 of this report. Certain questions addressed in this report are previewed herein, presented in the order of their coverage by Chapter.

1. What is the relative scale for long-distance rail compared with metropolitan rail in airport access? How does the number of rail passenger-kilometers accessing airports compare with the number of rail passenger-kilometers diverted from airports?
2. What are the characteristics of successful European projects that integrate long-distance rail with major airports?
3. What has been the experience in the United States with long-distance rail to gain access to airports, and how does Amtrak evaluate additional stops at airports?
4. What are the characteristics of successful European projects in which HSR has diverted air passengers?
5. What is the experience in the United States with HSR diverting air passengers?
6. What is the potential scale of markets for rail impacting the airports of the Midwest?
7. What are lessons learned from analyzing the potential role of HSR in aviation planning in the San Francisco Bay Area; from a regional perspective and from a site planning perspective?
8. What are the potential interactions between air and rail in the context of major airport configuration studies ongoing in San Diego?
9. What are the funding options available to support this kind of planning?
10. What are the kinds of tools needed by the analyst, and where do they stand in development?
11. How can the market decisions of the airlines be better incorporated into a usable, planning-oriented air/rail diversion model?
12. What are the major lessons learned and conclusions from this project?

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CHAPTER 2

Complementarity: European Air/Rail Stations Served by Long-Distance Rail

Introduction and Structure

The role of rail in a complementary mode to air is discussed in Chapter 2 in terms of the European experience and in Chapter 3 in terms of the United States' experience. This Chapter explores the potential of long-distance rail to provide truly integrated services in which air and rail work together on a complementary basis. This analysis is based on an up-to-date summary of the extent to which European airport users access their airports by long-distance rail, specifically HSR. From this review, it is possible to form some early "lessons learned" about the relationship between feeder rail and feeder air and how this relationship could affect capacity at major airports.

While the scope of this project did not include a total review of all air/rail services in Europe, the Research Team identified over 24 million non-metropolitan rail trips to those European airports specifically designed to gain access from long-distance rail systems, as shown in Tables 2-1 and 2-2. Each of these airports was designed to benefit from a physical presence on the long-distance rail infrastructure, with long-distance services specifically designed to gain market share from airport passengers (additional airports located on national rail corridors are noted later in this Chapter). Airport links used only by metropolitan rail systems were specifically excluded from this study; these have been documented by *ACRP Report 4: Ground Access to Major Airports by Public Transportation.* While the relative scale and importance of metropolitan and long-distance markets was noted in Chapter 1, metropolitan markets are not examined in this Chapter.

Consistent with its scope of work, the Research Team started by documenting the known characteristics of the HSR services at Frankfurt (FRA) and Paris CDG. Categorizing rail services by the volume of riders they attract at airports, rather than the speed of train, revealed that airports in Amsterdam, Copenhagen, and Zurich have intercity rail volumes that are higher than Paris CDG, even though none of the three were characterized as having extensive HSR services (HSR services in the Netherlands have had a difficult experience in early implementation). Importantly, the Research Team found no correlation with the existence of integrated ticketing schemes and high rail market share. The most successful ticketing system to date, offered from SNCF at Paris CDG, was found to be used by only 4% of the rail riders at the host airport. Integrated ticket schemes were simply nonexistent at most of the most successful airports for long-distance rail programs.

The sheer range of results is important for the central themes of this ACRP study; one of the most ambitious examples of good site planning and architecture is the Lyon St. Exupéry Airport, which serves to underscore the fact that, unless the market characteristics are positive for the rail operation, rail operators will not provide services at the unwanted airport stop.

In theory, short-distance flights could simply disappear in competitive corridors, such as in those under 300 miles, and be replaced by HSR. Examined in this Chapter is the question of under what circumstances rail could provide center-city-to-center-city services that are so superior that origin-to-destination (O-D) passengers would abandon air for rail; this question is reviewed for relevance in the United States in the next Chapter. Chapter 2 documents the role of both air and rail in markets that could be served by feeder air flights. This research shows that high-quality rail service can replace the vast majority of O-D trips in a corridor, but there is little evidence that this change in the O-D market would result in the airlines providing fewer feeder flights than needed for their network operations strategies. This section of the report concludes that the two cases of air feeder services being discontinued (FRA to Cologne, and Paris CDG to Brussels) are, in fact, highly unusual even in the European context. Thus, there may be very few additional opportunities to carry out a prime goal of air/rail complementarity—the freeing up of "slots" at airports for more efficient use.

This Chapter documents that longer distance rail plays an important role in providing access to major European airports—providing high-quality collection/distribution to

Table 2.1. Estimate of scale of airport ground access by long-distance rail, 2010.

Airport	*Total Annual 2010 Airport Passengers (in millions)*	*Estimated Long distance Rail Users to Airport (in millions)*
Frankfurt (FRA)	53	5.5
Amsterdam (AMS)	45	4.0
Copenhagen (CPH)	21	3.9
Zurich (ZRH)	23	3.8
Paris CDG (CDG)	58	2.6
Geneva (GVA)	12	2.2
Manchester UK (MAN)	18	1.3
Dusseldorf (DUS)	19	.9
Lyon (LYS)	8	0
Study Total	***257***	***24.2***

Source: Case studies in Chapter 2.

Table 2-2. Case study airports, ranked by mode share to long-distance rail.

Zurich	25%
Copenhagen	24%
Frankfurt	22%
Geneva	21%
Amsterdam	16%
Manchester UK	7%
Paris CDG	6%
Dusseldorf	5%
Lyon	1%

Source: Case Studies in Chapter 2.

at least 23 million longer distance air passengers each year. The study will review success stories in airports that are served by HSR (Frankfurt and Paris CDG) and in airports that are not served by HSR (Copenhagen and Zurich) as well as one in which the transition from medium speed to high-speed is just now being carried out (Amsterdam). This Chapter will also review case studies in which the enthusiasm of the long-distance rail managers was diminished after disappointing market results. The Chapter study concludes with a summary of major themes, recapping the conclusion of a pioneering intermodal manager from Frankfurt who concludes that their major success in one single airport is probably not a model for most airports, but it could serve as a model for the biggest and most competitive airports.

Markets for Air and Rail in Europe

Individuals interested in the possible role of HSR in the United States consistently look to Europe for examples of what mature HSR systems can and cannot do. Some believe that with a robust rail system, there would be no market for air travel at under 300 miles, 400 miles, or even 500 miles. This ACRP study seeks to put the relationship between successful HSR and aviation service into the context of actual empirical observations based in Europe. It finds that such patterns are simply not supported by the empirical conditions in Europe, nor with the visions of the future held by the rail or the aviation industries. Indeed, the observed patterns between London and Paris, Paris and Lyon, and Madrid and Seville might portend a world where much of the demand for aviation services simply goes away, with a much more powerful successor in high-quality rail systems. However, seen in a larger context, this simply is not the case.

A classic source of data in the analysis of rail and air was created for the Union Internationale des Chemins de Fer (UIC) by Intraplan, INRETS, and IMTran (Intraplan et al. 2003). This highly used source of overall data for travel within Europe examines the next generation of rail investments—covering the period from 1999 to 2020. Rail traffic is projected to grow from 189 billion passenger-kilometers in the base case to 315 billion on the basic scenario, or a growth of 67%.

Multimodal Demand

Looking at the growth predicted as a result of the extension of the high-speed network, Figure 2-1 shows that approximately 28% of that increment will be attracted away from the airlines. But seen in a multimodal context, the growth predicted by the rail industry is modest when seen in the context of the growth expected in the total amount of aviation travel; air travel—specifically allowing for the diversion from air to an improved rail network—grows from 401 billion passenger-kilometers to 857 billion, representing a growth of over 110% over the same period (Intraplan et al. 2003), as shown in Figure 2-2. Resulting mode shares show that air is expected to provide more than two and one half times the passenger-kilometers of the rail system (and this is without considering intercontinental flights).

All of this suggests that rail is a viable strategy to deal with a massive increase in the amount of air travel (as in the United States), rather than a competitor that will lower the amount of air travel.

Rail is expected to interact with air markets in two separate ways; the 2003 UIC market study suggests that of the increment of new riders from the next generation of rail,

- 28% of the rail passengers will have been diverted to a train in competition with an airplane; while
- 6% are taking a train in order to gain access to an airport, perhaps lowering the need for a feeder flight to provide access to the longer distance flight.

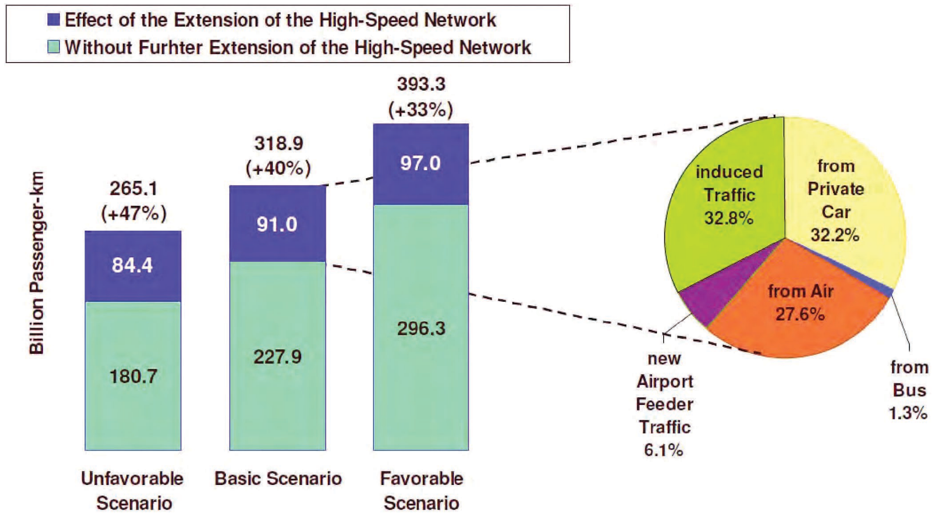


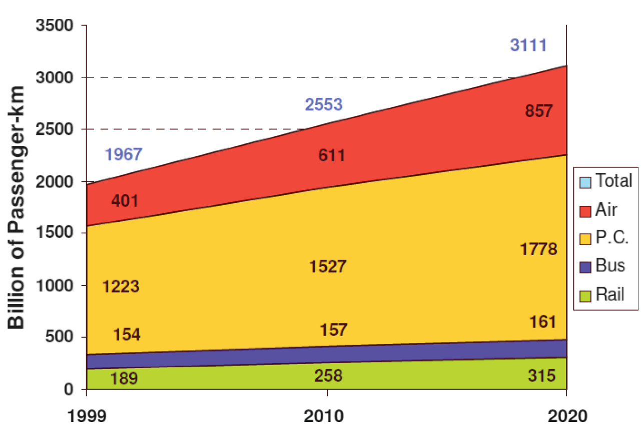
Figure 2-1. Source of new rail passengers with extension of HSR network. Source: Intraplan et al. 2003.

The extent to which this vision of the new rail growth has or has not been supported by empirical findings of the subsequent decade (2001–2010) could be a subject of ongoing monitoring and further research.

How Rail Affects Air, and Vice Versa

The evidence of the research suggests that the relationship between the two industries may be observed as occurring in three phases:

- Phase One: the rail sector makes a vast improvement in travel time, which lowers the amount of O-D traffic between the major airports in the corridor.



Note: "P.C." in the index refers to automobile trips.

Figure 2-2. Growth in air travel will vastly exceed growth in rail travel in Europe. Source: Intraplan et al. 2003.

- Phase Two: the existing airlines react with an initial lowering of the amount of service to a schedule modified to accommodate the network connections needed to make their major hubs work.
- Phase Three: the aviation sector refines its response, often with the creation of new lower cost services in a general corridor of influence, but not necessarily between the original airports. More recently, low-cost carriers (LCC's), such as EasyJet, have developed services to traditional hub airports.

Based on the simple pattern described herein, the evidence does not tend to support the concept that airlines will leave markets, opening up all the slots used for short distance in the corridor for longer distance services utilizing larger planes. The two exceptions to this rule, FRA-Cologne and CDG-Brussels, will be discussed in the following sections in exactly those terms: exceptions to the rule, and not precursors of a larger movement of abandonment of key markets by airlines. Looking at the rail and air market data together suggests the following:

- Rail systems and air systems operate in parallel; a given change in the economic supply characteristics of one mode will stimulate a market response from the competitive mode.
- The given service balance between modal services will be determined less by the characteristics of the segment, and more by the characteristics of the full network.
- Particularly in longer distance segments, the concept that the rail systems can rely on their superior line haul times from point-to-point to dominate market share is challenged by the observed ability of the low-cost airline carriers to provide many services at a lower cost than the railroads, providing the ability to capture market previously considered basic to

the railroads. The effect of lowered airline operating costs on the trade-off between distance and mode choice is currently poorly documented in the literature. In the United States, low-cost carriers have increased fares, partly because of increased fuel costs.

The German Experience with Air/Rail Complementarity

Frankfurt and the Development of the "AIRail" Service Model

Deutsche Bahn (DB), the German rail company, has built new stations to serve airports at Frankfurt, Dusseldorf, and Leipzig Halle—all of which are directly on major HSR lines. As Leipzig Halle is a lightly used airport, this Chapter will focus on services and markets at Frankfurt and Dusseldorf airports. Additionally, the Cologne Bonn Airport station is served by a spur line of the main HSR alignment; although it could be used by HSR services, the rail company has chosen not to route them through that station. A new HSR station is in place in Berlin, and will be opened at some point in time. According to interviews, the management at Munich would like to see some trains with long-distance service directly serve the airport, but the alignment and configuration does not support such services at this time.

By contrast, Frankfurt Airport (Figure 2-3) is Germany's most important airport, with more airline passengers gaining access by long-distance rail than in any airport in the Western world—roughly twice the amount at Paris CDG. There were 53 million passengers in 2010 (Frankfurt Airport 2011) nearly equally divided between transferring and originating markets, (Phranger 2011.) Its two train stations (one for high-speed and one for traditional rail) serve about 170 high-speed trains, and 220 regional trains per day. Of the 25 million O-D passengers in Frankfurt (Table 2-3), about 22% of them use the national (beyond commuter) rail system at present, or approximately 5.5 million yearly passengers (Phranger 2011). Its success is the result of several decades of both physical and institutional work.

Table 2-3. Summary statistics (FRA).

Frankfurt Airport	
2010 total air pax, in millions[1]	53
Total air pax by rail, in millions[2]	8.7
Estimated air pax by long-distance rail[2]	5.5
Estimated long-distance rail mode share[2]	22%

Sources: (1) Frankfurt Airport 2011; (2) Phranger 2011.

Catchment Area

In order to provide a consistent analysis of the catchment areas of several major airports, the Research Team utilized data from a simulation model that describes the European air transport market in detail. The entire model system is calibrated with a vast array of statistics and industry information, and is used by major airports and airlines. Due to its underlying

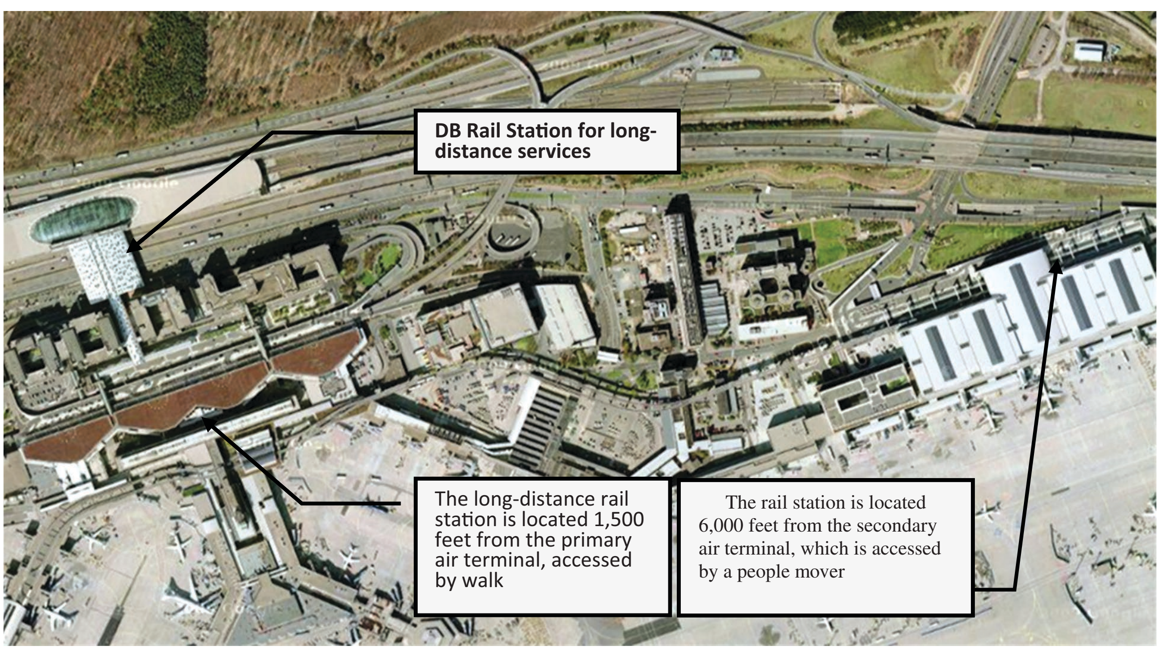


Figure 2-3. In Frankfurt, the long-distance rail station is 1,500 feet from the original terminal and 6,000 feet from the newer terminal. Image © GeoBasis-DE/BKG, Google.

Table 2-4. Distribution of FRA users.

Distance Band [km]	Distribution of Rail Users by Distance	Distribution of Air Pax by Distance
0 - 100	41.4%	50.7%
101 - 200	24.2%	23.9%
201–300	22.2%	17.6%
301–400	9.1%	6.0%
401–500	2.0%	1.3%
501–600	1.0%	0.5%

Source: STRATA Consulting for ACRP.

region-to-region travel demand information, the system is appropriate for analyzing landside accessibility of air supply, and has been applied for ACRP by STRATA Consulting. Table 2-4 displays the distribution of rail passenger in table format, and Figure 2-4 presents the origins graphically.

As this research will demonstrate, the provision of high-quality, long-distance rail service for Frankfurt is associated with a wider catchment area than any other airport examined in the ACRP research. Table 2-4 demonstrates how the share of total rail users varies by distance band from the airport. Nearly half of all the air passengers come from more than 62 miles (100 km) from the airport, revealing a very strong pull from market areas outside of the immediate metropolitan catchment area. Over 58% of the rail origins are estimated to come from beyond this ring, with the share of rail passengers to overall air passengers growing with increasing distance. As will be discussed herein, while 49% of the Frankfurt ground access market comes from beyond 100 km, the corresponding number for Paris CDG is only 32% and only 23% for Schipol. Simply stated, FRA has a very large geographic catchment area for those arriving by modes other than feeder air.

Intermodal Ticketing Agreements

There are three intermodal agreements in place:

- AIRail: consortium between Lufthansa, Fraport (the owner of the airport), and DB since 2003, as discussed herein.

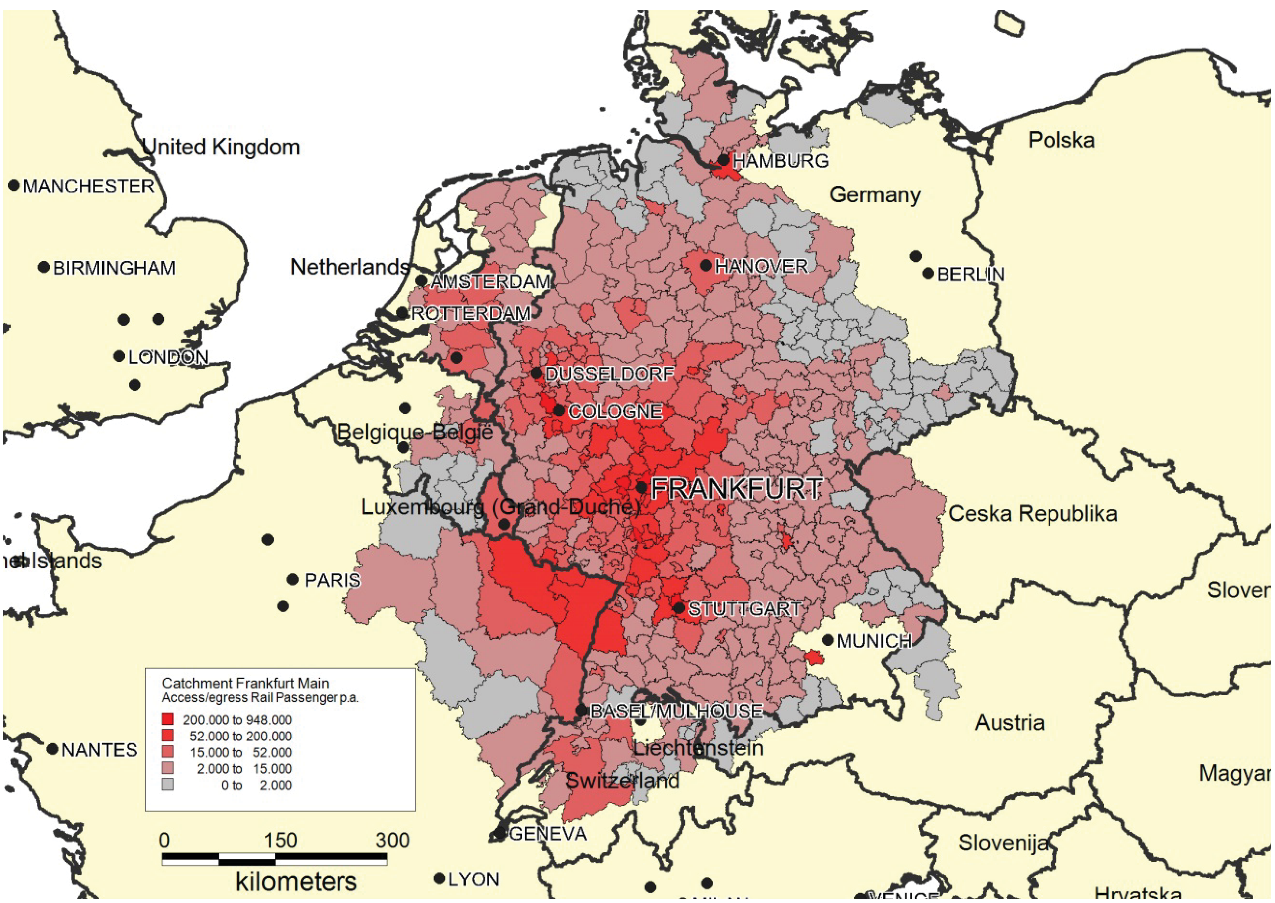


Figure 2-4. Air travelers access FRA by rail from a geographically wide catchment area. Source: STRATA Consulting for ACRP.

- Rail&Fly: agreement between DB and a large number of airlines. Airlines can offer their customers a long-distance train ticket to FRA when purchasing an international airline ticket. For instance, Lufthansa offers the customer the option of a single, one-way, second-class "Rail and Fly" ticket for 29 Euros, which is good for accessing the flight to/from anywhere in Germany. The voucher is good at more than 5,600 DB stations and may be used the day of the flight, the day before, or the day after the flight on all rail services in Germany. The traveler is issued an account code that must be entered into an automated rail ticketing kiosk, which provides the actual rail ticket.
- Good for Train: agreement between Lufthansa and DB. Flight ticket can be used for traveling by train in case of flight cancellations.

The Development of the German AIRail Service Concept

Working in close cooperation with the German government, intermodal planners at Frankfurt in the 1980s began to develop a strategy to replace air feeder services with shorter distance rail feeder services. This was driven by a policy aimed at reducing the number of "slots" allocated to short-distance services, thereby making them available for longer distance services; since the adoption of this policy, the airport has added a new runway. In exploring how to accomplish this, the Fraport, Lufthansa, and DB consortium developed a model that was first attempted in the market between Frankfurt and Stuttgart, and shortly thereafter between FRA and Cologne (Fakiner 2003).

In this prototype model, the rail feeder services would mimic the quality of air services in every way possible. Most importantly, baggage on the rail "flights" would be handled exactly the same way as baggage on traditional feeder flights (Weinert 2003). The system would add customs agents at the baggage pick-up areas in both the Stuttgart and Cologne train stations to accommodate international passengers. In addition, Lufthansa passengers would sit in rail cars specifically serviced by flight attendants offering the same free beverage and snack combination as on flights. During the start-up of the Stuttgart service (before the 2003 expansion to include Cologne), rail passengers from all classes of airline ticket were seated in the first class section of the train. This was rectified in May 2003 with the design of a new service to Cologne. The formal agreement between Fraport, Lufthansa, and DB was signed in 2000, with the prototype Stuttgart service started in 2001. In 2003, DB expanded their schedule with a 70% increase in long-distance services to the airport, and the AIRail service was expanded to Cologne in May 2003.

It is important to note that all of the participant stakeholders wanted the AIRail joint service to succeed. Thus, Lufthansa entered into the FRA–Stuttgart project with an aggressive approach to problem solving and defining strategies needed to carry out their vision that the train experience must look and feel like the competing feeder air experience. As noted by the Lufthansa project manager, "feeder trains have to compete with feeder planes" (Weinert 2003). The FRA–Stuttgart rail project solved some early Computer Reservations System (CRS) issues and created a minimum connecting time of 45 minutes, which required the creation of new baggage handling systems in FRA. Most importantly, the AIRail program offered through-baggage check-in and off-airport baggage claim at the rail station, a service that today is no longer available.

To provide these specialized rail services, the airline bore a series of costs: first, Lufthansa had to pre-buy a block of seats on the train, regardless of whether the seats actually sold. The airline initially booked/pre-bought 46 first class seats for its passengers—even those flying in coach. Second, "in flight" service with snacks and beverages was created—at a higher level than experienced on the corresponding air route.

Also, the airport had to connect the baggage system with the somewhat isolated HSR station, and the railroad had to establish a baggage handling system between Stuttgart and FRA. All of this was successfully accomplished, before its later abandonment.

Market Reaction to the Integrated Air/Rail Product

The project, by many accounts, did not go well—especially in the early years (Weinert 2003). The load factor for the purchased seats on the original Stuttgart service was only 50% after the first two and one half years. What went wrong? It was not the quality of the product, which was specifically over-designed to make the experiment work. More than 90% of the customers liked the product. The managers noted that, despite all the improvements, coverage on the CRS was spotty—infrequently appearing on the first page seen by travel agents.

The airline evidently took the marketing challenge seriously. They report that Lufthansa spent more than three times the average (air service) start-up budget on the Stuttgart project. As reported in Weinert 2003, reactions to the new service included (paraphrased):

- "I do not know what I have to do at a train station."
- "When I buy an air ticket, I expect a flight not a train."

Replacing the Feeder Flights to Cologne

As shown in Table 2-5, the airline and the rail company built an ambitious schedule for the AIRail service between

Table 2-5. Trains on which AIRail service is offered (FRA–Bonn–Cologne).

Depart FRA Airport	Arrive Bonn	Arrive Cologne
07:09	07:47	08:05
08:09	08:47	09:05
08:32	09:21	09:39
09:09	09:47	10:05
10:09	10:47	11:05
12:09	12:47	13:05
13:09	13:47	14:05
16:09	16:47	17:05
17:09	17:47	18:05
18:09	18:47	19:05
20:09	20:47	21:05
21:09	21:47	22:05
22:09	22:52	23:09

Source: Lufthansa 2011.

FRA and downtown Cologne, with more rail service than that offered in the Stuttgart segment (Table 2-6). Between its inauguration in 2003 and 2007, the share of through-ticketed Cologne passengers choosing rail grew to over 50%, and in 2008, Lufthansa carried out the original plan and abandoned the air segment between FRA and Cologne/Bonn airport, as shown in Figure 2-5.

Retaining the Feeder Flights to Stuttgart

However, passengers offered the option of through-tickets between Stuttgart, and connecting FRA flights via rail or via air, overwhelmingly chose the air mode for the feeder service, as shown in Figure 2-6. In effect, Lufthansa offered three

Table 2-6. Trains on which Lufthansa service is offered (FRA–Stuttgart).

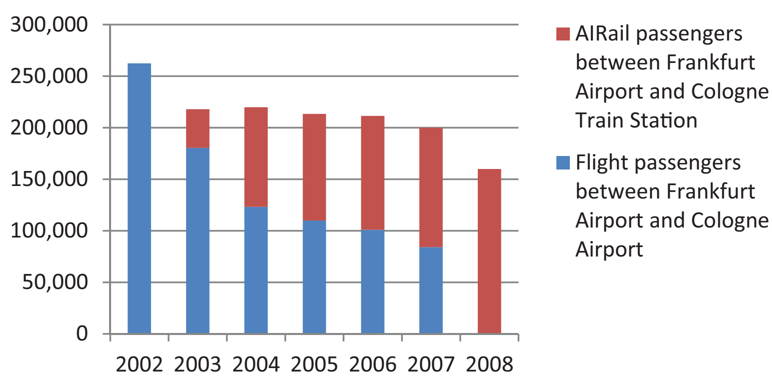
Depart FRA Airport	Arrive Stuttgart
09:20	10:34
15:20	16:34
17:20	18:34
19:20	20:34

Source: Lufthansa 2011.

combinations from the Stuttgart area to FRA. The passenger could choose from among:

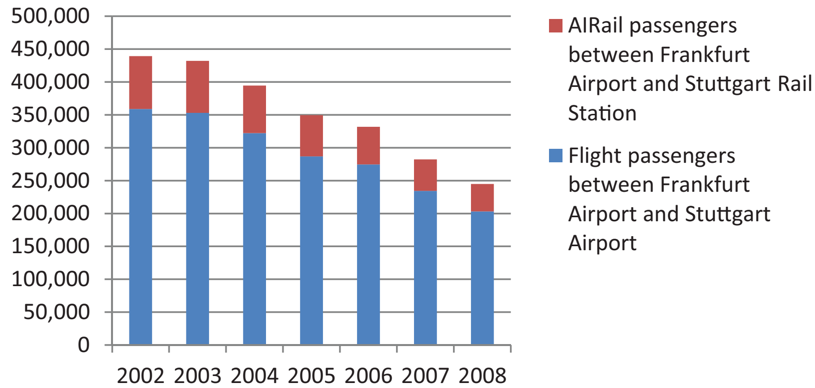
- 4 trains on which Lufthansa provides the seat and offered “in flight” snack service;
- 60 normal trains a day that serve the same corridor; and
- 12 feeder flights a day.

Interviews with Lufthansa and DB officials at the time suggested that their market research showed that people who were unfamiliar with train service in general used the AIRail service (bought the joint air/rail ticket) once, but not a second time. In short, the pilot project to provide high-quality rail service with an “in flight” customer experience failed primarily because the customers did not choose it. Rail passengers evidently prefer the spontaneity of last minute rail connections over pre-established reservations on a small number of trains. Among other reasons, off-site baggage check-in failed because the customers did not choose to use it in either Cologne or Stuttgart. Something in the nature of 25% of passengers who could use the check-in service chose to do it, while the rest did not.



Source: *ACRP Report 31: Innovative Approaches to Addressing Aviation Capacity Issues in Coastal Mega-regions.*

Figure 2-5. Rail now captures all those between FRA-Cologne purchasing the integrated ticket.



Source: *ACRP Report 31: Innovative Approaches to Addressing Aviation Capacity Issues in Coastal Mega-regions.*

Figure 2-6. Integrated ticket buyers choose feeder air over feeder rail between FRA and Stuttgart.

Selling the Integrated Ticket

When an airline chooses of its own volition to substitute rail for all its access (e.g., FRA–downtown Cologne and CDG–downtown Brussels), it is taking a gamble that the well-informed traveler will understand the superiority of the overall service being offered. The Research Team undertook a sample test of this case where the product is nearly optimal; all the options revealed through a major travel information provider (Expedia, USA) for flights from Boston (United States) to Cologne (Germany) were examined for a (random) specific day in midweek in spring of 2011. What the travel agent, or customer sees on the CRS screen is shown as Table 2-7.

A seasoned traveler—perhaps one who has taken the train before—will know that, for those whose destination is at the tourist/business center of the city (downtown), the Lufthansa offering has the best travel time duration. However, what is actually shown on the screen is that "durations" via Paris are similar to durations via FRA and train. In fact, the travel information system used requires the user to select between the airport and rail station before any flight details are produced. Thus, for someone who simply clicks the Cologne Bonn Airport (a reasonable guess) flights are offered via Paris and via London before any product from Lufthansa appears, in which transfers via FRA and Munich or FRA and Hamburg are offered—each of these are several hours longer in duration than the single transfer at CDG.

A similar test was undertaken from Boston (BOS) to Stuttgart. Table 2-8 shows the extent to which the market between the United States (in this case Boston) and Stuttgart has a wide variety of competition, each of which is a threat to a decision to rely solely on rail as a feeder strategy.

In a small, non-scientific test, the Research Team traced a BOS-FRA-Stuttgart trip and assumed the user waited for the next train. The flight arrives at 11:30 a.m., and the train leaves at 12:55 p.m., arriving at 2:08 p.m. This is 7 minutes faster than the best flight connection via FRA, and one hour 16 minutes faster than the Lufthansa-branded train. In short, the fastest Lufthansa connection would have been via the traditional rail (with a one hour 25 minute transfer time). But even that duration (9 hours 53 minutes) would have appeared

Table 2-7. CRS information, BOS–Cologne.

Flight Choices: Boston Logan to Cologne	
Hours and Minutes Duration	**Route and Mode**
9:30	via Amsterdam
9:40	via Paris
9:40	**via FRA and train**
9:55	via Munich
12:15	via London and Munich
13:35	via Newark and Berlin

Source: Expedia 2011.

Table 2-8. CRS information, BOS–Stuttgart.

Flight Choices: Boston Logan to Stuttgart	
Hours and Minutes Duration	**Route and Mode**
9:10	via Paris
9:40	via Zurich
9:50	via London
9:55	via Munich
10:00	via FRA (feeder flight)
10:25	via Amsterdam
11:09	**via FRA and train**

Source: Expedia 2011.

on the reservations screen as a longer duration than that shown on the screen for the flight connection via Paris. The search found 36 trains per day between the cities and the airports.

All of this tends to show the extent to which markets like BOS to Stuttgart (or BOS to Cologne) are fiercely competitive and that the airline must make its "segment" decision primarily on the basis of network characteristics, rather than segment characteristics.

In short, the provision of integrated tickets did not prove to be as effective a strategy as its proponents had hoped.

Currently, some form of specialized rail service is offered to the three cities on Figure 2-7. While the first class passenger on the Cologne service is offered a complimentary "in flight" snack at their seat, the same passenger on the Stuttgart train is offered a voucher for use in the bar car. There are no amenities offered to the second-class passenger. Alternatively, the passenger can simply purchase the connecting ticket from the rail company, either independently or as part of a Flyrail voucher system. The consumer seems to be favoring the more flexible options.

Similarly, the initial vision of the AIRail service mimicking the services of the airline suffered another loss when the check-in facilities at both Cologne and Stuttgart rail stations were closed by Lufthansa due to lack of use by the passengers. This loss of downtown-to-airport check-in parallels the experience of London, where labor-intensive check-in services to Heathrow and Gatwick were also abandoned.

Table 2-9. Summary statistics (DUS).

Dusseldorf Airport	
2010 total air pax in millions[1]	19
Total air pax by rail, in millions[2]	3.2
Estimated air pax by long-distance rail, in millions[2]	0.9
Estimated long-distance rail mode share[2]	5%

Source: (1) Dusseldorf Airport 2012; (2) Calculated from Krieger 2006.

Dusseldorf Airport

The Dusseldorf Airport (DUS) developed a specific strategy for increasing its catchment area and has been investing in ground transportation infrastructure for several decades, attracting some 3.2 million total rail riders (Table 2-9). The airport created a 1.5 mile people-mover connection to a strategic point on the German HSR system (Figure 2-8); in this site plan, the rail has not been re-aligned to detour into the airport and the station is on a straight tangent track.

Conceptually, the site planning solution for the Dusseldorf's new long-distance rail station is similar to that in Newark (see Chapter 3)—with one major exception. Dusseldorf Airport already had an existing commuter rail connection from the downtown. In 1975, well before the recent investment to connect to the HSR system, a connection was built between the airport passenger terminal (left arrow) and the city center (Krieger 2003). Thus, the motivation for the additional $160 million connection to the HSR line was to expand the

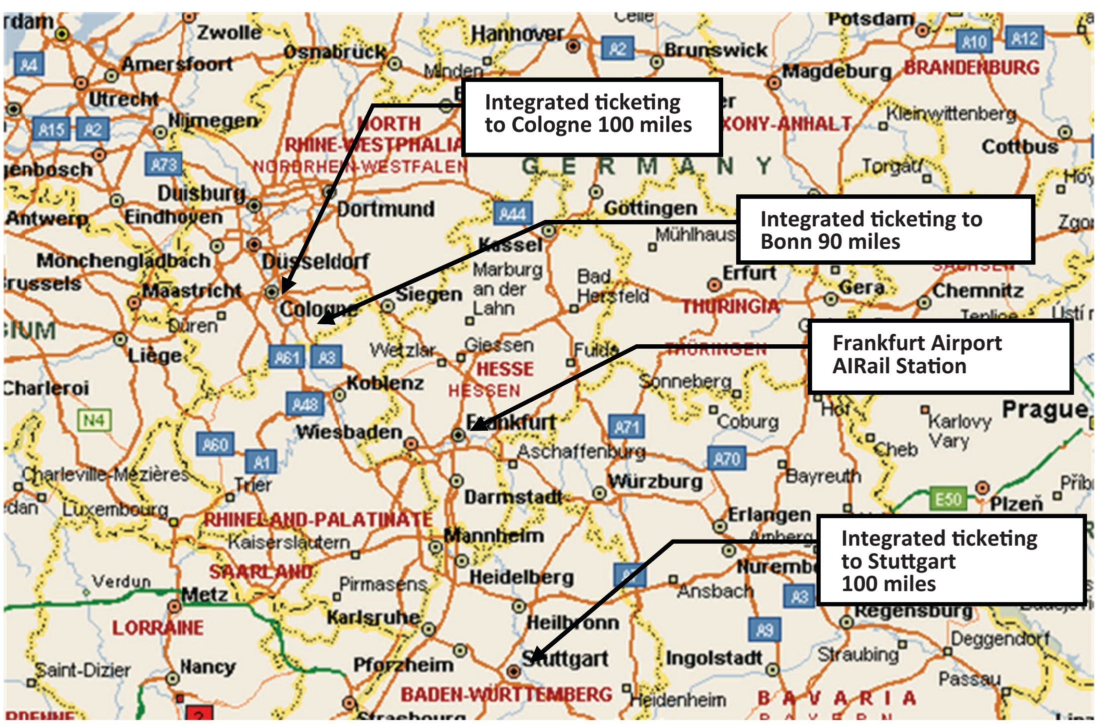


Figure 2-7. Location of the three destinations in Germany where integrated tickets are offered. Base map: Microsoft AutoRoute 2007.

Figure 2-8. The long-distance rail station (upper right) is located 7,200 feet from the main check in terminal at DUS. Image © GeoBasis-DE/BKG, Google.

markets already established by widening the effective area of air/rail service beyond the downtown and S-Bahn (suburban commuter rail system).

Dusseldorf is geographically located in a region that is an economic powerhouse, with nearly 15 million residents within a 90-minute drive, and 18 million within 120 minutes. Thus, the highly decentralized region is on the scale of the New York City metro area. Noting that only 17% of air passengers came from the city of Dusseldorf, the DUS strategy to increase its catchment area was to tap into the access of the HSR corridor adjacent to the airport, which ultimately links Frankfurt to Hamburg and Berlin. The logic of the new station was based on the desire to connect directly with rail trunk line services. Thus, the people-mover with 2.5 minute headway was designed to meet passengers on the HSR line, and a full airline check-in terminal was built at the mezzanine level, connecting down to the tracks (Krieger 2006). The check-in station includes restaurants and shops to serve transferring passengers. Like the similar station in Newark designed to induce the passenger to use near-airport, off-site check-in, the baggage service was used by less than one quarter of the air passengers, and was closed a few years later.

The new rail station offered 340 trains per day, including stops by the longest distance DB high-speed trains. Frequent service was provided to such potential air passenger markets as Hannover (100 miles northeast) and Dortmund (30 miles north). Importantly, market researchers in Dusseldorf noted that rail attained higher mode share for longer distances than for short, reflecting the competitive position with the automobile. Thus, while the mode share to neighboring Cologne was 18%, the rail mode share to more distant Aachen was 67% (Krieger 2006).

However, in the summer of 2010, the DB made the decision to substantially decrease the number of long-distance trains that would stop at the new station, located just a few miles away from the major Dusseldorf station downtown. According to those interviewed for this project, DB came to the conclusion that the longer distance riders were simply not using the airport. Unlike the Frankfurt Airport, Dusseldorf does not play a major role in intercontinental travel; therefore, air passengers from areas like Hannover could make network connections just as easily from their nearby local airport as they could by traveling by train to a distant airport with limited direct services not available at the closer airport.

Interpretation of the German Experience

The ACRP interviews included a day-long interview with Hans Fakiner, considered to be the architect of the Frankfurt intermodal system and expediter for the Lufthansa, Fraport, and DB consortium. He is of the opinion that most airports will not succeed in expanding their catchment areas simply by having high-speed rail available; it is only when the "distant" airport provides superior aviation market offerings compared to a closer airport that there is an inherent advantage for adding the train ride to the journey. This is the same conclusion given to us by managers in Lyon, and the same conclusion that emerges from similar rail service changes at Dusseldorf Airport.

Fakiner is critical of the transportation planning philosophy that, in the United States, is known as "if you build it, they will come" and points to the oversimplified notion that many planners seem to subscribe to that establishing a link between a rail system and airport would result in a marketable product. He noted that a spur track would allow for German HSR trains to veer off the main line, serve the Cologne Bonn Airport, and then return to the main line. Such a diversion might add 15 minutes to the main schedule of the rail, and such a diversion has not been agreed to by DB, which does provide a local commuter link to the airport, which allows for a transfer to the HSR at the Bonn station.

He argues that for rail to take the place of the feeder air system in a meaningful way, nearly hourly service is needed throughout the day to meet flights—whether on-time or delayed. Thus, the national rail system requires market volumes from an airport sufficient to justify frequent trains all day—a requirement that few airports can provide on the scale needed by the rail managers.

Most importantly, Fakiner argued that the airport must provide a product that is not available in the more proximate local airport in the far catchment area sought out by the HSR advocates. Frankfurt has succeeded in being the nation's airport of choice for intercontinental flights; thus, Germans must access that airport for these unique services. If any airport, such as Munich or the new Berlin airport, were to gain dominant roles in the intercontinental market, the long-distance rail volumes to FRA will predictably come down. While Berlin will be integrated into the long-distance rail system, managers at Munich are trying to convince national rail managers to provide long-distance services there.

Even for the airport managers themselves, the additional revenues gained from riders in an expanded catchment area needs to be weighed against a decrease in parking revenues associated with the riders who had simply changed modes to get to the same airport.

In short, Fakiner shared his position that a successful intermodal system only occurs when it is in the business interest of the airport, the airlines, and managers of the rail system. He predicts that, outside of major intercontinental players like Heathrow, Paris CDG, and Amsterdam, there will not be many more examples of the success story of HSR in Frankfurt.

The French Experience with Air/Rail Complementarity

Paris Charles de Gaulle (CDG) Airport

Charles de Gaulle Airport (Figure 2-9) had 58.2 million passengers in 2010, of which 77% were not transferring. In 2008, 2.5 million air passengers accessed the airport by HSR, with 2.75 million reported in 2011 (Bouffard-Savary 2011); this is up considerably from its 2002 level of 1.6 million air passengers. As shown in Table 2-10, 2.7 million air travelers using the HSR in 2010 would represent about 6% of the non-transferring—or ground access—market. A larger portion of the ground access market uses the metropolitan system, the RER, at a rate three times that of the long-distance system (Coogan et al. 2008).

Based on the TGV services that have been integrated into the system, the long-term plan (Leboeuf, 2003) calls for ridership for the service to increase from a 2005 base of 1.8 million

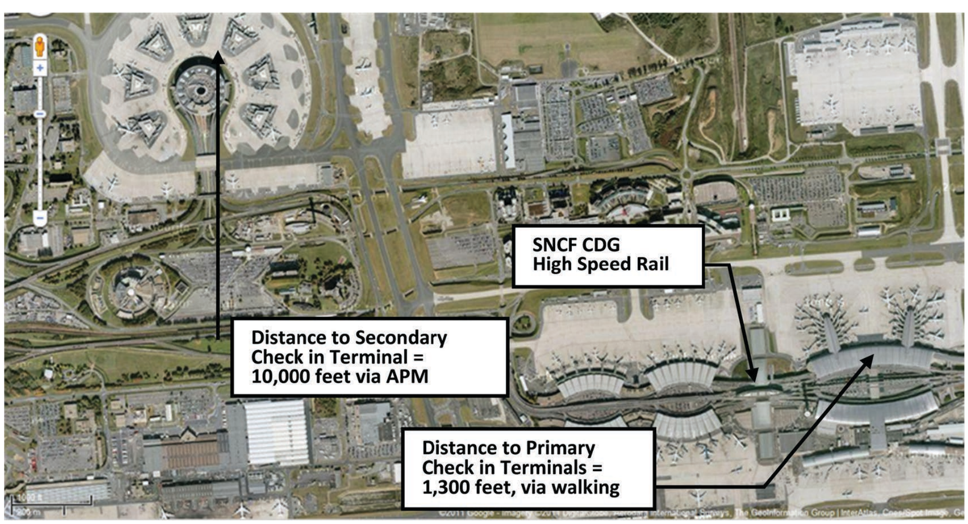


Figure 2-9. At Paris CDG, the older air terminal is nearly two miles from the long-distance station. Imagery © 2011 Aerodata International Surveys, One/Spot Image, DigitalGlobe, Landsat, The Geoinformation Group/InterAtlas, Map Data © 2011 Google.

Table 2-10. Summary statistics (CDG).

Paris CDG Airport	
2010 total air pax, in millions[1]	58
Total air pax by rail, in millions	11.3
Estimated air pax by long-distance rail, in millions	2.7
Estimated long-distance rail mode share[2]	6%

Source: (1) ACI-Int. 2011; (2) Bouffard-Savary 2011.

passengers to 4.3 million in 2020. In 2005, 2.7 million riders used the station, of which

- 1.8 million (66%) were transferring between a train and a plane;
- 300,000 were transferring from one train to a second train; and
- 600,000 were not transferring.

The French High-Speed Rail (TGV) to CDG is generally not used to access domestic flights, as there are better inter-city options available to the traveler. According to an extensive series of studies of the intermodal patterns in France by the civil aeronautics commission (DGAC 2009), 62% of those using the TGV to the airport were on long-distance flights to the Americas, Asia, and Southern Africa; 36% were going within the EU or to the far Mediterranean; and only 2% of train users were going to a destination within France. In 2008, the average airplane trip time was 8 hours and 7 minutes, which is longer than the 2005 figure of 7 hours and 15 minutes. In 2005, the average connection time between the plane and the train was 3 hours and 40 minutes (an increase of 20 minutes since the previous survey three years prior). Travelers making long-distance flights ended up with longer (more cautious) connection times (4 hours) than those on short-distance flights at 3 hours. The average time (2005) for a train trip to/from CDG is 2 hours and 15 minutes (DGAC 2006).

In 2008, passengers approached CDG by rail from all parts of France, with 38% from the west, 30% from the Mediterranean, 20% from the north, and 12% from Brussels. Interestingly, only 2% were coming from the east, in the Strasbourg corridor; but this was before the new TGV line to Strasbourg was commenced.

In terms of the mode choice of the traveler, the DGAC has concluded that, for the market area that has both air and rail feeder mode options available, 55% chose the air, with 45% choosing the rail (DGAC 2006). It is believed that areas with robust air feeder options will have higher than average mode share to air, forming, in effect, two market segments.

Catchment Area

The catchment area of CDG covers most of France (Figure 2-10), with the exception of the most southerly portions

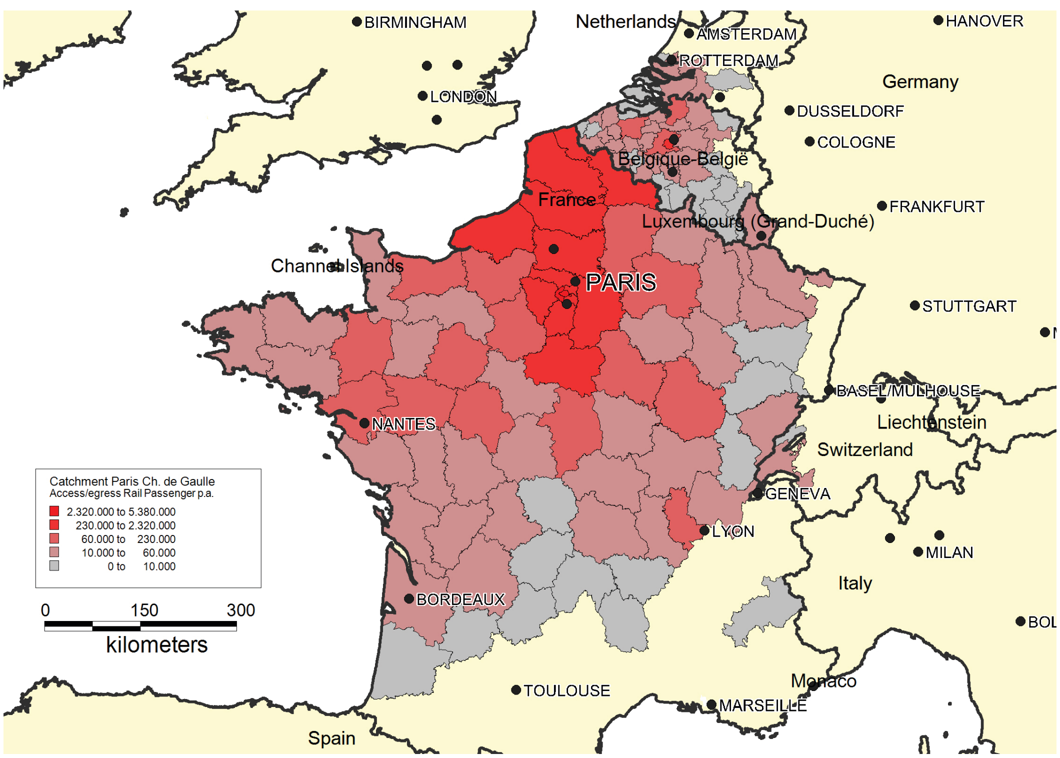


Figure 2-10. Rail passengers to Paris CDG come from a shorter distance than those to Frankfurt. Source: STRATA Consulting for ACRP.

Table 2-11. Distribution of CDG users.

Distance Band [km]	Distribution of Rail Origins	Distribution of All Air Pax
0 - 100	67.8%	68.7%
101 - 200	12.4%	14.5%
201–300	9.6%	9.3%
301–400	5.6%	4.4%
401–500	4.0%	2.7%
501–600	0.6%	0.3%

Source: STRATA Consulting for ACRP.

near the Mediterranean. While most of the air passengers come from within a 100 kilometer radius, almost 8% come from farther than 300 kilometers, with the rail users from this distance comprising more than 10% of the sample of all rail users (Table 2-11). But, in general, the trip length to CDG is shorter on average than that of FRA, reflecting the dominance of Paris as a destination. While only 41% of the rail users to FRA travel less than 100 kilometers to get to the airport, 68% of those to CDG travel less than 100 kilometers.

About one third of the TGV/air passengers reported that their previous mode was rail, implying a trip from their origin into a traditional Paris terminal station (50% of which went through Montparnasse) and then working their way out on the RER-B, the existing commuter rail link to CDG. Thus, of the 6% estimated long-distance share of ground access trips, perhaps 2% were borrowed from the local rail mode share (DGAC 2009).

Two Intermodal Agreements

The following two legal agreements have been created to integrate rail and air in France:

- TGV/Air: agreement between French National Railways (SNCF) and Air France, Air Austral, Air Caraibes, Air Madagascar, Air Tahiti Nui, Cathay Pacific, Corsairfly, Gulf Air, Middle East Airlines, Openskies, and Qatar Airways, established in 1994 for substituting rail in place of Air France flights between Paris CDG and Lille. TGV/Air train connections have a dedicated flight number and can be booked via reservation systems worldwide. On trains, luggage must be carried by travelers, luggage check-in is available only for flight segments at the airport.
- Thalys International: intermodal agreement between Thalys and Air France, stopping all Air France flights between Brussels and CDG. Thalys increased frequencies and reserves at least one car per train for Air France passengers. Passengers (but not their baggage) will be checked through from the station to the final airport (or from the airport of origin to the final rail station). Through ticketing for this segment is offered by American Airlines.

French Cities with Integrated Ticket Sales through CDG

There are currently twelve train stations in France, and one in Belgium, where an integrated air ticket can be purchased for an international flight to/from Paris CDG. The French stations are Angers—St-Laud, Avignon, Champagne, Le Mans, Lille Europe, Lorraine TGV, Lyon Part-Dieu, Nantes, Poitiers, Tours—St-Pierre-des-Corps, Toulon, and Valence (Air France 2012). As previously noted, Germany has only three such non-airport stations in its program. By way of an example of a competitive corridor, a theoretically good candidate for the use of HSR as a feeder mode to longer distance aviation will be explored—the connection between Lyon and Paris CDG Airport.

Marketing the Integrated Air/Rail Ticket

Given that the Paris to Lyon route is one of the great success stories in HSR, and given that the origin-to-destination market essentially abandoned the air system for the rail system, the corridor might be seen as an obvious location for the rail to air market. However, the airline has kept about seven flights per day in each direction, for purposes of network competitiveness. One of the reasons for keeping a flight option in this corridor so well served by rail is that the competing companies offer such a service. The Research Team examined all options for a trip and found these modal options on Expedia. The information provided to the consumer is shown as Table 2-12.

For the traveler who is destined for downtown Lyon, the air/rail product is probably the best total trip offering (both are offered by Air France). In this particular trip, a reported 50-minute travel time advantage for the air option might not trump the additional time and congestion uncertainty associated with the taxi ride from the airport into the downtown. However, as noted in the Frankfurt study, the traveler would have to be already aware that this was the case. In fact, unless the user had specified to the CRS that she/he wanted to end up

Table 2-12. CRS information, BOS–Lyon.

Flight Choices: Boston to Lyon

Hours and Minutes of Trip Duration	Route and Mode
9:15	via Paris (flight)
10:06	via Paris and train
10:10	via London
10:20	via Zurich
12:25	via Amsterdam

Source: Expedia 2011.

in the rail station, the rail option would not even have appeared on the screen.

Importantly, the joint ticketing schemes have not caught on. Most (88%) of the air/rail passengers simply bought their tickets separately; only 4% purchased their tickets from the French air/rail ticket offering, with 8% purchasing from other ticket-selling mechanisms. In the more recent 2011 study, DGAC found that less than one air traveler in five had even heard about the TGV/Air ticketing option. Most of the tickets were bought in the simplest way possible, with the majority of rail tickets purchased on the Internet:

- 66% were purchased directly from SNCF.
- 6% were purchased directly from an airline (of which Internet purchases comprised 66%).
- 28% were purchased for them by someone else (DGAC 2006).

At present, all departing users of the integrated ticket check in at a special counter at the rail station for the entire trip. Those with paper airline tickets are given a paper ticket for the rail segment. Those with an Internet-based ticket can use that ticket for both the rail and the air segments of the trip. Those arriving at CDG are instructed to check in at the special counter, even if they hold an Internet-based printed ticket. Buyers of the joint ticket tend to be older than other aviation users, but otherwise consistent with the average demographics

Market Segments for Rail Users to the Airport

French analysts divide the market into two groups: those for whom there really are good alternatives to the rail, and those for whom there are not good alternatives. Poitiers, Tours, Angers, and LeMans are not served by a major airport, as are Lyon and Brussels. For these towns, the rail access trip is better than going by car, with 41% of residents reporting choosing the train because it is more comfortable (19%), faster, and cheaper (32%) than other modes, with good departure points (24%) (Leboeuf 2003).

A second market segment is those who have good alternatives, for whom the feeder air service is still there, including Lyon, Nantes, Rennes, Bordeaux, and Montpelier; for this group, their reasons for choosing rail include cost (51%), speed (40%), and proximity of the departure terminal (31%). The authors of the study conclude that for the business traveler, TGV is chosen when it gains time; for vacation and personal business travelers, a combination of cost and sensitivity to time play out equally.

All in all, 93% of those who have chosen the TGV alternative are happy with it, which is basically the same as 3 years earlier. The choice-based sample of those who had selected the TGV service revealed high levels of satisfaction with the product. Most surprising of these might be the 77% of the sample who were satisfied with treatment of baggage. This is revealing in that there is no baggage handling system, except a partial service between Brussels and CDG. Other than that, baggage is simply not handled by anyone other than the passenger. In a 2008 DGAC survey, 74% of the users thought that handling baggage was "easy," with only 6% selecting "difficult" (DGAC 2009).

The 2008 survey managers offered two abstract concepts to the existing air/rail users. First, station-to-station check-in/reclaim users, phrased as check-in at airport of origin, reclaim their bag at TGV station of destination. In the second alternative, the passenger keeps bags while on the TGV, but gets airline check-in functions in the airport rail station. The first was found interesting by 85%, while the second was found interesting by only 75%. The public is mixed about checking bags—they are happy not to have it, but claim they want it. Finally, they asked the sample which improvement they would like; 67% said baggage, and 33% said wider use of the joint ticket (DGAC 2009).

Although fewer than one passenger in six said they had problems, the difficulties that were reported included: getting schedule information, reservations, buying the tickets, and research about fares. Other concerns noted were air delay caused a missed train (32%), getting the tickets (20%), baggage (16%), signage/wayfinding (15%), and connections between plane and train (13%). Finally, over 90% of CDG intermodal passengers were interested in a single Internet site that would integrate travel information from rail, multiple air companies, Aeroports de Paris, and the Paris Metro (DGAC 2009).

The Unique Corridor Between Paris CDG and Brussels

On the whole, when French passengers have a choice between feeder rail and feeder air to Paris CDG, the majority choose the air option. There is one market, however, in which the airline chose not to provide a competitive alternative to the HSR service; the corridor between CDG to downtown Brussels service, where Air France did abandon the air option, much as Lufthansa abandoned its air service to feed FRA from downtown Cologne.

In this highly unusual setting, Air France determined that they would attract more fliers through CDG by introducing a non-stop train from downtown Brussels instead of continuing an air service from the nearby Brussels Airport. The service is something of a hybrid, as the long-distance air traveler checks in at the downtown rail station in Brussels, and gives the baggage to the staff. The staff places the baggage on a baggage car on the high-speed train; at Paris CDG Rail station, the staff removes bags from the train and places them on the rail plat-

Table 2-13. CRS information, BOS–Brussels.

Flight Choices: Boston to Brussels	
Hours and Minutes of Trip Duration	**Route and Mode**
8:45	via Amsterdam and flight
9:20	**via Paris CDG and train**
9:50	via Munich
9:55	via London
11:52	via Amsterdam and train

Source: Expedia 2011.

form for passengers to pick-up. The passenger must take them to the standard check-in desk at CDG terminal and proceed through security. Reportedly, most of the passengers using the train choose to keep their bags with them throughout the journey, as they are accustomed to do on an inter-city train.

Just as it is in the interest of Air France to offer a high-quality trip from downtown Brussels to Paris CDG airport, it is not in the interest of Brussels Airlines for the rail system to provide service from its home market to its competitor's hub. This airline has recommenced flights between CDG and Brussels Airport, thereby using three slots for this very short trip.

In France, as in Germany, the airline that has selected the rail-only access option must make sure that its final product is competitive in the open market. In the words of the Lufthansa manager previously quoted, "Feeder trains have to compete with feeder planes." Looking at Table 2-13, Air France and its feeder rail partners in Thalys probably offer the superior product for a traveler from the United States to Brussels, at least for those whose destination is downtown. However, as in the previous examples, it is worth noting that the CRS does not provide many details about the product that the screens offered, giving the impression that the KLM trip, via Amsterdam and its "City Hopper" propeller plane system, offers the fastest trip to "Brussels." Nor is it clear that the management of KLM would do well to abandon that feeder flight for the alternative of using the present rail network to feed Schipol airport, given the terminal-to-terminal travel times shown in Table 2-13, which represents only one example of many schedule possible combinations, in this case Boston to Brussels.

Lyon Airport

This research documents that approximately 2.6 million air passengers each year gain access via long-distance rail to flights from Paris CDG airport, offering a high level of mobility choice to a large geographic catchment area. For some, the TGV is an alternative to the feeder flight; for others, the TGV is an alternative to driving and parking at Paris CDG. However, the clear success story in Paris has not been replicated in further French intermodal connection schemes. As shown in Figure 2-11, Lyon's St. Exupery Airport was conceived to be one functionally integrated air/rail terminal, with the highest of architectural standards.

The problem with the intermodal transfer facility is that it has not attracted many transferring passengers. At the time

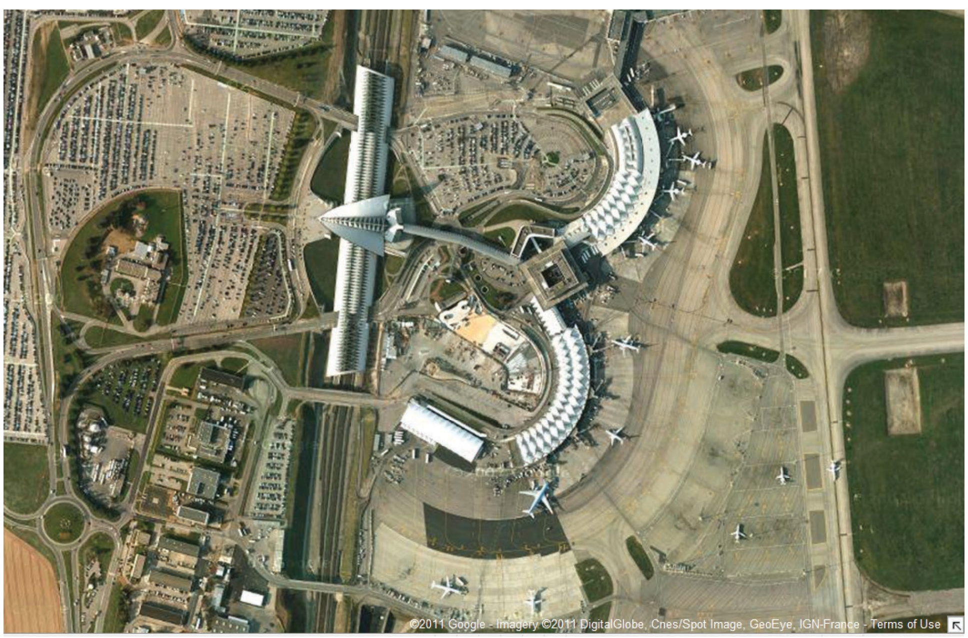


Figure 2-11. The airport rail station is 400 feet from the air terminal Lyon Saint Exupery Airport. Imagery © 2011 One/Spot Image, DigitalGlobe, GeoEye, IGN France, Map Data © 2011 Google.

Table 2-14. Summary statistics (LYS).

Lyon Airport	
Total air pax in millions[1]	8
Total air pax by rail, in millions[2]	1
Estimated air pax by long-distance rail[3]	70,000
Estimated long-distance rail mode share	1%

Source: (1) Anna.aero 2011; (2) Calculated from Lyon Airport 2010; (3) Bouffard-Savary 2011.

of the 2008 survey, of the 8 million air travelers boarding or disembarking airplanes at Lyon, only about 40,000 of them used the long-distance train to access a plane—a ground access mode share of .05%; of those boarding the trains at the station, about 92% were not air passengers (Lyon Airport 2010). The most recent DGAC survey (Table 2-14) found an uptick in intermodal use to about 70,000 in 2011, which raises the ground access mode share to almost 1% (Bouffard-Savary 2011). For metropolitan use, a new dedicated light rail line now serves the airport, replacing the local bus connections; this line is estimated to carry over 15% of non-transferring air passengers (Personal communication, Lyon Airport management).

A wide variety of managers associated with the airport and rail systems affecting Lyon were interviewed over several days. In short, the very same SNCF that built the monumental rail station structure is the agency that decided that there was no business case for stopping many trains there. In an interview with an airport manager, it was explained that Lyon was not an international hub, but rather a secondary airport from which the local traveler gains access to other airports for the longest segment of their trip. There is no logic for starting the journey with a train to this second-tier airport if one lived in a non-hub city in the south of France and had a choice of: (a) taking a feeder aircraft to a network connection; or (b) taking a train to Lyon, and there boarding a plane that similarly connects into the aviation network. The managers of the airport were quick to point out, of course, that rail could well be chosen as an access mode in situations where the airport fed by rail offers direct services not available from the airport near the point-of-origin. Evidence for this was provided by a recent experience with non-stop service from Lyon to New York, at which point long-distance rail volumes accessing air grew by about half. More relevant may be the decision of easyJet Airlines to make Lyon Airport a focal point for its French service, providing their direct, low-cost flights.

From the point of view of the rail operators, however, not even a significant rise in the scale of the present market would justify the kind of all day rail service that seems to be required for successful airport access (see Frankfurt discussion). Any train between downtown Paris and the south of France that makes an additional stop at Lyon Airport for the purpose of gaining (relatively short-distance) riders from the airport's natural catchment area simply means that total travel time for most riders will increase by (roughly) 5 minutes. This is particularly important in the Paris–Marseilles corridor, where distances are long and high average rail speeds are essential.

Lessons from the French Corridor Services

The European model, then, is offering a HSR alternative in carefully selected markets, while encouraging its use without broader market promotions. The dominant model is the provision of good high-speed feeder services, without the deletion of flights. The continuation of flights will be determined by network conditions, and the logic of the network system. Given that, for the most part, the tickets are purchased separately, the rail services in a feeder mode model must be designed to meet the difficult schedule needs of the aviation system. Empirically, the distance at which feeder rail can be competitive with feeder air is somewhat under 300 miles, based on the pattern of mode choice in France.

Other Examples of Air/Rail Complementarity in Europe

Amsterdam Schipol Airport

In 2010, Amsterdam Airport served 45.2 million passengers, of which 58% were O-D passengers starting or ending their trip at the airport (Table 2-15). This means there were 26 million non-transferring passengers, of whom approximately 40% came by rail. Based on the interviews with Schipol management, it is estimated that of the rail passengers, 40% came from outside of the metro area.

As shown in Figure 2-12, the Schipol Railway Station is located directly beneath the terminal building of Amsterdam Airport. With direct intercity train connections to all large cities within the country, the Netherlands Railway (NS) provides good rail access to the airport. About two-thirds of the air passengers are heading for destinations in Europe and 91% of passengers are using scheduled flights.

Catchment Area

It is worth noting that Amsterdam's Schipol airport has a geographically smaller catchment area than that of either FRA or CDG. Specifically, Table 2-16 shows that essentially

Table 2-15. Summary statistics (AMS).

Amsterdam Schipol	
2010 total air pax in millions[1]	45
Total air pax by rail, in millions[2]	10
Estimated air pax by long-distance rail, in millions[2]	4
Estimated long-distance rail mode share	16%

Source: (1) ACI-Int. 2011; (2) Schipol Airport 2010.

Figure 2-12. Both long-distance and metropolitan rail services are provided within the passenger terminal complex at Amsterdam Schipol. Imagery © 2011 Aerodata International Surveys, DigitalGlobe, Map data © 2011 Google.

all of the trips going through Schipol come from a distance of less than 300 kilometers, generally drawing patrons from the Netherlands, Belgium and Germany (Figure 2-13).

According to interviews, the management at the Amsterdam Airport is focused on utilizing the new Dutch HSR system to increase the functional catchment area of the airport, as was successfully done in Copenhagen with the new bridge/tunnel from the airport to Sweden.

Integrated Ticketing at Schipol

Arriving passengers traveling on to Belgium, and holding an integrated KLM or Air France ticket, can pick-up their train tickets (including seat reservation) at Netherlands Railway (NS) service desks at the airport. Travelers starting in Belgium and heading to Schipol can change their flight coupons into rail tickets at the international desks of railroad stations in Antwerp and Brussels South. KLM also operates a bus from Antwerp to Schipol. As in the previous European examples, most Schipol users do not use any integrated ticketing scheme.

Table 2-16. Distribution of AMS users.

Distance Band [km]	Distribution of Rail Users by Distance	Distribution of Air Pax by Distance
0 - 100	76.9%	76.5%
101 -200	18.2%	18.5%
201–300	5.0%	5.0%
301–400	0.0%	0.0%
401–500	0.0%	0.0%
501–600	0.0%	0.0%

Source: STRATA Consulting for ACRP.

Copenhagen

Copenhagen Airport (CPH) (Figure 2-14) currently has about 16 million non-transferring passengers (Table 2-17), of which 5.9 million access the airport using the services of the national railroad (37% mode share) with another 15% by local metro (Copenhagen Airport 2010(a)). The combination of the two shares would represent the highest rail mode share of any airport in Europe (Coogan et al. 2008). Given the coverage of the local metro, it was estimated that two thirds of the national rail passengers are from outside the metro area, resulting in an estimate of about 3.9 million long-distance rail riders per year at CPH.

CPH has been transparent in the commitment to expand the geographic scale of their catchment area (Figure 2-15) by cooperation with various forms of ground transportation improvements, noting "There is a clear connection between the size of a catchment area and the number of passengers and routes, so Copenhagen Airport is working to increase its catchment area from four to eight million people in the longer term." The airport undertook a study "to determine which infrastructure measures would have the greatest effect on the size of the catchment area" (Copenhagen Airports A/S 2010). The research found that hourly high-speed trains to Danish

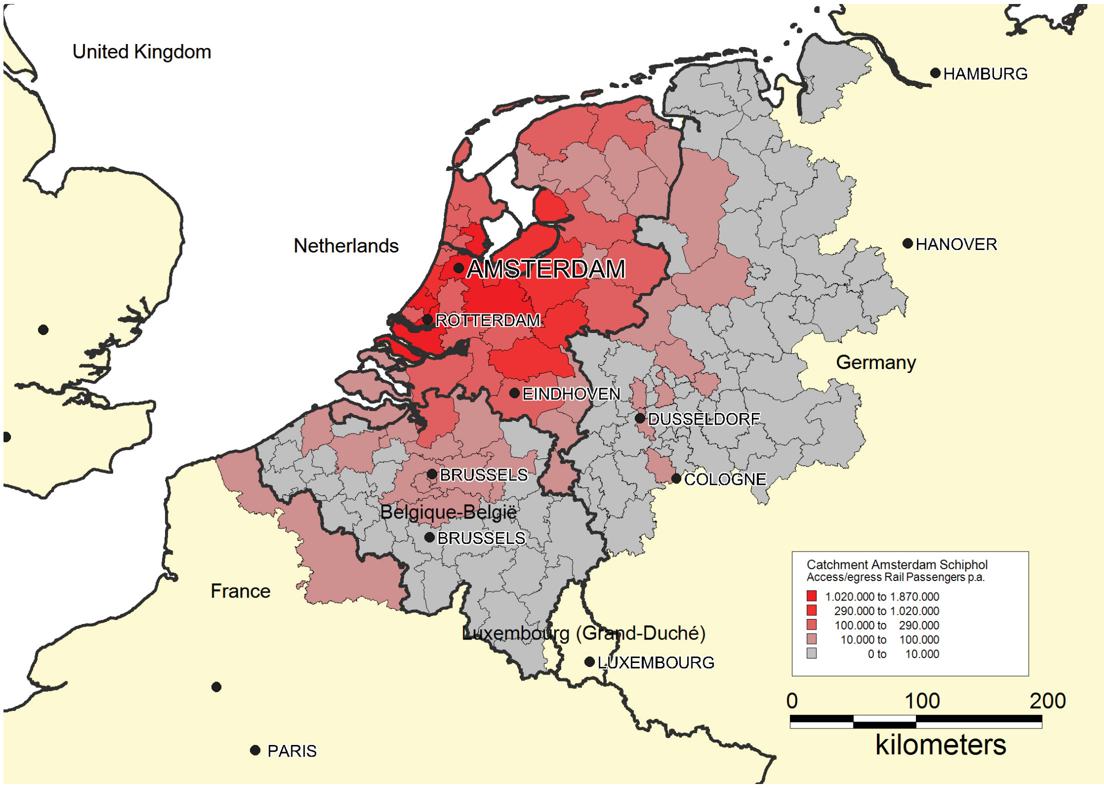


Figure 2-13. Amsterdam Schipol draws train users from a smaller catchment area than CDG or FRA. Source: STRATA Consulting for ACRP.

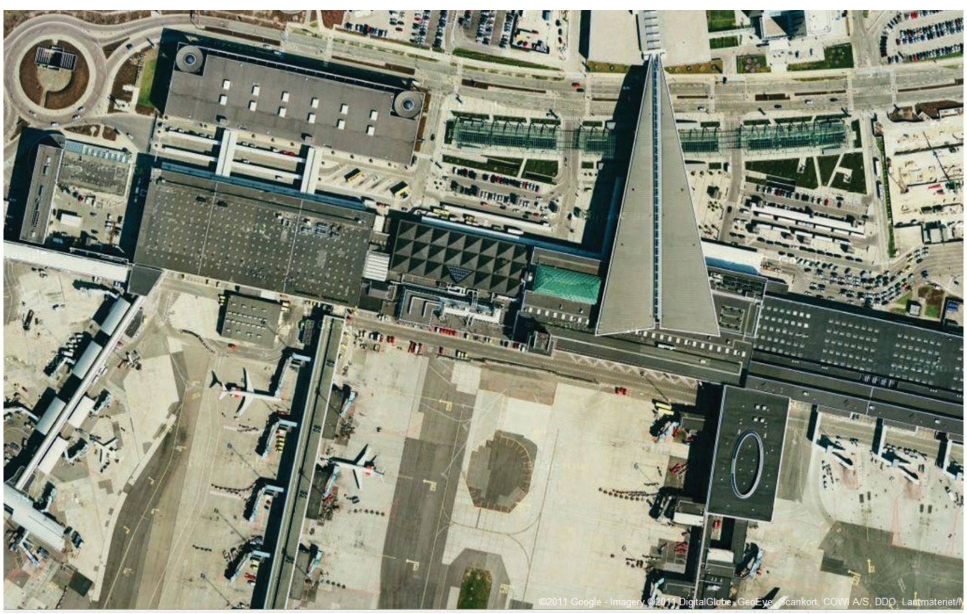


Figure 2-14. The rail station at Copenhagen's Kastrup Airport is located at the Central Baggage Claim area. Imagery © 2011 DigitalGlobe, Scankort, Lantmateriet/Metria, Map Data © Google.

Table 2-17. Summary statistics (CPH).

Copenhagen Airport	
2010 total air pax in millions [1]	21
Total air pax by rail, in millions[2]	8
Estimated air pax by long-distance rail	3.9
Estimated long-distance rail mode share	24%

Source: (1) Copenhagen Airport 2011; (2) Copenhagen Airport 2010 (a).

Table 2-18. Distribution of CPH users.

Distance Band [km]	Distribution of Rail Users by Distance	Distribution of Air Pax by Distance
0 – 100	88.1%	87.3%
101 – 200	4.4%	3.8%
201–300	4.1%	5.4%
301–400	2.5%	2.7%
401–500	0.8%	0.8%
501–600	0.0%	0.0%

Source: STRATA Consulting for ACRP.

cities would increase the catchment area by 800,000 persons and that high-speed trains to Gothenburg, Sweden, would further increase the catchment area by another 720,000 persons. Interestingly, they cite the need to be competitive with the ground systems of competing airports. In a report on social impacts of the airport, the management notes:

> The European high-speed train network will be expanded in the years ahead, and this will increase the catchment areas of the major airports considerably. Expansion of such networks continues, and new high-speed train projects are underway in France, the UK, Germany, the Netherlands, Spain, Portugal and Italy. Airports such as Charles de Gaulle in Paris and Schipol in Amsterdam already have high-speed trains (Copenhagen Airports A/S, 2010, page 18).

Use of Integrated Ticketing in Copenhagen

In a reaction to the early development of the German AIRail concept, railway planners in Denmark established a strategy in which rail services to the major airport are fully integrated with the rail network, with no attempt to provide specialized air/rail services. The Danish rail authorities took the position that there would be no need for off-airport check-in services on the rail system, nor for integrated ticketing. Instead, the rail system provides a high level of frequent rail service with extensive geographic coverage of the country. Having brought about

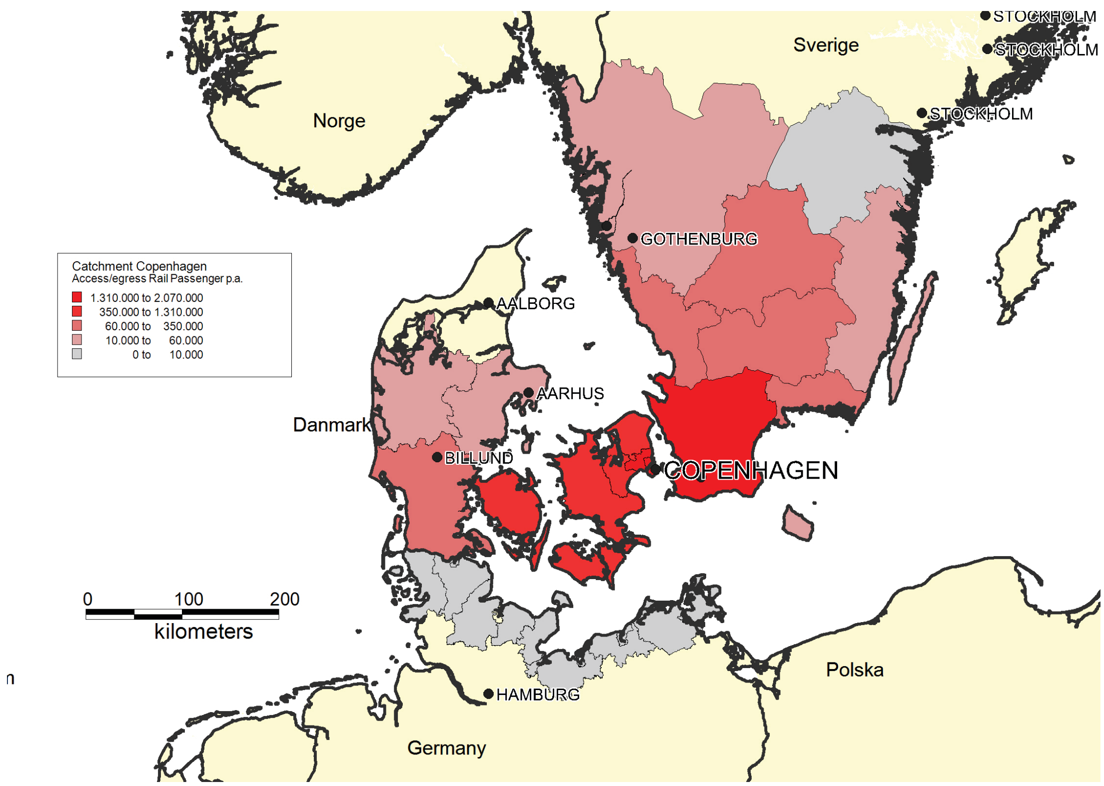


Figure 2-15. The catchment area for CPH reaches far into southern Sweden. Source: STRATA Consulting for ACRP.

Figure 2-16. At the Zurich airport, the rail station is located within the unified air/rail complex. Imagery © DigitalGlobe, GeoContent, Map data © 2011 Google.

the highest overall rail share for any airport in Europe, it can be observed that their overall strategy has been successful.

Zurich Airport

The European strategy to connect a national airport directly to the national, or long-distance, rail system was essentially invented in Zurich in 1980, with the opening of its air/rail station at Zurich Airport (Figure 2-16). Before this time, earlier airport rail stations, such as the Brussels station, built for the 1958 World's Fair, were designed to serve as part of the regional commuter rail system, with service primarily to a downtown station, rather than for a national system of destinations. Today, Zurich ranks among the highest in terms of the percent of originating passengers coming by rail from origins beyond the immediate metropolitan area (Table 2-19) with a catchment area that extends into Germany, Austria, and France (Figure 2-17).

Table 2-19. Summary statistics (ZRH).

Zurich Airport	
2010 total air pax in millions[1]	23
Total air pax by rail to airport, in millions	6
Estimated air pax by long-distance rail, in millions	3.8
Estimated long-distance rail mode share	25%

Source: Zurich Airport 2011

Zurich Airport had 22.9 million passengers in 2010, of which 14.9 million were non-transferring, making 35% of passengers O-D in nature (Zurich Airport 2011). Applying a mode share rate of 42% rail, about 6.3 million air passengers use the rail system. They are serviced by over 350 trains per day, which is supplemented by over 720 bus and 340 light rail connections. Of the originating air passengers, 60% are coming from beyond the area served by Zurich's metropolitan rail services (Zurich Airport 2012), which implies that about 3.8 million intercity rail passengers are using the service. In the Zurich market, cities and towns further from the airport have higher rail mode shares of their respective markets than the Zurich area itself; Bern was reported at 50% rail share, while the bedroom suburbs of Zurich had 8% mode share (Coogan et al. 2008 and Leigh Fisher Associates et al. 2000).

Integrated Ticketing at Zurich

For the vast majority of Zurich Airport (ZRH) users, the rail ticket is purchased directly from the national railway (SBB) and not through any collaborative arrangement. The one exception to this is tickets booked via Zurich to or from Basle, where SBB operates eight trains per day in each direction, each of which goes directly to the airport without the route's normal transfer at the Zurich downtown train station. With a travel time of 80 minutes, this train would be competitive with any potential feeder air mode, which is not operated

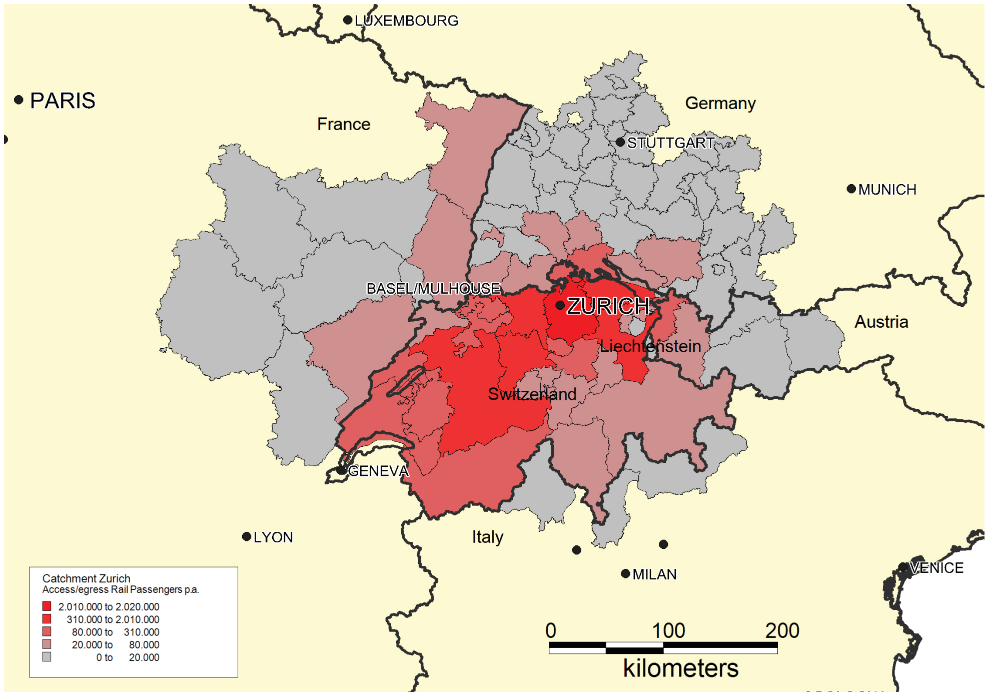


Figure 2-17. The Zurich airport's catchment area includes most of Switzerland. Source: STRATA Consulting for ACRP.

between Zurich and Basel. For this destination—and this destination only—Swiss International Airlines (SWISS) offers a single ticket from the airport of origin to Basel. While a limited airline "check-in" function is available at the Basel train station, airline users are asked to have an Internet e-ticket already printed out before arriving at the train station. There is no baggage service of any kind offered at the time of departure of the "AirTrain."

As shown in Table 2-20, the actual travel times for this airport rail service are positive. However, during the travel time data collection period, the ticket option with air and rail together did not appear from either Expedia or Travelocity, even when additional queries were undertaken with the proper code for the train station. Again, the airline that offers this specialized ticket seems to run the risk that the existing CRSs may not properly display it.

Table 2-20. CRS information, BOS–Basle.

Flight Choices: BOS to Basel	
Hours and Minutes of Trip Duration	**Route and Mode**
9:40	Zurich with train*
10:23	Via Paris
11:33	Via Paris and Lyon
12:11	Via Amsterdam

*Note: Rail service did not appear on CRS
Source: Expedia and SWISS Airlines website.

Integrated Baggage Systems in Switzerland

SBB, the national railway, has developed the most comprehensive airport baggage system in operation anywhere. In the incoming direction, the rail company offers a service in which the user of any airline places an additional tag on the baggage, which shows the user has paid a $15-per-bag fee to send it to any rail station in Switzerland. Most of the larger stations offer baggage pick-up on the flight arrival day, while at smaller stations an extra day is involved. Swiss citizens are not allowed to include in those bags any items that would normally be checked by customs, such as "goods received or purchased while abroad."

The depth of the outbound (from Switzerland) baggage handling depends on the cooperation of the long-distance airline. Most airlines operating in Zurich will allow the baggage given to the railroad on the previous day to be checked through; at present, no American airline offers this service. For the second group, the SBB offers a service at the same cost (about $ 20 per bag), that allows baggage pick-up at the rail desk near the airport check-in desk, where the traveler is responsible for giving the baggage to their airline. For the cooperating airlines, on routes where the service is allowed, the computer at the major rail station prints a baggage tag that covers the full airline trip. No attempt is made to integrate passenger airline tickets and rail tickets under this system. In a French study of intermodality, Pavaux (1991) estimated that 4% of Zurich air passengers used the system.

Table 2-21. Summary statistics (GVA).

Geneva Airport	
2010 total air pax in millions[1]	12
Total air pax by rail, in millions[2]	3.3
Estimated air pax by long-distance rail, in millions	2.2
Estimated long-distance rail mode share	21%

Source: (1) Geneva Airport 2011; (2) Geneva Airport 2011a.

Geneva

Geneva Airport attracts about 12 million passengers (Geneva Airport 2011), the great majority of whom are non-transferring passengers who gain access over the ground system, as summarized in Table 2-21. Using the most recent rail mode share of 31% of air passengers (Geneva Airport 2011a), it is estimated that about 3.3 million passengers are using rail from all ground origins/destinations. The airport draws from a nationwide catchment area, with only about a quarter of the airport users coming from the city of Geneva. Looking for rail riders beyond the metropolitan area, the Research Team estimates that two thirds of the rail riders can be meaningfully categorized as "long-distance" rail users. This results in an estimated volume of 1.6 million long-distance rail riders per year. Of the total airport market, 18% come from Lausanne, and most of the rest are from the western, French speaking portion of Switzerland (Coogan et al. 2008). In 2011, over 40% of the non-transferring passengers were on easyJet, whose presence in Geneva is about 2.5 times that of SWISS (Geneva Airport 2011).

While there are no examples of an integrated air/rail ticket offered at Geneva, the entire SBB railway baggage system is offered at Geneva as in Zurich.

Manchester, UK

For several decades Manchester Airport has been building a ground access strategy that is based more on attaining high rail mode shares outside of the metropolitan area than on the traditional connection to the downtown. The airport attracts about 18 million airline passengers who are overwhelmingly O-D in nature and not based on transferring between planes (Table 2-22).

Table 2-22. Summary statistics (MAN).

Manchester Airport , UK	
Total air pax in millions[1]	18
Total air pax by rail, in millions	1.8
Estimated air pax by long-distance rail, in millions[3]	1.25
Estimated long-distance rail mode share[2]	7%

Source: (1) anna.aero 2011; (2) Longworth 2010; (3) Longworth 2010a.

The airport managers report that more than two thirds of the users of the rail system to the airport are not going to the Manchester area, but rather to more distant destinations in the north of England, such as York (Longworth 2010a). To deal with this demand, the rail authorities created a system called the Transpennine Express to Leeds, York, and Scarborough, which attracts some 1.7 million rail users. Rail mode share of air passengers has increased from 5% in 2004 to 10% in 2009. Including non-air passengers, the small airport station attracts some 2.5 million rail passengers a year, which is significant for a system that does not benefit from HSR services (Longworth 2010).

Airport market research shows that rail gains a higher mode share to/from Manchester Airport for the longer distance feeder function. Long-distance rail gains over 60% market share to the city of York, some 55 miles away, with market share penetration of between 30% and 60% to areas surrounding York (located generally to the north and east of the airport) and under 5% mode share to Manchester and its immediate suburbs (Longworth 2010).

Additional Airports Located on National Rail Lines

As noted in the opening discussions of Chapter 1, there are several airports in Europe that were built primarily to serve a given metropolitan market but are located on the national rail system, which allows some amount of non-metropolitan markets to be served. Examples used in Chapter 1 include, London–Gatwick, London-Stansted, Oslo, Stockholm Arlanda, and Milan Malpensa. Often, these services are not aggressively marketed. For example, while two trains a day from Milano Malpensa Airport proceed to Florence, higher speeds and better travel times are attained by shuttling into the downtown rail station and taking a high-speed service from there. However, good connections can be made between London Gatwick and the Southampton area, and between London-Stansted and Cambridge. Hourly service is available between Oslo Airport and the Lillehammer area. The Stockholm Arlanda Airport website reports there are "70 long-distance trains to districts in the Lake Mälaren Valley region around Stockholm, and to the counties of Dalarna and Norrland to the north" (Swedavia 2011).

Airports Not Connected to Long-Distance Rail

In addition to noting these airports in Europe that are directly served by long-distance rail, it is worth commenting on some of those that are not included in this review of intermodal connections. While some countries are placing a high value on connections between air and rail, others are not.

London Heathrow—Connecting to the High-Speed Rail System

In the next phases of investment for the British HSR system, called HS2, there will be no new rail right-of-way to directly serve Heathrow Airport. Design attention is now focused on the existing Heathrow Express alignment to a point on the proposed HSR system where a long-distance train would stop to provide a transfer with the new Crossrail system. The new HS2 line, as designed, will have a major transfer terminal at Old Oak Common, a point of convergence of several rail lines about 5 miles from the center of London, where one transfer facility would serve Crossrail, HS2, and a rail shuttle to Heathrow, as shown in Figure 2-18 (Crossrail 2011). The focus of Heathrow ground access planning is on connections to the downtown and to the City rather than any direct connections to national destinations; the national plan for HSR adds a spur connection to Heathrow in a later phase of implementation, making its future somewhat in doubt. The concept of routing the main line of HS2 via Heathrow was rejected by an independent review for the government, which concluded that,

> "[I]t is clear that changing the route of the main high-speed line to run via Heathrow, at an additional cost of £2 billion to £4 billion, would connect Heathrow to HS2 at a point in time when this connection is not likely to represent value for money to the taxpayer or the train operator. In any event, such a route is not supported by the evidence of benefits. I recommend that this route should not be pursued" (Mawhinney 2010).

Another group in the UK, called "Heathrow Hub," advocates leaving the main line rail alignment where it is, but adding a new "Heathrow Hub" station about 3.5 kilometers north of Heathrow Terminal 5. This, the proponents noted, is "about the same distance as between existing Terminals 2 and 5–Heathrow Hub includes a railway and bus/coach station, car and taxi facilities and a fully integrated airport passenger terminal, allowing passengers to check in and transfer to a fast airside transit direct to their aircraft" (Heathrow Hub 2012). In this concept, HSR service at the new Heathrow station would be extended beyond downtown London and onto the European continent.

Although London Heathrow does not have any direct services to the UK's long-distance rail network, it could handle them physically. Heathrow is an interesting case study, in that the tunnel alignment built for the Heathrow Express is designed to accommodate rail equipment that shares rights-of-way with high-speed, intercity services. Thus, from a geometric point of view, it could handle equipment that was through-routed to the Channel Tunnel to the Continent, but Government has decided against strategies which would connect the present HS1 system with the future HS2 system.

Rail as a Feeder Mode from Heathrow to Paris and Brussels

Given the rail tracks already in place, service could be provided, in theory, to gain access to CDG from downtown

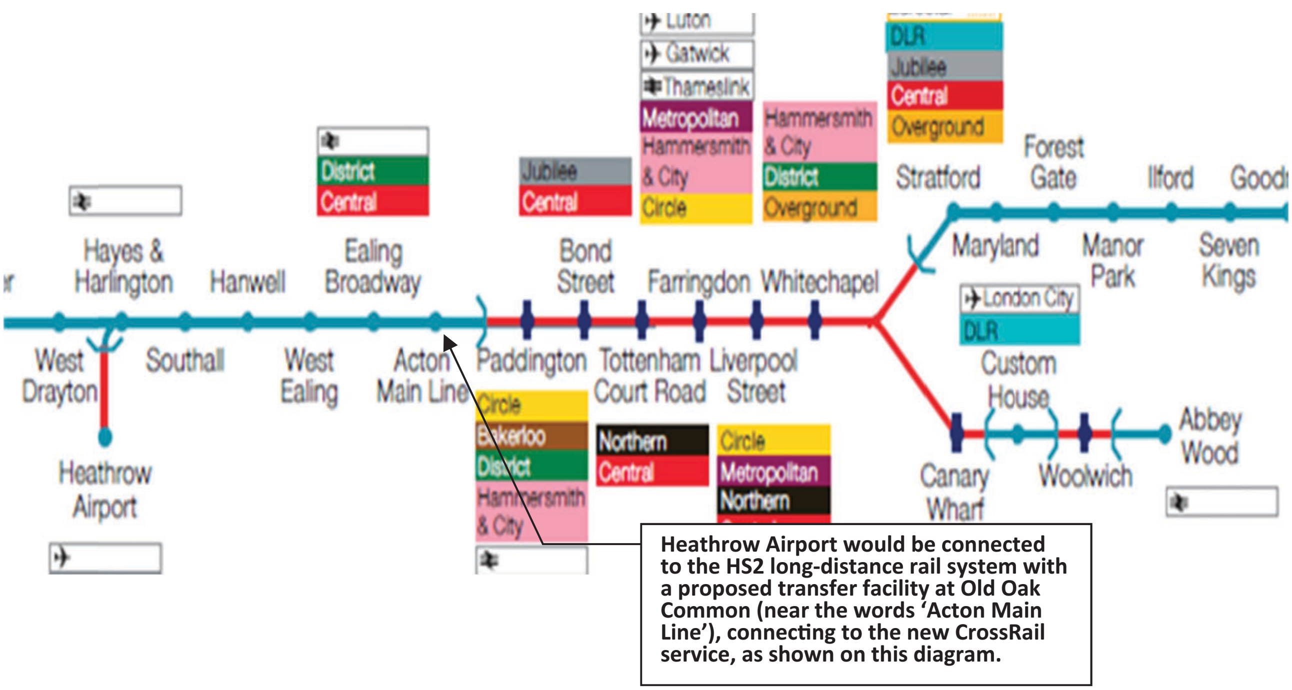


Figure 2-18. A map of the Crossrail system, showing possible connections between Heathrow Airport and a proposed HSR station at Old Oak Common. Source: Crossrail 2011.

London. In a similar manner, connections could be provided to gain access to Heathrow from downtown Paris. Although Eurostar does not provide a service from London to CDG, the existing track infrastructure is in place to do so; indeed, Eurostar does provide service between London and the Paris Disneyworld Resort, which is close to CDG. Likewise, under certain infrastructure assumptions, the Eurostar train would commence at stations in the Heathrow Express tunnel at Heathrow, which would allow a traveler to go to Heathrow by air, connecting by rail to Paris or other destinations on the Continent.

This question was recently addressed in research undertaken for the HS2 project in the United Kingdom. In 2008, about three million air trips used Heathrow to travel onward to destinations connected to London by the existing rail network (Atkins 2011). The HS2 research, based on somewhat basic modeling assumptions, concluded that a high percentage of the long-distance air passengers transferring at Heathrow to Paris or Brussels could be diverted to rail. In this analysis, rail services between Heathrow and Paris or Brussels could attract about 1.35 million annual riders in the analysis year of 2030. Beyond those two destinations, however, the market seems to be small; the Paris and Brussels markets together represent about 90% of the total number of rail passengers projected between Heathrow and the continent (Atkins 2011).

Madrid—No Direct Connection with High-Speed Rail

Similar to the present design of HSR in London, Madrid is another example of a rail system that has a massive investment in new rights-of-way, but no direct service to airports. The HSR services go to two downtown Madrid stations, one of which connects by a new commuter rail line to Terminal 4 of Barajas Airport. Connections between Barajas Airport and Atocha station (the other high-speed terminal) exist only by multiple transfers on the metro system. Interviews with Spanish managers suggest that integration with airports, local services, and local town centers was not a major design priority in the creation of the Spanish HSR network. In short, the concept of long-distance rail as a feeder to the major airports of Spain has not been adopted.

Conclusion: The European Experience in Connecting Airports with Long-Distance Rail

The Importance of Merged Ticketing and Operations

It can be argued that the importance of integrated ticketing and merged service concepts may have been over-estimated by the industry in the 1990s and the first decade of this century. In Stuttgart, Lufthansa kept investing the rail-as-feeder mode concept, even as it was proving not to work.

When faced with decisions between complex, multi-entity tickets, and dealing directly with the supplier, travelers are voting with their feet and choosing the flexibility associated with the direct relationship with the carrier. In Paris CDG, users of the train tend to buy the rail tickets from the rail company, rather than from the air company. In both Cologne and Stuttgart, most rail users chose to keep their bags with them rather than rely on the extensive checked baggage system developed for them. Consumers are tending to purchase the simpler set of services, and the services with the least downside risk when faced with more complex alternatives.

Airlines Abandoning Network Services?

All of this comes together on the question of eliminating feeder flights entirely. The most dramatic decision in the provision of competitive services here was the decision by Lufthansa to eliminate all flights between Cologne and Frankfurt airports, and to route all air travelers by rail in the corridor. This is critical because without the cancellation of flights, the presumed impact of high-quality rail on airport operations (i.e., the lessening of runway congestion) does not occur.

Between Lyon and Paris CDG, about eight flights per day are maintained. Thus, in a market where there is virtually no origin-destination traffic choosing the airline, a basic service of eight flights each day is maintained between the two airports. Removing those flights would provide the dominant airline with fewer marketing options in a fiercely competitive situation. Passengers make choices based on the network options offered to them, not on the details of the segment. As noted by an aviation expert in an interview at the PANYNJ Aviation Department, "It's all about networks and no one understands that. People make travel decisions based on the overall characteristics from point of actual origin to point of actual destination." Thus, when a decision is made to delete all flights, and offer rail to 100% of the users of that segment, this does not mean that 100% of the travelers will use the rail service—they can and do find other ways for the competing networks to meet their travel needs.

Chapter 2 has concluded that the actual number of integrated services, including joint ticketing, in Europe is small; there are twelve locations in France, three in Germany, and two in Belgium where joint ticket options are offered. And among these 17 destinations, only two have resulted in the withdrawal of all aviation flights for that corridor. Thus, it is not possible to use the present state of air/rail integration in Europe to argue that rail, when serving as a feeder system to airports, presently results in a significant lowering of the number of takeoffs/landings at major congested airports.

Such a shift in demand is revealed in two different impacts of HSR on aviation. As HSR increases focus on massive capital investment, the rail systems have priced themselves out of long-distance markets while capturing medium-distance markets. In many cases, rail simply cannot compete with the low-cost carriers for long-distance markets they dominated for many decades.

Thus, the relationship between distance and mode is somewhat more nuanced than might be expected. In Europe, the successful pairing of two cities does indeed lower the number of flights, but the number of remaining flights has little, if anything, to do with point-to-point. Remaining flights are explained by network configuration, not by city center-to-city center flows—and they do not go away. At the same time, competing flights influence point-to-point rail volumes, with costs lower than what the HSR operation charges.

Rail as a Feeder Mode in Europe: Implications for Physical/Site Planning

This review of successful integration of rail as a feeder mode to an intermodal system suggests that the fundamental relationships between long-distance rail alignment and major airport passenger terminals in Europe are very similar to those observed in the United States, as discussed in Chapter 3. Three categories of solutions are introduced, which would apply to both the European and the American design challenges.

Site Planning Considerations from the European Case Studies

Greenfield vs. Brownfield Site Planning Categories

A basic observation from the review of successful European airport rail stations is that they do not all look alike. In rare cases, the airport and the rail link were conceptualized together, in a "greenfield" context, where the designer starts from scratch. In most cases, however, the rail line is added to an existing terminal complex, and must deal with the decentralized patterns of those separate airport landside terminals. Thus, in the most successful system in this study—Frankfurt Airport—the long-distance rail passenger must walk about 1,500 feet to the original terminal building and board a people-mover for a 2,000-foot ride to the newer, more remote terminal; at that point, the traveler can proceed through security. Similarly, Paris CDG requires a 10,000-foot people-mover ride, with several stops between the HSR station and the furthest air terminal.

In a few cases, the airport rail station was planned from the beginning, including Oslo Airport, London Gatwick, and London-Stansted; in most cases, however, the train system had to be added to an already functioning airport, which poses more difficult design decisions for the "brownfield" situation.

Site Planning Concept #1: Full Integration at Airport: Route the Long-distance Rail Line to Go to a Point from Which the Air Traveler Can Walk a Short Distance from the Train to the Check-in Terminal

Within the concept of full integration between air and rail, there are two major site planning sub-categories. First, an air terminal can be planned from conception to be located at the rail alignment. The first of these was the opening in 1958 of a single air terminal structure at London Gatwick that incorporated a train station, a bus station, and facilities to serve those approaching by auto. Importantly, London Gatwick is located on the national rail line, which allows for riders to approach from origins above and beyond the dominant metropolitan area served by the airport. Other "greenfield" examples, where the design of the air terminal was conceived from the outset to include a long-distance rail station, include Oslo, Norway and Lyon, France.

Second, an existing air terminal area can be adapted to incorporate a rail tunnel, usually from a rail alignment diverted into an edge of the air terminal area. This is the option first accomplished in Zurich, which was the first long-distance trunk line to be placed in a subterranean level of the airport terminal, followed by Amsterdam Schipol, Frankfurt, Geneva, and Copenhagen. In the case of Zurich, Geneva, Amsterdam, and Frankfurt, new tunnels were diversions from existing rail alignments; in the case of Copenhagen, the tunnel to the edge of the airport terminal area was built as part of a new rail system. A more recent project saw the opening in June 2012 of a new rail tunnel under the Brussels Airport, which converts an original stub-end commuter line to a through-route service towards Antwerp to the north of the airport. While improved local connections within Belgium have been inaugurated, exact plans to incorporate this new line into long-distance service, such as Paris, Brussels, Antwerp, and Amsterdam has not been announced (Railway Technology 2011).

Attempts at full integration between rail and air terminal check-in facilities are often complicated by the need for airport terminal expansion. Expansion at Gatwick took the form of a "North Terminal" that the rail user can access by a short people-mover from the original air/rail complex to the check-in function in the newer terminal. Similarly, expansion at Frankfurt caused the rail user (from both the local and the long-distance stations) to board a "within security" people-mover to get to the newer Terminal Two. While an originally promised people-mover from the long-distance rail station was never built, a compromise was developed in Frankfurt in which users of the long-distance rail station are offered a check-in hall within the rail station complex. Expansion of Zurich Airport was carried out with all airline check-in remaining in the original terminal location, within the existing air/rail station; the addition of a "midfield" terminal was accompanied by a program to increase the number of air passengers checking in at the mezzanine level of the rail station.

By contrast, the original master plan for Paris CDG did not call for direct access by rail to any of the decentralized passenger terminals originally planned. That master plan was later altered to allow rail to directly serve the Terminal Two complex, from which users of the older Terminal One must take a 10,000-foot ride on the connecting people-mover, with several stops; indeed, walking distances for rail users within the Terminal Two complex to distant gates are sometimes problematic.

Site Planning Concept #2: Shuttle to Nearby Rail Alignment: Build a Separate Airport Rail Station on the Rail Alignment at a Point As Close As Possible to the Airport Passenger Terminal Complex

This site planning concept is particularly relevant to the integration with higher speed, long-distance services, where both horizontal and vertical track curvature must be minimized. Thus, Dusseldorf chose to a make a 1.5-mile connection to the closest point on the HSR alignment, even though the airport already had a stub-end commuter line in the basement of the existing terminal. The Dusseldorf people-mover is similar in concept to that between the Northeast Corridor rail alignment and the three airport terminals at Newark, as the main rail line was not moved closer to the airport. Although it is not an official plan, London's Heathrow Hub concept is based on the idea that it is cheaper to connect the airport to the rail alignment via people-mover than it is to reroute the rail through the airport (Heathrow Hub 2012). From a design perspective, Paris Orly was the first European airport where an automated people-mover connected to an existing rail station, the so-called Orly-Val system; however, no connections are offered to long-distance rail services from Paris Orly, and thus it is not included in the sample of relevant airports.

Often, it is cost effective to bring the rail as close as possible to the terminals, but without attempting physical integration with the airport terminal buildings themselves. An example of such an airport rail station with long-distance rail connections is Manchester Airport (UK) where the moving walkways each average about 1,000-feet in length to connect with the airport terminal buildings.

From the passengers' perspective, some airports could be categorized as partially offering direct connections, and partially offering shuttle connections. As noted previously, long-distance rail users at Frankfurt, Paris CDG, and London Gatwick may require shuttle services to gain access to their actual check-in terminals, affecting the overall travel times of the air/rail combination.

Site Planning Concept #3: Connect to Network at a Central Place: Connect with the Best Consolidated Rail Transfer Point Possible

The review of major site planning concepts in Europe reveals that many airports have chosen not to bring long-distance services onto or adjacent to the airport fields. Included are airports in London (Heathrow), Madrid, Barcelona, Vienna, Munich, and Hamburg, all of which have high-quality, metropolitan-scale connections to downtown stations. While the details of HSR implementation in the UK are far from clear, the official plan for Heathrow is to connect with the HS2 alignment at the location already planned for the transfer with Crossrail, where most trains will stop anyway. In the Heathrow Hub scheme, an additional HS2 stop is planned for Heathrow users at a location closer to the airport. In short, airport travelers will be shuttled to a point of maximum transfer possibility for the rest of the rail systems, and the HSR operator will not endure the additional stopping time. Another early example of this strategy was the plan to connect Munich airport with a non-stop Maglev service to the downtown Central Station, but this plan has been dropped.

Implications from the three site planning concepts. Based only on the review of European examples, the pros and cons of each of the three categories of interconnection can be observed.

1. Re-routing the main line (long-distance) rail alignment into an airport is expensive, unless both the airport and the airport rail are built at the same time. Thus, it is highly unlikely that many more examples of re-routed main line track will be built as in Amsterdam or Zurich. Similarly, there will be few additional chances to replicate the "greenfield" solution of Oslo or Berlin, where new track is built with new terminals. However expensive, this is the design concept with the fewest transfers for the air passenger.
2. Connecting an airport, a rail line, and a people-mover will be cheaper than re-aligning a long-distance rail right-of-way. This was accomplished at Dusseldorf Airport, connecting to a station with long-distance service, and at Paris Orly, which connected to a station without long-distance service. However inexpensive, this design concept requires an additional mode between the long-distance service and the airport terminal.
3. Providing high-quality shuttle service from the airport to a station on the rail system where high levels of transferring already occurs may provide the highest levels of overall system connectivity, even if that rail station is not close to

the airport. However it is effectuated, this design concept minimizes the perception that the airport has been connected to the rail system.

Major Themes from Chapter 2

- The European research suggests that developing feeder rail services to the level where they actually replace feeder air services has been rare in Europe; this seems to hold true even in city pairs where O-D traffic has moved almost entirely from air to rail. From this view, any given candidate for deletion will be reviewed critically both by the airline affected and the long-distance rail carrier. Clearly, the business case for deleting a feeder flight and substituting a rail connection must be beneficial to both parties before such a deletion will occur. The putative benefit of the rail service for lowering airport congestion is not established unless the number of flights is lowered.
- Research about the European experience in making HSR serve as the sole feeder function to longer-distance air services suggests that early successes in Frankfurt and Paris CDG airports may be difficult to replicate elsewhere in Europe. Further development of this intermodal service concept, beyond such existing cases as Paris CDG to Brussels and Frankfurt to Cologne, may be unlikely.
- The European research suggests that some airlines are losing interest in the process of selling joint air/rail tickets—except where their own decisions have resulted in removing air service to a given destination, such as Cologne from Frankfurt Airport or Brussels from Paris CDG. A quick examination of schedules suggests most airlines are hedging their bets by offering both a feeder air service in addition to major rail-as-feeder; for example, between Boston and Cologne, Lufthansa offers air feeder service via Munich and rail feeder service via Frankfurt. Between Boston and Lyon, Air France offers one service by air and one by rail.
- Other cities have opted not to send long-distance rail to airports: Madrid is an example of a rail system with a massive investment in new rights-of-way that does not integrate well with airports. The HSR services go to two downtown Madrid stations, only one of which is connected directly by rail to the airport. EU and Spanish managers who have studied the integration of HSR with Madrid airports were interviewed; they concluded that air/rail simply was not a priority in these locations, and certainly not aimed at the replacement of feeder flights. In short, there is no universal adoption of the rail-as-feeder strategy in Europe.
- The market share data presented in this case study strongly suggests that high rail market share for the complementary trip cannot be accomplished by design quality alone; the most architecturally integrated of the examples is Lyon, which did not succeed in creating a pattern of access to the airport by long-distance rail. Good market share penetration has been accomplished in both Frankfurt and Paris CDG—airports with lower-quality connections—where the people-mover connections to some air terminals are confusing at best, with distances of 6,000 feet in FRA, and 10,000 feet in CDG. The research examples support the concept that the design quality at the airport alone cannot explain the use of rail to major airports; clearly other factors are at play, including the kinds of air services offered at the host airport.

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CHAPTER 3

Connecting Airports with Long-Distance Rail in the United States

Introduction and Structure

Chapter 3 now examines the North American experience with accessing airports by long-distance rail, presented in three parts. Part One presents a brief introduction to the five United States airports where rail stations have been built on rights-of-way served by Amtrak, and reviews what is known about their markets in general and the extent of their use by intermodal passengers using rail from beyond the traditional metropolitan area of the host airport. Part Two presents an original analysis of the roles of various parties in determining whether or not to have a long-distance rail stop at a candidate airport; a detailed analysis is presented concerning the business case for stopping and not stopping longer distance trains to serve an airport. Part Three uses the North American experience to update the Site Planning Typology presented in Chapter 2, which had been based on European observations, and notes the similarities and dissimilarities between the two sets of site planning characteristics. The Chapter concludes by noting that, in many cases, the manner in which rail services participate in a fully integrated multimodal transportation system may have little to do with whether or not service is provided directly to the physical site of an airport.

Part One: United States Airports Served by Long-Distance Rail

A key aspect of analyzing the potential for improving rail access to airports is to provide an assessment of the effectiveness of regional and intercity rail service in operation today at selected airports in the United States. To this end, five airports where long-distance rail access is currently in place were examined with regard to their physical planning/design characteristics, current ridership/modal split, and their degree of success in attracting air travelers to the rail mode for access/egress within their regions. The five airports are: Baltimore/Washington International Thurgood Marshall Airport (BWI), Bob Hope/Burbank Airport (BUR), Milwaukee's General Mitchell International Airport (MKE), T. F. Green Airport, serving Providence (PVD), and Newark Liberty International Airport (EWR). In Canada, examples of connections between long-distance rail and airports include a shuttle car service (upon a telephoned request) between Via Rail's Dorval station and the passenger terminal of Montreal-Trudeau International Airport, a distance of about 4,500 feet. This Chapter will focus on the five airports in the United States.

Examination of these airports will provide a framework that can be utilized to interpret the efforts undertaken to date in the planning, design, and implementation of rail as a feeder mode to O'Hare (ORD), San Francisco (SFO), and San Diego (SAN) in Chapters 6, 7, and 8. Each of the five airports has been examined and illustrations have been created to describe the rail alignment's proximity to the airport terminal complex, as well as the modes of transport providing connections to the terminals from the rail station.

The results of this analysis can serve as the framework for intermodal terminal development in other study airports and offers "lessons learned" for airports where intermodal terminals are being considered as part of an expanded regional rail network and HSR.

Baltimore/Washington International Thurgood Marshall (BWI) Airport Rail Station

The Setting: The Airport and Long-Distance Rail

The Baltimore/Washington International Thurgood Marshall Airport (Figure 3-1) has had rail service for over 25 years. The State DOT, the Airport Department, and Amtrak have sponsored numerous planning studies to investigate ways to enhance and expand the service. Amtrak developed a small station west of the airport terminal along the Northeast Corridor

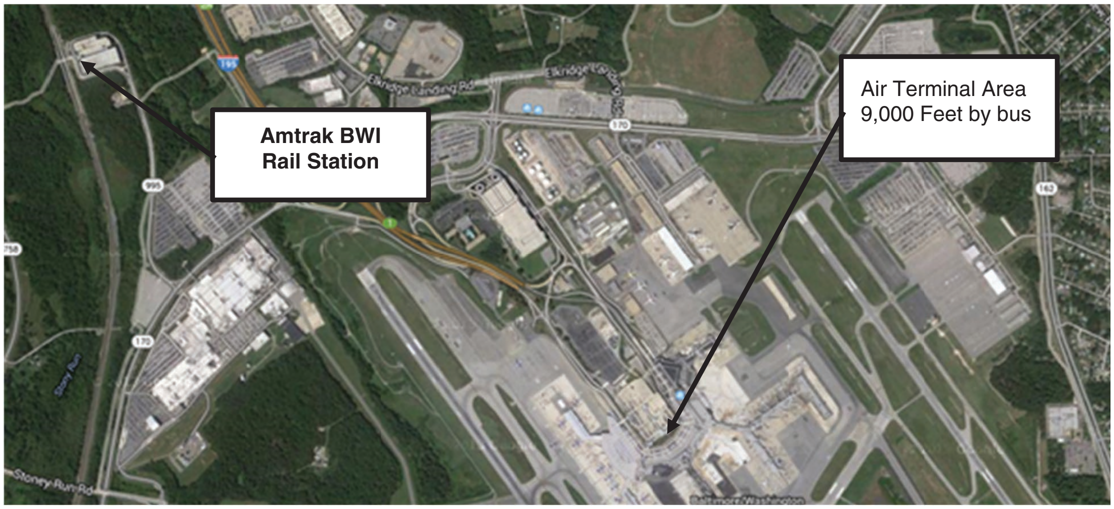


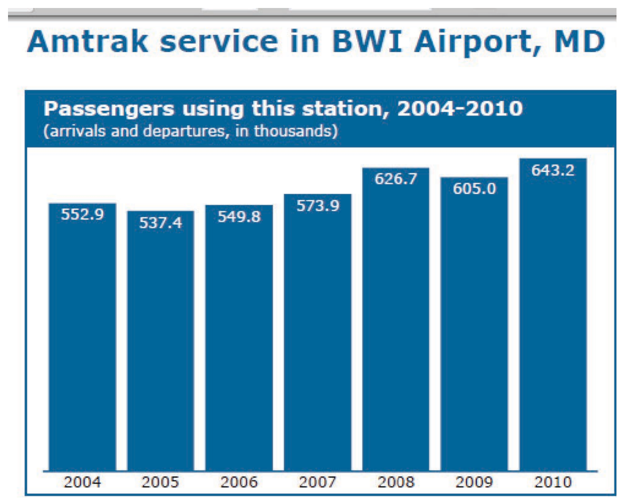
Figure 3.1. The BWI Marshall Airport Rail Station is located 9,900 feet from the passenger terminal. Imagery © 2014 Commonwealth of Virginia, DigitalGlobe, U.S. Geological Survey, USDA Farm Service Agency, Map Data © Google, 2014.

(NEC) in the 1980s. Between Amtrak and Maryland Area Regional Commuter (MARC) train service, there is frequent service from Baltimore's Penn Station and Washington's Union Station to the BWI train station, with travel times of 15 minutes and 30 minutes, respectively. Passengers transfer onto a bus at the BWI station to access the airport terminal, approximately 2 miles away.

Estimates of Intermodal Ridership

In the 2009 survey conducted by the Metropolitan Washington Council of Governments (MWCOG), there were 8.7 million originating passengers at BWI (MWCOG 2010). According to that multi-state survey effort, 140,000 passengers (annually) traveled by Amtrak and MARC combined. If Amtrak is getting half of that, that would be 70,000 air passengers, or about 200 per day. About 880 passengers board Amtrak services every day (with a similar amount disembarking from trains), which suggests that airline passengers are not the largest segment of users of this station. Intercity Amtrak riders who board at this station are going primarily to Philadelphia, Newark, and New York City, as shown in Figure 3-2.

The station is located in a prosperous suburban area south of Baltimore; it would be a good candidate for both park-and-ride and kiss-and-ride patrons making the trip north. A major feature within the station area is a large parking garage that is well utilized by Washington-bound, MARC commuters living in the airport area. Although the current station is outdated in terms of basic amenities, it was recently updated by Amtrak to assure longevity—new high level platforms, lighting, and elevator enhancements. Light rail serving



Quick recap, 2010 (arrivals and departures)

	Coach/ Business	First/ Sleeper	Total
Passengers	634,162	9,005	643,167
Average trip	137 miles	198 miles	335 miles

Top city pairs by ridership, 2010

1. New York, NY	196 mi
2. Washington, DC	30 mi
3. Philadelphia, PA	105 mi
4. Newark, NJ	186 mi
5. Wilmington, DE	80 mi
6. Metropark, NJ	172 mi
7. Stamford, CT	232 mi
8. Trenton, NJ	138 mi
9. Newark--Liberty, NJ	183 mi

Figure 3-2. Amtrak station summary. Source: Amtrak 2011.

downtown Baltimore also has its southern terminus at BWI at the extreme west end of the terminal complex.

The Research Team concludes from the continuous surveying process of the local metropolitan planning organization that the BWI catchment area has shrunk over the last decade. The Research Team estimates that in 2000, 28% of the BWI-originating passengers came from outside the suburban ring of communities surrounding Baltimore and Washington DC. By 2007, that portion of originating riders had shrunk to 17%.

MWCOG noted this change and a decrease in relative importance of the District of Columbia as an origination source over that period; they write, "the percentage of passengers originating in the District of Columbia declined by 22 percent and by 43 percent from the outlying areas between 2000 and 2007" (MWCOG 2010).

This direct evidence suggests that BWI is gaining strength from its close-in markets, well served by modes such as taxis and shared ride vans, rather than by fast trains in either direction. Coincidentally, the period in question represents a time when Southwest Airlines altered its strategy of serving the Philadelphia area from BWI, and started serving other more NEC airports. According to the interviews, air passengers' use at the BWI Amtrak station was highest during the period when Southwest did fly to BWI, but did not fly to PHL. Today, the Texas-based airline flies to PHL, EWR, and LGA, and will expand its regional presence considerably with the ongoing consolidation of services of its AirTran airlines subsidiary.

Background and Other Activities

Shortly after September 11, a major feasibility study was conducted to develop a remote intermodal terminal complex (ITC) to consolidate some rail access modes, future maglev service, and consolidation/centralization of air passenger processing functions, including ticketing, security, check-in, and bag claim. An automated "people-mover" system would provide the landside distribution system to the airline gate boarding piers. The motivation for this study focused on:

- Enhancing BWI's competitive position in the region;
- Alleviating ground access congestion and parking shortages;
- Providing more airline gate positions;
- Creating joint development opportunities, such as conference/meeting centers, hotels, airport-related offices, etc.; and
- Improving intermodal connections and convenience to attract a higher rail mode share (at least in theory, if the people-mover were later extended to the rail station).

No tangible steps were taken to implement this concept to date; however, the level of improvements at the airport since this timeframe would not preclude future consideration of this concept. The concept allows for a re-routing of the current airport light rail line to make way for major runway construction on the eastern portion of the airport. However, the concept would take a direct connection between the light rail and the terminal complex and replace it with an indirect one, relying on a transfer to a people-mover to gain access to the terminal complex. Importantly for the themes of this case study, the existence of the "intermodal terminal" did nothing to overcome the problem that the long-distance rail station is located a considerable distance from the airport passenger terminal, dealing instead with a highly unlikely maglev line.

Bob Hope/Burbank (BUR) Airport Rail Station

The Setting: The Airport and Long-Distance Rail

The local commuter rail system (Metrolink) and Amtrak's Pacific Surfliner route (10 trains per day) service the Burbank Airport Rail Station (Figure 3-3) daily. The Surfliner is the second busiest service in Amtrak's national network. With a boarding platform only, it is not supported by a separate station structure, service amenities, or parking lots, although rail users can park at airport rates on the airport lots.

Estimates of Intermodal Ridership

The majority (about 60%) of Amtrak users at BUR are traveling to destinations within 100 miles, including Santa Barbara and Oceanside, while about one third are going to San Diego. Figure 3-4 shows that very few are going to Los Angeles, as there are other, cheaper modes in the region, including Metrolink from the station. At present, about 60 passengers per day board one of the five Amtrak Pacific Surfliner trains (in each direction) serving BUR. Because this is the only Amtrak stop in the city, it must be assumed that some of the users are gaining local access, and not airport access. The two highest origins for Amtrak users are San Diego and Santa Barbara. The Research Team estimates that, if there are any airport users on the train, most do not come from either San Diego or Los Angeles, because both airports offer better air service, including service by Southwest Airlines, the main operator in Burbank. Thus, it is estimated that only a very small number of the persons boarding the long-distance train daily are coming from markets that would logically feed the airport.

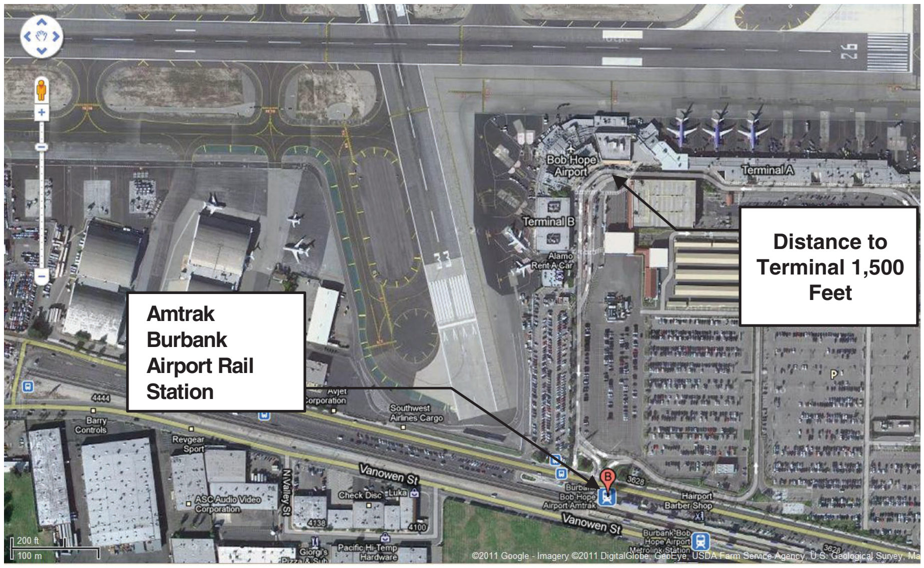
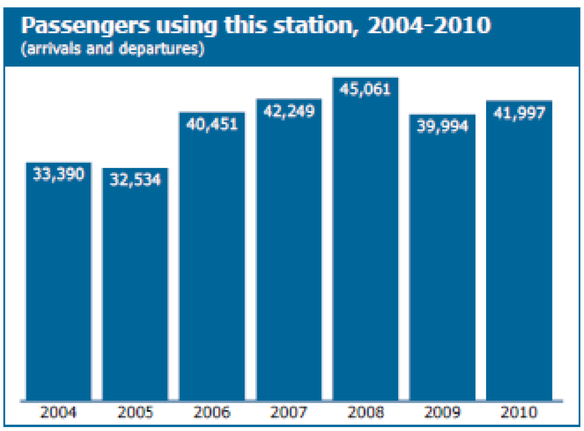


Figure 3-3. The Amtrak rail station is 1,500 feet from the Bob Hope/Burbank Airport.

Amtrak service in Burbank--Airport



Quick recap, 2010 (arrivals and departures)

	Coach/ Business	First/ Sleeper	Total
Passengers	41,997		41,997
Average trip	94 miles	n/a	94 miles
Average fare	$ 24.00	n/a	$ 24.00
Average yield, per mi	25.3¢	n/a	25.3¢

Top city pairs by ridership, 2010

1. San Diego, CA	142 mi
2. Santa Barbara, CA	90 mi
3. Solana Beach, CA	117 mi
4. Oceanside, CA	100 mi
5. Oxnard, CA	53 mi
6. Ventura, CA	63 mi
7. Goleta, CA	98 mi
8. Los Angeles, CA	13 mi
9. San Luis Obispo, CA	209 mi

Figure 3-4. Amtrak station summary. Source: Amtrak 2011.

Burbank Airport Station is an example (similar to Lyon Airport, Chapter 2) of an airport well situated from a physical perspective, but with little market for intermodal services.

Background and Other Activities

In the fall of 2012, the Burbank Airport commenced the construction of the Regional Intermodal Transportation Center, across Empire Avenue from the Amtrak rail station. According to the airport management,

> "The RITC will be a three-level structure housing a consolidated rental car facility and rental car customer service building and will include a bus transit station on the ground level. An elevated moving walkway will convey rental car customers and rail and bus passengers between the airport passenger terminal and the RITC, making Bob Hope Airport uniquely convenient and accessible via multiple transportation modes" (Bob Hope Airport 2012).

Relationship with HSR

According to the Research Team's interviews California High-Speed Rail Authority (CHSRA) is very skeptical about adding additional stops to its main line HSR service, even when the station would be close to an airport. At the time of this writing, the CHSRA plan calls for a single combined Burbank/Glendale station that is not in downtown Burbank and not at the BUR location. This station plan could, of course, change over time, as the plans for rail investment are still evolving. Thus, the rider would be encouraged to take some other form of rail, possibly a future Orange Line, to get to a transfer point with the HSR corridor. Reportedly, BUR was looking to the Orangeline Development Authority (OLDA),

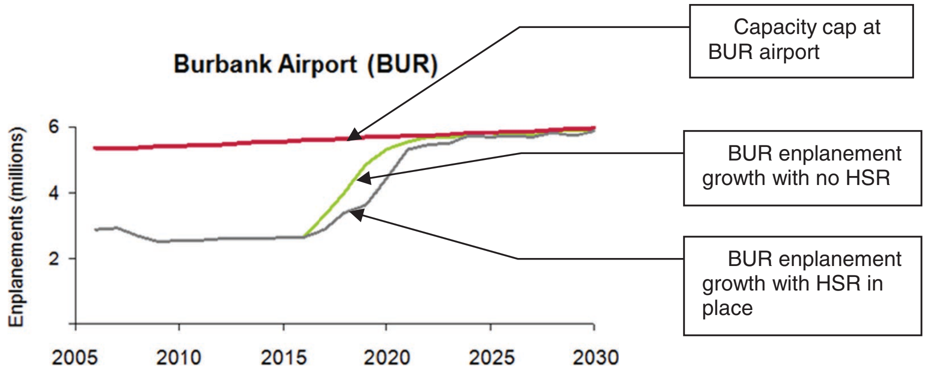


Figure 3-5. Capacity constraint at Burbank Airport. Source: Jacobs Consultancy, Presentation #2 Preliminary Findings–Remaining Scenarios, Slide 39, Dec 9, 2010. Annotations added.

now renamed as Eco-Rapid Transit, to develop a regional high-speed transit connection to cities between Santa Ana and Santa Clarita, with stops in Glendale, downtown Burbank, and BUR (AirRail News 2011, Orangeline Development Authority 2011).

In examining the possible future role of a Burbank Rail station as part of a larger strategy to maximize the quality of access to key airports, it is important to note that Burbank Airport is highly constrained in its growth potential. A regional analysis done in Southern California suggests that BUR will experience a significant capacity constraint by the year 2020. As part of the San Diego Regional Airport Strategic Plan, the firm of Leigh|Fisher (operating as Jacobs Consultancy at the time) concluded that the existence of HSR between Los Angeles and northern California would delay the impact of the capacity constraint at Burbank Airport by several years; however, it would still occur by 2025, as shown in Figure 3-5. In light of this capacity problem, it would make little sense to use HSR to feed the development of this airport.

General Mitchell International Airport (MKE) Rail Station

The Setting: The Airport and Long-Distance Rail

The MKE rail station was intended to serve as an airport rail link for General Mitchell International Airport, which serves the Milwaukee area. Figure 3-6 shows the location of the Amtrak Airport Rail Station, which is connected by shuttle bus to the primary passenger terminal check-in area. The station serves about 156,000 passengers per year (Figure 3-7); by way of comparison, the downtown Milwaukee terminal of the same line attracts about 576,000 passengers per year.

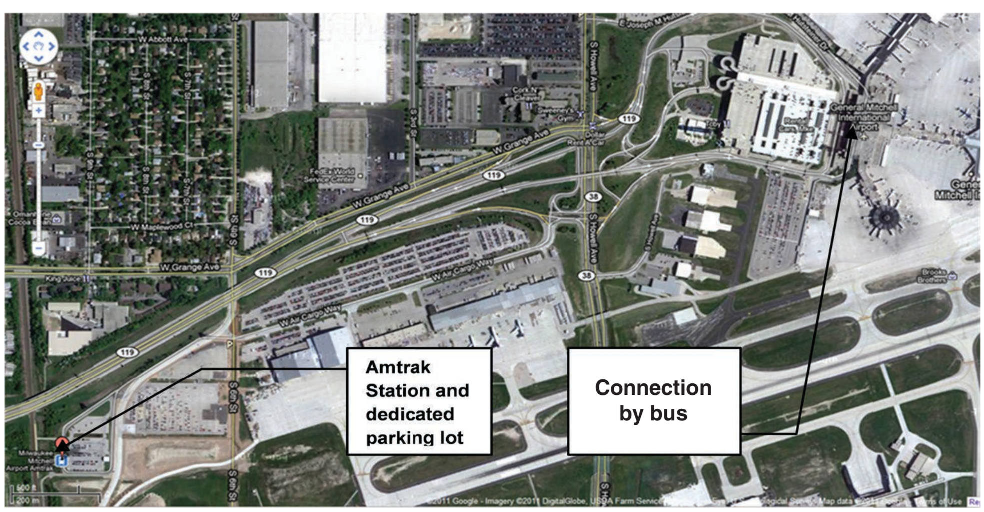
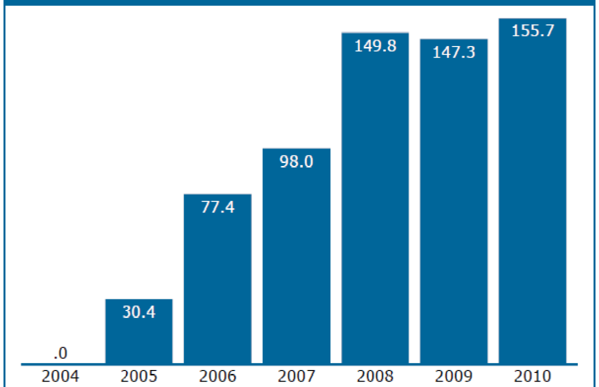


Figure 3-6. Amtrak station is 7,500 feet from General Mitchell International Airport. Imagery © 2011 DigitalGlobe. USDA Farm Service Administration, US Geological Survey, Map Data © Google.

Amtrak service in Milwaukee--Airport

Passengers using this station, 2004-2010
(arrivals and departures, in thousands)



Quick recap, 2010 (arrivals and departures)

	Coach/ Business	First/ Sleeper	Total
Passengers	155,726		155,726
Average trip	76 miles	n/a	76 miles
Average fare	$ 18.00	n/a	$ 18.00
Average yield, per mi	24.1¢	n/a	24.1¢

Top city pairs by ridership, 2010

1. Chicago, IL	78 mi
2. Glenview, IL	60 mi
3. Milwaukee, WI	8 mi

Figure 3-7. Amtrak summary. Source: Amtrak 2011.

The station includes a Quik-Trak ticket vending machine, restrooms, a seating area, covered walkways to both the drive-up/drop-off area, and a parking lot. As the station is unstaffed, all tickets from the station must be purchased from an onboard conductor or from Quik-Trak in advance. The station parking lot contains 300 spaces and costs $5 per day per vehicle. All revenue generated from parking fees is used to finance the station's operating costs.

MKE is served by the Hiawatha Service, an intercity passenger rail service operated by Amtrak that comprises an 86-mile train route on the western shore of Lake Michigan. At present, 14 trains (seven round-trips, six on Sunday) run daily between Chicago, Illinois and Milwaukee, Wisconsin; these trains make intermediate stops in Glenview, Illinois; Sturtevant, Wisconsin; and General Mitchell International Airport. The line is partially supported by funds from the state governments of Wisconsin and Illinois.

The corridor rail service carried 783,060 riders in FY 2010, a 6.1% increase from FY 2009's total of 738,231 passengers (Amtrak MPR). It is Amtrak's ninth-busiest route, and the railroad's busiest line in the Midwest. A one-way trip between Milwaukee and Chicago takes about 90 minutes. MKE views itself as Chicago's third airport, attracting a significant number of airport users from the north side of the city (*Trains* 2006). Before its demise, Midwest Airlines (whose hub was MKE), supported the airport station because it identified North Shore customers as a potential market. Midwest attracted more than 6% of its customers from northern Illinois (*Destination: Freedom* 2004).

Estimates of Intermodal Ridership

There is no evidence that an appreciable number of air passengers are using Amtrak to gain long-distance access to this airport. A recent study by the Texas Transportation Institute concluded that "[u]se of the airport rail station to transfer to airline service was minimal, reported by 6 percent of current Hiawatha Service passengers" (Sperry and Morgan 2011). Their calculations found 9,600 passengers per year used the station to transfer to the airport. This is about 26 passengers per day, or 13 passengers boarding the train at the airport station.

Background and Other Activities

Station History

The idea for an Amtrak station at the airport came from executives at Milwaukee-based Midwest Airlines in 1991. Midwest executives hoped to generate revenue partly by negotiating a deal with Amtrak that would allow customers to use one ticket for their rail and air travel. The airline allowed its customers to use their Amtrak travel for frequent flier miles (Allison 2004).

The project began with a 2000 tour of the site by then-Wisconsin Governor Tommy Thompson, who had served as a director of the national railroad from 1990 to 1994. In 2000, it was thought the station would become part of a statewide HSR network that had been proposed. The project hoped to attract airport passengers and commuters living in Milwaukee's southern areas who did not want to cope with traffic and parking downtown. Under the then-proposed $4 billion Midwest Regional Rail Initiative, the existing Hiawatha Service would be expanded, and perhaps extended, to serve Green Bay and Madison (Allison 2004).

In 2001, Midwest Airlines and Amtrak reached an agreement to allow for code-sharing, construct a station, and increase the number of trains serving the station by 10. The plan envisioned a net positive cash flow as a result and collaboration with the freight railroad (Martin 2011). The September 11 terrorist attacks forced the suspension of planning to provide direct baggage handling to MKE via Amtrak. Funding the construction of the station was an issue; neither the airport nor Milwaukee County officials were willing to commit funds.

The station opened for service in January 2005. At the time, it was only the fourth Amtrak station to have direct service to an airport; the others included Baltimore, Newark, and Burbank. Amtrak's vice-president of sales and marketing noted at the opening ceremony, "Amtrak looks forward to building upon its growing Hiawatha Service by introducing another rail to air connection. The successful experience in the East with the Baltimore/Washington International Airport (BWI) station demonstrates the great potential for the Milwaukee airport station" (*Destination: Freedom* 2005). Midwest Airlines chairman and chief executive officer at Midwest summarized their hopes: "It will provide passengers traveling to and from northern Illinois and Chicago faster and more convenient access to Mitchell International Airport and Milwaukee's hometown airline" (Mitchell Airport 2009). On June 23, 2009, Republic Airways Holdings acquired Midwest Airlines and discontinued the code-sharing arrangement between the airline and Amtrak (Daykin 2009).

Relationship with HSR

The Milwaukee Airport Rail Station is included in every long-term HSR plan now under consideration, as described in Chapter 6. It is seen as a major potential air/rail transfer point in both the near-term plans for 110 mph service in the region, and in the longer term vision of 220 mph rail in the region. When the state decided to cease planning for services between Milwaukee and Madison, plans for investing in services between Milwaukee and Chicago were not abandoned.

Providence/T. F. Green Airport (PVD) Intermodal Center

The Setting: Airport and Long-Distance Rail

In the winter of 2010–2011, a new air/rail station was opened at PVD (Figure 3-8), which serves Providence, Rhode Island. Amtrak would not serve the station, but there was a hope that MBTA commuter service would provide service appealing to some air passengers. The rail service is viewed as a park-and-ride for commuters to Boston whose origins are actually south of Providence. The parking at the intermodal station is designed for daily commuters, with overnight parking discouraged.

The intermodal facility can be seen as having six component elements, including:

- Commuter parking garage ($28.1M);
- Rental car garage ($46.9M);
- Rental car desk and service areas ($40.2M);
- Commuter rail platform ($22.9M);
- Skywalk, 1250 feet ($43.5M); and
- Connection from airport terminal to skywalk ($14.1M).

Estimates of Intermodal Ridership

Since the summer of 2012, there are eight trains per day departing T. F. Green station with service to Boston. There are seven trains per day departing from Boston going to T. F. Green. The train departure times are not designed to serve air passengers, as the service is primarily designed to take commuters from the area of the airport to Boston. By way

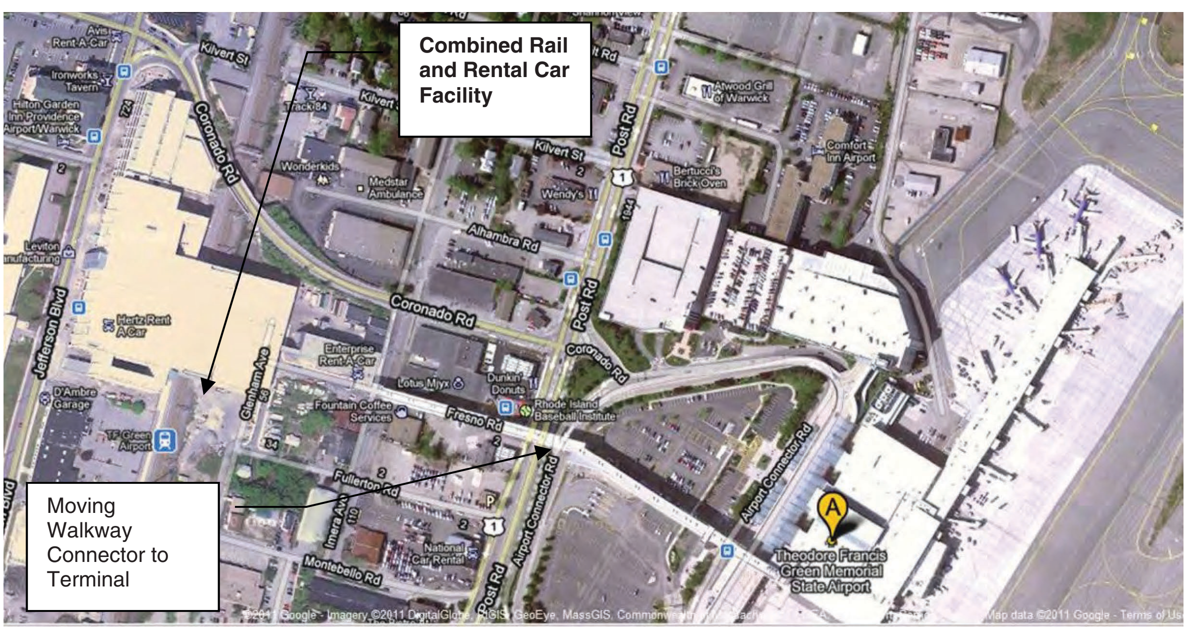


Figure 3-8. The airport rail station is 1,300 feet from the air terminal area. Imagery © 2011, DigitalGlobe, dGIS, GeoEye, MassGIS, Commonwealth of Massachusetts, Map data © Google.

of example, after 4:00 p.m., the only train from the airport to Boston departs at 10:30 p.m., with four trains in total between 7:00 a.m. and 4:00 p.m. Similarly, there are only four trains to take passengers from Boston to the airport before 4:00 p.m. The number of air passengers on the service is expected to be minimal given the difficulty of pairing rail schedules with air schedules.

Background and Other Activities

The Intermodal Center at PVD was conceptualized as a major application of the principles of passenger intermodalism, with the hope of uniting air and rail services at a rapidly growing "low-cost" airport. Most relevant for this case study is the fact that Amtrak, unlike service decisions at BWI and at Newark, decided not to stop any trains at the new facility. In order to understand the dynamics of these decisions, this report includes a thorough review of the business case for providing a new stop at this airport, which is presented in Part Two of this Chapter.

Relationship with HSR

At present, there is no planned activity to link the airport serving Providence, Rhode Island into the HSR system of the NEC. Amtrak's original NextGen proposal, for example, did include new stops at Philadelphia and Westchester Airports, but not at the existing facility at T. F. Green.

Newark Liberty Airport (EWR) Rail Station

The Setting: The Airport and Long-Distance Rail

The Port Authority of New York and New Jersey (PANYNJ), in partnership with New Jersey Transit and Amtrak, developed a new ITC on the NEC (see Figure 3-9) immediately adjacent to Newark Liberty that became operational in 2001. This very significant development included an airline baggage check-in facility and a direct connection to an extended landside automated people-mover system—AirTrain—that had been serving the airport complex's parking, rental cars, and three terminals since the mid-1980s.

Currently, Amtrak stops only 10 trains in each direction at the Airport Rail station. By contrast, New Jersey Transit (NJT) operates more than 80 trains in each direction on weekdays, resulting in a good amount of service, but sometimes with gaps inappropriate for an airport rail service. The primary features of this intermodal terminal include very frequent rail service from Manhattan and Newark by NJT, the regional commuter rail provider. While the 10 Amtrak regional trains do stop, there is no Acela service. Taking boardings and alight-

Figure 3-9. The center of the terminal area is about 6,500 feet from the rail station at EWR. Imagery © Bluesky, DigitalGlobe, Landsat, Sanborn, USDA Farm Service Agency, Map data © 2011 Google.

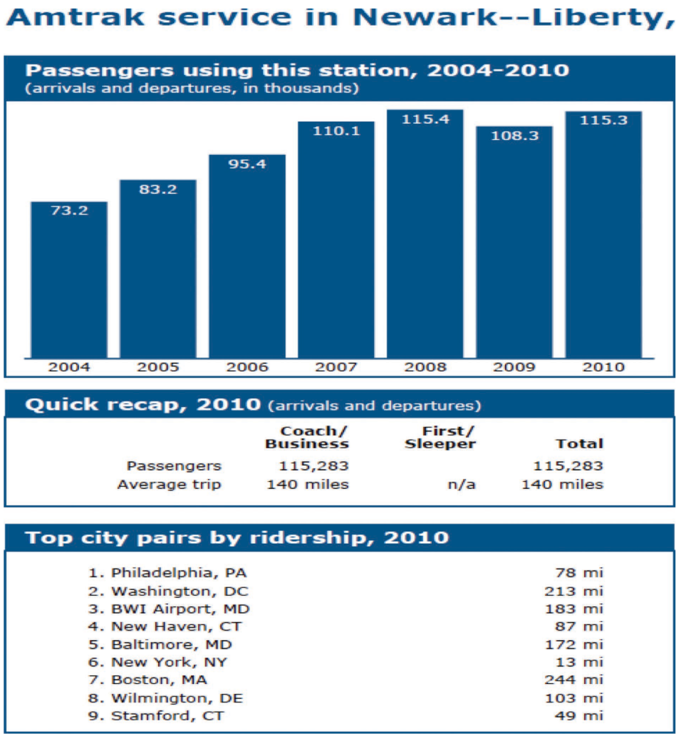


Figure 3-10. Amtrak Summary. Source: Amtrak 2011.

ments together, Amtrak serves about 115,000 riders per year at the station (Figure 3-10). Overwhelmingly, these are airline passengers rather than employees, as lower cost alternatives are available for most employee destinations.

Since the opening of the station, annual ridership on Amtrak has risen from 55,000 to 115,000 in 2010. However, as shown in Figure 3-11, the Newark Airport Rail station is dominated by NJT rail services and not Amtrak. The Research Team concluded that persons using the stations were from the airport, a majority being airline passengers; this is because local park-and-ride or kiss-and-ride users are barred from using the station.

In addition, the rail station at EWR benefits from the only surviving air/rail joint ticketing agreement in the United States, which is documented in *ACRP Report 4*. Although the number of tickets sold through this program is considered proprietary, the reader can gain a sense of the scale of the program from the more general discussion of long-distance ridership that follows. Additional studies of the intermodal operations at EWR were undertaken by the I-95 Corridor Coalition; these studies are available through the I-95 web site (I-95 2004 and I-95 2004a).

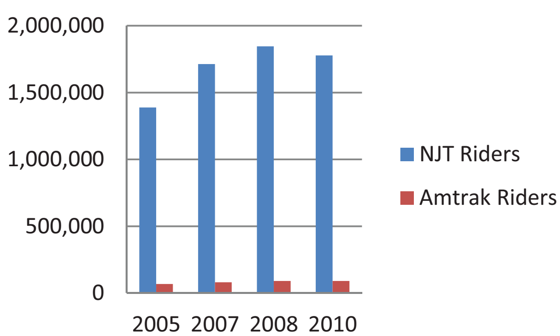


Figure 3-11. Relationship between local and long-distance markets. Source: NJT.

Estimates of Intermodal Ridership

Understanding the Long-Distance Market to Newark

Given Newark's prime location along the main intercity rail line of the nation, it is reasonable to expect that the mode share to rail for the long-distance traveler would be good, and it is. Table 3-1 shows that 9.6% of those EWR air passengers who are coming from beyond the metropolitan area are coming by rail and transferring to the Newark "AirTrain" people-mover (Zupan, et al. 2011). This percentage is in stark contrast to findings at MKE, BUR, and PVD; it is also seemingly stronger than at BWI.

The Research Team has compared the mode share of the long-distance ground access market in EWR to that of JFK in order to place this relatively high American mode share to rail in context. JFK is not located on a major interstate rail corridor (although the volumes from Long Island are important). For those who do not live on Long Island, gaining access from a long-distance ground origin requires making a transfer in Manhattan to either the subway or the Long Island Railroad. From there, the air passenger from beyond the metro region gains access to the AirTrain at either Jamaica or Howard Beach. Table 3-1 shows that the mode share to rail/AirTrain at JFK is virtually the same as at EWR. Approximately 1.4% of all non-transferring airline passengers boarding a plane at EWR were long-distance rail users, transferring onto the AirTrain. For comparison, of all non-transferring airline passengers boarding a plane at JFK, about 1.0% of them were from a long-distance origin and arrived by rail/AirTrain (calculated from Zupan et al., page 130).

Background and Other Activities

In light of the fact that EWR offers competitive air service for mid-haul, long-haul, and overseas flights, PANYNJ is studying the potential of extending their existing rail system (PATH) from downtown Newark at Penn Station to EWR. This service would reduce transfers for PATH travelers coming from lower Manhattan, Hoboken, Jersey City, and other major employment and emerging residential centers en route to the airport. The initial service would tie into the ITC and require a transfer to AirTrain.

Table 3-1. Mode share for long- and short-distance access to two NYC airports.

	EWR			JFK	
Mode	**Mode Share of Short-distance Group**	**Mode Share of Long-distance Group**		**Mode Share of Short-distance Group**	**Mode Share of Long-distance Group**
Personal Car	48.5%	54.5%		45.1%	42.4%
Hired Car	30.4%	21.9%		32.2%	27.8%
Rail to "AirTrain"	***14.2%***	***9.6%***		***12.4%***	***9.6%***
Bus	4.4%	3.3%		3.6%	3.5%
Local Shuttle	2.6%	10.7%		6.6%	16.8%
Total	100.0%	100.0%		100.0%	100.0%

Source: Zupan, et al. 2011.

Future Options for Long-Distance Rail to Connect to Newark Liberty Airport

PANYNJ recently began investigating the possibility of extending PATH directly into the terminal complex itself, providing seamless access to the three unit terminals at their "front doors." This was a result of increased interest in improving rail access to EWR and recognizing the current limitations of the automated people-mover in terms of capacity. The current people-mover system is located near the airside of the terminals and travelers must backtrack to the ticketing areas for check-in unless pre-ticketed, with boarding passes and carry-on luggage only. PANYNJ is giving this concept further consideration as enhanced HSR is being studied for the NEC.

Figure 3-12 shows four options defined in the Regional Plan Association (RPA) study undertaken for the Port Authority:

1. **New AirTrain to Newark Penn Station.** The EWR AirTrain, built in 1996 currently has insufficient peak hour capacity and will have to be replaced with a higher capacity, more technologically advanced and reliable system. This provides an opportunity to extend the replacement service from the NEC station northward into Newark Penn Station.
2. **Extension of PATH to the NEC Station Combined with AirTrain Upgrade.** With this option, the PATH service now terminating at Newark Penn Station would be extended about 2 miles to the NEC station, creating a two seat ride (PATH and AirTrain) for Lower Manhattan and Jersey City riders.

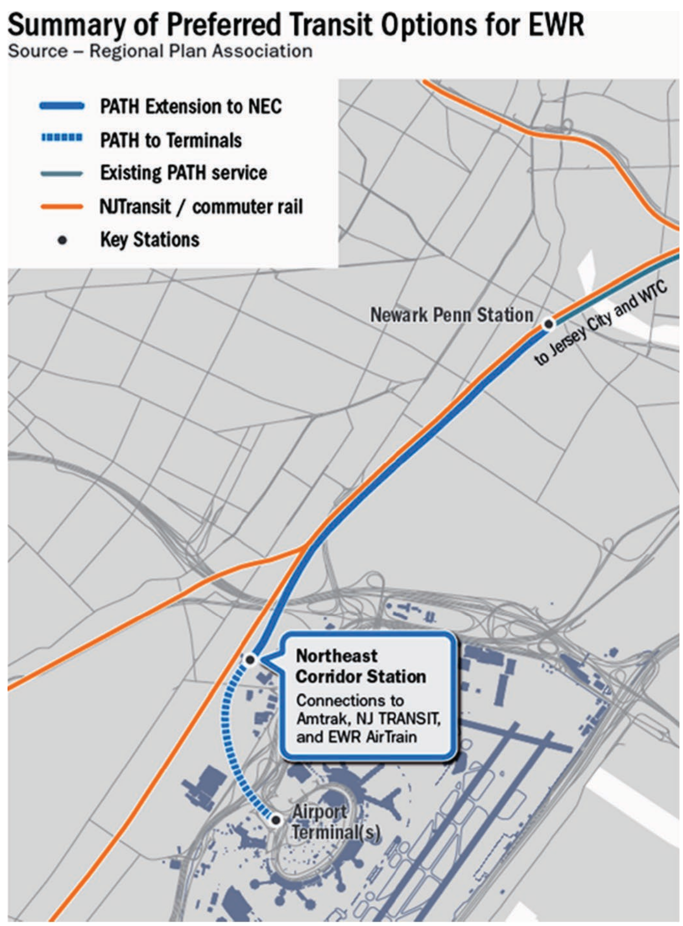


Figure 3-12. Options for the future. Source: Zupan et al. 2011.

3. **Extension of PATH onto EWR.** This option takes the previous option a step further by extending PATH onto the airport to one or more terminal stations. This would eliminate the transfer for Lower Manhattan, Jersey City, and Downtown Newark originating passengers.
4. **Amtrak Service Added at NEC Station.** Theoretically, Amtrak could stop more than the nine trains each way each day that stops today. However, the trade-off would be greater intercity travel time for the passengers not destined for the airport (Zupan, et al. 2011).

Part Two of this Chapter will review the logic of adding more Amtrak trains, where option four is explored from an operations perspective.

The remaining three options are combinations of design options. Option 2 has the advantage of administrative simplicity, at the cost of direct service for any group. Under this option, automated, driverless service could continue to be supplied for whatever schedule/frequency required for airport operations or integration with other market needs, such a supplying a continuous level of service for the users of the rental car facilities.

A remarkable design opportunity exists because of the fact that the existing EWR AirTrain needs to be re-conceptualized, redesigned, and rebuilt in any event; at the same time, new runway configuration needs are causing the re-examination of the present terminal locations. From a design point of view, "one or more" terminal stations could be rebuilt with clearances appropriate for PATH vehicle technology. This makes possible the consideration of the RPA's option three. It also makes possible a hybrid solution in which the PATH vehicle serves as the airport people-mover only when it is needed for its regional schedule requirements. The same track built for the PATH train could support an "extension" of the redesigned airport people-mover to Newark Penn Station. This would allow the PATH vehicle to operate in all three passenger terminals when its regional schedule justifies it; this would also ensure the ability of the airport managers to provide internal circulation at a frequency appropriate for the other requirements of the airport.

As noted in the RPA study, all of this allows for the possibility of running the appropriate frequency of service from the airport to the regional system, perhaps by keeping the existing station, and perhaps operating an adequate amount of service to Newark Penn Station and abandoning the existing Newark Airport Rail station altogether. The RPA notes some of the complications in its report:

> "A sub-option would eliminate the NEC stop altogether, shifting the transfer point for NEC riders to Newark Penn Station . . . Those coming from the south on the NEC would have to backtrack from Newark Penn Station if the NEC station were dropped. Eliminating this station may also create complications, since the Passenger Facility Charge levied on passengers at EWR was used to build the station" (Zupan, et al. 2011).

The implications of providing better travel times for a minority of corridor riders, at the cost of worsening travel times for the vast majority of train riders on the corridor, needs some additional analysis and documentation. Chapter 3 provides that analysis in Part Two. Looking at the Newark design options issue only from the vantage point of the major themes of this study (i.e., as if other concerns did not exist), Amtrak would be a major beneficiary in the option of abandoning the existing NEC station. One-transfer airport connections would be offered for every train operating through Newark Penn Station. However, Amtrak would not be the only operator that could provide faster running times for its patrons; NJT could improve the travel times and speeds on more than 160 trains per day.

If people-mover-like schedules (such as those in operation at JFK) could be provided to Newark Penn Station, the intermodal connecting options would be exceptional. From that location, there are over 375 train movements by NJT and Amtrak (not including the PATH services, nor local light rail) presented as Table 3-2 from data reported in Wikipedia.

The PANYNJ announced in February of 2014 that it plans to fund a $1.5 billion extension of the PATH rail system to Newark Liberty International Airport (*Wall Street Journal* 2014). This is highly interrelated with the agency's study of possible reconfiguration of the airport passenger terminal area, associated with possible construction of new runways. In effect, this funding decision focuses planning attention on RPA's Options 2 and 3. In Option 2, PATH service would meet an airport people-mover at the existing NEC rail station; in Option 3, the PATH service would be further extended to some number of on-airport terminals. Thus, questions of how future rail facilities would interact with the future terminal facilities are being addressed on an ongoing basis by the PANYNJ.

Part Two: The Business Case for and Against an Airport Rail Station

Chapter 2, in its summary of the European experience in access to airports by long-distance rail, reported the conclusion of one of the architects of the Frankfurt air/rail system,

Table 3-2. Potential rail connections at Newark Penn Station.

Corridor	Number of Trains (weekday)
Westward from Newark	188
NJ Transit from New York Penn	106
NJ Transit from Hoboken	5
NJ Transit to the CNJ main line	26
Amtrak	51
Total Daily Train Movements	376

Source: Wikipedia 2011.

that for such a scheme to work, there must be buy-in from all parties—something he doubted would happen in many attempts to replicate the Frankfurt experience. As noted earlier, for an airport railway connection to work, it must be in the interests of a wide group of stakeholders—including the public, the airport, the airline, and the railroad company. This section of Chapter 3 reviews the role of various players, and then focuses primarily on the role of the long-distance rail company in examining the business case for stopping its long-distance trains at the airport station.

The Public

It is unclear exactly who represents "the public" in their dealing with the airports, the airlines, and the rail companies (each of whom have business cases to justify). However, it is clear that public, civic concerns do exist; in some cases, these issues are clearly defined (e.g., European Union public policy) and in some cases they are not. Connecting railways to airports could satisfy a number of social objectives, including reduction of pollution and CO_2 emissions, reduction of highway and airway congestion, improvement of safety, and focusing use of airport capacity on longer-haul services rather than making short, intercity hops, among others. In principle, the European Commission has decided that the public investment needed to improve rail/airport connections will be justified by these benefits. The Commission's clear emphasis on HSR airport connections indicates that the objective will include shifting air traffic to rail for short-haul trips and improving local connections. In practice, this suggests that much of the existing air traffic between major airports in France, Belgium, the United Kingdom, the Netherlands, and Germany might eventually shift to center-city rail—a transition that was reported in Chapter 2.

The Airports

Reliable, local rail connections could be in the interest of airports, subject to there being enough volume to justify the airport's share (if any) of the cost of the airport railway station, and subject to the impact of loss of parking revenues, if any. It may not be in the interest of that airport to see improved rail service to other airports if the airports are competing for the same traffic. On a local level, for example, DCA might lose passengers to IAD when the new Metro line is completed (though this might well be in the overall public interest). Connecting HSR to an airport extends the airport's catchment zone. As a result, a traveler through a major hub (international or domestic) can choose an air connection to his or her eventual destination or take rail instead. A major hub with good HSR service might benefit from a larger service area and an improved competitive position vis-à-vis a hub without rail service. The airport would then calculate whether the cost of the airport rail station is justified by added traffic.

The Airlines

The airline calculation is more complex. In general, airlines would not favor a HSR link at an airport if it led to increased competition for a given profitable air market. If the market in question is short and/or unprofitable, the airline might look at the question differently, especially if the airline also operated the railway service and could do so profitably. Airlines might also favor HSR connections to some of their "spokes" if shifting some of the "spoke" traffic to rail would permit better (or increased) longer-haul air service at the hub. In a more general way, airlines might also favor HSR connections if the rail service permitted better and more frequent service to a number of spokes than the airline can offer, thus (in principle) generating more demand for the longer-haul air links. It deserves emphasis that the institutional relationship among airlines and railways is important. First, if the passenger perceives the link as seamless (single ticket and baggage, integrated schedules, improved service), all might benefit. If airline and railway are competitors, they are unlikely to provide such service (and, indeed, many air/rail connections suffer from this problem). If the airline and railway are separately owned and managed, it may be more difficult for them to devise a common ticketing service if one of the stakeholders derives more benefit than the other.

The Railway Company

In order to better understand the business case for and against the addition of intercity rail stations on existing (or proposed) rail lines, this project commissioned a study of the detailed economics faced by the rail managers (Thompson 2011). This section of Chapter 3 summarizes key aspects of that study of concerns experienced by the railroad managers concerning joint air/rail projects.

For a local rail connection, the calculation for the railway is simpler: do the added passenger revenues (and related public subsidy, if any) cover the investment and operating cost involved. In some cases (the WMATA link to IAD), the calculation will include the fact that the airport link will also develop a major new, local market (Reston and Tyson's Corner) that is of interest to the rail operator. In the longer run, most local rail connections tend to generate related economic activity that adds to the financial and economic performance of the local link.

Adding an intercity rail link (including HSR) to an airport would raise a different calculation (unless the link is simply a stub connection to an airport having the effect of better local connectivity). In this case, the rail operator would be adding a new market (air travelers that will complete their trip by rail rather than by air), but doing so at the cost of increasing the trip time for existing rail passengers. This could then pose a trade-off for the rail operator between the passengers gained by the airport link versus those potentially lost because of longer trip times for existing passengers and the added costs of establishing the station, along with the added operating costs of maintaining the station and of stopping trains at it.

There are no completely clean examples of this issue because all connections are a blend of local and intercity connectivity. One example might be the new airport connection at T.F. Green Airport in Providence, RI (PVD). If Amtrak's Acela trains stopped at the PVD airport station, they would clearly increase the trip times between other markets on the line [including New York Penn Station (NYP), New Haven (NHV), and New London (NLC) to Route 128 (RTE), Back Bay (BBY) and South Station (BOS)], thus exposing those passengers to increased competition from air between New York and Boston and to diversion to road. On the other hand, a direct stop at PVD could at least theoretically increase rail traffic by diverting some longer-haul air traffic from the congested Logan Airport to PVD, with an excellent rail link into Boston, or from LaGuardia (LGA) with an excellent rail link into NHV. Other examples might involve travelers going through BWI rather than PHL to Wilmington, which would expose the rail market south of NYP to the added stopping time at BWI. Travelers could go through EWR rather than LGA or JFK on the way to PHL or NHV (or, indeed, to many areas in the New York metropolitan area that are poorly served by congested access to LGA and JFK), but this would again expose some of the travel market south of NYP to stopping delays.

In more general terms, total travel demand between two markets is a function of the populations of the markets, the incomes (and values of time) of the population, and the trip time between the markets. Each of these factors can only approximate reality. For example, the total population of an area can be spatially distributed in a number of ways that will affect the trip generation of the market. Also, income distributions can be skewed in ways that will affect total demand and modal preference; trip times as perceived by the passenger include not only the line haul time of the trip, but also access/egress times, waiting time (trip frequency), and the probability and severity of delays. Moreover, acquiring actual data on travel can be difficult because some of the most important data (auto travel) are often not collected, while other data (intercity air and rail passengers) are subject to various levels of confidentiality. The net result is a model of total demand that must be calibrated to specific O-D pairs and can give only approximate results subject to a significant range of variation.

Modal split models are then used to allocate demand among the available modes, based on the relative cost (line haul plus access/egress costs), trip time (line haul, average waiting times that are determined by service frequency, schedule reliability, and access/egress), and a number of other factors (perceived safety and comfort). Modal splits are also commonly segregated by trip purpose—business versus pleasure. The effect of the modal split variables can be significant. For example, business travelers attach a much higher weight to the value of their time (and comfort) and less to cost than do nonbusiness passengers. As with the total demand estimates, modal split projections are specific to particular markets and, if experience is any guide, subject to a great deal more uncertainty than developers would like to acknowledge.

As a consequence, the rail planner considering the addition of an intercity stop (HSR or otherwise) faces a decision in which the ratio of qualitative to quantitative measurement can vary widely. Generally, the measurement of costs (investment and operating) is somewhat more precise (though still subject to error) than the ability to calculate benefits, so conservatism will be natural. This is especially true for rail carriers that will not receive any explicit public support for the new service. These carriers must predict some level of financial (as opposed to economic) surplus from the service added; this must be done while the effect on demand is questionable and while the rail carrier's costing information is aligned more to accounting for public support than it is to measuring financial profitability. Where no demand forecasting tools exist, the resulting decision is based on judgment and tends towards the negative if financial performance matters—and towards the political where it does not.

In a few cases, such as the new connection at the PVD airport station, Amtrak would have the option of an experiment. Since the station is already built, Amtrak could add an Acela or Regional stop at PVD and measure the effect on demand and cost. This would add a data point that does not now exist, and it might permit a more confident assessment of effect on demand in other cases. Unfortunately, addition of one stop might not make much difference, because there are so few services offered. In addition, the PVD airport station does not have electrified tracks connecting to the high-speed main line, so adding an effective high-speed connection would require significant investment from either Amtrak or the airport authority before the service could be added (current service by MBTA is provided by diesel traction).

In some cases on the NEC, the rail planner would have both approximate existing traffic data and a demand model calibrated on the available dataset. The Research Team cannot replicate their exact information since Amtrak has not historically released detailed market flows by O-D and by passenger class. An approximate set of O-D flows was, however, constructed by class based on data that Amtrak has released over the years in its Monthly Performance Reports (MPR from Amtrak website) and a judgment as to the relative populations involved—a "stylized" set of O-D flows. The base data table is meant only to illustrate the analysis in a reasonable way, and was not based on recent, actual information. Actual Amtrak tariffs and scheduled trip times taken from the Amtrak website have been added to this information, along with approximate Acela and NEC Regional cost information taken from the MPRs.

Airline data are likewise taken from a combination of the T-100 dataset along with scheduled flight times from airline websites and from the Kayak.com website. Again, these data only reflect a single point in time, both for demand and for schedules, and say nothing about individual airline flows. Given the complexity and volatility of yield management pricing and the multiplicity of aircraft types in use depending on volumes and length of haul, it is not possible to characterize airline fares in detail.

Two examples represent the planner's challenges: addition of an intercity stop at Providence airport and addition of more trains stopping at EWR.

Intercity Service to the Providence Airport (PVD)

For simplicity, one can focus on the potentially adverse impact on the NYC to BOS market (other markets would be handled similarly) where there are approximately 570,000 Acela passengers and 460,000 Regional passengers annually as of 2007 (when the air data were available). First Class Acela fares north of NYC are $108/passenger plus $0.37/mile (based on a regression of data from the Amtrak website) and Acela Business Class fares north of NYC are $67/passenger plus $0.22/mile. Regional Business Class fares north of NYC are $33/passenger plus $0.44/mile and Regional Coach Fares are $24/passenger plus $0.34/mile (Thompson 2011). The ratio of First Class seats to total seats on Acela trains is about 15 percent, so 570,000 passengers would be around 85,000 First Class and 485,000 Business Class (assuming a passenger balance close to that of the seating). This would produce Acela revenue of about $73 million and an average revenue/passenger-mile of about $0.57. In past years, Amtrak has published an estimate of avoidable costs (AC) and Fully Allocated Costs (FAC) for each route (e.g., the Amtrak MPR for September 2008, pg. C-1) that calculated that, on average, the AC/passenger-mile for all Acela passengers is about $0.22 and the FAC/passenger-mile is about $0.42. This means that each Acela passenger in the NYC to BOS market is yielding around $0.15/passenger-mile over FAC, and $0.35/passenger-mile over AC: at an average distance of 225 miles, this would be between $33.75 and $78.75 of contribution lost for every passenger that is lost if the additional stop causes any shift in market share.

Similarly, the 460,000 Regional passengers would represent revenues of about $48 million. This figure assumes that Business Class passengers are about 10% of the total and would yield average revenue of about $0.46/passenger-mile. This is compared with AC of $0.16/passenger-mile and FAC of $0.32/passenger-mile, thus losing Amtrak a contribution of $67.50/passenger over AC and $31.50/passenger over FAC for every passenger lost if the additional stop causes an adverse shift in market share.

The current trip time from NYC to BOS is 3 hours and 40 minutes (220 minutes) for Acela. For Regional service, it is about 4 hours and 30 minutes (270 minutes). An extra stop at the Providence airport would add about 3 minutes, or about 1.4% to the Acela schedule and 1.1% to the Regional schedule. The time elasticities for these services are not available, but assuming that the loss is the same as the percentage increase in schedule time, this would mean 8,000 Acela passengers/year and 5,000 regional passengers/year. In total dollar terms, this would be around $500,000/year over FAC and nearly $1,000,000/year over AC. These losses do not include losses in smaller markets also affected (NHV to BOS, or NLC to BOS). A more accurate calculation would look at these markets and might add 10–20% to the above numbers.

The increase in passengers arriving at PVD would then be examined, with the primary question being where they might go and how the added traffic would affect the intercity traffic. Table 3-3 summarizes the revenues and related costs for both the added traffic that the connection might generate and the traffic losses that might result from the lengthened schedule from NYC to BOS. It is clear that an added passenger from the airport stop will not balance a lost passenger from the NYC/BOS market, even given that the costs in the Providence to Boston traffic are almost certainly understated. In fact, the outcome would be dependent on the cost to Amtrak of using the station and on whether the diverted passengers used Acela service or Regional trains. Since the trip time of Regional service to BOS is essentially the same as Acela, it seems likely that most diversions, if they occurred, would be to Regional trains rather than Acela. With this said, the Providence airport has around 2.1 million boardings annually: if only 1% of the passengers were going to/from Boston and could be diverted to rail (from road), there could be a rough balance of losses and gains, assuming that the existing MBTA service would not continue to carry a significant share of the traffic. Only an experiment would answer this question.

Intercity Service to the Newark Airport (EWR)

Calculations of the effect of adding station stops at EWR are more complex because there are more markets potentially

Table 3-3. Gains and losses from an additional stop at T. F. Green Airport.

Gains to/from Providence airport and BOS ($/passenger)	Average Revenue	Avoidable Costs (AC)	Total Attributed Costs (TAC)	Margin over AC	Margin over TAC
Acela 1st Class	124.28	9.68	18.48	114.60	105.80
Acela Business	76.68	9.68	18.48	67.00	58.20
Average	83.82	9.68	18.48	74.14	65.34
Regional Business	52.36	7.04	14.08	45.32	38.28
Regional Coach	38.96	7.04	14.08	31.92	24.88
Average	40.30	7.04	14.08	33.26	26.22

Losses to/from BOS to NYC	Average Revenue	Avoidable Costs (AC)	Total Attributed Costs (TAC)	Margin over AC	Margin over TAC
Acela 1st Class	191.25	49.50	94.50	141.75	96.75
Acela Business	116.50	49.50	94.50	67.00	22.00
Average	127.71	49.50	94.50	78.21	33.21
Regional Business	132.00	36.00	72.00	96.00	60.00
Regional Coach	100.50	36.00	72.00	64.50	28.50
Average	103.65	7.04	14.08	96.61	89.57

in play. A station stop at EWR would add 3 minutes to the schedule of essentially all passengers to and from all points south of NYP to NY Penn, the most important single Amtrak market. In addition, Amtrak tariffs are structured differently south of NYP than north, with southern fares cheaper for short trips and more expensive for long trips, while northern fares are more expensive for shorter trips and less expensive for longer trips (Thompson 2011).

Table 3-4 shows the gains per passenger that Amtrak might realize if the added station stop at EWR were to add a passenger to or from WAS, BAL, and PHL. Table 3-5 shows the Amtrak passengers, revenue, and contribution that would be at risk by lengthening the trip times between NYP and WAS and BAL and PHL, along with the percentage impact on trip times of an added 3 minute delay added by a stop.

It is difficult to say with any confidence whether the gains would balance the losses. From one point of view, since all of the markets are well within the 3.5 hour "barrier," there might not be any significant demand losses, so that any passengers gained would be worthwhile (of course, this would be true of any added stop within the 3.5 hour limit, which would be a reduction ad absurdum that few planners would accept). At the other limit, it is possible that demand in each market would be reduced by as much as the percentage trip time increase, which could cost Amtrak a contribution of $6 million over FAC, and $9 million over AC. This loss could go up if the ridership loss is greater than the percentage increase in trip time, which could happen on the longer trips affected, especially Washington to NYP.

The gains to Amtrak are equally hard to estimate. Potential gains can be approximated by assuming that the traffic gained would have the same distribution of O-Ds as existing traffic south of NYP, and that the distribution of Acela versus Regional passengers would also remain the same. Under these assumptions, added demand at EWR would have to be around 110,000 passengers annually to make up for the $9 million AC and $6 million FAC contributions estimated above (see Table 3-4). This would make the Amtrak EWR station one of Amtrak's larger stations, but would only constitute about 0.6% of the roughly 17 million airline passengers boarding annually at EWR. As was the case with Providence, this does not seem to be an implausibly large percentage, especially given the ease of the air/rail connection at Newark, but it would in effect put Amtrak in competition with NJT, which might split the total rail traffic to the detriment of both.

Table 3-4. Potential gains per passenger diverted to rail at Newark Airport.

WAS ACELA		**WAS Regional**	
Distance	212	Distance	212
Revenue ($)	197.5	Revenue ($)	110.2
Avoidable Cost ($)	46.6	Avoidable Cost ($)	33.9
Total Attributed Costs ($)	89.0	Total Attributed Costs ($)	67.8
Margin over AC ($)	150.9	Margin over AC ($)	76.2
Margin over TAC ($)	108.5	Margin over TAC ($)	42.3
BAL ACELA		**BAL Regional**	
Distance	182	Distance	182
Revenue ($)	173.5	Revenue ($)	95.6
Avoidable Cost ($)	40.0	Avoidable Cost ($)	29.1
Total Attributed Costs ($)	76.4	Total Attributed Costs ($)	58.2
Margin over AC ($)	133.4	Margin over AC ($)	66.5
Margin over TAC ($)	97.0	Margin over TAC ($)	37.4
WIL ACELA		**WIL Regional**	
Distance	103	Distance	103
Revenue ($)	110.0	Revenue ($)	57.4
Avoidable Cost ($)	22.7	Avoidable Cost ($)	16.5
Total Attributed Costs ($)	43.3	Total Attributed Costs ($)	33.0
Margin over AC ($)	87.4	Margin over AC ($)	40.9
Margin over TAC ($)	66.8	Margin over TAC ($)	24.5
PHL ACELA		**PHL Regional**	
Distance	78	Distance	78
Revenue ($)	90.0	Revenue ($)	45.3
Avoidable Cost ($)	17.2	Avoidable Cost ($)	12.5
Total Attributed Costs ($)	32.8	Total Attributed Costs ($)	25.0
Margin over AC ($)	72.8	Margin over AC ($)	32.8
Margin over TAC ($)	57.2	Margin over TAC ($)	20.4
AVERAGE ACELA		**AVERAGE Regional**	
Distance	167	Distance	167
Revenue ($)	161.4	Revenue ($)	88.4
Avoidable Cost ($)	36.7	Avoidable Cost ($)	26.7
Total Attributed Costs ($)	70.1	Total Attributed Costs ($)	53.4
Margin over AC ($)	124.7	Margin over AC ($)	61.7
Margin over TAC ($)	91.3	Margin over TAC ($)	35.0

Average for both Acela (32.3%) and Regional (67.7%)

Margin over AC	82.0	
Margin over TAC	53.1	
Extra passengers to cover AC losses		109,980
Extra passengers to cover TAC losses		113,078

Table 3-5. Passengers, revenue, and contribution potentially lost by stopping at Newark Airport.

ACELA	WAS	BAL	WIL	PHL	Total
Passengers (000)	650	265	175	475	1,575
Distance	225	195	116	91	
Percent time increase	1.8	2.3	3.9	4.1	
Potential Passengers Lost	11.7	6.1	6.8	19.5	44.1
Revenue ($000)	2,433	1,121	822	1,956	6,332.1
Avoidable Cost ($000)	579	261	174	390	1,404.7
Total Attributed Costs ($000)	1,106	499	333	744	2,681.7
Margin over AC ($000)	1,854	859	648	1,566	4,927.4
Margin over TAC ($000)	1,328	622	490	1,211	3,650.4

Regional	WAS	BAL	WIL	PHL	Total
Passengers (000)	1,260	580	275	1,165	3,280
Distance	225	195	116	91	
Percent time increase	1.5	1.8	3.3	3.3	
Potential Passengers Lost	18.9	10.4	9.1	38.4	76.9
Revenue ($000)	2,201	1,064	578	1,984	5,827.8
Avoidable Cost ($000)	680	326	168	560	1,734.3
Total Attributed Costs ($000)	1,361	651	337	1,120	3,468.6
Margin over AC ($000)	1,521	739	410	1,425	4,093.5
Margin over TAC ($000)	840	413	241	865	2,359.2

Total					
TOTAL GAIN OVER AC	3,375	1,598	1,058	2,990	9,021
TOTAL GAIN OVER TAC	2,168	1,034	731	2,076	6,010

Part Three: Typology of Options to Connect with Long-Distance Rail

Planning Considerations from the Research

Consistent with the European experience, market analysis of the five airports reviewed in this Chapter reinforces the observation made in Chapter 2: the relationship between the airport and its catchment area primarily explains the market share gained, rather than the details of physical interconnection. Clearly, sheer proximity is not the answer. Chapter 3 shows that the two United States rail stations closest to the major air passenger check-in terminals are Providence airport and Burbank. In Providence airport, a high-quality moving sidewalk equipped "skybridge" makes the 1,300-foot connection. In Burbank, the same distance can be traversed on foot. Neither is currently serving a meaningful number of long-distance rail riders to the airport. The parallels with France's Lyon Airport rail station are striking: while the architecture of the connection is unique in its grandeur, most of the trains passing through the station simply do not stop, consistent with the experience in Providence. While the question of the logic of the rail operator was explored in Part Two, the characteristics of the physical site planning considerations are reviewed here.

Three Options for Connections to North American Airports

Planners in the North American experience have examined many approaches to the question of how to best get rail access to airports. This Chapter focuses on three major approaches to this question, which include: (1) full integration; (2) connection by shuttle to nearby air terminals; and (3) connections with regional systems, which may not be close to the airport. Thus, the three categories of connection type developed in Chapter 2 for European airports are reviewed here for their relevance.

Site Planning Concept #1: Full Integration at Airport: Reroute the Long-distance Rail Line to Go to a Point from Which the Air Traveler Can Walk a Short Distance from the Train to the Check-in Terminal

To date, no North American airport has routed its longer distance rail tracks into the terminal complex itself. This is the design concept first accomplished in Zurich, which was the first long-distance trunk line to be placed in a subterranean level of the airport terminal, followed by Amsterdam Schipol, Frankfurt, and Copenhagen. In the optimal case, all distribution between the rail station and the passenger processing areas is by foot, as was the case in the single terminal configuration at London Gatwick. Perhaps importantly, a review of the North American experience reveals no airport that has succeeded in providing long-distance, intercity rail directly into the air passenger terminal complex. Design visions of such a solution could be gleaned by looking at successful examples of local, metropolitan on-airport rail stations, including Reagan–National, Atlanta, SFO, Portland, St. Louis, Chicago, and Cleveland, among others.

Planning considerations for Site Planning Concept #1 are dominated by costs and the horizontal and vertical design requirements of the rail alignment. Indeed, when examining the option of full architectural integration, the more common approach is "bring the airport to the rail" by moving the air passenger terminal, rather than re-routing the rail. This is clearly under discussion in San Diego (see Chapter 6), and is one of a family of options that must be considered at Newark Airport if the plans for a third parallel runway are pursued. Another variation on the "bring the airport to the rail" theme would occur if the City of Chicago revived the Terminal 7 concept as discussed in Chapter 6 of this report.

Site Planning Concept #2: Shuttle to Nearby Rail Alignment: Build a Separate Airport Rail Station on the Rail Alignment at a Point As Close As Possible to the Airport Passenger Terminal Complex

The present rail station at Newark Liberty International Airport is a good example of placing a new station on an existing rail alignment, from which some form of connection is built to connect with the airline terminal complex. The long-distance railways did agree with this solution in Burbank and Milwaukee, but the long-distance railway did not agree with this solution in Providence. Compromises were reached in Newark and BWI, in which some, but not all, long-distance services use the station.

This site planning option is now under consideration for a long-distance rail station along the NEC alignment proximate to Philadelphia International Airport, as shown in the Amtrak NextGen HSR proposal. Questions of just how many Amtrak trains would option to use the additional stop were not resolved in that conceptual plan. In virtually any rail operations plan, the traveler who chose to transfer at this station, as opposed to the existing 30th Street station, would be offered far fewer trains, and thus longer waiting times.

Site Planning Concept #3: Connect to Network at a Central Place: Connect with the Best Consolidated Rail Transfer Point Possible

A review of the possible options for the future of rail service to Newark Liberty International Airport highlights the possibility of not having an airport rail stop at all. Instead, a connection with a major, existing intercity rail terminal could be created. As will be documented later in this report, serious consideration to schemes that do not include on-airport or near-airport long-distance rail stations is being given in San Diego and Chicago, in addition to Newark. In this manner, the number of trains that will in fact stop at the designated airport connector is maximized, with potential interface with other intermodal connections existing at the main rail station. In Europe, cities in which long-distance access schemes do not include an airport rail station include London, Madrid, Barcelona, Munich, Vienna, Hamburg, and many others with metropolitan rail connections only.

Conclusion

Air/rail connectivity is often presented as a design issue. The empirical observations from Chapters 2 and 3 suggest that a successful air/rail transfer could be first examined from a point of the view of the markets for the services offered. When a given airport offers some kind of unique service, whether differentiated by directness of service (hubbing) or by price (the "Southwest Effect"), passengers can be expected to arrive from originating distances beyond the airport's logical catchment area. When a less unique airport offers essentially the same set of airline connections as those airports surrounding it, the logic for taking a long train ride to access a similar set of aviation options is weak.

At face value, this observation might be seen as a positive for rail feeder links at airports in Newark, Philadelphia, Chicago, and JFK. For example, each of those airports offers some kind of direct air service to long-distance destinations not offered by competing airports. A trip optimized from the viewpoint of the passenger might include the selection of a check-in airport outside of his/her metropolitan area, implying that the market for rail access might be seen as a set of longer-than-usual ground access links, rather than the replacement of existing feeder flights from more distant origins.

Thus, the market package needs to make sense to a wide variety of stakeholders in the process; the case study of Midwest Airlines in Milwaukee was, for a time, a good example of where good rail service might improve the business case for all the parties. When a new airline management was less focused on the Milwaukee hub, efforts to create better coordination with Amtrak came to a close. And with this, the ability to deal with the serious structural challenges of serving an airport with six trains a day was weakened.

Arguably, the need is to get the air traveler directly to that point on the rail network where the connecting options are best. By way of example, it may make more sense to carry Heathrow connecting rail passengers to a point where all HS2 trains are going to stop, than to reroute a portion of rail line haul services into a transfer point more proximate to the airport, at which some form of transfer would still be needed to get to the decentralized terminals. In a parallel manner, if the funds could be found to connect all Newark Liberty air passenger terminals to Newark Penn Station, it might make sense for Amtrak to abandon the "airport station" stop entirely, encouraging a transfer at the major point of system connectivity. The case has been made in this Chapter that it is not in the interest of operators of HSR services to incur the added travel time involved in stopping at airport stations that generate relatively few additional passengers.

The traveler will base his/her choice of service on a service's door-to-door times and costs. Unless the impediment of transfer time (reflecting poor schedule coordination) is minimized, the empirical evidence suggests that efforts to integrate ticketing, or even baggage handling, will be of little comparative effect.

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CHAPTER 4

Rail in a Competitive Role: Diversion from Air in Europe

Introduction and Structure

In Chapter 2, the Research Team examined the use of rail services in Europe to serve in a feeder function to give access to longer distance aviation flights, which it labeled a "complementary" function for rail. Chapter 4 explores European experiences where rail operates in competition with air in the provision of corridor services dominated by center-city-to-center-city higher speed services. Consistent with the approach in Chapter 2, this project provides a significant update of the estimated total diversions from air to rail in the major European projects documented to date.

Major Themes Emerging from the Research: Rail in a Competitive Role

Chapter 4 focuses on the role of rail as a component of the intermodal system, this time making its contribution by lowering the number of passengers that need to be accommodated at airports, allowing the managers of the aviation system to alter the supply of aviation services.

The Research Team's North American interviews consistently demonstrated that the rail system makes its most meaningful contribution to the overall intermodal system when it is attractive to long-distance city center-to-city center markets, which are influenced by terminal-to-terminal travel times. Chapter 3 presented a "business case" for the rail operator, which often tends to argue against the addition of airport stops for higher speed intercity rail services. Chapter 2 demonstrated that strong markets exist for rail to carry people over long distances to airport rail stations in Frankfurt, Paris, and Amsterdam; however, such specialty markets are hard to initiate and hard to keep. This Chapter focuses on how HSR has already been a success in lessening the volume of passengers at busy airports in Europe by focusing on providing high-quality center-city-to-center-city services.

The Chapter reviews eight corridors in Europe and documents the manner in which new HSR services influence the aviation market, noting the change in air volumes on a month-by-month basis.

Rail Diversion from Air in Europe

This section summarizes the results of reported diversions from air to rail as the result of improvements to rail travel time in eight European corridors, as shown in Figure 4-1. HSR has diverted an estimated three million air passengers from the several corridors connecting Paris with the rest of France, and Europe. A diversion of one million passengers from Paris to Marseilles, one million between Paris and Strasbourg, 0.7 million air passengers from Paris to London, and about 0.1 million between Paris and Lyon is observed. In addition, lesser amounts of diversion have occurred in other corridors; a diversion rate of 20% has been estimated between Paris and Bordeaux, with varying rates associated with early improvements to Paris–Amsterdam to 4.5-hour travel times (Wardman et al. 2002).

In the newly developing system in Spain, the diversions have been similar, with rail now carrying about 46% of the 5 million passenger market between Madrid and Barcelona, representing a shift of 1.8 million passengers from air to rail. For Madrid–Seville, air played a relatively small role in the corridor before the rail investment, with an estimated 0.25 million now diverted from the air to the rail. An estimated 0.35 million travelers have been diverted from air to rail on the Madrid–Malaga corridor (anna.aero 2010). In a rail corridor which had yet to open, it was reported that air officials believe that the Madrid–Valencia corridor will lose 0.67 million air passengers to rail (anna.aero 2010).

Thus, both France and Spain are looking at levels of diversion in the range of 3 million riders each from air to rail. This scale of long-distance rail riders diverted from air is distinctly smaller than the 23 million European long-distance rail riders who are accessing a major airport, as documented in Chapter 2.

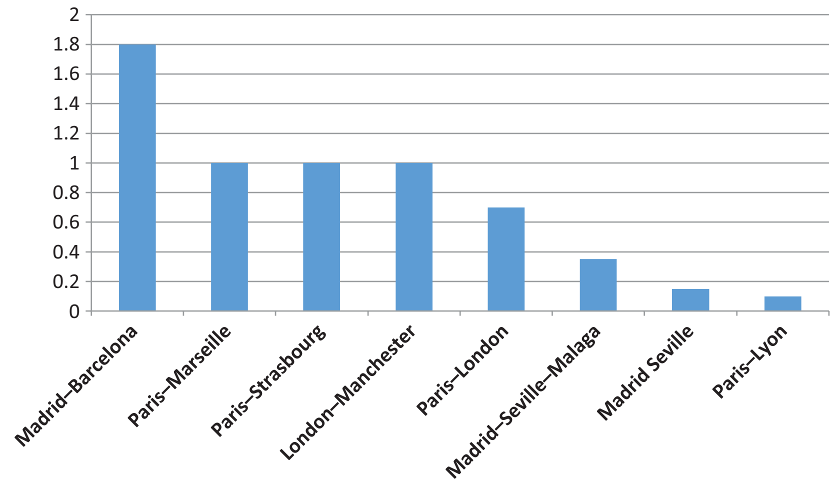


Figure 4-1. Annual European rail riders diverted from air by city pair, in millions. Source: Case studies in this chapter.

This contrasts with the prevailing view accepted in the United States: that competitive rail is the most important concern.

The corridors reviewed include:

1. Paris–London
2. Paris–Lyon–Marseille
3. Paris–Strasbourg
4. Madrid–Séville–Malaga
5. Madrid–Barcelona
6. London–Manchester
7. London–Glasgow
8. Amsterdam's Corridors (predicted diversions)

Relationship Between In-vehicle Rail Time and Share to Rail

The relationship between the in-vehicle travel time of the rail service and the rail portion of the air plus rail market is well documented in the literature. Figure 4-2 documents all mode share data collected or updated for this research, including different mode shares over time in a given corridor. Because of possible differences in definitions over many separate sources, the data could be seen as illustrative rather than definitive. However, this figure attempts to show only those mode share values that represent the corridor rail passenger volume compared with the corridor air passenger volumes

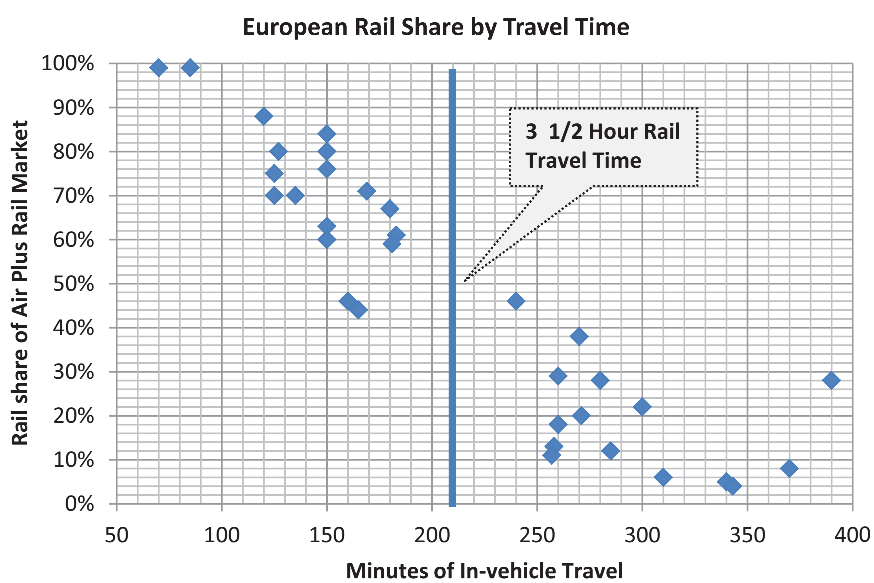


Figure 4-2. European rail mode share by travel time.

as defined to include those air passengers making connecting flights. Later, a smaller number of European mode share statistics that only focus on O-D markets is presented, which can then be compared with similarly defined American mode share data.

In either case, it is notable that in this chart, the only corridors with rail mode shares higher than 50% are those whose rail in-vehicle travel times are lower than 3.5 hours, expressed on the X-axis of the graph as 210 minutes. The Research Team's database shows only two situations in which a rail travel time of less than 3.5 hours failed to produce a mode share above 50% (see Table 4-1). Historically, during the incremental development of the London-Brussels service, there was a period where a travel time of 2 hours 45 minutes was associated with only a 44% share of the air plus rail market—including all connecting air passengers in the calculations. Since the more recent improvement of rail speeds in the United Kingdom, the most recent reported mode share estimate is 75% to rail, by the same definitions. More importantly, between Madrid and Barcelona, the mode share of rail to the air plus rail market is still under 50% when the connecting air passengers are included in the calculation. As discussed in Chapter 5 (structured to allow direct comparison with the best North American data), the rail share is above 50% when the connecting air passengers are excluded from the calculation.

Diversions in Corridors: France

Figure 4-3 shows the change in mode share for two major rail corridors and single observations for service between Paris and several major cities. When the best rail travel times between Paris and London went from 6 hours to 2.5 hours, the mode share rose from 14% to 60%; further improvements in travel time increased mode share to 75%. When travel times between Paris and Marseille went (in total) from 4 hours 40 minutes to 3 hours 6 minutes, mode share rose from 22% to 69%. The graph shows that when the value on the X-axis shifts to the left, the value on the Y-axis will increase; in other words, as rail travel times improve, their mode share will increase.

Corridor #1 Paris–London

The Setting

The present service between Paris and London takes between 2 hours 15 minutes and 2 hours 45 minutes based on the Spring 2011 schedule. London–Paris travel times shot from between 6 and 8 hours (depending on channel crossing vessel) to 3 hours, and mode share jumped from 14% to 54% after the first full year of operation. Annual air passengers have fallen from roughly 3.6 million (averaged) in the early 1990s to roughly 2.9 million in 2009, as shown in Figure 4-4

Table 4-1. European rail mode share, by rail travel time.

	Minutes	Share		Minutes	Share
FRA-Cologne, 2006 *(1)*	70	99%	Madrid- Barcelona, 2010 *(8)*	160	46%
Paris-Brussels, 2008 *(3)*	85	99%	Paris-Amsterdam, 2003 *(7)*	240	46%
Paris-Lyon, 2003 *(1)*	120	88%	London- Brussels, 2002 *(3)*	165	44%
Madrid-Seville, 2006 *(1)*	150	84%	Rome-Milan, 2005 *(2)*	270	38%
Madrid-Seville, 1994 *(4)*	150	80%	London-Edinburgh, 1999 *(1)*	260	29%
London-Manchester, 2009 *(9)*	127	80%	Madrid-Malaga, 2005 *(10)*	280	28%
Paris-London, 2009 *(3)*	150	76%	London-Edinburgh, 2004 *(1)*	260	18%
London-Brussels, 2009 *(3)*	125	75%	Paris-Marseille, 2000 *(3)*	300	22%
Rome-Bologna, 2003 *(7)*	169	71%	Madrid-Seville, 1991 *(4)*	390	28%
Paris-Bordeaux, 2008 *(5)*	125	70%	London-Glasgow, 2010 *(9)*	271	20%
London-Manchester, 2008 *(9)*	135	70%	London-Cologne, 2011 *(6)*	258	13%
Paris-Marseille, 2006 *(3)*	180	69%	Madrid-Barcelona, 2005 *(1)*	285	12%
Madrid-Malaga, 2008 *(5)*	150	63%	London-Amsterdam, 2011 *(6)*	257	11%
Paris-London, 2003 *(3)*	183	61%	Madrid-Barcelona, 2002 *(1)*	370	8%
London-Manchester, 2004 (1)	150	60%	London-Glasgow, 2004 *(9)*	310	6%
Stockholm-Goteborg, 2003 *(7)*	181	59%	London-Lyon, 2011 *(6)*	340	5%
			London-Frankfurt, 2011 *(6)*	343	4%

Sources: (1) SDG, 2006a; (2) SDG 2006; (3) SKM 2010; (4) Wardman, et al 2002; (5) IARO 2009 (6) Atkins 2011; (7) M3 Systems 2004; (8) Spanish Civil Authority, 2010; (9) Virgin Trains 2011.

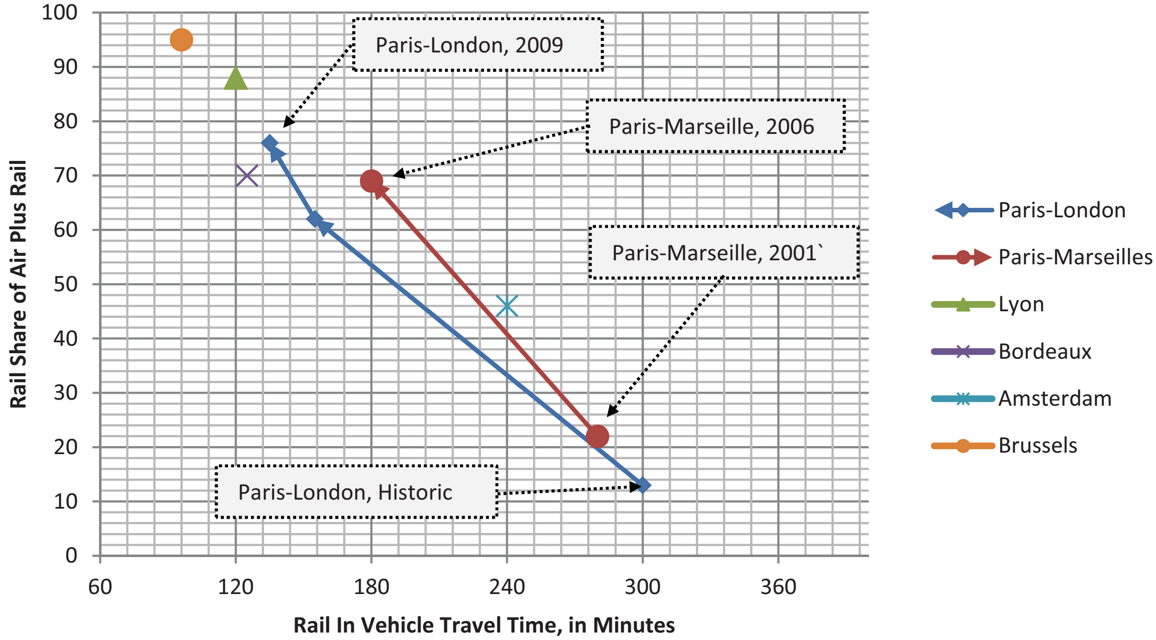


Figure 4-3. Change in mode share by travel time (France).

(anna.aero 2010). This occurred after the opening of the Eurostar service through the channel tunnel in November of 1994, which included new rights-of-way in France. This was followed by travel time improvements on the United Kingdom portion of the trip. This loss of 0.7 million air passengers represents a decrease of about 20% of all air passenger traffic, which is generally consistent over sources (Wardman et al. 2002). Eurostar—as a portion of Eurostar plus all air in the corridor—has a mode share of about 75%. SDG has estimated that rail captured more than 80% of the O-D market in 2005, which implies that it is attracting about 85% of such travelers today (SDG 2006a). From examining Figure 4-4, the reader can observe the initial jump in rail mode share upon completion and stabilization of the service (to 1997), followed by a stable period (to 2004). This stable period was followed by market improvements, with improvements in in-vehicle travel time on the United Kingdom end of the corridor.

What Happened to the Flights?

Reportedly, the number of flights between London and Paris fell by about 40% with the opening and stabilization

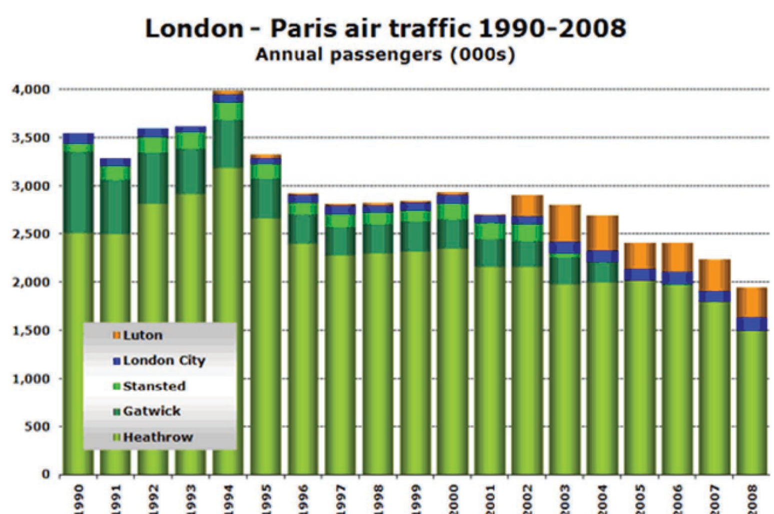


Figure 4-4. Yearly change in air traffic between London and Paris. Source: anna.aero, 2010.

of the Eurostar service between the two city centers (SDG 2006). The Research Team found 40 flights between London and Paris via the legacy carriers, three flights via easyJet, and none on Ryanair. Importantly, this is in a market where the rail system largely absorbed the point-to-point market.

Corridor #2 Paris–Marseille

The Setting

Paris–Marseille is one of the longest corridors—approximately 420 miles—where rail improvements have impacted air volumes. Present travel times range from between 3 hours 6 minutes to 3 hours 20 minutes. Initial service improvements occurred in 2001, improving travel time to 4 hours 40 minutes, with reported decreases in air travel by about one million, from approximately three million passengers to two million (SKM 2010). With the improvement to the present travel times, mode share has increased from 22% in 2001 to 69% in 2006 (SKM 2010). DGAC estimated the present mode share as 67% (SDG 2006a). At present, the O-D market is estimated to be between 80% and 85% to the rail system (SDG 2006a).

Within this larger corridor lies the historic Paris–Lyon service opened in the early 1980s. Before the HSR service, air volumes were reported as 180,000 per year (Wilken, reported in Wardman et al. 2002), which fell to 100,000 after the opening and stabilization of the TGV service, a diversion of 45% of air traffic. MVA has estimated a 90% substitution rate from planes to trains for the O-D market (Wardman et al. 2002).

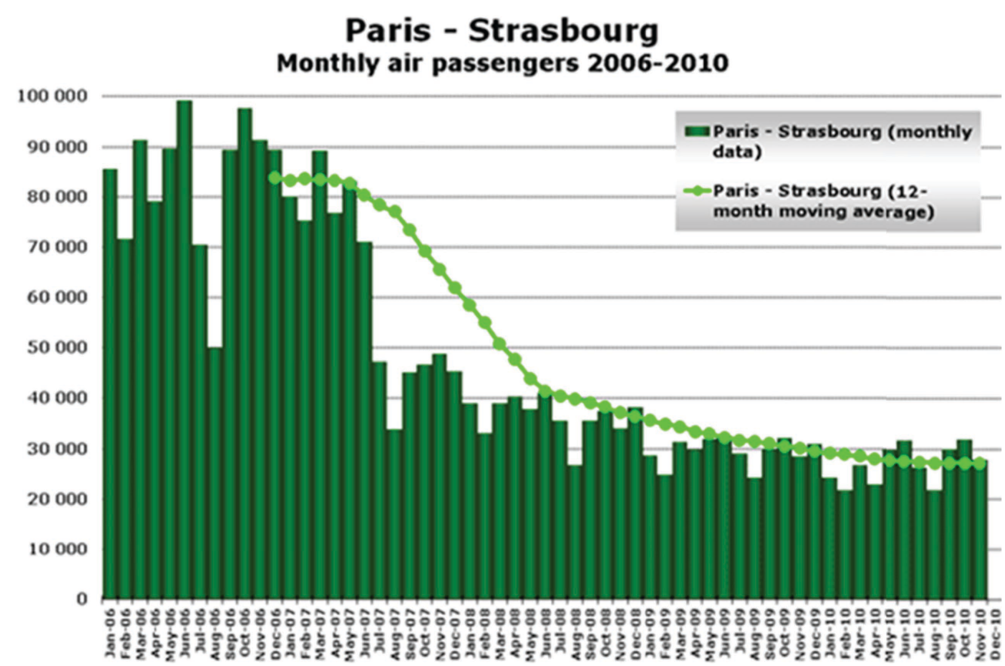
What Happened to the Flights?

Air France operates approximately 25 flights between Paris and Marseilles, down from 45 flights at its peak before the rail improvements (a decrease of 45%) (SDG 2006). A low-cost carrier entered the market, but left in 2001. In the report of the International Air/Rail Organization titled HSR Competition, its Director General, Andrew Sharp, reports that the Marseille Airport had lost 1.1 million passengers, mainly because of the competition between air and rail on the Marseille–Paris routes (Zunino 2007). Sharp summarizes that "the Orly route had lost about 30%, but the impact on the Paris Charles de Gaulle route had been much less because of the volume of interlining traffic. Since 2001, Orly traffic has dropped by 43% (although it is still the top destination, with 1.34m passengers in 2005, 23% of the total, compared with Paris Charles de Gaulle at 0.57m and 9.7%) . . . percentage drops in passenger numbers were 8.2 (2001), 8% (2002) and 1.7% (2003)" (Zunino 2007).

Corridor #3 Paris–Strasbourg

The Setting

Service between Paris and Strasbourg was improved in July 2007, improving rail travel times from 4 hours 20 minutes to 2 hour 20 minutes. As shown on Figure 4-5, the 12-month



Source: anna.aero, 2010.

Figure 4-5. Monthly change in air traffic, Paris—Strasbourg. Source: anna.aero, 2010.

moving average of air ridership fell from about 1 million trips to about 325,000 in 2010, a decrease of about two-thirds (anna.aero 2010). During this period, volumes between Strasbourg and Orly fell nearly twice as much as volumes between Strasbourg and CDG, reflecting the lack of diversion by the network connecting traffic at CDG (SKM 2010). IARO's Sharp noted that these travel time improvements "allowed Paris–Stuttgart times to be reduced from 6 hours to 3 hours 39 minutes, Paris–Zürich times to 4.5 hours, Paris–Nancy to 1½ hours, Paris–Metz to 1 hour 24 minutes, and Paris–Luxembourg to just over 2 hours" (Perrin 2007).

What Happened to the Flights?

IARO reports that "A reaction by Air France was to reduce Paris–Strasbourg frequencies from 12 to 8 return trips a day and to withdraw from the Paris–Metz market entirely (Redman 2007). Anecdotally, it also damaged the Paris–Stuttgart air market (Laistner 2008). An article in Jane's Airport Review noted that Traffic to Lille and Nantes was also hit" (Citrinot 2010).

Diversions from Air to Rail in Spain

Figure 4-6 shows the changes in rail mode share resulting from travel time improvements in three markets: Madrid to Seville; Madrid to Malaga; and Madrid to Barcelona. It shows that rail share went to 80% when rail travel times improved from 4 hours to 2.5 between Madrid and Seville. Mode share rose to above 60% when rail travel times between Madrid and Malaga dropped from nearly 5 hours to under 3 hours. While there were two phases in the improvements between Madrid and Barcelona, most ridership change occurred with the adoption of the present travel time of 2 hours 40 minutes, resulting in a mode share of 46%. Again, mode share numbers reflect the use of air segment volumes, which include air passengers connecting with other flights.

Corridor #4 Madrid–Seville–Malaga

The Setting: Madrid–Seville

The first HSR investment in Spain was made in 1992, in the relatively small market between Madrid and Seville, where travel times ranged between 2 hours 30 minutes and 2 hours 40 minutes (i.e., almost no range at all). The distance on the route of the train (via Cordova) is about 290 miles.

With the HSR opening, the sole air carrier, Iberia, lost about 35% of its air passenger market (SDG 2006), and the rail volumes have grown considerably (e.g., 28% growth between 1999 and 2004) (SDG 2006).

Before the new rail service, rail had 56% of the air plus rail market; afterward, rail had 93% of the air plus rail market. It is important to note that before the new HSR service, the buses were carrying more than the rail. For this reason, Table 4-2 presents the mode shares for all modes, which is not reliably available for most of the corridors presented in this Chapter.

What Happened to the Flights?

Four flights per day were found from Madrid to Seville, thus eight flights between the two cities. This represents what airlines need to keep network connections marketable, in a

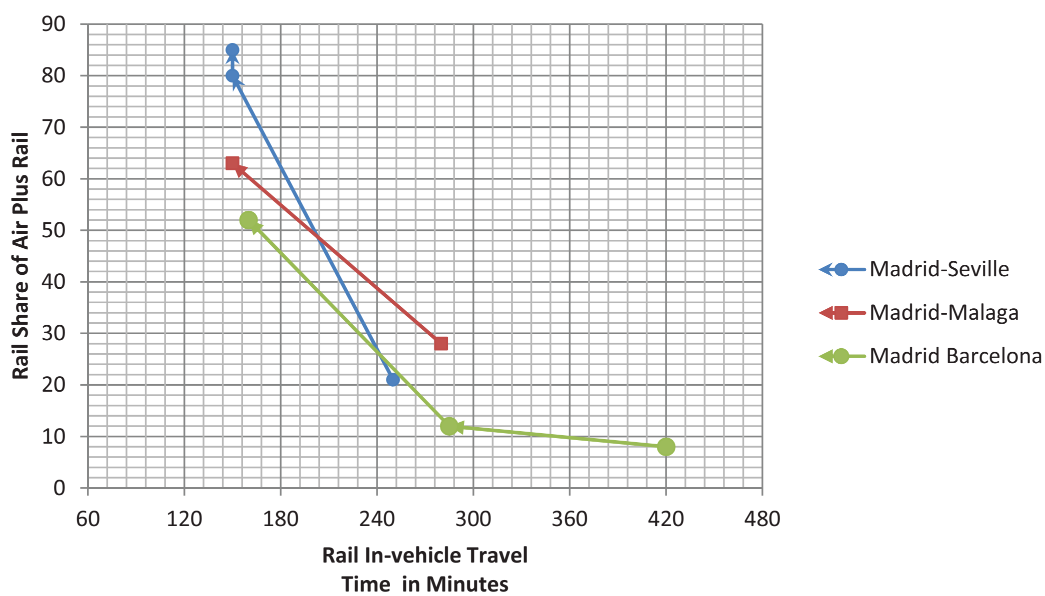


Figure 4-6. Change in mode share change by travel time—Spain.

Table 4-2. Madrid-Seville mode share change.

Mode	Share Before HSR	Share After HSR
Auto	60%	34%
Bus	15%	8%
Air	11%	4%
Rail	14%	54%

Source: SDG 2006.

corridor where the air service is largely irrelevant for the O-D (i.e., non-transferring) market—in a corridor where the train diverted as many riders from bus as from air.

Madrid–Malaga

In late 2007, RENFE established a new high-speed link between Madrid and Malaga, using infrastructure from the original Madrid–Seville line, with new track between Cordoba and Malaga. Travel times were between 2 hours 32 minutes and 2 hours 50 minutes in the timetable for spring 2001—improved from 4 hours 20 minutes. Reportedly, air traffic has fallen by 25% (Railway Gazette International 2009). IARO reports that since 2007, market share has grown from around 50% to nearly 70%. IARO reports that the route had 20 flights each way each day, carrying over 1.4 million passengers in 2005. Thus, a loss of 25% of this air volume would represent a diversion of 350,000 air travelers to rail.

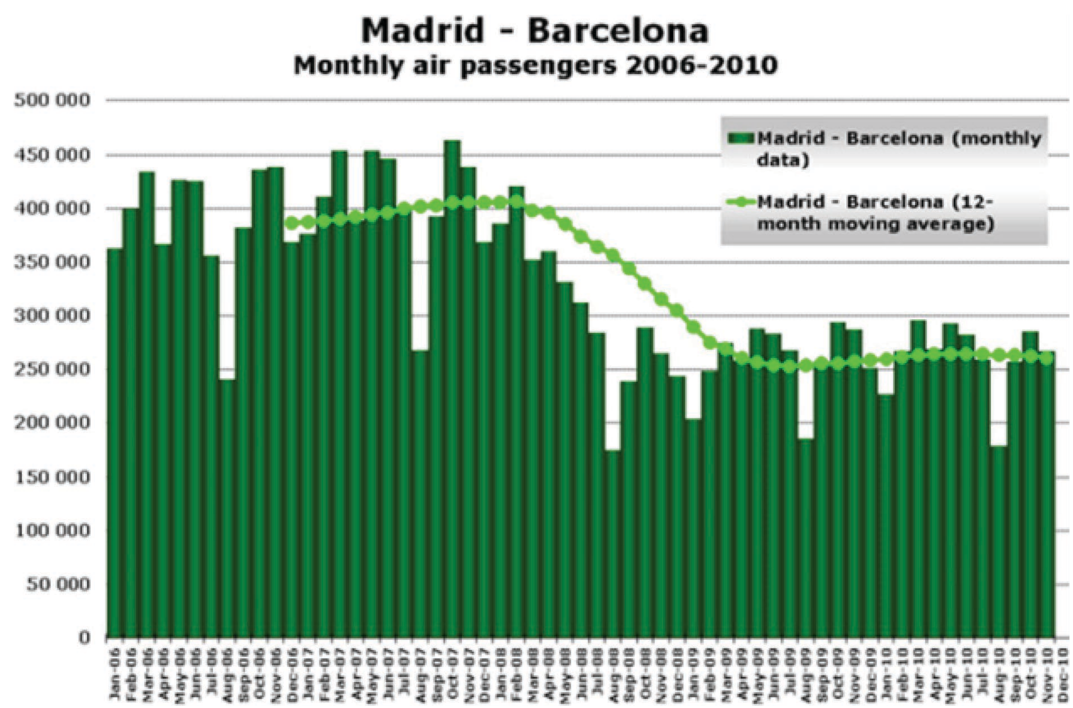
Corridor #5 Madrid–Barcelona

The Setting

In the important Madrid to Barcelona corridor, some 1.8 million air travelers have been diverted away from air to the new HSR services. After London–Dublin, Madrid–Barcelona is the highest volume air corridor in Europe, and the scale of diversion is the largest reported in this report.

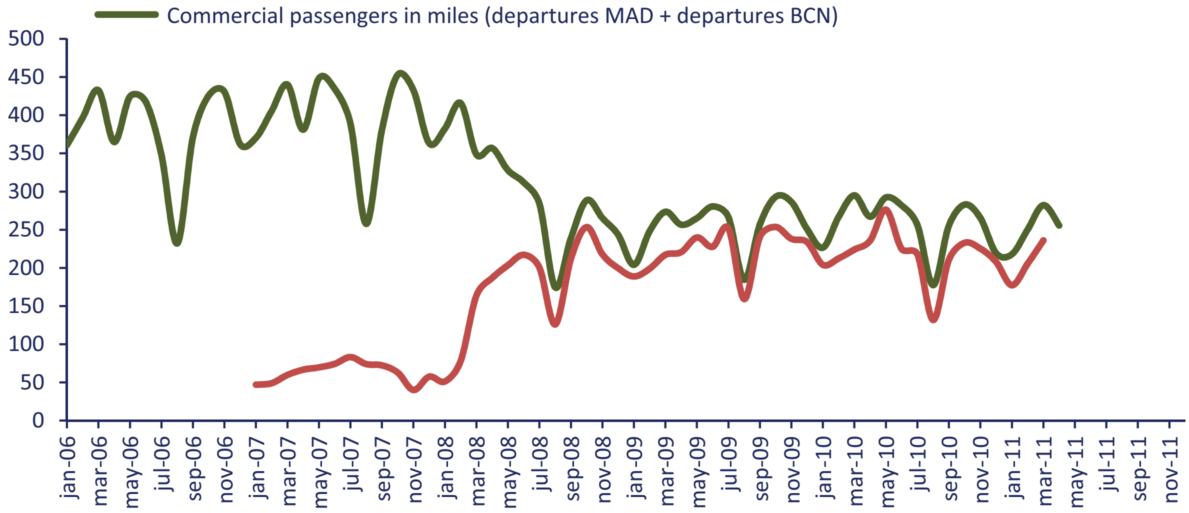
Scheduled travel times were between 2 hours 43 minutes and 3 hours 18 minutes. The HSR service opened in February 2008; since then, "numbers have fallen from 4.9 million in 2007 to just 3.1 million in 2009, a drop of 37%" in the corridor's air travel market (anna.aero 2010). Figure 4-7 shows that the air market took a hit between January 2008 and the beginning of 2009, but that it has stabilized between that time and the present. In fact, the air market share has doggedly remained higher than the rail share, as can be concluded from Figure 4-8, which traces the absolute volumes of both air and rail on the same graph. Visually, the rail volumes, on occasion, closely approach the air volumes but never surpass them, ending in a 46% rail mode share.

It is reported that between 12–15% of passengers on the Iberia flights between the two cities were connecting network



Source: anna.aero, 2010.

Figure 4-7. Volumes of air and rail passengers between Madrid and Barcelona. Source: anna.aero, 2010.



Note: The upper line represents air passengers; the lower line represents rail passengers.

Figure 4-8. Volumes of air and rail passengers between Madrid and Barcelona. Source: Spanish Civil Aviation Agency.

passengers before the HSR service began (SDG 2006). Rail now captures approximately 55% of the air plus rail market for the O-D market of travelers between the two regions, assuming that those individuals did not divert to rail.

What Happened to the Flights?

The airlines are not giving up on this market. The timetable for spring 2011 showed three flights per hour, leaving Madrid to go to Barcelona—an intensity of service that could match almost any shuttle service in the United States. Both airports are relatively well located and served by reliable public transportation; years of market loyalty to the "air-bridge" concept of continuous flight offerings will be tested in coming years. A review of off-peak flight schedules revealed that three airlines were serving the market with a combination of Boeing 737 and Airbus 310 and 320 aircraft. There is no evidence of a shift to regional jets or propeller aircraft.

Corridor #6 London–Manchester

Figure 4-9 shows the change in mode share for three corridors, and present mode share between London and several major destinations. While the London to Glasgow share reflects the fact that the service is not under 3.5 hours of terminal-to-terminal travel time, the other two corridors look remarkably similar. The corridors between London and Brussels and London and Manchester show marked share growth related to travel time improvement.

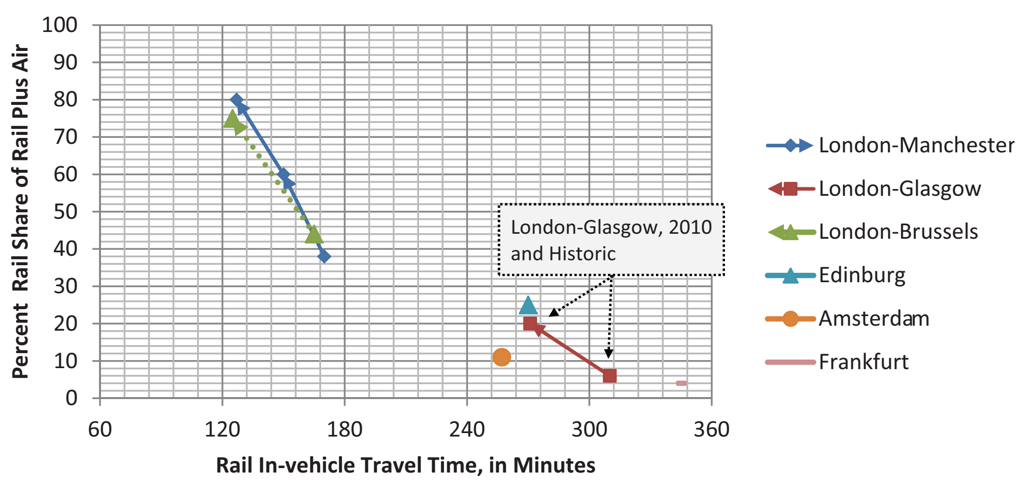


Figure 4-9. Mode share by travel time—United Kingdom.

In London-Manchester, the corridor of principal concern, the train trip takes 2 hours 8 minutes (spring 2011 schedule) making the corridor a prime candidate for majority mode share over air, in a corridor of under 200 miles. Importantly, a quick survey of schedules showed three direct trains per hour. This represents a major difference in emphasis from the French/Spanish focus on the speed of the train versus the United Kingdom's present experiment with "Very High Frequency" services. HSR services started in 2004, but major reliability problems plagued the operation for some years, until the period around 2004–2005. The present time of 2 hours 8 minutes is 22 minutes faster than service offered in 1999. The IARO reports that, "The rail share of the London–Manchester traffic changed from 49% in 2003 to 70.4% in 2008, with the total market growing from 3.8m to 4.6m passengers (Modern Railways 2009)." In the first full year of operation of the Virgin High Frequency service, the rail market share grew to over 80% (http://www.travelagentcentral.com).

In a thoughtful analysis, SDG argues that the analysis of short-distance markets should cautiously apply the metric rail divided by air plus rail. For a given year (2004–2005), the use of one market definition (dominant rail station in Manchester to dominant rail station in London) the rail volumes would make up only a 45% share of the air plus rail market. "If we define London–Manchester as all travel from a broad area of southeast England to all of Manchester and the area around it, the market share is substantially higher (60% compared with 45%)" (SDG 2006). Methodological issues such as this are key concerns to this report. In the Northeast Corridor in the United States, similar fluctuations on rail mode share are seen as a function of regional definitions.

During the period between the commencement of service by the new operator in 1997 and 2004, rail travel times did not get better, and rail mode share did not get better. Then, a new strategy of higher frequency rail service, with improved reliability, has seen significant increases in rail ridership and reported mode share. If rail mode share has gone from 60% in 2004, to 70% in 2008, to 80% in 2010, this implies that between 2004 and 2010, rail volumes have increased by roughly one million persons who might have gone to air. However, not calculated is a single "rail diversion from air." In a corridor of this length, it is not clear what portion of those million riders has been diverted from air or auto or induced demand.

Corridor #7 London–Glasgow

Trains between London and Glasgow take 4 hours 30 minutes, travel approximately 350 miles, and occur hourly. In the spring of 2010, Virgin Trains reported,

> "Based on a comparison of rail industry figures with data published by the Civil Aviation Authority (CAA), a long-term change in travel patterns has been identified. CAA figures show that between 2006 and 2010, passenger journeys by air between Glasgow and London airports went down by 22.4%, while ATOC information confirms a remarkable 85.8% increase in rail passenger journeys between the cities. Rail's share of the rail/air market between Glasgow and London had been as low as 6% in the early years of the 21st century but has grown significantly since then, reaching 10% in 2006, 12% in 2008, 16% in 2009 and 20% in 2010" (Virgin Trains–The Media Room 2011).

Corridor #8 Amsterdam

Just as HSR has become a reality in the corridors documented, the full implementation of the national scheme in the Netherlands has been delayed by a variety of factors, with HSR service commenced only in 2012. However, during the recent period, considerable research has been examining the effect that HSR might have on Schipol, and the extent to which potential air passengers will be diverted away to rail systems. Forecasts, with a 4% to 13% decrease, have been made for Schipol air passenger volumes (Wardman et al. 2002).

Amsterdam and the Potential for Substitution

Looking at the present use of rail, Jorritsma has summarized that the rail market from Amsterdam has,

> ". . . a volume of about 3.5 million passenger journeys to France and Belgium. About one-third (1 million journeys) is accounted for by the high-speed train to Paris (Thalys). The other 2.5 million concern journeys to destinations in Belgium, including transfers to London (Eurostar) at Brussels. As a result of the introduction of the HST, the amount of journeys on the southern corridor will increase to 5.7 million journeys in 2010. In particular, the market with London will be growing rapidly. Intraplan (Intraplan 2003) estimates a growth of 23% in railway journeys on the market to Brussels, 28% growth to Paris, and an increase of 42% to Frankfurt in the period 2010–2020" (Jorritsma 2009).

Jorritsma has calculated the following volumes of passengers from Amsterdam in 2020 would be diverted from air to rail:

- From the Brussels market: 125,671
- From the Paris market: 299,351
- From the London market: 1,152,092

This results in 1,500,000 diverted passengers. How would this level of diversion impact the airport and its levels of congestion? In dealing with a key issue examined in this report, Jorritsma concludes,

> "This results in a total of 1.6 million potential passengers to substitute from airplane to HST in 2020. The amount of flights *that can be reduced* on Schipol airport in 2020 would be about

> 16,000 per year (assuming 100 passengers per flight). This means a total reduction of approximately 2.5% of all flights that will be handled in 2020" (Emphasis added) (Jorritsma 2009).

Thus, the major rail investments surrounding the Schipol airport—and those directly connected to it—could lower the number of flights by 16,000 per year, or 2.5% of flights. The professional literature on this subject does not address the extent to which the airline managers will be motivated to lower the number of flights or lower the number of seats on a fixed number of flights.

This report addresses the airlines' responses. Given that there could be a reduced number of flights between Schipol and Brussels, Paris, Frankfurt and London, the research question asks how airlines will respond to the decrease in O-D traffic while defending the highly prized hub-based network connections. As a reminder, even though rail claims an estimated 85% of the O-D air market between London and Paris, some 40 flights per day remain in the corridor.

Major Factors Influencing the Aviation Market

The available data show there has been a three-phase reaction to effective city-to-city services. In the first phase, the legacy carriers did what would be expected and significantly decreased the number of flights in the corridor (Madrid–Barcelona seems to be an exception). With estimated point-to-point rail market shares often above 85%, a pattern emerges in which the network connections desired by the dominant carrier at a major hub do not disappear, and take the form of day-long series of connections justified by network demands. In the third phase, point-to-point low-priced carriers challenge the role of dominant hubs. The interest of these carriers in serving the traditional hub airport is not known; these carriers prefer airports like Luton and Stansted for London, Hahn for Frankfurt, and Charlerois for Brussels. The evidence suggests it may be misleading to look at transfer of volumes to rail without examining simultaneously the nature of the network role and the shift in demand to aviation products less reliant on traditional hub airports. Eisenkopf (2006) has estimated that low-cost airlines have a substitution rate of air trips for rail trips at 5% from Cologne to Hamburg and 13% between Cologne and Munich, while rail has gained market during the period of significant infrastructure (speed) improvement (Jorritsma 2009).

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CHAPTER 5

Rail Diversion from Air in the United States: Data and Methods

Introduction and Structure

Chapter 5 now focuses on the Northeast Corridor (NEC) of the United States. First, new data comparing the rail share of the air plus rail market in the NEC is compared with similarly defined data from major HSR corridors in Europe. Second, the Chapter presents an in-depth analysis of the change in air travel demand in the NEC—in terms of segment volumes, O-D volumes, number of flights, and the size of the aircraft used in the corridor—following increased competition from other modes. Initial airline response research for the ACRP project's model building is presented in terms of a description of cost per operation, cost per seat, and an early cross-sectional analysis of change in supply. The analysis of data needs and the adequacy of planning tools continues with an examination of several recent analysis efforts concerning the modeling of demand on the corridor, including a major multimodal planning effort undertaken for the PANYNJ by the Regional Plan Association (RPA), and a discussion of the structures of models currently being applied in the area. The Chapter closes with a review of key questions concerning the adequacy of models and tools being applied in the NEC today.

Part One: Diversion to Rail and its Effect on Air Service

The NEC is the ideal corridor in the United States for learning about the substitutability of HSR trips for air trips. There are both observed data stemming from the fact that this corridor is the only corridor served with HSR (Acela), and stated preference data from several studies of existing and improved rail service along the entire corridor. However, it is difficult to separate the effect on air travel from observed data on the gradual introduction of Acela between 1999 and 2005; this is because additional events since 1999 affected air travel in the corridor (e.g., September 11, increased airline screening delays, economic volatility, and the introduction of frequent and very cheap bus service, etc.). This can be seen in Figure 5-1, which shows a time series of Amtrak's share of the air plus rail market between Boston and New York between 2000 and 2010.

There are, however, several recent studies of the impact of improved rail service on NEC air travel, including some studies that use stated preference data. This Chapter will discuss the results of recent studies that include this impact and discuss how these studies were conducted. An important recent RPA study of ways to improve the operation of New York Region airports is included; this study evaluated HSR's ability to free up capacity at the airports. This study illustrates the limitations of available data on corridor travel by all modes and their effect on conducting such a study.

The previous Chapter presented the rail portions of the air plus rail markets for major European city pairs. Consistent graphics were presented for summary observations about markets in France, Spain, and the United Kingdom. As noted in the text, these calculations were based on the air passenger volumes for the corridor, specifically including those using air to connect with other flights.

Comparing United States Market Behavior with that of Europe

Mode share data in the United States, shown in Figure 5-1, has been designed to help the analyst understand rail's success in capturing a given market between Region A and Region B. In the NEC, this analysis uses station-to-station rail flows for a group of stations at the origin end of the trip and a group of stations at the destination end of the trip; these are then compared with U.S. DOT data that specifically excludes air passengers transferring to other final terminals.

In order to make a comparison of the American experience with rail diversion from air with that of the Europeans, a smaller database of European corridor data estimated on an O-D basis has been created—this specifically excludes air passengers destined for network connections. Table 5-1 presents the data from the two continents, which is graphed in Figure 5-2.

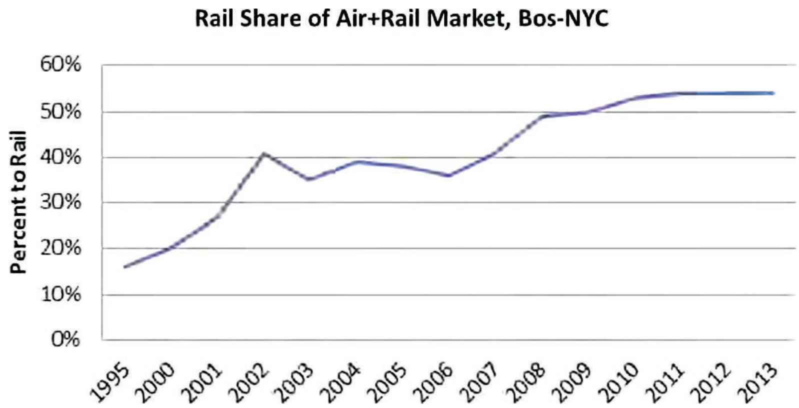


Figure 5-1. Change in rail share of air plus rail market between Boston and NYC airports. Source: Amtrak 2014.

Similarities and Differences

Arguably, the most visible characteristic revealed by the chart (Figure 5-2) is the similarity of the data points from the two separate continents; however, the linear equation for the United States shows a slightly lower propensity for high mode share to result from good in-vehicle travel time. When the European data is organized in this manner, the 3.5 hour observation is supported. The Madrid-Barcelona corridor has an estimated 55% market share, when it is defined in terms of O-D markets only; this reflects its very low rail travel times of 2 hours 40 minutes. In order to gain a majority of the air plus rail market, having a travel time of better than 3.5 hours appears to be a necessary, but not sufficient, condition for achieving a majority market share.

Table 5-1. Comparison of U.S. city pairs with European city pairs—O-D market only.

NEC Data	Minutes	Rail Share of O-D Market
Albany - New York	60	97%
New York - Philadelphia	70	95%
Philadelphia –Washington	130	89%
Providence -New York	150	90%
New York - Washington	190	63%
Boston-New York	200	55%
Boston -Philadelphia	280	17%
Boston -Washington	420	7%
European Data		
Frankfurt- Cologne	70	99%
London- Paris	150	90%
London- Brussels	125	90%
Paris- Marseille	200	82%
Madrid - Seville	150	92%
Madrid–Barcelona (*post*	160	52%
Madrid - Barcelona (*pre*)	420	10%
London- Edinburgh	270	25%
Milan-Rome	270	43%
London - Manchester	127	80%

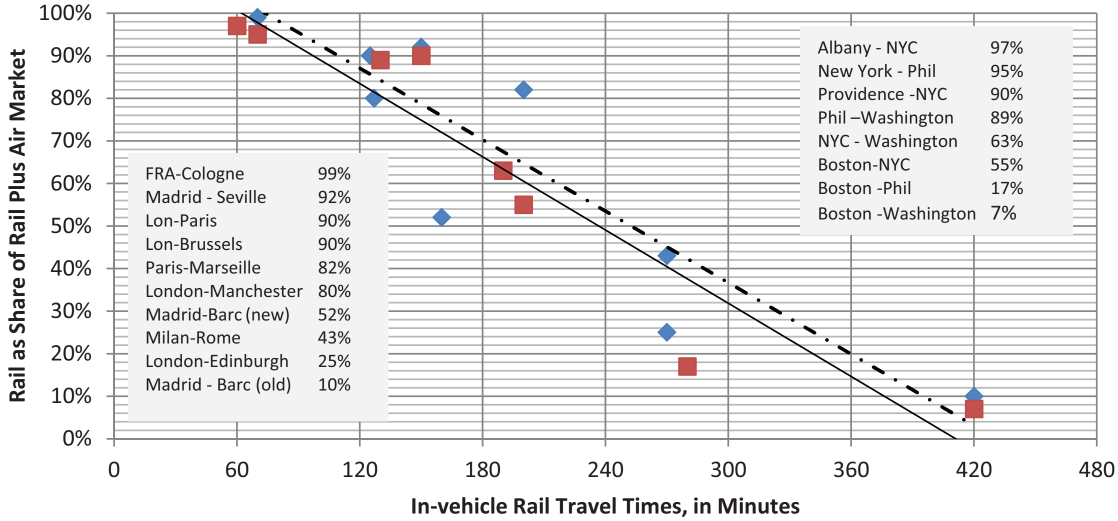
Sources: SDG 2006, Amtrak 2009

Effects of Improved Rail Service on Diversions from Air: Boston to New York City

In 2000, Amtrak's regional NEC rail service captured 20% of the rail plus air passenger trips between Boston and New York City. The Acela service that Amtrak introduced in December 2000 offered travel times between Boston and New York of approximately 3.5 hours for the 200-mile trip, representing a reduction of between 30–50 minutes compared to the comparable regional trains. The net result of this new service has been a significant increase in the rail share, to 54% of the air/rail market.

Over the corresponding period, the total O-D air passenger volume in the Boston to New York City market declined by almost half, as shown in Figure 5-3. There were also shifts in the distribution across New York airports and a shift to JFK following the introduction of JetBlue service. There were also some changes in patterns at the regional airports in the Boston area (MHT and PVD), but the overall pattern is clear: introduction of Amtrak's Acela service resulted in a significant increase in rail passenger volumes between Boston and New York City, with corresponding large decreases in air passenger volumes in this market.

In total, the air passenger volumes in the Boston to New York City origin-to-destination market decreased by almost half between 1999 and 2010. During this same period, the



N.B. European data points are represented as diamonds, with a solid trend line: American data points are represented as squares, with a dotted trend line. The two shares for Mardrid-Barc. present shares before and after HSR.
Sources: Amtrak 2009, SDG 2006.

Figure 5-2. Relationship between rail travel times and rail market share for American and European data for origin-destination markets only.

number of air passengers who used Boston to New York City flights to connect to flights going elsewhere increased by 13%. However, the much larger decrease in O-D volumes resulted in a 30% decrease in the passenger volumes on flights between Boston and the New York airports, as illustrated in Figure 5-4.

Figure 5-5 illustrates the net effect of the 50% decline of air passengers traveling between Boston and New York on the number of flights operated.

The number of flights between Boston and New York declined by only 16% between 1999 and 2010 (Figure 5-5). The fact that a segment volume decrease of 30% led to only a 16% decrease in flight volume is a result of shifts in plane size.

In this market, the average plane size decreased by 24% between 1999 and 2010. This down-gauging allowed airlines to offer only slight reductions in flight frequency in response to much larger reductions in air passenger volume, as shown in Figure 5-6, and in table format in Table 5-2.

In summary, HSR services, such as Acela, can significantly affect air passenger volumes in markets like Boston to New York City. However, reductions in the air passenger market do not necessarily translate directly into reductions in flight volumes. In particular, O-D passenger volumes between any two major airports represent only a portion of the total segment passenger volumes; as a result, reductions in O-D passenger

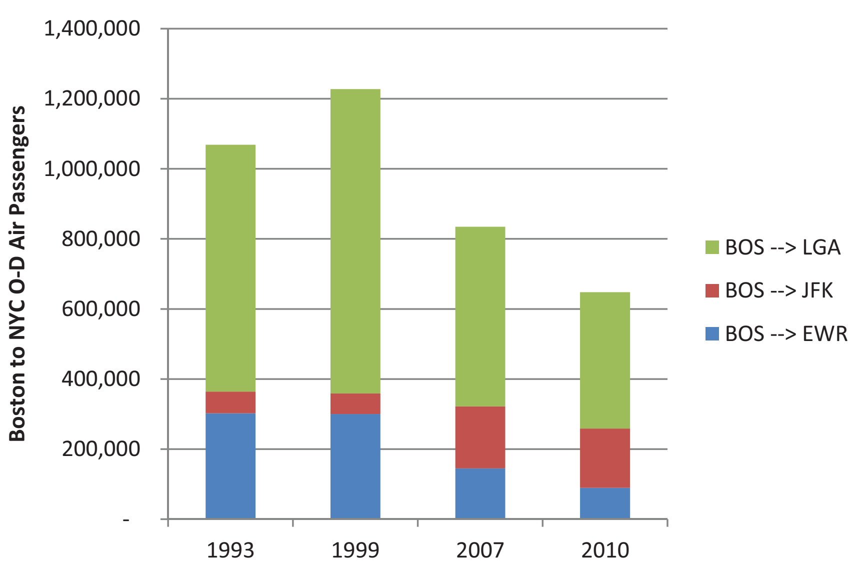


Figure 5-3. Change in segment volumes Boston to NYC. Source: BTS, DB1B data.

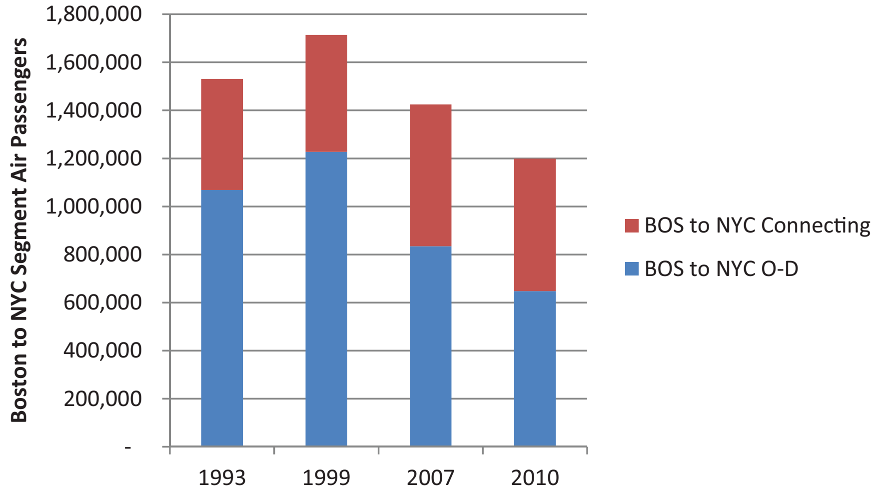


Figure 5-4. Change in air passenger volume for connecting and O-D markets. Source: BTS T-100 and DB1B data files.

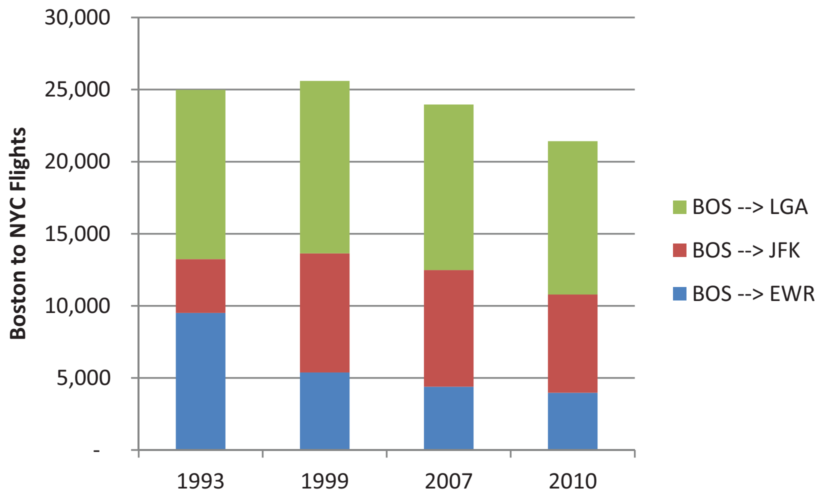


Figure 5-5. Change in number of flights between Boston and NYC. Source: BTS T-100 Files.

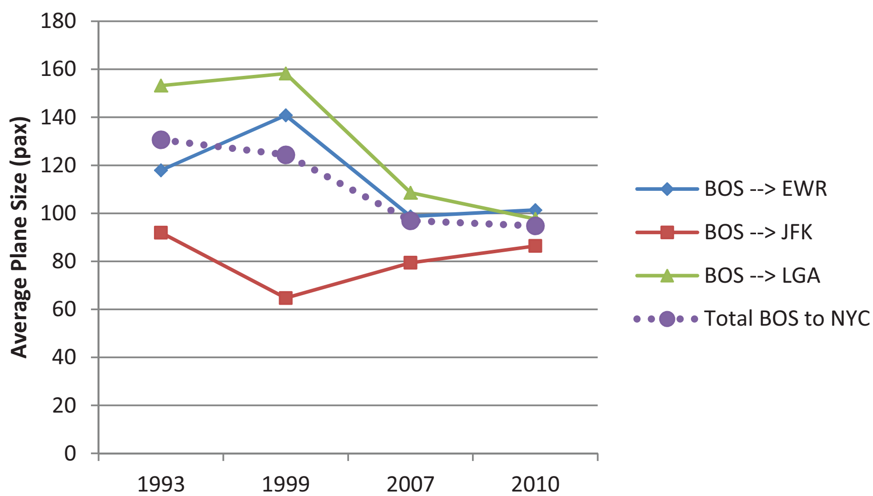


Figure 5-6. Change in size of plane by airport pair and by total corridor. Source: BTS T-100 Files.

Table 5-2. Summary statistics, Boston to NYC.

	1993	1999	2007	2010
Average Aircraft Size				
BOS --> EWR	118	141	99	101
BOS --> JFK	92	65	79	86
BOS --> LGA	153	158	109	98
Operations				
BOS --> EWR	9,511	5,379	4,394	3,978
BOS --> JFK	3,729	8,266	8,089	6,809
BOS --> LGA	11,741	11,959	11,478	10,632
Total Segment Volumes				
BOS --> EWR	564,070	500,843	289,290	270,680
BOS --> JFK	176,229	249,127	471,292	429,683
BOS --> LGA	790,269	963,948	664,383	498,703
Average Passengers/Flight				
BOS --> EWR	59	93	66	68
BOS --> JFK	47	30	58	63
BOS --> LGA	67	81	58	47
Total BOS to NYC	61	67	59	56

Source: BTS T-100.

volumes do not translate into proportional reductions in segment volumes. Further, carrier response to passenger volume reductions can cause reductions in plane size, which means less proportional reduction in flight volumes. In the case of the Boston to New York City market, a roughly 50% increase in rail volumes resulted in a similar 50% reduction in Boston to New York O-D air passenger volume. This reduction, in turn, lowered the total air passenger volume between those cities—including connecting passengers—by 30%. Finally, changes in plane sizes meant that the number of flights between Boston and New York decreased by only 16%; the net effect on airport runway loads was only one-third of the effect in O-D air passenger volumes. To the present, models have been built to capture mode shifts between air and intercity rail, but there are not companion models that similarly estimate the net effects on airport service and capacity following carriers' responses to market shifts. These effects are equally important in understanding how HSR will affect airport service and capacity.

Response of the Aviation Industry to Shift in Demand

Aircraft Size Changes, Boston to New York

The Research Team has evaluated the change in costs seen by the operators of aircraft between Boston and New York airports: LGA, EWR, and JFK. Significant trends in aircraft size changes were observed in operations between Boston and the New York airports, as discussed in the following paragraphs.

The average number of seats per aircraft has declined in two markets and increased in one market. The decrease in segment volumes partially explains these changes. However, the average passengers per flight decreased in these markets; overall, there are additional incentives for airlines to choose to fly smaller aircraft, as discussed herein.

Airlines may have a cost incentive to down-gauge. A linear jet operating cost model was used to evaluate changes in cost (Ryerson 2010). The model takes fuel price, seats per operation, and distance as inputs and determines the operating cost (in 2006 dollars). Using this model, a cost per operation and an average cost per seat for four years in 2006 dollars were estimated. A constant fuel price of $2.00/gallon is used so that the change in cost is not overwhelmed by the large fuel price fluctuations between 1993 and 2010.

The average cost per seat increased by about 16% (Figure 5-7) for the two markets where seats per operation dropped average. However, when the cost is considered on a per operation basis, cost per operation for these two markets dropped by 18% (BOS → EWR) and 25% (BOS → LGA), as shown in Figure 5-8. Considered on a cost per operation basis, there is an incentive to down-gauge.

Additionally, six airlines served the BOS → EWR segment in 2010, according to BTS data. Competition is high, which also keeps aircraft sizes low. Airlines compete in the marketplace on a few key variables: fare, frequency, and service components (like frequent flier programs, first and business class cabins, etc.). However, evidence has shown that airlines can increase their market share by increasing frequency rather than altering the other service variables (Wei and Hansen 2005). Beyond

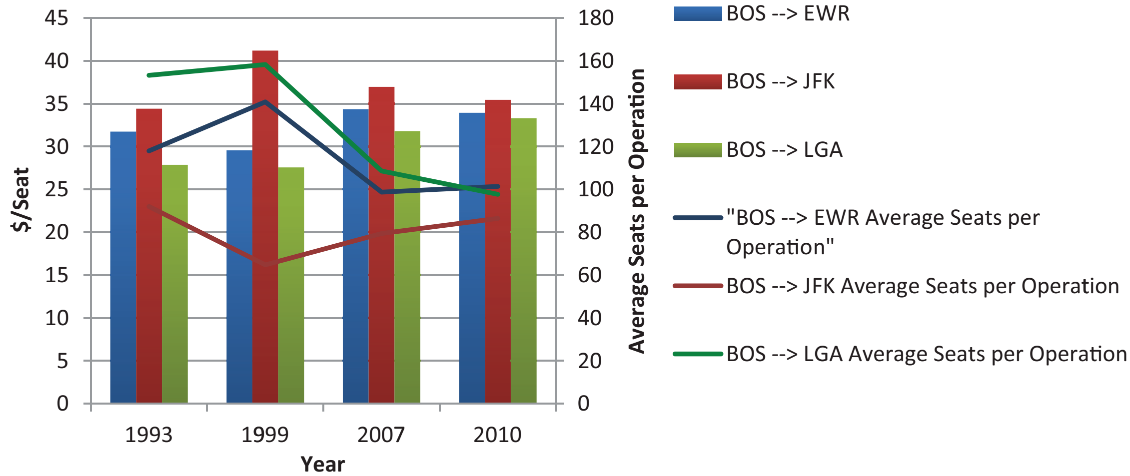


Figure 5-7. Average cost per seat and seats per operation.

increased frequency, airlines can increase their competitiveness through targeted frequency, most notably by scheduling flights at times very close to those of their competitors as put forward by Borenstein and Netz 1999. This is an example of airlines acting in their own self-interest; however, it is also a classic game theory problem—once one carrier schedules an operation at a particular time, the other carriers must follow, depleting the breadth of available flights for everyone.

Congestion

Changes in airport congestion due to aircraft down-gauging were also considered. Two scenarios of demand were compared at LGA. The first scenario, the baseline, is the 2010 operational level. The second scenario is the 2010 operation level if all flights from BOS to LGA were on the maximum aircraft size observed across the 4 years shown in Figure 5-8. The number of operations between BOS–LGA on this maximum aircraft size was found; operations in the 2010 schedule were reduced to reflect the decreased level of operations. The operational demand and the airport acceptance rate (AAR) over time for the entire day—a June day at LGA in 2010—are then obtained from the Aviation System Performance Metrics database. Delay can then be estimated in both scenarios. In scenario two, with decreased operations, there is no observed delay. For scenario one, there are two time regions of observed delay: from 9:00 a.m. to 1:00 p.m. and from 4:00 p.m. to 7:00 p.m. The total delay is 11 aircraft hours, or about 1.2 minutes per flight for flights scheduled to arrive during the delayed period. There is almost no incentive for airlines operating at LGA to up-gauge their aircraft as the delay savings are negligible.

The negative externalities are high even though this is a low level of delay. If all the delay occurs in the air, the fuel consumption waste could be up to 33,000 lbs. of fuel (Ryerson and Hansen 2011).

Cross-Sectional Analysis of Flight Service from Logan Airport

In this section, the flight schedule from Logan airport is analyzed to determine whether competition from intercity

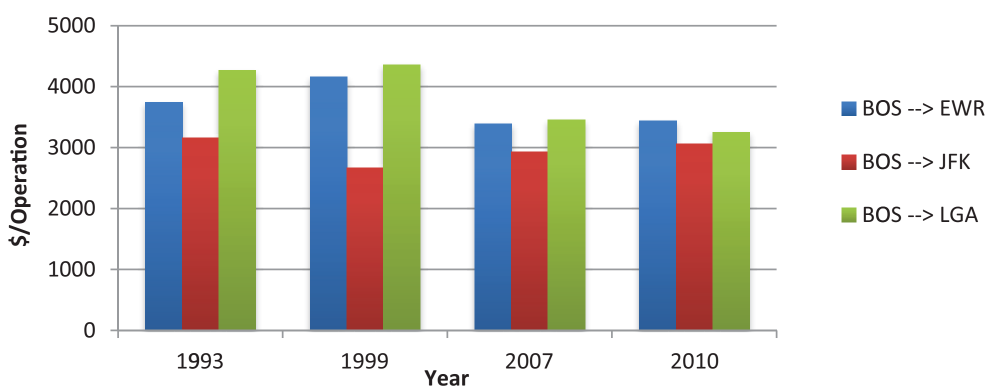


Figure 5-8. Cost per operation.

rail has a discernible impact on airline service. Specifically, cross-sectional regression analyses are performed on airline seats (expressed as log seats per month in July 2007) provided and average aircraft size between BOS and U.S. domestic destinations. Observed values are compared with model predictions for two classes for destinations: those with significant competition from Amtrak and those without significant rail competition.

In practice, the rail competitive class contains only the New York area airports of EWR, LGA, and JFK. In 2008, rail accounted for 49% of the total travel by rail and air between Boston and New York in 2008 (Amtrak 2014). The only other market from Boston with meaningful competition was Philadelphia, where the rail share was 17%. Philadelphia will not be considered rail competitive for this analysis since the rail share is significantly less than in the Boston-New York market.

Using the Official Airline Guide flight schedule of July 2007, seats per month were regressed from BOS to 68 domestic destinations. Two main explanatory variables were used: total airport seats per month at the destination airport and distance to the destination airport. A log-log model was used and introduced second-order terms (such as the square of airport seats per month) that were found to be statistically significant. The resulting model, based on 68 flight segments, has an adjusted R^2 of 0.74 (Table 5-3). If rail competition had an impact on airline capacity supply then the model would over-predict supply in the rail competitive markets. This did not turn out to be the case. In two of the three segments—JFK and LGA—the model under-predicted seat supply; only in EWR did it over-predict. Overall, the model slightly under-predicted seat capacity from BOS to the New York airports.

The effect of rail competition on aircraft size was then analyzed. A previously developed aircraft size model (Wei and Hanson 2005) was used on flight segments with at least one end at a major U.S. airport. The prediction errors of this model for segments originating from BOS were compared. One would expect rail competition to result in reduced aircraft size so that airlines can maintain frequency in order to compete with the rail service. Results confirmed this expectation: aircraft sizes for segments from the New York airports are, in aggregate, 18% less than those predicted. For other segments originating from BOS, observed aircraft size was 7% less than predicted. BOS is primarily a low-gauge airport, but the effect is pronounced on the segments with rail competition.

In summary, an early cross-sectional analysis provides initial evidence that rail competition affects air service from BOS by encouraging down-gauging, but it does not show evidence that overall seat capacity is affected. Further analysis would be required to verify and refine these results in later research studies.

Other American Diversions from Air to Rail

The corridor between New York City and Boston was selected for this research project for several reasons, including the clear-cut improvement in travel times associated with the implementation of electrification between New Haven and Boston and the simultaneous commencement of the Acela service line. By comparison, incremental improvements on the service between New York City and Washington, D.C., have occurred over several decades, beginning with the development of Metroliner services in the 1970s. While a full analysis of the impact of such changes on air ridership requires the kind of airline data presented in this Chapter, some observations of scale can be made about the scale of diversion in the NYC/D.C. corridor. As shown in Figure 5-9, Amtrak reports that between 2004 and 2013 the mode share of O-D passengers grew from 50% to 75%. Given that the section of the NEC between New York City and Washington has the highest ridership, it would be desirable for further research in this area to undertake an analysis similar to that presented here for the relationship of rail service characteristics to change in air passenger volumes.

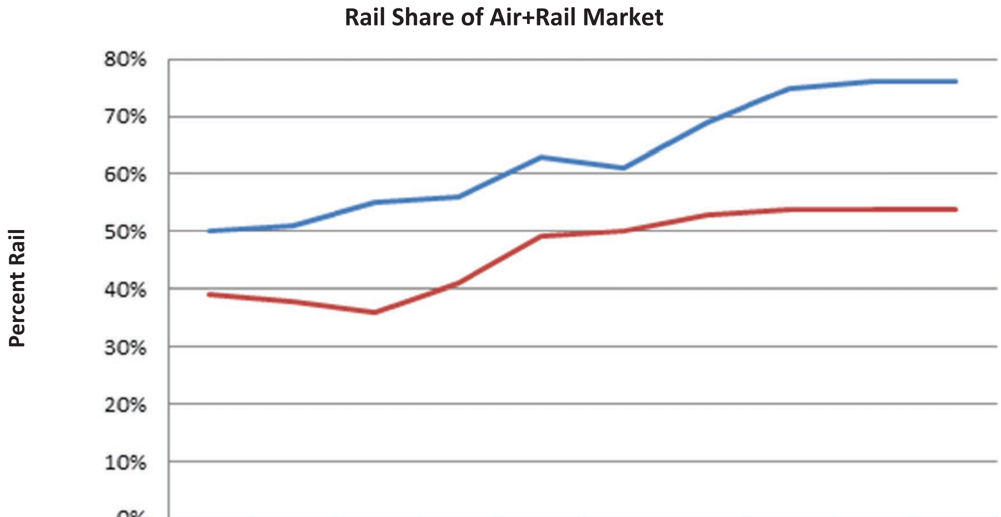
The research has not identified any other corridor in the United States where significant diversion to rail has occurred.

Table 5-3. Model results for cross-sectional analysis.

Dependent Variable: log(seats per month)

Parameter Estimates

Variable Estimate		*DF*	*Parameter*	*Standard*	*t Value*	*p*
Intercept		1	-3.20261	3.96205	-0.81	0.4219
lstm	log(distance in stat. miles)	1	2.5711	1.1596	2.22	0.0302
lap_spm2	log(seats per month at destination airport)^2 log(seats per month at destination airport)*log(distance in stat. miles)	1	0.08512	0.02248	3.79	0.0003
R^2=.7382						



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
NYC-DC	50%	51%	55%	56%	63%	61%	69%	75%	76%	76%
NYC- BOS	39%	38%	36%	41%	49%	50%	53%	54%	54%	54%

Figure 5-9. Market share for two NEC markets. Source: Amtrak, 2014.

Part Two: Data Needs and Modeling Capabilities Applied in the NEC

Recent Data Analysis Activities in the NEC

This section of Chapter 5 now turns to the review of analyses, by others, concerning how air and rail interact together in the Northeast Corridor of the United States, with an emphasis on the data needs and modeling capabilities employed. At present, the Federal Railroad Administration is undertaking a Tier 1 Environmental Impact Statement examining all aspects of the future of rail operations in the Northeast, notably merging the analysis of long-distance rail with that of metropolitan commuter rail operations. That project includes the analysis of the relationship of rail operations and airport activities in the Corridor. It is particularly relevant that the FRA project emphasizes the integrated analysis of commuter rail operations with those of long-distance operations, as two of the region's largest airports, John F. Kennedy International Airport and Philadelphia International Airport are currently served by rail operators providing commuter rail services.

This section of Chapter 5 reports on relevant multimodal analyses done at Amtrak, the FRA and the Office of the Inspector General. The section commences with a review of an important intermodal study undertaken by the New York's Regional Plan Association, on behalf of the Port of New York and New Jersey.

The 2011 RPA Study of the New York Region's Airports

The January 2011 report, "Upgrading to World Class: the Future of the New York Region's Airports," prepared by the RPA in New York City for the PANYNJ represents a major breakthrough in the application of both multimodal and multijurisdictional methods. The RPA study evaluated NEC HSR improvements as one of six categories of potential investments to reduce delays at New York region airports. The other categories included improved air traffic control systems, building a new airport, encouraging the use of outlying airports in the region, expanding runway capacity at the three major airports, and managing demand to reduce peak period flights (Regional Plan Association 2011).

With regard to the impact of true "California-style" (i.e., with line haul speeds significantly higher than that of presently used rail technology) HSR on New York Region airport use, the report states that, on an average day, almost 160,000 people left the New York region by either air or rail in 2008. Of these, 145,200 flew, including connecting passengers, and 13,200 used intercity rail. However, for the five destinations on the spine line of the NEC with air service (Baltimore, Boston, Philadelphia, Providence, and Washington), the number of daily departing rail passengers is reported as 9,200, with a rail share of over 50% (air passengers were 8,400). However, 9,200 rail passengers is less than 6% of the total air passengers using the three airports on a daily basis. True "California-style" HSR in the NEC is estimated to divert 2,049, or 24.4%, of the 8,400 total departing passengers (as of 2008) to the five NEC cities. This is because connecting passengers make up more than half of departing air passengers, and they were not included in the pool of passengers who might divert to rail. The percentage of passengers connecting from other flights to Boston are 67%, 60%, and 22% from JFK, EWR, and LGA, respectively. To closer cities like Philadelphia, the percentages are much higher, at 94%, 89%, and 90%, respectively. The diversion of air passengers to Boston, including connecting passengers, was also 24%, while the diversion to Washington was higher at 36%; it was much lower to closer cities like Philadelphia (9%) since so much of the air travel is connecting passengers. Even "California-style" HSR would divert approximately 2,050 passengers—or 1.4% of the total 145,200 daily air passengers—departing the three major New York airports in 2008.

This study is unusual in relating the potential diversion of air passengers to the total air passengers using the airport(s), especially considering the difficulties faced by the report authors with the input data discussed herein. The study dealt with both connecting and true O-D passengers. In addition, the reported results are for diverted air passengers between specific cities rather than for all passengers using specific airports.

Interestingly, the RPA study estimates available airport capacity from the diversion of air passengers to a specific HSR proposal. This additional capacity could be used for flights to other destinations not served by rail and/or to reduce delays at the airport(s). Either way, the additional capacity provides benefits.

Calculating the additional capacity at New York's three major airports involves making important assumptions about the supply response of the airlines to the reduced number of passengers, in the context of important institutional constraints imposed by operations at these airports. Quoting the study,

> "JFK and EWR serve as major hubs for travel to long-distance and international markets. The airlines rely on shorter flights to feed these routes. Rather than eliminating flights or reducing the frequency of service that could create longer connections, airlines may instead shift to smaller aircraft and keep the same number of flights. . . . Further, the size of the flights or individual markets may not make it practical for the airlines to reduce the number of flights. Their reluctance to drop flights may also stem from their interest in retaining peak hour slots where capacity is capped by the FAA" (Regional Plan Association 2011).

The report makes the important observation that "destinations with large markets such as Boston or DCA, are the most likely candidates for fewer flights where the airlines can accommodate the loss of air passengers to rail more easily" because of the higher frequency of flights (Regional Plan Association 2011). Given the uncertainties in making these estimates of available slots, the estimates in the report "are likely to be the maximum possible values for capacity freed up, rather than probable impacts" (Regional Plan Association 2011). Thus, introducing HSR in the most heavily traveled intercity corridors maximizes the benefits to potential HSR users and non-users who remain on air between the same cities, particularly connecting passengers, and maximizes the benefit to air travelers making use of the available slots for higher value, longer distance travel.

In 2010, about 104 million people accessed the three major New York airports. The report expects "the demand for passenger volumes would reach 150 million, if the capacity is available, as early as 2030." With this overall demand, the report projects 19 peak hour slots freed up from "California-style" HSR in the NEC distributed as follows: 3.5 slots at JFK, 3.2 slots at EWR, and 12.3 slots at LGA. The much higher impact on LGA is due to its larger percentage of traffic to nearby destinations and a smaller share of passengers connecting to other flights.

The report concludes that:

> "a successful expansion or reconfiguration at Kennedy and Newark, along with NextGen (ATC), can meet the twin goals of capacity and delay reduction in the 2030s and beyond. . . . The inability of the combined impacts of NextGen, outlying airports and faster intercity rail to stem the need for eventual airport capacity expansion should not be viewed as a reason to deemphasize these actions. To the contrary, they are each of great value. . . . Faster rail travel, particularly in the Northeast Corridor, will divert travelers from the highways and knit together the economies of the Northeast" (Regional Plan Association 2011).

In summary, this RPA study demonstrates that building a HSR system, even in the NEC, is not a panacea for solving the airport congestion problem. The contribution to reducing delays at airports or increasing airport capacity for higher value long-distance routes is "only one of the environmental, economic and social benefits of having a high-quality passenger rail service and only one of the many reasons that justify major investments in our rail network."

Data and Analysis Needs Identified in the RPA Report for Integrating Air Rail Planning

The RPA report, like most United States studies of the substitution of rail trips in place of air trips, suffered from severe limitations of available data. The published report describes these limitations:

> "Both the rail and air data are station-to-station (or airport-to-airport), and do not provide information of the specific origin or destination within the metropolitan areas for each end of the trip. More refined trip data would have made it possible to create a more nuanced demand model. However, these data either do not exist or are not available from the carriers. Reliable intercity automobile travel data is unavailable. If it were, the interplay among the three modes and their shares would have been of great interest. The lack of auto data has long been a handicap to intercity travel modelers, and its continued absence prevents credible estimates from being made of how well speedier rail service can attract auto travelers" (Regional Plan Association 2011).

This lack of trip end intercity travel data by all modes handicaps any attempt to estimate the relative advantage of city center rail service over air service since air airports tend not be located in city centers per se.

A series of additional data shortcomings were cited by the RPA study authors:

- A depository of intercity travel data by all modes is needed; such a depository could be accessed by analysts performing studies like the RPA study.
- The intercity travel data for each mode should include travelers by trip purpose, group size, household income, and other socioeconomic characteristics that influence travel mode choice and trip making.
- The authors of the RPA study desired better access to a wide variety of data collected, or funded, by Amtrak, including station-to-station flows and general data about hypothesized highway vehicle flows, a major weakness in American multi-state data.
- The authors desired data in which both the rail destination and ultimate destination were known, together with similar data for air trips; but no one believed data were collected in this manner.

In general, the RPA study authors wanted better data. The authors also commented on models for forecasting rail ridership and revenue, especially the interaction of rail improvements with air.

- They argued that there should not be a single model required by all federal agencies or other governmental body. This is because conditions between studies vary, both the study context and the study goals, to say nothing about time and budget restrictions;
- They suggested that a peer review process is needed to review the models and provide reasonableness tests; and
- They took the position that the federal authorities should provide modeling guidance and standard setting, but they should not impose models.

Amtrak's Next Generation High-speed Rail Proposal

In September 2010, Amtrak issued "A Vision for High-Speed Rail in the Northeast Corridor." As described in Amtrak's 2012 Business Plan,

> The "Vision" outlined a conceptual framework and provided an initial review of the feasibility of improving the existing NEC alignment to handle growth in regional, commuter and freight services, while simultaneously planning and building a new, dedicated, two-track, high-speed rail alignment between Boston and Washington to serve the fast-growing intercity rail market, provisionally known as the NEC Next Generation High-speed Rail or "NextGen HSR" system. . . . This Vision is currently being further evaluated and refined so that it may serve as one of the bases for the more significant planning efforts in FY 2012 and beyond (Amtrak 2012).

Amtrak's $117 billion "Vision for High-Speed Rail in the Northeast Corridor" proposal would cut the travel time between New York and Boston to 1 hour 24 minutes and 1 hour 36 minutes between New York and Washington for its "Nextgen High-Speed Express" service. Amtrak projects that NEC Nextgen HSR ridership in 2050 would be five times Acela levels; overall NEC rail ridership would be three to four times the current level of 11.8 million riders. Interestingly, Amtrak's 2050 projection predicts only 23% of the overall NEC ridership increase to be diverted from air, with the rest diverted from auto (47%) and induced new riders (30%) as shown in Figure 5-10. However, between Boston and New York, Amtrak envisions a larger shift to rail from air and auto "where the most dramatic improvement in rail travel times is predicted."

In 2050, their diversion from air would eliminate "true O-D" air travel between New York and Boston. Early documentation does not address the persistence of feeder flights.

However, the aforementioned studies do not investigate the response of the airports and airlines in scheduling flights to achieve the congestion reduction benefits at specific airports. This is especially relevant to this study of the New York–Boston corridor since the delays in minutes per air passenger using the three major New York region airports [Newark (EWR), LaGuardia (LGA), and Kennedy (JFK)] are the highest in the country, with delays at these airports rippling through the entire national aviation system. However, the Next Generation rail analysis is complemented by the results of the PANYNJ/RPA study described in the paragraphs herein.

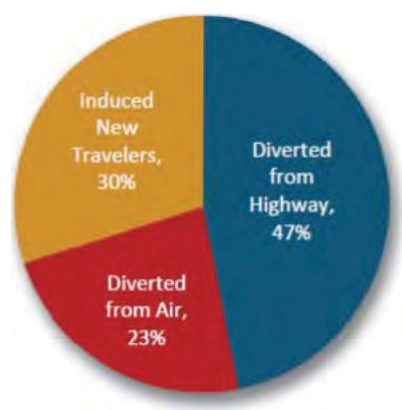


Figure 5-10. Sources of new ridership in Amtrak's next generation plan. Source: Amtrak.

The Analyses of the Office of the Inspector General

The OIG Report on the Completion of the NEC

The NEC has been analyzed using a variety of methods and tools. Substantial work to evaluate the impact of NEC rail travel time improvements on rail and air travel in the NEC was undertaken by the Office of The Inspector General (OIG) of DOT with the assistance of Charles River Associates (OIG 2008). Presently the Boston–New York travel time is 3 hours 20 minutes at best, with the current schedule showing 3 hours 26 minutes. The current Acela schedule shows New York–Washington running times of 2 hours 45 minutes or longer.

The OIG report focused on two scenarios for HSR. The first scenario achieves travel times initially envisioned in the 1976 enabling legislation (i.e., 3-hour service between Boston and New York and 2.5-hour service between New York and Washington). Scenario two estimated the impact of achieving travel times that are .5 hours shorter on both ends. The results were 10.6 % and 20.3% reductions in NEC air travel for scenarios one and two, respectively. Air travel between Boston and New York was reduced by 11% and 21% for the two scenarios, respectively (OIG 2008).

The OIG Best Practices Report

One response to the desire for more modeling guidance noted by practitioners has been the release in 2012 of the document High-Speed Intercity Passenger Rail Best Practices: Ridership and Revenue Forecasting, prepared by Steer Davies Gleave for the OIG at U.S. DOT. The document is one of five separate reports prepared for OIG on "best practice" relevant to the examination of High-Speed Intercity Passenger Rail (HSIPR) projects in the United States. According to the OIG, the report was positively received by the Federal Railroad Administration (FRA) and will influence their management of the analysis process for candidate investments. Their report is largely consistent with the assessment of the status quo reported earlier in this Chapter: The OIG report addresses the problem of dealing with airlines' service alteration uncertainty in reaction to change in competition. The OIG study took the position that:

> [T]he likely competitive response of common carrier service providers to the introduction of HSR service is impossible to predict with any certainty in advance. Absent information to the contrary, it is generally assumed that future common carrier LOS characteristics will mirror base year conditions, so the precision of future year level of service characteristics is of second order importance. Accordingly, the impacts of potential changes in future year service frequencies, fare levels or other LOS variable may be most appropriately examined in the context of a sensitivity analysis (SDG 2012).

In this approach, this type of sensitivity analysis would occur late in the analysis process and could be applied to a wide variety of responses by the airlines, with "each of the scenarios modeled to determine their ridership and revenue impact."

Mode Choice Modeling to Forecast the Diversion of Intercity Trips from Air to HSR

Much has been written about mode choice models over the last 50 years, and this brief review is certainly not intended to duplicate the many volumes and articles on the subject. For example, the classic text book on the subject is *Discrete Choice Analysis* (Ben-Akiva and Lerman 1985). Until the release of *HSIPR Best Practices: Ridership and Revenue Forecasting* there had been no current text available that comprehensively covers forecasting demand for HSR, much less remedies the need to be identified herein for some guidance on this subject. This book has complete chapters on Binary and Multinomial Choice models, which are the two main modeling types briefly referred to here. A thorough international review of methods for forecasting the competition between air and rail was undertaken at the University of Leeds for the European Organization for the Safety of Air Navigation, EUROCONTROL (Wardman et al. 2002). Travel choice models predict the travel behavioral response of people to the transportation choices confronting them. The best mode choice models aspire to be "behavioral models," meaning they include all the important variables that affect modal choice. These variables include all the important characteristics of the transportation system affecting modal choices, and all the important influencing socioeconomic characteristics of the trip makers themselves. Consistent with the analysis presented in the OIG Best Practices reports, three forms of mode choice models are reviewed here: diversion choice, multinomial choice, and nested choice.

Binary Diversion and Multinomial Choice Models.

Two types of models are commonly used to forecast HSR ridership and revenue. Binary or diversion models simply forecast the diversion of travelers from one mode (e.g., air) to another (e.g., HSR). These diversion models have a binary form, as shown in Figure 5-11.

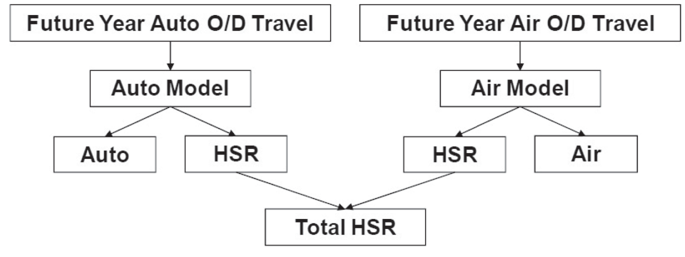


Figure 5-11. Diversion choice model example.

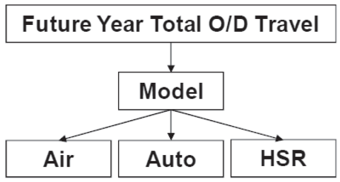


Figure 5-12. Multinomial choice model example.

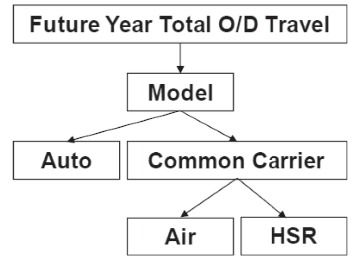


Figure 5-13. Nested choice model example.

The second type of mode choice model is the multinomial model. This model includes the choice between all available modes in a single mathematical formulation. The general form of a multinomial model is shown in Figure 5-12.

The third type of mode is the nested choice model. This model restricts the number of choices in any one nest to a subset of the available alternatives, as shown in the Figure 5-13.

Different modeling approaches have been applied in the studies described in this Chapter. Both work done directly for Amtrak and work now being undertaken for the FRA's NEC Future project utilize the nested choice model approach. Work done for the OIG has used the diversion choice approach. Because this Chapter is most concerned with the potential for substituting rail trips with air trips, it begins with a discussion of a simple binary or diversion choice model approach. This approach involves developing separate single mode choice models of the attractiveness of HSR with air. Separate models would be developed for separate trip purposes (e.g., business and nonbusiness). Consequently, intercity travelers' preferences for a new mode can vary not only by trip purpose but also by the intercity mode they currently use. This approach has the great advantage of simplicity and transparency. For example, a research study (Brand 1996)(Table 5-4) shows the values of travel time savings by HSR for intercity air travelers for trips under 500 miles in the United States estimated in studies using these models in several major corridors in the United States, reflecting the conditions operant in those corridors.

Modal Level of Service (LOS) characteristics Influencing Air Rail Mode Choice

In these models, the most important LOS characteristics influencing the diversion of air trips to a potential HSR service include:

- Line haul travel times;
- Access/egress times and costs;

Table 5-4. Implied values of time savings for air and private vehicle business and nonbusiness travelers derived from HSR mode choice models in several intercity corridors (1992).

Market Segment	Corridor	Incremental Value of Time	Mean Gross Annual HH Income	Percent (%) of "Wage Rate"
Air Business	Texas-Southwest Airlines	$35.65	$83,502	85
	Texas-Other Airlines	$55.29	$86,370	128
	California	$39.07	$77,438	101
	Pooled Corridors	$50.77	$77,000	132
Air	Texas-Southwest Airlines	$24.38	$74,644	65
Nonbusiness	Texas-Other Airlines	$27.10	$62,191	87
	Pooled Corridors	$27.29	$68,500	80
Auto Business	Texas	$28.95	$52,825	110
	California	$23.38	$59,304	79
	Pooled Corridors	$26.19	$55,000	95
Auto	Texas	$13.59	$42,632	64
Nonbusiness	California	$12.45	$54,278	46

Source: Brand 1996.

- Fares;
- Frequency;
- On-time performance; and
- Number of transfers.

Most of these variables are simple to define and measure. The costs include all the out-of-pocket costs of travel, including operating and parking costs per passenger for auto access/egress to airports and HSR stations. For business trips, peak period access/egress times from the local MPO coded networks are normally used; for nonbusiness trips, off-peak times are used. For frequency, the average headways during peak and off-peak periods are used. On-time performance can be more complicated. U.S. DOT compiles statistics on the percentage of flights arriving within 15 minutes of their scheduled arrival time, and the percentage of flights cancelled. Amtrak is the only source of on-time performance data for rail in the United States, and these data can be hard to obtain. The main challenge in specifying these service variables, however, is likely to be the on-time performance of the proposed HSR improvement. Presuming that the excellent on-time performance records of HSR in Europe and Japan translate easily to applications in the United States may be too simple and incorrect. Due diligence is required.

Determining the influence of each of these variables on diverting air trips to HSR is, of course, the key element in modeling HSR ridership and revenue. The Brand (1996) article provides the values for the first four of these variables for a series of forecasting studies in the United States. Similar information for a series of studies in Europe is found in "Air and Rail Competition and Complementarity" (SDG 2006), particularly in Chapter 4, "The Market Share Model."

The SDG model created for their European Union study of air/rail competition had four kinds of input.

They describe the four inputs as,

- **Schedule related factors:** These include journey time, check-in time, time required to leave the rail station or airport, and frequency.
- **Price:** We have estimated average one-way ticket price for each mode on each route, based on a large sample of fares collected from the operators.
- **Access time and cost:** The average time required to access the terminals and the cost of journeys to/from the terminals.
- **Other factors:** We have also taken into account other factors such as reliability, service quality and connections to airports (SDG 2006).

Other LOS attributes of air and HSR influence the diversion of air trips to HSR. These so-called "non-traditional" LOS variables are much harder to define and measure. They include descriptors like comfort, convenience, reliability, baggage handling, safety, and security. Some of these attributes are included, at least in part, in the more straightforward variables defined herein (e.g., reliability in on-time performance and security delays can be measured and included in access times).

However, the most common way of measuring their influence is in the modal constant. The modal constant, like all constants in such statistical models, measures the effect of the "unobserved variables" in the model or equation. In this case, the unobserved variables are simply the LOS attributes not included as separate variables in the mode choice model (i.e., in the list of LOS variables given herein). Modal constants in binary diversion models measure the preference for one mode over the other ceteris paribus, everything else being equal (i.e., all the other variables in the model, including the time and cost variables having the exact same values). The constants are usefully described as the equivalent fare in dollars. This results in the traveler of a certain type and traveling for a certain trip purpose indifferent between the two modes. An example would be a value of $5 in favor of HSR, meaning that an airfare reduction of $5 would make the traveler indifferent between air and HSR if the values of all the LOS variables explicitly included in the model were the same. In fact, $5 in favor of HSR is a common default value of the air modal constant in NEC studies, but it must be stressed that the value is completely dependent on the LOS variables explicitly measured and included in the diversion model. For example, airline security delays are explicitly included in access time in these models.

Attempts to "unbundle the modal constant" using very sophisticated stated preference surveys have been made in the United States. A more subjective way of quantifying the modal constant is included in the SDG Report on competition and complementarity. In this case, the model developers assigned "factor scores" by city pair, separately to rail and air, for four "other factors" (Table 5-5). These other factors were airport links (for connecting passengers), price variability (availability of a low-priced air carrier), reliability, and service quality. Air was superior on the first two factors, while rail did better on the last two. These factor scores were included in the model in place of a statistically estimated modal constant.

Data Collection and Modeling in the Northeast Corridor by Amtrak and FRA

The Tier 1 Programmatic Environmental Impact Statement process for the future of rail in the Northeast has been begun by the FRA. That process, known as the NEC Future project, will include a significant refinement of the models previously used by Amtrak in its Next Generation rail studies. While Amtrak has historically considered its ongo-

Table 5.5. "Other Factors" influencing choice of mode.

Route	Reliability		Airport links		Price variability		Service quality	
	Rail	Air	Rail	Air	Rail	Air	Rail	Air
Frankfurt - Cologne	9	8	6	10	7	9	6	5
London - Edinburgh	2	5	0	10	5	10	7	5
London - Manchester	2	5	0	10	5	9	6	4
London – Paris	8	2	0	10	6	9	9	4
Madrid - Barcelona	8	6	0	10	0	6	8	5
Madrid – Seville	10	6	0	10	0	5	9	5
Milan – Rome	9	6	0	10	7	7	7	4
Paris - Marseille	6	5	2	10	5	5	7	3

Source: Reproduced from SDG 2006. N.B., Original table notes that "Ten is Best"

ing modeling process to be partially proprietary in nature, some details have appeared in the professional literature (ConnDot 2010). As described by AECOM, the 2007 surveying effort included new travel surveys in Maryland, New Jersey, and Massachusetts; these were supplemented by a telephone survey of Amtrak customers and a telephone survey of random NEC travelers (AECOM 2007). The highway surveys generated over 4,600 completed responses, with 5,000 phone surveys from Amtrak users and 10,000 from the random travelers. They report that the highway survey was "used to adjust data from the random traveler telephone survey to account for under-reporting of auto trips." The survey of Amtrak users was used to increase the understanding of trip purpose (not available from ticket sampling) and to model "stated travel intentions." These factors are used to predict overall rail demand rather than diversion from air.

- Level of Service;
- Travel time (line haul and access);
- Departure frequency and time slot;
- On-time performance (OTP); and
- Travel cost/income.

The document is also interesting in that it places predicted rail volumes in the context of highway vehicle volumes, which are difficult to forecast; it also places predicted rail volumes in the context of bus ridership forecasts, which are nearly impossible to forecast given the lack of agreement about base case volumes. In any event, there is a great deal of information included in available descriptions of the AECOM model, which will be very helpful in future studies of the substitution of HSR for air trips between city pairs in the NEC.

In 2014 the FRA's NEC Future Project will complete a new survey to be used to develop a new model, whose structures are being developed as diagrammed in Figure 5-14. The

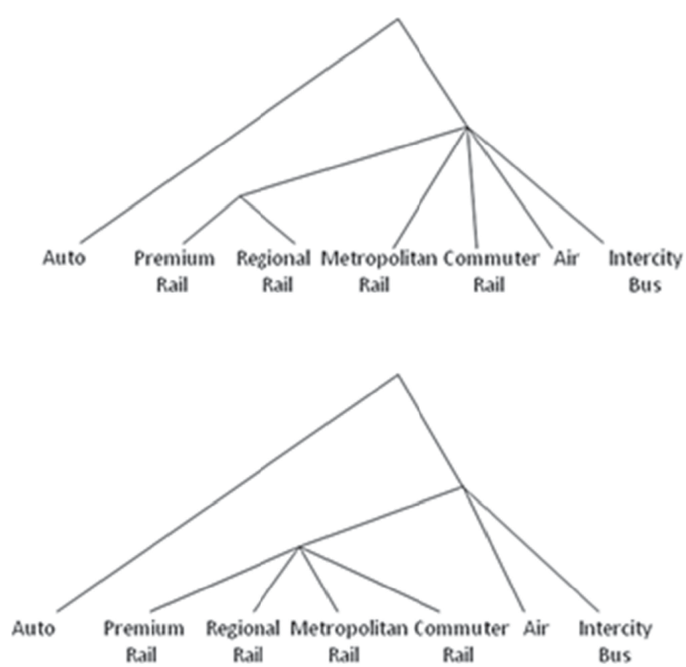


Figure 5-14. Structures being developed in the FRA NEC Futures model. Source: AECOM 2014.

project is designed to produce between 10,000 and 15,000 completed household surveys in the study area, defined in Figure 5-15. This will build directly upon an existing data base from 10,000 non-customers, and 5,000 existing Amtrak customers (NEC Future 2012). The study managers believe this will provide a solid data base to describe current travel by trip purpose, by mode and geography and trip length, providing an adequate number of survey records for each combination of mode and purpose, including intercity bus. At the same time, working in cooperation with the Northeast Corridor Commission, a highway intercept study was undertaken in 2013 to better understand travel flows in the region, using a highly innovative program to survey drivers who use the region's E-ZPass Program.

Recap: Responses to Key Questions

Chapter 5 has reviewed several aspects of the way in which air and rail compete in the Northeast Corridor of the United States. In interviews with leaders in this area, three common questions were explored; those questions, with their evident answers, are presented herein:

1. *Did local planners and managers have access to data that would allow a quick summary analysis of descriptions of performance for the long-distance trips in the corridor?*

Interviews with key players suggest the answer is no. The NEC is the most well-studied intercity rail corridor in the United States, as noted at the beginning of this Chapter. Even

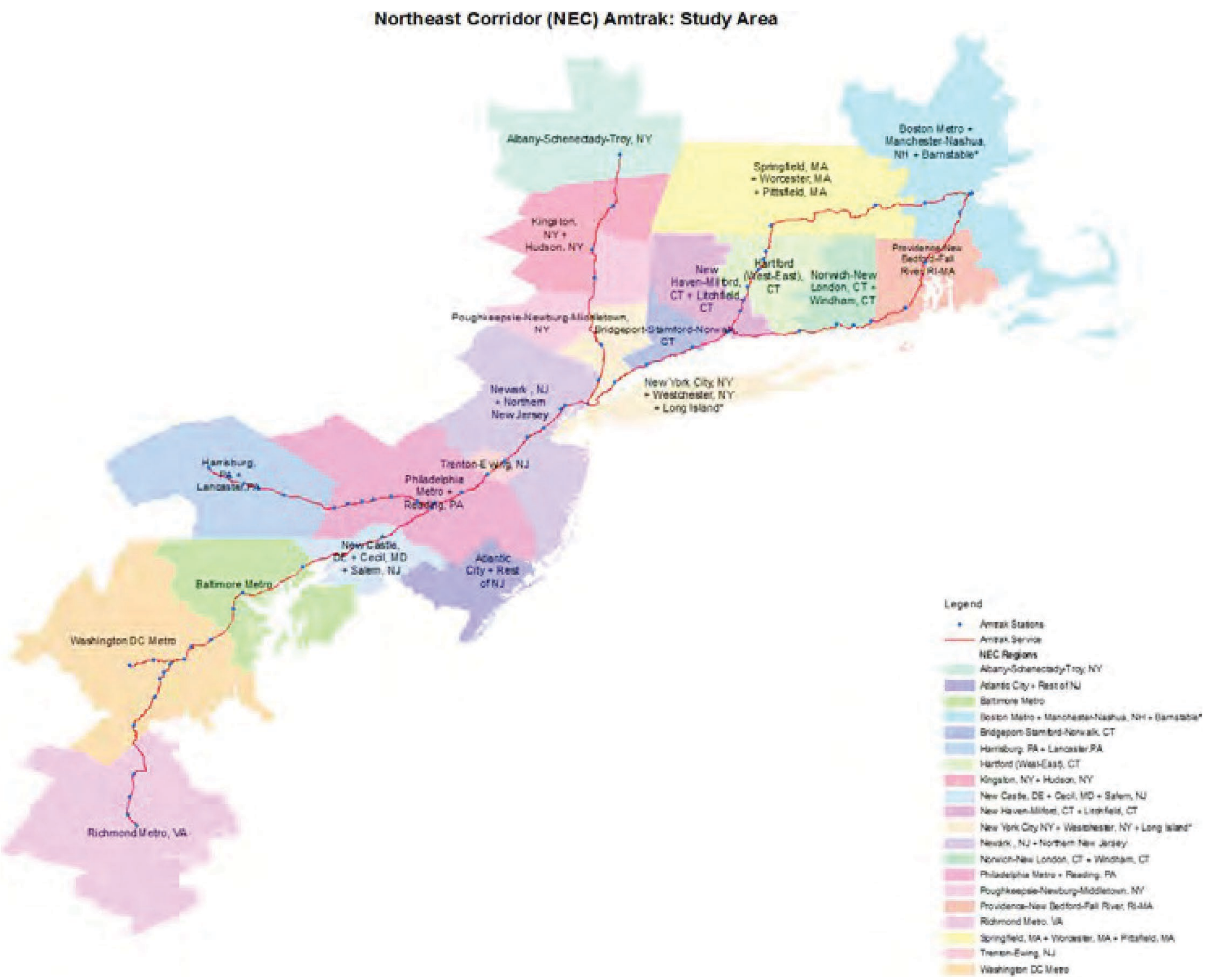


Figure 5-15. Data collection area for FRA's NEC Future modeling process, 2014. Source: FRA.

the comprehensive RPA study of the substitution of HSR for rail trips lacked access to the detailed trip end (geographic) distribution data for air and rail. The local practitioners felt that Amtrak's (then) traditional approach to the proprietary nature of their demand data added to the problems in undertaking a "quick summary analysis" of multimodal strategy options. The contributions of Amtrak to FHWA's Travel Analysis Framework (which occurred after the Research Team's project interviews) will go a long way in improving the quality of data available to groups such as the RPA.

In interviews with the RPA and the Port Authority, participants are concerned with the poor availability of regional intercity data and the models used to help interpret it. RPA representatives were particularly concerned with the lack of good data on intercity automobile flows.

2. *Did the airport strategists feel they have adequate information about the possible use of rail in various ways to help with the major capacity issues looming over major airports, such as New York City area airports?*

No. The RPA planners made a heroic effort to model the diversion of air trips to HSR, but they had the serious data problems detailed herein. The airport managers interviewed had, in fact, just financed the RPA study, so they were in a position to understand the strengths and weaknesses of the data and tools available.

The Research Team's interview with NJ Transit revealed a concern about the quality of the modeling done in some cases. Concern was raised that many participants in the planning process do not understand the need to base the stated preference modeling process (used in analyzing access to airports and diversions from air) on the experience with these particular modal circumstances, and not simply lifted from the modeling process used in the metropolitan areas. Like colleagues at New Jersey Transit (NJ Transit), the PANYNJ staff was directly aware of possible misuses of the modeling process when traditional metropolitan planning models are applied to such subtle issues as rail-as-feeder or sub-mode of access to airports in general.

3. *Would they benefit from the creation of an accepted set of longer distance travel descriptions, including data organized at a sketch planning level for all modes?*

Again, those interviewed felt a certain amount of frustration with the lack of the most basic multi-state travel information, such as automobile trip tables, etc. There was a feeling that the government might be able to help, along with a healthy skepticism of what might happen with too much federal intervention. The development by FHWA of the Travel Analysis Framework, which occurred after the interviews for this project, has been undertaken to deal with these historically recurring issues and concerns.

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CHAPTER 6

Air and Rail in the Midwest

Introduction and Structure

Chapter 6 reviews key issues for integrating air and rail in the Midwest of the United States. These issues are presented in four parts.

Part One examines Chicago's O'Hare Airport (ORD) as a case study in the sheer difficulty of providing a "seamless connection" from a long-distance rail station to a dispersed set of airside concourse piers that are already built, in operation, and unlikely to be moved. Unlike the luxury of having a "greenfield" setting, planners at ORD must deal with the extensive infrastructure already in place, which constrains the realistic options for locating a long-distance train station on the site, and with institutional partners concerned about capital costs.

Part Two reviews recent proposals for long-distance rail improvements that influence air in various ways in light of the site planning constraints described in the opening section; Part Two also helps understand the demand characteristics that are discussed in the succeeding section.

Part Three documents the demand for travel between the Chicago area and 300-mile radius of the surrounding area. The possible role for Midwest HSR to serve in a competitive mode is examined first by exploring the possible scale of diversion of under-300-mile trips away from air to HSR. For the complementary role, the section first examines the logic of HSR services serving as a feeder mode to longer distance flights; then, it examines the logic of HSR serving to divert ground access trips to the airports away from the automobile to rail.

Part Four reviews the results of interviews with air and rail managers in the Midwest about the adequacy of existing tools and resources to undertake complex, multimodal planning and decision making.

Part One: Rail at Chicago O'Hare—Dealing with Uncertain Futures

Introduction

Recent events in the planning of Chicago O'Hare (ORD) airport illustrate the challenge of retrofitting an existing, largely decentralized airport to allow for high-quality transfer from long-distance rail to long-distance air. In Chapter 3, Newark Liberty International Airport (EWR) was seen as an example of an airport where major improvements to rail connections may be possible. There, terminal reconstruction will take place with or without the context of a rail strategy. With the option open for a higher quality Automated People-Mover (APM) connector, the possibility exists for either sending regional service (PATH) directly to the passenger terminals; alternatively, the airport APM can be directly taken to the rail location with the greatest amount of train connections. Later, in Chapter 7, the San Diego Airport (SAN) is examined, where highly promising site planning options to connect the airport with long-distance rail are possible, and where planners can choose from among a set of good options for intermodal connections.

Here, by contrast, the case of ORD is presented where there are no easy or simple options to connect the air terminals with long-distance rail—some form of compromise will be needed. This is largely because of the decentralized nature of the terminals. The airport currently has four terminals, named Terminals 1, 2, 3, and 5 (Figure 6-2). Planning has proceeded for several years on a possible fifth terminal, named Terminal 7 (Figure 6-1). For the airport site planner, designing a good connection between a long-distance rail station and the gates in airports at Tampa, Orlando, Atlanta, Pittsburgh, or Denver would be comparatively easy, as each of these airports consolidates almost all landside passenger processing at one point. In theory, if the long-distance rail station could be located in or close to such a dominant landside terminal, the problem would be solved.

Connecting a single long-distance rail station to all the gates at ORD would be harder, but it is theoretically possible. Figures 6-3 and 6-4 show the location of a new "West Terminal Area" developed by the planners of the ORD Modernization Program planning process at the Chicago Department of Aviation, where Terminal 7 is the westernmost structure. The planning process documented that, in the long term, new

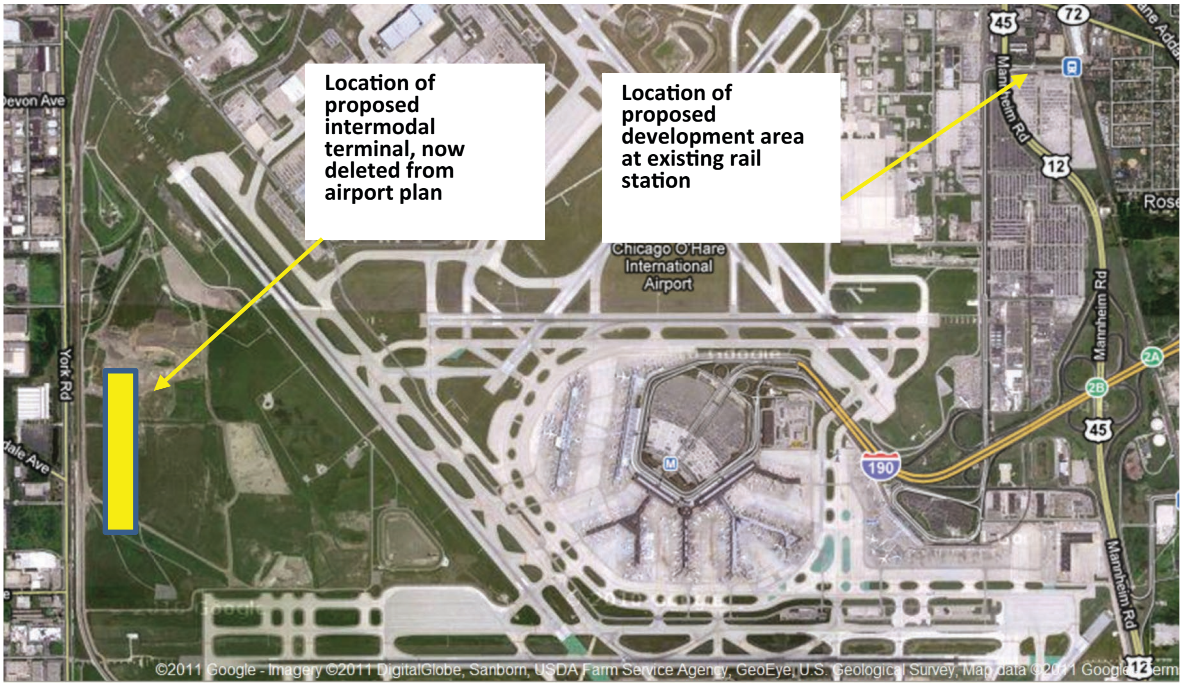

Figure 6-1. Possible locations for Air/Rail transfer at Chicago O'Hare International Airport. Imagery © 2100 DigitalGlobe, Sanborn, USDA Farm Service Agency, GeoEye, US Geological Survey, Map Data © 2011 Google.

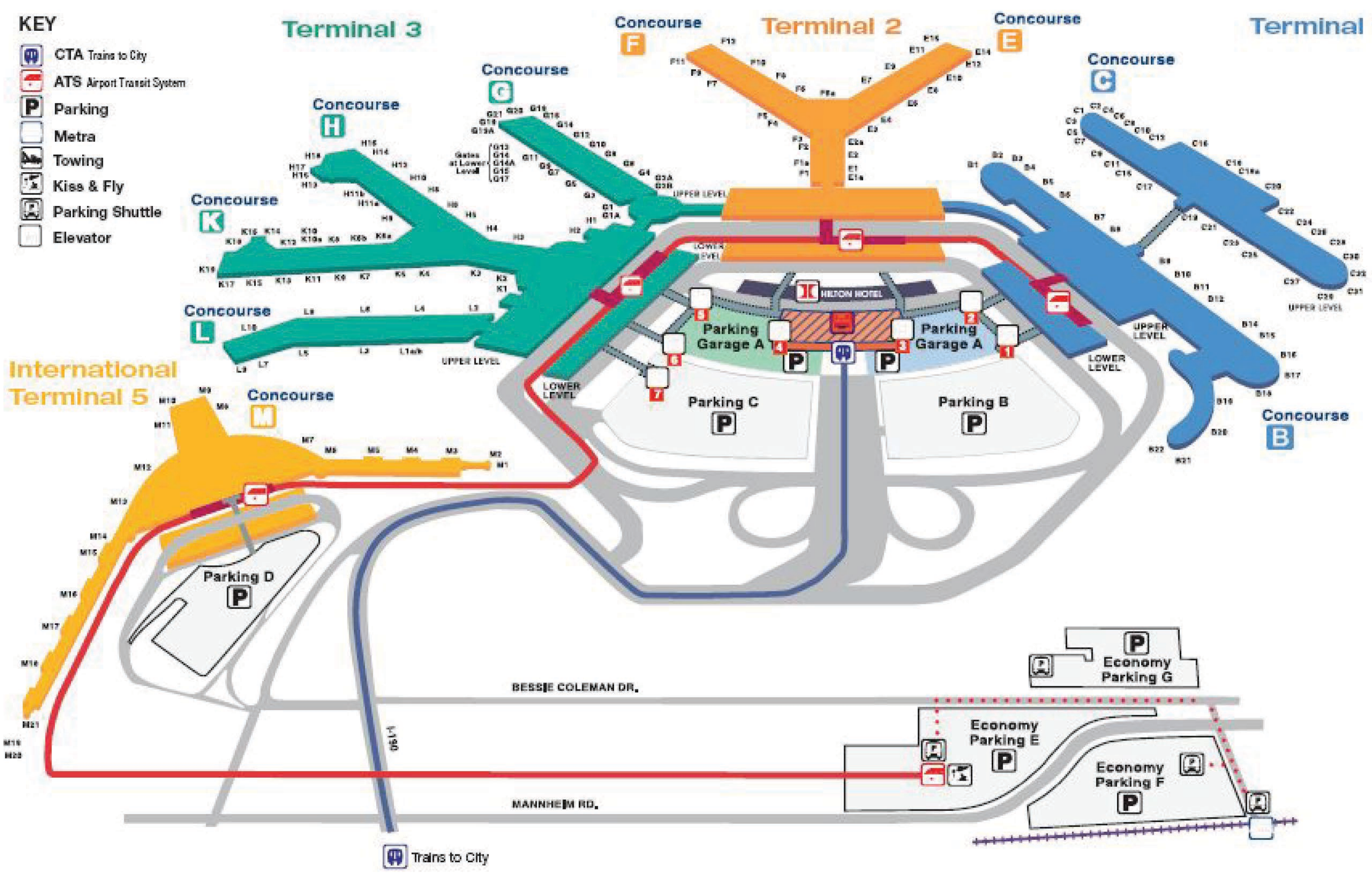

Figure 6-2. The existing O'Hare terminals. Source: O'Hare Airport.

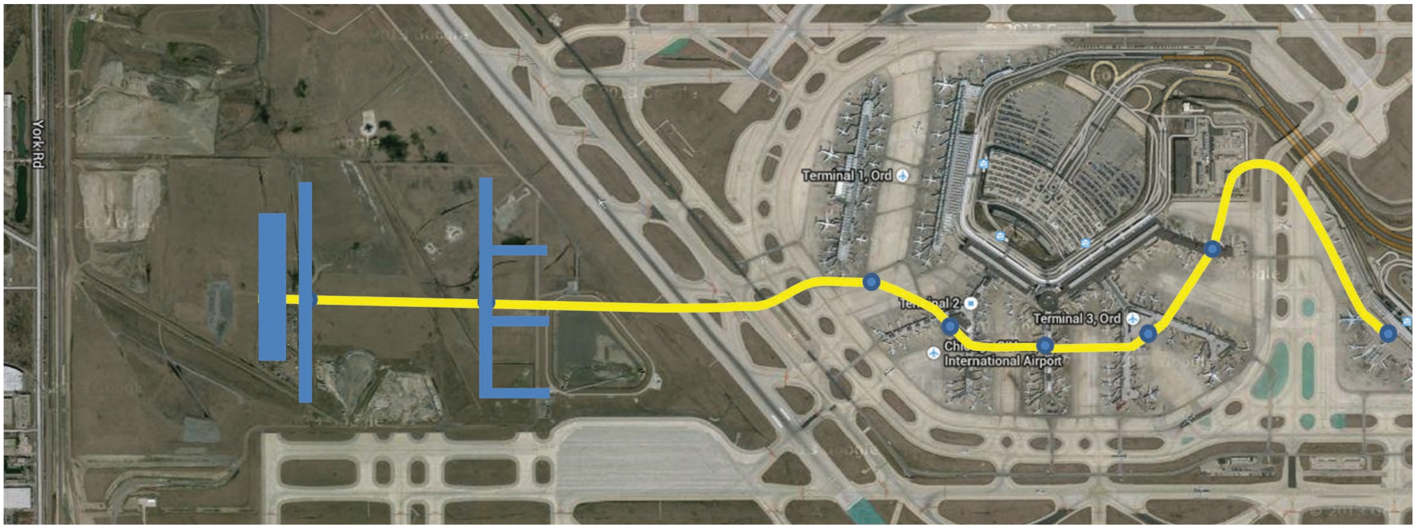

Figure 6-3. Schematic Diagram of people mover connecting West Terminal area with all concourses. Redrawn from diagram supplied by Chicago Department of Aviation, O'Hare Modernization Program. Image © 2014 DigitalGlobe, Landsat, U.S. Geological Survey, USDA Farm Service Agency. Map Data, © 2014 Google.

gates could be located to the west of the present terminals; planners had worked closely with the Illinois Department of Transportation in the planning of new ramps from the highway system to the new Western Terminal. The long-distance rail station would have been located here, along with a second CTA transit station.

Advocates of integrated HSR in the Midwest were strong supporters of the Terminal 7 concept, and lobbied for its development as a key intermodal terminal, served by the list of transportation modes shown in Figure 6-5 (Midwest High-Speed Rail Association 2011).

Connecting to the Airport Terminals

The plan was ambitious and expensive. As diagrammed in Figure 6-3, all airport users could access the new Terminal 7 check-in; they would then be connected to the airside concourses of some of the four existing terminals.

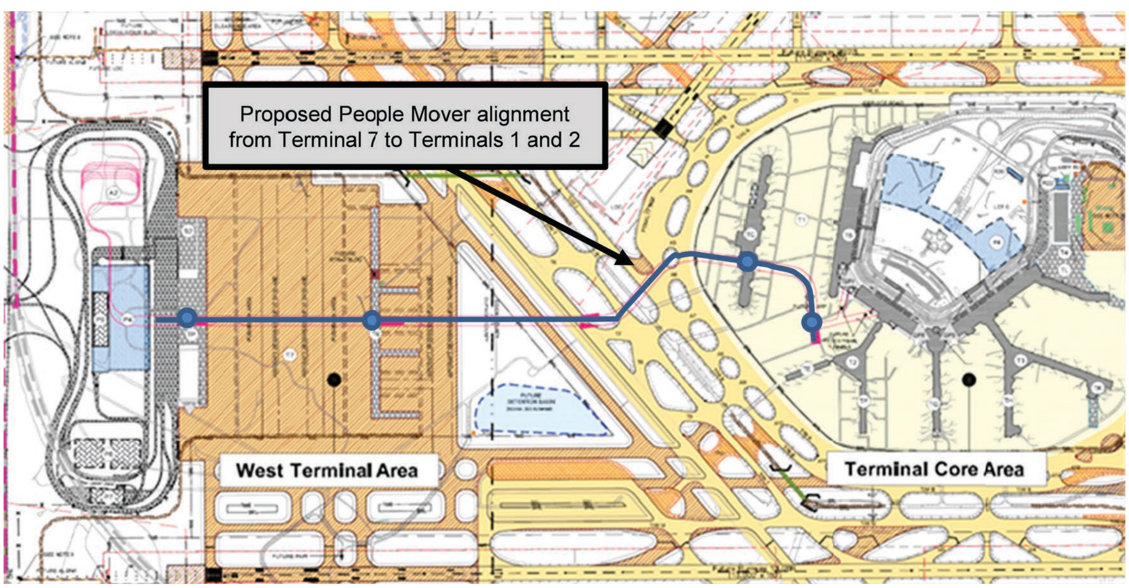

Figure 6.4. In the O'Hare Preferred Development Plan, the people-mover was to extend from the West Terminal Area to Terminals 1 and 2. Source: Chicago Department of Aviation, O'Hare International Airport Master Plan, Preferred Development Plan (Annotations and emphasis for people-mover alignment added).

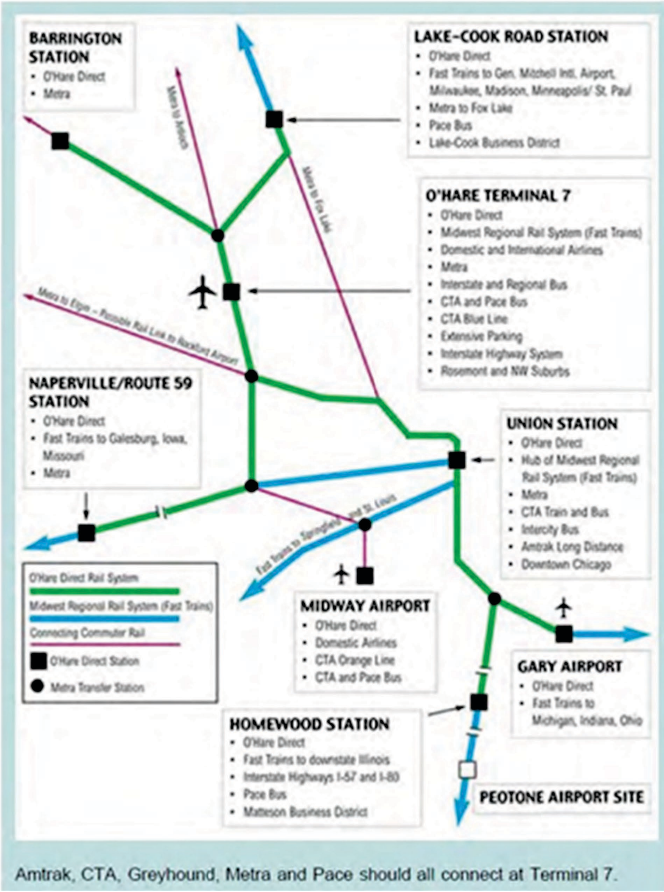

Figure 6-5. Role of Terminal 7 in the Chicago intermodal system. Source: Midwest High Speed Rail Association.

As shown in Figure 6-3, the inside-security, airside APM would directly serve a new midfield airside passenger concourse and proceed under the existing runway. At that point, the APM system would have a tunnel station with connections to both Concourse B and Concourse C of the Terminal 1 complex (United Airlines). The airside APM could continue to the International Terminal with direct services to midpoints in the airside piers of Terminals 2 and 3, labeled as Concourses G, H, K, and L in Figure 6-2. In the airport's Master Plan's Preferred Development Plan, the people-mover operates from Terminal 7 to Terminals 1 and 2, as shown in Figure 6-4.

Because the air passenger would alight the APM in the middle of the existing airside concourse piers, it would be essential for baggage check-in for all carriers to be located at the new Terminal 7. Because some airlines would oppose dividing their check-in services over several locations, some form of common or pooled services would be required. In addition, a baggage pick-up strategy would need to be found.

Strictly from the vantage point of this study of site planning options for long-distance rail at airports, the full scheme developed in the Modernization Program offered an optimal level of facility service: immediate check-in at the "rail" station, followed by the kind of post-security, on-airport connections operated successfully in airports worldwide. In terms of the high-quality European services described in Chapter 2, this Chicago concept would be similar in concept to Zurich, where highly centralized check-in is located at/near the rail station, followed by security and airside people-mover access to some concourses. It would be more integrated than solutions in Paris CDG and Dusseldorf, where major air terminals must be accessed by landside people-movers, which deliver the passengers to various locations external to security clearance. The Chicago Terminal 7 site planning concept would be superior to that of Frankfurt, where no APM system connects directly with the long-distance rail terminal; there, rail riders must walk to Terminal One, where the APM connects Terminal 2 with both airside (secure) and landside (non-secure) shuttle services.

What Happened?

The reaction of the airlines to the creation of a new Western Terminal at ORD was predictable. The major airlines took the City of Chicago to court to kill the project, and, in March 2011, they prevailed. Their position was that the full program was too expensive.

As of the summer of 2012, the website for the Chicago O'Hare Modernization Program (OMP) still refers to a planned Western Terminal. The website states simply, "The OMP will also bring a new Western Terminal facility with more airline gates and parking. The Western Terminal will be connected to O'Hare's main terminal core by an APM system" (O'Hare Airport 2012).

Interviews with the Chicago Department of Aviation made clear that the airport plan does not include the additional terminal or the additional gates designed in the modernization plan. The legal agreement clarifies that the Western Terminal is no longer part of the airport's plan, but leaves certain issues unresolved. Plans had progressed for new roadway access to a major parking facility, and these plans will have to be reassessed. Given the increase in the throughput of the runway system, the issue of more gates undoubtedly will be addressed at some time, and in some way. During the interview process, the Research Team was told that not having more gates was strongly in the interests of the dominant airlines, who did not want any more gate capacity for new airlines.

A New Site for a Long-distance Rail Station?

However, the airport planners already had a second (and much lower cost) option available for siting a rail station for a future higher speed rail program. Looking at the location labeled "Economy Parking F" in Figure 6-2 (and marked with an arrow on Figure 6-1), the Chicago Aviation Department has already commenced the process to develop the site into a mixed-use complex. The site development package shows an extension of the existing landside airport people-mover into the new site, close to the existing, but infrequently used, Metra rail station.

Thus, it is possible to locate a larger rail station at this location. At this ITC, there would be no security clearance, as the rest of the APM system is totally outside of security. If any baggage check-in were attempted, it would most likely utilize trucks and tugs, but not the APM system; its stations in the terminal area are not well integrated into the passenger terminals. Similar truck delivery systems were used for the entire Newark baggage check-in at the rail station; these systems were also used for the on-airport segment of the Heathrow Express service, before both of these baggage systems were abandoned because of a lack of customer use.

The options examined in ORD planning to date can be reviewed in terms of the site planning categories presented in Chapter 2.

Site Planning Considerations

Consistent with the typology developed earlier in this report, the site planning options at the Chicago O'Hare International Airport can be reviewed in terms of an international perspective. A review of international airport stations suggested three major categories for airport rail station solutions:

Site Planning Concept #1: Full Integration at Airport: Reroute the Long-distance Rail Line to Go to a Point from Which the Air Traveler Can Walk from the Train to the Check-in Terminal

As discussed, the full conceptual plan developed for the O'Hare Terminal 7 scheme would have been comparable in quality with the most expensive of the European examples of transfer efficiency. In fact, the contemplated people-mover tunnel to the midpoints of existing airside pier concourses would provide a higher quality of retrofit of existing facilities than has been attempted elsewhere.

Site Planning Concept #2: Shuttle to Rail Alignment: Build a Separate Airport Rail Station on the Rail Alignment at a Point As Close As Possible to the Airport Passenger Terminal Complex

If the HSR connection is made by connecting the existing airport people-mover to the existing Metra station, shown on the upper right hand corner of Figure 6-1, a shuttle to rail alignment would result, as exemplified by the present station connection at Newark. With a single transfer, a high-speed train rider could gain good access to the International Terminal, with continuing APM service to Terminals 3, 2, and 1 within the main terminal complex. While often called a "two seat ride," such a system would be comparable in quality with landside people-mover concepts in Paris and Dusseldorf. In this concept, the passenger transferring from rail would remain outside security until arriving at existing passenger terminal facilities.

Site Planning Concept #3: Connect to Network at a Central Place: Connect with the Best Consolidated Rail Transfer Point Possible

In this option, the need for any new rail line with long-distance through service stopping at ORD is avoided, saving a considerable amount of travel time for the riders on the corridor between Chicago and Milwaukee, generally consistent with the rail operator business case arguments made in Chapter 3. In such an option, the City of Chicago would seek partners to build a high-quality shuttle between ORD and Union Station. The strategy would quickly (and as seamlessly as possible) get ORD users to the point in the region's transportation system with the most connecting train options. Thus, the transferring air passenger would have a good connection to the major rail terminal from which higher speed trains would radiate out in four directions, rather than one. Importantly, this is the option currently being most aggressively pursued by the City of Chicago, which (under the previous mayor) issued a Request for Proposal (RFP) for international consortia interested in providing such service at their own financial risk.

Left unstated in that RFP is just how such a service would interface with the airport itself. With the demise of the Terminal 7 concept, this leaves the Economy Parking F location as the most probable terminus for this local train option, given the cost of any rail tunnel that might take the train to the International Terminal and on to the central terminal complex—a route already covered by the existing people-mover and its extension. Direct rail service only to the Economy Parking station would create, in effect, a "three-seat ride" from long-distance rail, to airport rail shuttle, to APM connecting to landside terminals.

Part Two: The Range of Higher Speed Rail Options in the Midwest

A conclusive analysis of the subject of the role of airports in the developing HSR system in the Midwest is impossible because there is no consensus about the long-term HSR system to be developed in the Midwest. Multi-state rail planning—examining a series of spokes emanating out of the hub at Union Station in Chicago—is divided between those pursuing a near-term system with maximum speeds of 110 mph, and those advocating early investment in a "220"-mph system for the same geographic area. The two orientations occasionally conflict. The near-term program is being developed by the Midwest Regional Rail Initiative, which is run mainly by state departments of transportation; the more ambitious high-speed program is advocated by the Midwest High-Speed Rail Association, a private group funded by private donations.

Midwest Regional Rail Initiative (MWRRI)

The Midwest Regional Rail Initiative (MWRRI) is a cooperative, multi-agency effort that began in 1996 and involves nine Midwest states (Indiana, Illinois, Iowa, Michigan, Minnesota, Missouri, Nebraska, Ohio and Wisconsin) and the FRA. In 2004, the MWRRI finalized a plan for a Midwest Regional Rail System that would incrementally build on existing infrastructure resources. By repairing and upgrading service on current lines, and restoring lines out of use for decades, the system would provide every major city in the Midwest with fast, frequent, and reliable passenger rail service on seven major branches joining in the Chicago hub.

The MWRRI plan elements include:

- Use of 3,000 miles of existing rail right-of-way to connect rural and urban areas;
- Operation of a hub and spoke passenger rail system;
- Introduction of modern, high-speed trains operating at speeds up to 110 mph; and
- Provision of multimodal connections to improve system access.

The goal of the initiative is to develop a passenger rail system that offers business and leisure travelers shorter travel times, additional train frequencies, and connections between urban centers and smaller communities. The project is funded by the FRA as part of its approved program of HSR corridors.

Based on the interviews conducted, the managers of the MWRRS proposal do not plan to divert alignments between Union Station and Milwaukee to serve ORD directly with the 110 mph rail system; this would add more than ten minutes travel time to the city-to-city trip.

Alternative Higher Speed Proposals

SNCF: Midwest Corridor

In December 2008, the FRA announced it would begin accepting Expressions of Interest (EOI) for the development of high-speed lines in the United States. By February 2009, more than 80 groups, including a number of states, train operators, and train constructors, had sent letters describing their interest in being part of the development of high-speed train travel in the United States.

The first major proposal for the Midwest was prepared by SNCF (Societe National de Chemin de Fer, the French National Railway) in September 2009. Because the US DOT policies have been encouraging private sector proposals, the exact legal status of the proposals is unclear. According to The Transport Politic (Freemark 2009), SNCF submitted a 1,000-page document detailing efforts in four corridors; one corridor was the Midwest. According to this online source, the first phase of rail investments for the Midwest would extend from Milwaukee to Detroit, via a bypass around Chicago, Fort Wayne, and Toledo by 2018, with a link to Cleveland opening by 2020. The full system would include new connections from Chicago to St. Louis; Chicago to Cincinnati; and Milwaukee to Minneapolis. SNCF predicts full operation by 2023, though further links along the Ohio 3C (Cleveland, Columbus, and Cincinnati) corridor and to Kansas City, Pittsburgh, and Toronto could be considered for future development.

SNCF expects that the system would more than cover operations costs, allowing the network's revenues to be used to repay some of the initial construction costs. The public would subsidize 54% of the $68.5 billion total cost of right-of-way, construction, and train sets. Benefits from reduced car and air travel, however, are expected to offset 150% of the government investment in construction costs over a period of just 15 years of operation.

By the calculations of SNCF, potential journey times would connect Chicago and St. Louis in 1 hour 44 minutes; Minneapolis and Chicago in 2 hours 42 minutes; Chicago and Detroit in 1 hour 53 minutes; and Indianapolis and Detroit in 2 hours 52 minutes. The first phase would attract 15.8 million passengers per year by 2022; the completed system would serve 42.3 million passengers by 2028. Although the SNCF vision has no legal standing as a "master plan" for HSR, its ambitious treatment of major corridors, like the routing of Chicago to Detroit service via Toledo to get the most appropriate alignment for super high-speed service, has evidently had a great effect upon the planning efforts of others.

The Midwest High-Speed Rail Association Plan

In the spring of 2010, an ambitious proposal was released by the Midwest High-Speed Rail Association (MHSRA), which represents the highest level of consensus yet about the form of a "220"-mph system for the Midwest. The key elements of the plan are represented in Figure 6-6 with the lines designated in the maps as "220 mph."

Figure 6-6. Composite map showing several separate Midwest HSR proposals. Source: Midwest High Speed Rail Association.

To give a sense of the scale of the differences in assumptions about the system, Figure 6-7 reproduces the summary table from the MHSRA's recent study of economic impacts (Midwest High-Speed Rail Association 2011). The MWRRI travel time calculations show that the application of 110-mph technology would not provide terminal-to-terminal service in under 3.5 hours in any of the four corridors analyzed. By contrast, adoption of 150 mph technology would provide 3.5-hour service in all four of the corridors; the assumption of 220-mph technology results in 2.5-hour terminal-to-terminal times in all four corridors.

In the plan published by MHSRA, new lines providing 220-mph service to corridors to St. Louis (via Champagne), to Indianapolis and Cincinnati (via Gary), and to Detroit and Cleveland (via Gary and Toledo) would all be routed through a new station at McCormick Place, and then to a new, underground Union Station. From there, the 220-mph alignment would proceed to ORD and then north to Milwaukee. Figure 6-8 shows that the alignment would allow trains from all three lines approaching from the south to serve Union Station directly, and proceed on to ORD—if demand and operations considerations determined this was desirable. Functionally, service to ORD before the main terminal would be possible for riders from the north (e.g., Minnesota, Madison, and Milwaukee) with all others having the physical potential of an airport stop after Union

Ridership Forecast Summary

	Annual Riders	Annual Revenue	Travel Time	Daily Roundtrips
CHICAGO – MINNEAPOLIS / ST. PAUL				
110 mph (MWRRI)	4,362,404	$158,030,000	6:29	6
150 mph	12,537,000	$634,220,000	3:30	25
220 mph	15,884,000	$842,150,000	2:30	25
CHICAGO – ST. LOUIS				
110 mph (MWRRI)	1,757,123	$65,760,000	4:27	8
150 mph	5,999,000	$249,090,000	2:40	25
220 mph	7,904,000	$336,750,000	1:55	25
CHICAGO – CINCINNATI				
110 mph (MWRRI)	894,669	$55,420,000	4:08	5
150 mph	5,877,000	$285,660,000	2:30	25
220 mph	7,226,000	$374,280,000	1:55	25
CHICAGO – DETROIT / CLEVELAND				
110 mph (MWRRI)	4,795,048	$179,360,000	4:24 / 4:48	9
150 mph	10,661,000	$561,770,000	2:25 / 2:50	25
220 mph	12,650,000	$685,190,000	1:55 / 2:15	25
TOTALS				
110 mph (MWRRI)	11,809,244	$458,570,000	-	28
150 mph	35,074,000	$1,730,740,000	-	100
220 mph	43,664,000	$2,238,370,000	-	100

Notes: Current project forecast year: 2030; revenue in 2010 dollars
MWRRI forecast year: 2025; revenue in 2002 dollars
MWRRI reported Michigan and Cleveland corridors separately; results combined above
MWRRI Minneapolis / St. Paul corridor also includes Green Bay
MWRRI total only represents ridership forecast in the four corridors

Sources: Midwest Regional Rail Initiative Project Notebook, June 2004; AECOM 2011.

Figure 6-7. System differences, by speed assumed. Source: Reproduced graphic from Midwest High Speed Rail Association.

Station, with a transfer for some under most operating assumptions.

In interviews, advocates of both the mid-speed systems and the high-speed systems agreed that a diversion of the Union Station to Milwaukee line to serve ORD directly was not practical with lower-speed systems. The same managers agreed that, if the kinds of travel times envisioned in the 220-mph vision could happen, the diversion away from the shortest airport alignment would be logical. The MHSRA plan refers to a 36-minute travel time to Milwaukee, which assumedly refers to the fastest train times (i.e., without a stop at ORD). With corridor travel times this low, a diversion into the airport might be justified without damaging long-distance travel times.

HSR advocates in Chicago have some interesting approaches to the question of the possible role of HSR as a feeder mode to airports in the United States. The benefits of the improved travel times occur with longer distances, perhaps well outside of the traditional catchment area of an airport. In Chapter 2, for example, demand for access services was strong in the natural catchment area of Dusseldorf Airport (served by medium speed rail), but poor in the cities served by the longer distance HSR trains. At Newark International Airport, demand for airport access using NJ Transit services is strong but somewhat weaker for access using the long-distance Amtrak services. However, advocates of HSR solutions for the Chicago hub system believe that once new rights-of-way are created for longer distance, high-speed systems, a new form of commuter hybrid service could be created, modeled after the Javelin service in the London area, which operates in both local and high-speed mode. This is an important concept, as it would create a system in which an air market from the farther points in the metropolitan area of the airport would be served by a newly improved service. In order to create this program, discrepancies between commuter rail schedules (overwhelmingly oriented towards commuter movements) and schedule requirements for air services (spread out over several peaks during the day and night) would need to be resolved.

Airports Connected in Alternative Proposals

In the MHSRA proposal, the new high-speed right-of-way would not serve Midway Airport directly. By contrast, the lines routed through Gary, Indiana, would make possible an air/rail station at that airport. As of the time this report is being written, debates continue over alignments near smaller airports, such as Madison, Wisconsin in the MWRRS (110-mph) plan. The authors of the SNCF plan for the region were explicit in

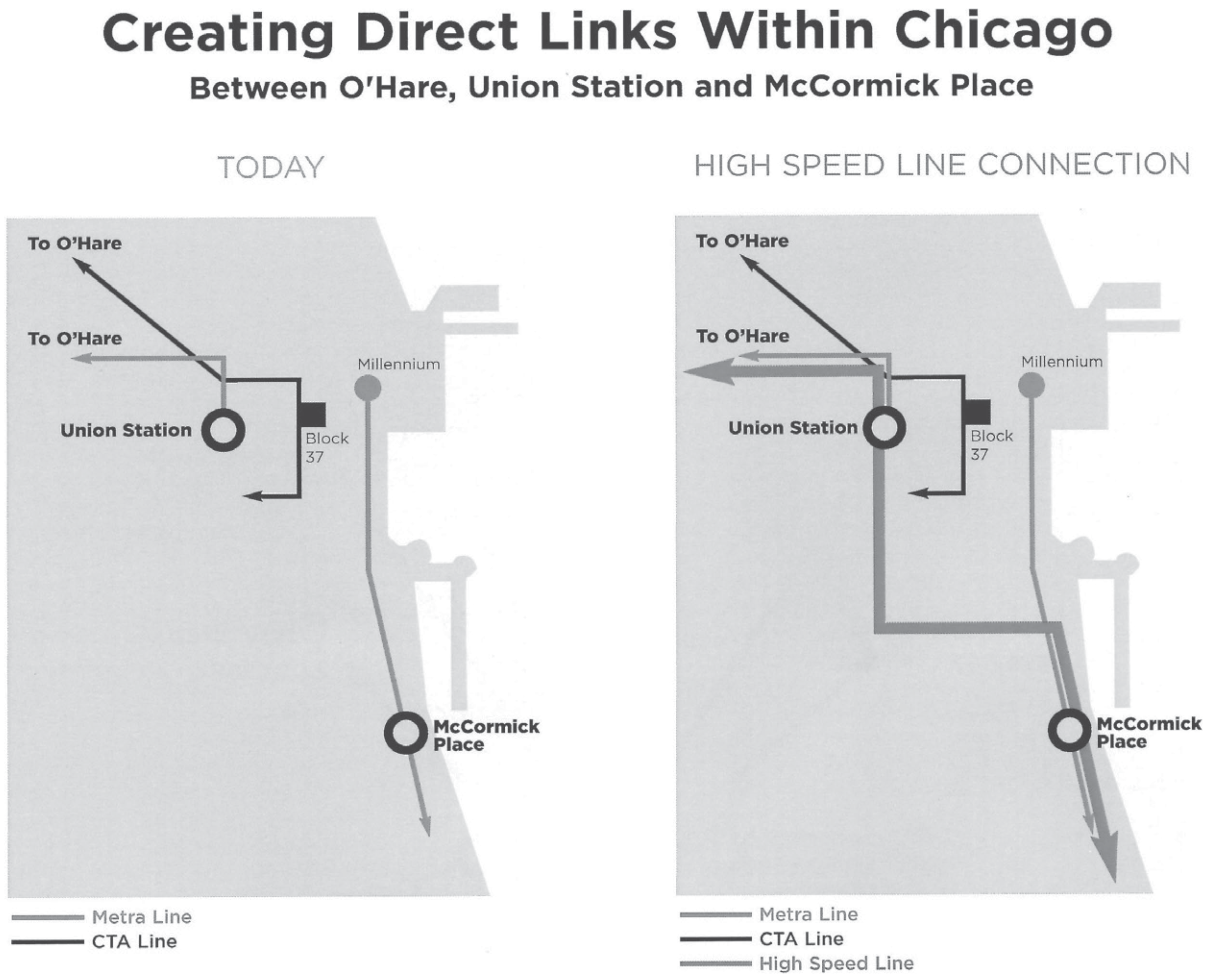

Figure 6-8. Diagram showing HSR alignment between McCormick Place and O'Hare Airport. Source: MHSRA.

the support for HSR (220-mph) alignment stops at airports serving Milwaukee, Gary, Cincinnati, Detroit, and Cleveland. The SNCF plan also includes a Chicago bypass loop that would allow their alignment to serve both MDW and ORD in Chicago, with no HSR track between Union Station and either airport.

Part Three: Understanding the Demand to/from Chicago's Airports

Understanding the Market for Air/Rail Competition in Chicago

The opening chapters of this report found it important to treat origin-destination (O-D) markets separately from the markets for connecting air passengers. This section of Chapter 6 examines only markets that reflect true O-D travel entirely within the study area. The following section will examine only those currently using feeder air services to begin/end a longer trip within the study area. As shown in Figure 6-9, there are 32 airports with service to ORD and/or Midway that are within 300 miles, representing nearly 5.9 million yearly flights in 2007. At present, ORD has approximately four times as many yearly boardings as Midway.

Diverting Air Passengers with Both an Origin and Destination in the Region: Establishing the Range of Diversion

It is clear that there is the potential for travel times similar to those in Europe reported in Chapter 2, which have resulted in significant diversions of O-D trips, based on travel times by so-called 150 mph and 220 mph technologies as shown in Figure 6-7. In Europe, HSR between Madrid and Barcelona garnered about half of the air plus rail O-D market—even while the airlines kept an exceptionally high quality of service. The Madrid–Barcelona case study is of great relevance to the United States application, as the Spanish airlines have made a far more robust defense of their markets than was the case in some early HSR applications in France.

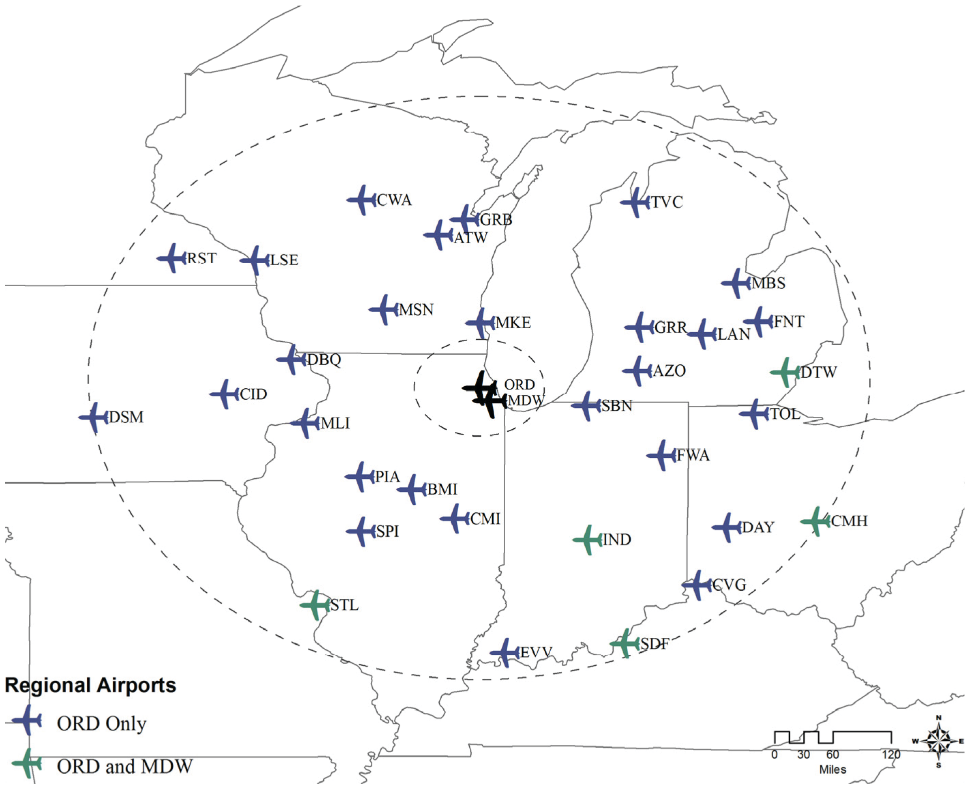

Figure 6-9. Regional airports with service to O'Hare and Midway 2007.

The following analysis examines the implications of rail diverting a high range of 50% of the air plus-rail O-D market, with additional sensitivity testing for a midrange at 35% and a low range at 20% of that market. Figure 5-4 in Chapter 5 showed that O-D air volumes between Boston and New York dropped by about 50% between 1993 and 2010. Wardman et al. (2002) reported that when the Paris–Bordeaux corridor attained a travel time of 3 hours, a 20% substitution rate was experienced along that corridor; similarly for the early years of the Paris–London market, they reported a 25% corridor level substitution rate (additional diversion occurred later). In a comparable analysis, Black (2005) reports a variety of substitution rates, from 15% to 53%, along the Northeast Corridor. Thus, the range of possible diversion rates applied seems reasonable for scenario testing purposes.

One can posit that, in markets like Chicago–Minneapolis and Chicago–Detroit, airlines will assertively defend their network markets. Thus, feeder flights will remain, and those seats can also easily be marketed to the O-D market. This supports the concept of testing both high and low scenarios for diversion.

The O-D Market from ORD—Data Descriptions

The DB1B and T100 air passenger data from the Bureau of Transportation Statistics provide origin, destination, and itinerary information about domestic air travel in the United States. These databases provide the total number of passengers traveling from airports within a range in which HSR could reasonably serve as an effective alternative. The range was set as between 50 and 300 miles from Chicago for this analysis. The planned HSR service could certainly serve some trips outside of this range, but the greatest potential would clearly lie within this range. Estimates for the potential size for this market can be determined by comparing the number of passengers that currently travel to these regional airports from ORD or Midway with the future alignment of the HSR network in the Midwest.

Focusing now on the markets for ORD, Table 6-1 shows that of the 18 million originating passengers boarding a plane at ORD, about 6% of these O-D passengers are going to an airport within 300 miles of Chicago, or roughly one million passengers. The Research Team has calculated that over 90% of them are in fact going to an airport that is within a 20-mile drive of a planned HSR station. Figure 6-10 shows the location of those airports and the scale of the volumes carried from ORD. Thus, about 946,000 departing ORD passengers were found to be logical candidates for diversion to rail in its O-D market function.

How many of these passengers might be diverted away from their present medium-distance mode (air) into a different medium-distance mode (rail)? Three diversion rates were

Table 6-1. Trips from ORD to study area airports.

	Total Boardings	With Destinations within the region	% of Total
Originating Boardings	18,154,235	1,019,710	6%
Boardings from Transfer Flights	15,932,074	3,843,273	24%

applied to that candidate market; however, for brevity's sake, this text will focus on the high end of the diversion estimates—with about 50% of the O-D passengers choosing rail instead of the base case assumption of air. Assuming that the new rail could reach out and attract the higher diversion number, this means that 473,000 of these annual O-D passengers would become rail users.

Remembering that there are 34 million annual air passengers boarding a flight at ORD, this diversion would represent a decrease of approximately 1.4% in ORD passenger volume. From this point, further sensitivity analysis can be applied; if the reader posits that HSR will capture 75% of that logical market, then the diverted passenger volume would jump to 2.1% of ORD's departing passengers. What is important in this scenario testing exercise is to establish the scale of change without implying the performance of actual forecasts, which were not done.

Figures 6-11 and 6-12 show the number of airplanes and number of seats in planes used in flights under 300 miles at ORD. Table 6-2 presents the results from three diversion scenarios ranging between 20% and 50%. The number of boarding passengers with both origin and destination in the study area that may be diverted at ORD in the scenarios range between 190,000 and 473,000, depending on how competitive the HSR service is in the future. If 473,000 of these originating passengers—who formerly made regional flights from ORD—now traveled via HSR, the number of regional flights from ORD could be reduced by about 5,750 flights per year, or about 16 flight departures per day, as shown on Table 6-2.

However, building directly on the analyses of air/rail competition presented earlier in this report, the question—again—turns to the speculation over how the airlines would react to a 50% reduction in the O-D component in any given city pair market. Thus, with the focus of this section of Chapter 6 only on the O-D passengers in the HSR study area, one simply cannot predict the change in number of flights that would occur. Rather, if the airlines wanted to do it, the number of departing

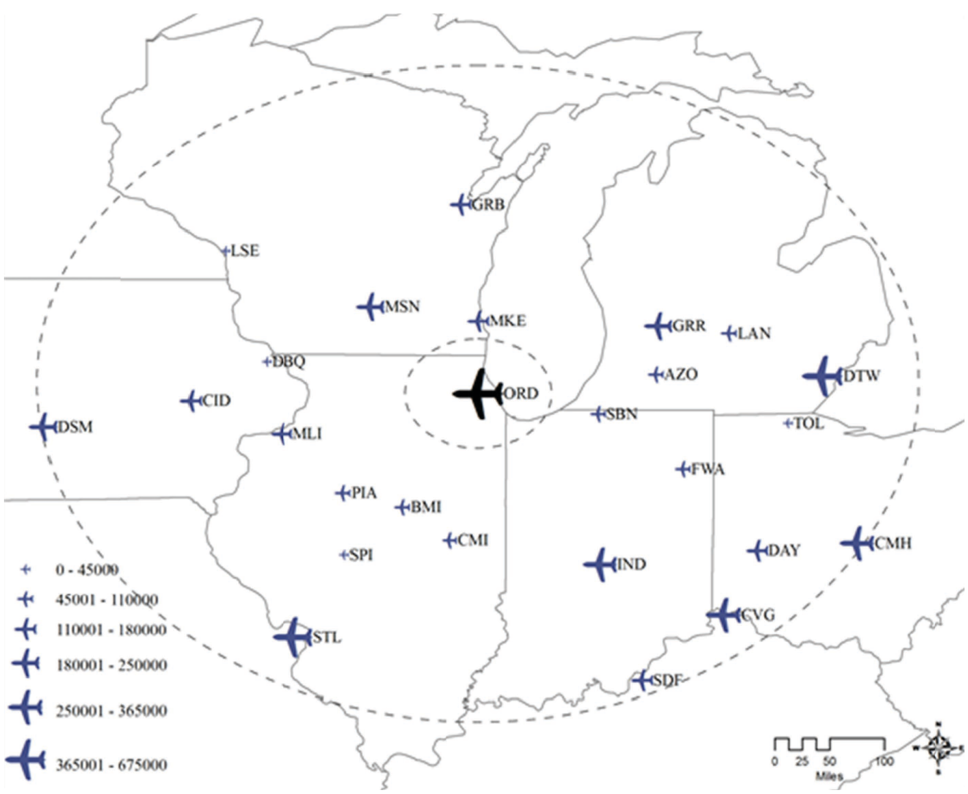

Figure 6-10. Study area airports to be served by HSR.

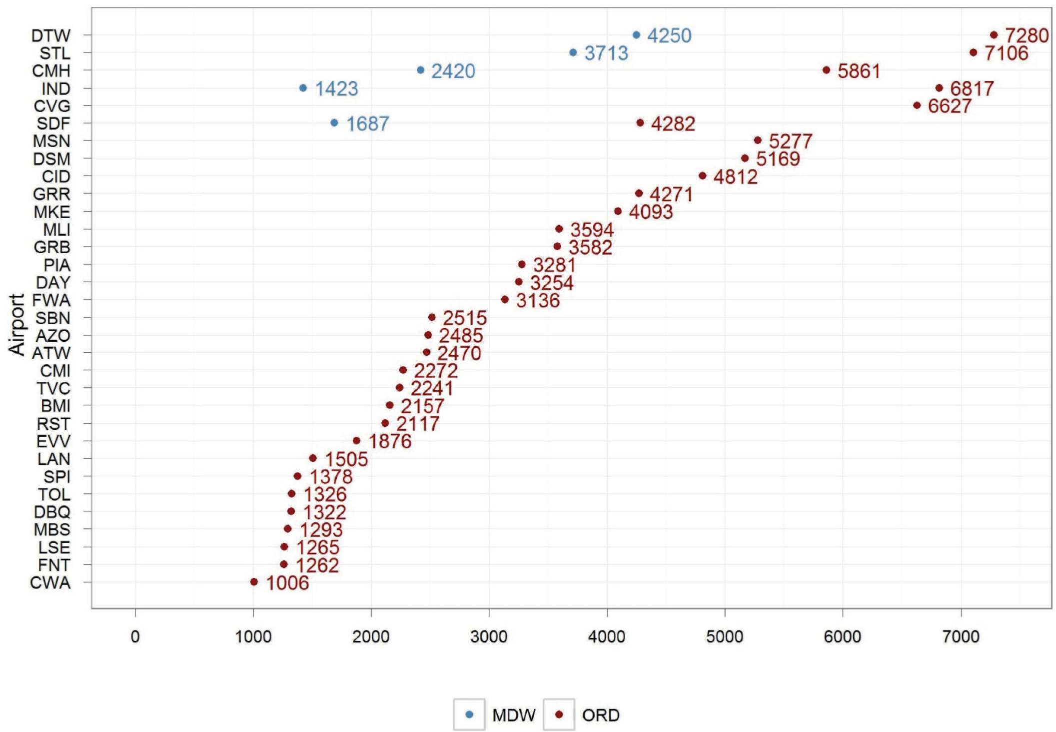

Figure 6-11. Annual flights in study area to MDW and ORD (2007).

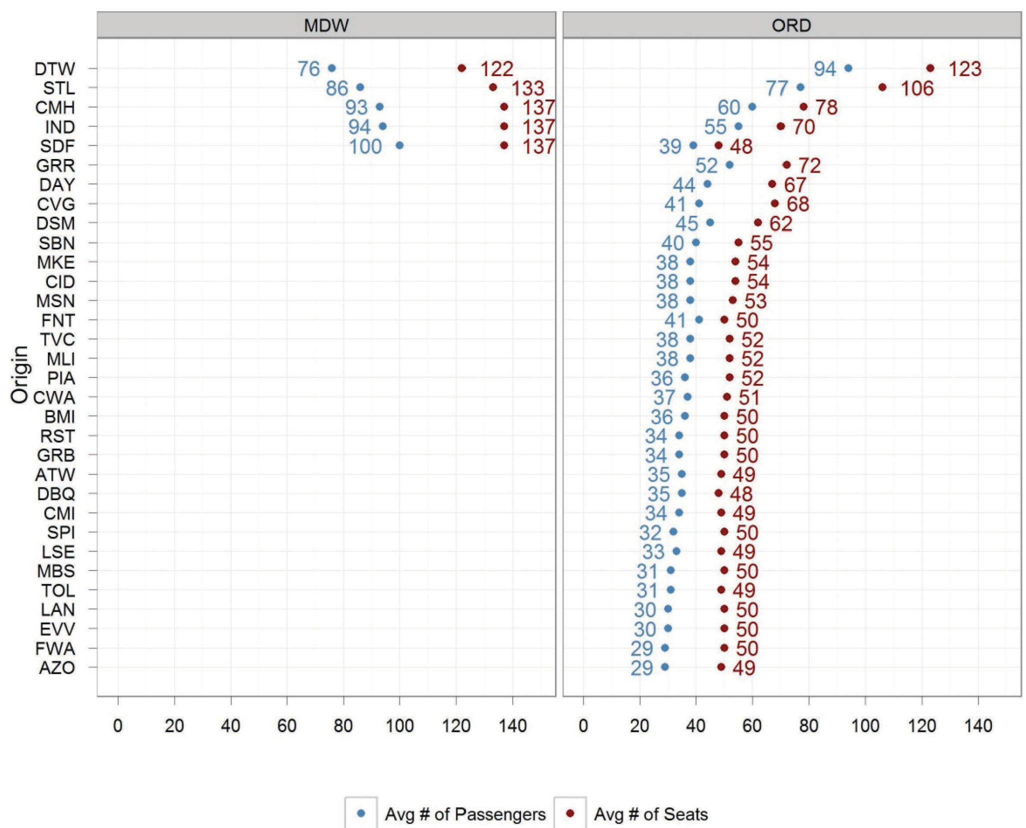

Figure 6-12. Average number of passengers and seats on study area flights (2010).

Table 6-2. Passengers diverted by competing rail, and market for reduction of planes.

	Boarding Passengers Diverted, by scenario			Potential Reduction in Number of Departing Planes		
	20%	35%	50%	20%	35%	50%
O'Hare International Airport	189,256	331,198	473,140	2,300	4,024	5,749

flights could decrease by 16 departures per day, assuming the size of the planes remains constant.

Who is on Those Flights?

It is important to review the basic scale of the two markets during the transition to the analysis of the feeder flight function in the study area. Table 6-1 showed that 14% of airport passengers boarding at ORD were destined to disembark at airports within the 300-mile radius study area. Of the people on those flight segments, almost 80% were not O-D passengers, but were connecting passengers.

Thus, if the total volume of O-D passengers on these within-study area flights were to decrease by half, the total volumes remaining on the flights would fall by only 10%. All of this is to set some scale for the amount by which the airlines will want to decrease the frequency of the feeder flight system. Phrased differently, it suggests that in theory the market for diversion of connecting air passengers from ORD is four times the size of the market for diversion of those traveling completely within the region.

Understanding the Market for Air/Rail Complementarity in Chicago: Rail Providing Feeder Services to the Airport

The following two sections of Chapter 6 will review the use of HSR to carry air passengers from ORD by diverting them from their present use of feeder aircraft to rail service designed to mimic the trip quality of the feeder airplane. These sections will also examine the scale of the market for HSR to carry air passengers from Chicago airports by diverting them from their present use of highway—using ground access modes, including auto and airport bus. The analysis in these sections assumes that the number of feeder flights and passengers into a major airport (ORD or MDW) is mirrored by an equal number out of that airport. Thus, the terminology "to" an airport is used to be more brief than the more accurate phrase "to or from" said airport.

Rail Complementarity: Diversion to HSR from Feeder Aircraft at ORD

Next examined are passengers flying in flight segments between ORD and other airports within the HSR study area—the focus is now on those connecting on to a later departing flight at ORD, usually from a long-distance flight.

The viability of HSR as an alternative to regional flights is related to the number of flights from each of the regional airports and the capacity of those flights. Not surprisingly, the largest number of flights to ORD and Midway come from the other large airports in the Midwest, including Detroit Metropolitan Wayne County Airport (DTW), Lambert-St. Louis International Airport (STL), and Port Columbus International Airport (CMH). These airports also happen to be near the border of the 300-mile radius of Chicago. Figure 6-12 includes the total number of flights from all of the regional airports to ORD and Midway; Figure 6-13 shows the average number of seats and passengers on those flights to ORD and Midway. Average load factors on these flights to ORD vary between 58% for Fort Wayne International (FWA) and 81% for Louisville International Airport (SDF). The majority of the flights to ORD are between 50% and 70% full. The distribution of load factors for flights traveling to Midway is more clustered, with a minimum of 62% for DTW and maximum of 72% for SDF.

A significant justification for connecting a HSR service directly to an airport is the concept that connecting air passengers would abandon the feeder flights to the extent that the number of flights could be lowered. The question is raised about what impact such diversion might have on the need for continued feeder flights to ORD. Getting the holders of a long-distance airline ticket to voluntarily choose rail for the first segment can be done, but only through a major institutional commitment by many parties. The data from Chapter 2 on consumer choice between an access flight and an access train ride is varied: from Stuttgart to FRA, approximately one integrated ticket holder in seven chooses the train as the feeder mode over air as the feeder mode. In a geographic area where both trains and planes are available to Paris CDG, it is estimated that 45% of air travelers select the train as feeder while 55% choose the plane as feeder, as reported by the French Civil Aviation Authority (DGAC). That study concluded that there was great variation in the market behavior: in essence, where the quality of competing air service was weak, rail mode share was strong; where the quality of competing air service was strong, TGV share was weak.

In the base case scenario, about 3.8 million persons from the study area are gaining access to ORD by airplane to connect onto a departing long-distance flight. Based on lessons learned from the previous chapters of this report, at the farther destinations of the study area, the rail travel times may not provide compelling alternatives to the flights. Thus, as feeder to ORD, it will be difficult for rail to be competitive from Detroit, St. Louis, Columbus, Cincinnati, or Minneapolis, based on distance alone. In addition, there is no compelling argument for the airlines to abandon air services to/from those markets, as discussed in Chapter 2.

This market assessment leaves open the question of markets for rail-as-feeder to longer distance flights at ORD from HSR stations like Springfield, Decatur, Champagne, Lafayette, Fort Wayne, Gary, Milwaukee, Madison, and La Crosse. With some exceptions, this list of logical potential markets is consistent with the conclusion of the French DGAC study that rail was chosen over air-as-feeder primarily in places where the air service was not very good.

Of course, not all HSR corridors would have equal access to ORD. Geography dictates that rail users in the best position to get the travel times required for this concept live along the alignment from Milwaukee, Madison, La Crosse, and Minneapolis. For every other corridor, some passengers on trains will have to transfer at Union Station with some, but probably not all, rail services continuing on to ORD. In short, some trains will get to serve the airport directly, while others will not.

What is Needed to Make Feeder Rail Work at ORD?

Consistent with the conclusions of Chapters 1 and 2, all parties would have to work together to produce ORD services that are comparable to the services produced in Frankfurt by the legal agreement between Fraport, Lufthansa, and Deutsche Bahn. To recap, the roles needed from the players are:

The Airport

The airport must buy into the concept by investing in a passenger and baggage movement system similar to the high-quality, but expensive, people-mover system envisioned in the Terminal 7 concept developed for the O'Hare Modernization Program. The standard set by all parties at Frankfurt Airport was that the entire connecting time—as published in the CRS—would be under 45 minutes, a challenging logistical task in an airport of the size and layout of ORD. That airport would have to be in a legal position to defend such an investment in case of litigation against it by an opposing airline.

The Airlines

If some airline found a market niche in which this combination could improve their product's competitiveness over other airlines, they might want to invest the energy into joint ticketing, and some kind of specialized baggage handling at the airport. This might include creating a legally binding system wherein the air passenger is guaranteed a flight, even if the feeder mode fails to perform. This might be the case with airlines with very long-distance (presumably international) tickets to sell. On the other hand, an airline with a hub in Milwaukee might strongly oppose the Chicago airport's investment in a program to attract more Milwaukee residents to another state's airport, and offer litigation against such an investment.

The Rail Operator

The rail operator must be convinced that there was a strong business case for veering off the straight shot alignment between Chicago and Milwaukee, adding time for the long-distance corridor riders (thus lowering the number of said riders)—all for providing access to the smaller number of riders destined for a long-distance flight, as analyzed in Chapter 2. Under the rules established by Fakiner in Chapter 2, that rail company could be providing at least hourly service to every corridor under consideration for the rail-as-feeder model, including hours in which the airport volumes peak and metropolitan volumes do not peak.

The Public

As noted in Chapter 3, the method for soliciting passenger feedback is unclear. In a multi-state consortium, is it realistic that a State DOT representative from Nebraska will lobby heavily for more expenditure in Illinois? In a fragmented decision making process, it is hard to locate any given leader that has the power to impose institutionally complex solutions which, when accomplished, might benefit everyone. At the time that the O'Hare Modernization litigation was being settled, the only organization lobbying for a better public understanding of Terminal 7 was the Midwest High-Speed Rail Association, which it did through its website.

Lowering the Number of Feeder Flights?

This analysis has not included a quantitative prediction of the diversion of connecting passengers away from feeder flights to feeder rail. Given the fact the largest airports in the study area are distant from Chicago (e.g., 300 miles), the most logical markets from such diversion seem to be those closer to the city, which now tend to be served by smaller aircraft. It is simply unclear how many of the flights from smaller markets would be eliminated, if any.

It is unclear that the airlines would choose to reduce their network presence much lower than the present frequencies, where flights are timed to meet major activity periods at the hub airport. The airline's business case arguments against a complete abandonment of air feeder services for any given city pair were noted in Chapter 2. The question of further reduction in feeder flight volumes because of diversion to rail in this mid-distance market must be placed in the category of an unresolved issue, needing better tools and better data.

Rail Complementarity: Diversion to HSR from Roadway-based Modes

As discussed in Chapter 3, most ground access issues at airports in the United States are primarily metropolitan in scale, not supra-metropolitan in scale. This tends to explain the high ratio of NJ Transit riders over Amtrak riders at the Newark Liberty International Rail Station, for example. However, the focus of this report is the examination of the possible role of longer distance rail services in solving airport-based problems—including airport ground access. The goal in this section is to explore the scale of the market for a possible major shift in the access patterns to Chicago airports if a radically improved rail system were built in the region. Such a multi-billion dollar investment might fundamentally change access patterns, and even choice of airports. For example, assume that HSR supplied fast travel times to ORD but not to Midway (MDW) from Champagne, Illinois. Under this scenario, the Champagne air traveler might switch to ORD for the trip. This section reviews the scale of the market of Chicago region air travelers starting the trip from more than 50 miles away from both Chicago airports.

Although major international airports, such as ORD, often have large geographic catchment areas, the research has established that less than 5% of Chicago airport passengers accessing the airport by ground do so from a distance of more than 50 miles (Table 6-3). From the vantage point of the study of long-distance rail, this represents a much smaller catchment area than that of FRA, which pulls about half of its passengers from distances greater than 61 miles, or Paris CDG, which attracts over 30% of its users from greater distances, as reported in Chapter 2. Of the Chicago air passengers who travel this distance, roughly two thirds come from areas to be served by the new HSR system.

Twenty-five of the airports with service from ORD are within 25 miles of a proposed HSR station. These 25 airports represent roughly 90% of the regional air service from ORD. Similarly, the 24 airports that are within 25 miles of an existing Amtrak service account for 83% of regional travel from ORD. Among the 29 total airports that are near future HSR or existing Amtrak, 20 airports will be serviced by both future HSR and Amtrak, four will only be serviced by Amtrak, and five will only be serviced by future HSR.

Data Sources and Analysis

In 2003, Chicago DOT undertook research for a ridership study of a proposed Rail Express service from downtown Chicago to ORD and Midway airports (City of Chicago, 2003). RSG conducted an O-D and stated preference survey to provide insight into these air traveler markets. The surveys were administered to passengers at the airports and collected information about origin, destination, itinerary, and mode choice to the airport. The survey data collected were expanded to represent the total number of trips made in 2003, as applied here.

An estimate of the divertible air passenger ground access market can be determined by comparing the geocoded home ZIP code information from the 2003 study to the proposed future HSR network, as shown in Figure 6-6. For the purposes of this analysis, it was assumed that passengers who lived between 50 and 300 miles were eligible to be diverted, see Table 6-4. Passengers who live outside this range were assumed to be unlikely to change their ground access behavior. According to the 2003 data, approximately 970,000 of the 22.1 million originating boardings at ORD and MDW came from passengers who traveled from a location between 50 and

Table 6-3. Scale of the long-distance ground access markets to two Chicago airports.

Boardings from 2003 Chicago Survey Data	Total Boardings	% Total	% of ground origins between 50 and 300 miles
Total Boardings	22,113,959	NA	NA
Ground origins between 50 and 300 miles	967,459	4.4%	NA
Ground origins between 50 and 300 miles within 25 miles of future HSR	622,737	2.8%	64.4%
Ground origins between 50 and 300 miles within 25 miles of existing Amtrak	850,704	3.8%	87.9%

Table 6-4. Mode share of air passenger from 50 to 300 miles from Chicago airports.

	O'Hare	Midway	Both
Auto	34.8%	71.4%	47.2%
Rental car	13.5%	13.4%	13.5%
Public Modes	51.7%	15.2%	39.4%
Total	100.0%	100.0%	100.0%

300 miles of the airport. The majority of these airport access trips would be served by a future HSR line (65%) and nearly 90% are currently served by an existing Amtrak line. Figure 6-13 illustrates the geographic distribution of the home ZIP codes for passengers accessing ORD or MDW who are located near the proposed HSR lines.

The analysis reveals that the potential diversion of these ground access trips from highway using modes to HSR is considerably lower than for air trips. Considering present demand to both airports, these passengers could provide a market for an airport HSR station service of between approximately 120,000 and 300,000 trips per year, based on the assumption of 20% to 50% diversion as summarized in Table 6-6.

Rail Diversions from the Highway System

This exercise examines the number of air passengers who could be diverted from their present "rubber tired" mode to HSR in the future. For a variety of reasons, moving passengers from the congested highway system to the rail system is generally seen as beneficial. But it cannot be assumed that all those coming to O'Hare from a distance of more than 50 miles are coming by automobile. According to the survey results, about half of these air passengers were gaining access to O'Hare by bus. Exactly how the rail would compete with specialty bus services is beyond this report's scope. The present ground access mode shares for air passengers from between 50 and 300 miles from the Chicago airports is presented in Table 6-4.

Conclusion: Demand in the Midwest, Market Categories Together

This section of the Chapter 6 analysis has explored the potential size of the future Midwest HSR network by examining two potential sources of ridership: HSR as a replacement for regional "feeder" flights and HSR as a replacement for long-distance ground access to ORD and Midway. The concept of rail as a feeder mode has been explored, but the results were not

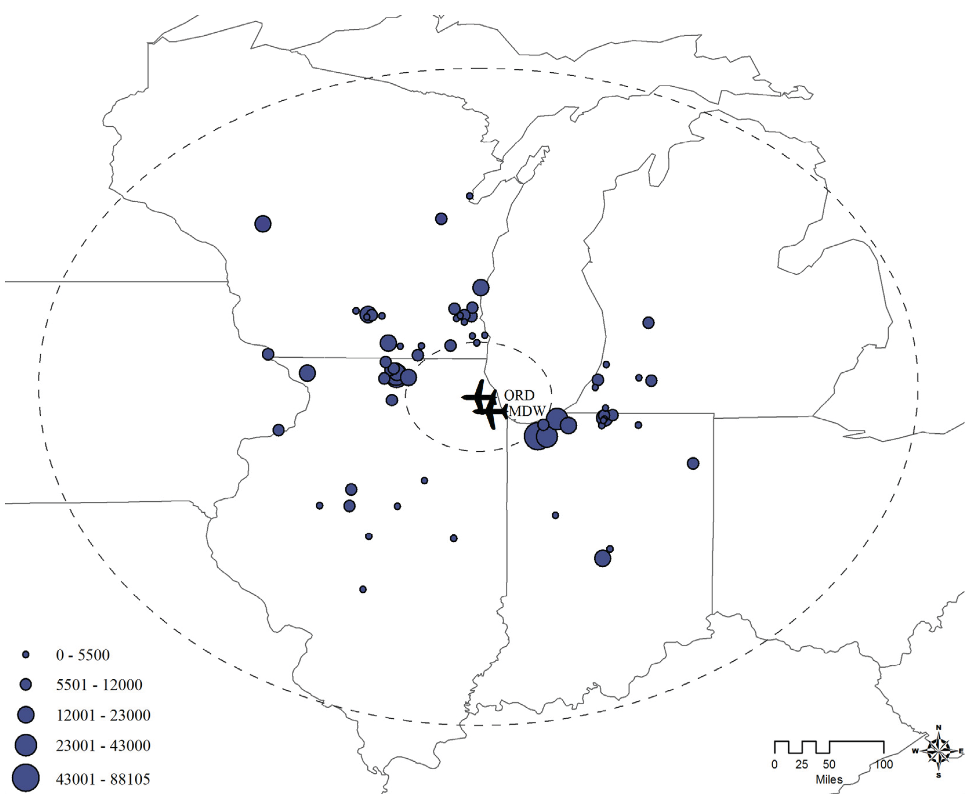

Figure 6-13. Markets between 50 and 300 miles located along HSR lines.

Table 6-5. Passengers diverted to rail for study area O-D market, by airport.

	Passengers Diverted, by Scenario			Potential Reduction in Number of Planes		
	20%	35%	50%	20%	35%	50%
O'Hare International Airport	189,256	331,198	473,140	2,300	4,024	5,749
Midway International Airport	109,320	191,310	273,300	831	1,454	2,076

Table 6-6. Categories of diversion to HSR for ORD and MDW together.

	Low Diversion (20%)	Medium Diversion (35%)	High Diversion (50%)
Trips within the study area (O-D Market)	298,576	522,508	746,440
Ground Access Market	124,547	217,958	311,369
Rail-as-Feeder Mode	(not quantified)		
Total	423,123	740,466	1,057,809

quantified. This analysis used readily available data sources and the experience from other corridors to determine the assumptions used to estimate the size of the potential HSR market. While the true size of the HSR market will depend heavily on the service characteristics of the future service and the integration with other transportation infrastructure, this analysis provides an initial outline for what may be possible in the future.

Table 6-5 presents three estimates for diversion of passengers from air to rail with both origin and destination in the study area—in total and broken out by airport. Table 6-6 summarizes the work on the scale of markets for each category, for both airports together. It shows the scale of the markets for diversion under three scenarios and indicates that between 400,000 and just over 1,000,000 trips are candidates for diversion to HSR in the two markets quantified. The analysis presented earlier suggests that the market of air-as-feeder passengers who could be converted to rail-as-feeder passengers would focus on the closer-in airports, whose passenger volumes are lower than those from the further out airports of Detroit, Minneapolis, Columbus, and Cincinnati; given that the response of the airlines in eliminating shorter flights cannot be estimated, the rail-as-feeder mode remains unquantified.

Part Four: Importance of Planning Tools and Data Availability

For most of the managers and planners interviewed, the lack of tools concerning the multimodal aspects of their jobs were not seen as a major problem to support current decisions.

The Airport Viewpoint

For the planners at Chicago ORD, the primary need is flexibility to deal with long-term options that might emerge at a much later date—and to avoid actions now that would preclude later solutions. During the development of the full O'Hare Modernization Program plan, airport planners developed the concept of the Western Terminal to deal with long-term issues of additional gates, additional highway access, additional parking—all above and beyond the desire to plan for possible rail investments, which might or might not be made in the future. Simply stated, there would be a role for the Western Terminal whether or not data about air/rail transfer demand were correct. Their primary job as planners was to keep options open should there be an interest by others, later, to provide high-quality rail services to the airport. They did not feel a strong need to procure highly refined data on numbers of passengers transferring from rail, as it was too early in the implementation process.

With the litigation-based decision to delete the Western Terminal from the airport plan, airport planners still had a strategy to allow their airport to be served by improved rail service, should that option be proposed and financed by others. Despite the loss of Western Terminal from the airport plan, a back-up location for an improved rail connection was already proceeding forward in the planning process for the re-use of the land at Economy Parking F.

As for questions about a long-term role for ORD in a sophisticated world of 220-mph rail services, airport planners felt there was no immediate urgency to deal with these issues at this time; they felt that others would be examining the issue at an appropriate level. At the same time, all parties concurred that having the rules spelled out, with a commonly accepted set of planning procedures, would be desirable in principle, and helpful when these issues require solutions.

Rail Planner Viewpoint

The responsibility for planning rail improvements over a six-state area is somewhat dispersed and not centralized in any one place. Those responsible for implementation of the present FRA HSR corridor program felt that issues—like how to serve airports—could be dealt with at some higher level, but they were not united about what form such oversight would take. One interviewee commented that FRA itself made all the decisions about the content of the multi-state project, as exemplified by decisions on how to serve the airport at Madison, Wisconsin.

At the early, conceptual phase of a nearly $80 billion investment in a new program, there is a tendency to make the assumption that "others" understand how to forecast complex tasks, like the demand for longer distance HSR services as a feeder mode to air, at a quality level that could result in the cessation of feeder flights. On face value, the need to better understand the tools and methods needed to assess and understand the impacts of rail investment on air travel would seem self-evident, as the scale of impacts in the Midwest is large; the SNCF proposal to the FRA predicts that HSR rail investment would result in the diversion of 3 billion miles of air travel, with air travel delay improved by a value of 2.2 billion dollars (2009) "by taking over some regional air traffic" (SNCF, page 27). They forecast that 3.8 million trips would be diverted away from connecting flights at ORD, with an additional .8 million at MDW. Of the users of the high-speed train, 15% were expected to be diverted from local, point-to-point trips, and 11% from connecting air trips. Together, they forecast that over 3 billion trips would be diverted to Midwest rail, from air. (Time period not specified.)

Diverted trips made by users who previously used a different mode accounted for about 86% of the total system demand (58% from auto, 1% percent from conventional rail, 15% from local, point-to-point air trips and 11% from connecting air trips). Transfers of air-connect traffic to high-speed trains have been considered at O'Hare Airport (3.8 million trips in 2028) and Midway Airport (0.8 million trips in 2028).

The planning documentation supplied by the advocacy groups is full of references to how this is a success in other areas (Paris and Frankfurt) and would be a success in Chicago. With all of the needs for early project development, and the attainment of support for long-term investments, high levels of quantification for these patterns did not emerge in interviews as a high-priority activity for the rail advocates.

Several rail managers interviewed did suggest that having the planning method rules established early in the process would result in a more stable planning process. And, of course, if better data were to become available, the planners would benefit from using it.

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CHAPTER 7

The Role of Rail in Airport and System Planning in Northern California

Introduction and Structure

Chapter 7 is presented in the following two parts, which follow after this introduction and review of major themes that are emerging from the research:

- Part One examines the experience of the Regional Airport System Plan Analysis (RASPA) in dealing with issues of integration with HSR planning in the region, and includes a discussion of the modeling tools employed (Figure 7-1).
- Part Two deals with the physical site planning issues associated with the most promising of the possible connections between the San Francisco International Airport (SFO) and the California High-Speed Rail alignment. The site planning case study provides a good example of how present design options may have been constrained (or even determined) by earlier physical infrastructure planning decisions.

Major Themes Emerging from the Research

- Some planners think they lack the tools to understand how passengers will divert from a specific airport. Managers at the Metropolitan Transportation Commission (MTC) believe people need to think bigger regarding modeling needs when considering diversion from air to HSR.
- HSR was not explicitly modeled as a feeder mode for air because earlier studies concluded that the potential of HSR as a feeder was minimal and also because of challenges related to data collection and modeling. Several organizations interviewed asserted a strong interest in evaluating air/rail complementarity.
- Managers of the modeling process believe that the response of the airlines to HSR is unknown, challenging the resulting impact on the operations and the financial health of the airport. HSR will affect airports' parking revenue, landing fees, etc., and it is unclear what this means for financial feasibility of airport bonds.
- The models developed for statewide project development and environmental forecasting are not well equipped to support an in-depth exploration of policy analysis and scenario analysis. A scenario analysis of different fares is an example of the difficulties with the tools as initially developed. Models which are slow to run pose an impediment to quick turn-around analyses appropriate for many policy questions.
- In interviews with airport managers, a critical institutional issue was the set of possible actions available to an airport acting as an essential player in intermodal planning. The airport authorities were indirectly involved in RASPA, sitting on the oversight committee, but felt constrained in their possible actions. The airport noted its interest in having a broader institutional relationship, yet airports, and SFO specifically, are restricted by the FAA and local authorities.
- In implementing a major new program like California High-Speed Rail, the site planning options are often fixed and difficult to change. Planners for the rail system at SFO are trying to figure out how to accomplish a one-transfer connection between the long-distance rail and the airport terminals, which may prove to be difficult because of existing infrastructure.

Part One: The Regional Airport System Plan and HSR

Overview of the RASPA

The introduction of HSR service in California presents new inter- and intra-regional transportation opportunities. For interregional trips, it has the potential to reduce congestion in the aviation system and on the ground. For intra-regional trips, it presents a new alternative to driving and a new airport access mode. In an effort to define the role of rail service in the context of air service in the Bay Area, the 2011 Regional Airport System Planning Analysis evaluated the possibility

Figure 7-1. Airports included in the northern California RASPA study. Source: RASPA.

of accommodating some air passengers on rail. The RASPA effort is an ambitious regional aviation system planning study for the San Francisco Bay Area, which is a joint effort between the Association of Bay Area Governments (ABAG), San Francisco Bay Conservation and Development Commission (BCDC), and MTC, under the direction of the RAPC (Metropolitan Transportation Commission 2011). The RASPA was managed by the Regional Airport Planning Committee (RAPC) made up of elected officials from the three regional agencies and staff from the region's airports. The RASPA provides both analysis and guidance on requirements for airports in the region; this is referred to by airports and the FAA when preparing airport master plans and environmental documents for proposed airport improvements. The results of the study are also used to plan surface transportation investments to provide access to airports by the MTC.

In evaluating the potential of accommodating some air passengers on HSR in the Bay Area, the RASPA analysis utilizes existing modeling tools. The RASPA therefore represents a comprehensive study that showcases the ability of existing models to address air/rail integration. Evaluation of the RASPA provides the opportunity to examine existing tools that model how HSR and the aviation system will interact. High-quality intercity rail could be either an alternative mode for intercity transportation in a regional system, a feeder mode for the air network, or both. By discussing the process and outcome of the 2011 RASPA, one can observe how existing tools allow for analysis of air and rail integration. The focus of the RASPA case study is also institutionally unique, as the agency that is home to the RASPA also sponsored development of the main forecasting tool, the California High-Speed Rail Ridership Model (CHSRRM). This allows for the focus to be on the substantive content of the models, rather than lack of communication between separate agencies.

Modeling Tools

Executing the RASPA, or generally modeling the integration of air and rail, relies on the fidelity, scope, and power of modeling tools. This section addresses existing tools—the current CHSRRM and a predecessor model—specific to modeling air and rail integration in the Bay Area. This section discusses their use, strengths and shortcomings, and additional tools that would greatly assist in modeling air and rail integration.

Models of air/rail integration must address a broad set of questions. A key question is passenger mode choice and the resulting ridership—how the presence of rail will impact air ridership as both an alternative mode and a feeder mode. Along with ridership, though potentially not directly correlated, comes the change in aviation operations due to the presence of rail. The changing landscape of transportation options will necessarily change the existing environmental footprint, necessitating environmental models.

Stakeholders the Research Team interviewed in the RASPA process tend to agree that, as it pertains to the relationship between rail and SFO, rail could play a strong dual role as a:

- Competitor to air, diverting passengers from interregional aviation travel; and
- Collaborator with air, with rail acting as a feeder service to the aviation system.

Modelers, regional planners, and SFO (as the main international airport in the Bay Area) recognize the importance of this dual relationship. However, the potential of HSR to play this dual role is not consistently understood due the complexity of the subject, which poses challenges to the existing modeling tools, as discussed in the following subsections.

Modeling HSR Ridership

The CHSRRM was developed to meet the following three objectives (Cambridge Systematics 2007):

- To evaluate HSR ridership and revenue on a statewide basis.
- To evaluate potential alternative alignments for HSR.
- To provide a foundation for statement planning purposes and for regional agencies to understand interregional travel.

The CHSRRM was used by the RASPA to explore HSR as an alternative to air travel in order to manage existing aviation capacity. In order to appreciate the capabilities and limitations of the model for this purpose, it is important to overview its structure and calibration.

The CHSRRM consists of five components, which depict travel behavior as a sequence of choices:

- Trip frequency (the most general).
- Where to go.
- What main (or line haul) mode to choose.
- What access mode to use.
- What route to take.

Component models are developed for eight trip categories based on distance (over and under 100 miles) and purpose (business, commute, recreation, and other).

The trip frequency model is multinomial logit, in which the household chooses to make 0, 1, or 2+ trips per day; utilities for the latter two options are constrained to be equal except for a constant. LOS variables, household characteristics, and location variables are included in the utility functions for 1 and 2+ trips. The service level variables include an interregional logsum that allows household responses to improved accessibility to interregional destinations by taking more trips. In essence, the logsum is a weighted average of the attractiveness of different destinations, based on the destination choice model.

The destination choice is also multinomial logit. The utility of a destination depends on distance, area type, destination district, destination "size" in terms of employment, and number of households. Regional interaction terms, which change the utility of certain destination zones for households located in certain origin zones, are also included. Finally, the destination choice model includes a mode choice logsum, a weighted average of the utility of different modes for traveling to the destination from the origin.

Given that a household has chosen to make a trip to a certain destination, it then chooses the "main" mode for the trip. The modes for long-haul trips are car, air, conventional rail, and HSR. The model includes mode-specific constants, cost, in-vehicle time, service headway, and schedule reliability. Household characteristics, such as size and income, affect some of the modal utilities. The model also includes logsums for access and egress models. In this context, the logsum is a weighted average of the utility of different access/egress modes for reaching the main mode. The main mode choice model is nested, with non-car modes occupying the same nest.

Two other nested models predict access and egress mode choices. Alternatives include drive/park, drop-off, rental car, and—occupying a single nest—taxi, transit, and walk/bike. Cost, in-vehicle time, and out-of-vehicle time capture the LOS for these alternatives. Distance, household characteristics, and airport dummy variables are included in the utility functions of selected alternative access and egress modes.

It may be instructive to trace through how interactions between air and HSR are captured in this model framework. Suppose, for example, that a HSR link is added between San Jose and Los Angeles. This will affect main mode choice, drawing some passengers from the air mode. Other HSR traffic will be drawn from the highway mode, from changes (mediated through logsums) in destination choice because Los Angeles is a more attractive destination, and (again because of logsum increases) from induced interregional travel. If the HSR terminal in either San Jose or Los Angeles were made more accessible through either relocation or improved access/egress linkages, the same effects would result, this time mediated through increases in the access/egress mode logsums for HSR. On the other hand, collocating a HSR terminal and San Jose airport would not have any clear impact, because HSR is not included as an access/egress mode for the airport.

Critiques of the Model

A number of potential issues with the CHSRRM were discussed in a review of the model (Brownstone et al. 2010). In broad terms, the approach taken by the MTC/CHSR modelers includes a model development phase and a model validation phase. In the model development phase, survey data were employed to estimate model parameters. The individuals surveyed were interregional trip makers, contacted through surveys; the mode choices of the individuals surveyed were not necessarily representative of California interregional travelers. For example, nearly 90% of long-distance (over 100-mile) business passenger trips are made by car, while 78% of the long-distance business travelers sampled for the study were traveling by air.

It is important, in these circumstances, to adjust results obtained from the raw data to take into account differences between mode choices of the sample and the population. The methodology for doing this was recently shown to be theoretically incorrect for the type of model employed by the modelers, though, at the time the study was undertaken the inaccuracy of this adjustment method was not known. The results, and the forecasts based on them (in particular of HSR mode shares), are therefore affected.

There were other issues identified in the model development. Specifically the model structure does not allow for travelers to choose between HSR stations, thereby potentially exaggerating the importance of having frequent service at the single station that is judged to be "best" for a given trip.

In the model validation phase, coefficients of the mathematical model were adjusted so that it accurately replicated observed travel patterns in the year 2000. Model predictions of trips by mode, trip type, and passenger boardings on particular air and rail routes were compared with observed values. Coefficients obtained in the model development phase were adjusted in order to obtain good agreement between predicted and observed values. As a result of this process, many of the model coefficients were assigned values that were considerably different than those obtained in the model development phase. In some instances, changes to the model coefficients were informed by professional judgments of the consulting team and the goal of replicating observed behavior.

The resulting "validated" model, which is used to generate subsequent HSR ridership forecasts, provides reasonably accurate "backcasts" for the year 2000, reflects certain patterns of behavior observed in the traveler surveys, and accords with professional judgments of the consultant. However, the combination of technical issues in the analysis methodology in the development step and subsequent changes made to model coefficients in the validation step implies that the forecasts could have large error bounds.

Modeling Diversion from Air to HSR

As stated in the objectives, the CHSRRM was developed to be a statewide model and generate statewide insights. The statewide ridership forecast includes estimates of the diversion of air passengers to rail. The number of air trips was forecasted in the No-Build case for HSR; this forecast was then compared with the forecast for a scenario that assumes a level of HSR service. The resulting change was the diversion of air travel to HSR in a given market (Gosling 2010). The calculated diversion rate was applied to the demand forecast for air travel for the RASPA study.

As presented in Table 7-1, the RASPA analysis came up with some interesting interpretations of the model forecasts for the effect of HSR on air travel in the Bay Area. The strategic application of the CHSRRM to the Bay Area airports revealed diversion of 6.1 million air trips away from the three airports combined. As expected, the greatest amount of diversion occurs at SFO, the largest of the three airports, where about 2.4 million passengers were now assigned to rail. It is important to note that the RASPA study team was, in fact, able to make an estimate of how many of these trips assigned by the statewide model to rail were diverted from a connecting flight, rather than a trip with both origin and destination in California, with 194,000 such trips revealed. In this analysis SFO has 2.4 million diversions from air to rail; ranking second in the total number of air passengers diverted was SJC with 1.9 million and OAK with 1.8 million Expressed as a percentage, SFO lost only 4% of its passengers to rail, with OAK losing 9%, and the smaller SJV losing 12% of its users to rail.

It is worthy of note that this quantitative analysis was undertaken using a statewide rail ridership prediction model that did not include an airport choice submodel within it, and assumes that people are assigned to the airport closest to their trip ends.

As described in some detail in the description of the analysis process, there are challenges associated with how the statewide model was applied in the regional RASPA planning process. Statewide diversion rates are being applied to the Bay Area; this contrasts to modeling diversion specific to the Bay Area. Additionally, from the calculation of the number of passengers who would divert to the HSR system, a calculation of how many flights are eliminated is performed. Several stakeholders agreed that this is an indirect way of estimating the impact of HSR on the aviation system as it assumes the airline response is linearly related to ridership. An additional issue is that the model does not consider a system-wide overall diversion, but rather adds diversion from certain markets. Thus, the analyst must select which markets to include.

Diversion from Airports. In the vision held by some staff members the Research Team interviewed at MTC, HSR can be seen as functioning as a fourth regional airport. As the model applies the statewide diversion rate, the tools to understand how passengers will divert from a specific airport are not available. In this view, the planning process needs to think bigger regarding modeling needs when considering diversion from air to HSR. The current model involves a line haul choice and then an access mode choice; according to those the Research Team interviewed at MTC, these two could be more fully integrated, such that the modeling reflects that HSR is essentially a fourth airport. The lack of a station choice

Table 7-1. 2035 diversion of Bay Area airport passengers to HSR in base case forecast–HSR initial phase, fares 83% of corresponding airfares.

	OAK	SFO	SJC
Total Annual Passengers	20,655,000	64,356,000	16,305,000
O&D Passengers Diverted to HSR	1,776,000	2,218,000	1,935,000
Connecting Passengers Diverted to HSR		194,000	
Undiverted Passengers	18,880,000	61,945,000	14,371,000
Percent Diversion	8.6%	3.7%	11.9%

Source: RASPA Report, 2011

component precludes this in the existing model, and further research into this aspect of future model refinement could be beneficial. For example, a model with airport/station choice integrated with airport ground access or station access mode choice might have allowed more scenario analyses (although that would have depended on the effort required to run the model for a given scenario) and could possibly have simplified the analysis process. The extent to which the results would have been more reliable is presently unknown.

Modeling HSR as a Feeder Mode for Air

In the ridership model, HSR was not explicitly modeled as a feeder mode for air. It was explained by the modelers that the possibility of rail as a feeder mode was excluded for two primary reasons. The first reason is grounded in the assertion by modelers that one tool cannot capture both competition and complementarity because of scope and underlying data. A different dataset would need to be collected to study complementarity compared with competition, including a survey of out-of-state travelers. It was deemed too expensive to do a separate survey of this separate market segment.

The second reason was the earlier finding that air as a feeder mode has little potential, which observation in turn supports the first reason. This was discussed by the Cambridge Systematics modelers and reported by Brownstone et al. (2010). The diversion of connecting air travelers was included in prior modeling efforts, and it was found that this market segment is small; an earlier unpublished study concluded that this market segment accounts for less than one percent of HSR ridership and revenue potential. From a public policy point of view, it may be productive to undertake a systematic analysis of the possible roles of rail to serve in the feeder function for longer distance flights, as was advocated in the Research Team's meetings with key managers of San Francisco International Airport—the persons who commissioned the earlier unpublished study. Given that the stated preference process reflects commonly held beliefs, the recent history of successful rail services in other parts of the world might result in a somewhat different set of perceptions. In wanting to better understand the potential for longer distance rail to widen their effective catchment area, SFO officials were acting in a manner consistent with the managers at the Copenhagen Airport, who accomplished exactly that in a short implementation period. While many analysts remain skeptical about this submarket for rail, others strongly argue for it, as reflected in the estimate by SNCF that their investment in the Midwest could reduce connecting air passenger miles by 3.8 million, as reported in Chapter 6.

Dealing with the Issue of Rail as a Feeder Mode. There are policy implications of the early finding that the potential for HSR to act as a feeder service is very low. The RASPA project dealt directly with the issue of diversion of trips from specific airports; however, according to those the Research Team talked to at MTC, there is little interest on the part of policymakers to explore in more detail the concept of rail as a feeder mode for air. This is because there is the belief that the potential is minimal. This tension is reported in several of the case studies in this report.

In the Bay Area, it is believed by the stakeholders that SFO is the only airport where using HSR as an air feeder mode makes sense. Planners at MTC believe that use of HSR as a feeder mode at the smaller airports such as SJC or OAK will not prove to be significant, because of issues of location and scale. High-speed rail is not currently planned near OAK; other concerns at SJC include a weakness in long-distance flights.

While the physical connection of HSR and air is easier at SFO with a short BART connection to the airport, it is still not seamless. The Millbrae intermodal station, which is nearby to SFO but not on the grounds, introduces this less-than-seamless connection (Figure 7-2). A traveler taking HSR to the airport will have to get to Millbrae and then connect to some kind of shuttle service to SFO; the design and site planning implications of this are explored in Part Two of this case study.

The ridership impact of alignment changes related to a physical connection between rail and air in the Bay Area is difficult to address with existing planning tools. An SFO airport task force was charged with looking at possible initiatives to improve the landside between air and landside modes. This task force considered encouraging the CHSRA to have the HSR alignment touching one of the terminals, with the assumption that the physical proximity would allow for a strong feeder service. However, it was not formally proposed because of the extreme expense; it was a "funding unconstrained" consideration. Some airport stakeholders argued that the costs and benefits of including a HSR station at SFO could have been more assertively explored.

According to the Research Team's interviews at both MTC and SFO, models capturing the ridership potential of rail as a feeder service for air could allow for more extensive scenario analysis. For example, such a model would optimally capture the potential for air/rail complementarity with the presence of joint fares—one ticket that includes the rail to air trip. The RASPA makes this recommendation and encourages CHSRA to pursue joint fares and joint baggage handling with airlines. It would also be useful to have better tools to support the modeling of possible seamless connection between HSR and air, and evaluate the relative cost of options related to connections between HSR and the airport if they cannot be connected. The airport expressed an interest in a possible modeling tool to support scenario analysis about the physical transfer location and properties.

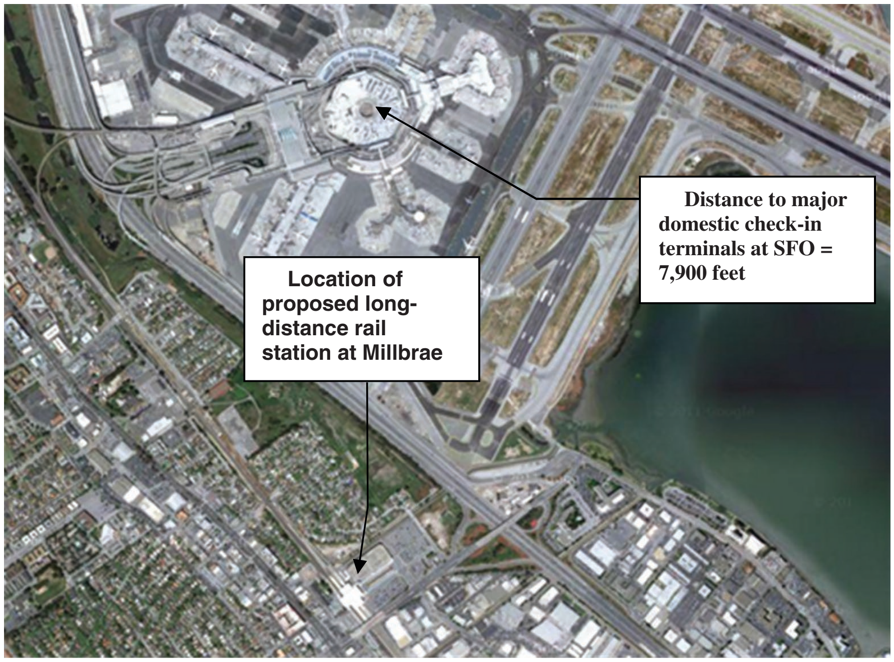

Figure 7-2. The proposed rail station is 1½ miles from the domestic terminal area at SFO.

Policy Scenario Analysis

According to the managers at MTC, existing modeling tools were not designed to support wide exploration of issues and scenarios. One of the main issues, as discussed by a member of the RASPA analysis team, is that the CHSRRM demand forecast uses zone-by-zone estimates that underpin the model. However, some early applications of the model for policy purposes use a fixed matrix, which presents strong challenges to scenario analysis because—in practice—this matrix was not updated when a demand forecast with different parameters was estimated.

An example of how this static matrix presents an issue is related to a scenario analysis of different fares. For example, in December 2009, new ridership estimates came out in the California High Speed Rail Business Plan (California High-Speed Rail Authority 2009), where the fare was assumed to be 83% of air. The ridership estimates were an update to the previous estimates that assumed HSR fare to be 50% of air. The zone-by-zone estimates were not re-estimated with the fare percentage change; rather, an updated zone-by-zone matrix was estimated offline using scale factors. While this represented a cost effective approach to model utilization, it is an example of a methodological decision having been made to deal with the realities of the complexity (and time consumption) of the main model.

All stakeholders were interested in the lack of understanding about the response of the aviation sector in terms of an area of policy scenario analysis. There was extensive discussion related to how air and HSR would exist in a market together. Additionally, there is much interest related to how the aviation modes will compete in a market with HSR. If air is competing with HSR, how will airlines compete with frequencies and fares? From the rail standpoint, there is acknowledgment and agreement that the airlines will respond; however, there is disagreement as to how they will respond. Airlines are private companies and it is not in their business interest to be forthcoming. The airport operational profile that results from the introduction of HSR is unknown and could have positive and negative impacts on the airport.

Capacity at SFO may open up if airlines reduce their intra-California service due to competition, or if airlines reduce their feeder aircraft service because of complementarity possibilities. SFO's long-term plan is in accord with this possibility. The airport is shifting focus to international traffic and long-haul domestic traffic away from short-haul domestic traffic. The urgency in dealing with the efficiency of operations is further underscored by SFO's standing as the West Coast's worst airport in on-time performance in 2010. Interestingly, these delays are in part due to efforts to increase short-haul domestic traffic in the earlier part of the first decade of the 2000s.

With this increase in traffic, the airport is seeking all possible alternatives for preserving regional mobility while focusing more on international and long-haul domestic traffic. As part of their fiduciary responsibilities, airport managers remain concerned about any possible major reductions in air services, (from whatever motivation) which might impact basic sources of income, which range from landing fees to parking lot revenues. Airport managers feel they must be ready to examine all impacts of changes in the operational status quo.

An additional issue related to ridership diversion from HSR to air is that airport planning is not driven by rail planning. The airport asserts that its plans cannot be dictated by activity in another mode; therefore, the San Francisco airport authority is not directly accounting for HSR in their master planning process. Their most important aspect of master planning is aligning their terminal capacity with their airfield capacity. Another challenge is that the airlines have a very short planning horizon, on the order of 2 years. This does not align well with the long-term planning of HSR.

Policy scenario analysis related to changes in the air transportation system is something that the MTC analysts desire. There is currently no feedback related to airport operational performance or delays. The current aviation systems model cannot incorporate the idea that as SFO delays increase, passengers divert to the other airports. The same issue is raised for HSR. If airport delays increase, passengers may divert to HSR, which needs to be incorporated into a future modeling process. Additionally, one of the underlying assumptions in the CHSRRM demand model is that HSR is a more reliable mode of transportation, because it is not affected by fog or weather, and passengers have certainty that the train is going to make it on-time as opposed to air travel. Alternatively, it would be important to include feedback due to higher air transportation reliability—possibly due to the implementation of advanced air traffic management technologies through NextGen—in the models of diversion to HSR from air. Furthermore, airports' capacity benefits could be included into a future integrated model. A critical scenario that needs to be investigated from the airport capacity side is that diversions to HSR do not cause airlines to reduce operations, but simply reduce the gauge of their aircraft; in such a scenario, airport revenues go down, and capacity does not go up.

The CHSRA ridership study assumes "the hassle and time variance of getting a boarding pass, checking luggage, and getting through security requires arriving at the airport earlier than at the train station without security checkpoints" (Cambridge Systematics 2007). HSR, on the other hand, will not have "elaborate security check-in procedures"; boarding passes will not be required to wait for a train; and seats are unassigned (Cambridge Systematics 2007). Therefore, under this assumption that the HSR will never have the same TSA security requirements as air transportation does, passengers do not have the stochastic security processing issue and the wait time is assumed to be 15 minutes. According to planners at the MTC, it was asserted that this would be a tremendous ridership advantage. However, it is uncertain whether security will be a small or a big issue; and, if this erodes, then some of the advantage of HSR disappears. However, due to challenges related to model transparency and ease of use, performing such scenario analysis would be difficult.

There are also issues with policy analysis due to the complexity of the demand model. The existing model is very complex and takes a good deal of computing power. This model is difficult to run, takes a very long time to process results, and also involves a high level of specificity. According to the stakeholders consulted, there is a need for a model that is more transparent and less computationally complex, and more flexible.

Integrated Environmental Model

An integrated ridership-diversion-environmental model would be extremely helpful, according to those the Research Team interviewed at the MTC. If HSR diverts a certain number of passengers and reduces flights by a certain amount, there could be a measurable change in environmental impact. This is particularly the case with noise and the change in the noise profile. HSR may have a noise benefit because flight operations are reduced, but others argue that HSR really just moves the noise because other people can then hear the new noise. In the Bay Area, there are residents on the peninsula in a new noise region, but it is unclear what the new HSR noise contour would look like. Tools are needed to study diversion and the implication of diversions, including noise, greenhouse gas emissions, and other pollutants.

Institutional Issues

A critical institutional issue is the set of possible actions available to an airport to be a player in intermodal planning. A key focus area of the RASPA is on the reduction of demand at SFO through airport diversion, intermodal diversion, or demand management.

The airport remains strongly in support of HSR because diversion to HSR directly supports their plans to focus on long-haul domestic and international transportation. However, the airport states that the potential of HSR to support their plans is unclear because of the lack of clarity of results from the analysis process. Given that lack of clarity, the airport also maintains some skepticism about the real potential of diversion to HSR. The airport and other stakeholders expressed concern that there will be some passenger diversion to HSR but that airlines will not shed their operations, simply operate smaller planes keeping frequency constant. They noted that all of this must be seen in the context of the question of political uncertainty that has surrounded the HSR program.

Institutionally, the airport stated that the official dealings of HSR fall under the auspices of the CHSRA. Therefore, they leave the parameters of HSR up to CHSRA and do what they can to facilitate air/HSR interaction.

Conclusion: Regional Airport Systems Planning Issues

The Bay Area case study reveals that, despite the propitious circumstance of having the same agency responsible for developing a detailed HSR demand model and the Regional Airport System Plan, the former was of limited value to the latter. In part, this reflects limitations in the demand model, particularly, its inability to address the role of HSR as a complement to the air transportation system and to explicitly model airport/station choice. In other cases, capabilities of the model were not used to their fullest extent, such as in the assessment of the sensitivity of demand forecasts to different HSR fare scenarios.

There is also a lack of tools to analyze the complementary mode. For example, it would be desirable—if very difficult—to predict how diversion of traffic to HSR, and the presence of HSR as a competing mode, will affect airline schedules. Lacking such a tool, planners often assume that flight frequency would change proportionally to passenger traffic.

Institutional limitations also played a role. While planners recognized that HSR could create new opportunities for airport demand management, there remain institutional and policy barriers to realizing these opportunities. This limits the application of existing tools to develop demand management strategies suitable for a multimodal environment and reduces the impetus to develop new ones.

Overshadowing the RASPA analysis related to HSR was the great uncertainty about whether and when the system would be built. Given this uncertainty, there was little incentive to perform anything beyond the application of a very detailed model for analyses it was not designed to perform. While the tools could have been improved, it was perceived, with considerable justification, that investing in their development could not be justified at the time of the study.

Part Two: Physical and Site Planning Issues at SFO

Part One of this Chapter has established that the managers of the SFO airport see the potential for HSR services to complement their overall strategy to emphasize long-distance (and especially international long-distance) flights in the allocation of the finite capacity of the airport infrastructure (Reisman 2012). Several years of studying physical expansion options, including filling in portions of the Bay, have resulted in adopted policies to make better use of the existing airport plant and infrastructure. The question now turns to the ability of the managers of both HSR and the airport to maximize the quality of the interconnection between ground services and aviation services.

To review a basic theme of this ACRP report, the provision of high-quality transfer between rail and air can be used to maximize the complementary role of rail with air. When viewed in terms of the competitive role for rail, it is often in the best interest of the rail operator seeking to minimize travel times to have no airport station stop whatsoever, as discussed in Chapter 3. By way of extreme example, the highly competitive travel times between Boston and Washington, DC, proposed by Amtrak in its "Next Generation Rail" proposal for the Northeast Corridor are based on a "Super Express" concept. This concept would stop only in New York City and Philadelphia, bypassing all other stations; such a concept is designed to create a product that would be highly competitive with the major air markets in the area. More realistically, the rail planner seeks a single station with significant intermodal connections, including parking priced for the intercity rail market, and local feeder services in place to serve local demand.

By contrast, the optimal rail station location for the complementary role would be within the air terminal area itself. Absolute minimization of the connecting times between rail vehicle and aircraft is desirable for the extreme case in which short distance feeder air service is eliminated and replaced by rail access; it is also desirable for the more common situation in which the traveler is offered both feeder air and feeder rail services to a major airport. The case study of the relationship between SFO and the California High-Speed Rail project reveals just how difficult it is to retrofit existing infrastructure to accommodate newly planned and highly desired services.

Application of the Site Planning Concepts

Consistent with the typology developed earlier in this report, the site planning options at the SFO can be viewed from an international perspective. The review of airport station locations in Europe and the United States suggests that the three major categories for airport rail station are relevant in the review of air/rail connections at SFO. Major infrastructure decisions were made at the time of the construction of the present BART extension to a point adjacent to the new International Terminal; during that process, many combinations of rail and people-mover options were examined. Thus, at present, the BART extension to a point near the International Terminal is in place as an elaborate "Y" connector in and out of the terminal area, as shown in Figure 7-3.

Present/planned Services

The site planning process must now take into consideration that, while the BART connection is in place, there is still a need to improve the connections between the airport's four passenger terminals and both long-distance high-speed rail services, and regional rail services over the present Caltrain system. That system currently operates as a diesel commuter rail system to San Jose and beyond, with 77 mile corridor and 32 stations.

Figure 7.3. Location of BART tracks in and out of SFO. Imagery © Landsat, Google Earth.

It currently operates 92 trains per weekday, and carries about 50,000 per weekday (Caltrain 2014). In development of its updated Strategic Plan during 2014, the railroad is committed to developing what it calls a "HSR/Caltrain Blended System," to deal with near-term electrification of the line. This will have major implications for the quality of the connections between SFO and the counties immediately to the south. Travel times between Millbrae and San Jose will improve to 21 minutes for the non-stop operations, and 25 minutes for a one stop service. This "blended system" concept will, first of all, improve the ability for SFO to increase its rail catchment area to the south. The alignment is shown in Figure 7.4

In addition, the electrification will improve service to the North, to the Market Street/Embarcadero area. At present, the

Figure 7.4. Proposed alignment for "blended service" between Transbay Transit Center and San Jose. Source: CHSR Authority, 2013.

fastest Caltrain travel time between Millbrae and the downtown rail terminal is 18 minutes with current diesel propulsion equipment. The investment in electrification currently under environmental analysis will increase acceleration and deceleration speeds, with travel time improvements to 13 minutes, and the ability to run 6 trains per peak hour over existing track (Caltrain 2013).

By way of comparison, these planned travel times from Millbrae could be similar to that currently offered on the Heathrow Express (15 minutes) between Heathrow and Paddington Station in London, which is provided four times per hour. In downtown San Francisco, the Caltrain line is planned to be extended by 1.3 miles to a new Transbay Transit Center, located immediately south of Mission Street with connections into the Montgomery BART station on Market Street. Present in-vehicle rail travel time between BART's Airport station and its Montgomery station is 30 minutes, with 11 stops. Caltrain is now planned to operate 13 minute service into the lowest level of the Transbay complex, as part of a 6 track joint station with HSR. Funding is currently being sought for the new Caltrain terminal facility (Transbay Joint Powers Authority 2014).

Site Planning Concept #1: Full Integration at Airport: Reroute the Long-distance Rail Line so That the Air Traveler Can Walk from the Train to the Check-in Terminal

In this option, the SFO would operate like airports in Zurich or Amsterdam where the trunk rail line is placed in the "basement" of the airport terminal. From a historical perspective, it can be noted that the original designers of the present domestic terminal area of SFO did, in fact, make provisions for some kind of rail to go under the area generally defined as Terminals 1 and 3. While an easement was originally left under the present central domestic garage, it was not anticipated in the 1970s that the airport would be served by both the regional BART trains and statewide rail trains. Construction of such a rail station potentially accommodating four (or more) tracks underneath a working airport would have posed a major challenge.

While finding an optimal "Zurich style" alignment would be difficult (and expensive) airport planners at SFO note the desirability of a close physical connection from rail to air, preferably by walking which they described as the "international standard" (Panel communication 2013). They note that enabling a walking connection would require a diversion of the rail alignment directly into the airport terminal area, preferably operated as a through service rather than as a stub-end terminal. Just where such a rail tunnel would be built is beyond the scope of this research. In previous planning efforts such a direct alignment was explored generally to the east of the International Terminal, with walking connections to it and to the three terminals on the loop. However, no such an alignment for the HSR right-of-way is currently under consideration by the High-Speed Rail Authority, which is examining staged construction options that would improve the existing two-track Caltrain alignment in the area, with early electrification. Airport planners told us that the presently planned investment in Caltrain could change the planning context, with a new downtown terminal complex, and with "faster speeds and higher frequencies which alone would justify an on-Airport stop even if California HSR is never built" (Panel communication 2013). Thus, it is not clear how many tracks would optimally be diverted into such a tunnel, or which rail markets would be served. The emergence of the blended concept of electrified services from Caltrain and CHSR makes the combination of potential markets even more challenging.

Site Planning Concept #2: People-Mover Shuttle to Rail Alignment: Build a Separate Airport Rail Station on the Rail Alignment at a Point As Close As Possible to the Airport Passenger Terminal Complex

This kind of connection, as exemplified by the existing airport rail station connection at Newark Liberty International Airport, would result if planners could build a new station parallel to the present rail alignment, getting the longer distance rail passenger as close to the airport as possible, with as short a people-mover connection as possible. The fact that these users could get short distance people-mover access to all four air terminals with only one transfer is a positive characteristic of this site planning concept.

Negative aspects of such a solution for the HSR station location include the fact that the existing Caltrain alignment is directly adjacent to several residential neighborhoods, as is evident in Figure 7-3. The aerial photograph in Figure 7-3 also shows how the BART rail tracks between the airport interchange complex and Millbrae station have been placed in a cut and cover tunnel to minimize impacts on these residential areas. Fitting any major new transportation facility around the highway and the residential neighborhoods would be challenging from an environmental perspective. Indeed, assuming that the new station were to require direct highway ramps, fitting all the needed infrastructure into the existing site would be nearly impossible.

Site Planning Concept #3: Connect to Network at a Central Place: Connect with the Best Consolidated Rail Transfer Point Possible

At the moment, the air/rail station planning by CHSRA is most similar to Site Planning Concept #3, in which the

Figure 7.5. The present BART/Caltrain station at Millbrae is about 2,000 feet from airport property. Image © 2014 Landsat, Google Earth.

airport rail stop is located to access the maximum amount of connecting services and other intermodal facilities. As shown in Figure 7-5, the present Millbrae station location provides existing infrastructure (including a major parking garage) to support interconnection between HSR, Caltrain regional rail, BART and an extensive local bus feeder system. The station is located in a community center consistent with local public policy to encourage "transit oriented development."

BART Connections Between SFO and Millbrae

The challenge for local designers to make the Millbrae transfer site work for air/rail complementarity is to provide high-quality connections between the rail station and the four air passenger terminal buildings at SFO. BART at some times in the past has offered direct service between SFO and Millbrae, and at other times has not offered it for many hours of the day–reflecting both operating and budgetary constraints. Even assuming 15/20 minute service between the two points for most of the day, which is consistent with good international ground access practice, they are not consistent with people-mover schedule patterns within an airport complex. Even if additional rail shuttle services were added between the regional BART trains, most travelers making the long-distance rail-to-airplane transfer would need to proceed from the International Terminal to terminals 1, 2 and 3, whether by existing people-mover or by foot.

In one interview conducted for this case study, a former CHSRA official commented that the best solution for the area would be the extension of the present airport people-mover (which loops around the original terminal complex) to Millbrae. Official statements from the Authority refer to some form of shuttle service on the existing BART track between Millbrae and SFO. The Research Team has not found any official agency reference to the option of extending the existing airport people-mover to Millbrae.

Previous studies of rail stations in the area explored building a 1.2 mile spur off the existing airport people-mover from the present BART station to Millbrae station. Alignments between the two points might either parallel South McDonnell Road (generally north of Route 101), or parallel the existing BART alignment (generally west of Route 101). The distance to Millbrae station is similar, but slightly longer than the distance of the existing people-mover to the consolidated car rental facility.

If a major investment were to be made in a people-mover between SFO and Millbrae station, another design option which illustrates the logic of Site Planning Concept #3 could include using Millbrae station as the only rail transfer point for the airport, with present BART service to the airport routed only to Millbrae. If all six presently planned Caltrain peak hour services were to stop at such a newly expanded station, for example, combined northbound Millbrae service to Downtown San Francisco (i.e., Montgomery/Transbay stations) could offer 14 peak hour trains, with eight on the BART track and six on the Caltrain track, with a composite average headway of shorter than 4.5 minutes; this would be one of the most frequent airport-to-downtown rail services offered in the world. Whatever additional service frequencies might result from later long-distance investment on the Caltrain/HSR alignment would further increase the diversity of services and destinations offered to the transferring air traveler.

Summary: Site Planning Challenges

The interface between the California High-Speed Rail alignment and the passenger terminal area of San Francisco International Airport represents one of the most important American case studies in the examination of a complementary role for air and rail. Site planning challenges include the potential to improve airport access utilizing new combinations of both the multi-stop BART trains, and limited stop express Caltrain in the metropolitan market, in addition to consideration of several possible roles for the "HSR/Blended Caltrain System" for longer distance rail markets. In terms of air markets served, SFO represents a highly successful hub operation in which the airport must assemble passengers for important longer term flights. Indeed, SFO is the primary location for Northern California to remain competitive in the long-distance air international market. Logically, rail could play some role in providing access to those long-distance flights. Given that CHSR will not serve LAX directly, and given that runway conditions at San Diego constrain the development of international flights, SFO would be the strongest candidate in California for a symbiotic relationship between air and longer distance rail.

Given the decision to focus major investments in the central portions of the HSR system first, California policy makers have the opportunity now to review their options concerning the connections to SFO. Methods to bring the future rail tracks into a tunnel under the SFO passenger terminal area could be reviewed, consistent with the logic of Site Planning Concept #1. Alternatively, Site Planning Concept #3 could emphasize methods to maximize the quality of the transfer between the four air passenger terminals and the Millbrae intermodal center. The planning process needs to continue, given that California will invest immediately in the Caltrain right-of-way. This will allow near-term design efforts to be informed by a better understanding of longer term needs for air/rail complementarity, involving metropolitan, regional and longer distance roles for rail at one airport.

This planning process could acknowledge concepts developed at the conclusion of Chapter 3, which emphasize the importance of understanding the needs of all stakeholders. Specifically, Chapter 3 concludes that often it is not in the interest of the long-distance rail operator to have additional stops for its fastest trains. If an airport stop is to be imposed on the long-distance system, it is logical to design that stop to serve as many markets as possible. Planning now underway for a major Millbrae station is consistent with the logic of Site Planning Concept #3.

Optimally, all those involved in these decisions could be supported by demand modeling tools and data-sources that can help determine the importance—or lack thereof—of good connections and services for those using longer distance rail to access long-distance flights at SFO.

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CHAPTER 8

Air and Rail Planning Together in San Diego

Introduction and Structure

Chapter 8 brings together many of the themes introduced earlier in this report. Chapters 2 and 3 compared and contrasted the experience in the United States with long-distance rail service to major airports with that of the Europeans; site planning considerations emerged from these comparisons. In Chapters 4 and 5, the experience in the United States, with rail as a competing mode to airports, was contrasted with the European experience in diverting air travelers to high-quality, long-distance rail systems. Chapter 6 introduced the concept of possible air/rail combinations in smaller markets, such as those of the Midwest. Chapter 7 described how a highly sophisticated regional planning process was constrained in its ability to influence the actual design of a major air/rail interface because so much infrastructure was already in place—all of which emphasizes the difficulty in dealing with uncertainty concerning the longer term implications of short-term decisions.

Threads from all these themes weave together in one final case study: the future of Lindbergh Field (Figure 8-1–8-4) at the San Diego International Airport (SAN). Not unlike the case of Northern California, the setting includes a major, high-visibility regional airport systems planning project (RASP); however, in this case, the infrastructure constraints are remarkably open and malleable for a major air/rail implementation. Of course, this is dependent on the local parties concluding that this is warranted in the local decision making process.

Chapter 8 covers six content areas:

- First, the setting is established, including the long history of planning activities for a new airport in a greenfield location, which had the unintended consequence of postponing badly needed infrastructure improvement in the existing terminal areas.
- Second, the Destination Lindbergh planning process is described, with an emphasis on the goals and objectives established by the participants in the planning process.
- Third, the site planning implications of these regional planning considerations are reviewed, including the need to coordinate with ongoing efforts to locate and plan the proposed California High-Speed Rail station somewhere in the project area.
- Fourth, an analysis is presented of the more recent RASP, which challenges some of the major directions set by the Destination Lindbergh process.
- Fifth, the results of interviews are summarized, a review of planning tools available to decision makers is presented, and the extent to which participants needed or requested better intermodal planning tools is noted.
- Finally, the typology of site planning concepts established earlier is reviewed for implications in San Diego.

Unique Air/Rail Planning in San Diego

A review of air/rail options at San Diego Airport suggests that there is more active examination of the relationship between airport physical investment and HSR investment in the San Diego area than anywhere else in the nation—and perhaps the world. Decision makers in San Diego, as part of several planning processes, have been considering:

- The possibility of rail service influencing the basic terminal configuration of the airport;
- The ability to expand the geographical market for desired air services; and
- The possible loss of riders to newly competitive airports because of rail.

The study team has undertaken a series of interviews with managers at the San Diego International Airport (SAN), San Diego Association of Governments (SANDAG), and technical managers at the consulting firm Leigh|Fisher. Key leaders from the airport, regional planning, and the consultant

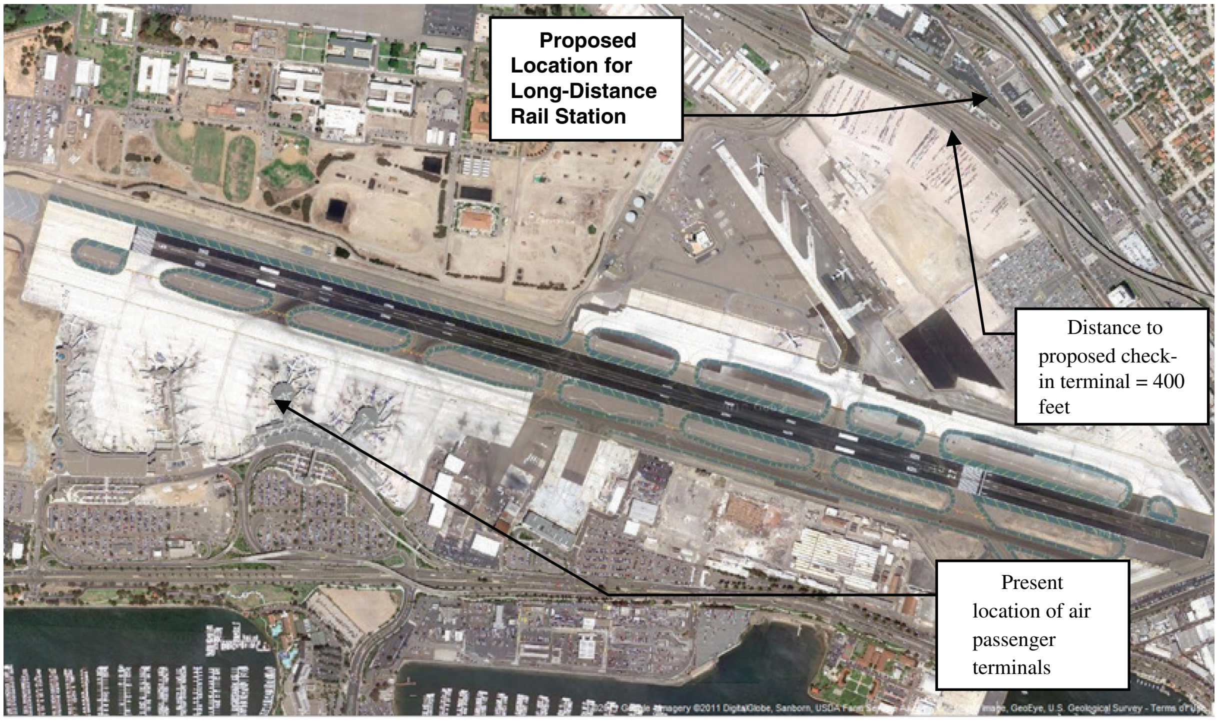


Figure 8-1. Destination Lindbergh locations for rail and passenger terminals. Image © Landsat, Google Earth.

Figure 8-2. Land north of the runway is located close to the rail and highways and available for development. Image © Landsat, Google Earth.

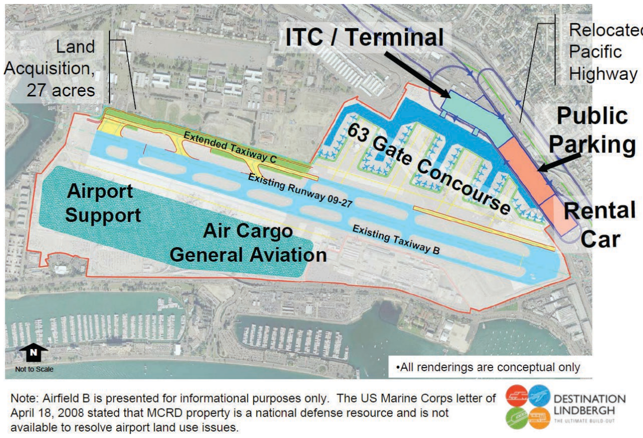


Figure 8-3. Land available north of the runway could support a complete passenger terminal if a taxiway were extended. Source: Destination Lindbergh.

communities were interviewed by the Research Team. Major observations include:

- The geographic location, site and environmental constraints, regional demographic characteristics, and organizational structure of SAN—including its relationship to other regional governmental entities—have had a considerable influence on the planning processes used in the evaluation of future aviation capacity and HSR in the San Diego region.
- The Destination Lindbergh design process has resulted in what its proponents call "the ultimate build-out"—a phrase for a vision that is somewhat short of a master plan for the airport terminal complex. The airport hopes to commence that master planning process in the immediate future.
- The ultimate build-out vision for the airport calls for all landside passenger processing to be moved to an open area to the north of the airport's sole runway, at a location where high-quality connections can be built with the interstate and the Pacific Highway, and where HSR would ultimately be located. In the recommended vision, all airside terminal facilities are located to the south of the runway, connected by a rather difficult-to-build tunnel. An alternative terminal layout would place the airside concourse facilities to the north of the runway; this would require the use of a strip of land currently used for non-aviation purposes by the United States Marine Corps, which caused planners to drop this option.
- Important arguments, cited by several managers interviewed, for moving the landside passenger terminals to the north were related both to highway ground access issues and to rail access issues. In any scenario, access by road will be the dominant mode.
- The RASP planning and analysis suggests that the best location for a single HSR station would be in the center of CBD (at the Santa Fe terminal), while the HSR planning process suggests the north edge of the airport.
- The case study includes recent analyses concerning the possible role of California HSR to either widen the natural market area of the airport towards the north, or to divert "swing markets" away from SAN to a revitalized Ontario International Airport (ONT).
- The case study concludes with a summary of the extent to which the planning tools and methods used in the reconfiguration debate and the RASP were believed to be satisfactory or to support the case for the development of new tools and methods in intermodal analysis.

The Regional Setting of the Planning Process

Development in the San Diego region is constrained because of its geographic position: north of the Mexican border, west of the mountains, and east of the Pacific Ocean. These geographic characteristics have concentrated regional development to the north of the city and impose constraints on airport expansion, HSR service, and development of alternative airports.

The region has traditionally enjoyed a stable economy driven by its desirable climate, geographic characteristics, a significant level of tourism, and a high level of economic activity in support of active duty military personnel, support contractors, and retirees. The San Diego—Carlsbad—San Marcos area is the 17th largest Metropolitan Statistical Area in the United States, according to the 2010 Census.

Site Constraints and Operations

Site constraints at SAN are significant barriers to further airport development. The Federal Aviation Administration (FAA) classifies the airport as a primary-service, large-hub airport. It was the nation's 27th busiest airport, boarding just under 8.5 million passengers in 2009, according to the FAA. However, at 661 acres, it is physically one of the smallest major airports in the country and its single runway serves as the primary commercial access to the National Aviation System for the region's three million residents. The site is further constrained by the presence of aeronautical obstructions to the east that limit aircraft operations in periods of reduced visibility and by the runway length of 9,401 feet that limits the airport's ability to accommodate extremely long-range flights.

Landings and takeoffs on the single runway occur primarily to the west for about 94% of the time. When landings and takeoffs must take place to the east, some heavier departures would suffer weight penalties due to the obstructions

Figure 8-4. The airports initially reviewed for the RASP are shown. Source RASP.

immediately to the east of the airport. In those conditions, the heavy airplanes depart to the west, against the predominant landing flow and create the need for the FAA air traffic control tower to apply greatly increased separations to maintain safety. This significantly reduces airfield capacity.

The runway divides the site into two parcels; the passenger terminal facilities are located in the southern area of the site. The lack of a dual parallel taxiway system serving the south side of the runway causes congestion between aircraft exiting the runway and aircraft pushing back from gates. Lack of a parallel taxiway system to the north of the runway makes it very difficult to provide access for landing aircraft bound for the northern portion of the site.

Ground access to the airport is also constrained, as no direct connection to the adjacent interstate highway exists; the airport relies on the congested local street system (North Harbor Drive) for all passenger access. By contrast, the undeveloped area immediately to the north of the single runway is directly adjacent to the Interstate 5 and the Pacific Highway, offering the possibility of direct access to two levels of the regional system without impacting local roadways. As discussed in the following section, the northern site is also adjacent to the existing rail alignment, used by the San Diego Trolley, Coaster commuter rail, and Amtrak's Pacific Surfliner intercity rail service. This general right-of-way will be the location of the California HSR service in the area.

The Three Studies in the Planning Process

Background

State legislation created the San Diego County Regional Airport Authority (Airport Authority) in 2003 to find a solution to the region's air transportation needs. The legislation also required a November 2006 ballot initiative to allow San Diego residents to vote on a new site for the presently constrained airport. However, relocating San Diego's Lindbergh Field was an extremely contentious issue that had been studied for more than 40 years without resolution. The San Diego County Airport Site Selection Program evaluated sites within approximately 100 miles of San Diego for their feasibility from aeronautical, ground access, and financial perspectives. In 2006, the study concluded that the most feasible solution was to co-locate a new airport with the United States Marine Corps Air Station at Miramar, either through an acquisition of property interests or a joint-use agreement. Despite a concentrated effort by the Airport Authority, the public referendum rejected the Miramar site and the issue of future aviation capacity in the region remained unresolved. Effectively, the policy orientation towards abandoning the old airport site, and replacing the facility at Miramar, had the effect of postponing normal capital investment and improvements at the existing airport site.

The current airport master plan was adopted by the airport authority in May 2008 after the failure to gain approval for a new airport site. That plan contemplated continued development of the passenger terminal complex to the west of the existing terminals, with 10 new gates and additional apron for aircraft parking. It also provided for:

- Construction of a new two-level roadway serving the terminal area;
- Construction of a new parking structure serving terminal two;
- Reconstruction of parking facilities on the north side of the runway;
- Demolition of the old and construction of a new general aviation facility;
- Construction of a new access road from local streets to the north area of the airport; and
- Reconstruction of taxiways and airplane holding aprons in the north area.

The adoption of the master plan raised community concerns about additional terminal development and the effect of the proposed new parking garage on traffic and congestion on North Harbor Drive.

Managing the Three Studies

In order to address the concerns raised by the master plan, regional coalitions were formed to undertake three related studies: Destination Lindbergh, RASP, and Airport Multimodal Accessibility Plan (AMAP). Guidance for the Destination Lindbergh project was provided by an alliance of the San Diego County Regional Airport Authority, the City of San Diego, and SANDAG, which formed the Ad Hoc Airport Regional Policy Committee, chaired by the Mayor of San Diego. The Ad Hoc Committee also invited other key participants to assist in this important effort, including policymakers from the Unified Port of San Diego, County of San Diego, Metropolitan Transit System, North County Transit District, and United States Department of Defense.

Destination Lindbergh

Destination Lindbergh was a year-long, comprehensive planning process (Jacobs Consultancy 2009) designed to:

- Determine the ultimate build-out configuration of SAN at Lindbergh Field;
- Evaluate and plan to minimize airport-related traffic impacts to adjacent communities; and
- Improve intermodal access to the airport, while considering the airport as a potential location for a regional transportation hub.

The Destination Lindbergh planning effort revised earlier forecasts and explicitly considered a constrained level of activity, based on projected levels of delay that were deemed acceptable by the study committee. This level of activity was projected to permit the airport to serve 14 million enplaning passengers in the year 2030 with acceptable levels of delay. The basic forecasting of unconstrained demand relied on commonly used regression analysis based on regional econometric forecasts (personal income) and airline fares (yields).

The Phased Implementation Program for the Preferred Alternative

After an extensive series of scenario evaluations, a phased implementation of a preferred scenario was adopted.

Phase 1

The first phase called for continuation of Terminal Two expansion to the west, adding 10 additional aircraft gates and supplementary aircraft parking. These are shown as the far-left gates on Figure 8-5. During this phase, all passenger processing, including ticketing, security screening, and baggage claim, remains south of the airfield. All passenger terminals would continue to be accessed by North Harbor Drive.

Phase 2

Figure 8-5 shows the full second phase, which would handle 20 million annual passengers and would include the Intermodal Transit Center (ITC); a Consolidated Rental Auto Center (CONRAC), using a shared bus system; a customer service building linked to the ITC by a pedestrian bridge; and a new dedicated on-airport road connecting the ITC and rental car garage to the terminals on the south side. The ITC would be constructed by SANDAG adjacent to the north side

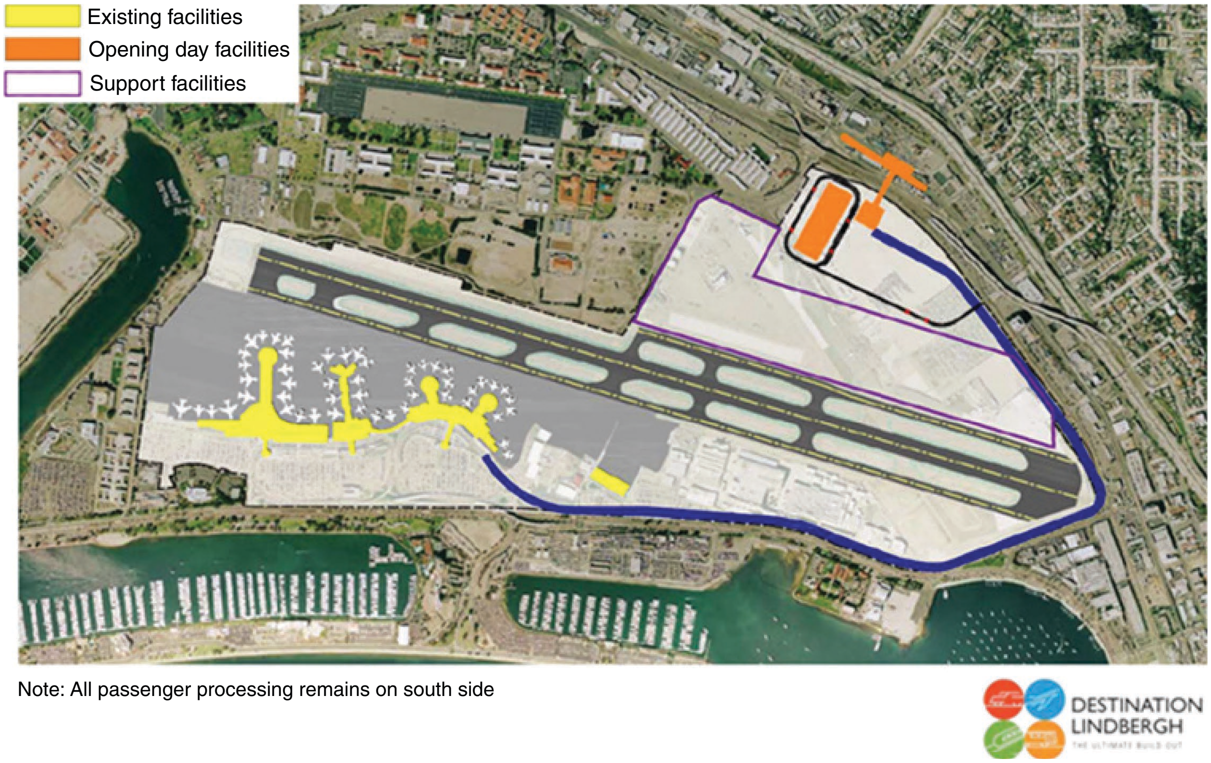


Figure 8-5. The first phases of the Destination Lindbergh implementation. Source: Destination Lindbergh.

of SAN serving the blue and orange trolley lines, as well as the Coaster, the MTS bus routes, and a future HSR station. Parking for both transit and airport users would be provided at the facility. The ITC plan includes surface roadway improvements between the airport and the regional highway system.

Phase 3

As shown as Figure 8-6, the third phase would accommodate 22 million annual passengers and consist of: improvements to the ITC; new passenger processing facilities, including ticketing and baggage claim facilities in the north terminal; construction of a new structured parking facility adjacent to the passenger processing facilities; and a new automated people-mover (APM) connection from these facilities to two new satellite concourses in the south. The ITC and transit facilities after this phase would handle approximately 7% to 10% of air passengers, representing approximately 760,000 to 1.1 million arriving annual passengers by public mode.

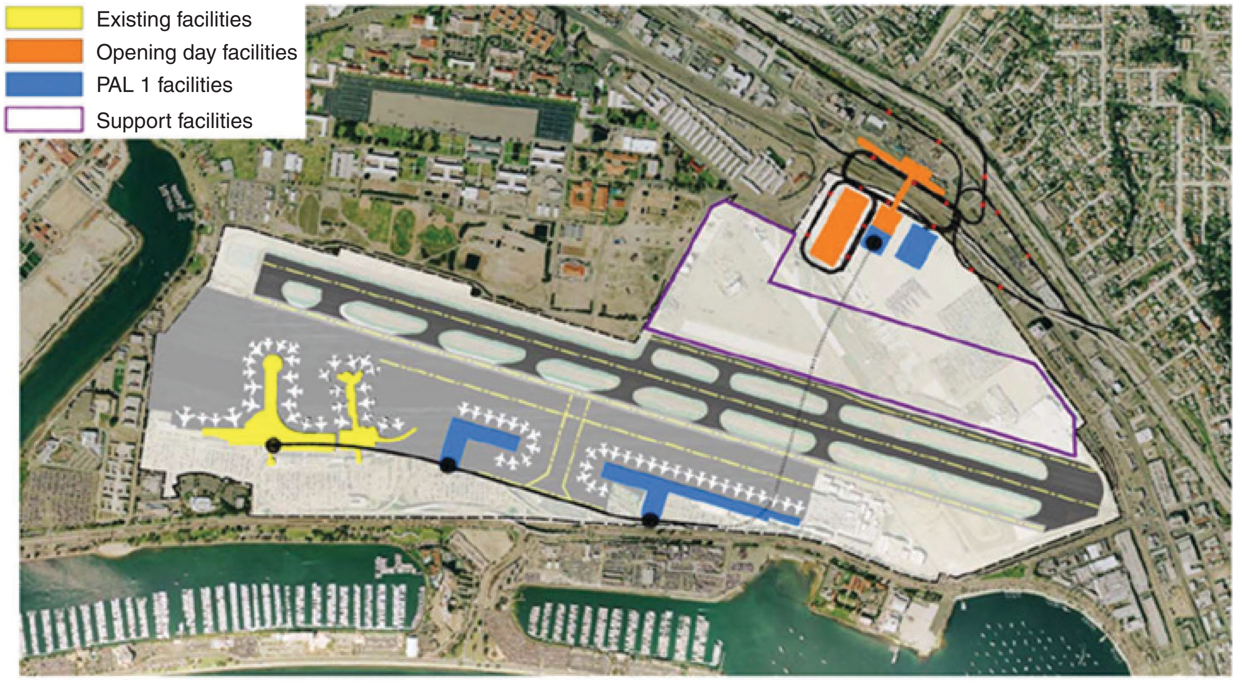
Phase 4

The final development phase proposed in Destination Lindbergh would accommodate 28 million annual passengers (14 million enplanements), shown as Figure 8-7. At this time, all passenger processing facilities would be located in the north terminal and passengers would travel to the concourses and aircraft gates via the APM. A conceptual model of the north side passenger processing facility is shown in Figure 8-8. The ITC and transit facilities would ultimately be able to accommodate 8.5% to 13% transit ridership, or about 1.2 to 1.8 million annual air passengers. The program's modeling indicated that the combined public transit ridership would increase to between 9% and 15% with the addition of a HSR stop at the ITC. The transit ridership forecast used in Destination Lindbergh was prepared by SANDAG and projected the levels of activity that were expected to use the ITC. The ITC would serve both airport-bound passengers and regional transit passengers connecting between public modes. The transit ridership forecast included review of comparative data from other airports and regions similar to San Diego, use of the SANDAG model to forecast non-airport ITC users, and a final review of the forecasts by a peer group of aviation and transit industry experts.

Site Planning Issues Raised in Destination Lindbergh

Background

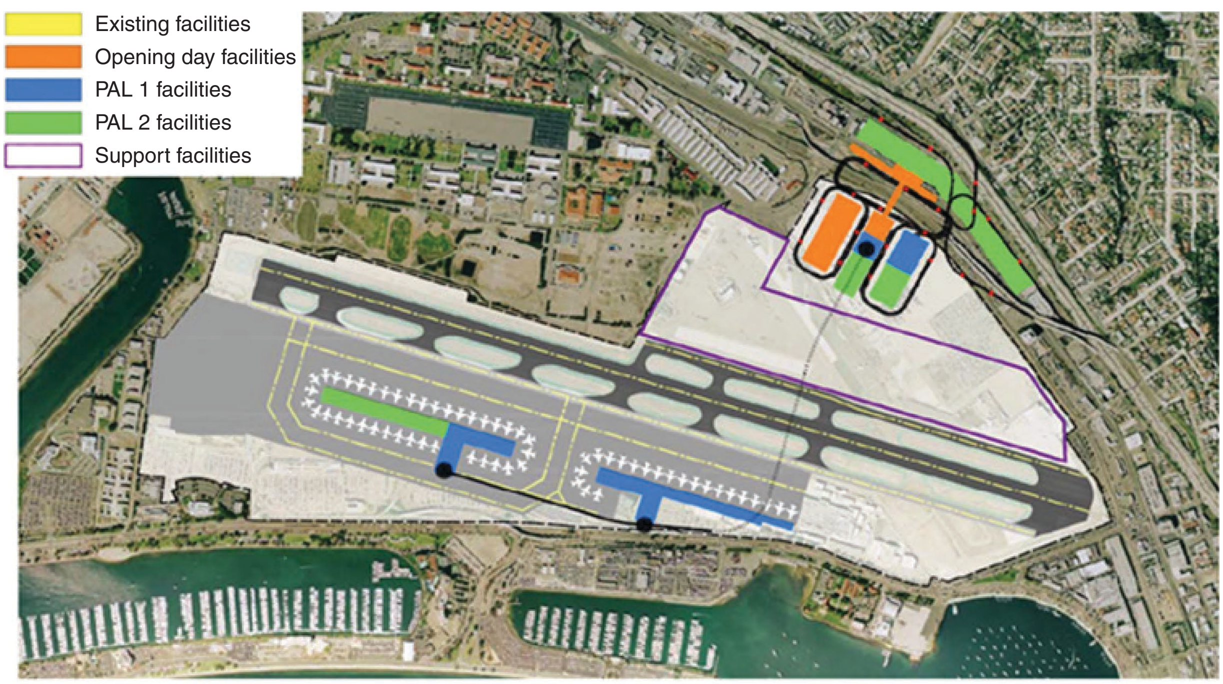
The potential for developing a dramatic new concept for integration of HSR, commuter, and light rail into a consolidated intermodal terminal serving Lindbergh Field has been under study the past four years by SANDAG, in collaboration



Note: Terminal 1 passenger processing is in north ITC; Terminal 2 processing remains on south side

DESTINATION LINDBERGH

Figure 8-6. The third phase would serve passengers on both sides of the runway. Source: Destination Lindbergh.



Note: All passenger processing is in north ITC

DESTINATION LINDBERGH

Figure 8-7. The final build out would process all passengers on the north side of the runway. Source: Destination Lindbergh.

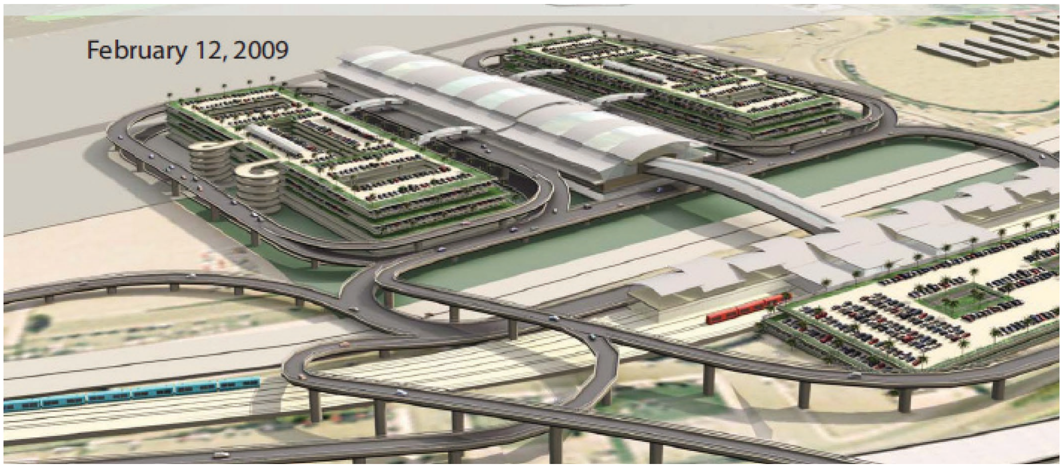


Figure 8-8. Concept design for a landside passenger processing facility, located north of the runway. Source: Destination Lindbergh. Design: Jacobs Consultancy.

with Caltrans, the San Diego County Regional Airport Authority, City of San Diego, and San Diego's two transit districts. The prospects of having the future California High-Speed Rail network adjacent to the edge of the airport provided the catalyst for the local, regional, and airport officials to produce three studies focused on long-term development of the airport with design goals specifically tied to regional ground access considerations. This section examines the site planning implications of Destination Lindbergh, followed by a discussion of both the RASP and the AMAP. The review of the details of this site planning process will help to understand the extent to which present modeling and analysis tools are adequate to support the kinds of decisions that must be made, both in the present and staged over a long implementation process. The implications for modeling tool refinement are discussed in the final section of the case study.

Development Plan

The Research Team's review of the referenced planning studies, the physical plans developed to date, and interviews conducted with key officials actively involved with these three studies provided the framework for an assessment of potential upside benefits and of obstacles to implementation. The physical planning concept's primary focus is the development of the ITC adjacent to the existing rail corridor to the north and east of the airport itself. The primary objectives for advancing this development are very similar to those considered at other airports in the United States examining improved intermodal connections:

- Improving intermodal connections and convenience to attract a higher rail mode share and maximize non-auto modes of travel to the airport.
- Alleviating future ground access and curbside congestion and parking shortages.
- Providing increased airline gate positions for medium- and long-haul services by diverting short-haul air feeder services to HSR where feasible.
- Centralizing airline ticketing, bag check-in, security/screening, and bag claim.

The proposed long-term development plan in Destination Lindbergh provides for all air passenger processing on the north site adjacent to the ITC; HSR, commuter and light rail services, consolidated rental car, and airport parking would be located north of the runway, with all airside concourses on the south of the runway. In this plan, the rental car facility is built on airport land, while the ITC is built on adjacent land. One architectural concept for this major integrated landside airport complex is shown in Figure 8-8, designed by Leigh|Fisher (formerly Jacobs Consulting). The central structure shown in Figure 8-8 is where all passenger processing occurs, transporting them through a people-mover at the subterranean level of the complex.

Observations on the Site Plan

The long-term development plan allows for substantial potential modal split to rail—up to 15% of the airport users—an optimistic percentage compared to most airports in the United States in operation today. The plan assumes all parking to eventually be consolidated at the ITC and all gates to remain on the south side of the runway with an APM system as the sole mode of access to the airline gates/aircraft boarding positions. The capital, operational, and maintenance costs to bring this phased program online are substantial, and the financial plan will require buy-in from the airlines and other tenants. Centralization of airline check-in, security screening, bag sorting/distribution, and bag claim in a single consolidated facility has its benefits from the point of view of operations, maintenance, and passenger convenience. However, the use of the people-mover system for all access to the gates must maintain a high level of reliability, have sufficient capacity and frequency to handle the passenger loads, and not result in long walking distances to the various gates. This centralized processing concept has been implemented (to a greater or lesser extent) in many airports in the United States, including Tampa, Orlando, Atlanta, Pittsburg, and Denver—but none of these airports have integrated their landside passenger processing operations with long-distance rail.

The Research Team's review of the long-term site plan accepted the basic assumption that it was not possible to acquire the necessary right-of-way from the United States Department of Defense and Marine Corps to build a taxiway connection to a new terminal/concourse gate area immediately adjacent to the ITC. If this institutional hurdle were overcome, the site plan would offer a direct connection to the new concourse/gates without the use of an APM. It could expand overall gate capacity, greatly enhance the phasing and staging of the ITC, and remove dependency of airline gate access on the APM system. Interviews conducted with key leaders in San Diego suggested local skepticism about the concept that the Department of Defense would never allow a land swap with other airport land, or other land.

The preferred long-term build-out plan also requires the people-mover investment at some phase of the phased development; its high cost is likely to be a source of concern in the overall funding scenario that will be required to bring Destination Lindbergh to reality. The existing terminals and expanded terminal now completed will also require significant demolition to eliminate all current processing functions other than boarding gates/aircraft parking positions, and to reconfigure the concourse piers for automated people-mover stations along with passenger conveniences/food services and shops.

Challenges to Implementation

Challenges facing local, regional, and state efforts to move forward with the long-range development include myriad classic issues associated with any major investment in an existing physical plant to enhance convenience, capacity, and maximize non-auto access to the airport:

- Demonstrating "real" demand for non-auto modal access.
- Establishing the commitment and timeframe for HSR service to be fully operational.
- Obtaining all necessary agreements among the various jurisdictions, rail providers, and airlines to implement a phased development plan with an agreed upon configuration, capacity, functions, and amenities to be provided in the ITC and the airline gates/concourses.
- Advancing the environmental process to a successful conclusion.
- Obtaining the required right-of-way for all major components.
- Advancing the planning and design of the incremental improvements to obtain reliable cost estimates for construction.
- Financing the capital investment.
- Assuring long-term revenue stream for operations and maintenance of all facilities, including rail modes, intermodal terminal, landside people-mover, and airline gates/concourses.

Regional Aviation Strategic Plan (RASP)

The San Diego Regional Aviation Strategic Plan was mandated by a state senate bill, and "requires that the Airport Authority, in collaboration with the SANDAG, identify workable strategies to improve the performance of the regional airport system in San Diego County" (San Diego International Airport 2011 and 2011a). Contrasting the Destination Lindbergh study's focus on the ultimate site plan for the airport, the goal of the RASP was to maximize the efficiency and effectiveness of existing and planned aviation facilities in the entire San Diego region. The RASP built upon Destination Lindbergh, but it also examined maximizing airport efficiency throughout the San Diego region. The RASP tested 15 aviation scenarios, including enhanced commercial, general aviation, and air cargo strategies.

Coordination with Other Regional Modeling

A regional econometric demand model was developed for the RASP, and it was used as a decision support tool to estimate travel to each airport in the county. The model was based on information regarding the propensity for people to travel and the factors that lead to a choice of airport, primarily the time and costs associated with accessing aviation services. The model predicted passenger enplanements for the various segments of aviation services (e.g., commercial, commuter, air taxi, private aviation, and military) and for broad categories of destinations (e.g., local domestic origin and destination, local domestic connecting, international [excluding Mexico], Mexico, and Northern California). Output from SANDAG's Regional Travel Demand Model was also incorporated into the RASP model to estimate ground transportation changes and access times.

The RASP incorporated the SANDAG ground access estimates from the 2030 Regional Transportation Plan, adopted their planning protocols, and worked to ensure incorporation of the RASP findings with the AMAP and the next update of the RTP. The intent was to maximize the integration of the various planning efforts. Coordination with SANDAG was accomplished via monthly meetings. The RASP was also coordinated to ensure it was consistent with the CHSRA's plans and other regional rail efforts.

Calibration with California High-Speed Rail Authority (CHSRA)

The forecasts of long-distance rail volumes in the RASP were calibrated to match the CHSRA's "83% scenario," in which rail ticket prices were assumed to be set as 83% of the air prices in the same corridor. These common assumptions about overall ridership result in a forecast that HSR will capture 24% of the air plus rail market between San Diego and Northern California, which is somewhat lower than the 31% of the market forecast between Los Angeles and Northern California. Given that the San Diego to Bay Area in-vehicle rail time for the trip is calculated at 4 hours, the 24% diversion rate is not inconsistent with the rules of thumb established in Chapters 4 and 5, in which such a travel time would not be associated with a rail share above 50% of the air plus rail market.

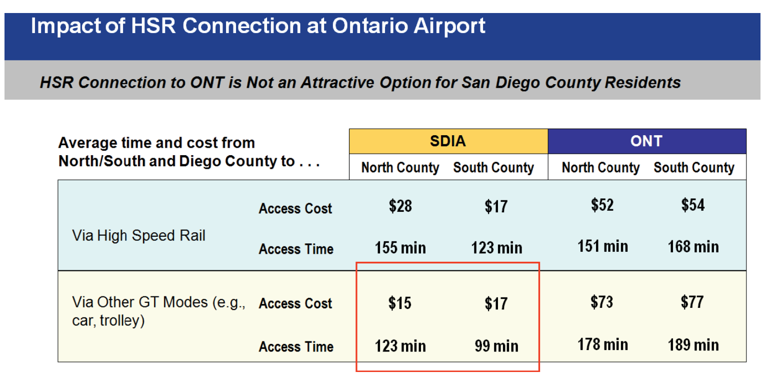
The Treatment of Air/Rail Complementarity in the RASP

The San Diego RASP study began the exploration of the concept of long-distance rail as a feeder mode to or from SAN. Looking at the treatment of HSR as a feeder mode to airport, the RASP examined the concept that the new rail system could mitigate over-demand at SAN by encouraging San Diego residents to use ONT instead. Following residents of the northern part of the county only, the RASP assumed that a trip to ONT would cost $52 by HSR, versus $15 for a trip to SAN by low-speed modes; the time to ONT was estimated to take 151 minutes, while the trip to SAN was estimated to take 123 minutes. In its recommendations to the SDCRAA Board of Directors, based on the data presented in Figure 8-9, the Leigh|Fisher consultant team concluded:

> "High-speed rail connection to Ontario Airport is not an attractive alternate for San Diego County residents and visitors because both access costs and time are substantially higher compared to direct access to SAN. Moreover, Ontario Airport would not provide alternate capacity for San Diego because the airport is projected to be as congested as SAN when mixed mode via HSR is introduced in 2027" (Jacobs Consultancy 2010).

A parallel issue concerning air/rail complementarity is whether the trips on HSR from the ONT natural catchment area to SAN mirror these relationships. If the airport did want to widen its catchment area by virtue of the investment by others in HSR, it would be problematic if the trip to SAN from the Ontario geographic area was around $52 for a 151 minute rail trip, versus something around $15 to gain access to the local airport by local modes with lower travel times.

The key observation for this case study, and indeed for the central themes explored in this report, is that the RASP process began the exploration of the possible use of rail either to expand the geographic scale of the SAN catchment area or, alternatively, use ONT as a relief strategy for its unmeetable demand. This study, combined with the fact that major policy decisions must be made about the configuration of the proposed rail system and the proposed airport site plan, represents one of the most relevant case studies of the relationship between air and rail in the United States. Chapter 2 notes that a similar analysis of the Copenhagen Airport led to recommendations that successfully influenced billions of dollars


Impact of HSR Connection at Ontario Airport

HSR Connection to ONT is Not an Attractive Option for San Diego County Residents

Average time and cost from North/South and Diego County to . . .		SDIA		ONT	
		North County	South County	North County	South County
Via High Speed Rail	Access Cost	$28	$17	$52	$54
	Access Time	155 min	123 min	151 min	168 min
Via Other GT Modes (e.g., car, trolley)	Access Cost	$15	$17	$73	$77
	Access Time	123 min	99 min	178 min	189 min

Figure 8-9. The RASP consultant team concluded HSR to Ontario would not attract many users from San Diego County. Source: Jacobs Consultancy, Presentation #2 Preliminary Findings–Remaining Scenarios, Slide 41, Dec. 9, 2010.

in local infrastructure investment. Initial work undertaken by New York's RPA for the Port Authority of New York and New Jersey is beginning to integrate rail planning policies with aviation policy issues. However, the initial results in the San Diego RASP, taken as an opening observation in a longer term debate, do not immediately support the concept of ONT as a relief strategy for SAN.

The Treatment of Air/Rail Competition in the RASP

In the work of the RASP, the greatest positive impact upon the airport is through air/rail competition rather than complementarity. Given the severe physical and geographic constraints of the airport, a key evaluation metric in this case is the amount of "suppressed demand" (i.e., demand for travel in the region that is not satisfied by the services of the system). For example, the study found that the modest amount of diversion away from SAN by the aggressive use of Tijuana International Airport would delay the effect of suppressed demand by 2 years, when compared with the base condition (Jacobs Consultancy 2010, Slide #31).

SAN, like Burbank, is unusual in its inability to expand its basic plant to accommodate the kind of demand desired for economic development in the region. Figure 8-10, prepared by Leigh|Fisher for the RASP Committee, shows that rising demand will finally bump up against the capacity limit sometime around 2024; the problem of suppressed demand becomes most serious at this point. With the projected arrival of HSR beyond 2030, some of the problem of unmet demand can be alleviated when the diversion of passengers away from flights to Northern California makes possible the use of those "slots" for longer distance flights. Thus, the diversion to rail increases the available supply of high-quality connections to/from the region. This also emphasizes the need for a long-term perspective, given the envisioned opening date of 2027 for the rail system.

Implication for San Diego Airport Station Location

In the RASP analysis, the most important contribution to airport systems planning comes from the ability of HSR to divert intra-California passengers away from flights, which could theoretically open up "slots" for use by aircraft making longer distance flights. As shown on the bottom right corner of Figure 8-10, two scenarios were created for the location of the HSR station in San Diego. The RASP's conclusion that access to the airport by HSR was not a significant issue, and their conclusion that maximizing the number of rail riders in the corridor was in the interest of the aviation system, supported their determination that California HSR station may not be located at the airport (as assumed in Destination Lindbergh). Instead, the team concluded that the station could be located at the tourist/business center of San Diego. Looking at both the issue of improved ground access and the issue of diversion to new capacity, the RASP study concluded that, if the HSR station were located at the airport, it would be chosen as the airport ground access mode by 1.1% of departing originating passengers (Jacobs Consultancy 2010, Slide 44). If the HSR were located in the downtown, it would be used by. 1% of departing originating passengers. At the same time, the RASP study concluded that, if the station were located in the downtown, it would divert 4.6% of SAN passengers away from air and over to rail. If the station were located at the airport, it would divert 1.4% of SAN passengers away from air, and over to rail.

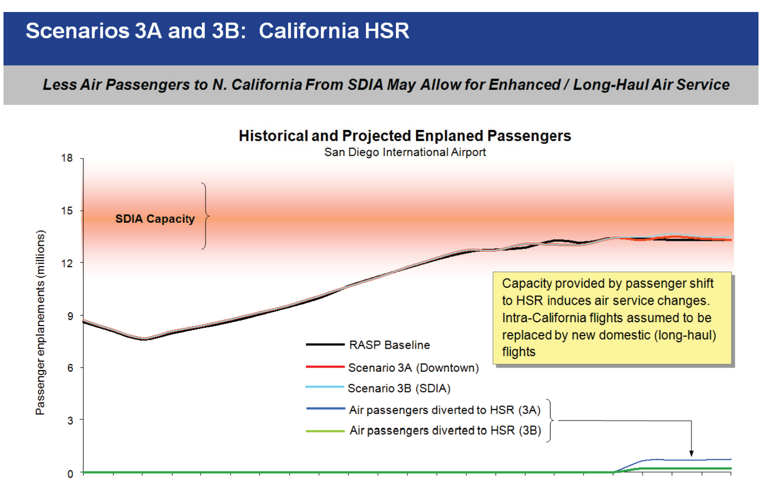


Figure 8-10. The diversion of some SAN users to HSR is seen in the year 2027. Source: Jacobs Consultancy, Presentation #2 Preliminary Findings–Remaining Scenarios, Slide 40, Dec. 9, 2010.

Following the assumption that economic decisions are rational, this implies that a station in the downtown would provide desired transportation services to 4.7% of airport users, while a station at the airport would provide desired transportation services to 2.5% of the riders.

The reader is referred to the bottom right corner of Figure 8-10, in which the number of airport passengers diverted to rail in Scenario 3A (the downtown station location scenario) is shown with approximately three times the number of passengers diverted to rail in Scenario 3B (which represents the airport location as assumed in Destination Lindbergh).

The RASP study suggests that, in the early years of implementation, the downtown station would attract significantly more riders to/from northern California than would a rail station in the intermodal complex adjacent to SAN. The model results show that the downtown rail station location would attract 25% of the air/rail market, while the airport station would attract only 8% of that market (Jacobs Consultancy 2010, Slide 42). In interviews, there was very little consensus that the models used for fine-grain ridership analysis (particularly facing issues of sub-mode of access to and from a candidate terminal) were appropriate for this level of detailed analysis. The concept that one mode share would be three times the scale of an alternative mode share because of a station location seems worthy of revisiting and refining at later stages of the analysis.

For reasons not entirely clear to an outside observer, the RASP analysis suggests that, after the first years of implementation, the differences based on station location would disappear. The summary notes that the, "Downtown station initially attracts more passengers to HSR. But ultimately, both scenarios have similar effects on the region's suppressed demand" (Jacobs Consultancy 2010, Slide 45).

From a policy perspective, SANDAG supports the ITC location at SAN as the HSR terminal point, rather than the existing rail complex at the Santa Fe Depot. Concentrating transit facilities (and transfer movements) at this location would result in an airport-plus-local service hub that is unusually close to the downtown center for any major airport. In addition, the relationship with both interstate and regional highway networks is exceptional to support access to the HSR rail terminal. Reportedly, CHSRA plans call for the station to be located at the airport complex, not at the site predicted to gain the highest ridership in the RASP analysis.

How HSR Interacts with Other Air Capacity Strategies

The RASP analysis offers some valuable insights into the question of how HSR, as an element of a multimodal strategy to improve services to the airport's clientele, might fit in and be merged with other strategies and actions. Again, the fact that rail strategies are on the same summary graphic as aviation-based strategies is itself a significant breakthrough. Figure 8-11, prepared by the RASP consultant team (annotations added), shows that in dealing with the issue of suppressed demand, the HSR program would provide high-quality ser-

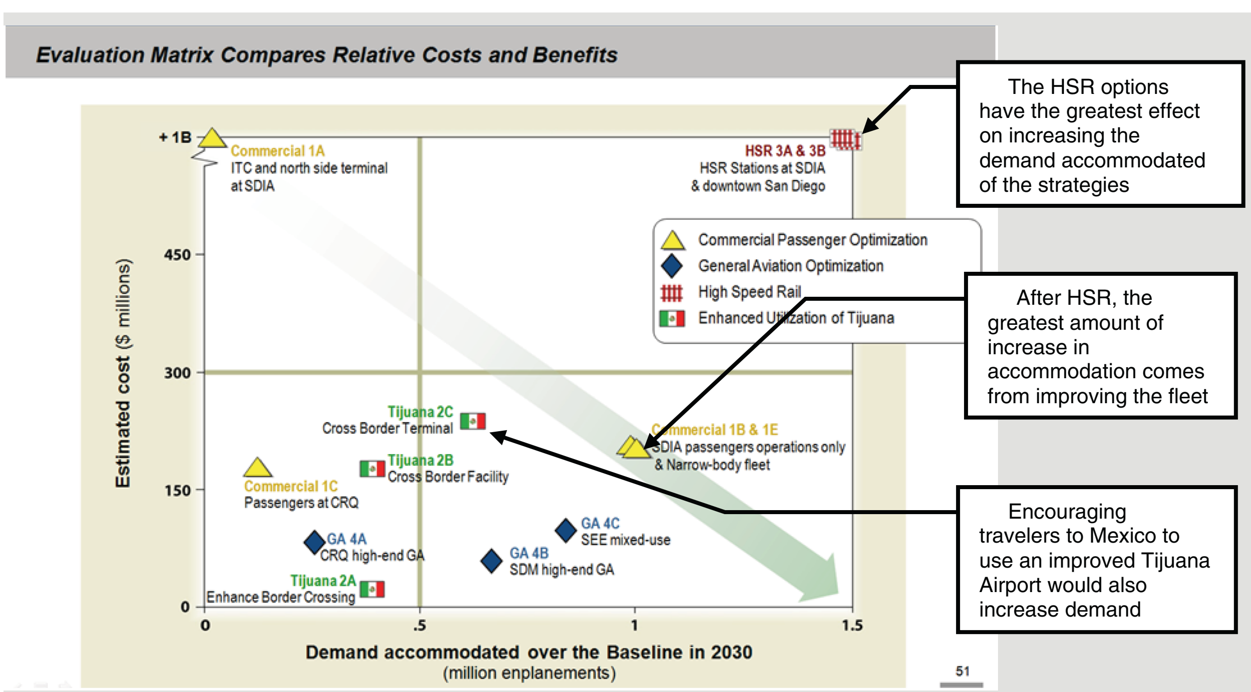


Figure 8-11. Summary of impacts of strategies examined in the RASP. Source: RASP system.

vices to 1.5 million users who would otherwise be associated with suppressed demand conditions. The second-highest level of additional supply (about 1.1 million passengers) would result from up-gauging the aircraft used at SAN, and this strategy would have the highest ratio of improvement to cost. The third greatest improvement in functional capacity would result from encouraging international passengers to the south to utilize the Tijuana Airport, providing good alternatives for about 600,000 passengers. Thus, HSR emerges as but one element of a total multimodal package that could provide good long-distance travel solutions for more than 3 million passengers over the base case scenario in the period of suppressed demand in 2030.

After reviewing aviation demand forecasts, current capacities, and future development potential at all of the region's airports and for HSR, planners from several agencies agreed that the RASP study offered no "silver bullet" to the region's transportation problems. The RASP identified extensive ground access and airport infrastructure improvements, including:

> " . . . (a) funding, policy, and political factors; (b) surface, rail, and cross border initiatives; (c) physical change in airport capability and/or capacity; (d) expansion of an airport's user base/market; (e) change to an airport's fleet mix; (f) federal, state and/or local aviation initiatives; and (g) changes to surface transportation infrastructure" (Jacobs Consultancy 2011).

However, it concluded that, although many of the improvements considered would contribute to the solution of the region's air service problems, some potential improvements were very expensive, legally challenging, or impractical to implement in full; in addition, even the most beneficial actions would have a nominal effect on the resolution of the region's commercial air transportation issues.

Airport Multimodal Accessibility Plan (AMAP)

SANDAG prepared the Airport Multimodal Accessibility Plan (AMAP), which evaluates and prioritizes ground access improvements to the regional airports identified as needing improvements in the RASP. The ultimate goal was to incorporate the results of RASP and AMAP in the 2050 Regional Transportation Plan. SANDAG has also prepared conceptual studies and cost estimates for the ITC that are consistent with the airport authority's plans for the phased redevelopment of the northern portion of the airport (CH2MHill and HNTB 2012).

The AMAP, released in March of 2012, acknowledged that the RASP had questioned the logic of moving the airport terminals to the north side of the runway as this "would have no effect on the projected enplanements because it would not provide airfield capacity improvements." However, the SANDAG-based AMAP study reiterated the logic of moving the terminals, noting that:

> "there are other reasons for full build out of the North side terminal complex as well as construction of the Phase 1 Airport ITC, including regional intermodal transportation connections, alternatives to driving alone to the airport, and congestion relief. The advanced planning and preliminary design for the Airport ITC is currently underway and will include connections from the north side airport development to trolley, commuter rail and local and regional buses" (CH2MHill and HNTB 2012).

The study sees two time phases, including: (1) Opening Day to include the rail/local bus/BRT center, pedestrian bridge, CONRAC, parking, and shuttle to terminals; and (2) Build Out—building upon the opening day facilities with the addition of direct access ramps from I-5 and the CHSR station.

Interviews with SANDAG and HSR Planners

Interviews

Interviews conducted by the Research Team reflected a high level of cooperation between the various agencies involved in transportation planning in San Diego. This appeared to be the result of the legislative direction to cooperate on the set of intermodal planning studies; however, it also seemed to reflect a genuine desire on the part of the staff and consultant teams to work together to find solutions to the very difficult regional infrastructure problems.

The Airport Viewpoint

Having spent considerable time and resources unsuccessfully to find an acceptable second airport site, the airport staff was extremely focused on developing plans that would permit the airport to best accommodate regional demand for air travel within the existing airport boundaries. Their development of a phased plan in the Destination Lindbergh study for future airport development—by including improved ground access, a consolidated rental car facility, and an ITC with potential air passenger processing on the north side of the airport—meshed well with SANDAG's goals for a regional multimodal transportation center and future HSR station at the airport. The Airport Authority's decision to incorporate the SANDAG regional transportation model and the CHSRA's input into their RASP demand model contributed significantly to the acceptance of their results by their regional planning partners. The RASP demand model used the SANDAG trip-origin zones, local access travel times, and the CHSRA estimates of rail fares, frequencies, travel times, and station wait times.

The airport staff educated the city and regional planners on limitations on the use of airport funds for non-aviation projects, which eliminated potential misunderstandings over the role the airport would play in future funding of the ITC. At the same time, they recognized the importance of the ITC and HSR to the region and shaped their future plans for the north area of the airport so that a future ITC and HSR station could be integrated.

The airport staff expressed disappointment that the California HSR plans did not include a direct connection to Los Angeles International Airport (LAX). They felt that such a connection would have contributed to substantially raising the demand model's estimate of diversion from air to HSR. The staff expressed their satisfaction with rail ridership estimates made by the CHSRA. They felt the projection that only 1% of originating departing airport passengers would use the HSR service to access the airport was so low that questions about its accuracy were not relevant. They did not question the CHSRA's plan to price HSR fares at 83% of air fares, and used that pricing as input to the RASP demand model. Their feeling was that the CHSRA was expert in rail fare setting and they were willing to accept their input on fares, pre-board wait times, and travel times. They did state that they would have been more actively involved in efforts to model the diversion of airport traffic to HSR had LAX been included as a destination. However, given that what they saw as a significant market for HSR to LAX was not viable in the state's plans, they felt that the relatively low air to rail diversion predicted by the model (e.g., 4.6% of airport passengers) was reasonable. In a situation where airport demand exceeds its capacity, as emerges in Figure 8-11, the single most effective element of a multimodal strategy to deal with the "suppressed demand" is the potential diversion of 4.6% of air passengers. Therefore, further efforts to refine modeling and analysis capability are warranted for use by airports in their long-term planning.

SANDAG and HSR Planner Viewpoint

Local interviews were conducted at the SANDAG offices. Both planners from SANDAG and planners working for CHSRA expressed disappointment with the low levels of ridership projected for HSR, both as a means of access to the airport and as a substitute for air travel. However, they did not voice serious doubts about the modeling methodology, given the low ridership estimates. They had reservations about the differences in the planning time horizons used by the airport studies—which contain projections to 2030—and the HSR services that are planned to commence in 2027.

SANDAG staff expressed reservations about the adequacy of their general-purpose regional travel model to accurately estimate local travel to airports and the lack of a multi-county corridor modeling capability. They plan to re-model regional access ridership as part of the next update of the Regional Transportation Plan, using their general transportation model, supplemented by input from airport modelers. However, they did state a desire for specialized modeling assistance, perhaps from FAA or FTA, for airport access work spanning several counties in a corridor, stating "Federal guidance on standardized corridor modeling would be helpful." They also expressed a desire to see more effort expended on modeling new estimates of rail ridership to ONT by passengers living in the northern portion of the county and the differences in ridership as a function of the San Diego HSR terminus location at either Santa Fe station, downtown, or at the airport.

Common Concerns

Most of the planners and managers interviewed agreed that, upon further analysis, the case for moving the passenger terminals to the north of the runways was based on the known superior highway access conditions. Access to terminals to the south of the runway will rely on one urban arterial boulevard with many at-grade crossings, an arterial that would have to be widened to accommodate all airport demand. Access to potential terminals to the north of the runway would be provided directly from both the dominant Interstate highway and major state highway in the corridor. This would have significant environmental implications in future scenarios that saw massive investment in local and long-distance rail, and in scenarios that did not. There was somewhat more disagreement among the parties concerning the importance of the public transportation infrastructure; those responsible for regional planning tended to put more emphasis on this aspect of the intermodal plan than those responsible for the management of the airport.

Several interviewees were concerned that the Destination Lindbergh plan was highly conceptual and would be subjected to ongoing revision over time. They note that as the conceptual plans for the new terminals north of the runway are progressing, the airport is building a double-deck roadway and 10 new gates at the present terminal location—all of which will have functional lives extending throughout the planning period. A concern was that the high-quality APM link between the ITC and passenger terminals on the south side of the airport and the development of passenger processing facilities on the north site might not be realized.

The airport staff pointed out that the Destination Lindbergh plan was only a concept and, although accepted as a concept, would be subjected to additional refinement in the upcoming revision to the master plan. Concerning the connection issue, they noted that the concept plan did provide a dedicated bus route between the ITC and CONRAC in the north, and the passenger terminal in the south, at a relatively early point in the development. All parties seemed to agree that, while an APM would provide a high LOS, a frequent bus shuttle on a dedicated roadway could offer the reliability and frequency that passengers transferring from rail to air would require. This view is consistent with the experience at BWI, BOS, and other airports where a reliable and high frequency bus link seems to provide a satisfactory LOS for rail passengers.

Issues Raised in the San Diego Case Study

This case study provides a microcosm of the strengths and weaknesses of intermodal air/rail planning practice. Three of these issues are summarized here.

The Fragmented Practice of Modal Planning

In the case of the San Diego region, as in many other locales, there was not a natural linkage between the airport planning and regional and rail planning. The issue became pressing when the airport plans raised concerns about the impact of traffic on North Harbor Drive from adding passenger parking and growth in the existing terminal area. From that time forward, the agencies involved performed an admirable integration of their planning processes. The initial lack of coordination is understandable, given the relative isolation of the various planners' worlds. The lack of plan integration is not surprising given the different models, model inputs, growth assumptions, and understandings of their respective industry results. This often stems from the different cultural and regulatory environments in which the different modal planners operate. As was noted by the SANDAG representative, better support for intermodal corridor planning by FAA and FTA may be a way to improve the quality of intermodal planning.

Incremental vs. Greenfield Planning

The planning history in San Diego illustrates the challenges associated with making longer term reconfiguration decisions concurrently with continuing capital investments in an airport's existing physical plant. The airport staff were comfortable that their plans to accommodate future passenger growth at the airport by incremental extension of facilities on the south side of the airfield were reasonable and prudent. The CHSRA and SANDAG visions featured a fairly radical change that would, ultimately, move all of the passenger processing activities to the north site, adjacent to the ITC, and served by superior levels of highway accessibility. The incremental approach by the airport planners cannot be ruled out given the limitations on the airside capacity of SAN and the failure to secure Marine Corps approval for land necessary to construct a taxiway, which is essential for aircraft access to passenger terminals on the north portion of the airfield. It is generally less expensive to expand facilities incrementally and, unless long-term forecasts indicate that a radically different development plan is required to meet future demand, planners are reluctant to abandon recent terminal investments and move to a wholly different concept.

However, the airport planners also realized that:

- A CONRAC could only be built on the north site;
- Improved airport access to the nation's second-largest rail corridor, and the regional highway system in the north, associated with an intermodal facility could greatly benefit the airport; and
- The incorporation of an ITC to satisfy SANDAG's plans for an intermodal station adjacent to the airport could be accommodated without major disruption to the airport's development.

The ITC is a natural adjunct to the CONRAC, where passengers will leave their rental cars and proceed to the passenger terminals via a high frequency consolidated shuttle bus on a dedicated on-airport roadway. The Destination Lindberg plan calls for relocation of all passenger processing to the north site, with an APM connection to gates on the south site. It also preserves the existing and short-term future investment in the south.

However, the problem of abandoning recently constructed infrastructure to adopt a radically different concept of operations is a difficult one that deserves more study. In some cases, it has been obvious to airport planners that the constraints of an existing facility will become untenable in the future and a dramatically different development concept is needed. This has been the case in Denver, Pittsburgh, Indianapolis, Kansas City, and among others, where old airports or old terminal complexes were deemed inadequate and new greenfield development was chosen. The economic impacts of totally new infrastructure investment—including the departure of Continental from Denver, and US Airways from Pittsburgh—have potentially serious implications. It is unclear how that kind of dramatic decision to invest in a new concept, while abandoning existing infrastructure, can be justified to facilitate an intermodal development plan, when the incremental development option still remains viable and cost effective.

Agreement on Forecasts of Rail Ridership for Competition and Complementarity

Much speculation has been made that differences in the estimates of rail ridership between airport and rail planners are an important problem in intermodal planning. While this may be correct, in the San Diego case study—and in general—it was not reported as a significant issue among the various planners.

The estimates made by either the RASP study or the CHSRA of the extent to which HSR would feed passengers to SAN did vary; however, percentages were in the low single digits. Both the airport planners and SANDAG staff agree that these numbers are disappointing, but they do not seriously dispute them. By way of comparison, Chapter 2 reported that, of originating passengers departing Paris CDG airport, only about 6% accessed the airport by HSR—again, in the single digits. The explanation given is that many passengers in northern San Diego County are currently driving to the Los Angeles area and would not be likely to take HSR to the south to access the airport in San Diego and make that trip by air. The studies did find an appreciable number of north San Diego County travelers who would use HSR to travel directly to the Los Angeles area; however, these were travelers who were mostly driving to Los Angeles today.

Similarly, the use of HSR as a complementary mode for local residents turning to adjacent airports in response to the capacity constraint resulted in differing—but still low—estimates, which were not disputed by local planners. Originating passengers, using a HSR station at the SAN to access ONT, were predicted as a miniscule 1,458 passengers in the RASP estimates for the year 2030. In any case, the planners did not seriously dispute those estimates.

In terms of air/rail competition, the regional planning process worked directly with the statewide process and applied the overall mode share data, in which rail gains 24% of the air plus rail market between San Diego and Northern California. By any definition, a diversion of this scale has implications for local planners creating local strategies.

The San Diego case study illustrates that the degree of cooperation and sharing of modeling data among the airport, city, HSR, and regional planners was such that there was no serious dispute over the various ridership forecasts. However, that does not mean that planners did not recognize a need for better forecasting tools; instead, this illustrates that many of the relevant estimates were too low to materially affect their plans. Particular attention seems to be appropriate on issues of micro-scale location (such as the difference between the two potential station HSR sites) where issues of sub-mode of access are difficult to model. In addition, it is not clear that planners and managers have adequate tools to understand the potential of HSR to feed airports under conditions where the air service mix at the "distant" airport is superior for the traveler to the air service mix at the "near" airport (even if access "costs" were higher for the distant airport). This was similarly shown in the Northern California case study earlier in this report.

In short, extensive cooperative planning has been demonstrated in San Diego, despite a lack of demand forecasting tools specifically designed to deal with the local issues. It is clear that the modest scale of predicted multimodal volumes allows for the separate modes to continue with their separate modal planning tasks. It is equally clear that when the policy questions focus on micro-scale design details, present tools will not be adequate to support the detailed site planning processes.

Site Planning Considerations from the Case Studies

Consistent with the typology presented in Chapters 2 and 3, the site planning options at the San Diego International Airport can be reviewed in terms of an international perspective. A review of airport station locations in Europe and the United States suggests three major categories for airport rail station solutions:

Site Planning Concept #1: Full Integration at Airport: Reroute the Long-distance Rail Line to Go to a Point from Which the Air Traveler Can Walk from the Train to the Check-in Terminal

While this is the "gold standard" option, accomplished in Zurich, Amsterdam, and Copenhagen, site planners in San Diego still have this option open to them in two realistic scenarios. If the HSR station is built at the site of the ITC, users of the California HSR system could walk from their long-distance train, across the bridge shown in the center of Figure 8-7, and into a centralized check-in location for the entire airport. Assuming that full implementation of the Terminal 7 concept at Chicago O'Hare has been deleted from the O'Hare master plan, San Diego International Airport emerges as the only case in the United States where the long-distance train platform can be connected to the landside passenger processing terminal via walking only. In one future option, airside people-movers would connect to concourses located on the south side of the runway; in another option, the concourses/gates would also be located adjacent to the rail station, to the north of the runway. In such an option, the high-speed rail train could continue on to the CBD, with an additional station.

Site Planning Concept #2: Shuttle to Rail Alignment: Build a Separate Airport Rail Station on the Rail Alignment at a Point As Close As Possible to the Airport Passenger Terminal Complex

This kind of connection, as exemplified by the present station connection at Newark, would result if the operations of Phase 3 of the Destination Lindbergh implementation scheme were, for one reason or another, made permanent by a lack of implementation of the "full build-out" scheme. For at least some terminals, auto access would be direct to the terminals, while transit access would be by people-mover connection from the ITC and CONRAC facilities in the north. In these schemes, those who come by personal auto have direct access to the passenger processing terminal, while those who come by other modes must be shuttled from the transfer facility to the air terminal some distance away.

Site Planning Concept #3: Connect to Network at a Central Place: Connect with the Best Consolidated Rail Transfer Point Possible

Conceptually, this is like a new solution being considered in Newark, in which a new guideway facility might be built from the three separate air terminal structures to the largest connecting rail terminal possible, Newark Penn Station. This maximizes the number of trains that will actually stop at the designated airport station. If the logic put forward in the RASP were accepted, a downtown location for California HSR would be seen as in the best interest of the airport and the city as a whole. The RASP put forward a concept in which some "trolleys" were dedicated to serve as a shuttle between the downtown train station and the airport ITC/CONRAC. Under this logic, the "Santa Fe" site is seen as in the best interest of the HSR system, and the "trolleys" would shuttle to and from the airport.

In an alternative interpretation of the same situation, the ITC itself would be seen as the "best" central place for the airport service to connect to—the logical location under Site Planning Concept #3. In this vision, the maximum number of trains, trams, buses, bus-rapid-transit services, etc., would be located at the ITC–not at the Santa Fe Depot. This would be true for all modes that must gain access over the Interstate systems, which does not serve the downtown site well. And, of course, the HSR train could continue on to a second station, near the present Santa Fe Terminal.

The San Diego case study concludes with the observation that the planners and managers in San Diego have a full set of site planning options by which to make the connection between HSR and the airport. Compared to every other airport included in the international review, San Diego managers have the least constrained set of facility and service options of the airports studied. It follows that the planning/analysis tools needed to understand both the macro- and micro-scale behavioral options could be improved before final decisions are made that will impact billions of dollars in transportation investments.

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CHAPTER 9

Federal and State Funding for Air/Rail Planning

Introduction and Structure

Before a facility can be constructed it has to proceed through the project development process, which includes both preliminary engineering and design engineering. Before those phases of project development, the project has to evolve through a process of planning and environmental documentation, and (usually) be selected for funding through a regional or state planning process. This Chapter explores the kinds of funding mechanisms which exist to pay for those planning efforts. In many cases, the nature of the planning process has been determined by federal law, where the state and local entities usually must participate through the provision of local share (while federal programs have existed with 100% share, these are the exceptions to the rule). Often the rules of funding mechanism are established under federal law, such as the FAA's Passenger Facilities Charge (PFC), or the FHWA's Transportation Infrastructure Finance and Innovation Act (TIFIA) loans, and then carried out as if the money were local in nature. Such situations represent a merging of federal and non-federal roles, where the funding is neither purely "federal" nor purely "local" as the money is collected in, and remains in, the local jurisdiction following federal guidelines.

This Chapter reviews the kinds of resources that are potentially available to support planning and is presented with the caveat that each project reviewed in this report has been developed in a unique (and possibly non-transferrable) manner. Thus, Chapter 9 presents a discussion of funding programs for planning that might be relevant to the air/rail concept being explored, without any implication that such funding would be available for a specific situation.

Structure

Chapter 9 will first present a summary of most relevant federal programs that might be applied to fund planning and early project development efforts for intermodal projects and programs which involve the integration of air and intercity rail planning. The review of many possible federal programs was conducted by the Policy Research Center of the Coalition of Northeastern Governors, an organization which has had decades of experience in encouraging intermodal solutions at the federal level, and a member of the ACRP Research Team. Second, the Chapter will note the nature of the state and local role in funding planning efforts, concluding that each individual project seems to have different kinds of non-federal contexts and characteristics. That section includes a recap of 24 separate projects and programs which have had a transportation planning component to them. The evident existence of a major state or local role for each is flagged in the review. Finally, the Chapter concludes with two case studies: (1) the Miami Intermodal Center (MIC) is reviewed in terms of the budget allocated for planning, and how that planning was ultimately funded; (2) the Interlink Project at T. F. Green Airport (Providence) is reviewed in terms of the funding mechanisms that were ultimately applied to bring the project to fruition. Both case studies suggest that planning activities undertaken for early project development may or may not accurately predict the funding needs and mechanisms that will ultimately be applied in the project; the need to reflect that uncertainty is noted.

Background: The Challenge of Intermodal Planning

Planning for transportation strategies and solutions which involve several modes and/or several institutions has been a challenge for major governmental institutions, many of which tend to be structured around the needs and responsibilities of managing a single mode. Thus, the question of where to find funding for planning for multimodal and multijurisdictional efforts is not an easy one, and not one that will be resolved within this Chapter. And yet, projects and (to a lesser extent), programs have been built, and somewhere, somehow, funding has been found to get them into the implementation phase. This ACRP report has reviewed over 20 American projects or planning processes in which the activities of rail operators impact upon the activities of airport operators, or vice versa. The exact sources of funding for the planning activities cannot be summarized in any precise way, as literally each of the 24 programs discussed in this report has a unique history of its development and possible implementation. In many cases, a conceptual idea is born within the day-to-day process of planning and management, whether as part of the regional planning process, or within an air-oriented or a rail-oriented operating agency. Then, external funding is often sought as the preliminary planning must be supplemented by preliminary engineering and other more costly project development activities. And, even at that point, it may not be known or understood exactly what combination of funding mechanisms will be used to repay early loans or bonding efforts supporting preliminary design and development.

The Federal Role in Supporting Planning of Intermodal Facilities

Transportation officials throughout the United States are increasingly determined to harness the latent potential of intermodal projects in their efforts to integrate and revitalize the country's sprawling transportation networks. Yet as with all transportation activities, rigorous planning represents an essential foundation to the development of any intermodal project. Moreover, intermodal planning will inevitably confront the same harsh budgetary realities that afflict all transportation efforts at the state and municipal levels. As a result, federal support for state and local intermodal planning is essential to the success of such projects. The federal government, however, has failed to adapt its transportation funding mechanisms to the realities of intermodal transportation. Most federal transportation programs remain narrowly targeted to individual modes, often with limited or no flexibility to expand their scope. At present, no ongoing federal program exists for the specific purpose of supporting intermodal planning per se. This is a significant challenge for supporters of intermodal planning at the state and local levels, yet it need not be a fatal one. A range of federal programs exists that have the potential to support intermodal planning, if advocates can creatively apply their statutes and make the necessary arguments. Some are more likely to succeed than others. But given the importance of acquiring federal support for intermodal planning, all deserve a sustained analysis.

Chapter 9 now provides a summary of the major federal programs which could be applied in the planning of intermodal programs. This quick review includes a summary of major federal funding in operation in late 2012, including the programs of "MAP-21," the latest legislation for transportation. While the focus of Chapter 9 is on the mechanisms to fund the planning of projects involving both airports and longer distance rail, reference will necessarily be made to the funding mechanisms for the development and construction of the projects themselves. Chapter 9 does not address the question of capital funding for the 24 projects noted in the text. In terms of the funding of intermodal projects themselves, a good example of the research in this field can be found in "Collaborative Funding to Facilitate Airport Ground Access (Report 11-27)," Mineta Transportation Institute (MTI) at San José State University (Gosling et al., 2012).

Air/rail intermodal development represents one of the most significant potential paths for the evolution of intermodal transportation in the United States. Unfortunately, air/rail intermodal planning is subject to the same fiscal constraints and difficulties that impede intermodal planning at the state and local levels. Nevertheless, many federal programs hold the potential to support the efforts of state and municipal transportation officials in overseeing air/rail intermodal planning activities. These programs fall within three broad categories: comprehensive transportation planning programs; transportation project programs, in which planning is an eligible activity for funding; and transportation pilot programs. None of these categories was designed to specifically support air/rail intermodal planning, but all of them hold the potential to do so in the right circumstances. Given the lack of direct federal action in the field of intermodal planning, such creative thinking will probably remain the best option for state and municipal officials to acquire funding for the foreseeable future.

Federal Programs, Part One: Comprehensive Transportation Planning

Overview

Several federal programs provide funding in support of comprehensive transportation planning documents at the state and local levels. These programs—such as the Statewide Transportation Planning Program (23 USC 135), the Metropolitan Transportation Planning Program (23 USC 134), and the State Rail Plans Program (49 USC 227)—are intended to assist the efforts of state and municipal agencies to create integrated transportation plans that encompass the entire transportation system. Their purpose is to broaden the vision of transportation planning and ensure that states and municipalities approach their future transportation issues in an organized and systematic fashion. Intermodal planning, including air/rail planning, is well within the scope of these programs, offering an opportunity for state and local transportation agencies to incorporate air/rail planning within their broader federally assisted efforts. However, the design of the programs will inevitably create a competition between air/rail planning and the other elements of the transportation plans for attention and resources. While air/rail planning will be eligible for portions of the available funding, the wide net cast by these programs—and the considerable number of requirements mandated by the programs in order for transportation plans to gain approval under federal standards—will necessarily limit the financial support available to air/rail planning. Comprehensive transportation planning programs hold the promise of hundreds of millions of dollars in overall funding, but it will largely depend upon the applicants themselves to emphasize the importance of air/rail intermodal planning and secure the necessary funding allotments in support of those requirements.

State Planning and Research (23 USC 505), FHWA

Potential Air/Rail Collaborative Planning

The program funds wide-ranging transportation planning and research on a broad spectrum of issues, including "intermodal transportation systems." Air/rail planning is undoubtedly eligible under this program, although a connection to either the interstate highway system or public transportation may be necessary.

Available Funding, Cost Sharing and Continuing Financial Obligations

Two percent of the annual funding available to states under the federal transportation formula is eligible for distribution under this program. The federal transportation formula is funded out of the Highway Trust Fund (23 USC 104). The federal share of any given grant is a minimum of 80%, with DOT discretion to assume a greater proportion of the cost (up to 100%) if deemed in the best interests of the federal-aid highway system.

Application Complexity and Rigor

The program is deliberately broad, and flexibility is reflected in the expansive set of "purposes" that govern project eligibility. However, at least 25% of the funds apportioned to a state in a given year must be allocated towards research, development and technology, unless the state can demonstrate that its statewide and metropolitan planning processes (23 USC 134 and 135) have already accounted for more than 75% of the state's annual formula grant.

Public/Private Eligibility

Funding is exclusively directed to state transportation agencies for planning and research purposes.

Statewide Transportation Planning (23 USC 135, 49 USC 5304), FHWA and FTA

Potential Air/Rail Collaborative Planning

Federal government mandates state transportation agencies to conduct statewide transportation planning. States are obligated to draft and submit Long-Range Statewide Transportation Plans and Statewide Transportation Improvement Programs, with both documents adopting a comprehensive approach to transportation systems and charged with "enhancing the integration and connectivity of the transportation system, across and between modes . . ." Intermodal planning is thus central to the process, and all modes—including air/rail—are subject to analysis. The funding mechanism is formula set aside.

Available Funding, Cost Sharing and Continuing Financial Obligations

Pursuant to Title 23, statewide transportation planning is eligible for a portion of the 1.25% of highway and surface transportation funds that is set aside specifically for that purpose under 23 USC 104. Also pursuant to Title 49, statewide transportation planning is eligible for 17.28% of the funding available for statewide and metropolitan planning under 49 USC 5338. Funds are apportioned to particular states based upon a formula that takes into account a number of factors, including urban population.

Application Complexity and Rigor

In addition to the required two planning documents, states may also prepare a financial plan that details the resources necessary to implement the planning documents, as well as possible funding mechanisms.

Public/Private Eligibility

Funding is exclusively dedicated to state transportation agencies.

Metropolitan Transportation Planning (23 USC 134, 49 USC 5303)

Potential Air/Rail Collaborative Planning

Similarly to the statewide transportation planning program, this program mandates metropolitan planning organizations to draft a 4-year transportation plan and a Transportation Improvement Program for the purpose of enhancing comprehensive transportation planning. Once again, intermodal planning is unambiguously included in the eligible criteria, including air/rail intermodal planning. The funding mechanism is formula set aside.

Available Funding, Cost Sharing and Continuing Financial Obligations

The funding sources for the Metropolitan Transportation Planning program are the same as the aforementioned sources for the Statewide Transportation Planning program. However, the funding proportions are different. Metropolitan planning is awarded a higher priority than statewide planning in receiving its portion of the 1.25% of highway and surface transportation funds that are made available under 23 USC 104. And 82.72% of the funding available through 49 USC 5338 is also designated for metropolitan planning. A formula also accounts for funding in regards to particular metropolitan areas.

Application Complexity and Rigor

Similarly to the statewide planning program, metropolitan areas may prepare a financial plan to consider resource requirements and potential remedies.

Public/Private Eligibility

Funding is exclusively dedicated to metropolitan planning organizations.

Federal Programs, Part Two: Transportation Projects

A number of federal programs provide funding in support of specific transportation projects at the state and local levels, with well-defined criteria for eligible activities, cost sharing, and time horizons. Some of these programs—such as the Airport Improvement Program (AIP) (49 USC 471), the Surface Transportation Program (23 USC 133), and the Intercity Passenger Rail Service Capital Assistance Program (49 USC 244)—designate both intermodal activities (including air/rail) and planning activities as eligible for financial support. As a result, the planning phase of air/rail intermodal projects can gain eligibility for funding from these programs in the right circumstances. However, there are significant obstacles that complicate any funding request from these programs. Transportation project programs are often targeted at precise types of projects, with strict guidelines to regulate the scope of the program. As a result, the funding eligibility of air/rail intermodal planning may depend upon finding the right project vehicle with which to carry it; the ability of air/rail planning to obtain funding may rely upon the general conditions and needs of the overall transportation system, rather than its own merits. This situation is far from ideal, and it has the potential to limit air/rail planning in states and municipalities that do not possess the right conditions for application to a given federal program. Transportation project programs hold open the prospect of significant federal funding for air/rail planning, as many of these programs are well funded on an annual basis. Yet they also threaten to constrain air/rail planning activities within narrow corridors and oblige state and municipal planners to structure their activities in less than optimal ways in order to gain funding eligibility. While individual projects can benefit substantially from the use of these programs, it may be difficult to forge a comprehensive approach to air/rail intermodal planning within the framework of transportation project programs.

Passenger Facility Charge Program (49 USC 40117), FAA

Potential Air/Rail Collaborative Planning

This program funds airport improvement projects and is governed by similar rules as the AIP, although it is a distinct program. It operates through competitive grants. Planning is an eligible activity, and air/rail intermodal projects are deemed to be suitable destinations for PFC funding, albeit operating under similar constraints as AIP air/rail projects. Examples include the AirTrain automated mover at JFK and Newark International Airports and the light rail extension and new station at Portland International Airport.

Available Funding, Cost Sharing and Continuing Financial Obligations

PFC funds are derived from airport-imposed fees upon enplaning passengers of up to $4.50 per passenger. Cost sharing proportions are similar to the AIP program, although for certain projects, PFC funds can be used towards the non-federal share of project costs under an AIP grant.

Application Complexity and Rigor

The constraints upon air/rail projects (including planning) are nearly identical to those established by the AIP program.

Public/Private Eligibility

Funding is exclusively directed towards "public agencies that control a commercial service airport," although coordination with local and regional transportation boards and other important actors is encouraged.

Transportation Infrastructure Finance and Innovation Act (TIFIA) (23 USC 601) FHWA

Potential Air/Rail Collaborative Planning

The program provides credit assistance for large-scale surface transportation projects, including intercity passenger rail, public freight rail and intermodal freight rail facilities, as well as corresponding projects to provide access to those facilities. Planning activities are considered eligible costs for TIFIA funding. Air/rail intermodal planning is seemingly eligible under these criteria, so long as the air facility component is integral to the value of the rail component. The use of a TIFIA loan for an intermodal air/rail project is explored in this Chapter with a case study of its use at the Miami Intermodal Center. Funding mechanisms include Secured Direct Loan; Loan Guarantee; and Standby Line of Credit.

Available Funding, Cost Sharing and Continuing Financial Obligations

TIFIA funds are derived from a capital reserve created by DOT under the Federal Credit Reform Act of 1990 (FCRA). The federal share of eligible project costs is a maximum of 33%. Interest rates are fixed and equivalent to Treasury rates. Maximum maturity of all credit instruments is 35 years after project completion, with the possibility of a 5-year deferral period after the end of construction at the discretion of FHWA. Repayment conditions vary based upon the specific credit instrument deployed for the project and are negotiated on a case-by-case basis.

Application Complexity and Rigor

Projects must satisfy five threshold requirements to gain eligibility for TIFIA funds: eligible costs must be "reasonably anticipated" to exceed $50 million; demonstrated ability to meet the statutory criteria for application submission; inclusion of the proposed project in both long-range state transportation plan and approved State Transportation Improvement Program (STIP) (23 USC 135); existence of dedicated revenue sources for purposes of repayment; and public approval of a privately sponsored project, if applicable.

Public/Private Eligibility

Funding is available to both public agencies and private entities, although private entities must gain state approval for any project as a prerequisite to applying for TIFIA funding. Public/private cooperation is encouraged.

TIGER/TIGER II, National Infrastructure Programs, All DOT Agencies

Potential Air/Rail Collaborative Planning

Initially created in the American Recovery and Reinvestment Act, these programs provided flexible funding to DOT for the purpose of rapid distribution to state and local transportation projects in an effort to enhance job creation. Project eligibility under TIGER/TIGER II is generally defined through existing statutes governing federal transportation grants, namely Title 23 and Chapter 53 of Title 49. As such, all planning activities eligible under those statutes are eligible for funding through the TIGER/TIGER II programs. Furthermore, all intermodal projects–including air/rail planning–with similar status are eligible as well. The program operates as competitive grants.

Available Funding, Cost Sharing and Continuing Financial Obligations

TIGER federal share may cover up to 100% of the project cost, although DOT guidelines state that priority will be given to projects that require federal funding for the rapid completion of a project that already possesses non-federal sources of funding.

TIGER II federal share may cover up to 80% of the project cost, with a potential waiver for rural projects elevating the federal share to 100%.

The TIGER II program also reserves $35 million specifically for planning grants, governed by the same eligibility as projects in general under the program.

Funding for these programs has been allocated. TIGER FY 2014 is authorized to award up to $35 million (of the program's $600 million total) for planning grants.

Application Complexity and Rigor

Both programs establish a set of broad selection criteria, such as "livability" and "sustainability." The context of both programs—the desire for accelerated federal transportation funding in an effort to promote job creation—produced a flexible application process that would allow for expedited applications. As such, an unduly burdensome requirement process does not constrain the application process.

Public/Private Eligibility

Funding is primarily intended for public agencies, including state and local transportation agencies and metropolitan planning organizations.

Congestion Mitigation and Air Quality Improvement Program (23 USC 149)

Potential Air/Rail Collaborative Planning

The program funds transportation projects that reduce transportation-related emissions. The statute is defined broadly, leaving significant flexibility in defining projects that improve environmental quality. Funding mechanism is formula set aside. Project eligibility is not discussed at length beyond the environmental criteria; however, funding eligibility is determined through 23 USC 104, thereby encompassing intermodal projects and planning activities that are traditionally eligible for Title 23 funding. The program has been used to fund intermodal air/rail projects in the past, and air/rail planning could be eligible upon meeting the particular environmental criteria of the program. Examples include Hiawatha Light Rail at Minneapolis/St. Paul International Airport.

Available Funding, Cost Sharing and Continuing Financial Obligations

Funding by state is determined through a formula that weighs a number of factors, particularly a state's population and its designated ozone and carbon monoxide nonattainment and maintenance areas. Federal share of all eligible projects is 80%.

Application Complexity and Rigor

Eligibility criteria are largely determined by the status of a project vis-à-vis "an area in the state that is or was designated as a nonattainment area for ozone, carbon monoxide, or particulate matter" under the Clean Air Act. However, some discretion lies with the Secretary of Transportation and the Administrator of the EPA to approve a broader category of eligible projects. Furthermore, states that have never had nonattainment areas possess nearly complete flexibility in submitting projects under the program; they must merely demonstrate that the project "would otherwise be eligible under this section," or be eligible for funding under the Surface Transportation Program (23 USC 133).

Public/Private Eligibility

Funding is primarily directed towards public agencies. However, public/private cooperation is permitted and encouraged.

Airport Improvement Program (49 USC 471), FAA

Potential Air/Rail Collaborative Planning

This program funds public agencies ("sponsors") for airport development, including all necessary planning activities. Certain types of air/rail projects are eligible for AIP funding. The program operates as a competitive grant funding mechanism.

Available Funding, Cost Sharing and Continuing Financial Obligations

AIP funds are derived from the Airport and Airway Trust Fund, supported by user fees, fuel taxes and other revenue sources. Federal share of eligible costs involving large and medium primary hub airports is 75% but 95% for small primary and general aviation airports.

Application Complexity and Rigor

Air/rail projects (including planning) are only eligible if transit rail connections are located on airport property or on property owned by "sponsor" (i.e., publicly owned). Projects are ineligible where they would not be located on airport or publicly owned property. Projects are also ineligible where they would possess "general use" functions that could serve non-airport passengers, regardless of the concurrent benefits to the airport. Only airports selected as members of the National Plan of Integrated Airports Systems (NPIAS) are eligible for AIP funding.

Public/Private Eligibility

Funding is primarily directed to public agencies and public airports; however, private airports are eligible upon meeting certain criteria or upon select designation by the FAA.

Surface Transportation Program (23 USC 133)

Potential Air/Rail Collaborative Planning

The program funds transportation projects linked to any federal-aid highway, including planning activities. It emphasizes highway and rail projects; however, no restrictions appear to exist upon the use of STP funds for intermodal projects, and air/rail planning would presumably be eligible as long as the proposed project incorporated an element of a federal-aid highway as well. Formula funding is used.

Available Funding, Cost Sharing and Continuing Financial Obligations

STP funds are derived primarily from federal fuel taxes that are deposited in the Highway Trust Fund, with additional spending from the general fund as deemed appropriate. Federal share is 80% for the majority of projects, with high federal share for certain safety-related or interstate projects.

Application Complexity and Rigor

Projects must be in accordance with either state or metropolitan transportation planning to gain eligibility for STP funds (23 USC 134 and 135). As stated earlier, projects also must connect in some fashion to a federal-aid highway. Otherwise, STP employs flexible criteria in evaluating projects, with few restrictions attached to any element of the transportation process, including planning.

Public/Private Eligibility

Funding is intended solely for public agencies, specifically state and metropolitan transportation agencies.

Railroad Rehabilitation and Improvement Financing Program (RRIF) (45 USC 822) FRA

Potential Air/Rail Collaborative Planning

RRIF funds improvements in rail infrastructure. Intermodal rail projects—not limited in any fashion, and therefore including air/rail—are specifically noted as a priority. However, the primary focus of the program is capital funding, rather than planning. Yet program guidelines do include the "development or establishment of new intermodal or railroad facilities," and FRA guidelines do not explicitly bar planning activities from program funding. As a result, some flexibility for air/rail planning does exist, although the initial lack of capital projects is an impediment that must be overcome. Finding mechanism is Direct Loans and Loan Guarantees.

Available Funding, Cost Sharing and Continuing Financial Obligations

The program authorizes $35 billion in loan authority to DOT. Loan repayment must be completed within 35 years from the date of the initial loan, although the specific repayment schedule for a given project will be determined on a case-by-case basis.

The program does not have a separate appropriation for direct loans. As a result, the cost to the government of providing the loan is passed on to the applicant in the form of a Credit Risk Premium, which is calculated based upon the projected risk of default.

Application Complexity and Rigor

Projects must meet a number of requirements in order to qualify for RRIF funding. Applicants must demonstrate that the loan is justified by both present and future demand for the proposed project. They must also establish that the obligation can be "reasonably repaid" and that capital operations can be sustained for the duration of the loan financing without recourse to the financing, since operating expenses are barred from the program.

Public/Private Eligibility

Funding can be directed towards both public agencies and private entities, such as railroads. Joint partnerships are permitted, so long as the partnership includes at least one railroad.

Urbanized Area Formula Program (49 USC 5307)

Potential Air/Rail Collaborative Planning

This program funds urbanized areas, either through state or local public agencies, for transportation projects. Planning activities are explicitly sanctioned as legitimate activities. Intermodal projects are not specifically mentioned in the statutory language, but considerable flexibility exists on the part of the petitioning agency, as long as the project is eligible under Title 49. Formula funding is used.

Available Funding, Cost Sharing and Continuing Financial Obligations

Funding levels are determined in accordance with particular formulas. Areas with a population between 50,000 and 199,999 are granted funding solely on the basis of population and population density. Areas with a population of greater than 200,000 are subject to a more complex formula that takes into account various transportation figures (such as bus revenue vehicle miles) as well as population and population density. Maximum federal share of all eligible costs is 80%.

Application Complexity and Rigor

Projects must be consistent with broader state and metropolitan planning processes (for example, 49 USC 5303). Urbanized areas with populations between 50,000 and 199,999 must dedicate at least 1% of their funding to "transit enhancements" as defined by 49 USC 5302.

Public/Private Eligibility

Funding is exclusively directed to public agencies: either metropolitan organizations (for areas with a population greater than 200,000) or an organization to be designated by the governor of the state (for areas with a population between 50,000 and 199,999).

State Block Grant Program (49 USC 47128) FAA

Potential Air/Rail Collaborative Planning

The program funds airport improvement projects by permitting 10 designated states to assume responsibility for the distribution of their allocated funding under the Airport Improvement Program (49 USC 471) in the form of an annual block grant. Eligible projects under AIP are similarly eligible for funding from a state block grant, including eligible air/rail intermodal planning activities, albeit with one additional restraint: "integrated airport system planning" is not an eligible activity. Also, primary airports are barred from receiving funding from a state block grant.

Available Funding, Cost Sharing and Continuing Financial Obligations

Available funding is equivalent to the amount that would have been distributed to the state under the standard AIP process.

Application Complexity and Rigor

States seeking to win a designation as a Block Grant recipient must overcome several hurdles. DOT must determine that the state is capable of administering the block grant properly; that the state possesses a satisfactory airport system planning process; and that the state programming process is acceptable by federal standards.

DOT places particular emphasis upon the state's ability to maintain safety and security standards in the distribution of funding to airport improvement projects.

Public/Private Eligibility

Funding is exclusively directed to state transportation agencies.

Transportation, Community and System Preservation Program (SAFETEA-LU Section 1117), FHWA

Potential Air/Rail Collaborative Planning

The program funds planning and research for comprehensive transportation initiatives, focusing upon the relationship between transportation and the larger community. Program language is deliberately broad, encouraging innovative solutions and creative interpretations that address transportation efficiency alongside environmental impact and economic development. Planning activities are a primary focus of the program. The program operates through competitive grants. Intermodal projects are not specifically mentioned, but eligibility standards are expansive enough to incorporate air/rail planning.

Available Funding, Cost Sharing and Continuing Financial Obligations

The federal share of funding is 80% for selected projects.

Application Complexity and Rigor

Eligibility criteria are broad; few obstacles immediately present themselves, although the program does emphasize "new and innovative" activities.

Public/Private Eligibility

Funding is intended for public agencies, namely state and metropolitan planning organizations, as well as local governments. However, private entities may apply for funding along with a sponsoring public agency.

Projects of National and Regional Significance Program (SAFETEA-LU Section 1301)

Potential Air/Rail Collaborative Planning

The program funds high cost surface transportation projects that possess particular importance to national or regional interests, whether in the realm of economic growth, infrastructure security or technological innovation. The statutory language is deliberately broad, creating significant flexibility in the range of potential projects. Project eligibility under Title 23 qualifies a project for funding under this program (subject to a variety of other restrictions, discussed herein). Planning activities are explicitly included as an eligible component of a given project. Thus, air/rail planning activities eligible for any Title 23 funding program meet the threshold.

Available Funding, Cost Sharing and Continuing Financial Obligations

The federal share of all eligible project costs is 80%. The program operates through competitive grants.

Application Complexity and Rigor

In addition to eligibility under Title 23, proposed projects must meet one of two additional requirements: the total eligible cost of the project must either be at least $500 million or constitute at least 75% of a state's annual federal highway assistance funding. Despite this considerable cost requirement, planning activities are still eligible for funding, as long as they represent the initial phase of a project that has a projected cost in line with the program framework.

Public/Private Eligibility

Funding is exclusively directed to state transportation agencies, although the size and complexity of eligible projects creates a situation in which coordination with local planning agencies and private entities is encouraged.

Efficient Environmental Reviews for Project Decision Making Program (23 USC 139), FHWA

Potential Air/Rail Collaborative Planning

The program funds federal, state and metropolitan transportation agencies that are obligated to prepare an environmental impact statement under NEPA in order to ensure that the environmental review process is conducted in an appropriate time frame that does not undermine the proposed project. Intermodal projects that are eligible for funding through 49 USC 53 are eligible for funding under the program, and "transportation planning activities that precede the initiation of the environmental review process" are eligible for funding as well. Thus, air/rail planning activities that meet the threshold of Title 49 are eligible for funding to assist in the completion of the environmental review process. The program operates through competitive grants.

Available Funding, Cost Sharing and Continuing Financial Obligations

Available funding is at the discretion of the Secretary of Transportation, for the amount deemed necessary to support "activities that directly and meaningfully contribute to expediting and improving transportation project planning and delivery . . . for the projects . . . participating in the environmental review process." There are no specific appropriations for this program; the Secretary of Transportation is permitted to fund it from "funds so made available under this title [23] or such Chapter 53 [of title 49] to affected agencies . . . participating in the environmental review process. . . ."

Application Complexity and Rigor

Projects must be "subject to the environmental review process established under this section and for which funds are made available to a State under this title or Chapter 53 of Title 49."

Public/Private Eligibility

Funding is exclusively directed towards public agencies.

Transportation Pilot Programs

The federal government may create, at its discretion, transportation pilot programs to provide a limited amount of funding to a project in the hope of testing the project's efficacy. These pilot programs can support air/rail intermodal planning if the structure of the program renders the planning activities eligible. The FAA's Sustainable Master Plan Pilot Program has been conceived with the potential to fund air/rail planning. Pilot programs can be a useful source of funding for a specific project, as the programs often encourage flexibility in project design, but the limited funding at their disposal can produce an extremely competitive application process. Furthermore, pilot programs cannot support large-scale air/rail planning efforts and lack the resources to sustain anything more than a solitary project. Thus, while pilot programs can be useful for creative air/rail planning activities that have the potential to become models for future use, they have limited utility in supporting air/rail planning of a more substantial nature.

Capital-Only Programs

A final noteworthy—and unfortunate—feature of the federal government's intermodal transportation funding structure is the prevalence of programs that restrict their funding support to capital expenditures. While some programs declare a wide range of activities associated with transportation projects to be eligible, including planning activities, many other programs explicitly establish that only capital expenditures are qualified to receive federal funding. This removes a significant source of federal transportation funding from consideration for air/rail intermodal planning. For example, two of the three funding programs established by the Passenger Rail Investment and Improvement Act of 2008—the High-Speed Rail Corridor Development Program and the Congestion Relief Program—both restrict their eligibility to capital projects. Such language is common among federal transportation programs and represents an impediment to federal support for state and local intermodal planning.

How State and Local Programs Work Together with Federal Planning Programs

Federal funding mechanisms for air/rail intermodal planning exist, but in order to be fully utilized, they depend on state and metropolitan transportation agencies to develop creative processes. Even with agency flexibility, the lack of emphasis among federal funding programs for intermodal planning and the absence of a rational structure for distributing funding to intermodal projects will place significant obstacles in the way of any comprehensive effort to acquire federal assistance for air/rail planning. In this context, state and metropolitan agencies seeking funding for air/rail intermodal planning may have no choice but to pursue multiple funding paths, based upon the circumstances of the project or plan. The task of merging these funding paths to create a truly integrated system of intermodal transportation facilities will be difficult, but given the current structure of federal assistance creative solutions may have to be developed at the state and local level.

The 24 examples of the intermodal planning reviewed in this report are presented in Table 9-1, in the order in which they appear in the report. In most cases, the planning efforts have been funded by a combination of federal and non-federal sources. This dependence of several funding sources parallels what is known about the funding projects in general,

Table 9-1. Combinations of federal and non-federal funding used in planning 24 air/rail projects.

	Project	Dominant Federal Program	State / Local Role in Planning Process
Chapter 3, which included			
1	BWI to Amtrak	NECIP	Minor
2	Burbank to Amtrak	Amtrak	Airport funding consolidated rental car center and walkway
3	Milwaukee Airport to Amtrak		Airport runs shuttle bus
4	T. F. Green to MBTA	Grants from FHWA	See case study in this Chapter
5	Newark Airport to Amtrak & NJ Transit	PFC (present), Unknown (future)	PANYNJ Revenues
Chapter 5, which included			
6	The Northeast Corridor Improvement Project	NECIP	Will increase under PRIIA
7	NEC Future	Mandated by PRIIA, included in HSIPR	No local funds
8	The Northeast Corridor Commission	Mandated by PRIIA	Will increase under PRIIA
9	The Amtrak Business Plan	Internal	Internal
10	The Regional Plan Association	None	PANYNJ
Chapter 6, which included			
11	Chicago O'Hare Master Plan	FAA Planning Funds	Internal
12	Midwest High-Speed Rail Association Plan	No	Private Donors
13	The Midwest Regional Rail Initiative Rail	FRA, approved HSR Corridor	Major role from nine states
14	SNCF HSR Proposal to FRA	None	Private Company
Chapter 7, which included			
15	The Regional Aviation Systems Plan Analysis	FAA Planning Funds	MPO Participants
16	The Planning Process within the SFO	Unknown	Airport internal funding
17	The California High-Speed Rail Authority	FRA	State bond issues
Chapter 8, which included			
18	The Destination Lindbergh Planning Study	MPO Planning Funds	MPO local share
19	The Regional Airport Systems Plan	FAA Planning Funds	Airport operating funds
20	Airport Multimodal Accessibility Plan	MPO Planning Funds	MPO local share
Chapter 12, which included			
21	Denver International Airport Commuter Rail	FAA Planning Funds	Airport internal funding
22	Miami Intermodal Center	TIFIA	State project funds, state investment bank
23	Orlando Airport Intermodal Terminal	FAA Planning Funds	Airport internal funding
24	JFK to Jamaica	PFC	PANYNJ Internal Funding

rather than funding the planning efforts. The American Association of State Highway and Transportation Officials (AASHTO) reports that, for transportation expenditures as a whole, the states raised $80.5 billion (44%), the local governments raised $66.4 billion (36%), while the federal government raised only $37.9 billion (20%) in their study year (2004).

In many cases the role of the federal government in planning is more dominant than it is in actual project implementation and construction. A review of Table 9-1 suggests that the great majority of planning activities covered in this report were, in fact, undertaken under encouragement of a federal planning program or requirement. Thus, initiative for actions in this area most often stems from existing planning programs encouraged or mandated by federal action and regulation. Early identification of airport access needs could come from the Metropolitan Planning Organization, whose purview is indeed multimodal and multi-jurisdictional. The MPOs, while managed locally, were developed in response to federal mandates, and are funded with federal dollars.

Two Case Studies

In order to explore the complexity of project funding mechanisms for projects actually built, Chapter 9 presents two case studies. The first, the Miami Intermodal Center (MIC) adjacent to Miami International Airport (Figure 9-2) had early funding from a FHWA TIFIA loan, a condition of which was the creation of annual reports to the public describing progress on, and alternations to, the budget established at the time of the loan approval, which included a line item for preliminary engineering and environmental documentation. The second, the Interlink Project at T. F. Green Airport, which serves Providence Rhode Island, received its early major funding support from an "earmarked" grant from the Federal Highway Administration, with a variety of funding mechanisms added over time.

Figure 9-1. The planning for the Miami Intermodal Center was partially funded by a federal TIFIA Loan, which will be repaid from a variety of state and local sources. Source: Miami Intermodal Center, Florida DOT.

Figure 9-2. Projected revenues from the Consolidated Rental Car Facility play a key role in the strategy to repay the TIFIA Loans used to construct the Miami Intermodal Center. Source: Florida DOT Miami Intermodal Center.

Case Study: The Miami Intermodal Center

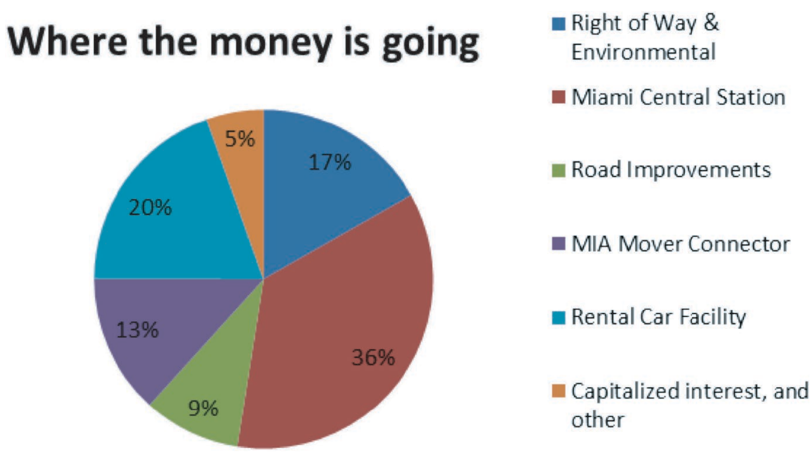
The Miami Intermodal Center (Figure 9-1) is the largest single intermodal project undertaken in the United States. With a capital cost of somewhat over 2 billion dollars, this is larger than the JFK AirTrain project, estimated to cost $1.9 billion, or the $1.5 billion for the SFO BART Extension, both more than a decade earlier (Gosling et al., 2012).

There are four major component elements of the MIC project. The largest element, at over $700 million, is the Miami Central Station, where Amtrak is now scheduled to provide service. The Central Station facility has both a commuter rail/intercity rail station and a rapid transit station, with locations for bus and taxi services. The cost for Metrorail and Metrobus facilities is $518 million, including $52 million for the people-mover within the station and $152 million for the rest of the station facilities (Florida DOT 2012).

The consolidated rental car facility costs somewhat under $400 million with the people-mover connection at about $270 million; road improvements in this budget are under $190 million. As shown in Figure 9-3, these component costs do include costs shared over the entire project, including right-of-way and environmental site preparation. (The characteristics of the air/rail connection are briefly discussed in Chapter 12 of this report.)

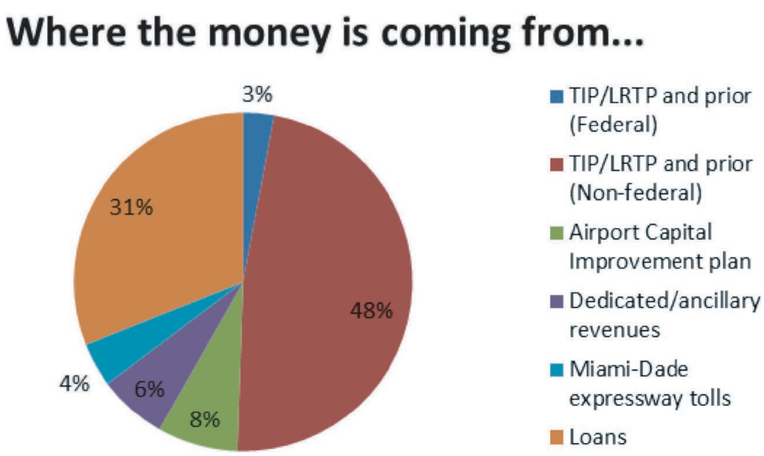
The history of the evolution of the funding program includes the receipt of $433 million in TIFIA loans. Parts of those loans have been repaid, and partly restructured to benefit from loan programs now available within the state government. Figure 9-4 shows the funding mechanisms defined by the Florida DOT in their year 2012 report on expenditures associated with FHWA's original TIFIA loan agreement.

FDOT's 2012 analysis stresses the role of projects funded through the established Transportation Improvement Plan, and the Long-Range Transportation Plan, together comprising about half of this budget. This present analysis by FDOT



Right of Way & Environmental	$339,524,000
Miami Central Station	$721,978,000
Road Improvements	$186,651,000
MIA Mover Connector	$269,762,000
Rental Car Facility	$395,049,000
Capitalized interest, "other"	$109,841,000
Total	***$2,022,805,000***

Figure 9-3. Project components of the Miami Intermodal Center.



TIP/LRTP and prior (federal)	$59,775,000	3.0%
TIP/LRTP and prior plus other state	$962,757,000	47.6%
Airport Capital Improvement plan	$155,196,000	7.7%
Dedicated revenues from RCC	$113,496,000	5.6%
Miami-Dade expressway tolls	$86,468,000	4.3%
Ancillary revenues	$17,783,000	0.9%
TIFIA loans plus capitalized interest	$312,305,000	15.4%
State transportation trust Fund loan	$245,140,000	12.1%
State Investment Bank Loan	$69,885,000	3.5%
Total	*$2,022,805,000*	*100.0%*

Figure 9-4. Funding mechanisms for the Miami MIC (2012).

shows that the overwhelming majority of those programmed funds were non-federal in nature.

It is difficult to define the exact cost of "planning" a $2 billion transportation project with a wide variety of sub-elements within this overall budget. The Research Team knows that of the $1.35 billion total project budget included in the July 1999 TIFIA application by the Florida DOT, the sum of $22,737,000 was allocated to "PE, Feasibility Studies and NEPA." That number fell to under $22 million in the 2002 budget, where it remained until 2012. Another line item called "Design-2" authorized $123,426 for design activities, which had been lowered to $97,225 million by 2012.

A Case Study of State Funding: T.F. Green Airport and Interlink Intermodal Facility, Warwick, RI

T.F. Green Airport is a primary commercial service airport, owned by the State of Rhode Island and operated by the Rhode Island Airport Corporation (RIAC), which manages all publicly owned airports within the state. In 2010, T.F. Green Airport served approximately 3.9 million passengers with over 220 daily aircraft operations (i.e., aircraft landing or departing) (T.F. Green Airport 2010). It occupies 1,100 acres of land and is located in the City of Warwick, RI, six miles south of the City of Providence. The airport is accessible via several major regional and national roadways, including Interstate Highways I-95 and I-295, U.S. Route 1, and State Routes 10 and 37.

As discussed in Chapter 3, the Interlink is an intermodal transportation facility, constructed about 1,500 feet west of the airport, which connects to the airport via a covered skywalk with moving walkways. The facility includes a consolidated rental car facility, commuter car parking, and a heavy rail train platform on the Amtrak-owned right-of-way of the Northeast Corridor line used for commuter service between Wickford Junction, Warwick, Providence, and Boston. The rail platform is integrated with the 2,500 parking space, six-level parking garage with a rental car facility that houses all airport rental car operations, including storage, washing, and fueling facilities. The intermodal facility is on a former chemical distribution brownfield site.

In the late 1980s and early 1990s, state and local officials began discussing the need for a rail station south of Providence along the I-95 corridor. Congestion on I-95 and the economic development of the area south of Providence were important considerations when considering a rail link. Importantly, in 1992, the City of Warwick's elected officials proposed a train station next to the airport (Lord 1992).

Initially, the plan was to build a train platform near the airport to accommodate an extension of Massachusetts Bay Transportation Authority (MBTA) commuter rail service from

Figure 9-5. The Interlink project at T. F. Green is served by MBTA commuter rail. Source: Rhode Island Department of Transportation–Intermodal Planning.

Providence to Warwick (Figure 9-5). MBTA service between Boston and Providence has been in existence since 1988. The plan expanded to develop an intermodal facility to centralize all existing and future ground transportation services, including Amtrak, commuter rail, Rhode Island Public Transit Authority (RIPTA), intercity bus, and rental cars.

The Rhode Island Department of Transportation (RI DOT) conducted a Rail Corridor Feasibility Study in 1994 to determine the potential for the use of existing rights-of-way for public transportation facilities and services using light rail, commuter rail, or busway technologies (Rhode Island Department of Transportation 1994). RI DOT analyzed nine rail corridors in the state and selected six with the best potential for public transportation. The Amtrak Northeast Corridor Shore Line was determined to provide the easiest opportunity to develop a fixed-guideway line in Rhode Island and the study recommended that the development of commuter rail service on the Amtrak Shore Line could proceed incrementally. The study was funded through a Federal Transit Administration (FTA) grant program.

The story of the early development has been chronicled in an article in *Public Roads Magazine,* written with the participation of Steven Devine, RI DOT's Chief of Intermodal Planning, whom the Research Team interviewed to follow up on key aspects of that article.

In 1997, former Governor Lincoln Almond, and then-Mayor of Warwick, Lincoln Chafee, proposed the airport train station idea and estimated a price tag of $15 million (Liberman 1997). By the next year the price was estimated at $25 million, including a people-mover to connect to the train station. In 1998, Congress authorized $25 million for the Rhode Island Integrated Intermodal Transportation facility with an earmark in the Transportation Equity Act for the 21st Century (Public Law 105-178).

Subsequent to the Congressional authorization, the RIDOT submitted a proposal and environmental assessment for the Warwick Intermodal Station to the Federal Highway Administration (FHWA) to construct an Amtrak and commuter rail station in the Hillsgrove area of the City of Warwick along the Northeast Corridor (NEC) and provide a people-mover connection between the train station and T.F. Green Airport. The FHWA issued a Finding of No Significant Impact (FONSI) in 1999 (Rhode Island Department of Transportation 1999). On March 27, 2001, and again on February 1, 2002, RI DOT submitted environmental re-evaluation to FHWA for project change from a surface parking lot with a stand-alone station to a multi-level parking garage, station, and consolidated rental car facility. FHWA accepted the findings that additional environmental impacts could be mitigated with the actions described in the re-evaluations (Rhode Island Department of Transportation, Federal Highway Administration 2001).

The proposed project was included in the State's 2001 transportation plan (Rhode Island Department of Administration 2001) and the RI DOT's July 2001 South County Commuter Rail Service Operations Plan (South County Commuter Rail Service 2001). The South County Operations plan recommended the extension of commuter rail service, provided by the MBTA, 20 miles south from Providence to Wickford Junction. The FTA issued a Finding of No Significant Impact to the South County Commuter Rail Environmental Assessment on February 26, 2003 (Doyle 2003).

Complicating the land acquisition procedure was that RIDOT was to own the land where the airport and intermodal facility are situated, while Amtrak owns the tracks where MBTA transit was to run the commuter service. In addition, the RIAC was to be in charge of operations. The difficulty of obtaining agreements among these entities challenged the project from the beginning, according to the Research Team's interviews.

A combination of state and federal funds, bonds, customer facility charges, and revenues were slated to be used to finance the facility. The RIAC had planned to invest $130 million in the people-mover and a garage that would consolidate rental car facilities and solve parking limitations at the airport. But, the events of 9/11 caused all parties to be concerned about their ability to pay for the facility.

Governor Donald L. Carcieri took office in 2003 and renewed negotiations with the various stakeholders. Also in 2003, RIDOT proposed the skywalk in place of the people-mover to lower operational and maintenance costs. By then, RIDOT had made all land purchases for the project. In 2005, the new United States surface transportation law, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, Public Law 109-59), authorized RIDOT to proceed with negotiations with Amtrak to extend the MBTA commuter rail service south of Providence to Warwick and North Kingstown.

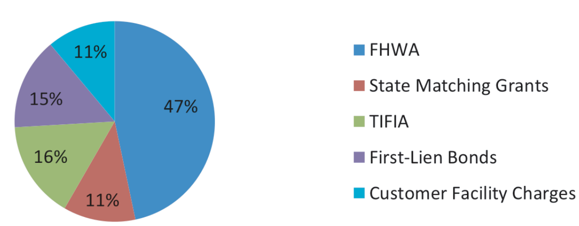
As shown Figure 9-6, FHWA summarizes that funding for this project included about 155.7 million in federal and state matching grants, with a combination of bonds, loans and customer charges at $111.2 million. The RIAC and RI DOT closed the TIFIA loan of $42 million in FY 2006. The TIFIA loan is secured by customer facility charges imposed by RIAC on people renting cars at the airports and payments by the rental car companies for tenant improvements in the intermodal facility.

With the pieces in place, and the General Assembly and rental car companies on board, the governor broke ground for the new train station in July 2006. The breakthrough with the rental car companies came when they agreed to relocate their operations from the airport into the new facility and to collect customer facility charges to subsidize operations and debt repayment for the project. RIAC led the effort to enter a new concession agreement with all nine rental car agencies serving T.F. Green. This was a challenge for RIAC, as the nine agencies do not speak with a unified voice.

Construction of the project began in fall 2007 and the facility was opened in October 2010. The first MBTA trains arrived for revenue service in December 2010.

The planning, construction, and operation of the intermodal facility required strong public-private partnerships across multiple jurisdictions. According to RIDOT Director Michael P. Lewis, construction is proving to be the easy part. Quoted in *The Providence Journal* July 17, 2009, he said, "What people can't see is the jigsaw puzzle of Federal and State agencies, agreements, financing bundles, and engineering

Funding Programs, T. F. Green Aiport



Funding Mechanisms	*Amount*
FHWA Grants	$124,600,000
State Matching Grants	$31,100,000
TIFIA Loans	$42,000,000
First-Lien Bonds	$39,600,000
Customer Facility Charges	$29,600,000
Total Funding	***$266,900,000***

Figure 9-6. Funding mechanisms used by Rhode Island DOT.

logistics that had to be pieced together. The $267 million burden is being shared by RIAC, the Federal Government, and the State through a combination of bonds, grants, and revenue streams."

Partners include RIDOT, Economic Development Corporation (EDC), RIAC, the Rhode Island Division Office of FHWA, Amtrak, the MBTA, the FTA, FRA, the City of Warwick, and rental car companies.

RIDOT continues to explore enhanced rail connections at the Interlink today. Alternatives include expanded MBTA commuter rail service to Providence and Boston, an in-state rail shuttle (Diesel Multiple Unit) service between Warwick and Providence, and adding an Amtrak intercity rail stop at T.F. Green/Interlink. Amtrak has recently agreed to revisit the concept of developing a NEC Regional Service station stop by undertaking a ridership demand and marketing analysis. RIDOT has estimated a capital cost of approximately $100 million for new siding, interlocking, electrification, and a station building (Devine 2012).

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CHAPTER 10

Analytical Tools and Data Sources for Policy Planning

Introduction and Structure

Introduction: Good Practices and Data Gaps

In the process of undertaking the case studies in the earlier phases of the project, the Research Team explored many data sources and interviewed several practitioners associated with the integration of air and rail planning in the United States and Europe. This Chapter presents a summary review of the status, quality, and availability of essential data; it summarizes key positions of those interviewed about data and tools, and presents a description of the key gaps in that data—some of which will be dealt with in the concluding chapters of this report, and some of which will remain significantly beyond the scope of this research.

Structure

First, Chapter 10 outlines a series of general observations about the attitudes and reactions of practitioners interviewed. Second, a brief review of selected sources of data in Europe is presented, emphasizing the range of their use for multimodal and intermodal analysis in the planning process. Third, similar sources in the United States are briefly reviewed, revealing the extent to which data types are and are not made available to the American analyst/planner in a manner similar to that observed in the European context. Fourth, this section reviews the substantive gaps that seem to exist, despite the considerable efforts summarized in the earlier sections of the report. This is followed by a summary table, which takes the form of a "checklist" of available data and methods, and their present status in existing and proposed research programs. This final section is a prelude to the presentation in Chapter 11 of the new modeling activity undertaken in the project to address some of the largest gaps in the tools available to practitioners examining combinations of air and rail.

Differing Views of the Urgency of the Problem of Lack of Intermodal Tools

In undertaking the case studies for this report, multiple experiences were found in identifying the quality of the data, the availability of tools, and the gaps revealed in the process. In summary, there was a major difference between the orientations of day-to-day practitioners in the field, and those of professionals vested with the responsibility to understand the public policy implications of decisions and policies. In general, those practitioners interviewed who were involved in operational management decisions had found "workarounds" to deal with the reality that multimodal data is usually not available or not shared across jurisdictional boundaries.

At the Amsterdam Airport, the Research Team was told, "They run their operations, we run ours." In Chicago it was found that, in absence of knowledge of how and if HSR would come to Chicago O'Hare International Airport, the management had developed a workable location for a new rail station that might, or might not, be developed. In short, airport planners there had figured out how to manage the contingency that rail policies might change, without endangering their need to continue with the planning of the airport. In interviews in San Diego, there was an acknowledgment that more data would be produced in the ongoing regional studies about the potential for rail to alter plans for the airport reconfiguration, but the parties agreed that the scale of inter-relationship was not strong enough to impede progress on making key capital investment decisions.

Importantly, in all of the interviews, no practitioners stated that the lack of optimally integrated data was keeping them from making the immediate decisions they need to make. Managers involved in market research for Amtrak have undertaken market research activities which support the immediate need for corporate management decisions, with or without optimal integration with data stemming from aviation planning. The managers of the private airlines have access to propriety programs that help guide their investment and service planning functions—without the detailed information about rail available to Amtrak managers. All of these are examples of how the managers in each mode have carried out their fiduciary responsibilities, without waiting for a next generation of improved intermodal data. At the same time, those interviewed agreed that better data and methods—if they were available—would improve decisions.

However, this must be sharply contrasted with the views of a smaller number of researchers and planners who were tasked with preparing truly multimodal and intermodal analyses. By far, the strongest feeling of frustration encountered was expressed by the authors of the path-breaking multimodal and intermodal study, "Upgrading to World Class: The Future of the New York Region's Airports" for the Port Authority of New York and New Jersey (Zupan et al. 2011). In the interview, the authors expressed concern about their ability to undertake good market analyses about the 100 to 400 mile trip with no knowledge of the number of vehicle trips in the corridor, and no publicly available data on the corridor's long-distance rail volumes. The report that was created, however, must be seen as a model of how solid analysis may be undertaken in a climate of less-than-perfect data.

> *A major concern expressed to us by the authors of the "Upgrading to World Class" study of the Regional Plan Association was the lack of a publicly available, citable data source of long-distance rail in the corridor; in addition, concern was raised over the absence of documentable vehicle flow data.*

Similarly, those involved in regional and system-wide multimodal analyses felt a far greater sense of urgency about the need to improve the quality of both the data and the tools available for integrated multimodal and intermodal analyses. Thus, those involved in the formulation of good public policy in northern California, for example, explained to us the urgency of improving the quality of basic data and the need to make that data available for all stakeholders in the political process. Senior agency officials at the public agency that managed the creation of the model were concerned that the major demand analysis resource available to support policy decisions about air and rail in California requires days of computation time to analyze a single scenario.

Importantly, within the modally based organizations, there was a core of transportation professionals who understood that new demands were about to be made on the transportation planning process, and that those demands would ultimately require the improvement of the tools and data sources needed for true multimodal and intermodal analyses involving both air and rail together. The exceptionally broad multimodal emphasis of the "Upgrading to World Class" report was developed in the aviation department of a public agency. The need to explore the possible role of rail in a feeder mode has been advocated (among other innovative strategies) at the highest management level at the San Francisco International Airport; the lack of evident consideration by rail officials of an on-airport HSR station at SFO is correlated with generally weak methods to analyze the potential for the role of rail as a feeder mode to air. The commencement of major environmental impact analyses on both east and west coastal areas has made rail decision makers aware of the need for commonly shared data, available to all stakeholders in the processes mandated for several decades by the National Environmental Policy Act (NEPA) of 1969. In short, practitioners who place high value on the creation of better tools for intermodal analysis were found; also, there needs to be more public availability of key data to support the application of analysis tools.

Other Concerns from the Project Interviews

Most of the interviewees did not focus on the quality of transportation modeling as a major concern. In one of the case studies, the strongest statement about the quality of ridership forecasts was that two proposing organizations had created two separate demand forecasts, and that this was a political negative for the advocates of HSR. Anecdotally, the quality of either of the two forecasts was not cited as a concern. But, while most of those interviewed did not focus on the quality of the models per se (interviews in northern California and New York being the clear exception), there are still anecdotal reports about problems with the results of the process in general.

One of the most important of these cases was in San Diego, where the question concerned the variation in HSR ridership in response to variation in the location of the southernmost terminal in the project. This was a rare case where the output of the planning process varied between studies undertaken contemporaneously. For those working with the SANDAG-based planning processes, terminating the rail line at a major intermodal transfer center adjacent to the airport was determined to be the preferred alternative. The airport-based RASP, on the other hand, suggested that more rail riders would be generated by a more central downtown location, by the present Santa Fe terminal—it also suggested that diversion from air to rail would be more pronounced with the station located away from the airport. This level of difference implies there is a need to improve the quality of analysis tools applied at this geographic micro-level.

This all suggests an underlying skepticism about the quality of the rail demand forecasting process, whether or not it was phrased in these terms during the interviews. On the one hand, it could simply be posited that a statewide demand modeling process might not be the best method to resolve a matter of station location in a scale of under 10,000 feet. The credibility of the demand modeling process is challenged by a lack of understanding of the importance of key variables (e.g., access time by car, access time by bus, access time by taxi, etc.) in both the decision to forgo air for rail in a total trip (e.g., competitive mode) and the decision to forgo air for rail as a first segment of a trip that later includes long-distance air (complementary mode). The reader is referred to a more general discussion of the adequacy of the airport access modeling process in *ACRP Synthesis 5: Airport Ground Access Mode Choice Models.* That report includes a discussion of the application of various modeling processes (airport specific vs. general) in the regional planning process, but the scope of the Synthesis study did not address the issue of substitution of long-distance rail travel for air travel, either for an entire trip or in place of a short-haul feeder segment.

Multimodal Planning Documents and Data Sources in Europe

In the ACRP project research in Europe, several good examples of data analysis that were truly multi-modal in nature were found, which result in publicly available data to support public policy debates. However, in almost all cases, documents created in Europe suffered from the same lack of automobile flow data as in the case of the United States. In Europe, there is no single strategy for attaining multi-country highway vehicle trip table data. The innovative project "KITE" (Knowledge Base for Intermodal Transportation in Europe) supported early studies in Switzerland, Portugal, and the Czech Republic (Axhausen 2010) with the hope of establishing prototypical applications that could be applied on a multi-national basis. But European decision makers have no plans to undertake any continent-wide survey on the scale of the earlier American Travel Survey (Bureau of Transportation Statistics 1995). In short, this section of the report will provide some anecdotal examples of multimodal data collection and data sharing; it does not conclude that fundamental issues concerning the cost of collecting highway vehicle flow data have been solved in Europe.

Multimodal Demand Forecasts by the UIC (International Union of Railways)

A brief review of the available literature on multimodal demand in Europe shows that much of the case-by-case (corridor-by-corridor) analysis was largely based on one seminal study. As discussed in Chapter 2, the study was commissioned by the UIC (International Union of Railways) and provides a corridor-by-corridor prediction of market share between air, rail, and auto. The document, titled "Passenger Traffic Study 2010/2020" (Intraplan et al. 2003) provides base data that set a multimodal context for understanding the role of rail and the role of aviation in Europe (Figure 10-1). The data can be purchased from the UIC in DVD format at a modest cost (under $200). There is currently no comparable document available about intermodal demand in the United States; recent work by the FHWA is noted herein. A major multi-disciplinary effort like this helps to establish the base case against which a wide variety of policy scenarios can be tested, and it provides a sense of scale to the question of the impact of HSR on other modes.

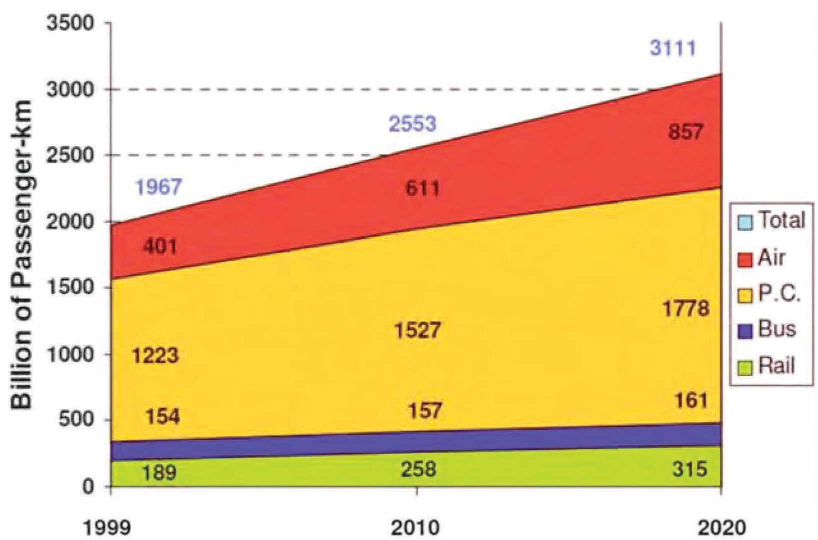


Figure 10-1. Multi-modal demand for long-distance travel in Europe is documented in a major study for the International Union of Railways (UIC), and is readily available to the public. Source: Intraplan Consult GmbH et al. 2003.

The effort to build one model of long-distance travel behavior by all modes was accomplished by merging forecasting techniques of several major research organizations. The demand modeling process based trip generation on such factors as "GDP, population, employment development, car ownership, market regulations, user cost, transport policies" (Intraplan et al. 2003) and changes in the nature of supply by modes. They note that the macro process "relies on projecting past pattern on the country level to the future by time series analyses, whereas the micro models calculate the demand effect on each origin-destination link, taking into account the development of structure in traffic zones and supply factors particular to each mode of transport." The demand response to new rail services were forecast by combining the results of two different micro models, the German Intraplan model, and the French M.A.T.I.S.S.E model developed at INRETS.

- An observation from Chapter 2 is that having a common vision of overall trip making, whether on a corridor-by-corridor basis, or for a continent as a whole, expressed in a multimodal context can serve as anchor from which more specific analysis can be based. While forecasts of aviation demand growth are readily available in the United States, publicly available forecasts of growth in long-distance travel by highway and rail have up until now been lacking.

The EU Study of Air and Rail Competition and Complementarity

The European Union's Directorate of Transportation and Mobility made a major contribution to the quality of the public dialog about the relationship between rail and air by commissioning its innovative study, Air and Rail Competition and Complementarity (SDG 2006). A key aspect of this EU study was the creation of a model of air/rail mode share that was purposefully simple and transparent; its authors note that "the ultimate objective of the model is to be able to test scenarios for the development of short-haul transport over the next ten years" (SDG 2006). Figure 10-2 illustrates how the results of this innovative study were shared with the public, taken directly from a PowerPoint presentation by the project manager (Rizzo 2007). As discussed in Chapter 4, the model has four elements: time-related factors; price; access time and cost; and a set of more subjective factors. The model allows the forecasting of market share for eight corridors in 2011 and 2016, and the calibration year of 2005.

- Reviewing the content of Chapter 4, it can be observed that the creation of a location-specific model (i.e., calibrated with the data from eight European corridors) allows the analysis of a wide variety of public policy scenarios. This was accomplished by overcoming the fact that several major railways did not volunteer to share their base data, and the analysts were forced to work around this condition. The result is a publicly available data source based on an understandable and largely transparent methodology, which can be used to support a public dialog and debate.

French Studies of Intermodal Connections

Of particular merit here are the series of studies undertaken by the "Executive Air Transport" of the French Directorate General of Civil Aviation (DGAC), which has conducted a survey every 3 years to better understand the relationship of HSR to longer distance aviation at Charles de Gaulle and Lyon

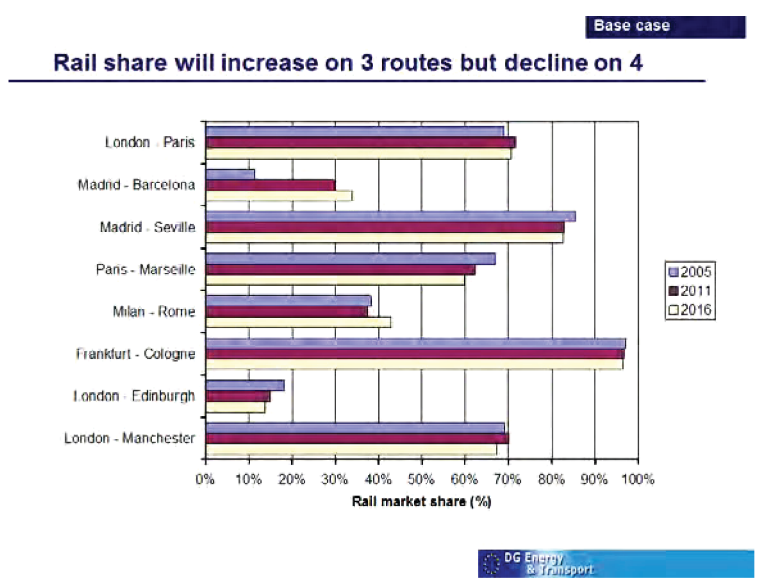


Figure 10-2. The EU has developed a model which is simple and transparent, supporting a public dialog about policy options. Source: Rizzo presentation, 2007.

Airports in France, including a survey undertaken in the year 2011. These studies provide publicly available data about such details as the wait time between train arrivals and air departures at CDG, which between 2005 and 2008 actually worsened to an average wait of 3 hours and 40 minutes. The extensive market research about the intermodal connection has been made available to the public, with summaries like Figure 10-3 on the DGAC website (DGAC 2009). This screenshot from the website presents the main reasons that air travelers selected the train over air feeder service; after cost, the second-highest reason was the lack of an air alternative.

Had such a research program existed in the United States, a government agency would have been able to document the number of long-distance rail riders at Newark or BWI, provided market research about how they purchased their ticket, and analyzed what factors would cause them to increase the use of the integrated service.

Knowledge Base for Intermodal Transportation in Europe (KITE)

The question of how to collect accurate descriptions of long-distance travel, particularly for modes where the traveler does not have to purchase a ticket is equally problematic in Europe. While there is a general belief that the EU would not support (or even encourage) a top-down approach, where data collection is forced on the member states, various research efforts have been undertaken to create what might evolve into a decentralized, or distributed, approach to data collection. The KITE study first reviewed the results of various national efforts to estimate the amount and location of longer distance travel in Europe. An additional element of the project developed "a survey methodology suited to capture long-distance travel in its complexity" (KITE Project) and apply that method in three countries. The project proposed "uniform design of intermodal passenger travel surveys" for use in later efforts. The logic is that, as individual European nations voluntarily chose to collect long-distance travel data, data collection would happen in a manner that could later contribute to the creation of a continent-wide database.

In short, accurate sources of data about the origins and destinations of long-distance, multi-national travel by private modes (e.g., car, van, truck, and motorcycle) do not seem to exist either in Europe or in North America.

Simulated Multimodal Demand in Europe

This report contains the first major United States application of recent academic and consulting teams' research in the simulation of major flows of long-distance travel, including access to and from airports. To develop the descriptions of a "natural" rail marketshed for each airport, the Research Team found that many airports did not have detailed descriptions of their success or failure in competing for wider geographic markets, or simply did not wish to share it with the public; thus, a newly developing process of simulating passenger flows affecting these airports was examined. Using the tool "x-via web" developed by MKMetric and jointly marketed with STRATA Consulting, a simulated answer to the question of airport ground origins was provided. As described by its developers, "x-via web currently covers all of Europe and focuses on air passenger transport for more than 2350 regions plus 1150 airports worldwide with land-based feeders and the air links connecting them" (Travelmatrix 2011). This information was used to create map-based summaries of the geographic scale of origins of airport users in seven major airports. That information reveals, for example,

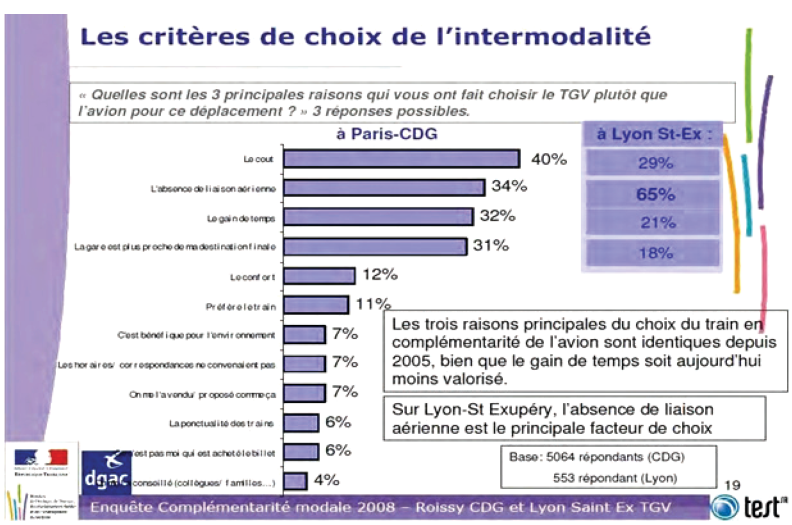


Figure 10-3. The French Civil Aviation Agency (DGAC) has published data on the use of HSR as a feeder mode. Source: DGAC.

just how different the marketshed for Zurich is from Frankfurt, and how different that of Frankfurt Airport is from all other airports in Europe.

- It would be highly desirable to have estimated airport origins (built up from actual ground access surveys when possible) available to American practitioners on a systematic basis. Reasonably, these would be an amalgam of the best available data, the quality of which would vary by location.

Use of Single Mode Data in Multimodal Analysis: The Civil Aviation Authority, London (CAA)

An ongoing source of support for the researcher in the United Kingdom is the continuous process of surveying that occurs at the major London airports and all others in the United Kingdom; the results are made available to the public via the CAA. The process is highly unusual in that the surveying at UK airports is continuous, with reports issued yearly by the CAA. A massive amount of data is made available through prepared tables via their website, with individual queries answered for a small cost, starting at under $200 (Civil Aviation Authority 2011).

Table 10-1 is presented to demonstrate the level of detail of airport market data that is routinely made available to the public by the CAA in London. By way of example, Chapter 2 noted that Manchester Airport has developed a long-distance (beyond metropolitan) rail system directly serving the airport in the feeder mode. Any analyst can access the characteristics of the marketshed supporting Manchester Airport by downloading a pre-made table. Table 10-1 shows that about 34% of those using the airport are from greater Manchester, with 66% from outside the metro area. Leisure travelers, and not business travelers, would dominate the market for longer distance rail, as the airport pulls its leisure travelers from a wider geographic area than its business travelers. Only 29% of United Kingdom leisure travelers are coming from the metro area; of those non-residents coming to the area for business, 41% have destinations in the metro area. Analysts who seek more information (e.g., the same categories with access broken down by mode) can purchase specific tabulations for a modest cost.

American Sources of Multimodal Data

American Aviation Data

The United States Department of Transportation (US DOT) has an active program of sharing with the public its available data about air travel. Available in many formats, the quick airport summary is shown in Figure 10-4, describing flows at Newark; the volumes of air travelers on the airport's ten most important airport pairs are shown on the bottom right on the figure (Transtats 2011).

The DB1B Origin-to-Destination (O-D) data available from the US DOT takes the form of a massive dataset, and can only be managed through tools capable of managing large amounts of data simultaneously. However, a good introduction to the O-D data can be found in the set of tables included in *ACRP Report 31*, which presented this information for all the major airports in the Northeast Corridor and in California. These tables present both O-D data from the DB1B system, and segment volumes from the T-100 system. Both the DB1B and the T-100 data are made available through the Bureau of Transportation Statistics, and their use is discussed further in the discussion of the ACRP Project 03-23 Air and Rail Simulation Model, presented in Chapter 11.

Improvement in Forecasting Aviation Data: Future Air Traffic Estimator (FATE)

In the longer term, the ability to merge the planning processes for air with those for auto and those for rail will require a standardization of procedures so that common assumptions can be made as input to the travel demand calculations. The "four-step" metropolitan transportation planning process is multimodal in nature, and its methods have largely been applied on a statewide level. Such methods include common assumptions about how travel demand is associated with demographic factors, including income and employment levels. However, the process of predicting aviation demand has to date been accomplished through a separate—and incompatible—mode-specific process. Then, in the seminal document titled "Capacity Needs in the National Airspace System—2007–2025" (referred to as the "FACT 2" report) the authors revealed a transition to an additional system for longer term forecasting (MITRE 2007). The method, known as the FATE, was different from previous forecasting methods used by FAA because it:

> "[E]stimates the amount of passenger traffic between metropolitan areas rather than estimating demand at individual airports. Population, income and market structure all influence passenger demand, as does a host of other factors. Inputs to the model include socioeconomic forecasts from the consultancy Global Insight, as well as historical data on O&D traffic from the Department of Transportation" (MITRE 2007, p. 29, Appendix D).

This evolution in the methodology of demand forecasting will facilitate the kind of integration of multiple data sources discussed in Chapter 12.

Amtrak has shared key ridership information with the public on its website (http://amtrak.com). Figure 10-5 shows an example of a station summary that includes a certain amount of station-to-station demand information

Table 10-1. Example of origin data by trip category, for use in defining marketshed of the airport.

Scheduled origin/destination patterns of terminating passengers at Manchester Airport in 2000.

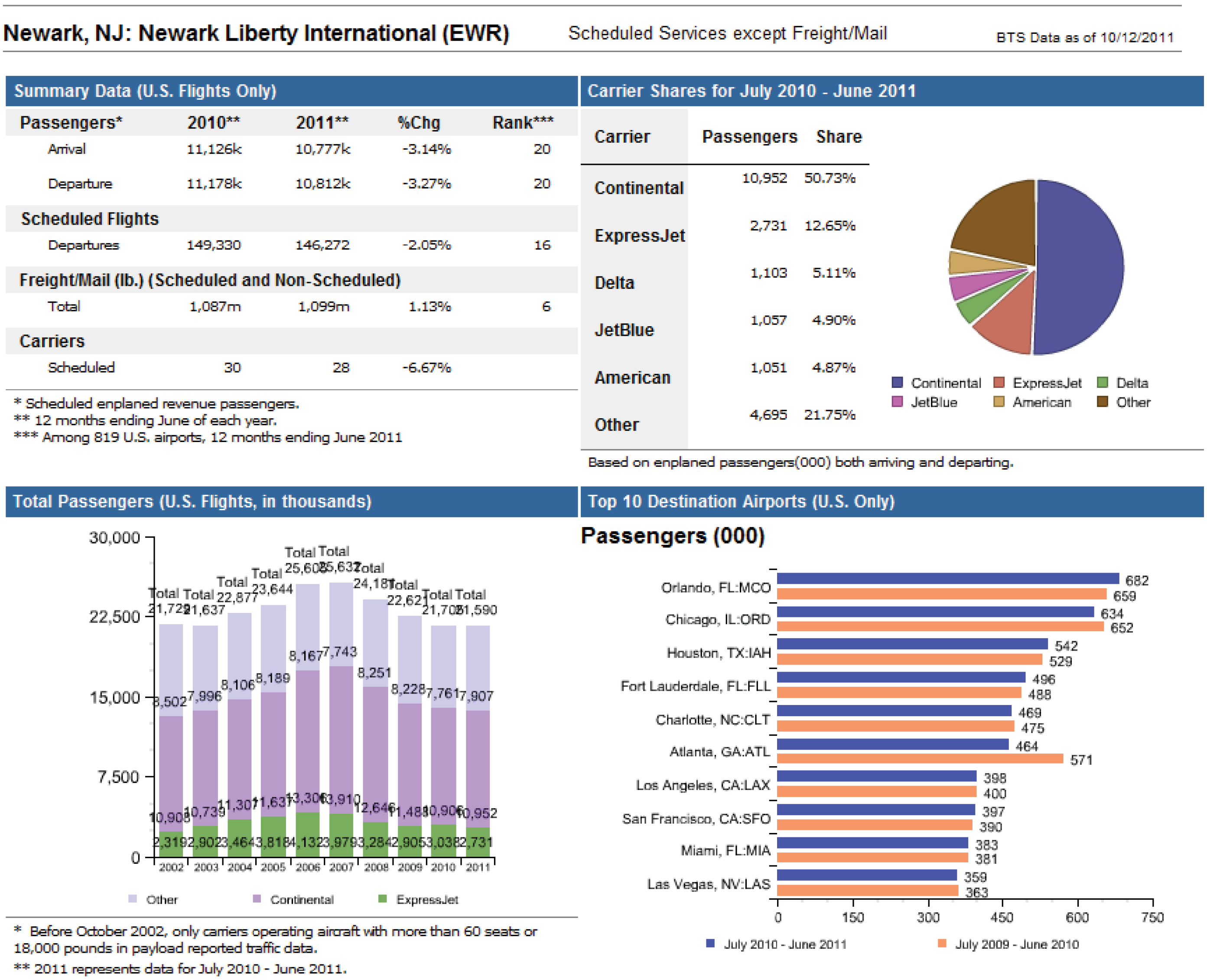
Region	County	UK				Foreign				Grand	
		Business		Leisure		Business		Leisure		Total	
		000's	%	000's	%	000's	%	000's	%	000's	%
East Anglia	Cambridgeshire	0.7	0.0	0.6	0.0	0.3	0.0	0.2	0.0	1.8	0.0
	Norfolk	0.2	0.0	1.4	0.0	0.0	0.0	0.0	0.0	1.6	0.0
	Suffolk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
East Midlands	Derbyshire	46.6	1.9	71.5	2.0	15.0	1.6	15.5	1.3	148.5	1.8
	Leicestershire	3.7	0.1	19.3	0.5	4.1	0.4	1.5	0.1	28.6	0.4
	Linconshire	2.6	0.1	9.3	0.3	2.3	0.2	1.4	0.1	15.6	0.2
	Northamptonshire	1.3	0.1	3.6	0.1	0.1	0.0	0.0	0.0	5.0	0.1
	Nottinghamshire	8.9	0.4	28.4	0.8	3.6	0.4	7.3	0.6	48.2	0.6
North West	Cheshire	488.7	19.7	386.5	10.7	148.9	16.1	118.4	10.3	1142.6	14.0
	Greater Manchester	921.2	37.2	1038.4	28.7	381.1	41.3	416.1	36.2	2756.8	33.8
	Lancashire	195.8	7.9	378.8	10.5	80.6	8.7	110.4	9.6	765.5	9.4
	Merseyside	228.1	9.2	349.9	9.7	83.7	9.1	105.3	9.2	767.0	9.4
Northern	Cleveland	2.2	0.1	18.2	0.5	0.2	0.0	5.0	0.4	25.6	0.3
	Cumbria	49.3	2.0	87.1	2.4	26.2	2.8	34.2	3.0	196.8	2.4
	Durham	3.3	0.1	19.0	0.5	1.3	0.1	2.3	0.2	25.9	0.3
	Northumberland	0.0	0.0	4.1	0.1	0.0	0.0	0.1	0.0	4.2	0.1
	Tyne and Wear	4.1	0.2	25.6	0.7	2.0	0.2	9.3	0.8	41.0	0.5
West Midlands	Hereford & Worcs	1.9	0.1	7.9	0.2	0.5	0.1	0.8	0.1	11.2	0.1
	Shropshire	22.7	0.9	40.5	1.1	7.1	0.8	6.4	0.6	76.8	0.9
	Staffordshire	65.3	2.6	110.2	3.0	19.6	2.1	22.4	1.9	217.5	2.7
	Warwickshire	1.1	0.0	3.0	0.1	0.0	0.0	0.2	0.0	4.2	0.1
	West Midlands	8.5	0.3	76.1	2.1	6.6	0.7	9.7	0.8	100.8	1.2
Yorkshire	Humberside	23.9	1.0	70.7	2.0	7.0	0.8	15.8	1.4	117.4	1.4
	North Yorkshire	39.7	1.6	112.0	3.1	20.5	2.2	41.4	3.6	213.6	2.6
	South Yorkshire	91.2	3.7	173.4	4.8	27.7	3.0	47.1	4.1	339.4	4.2
	West Yorkshire	164.8	6.7	389.8	10.8	55.3	6.0	97.2	8.5	707.1	8.7
Wales	Clwyd	67.8	2.7	86.6	2.4	18.5	2.0	37.7	3.3	210.6	2.6
	Dyfed	1.0	0.0	3.0	0.1	0.0	0.0	0.5	0.0	4.5	0.1
	Gwent	0.9	0.0	3.2	0.1	0.4	0.0	0.0	0.0	4.5	0.1
	Gwynedd	15.5	0.6	21.9	0.6	3.6	0.4	16.0	1.4	57.0	0.7
	Mid Glamorgan	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
	Powys	2.7	0.1	5.9	0.2	0.4	0.0	1.6	0.1	10.7	0.1
	South Glamorgan	0.0	0.0	0.6	0.0	0.7	0.1	0.2	0.0	1.6	0.0
	West Glamorgan	0.2	0.0	0.8	0.0	0.1	0.0	0.0	0.0	1.2	0.0
Scotland		2.6	0.1	43.3	1.2	1.5	0.2	17.6	1.5	65.0	0.8
Grand Total		2474.8	100.0	3617.2	100.0	923.0	100.0	1149.8	100.0	8164.7	100.0

Source: CAA.

that was provided in 2011. At a higher level of aggregation, yearly ridership by line is available on the website, which allows the analyst to derive trend data over time. Until the recent decision to participate directly in the ACRP Project 03-23 modeling effort (see Chapter 11), Amtrak did not have a formal method to make rail demand data available to other practitioners; this meant that while key aviation data had been restructured to be compatible with the traditional transportation planning process, rail had not. Although detailed station-to-station demand data will not be publicly available, data on county to county flows have been incorporated in the FHWA's publicly available data program. Amtrak's decision was a major breakthrough for inclusion in both the ACRP Project 03-23 modeling process, and that of the FHWA's research program, as discussed in Chapter 11.

Long-Distance Highway Vehicle Flow Data from the U.S. DOT

As noted herein, the overwhelming gap in the analysis of long-distance flows does not involve air or rail, but the



Passengers*	2010**	2011**	%Chg	Rank***
Arrival	11,126k	10,777k	-3.14%	20
Departure	11,178k	10,812k	-3.27%	20
Scheduled Flights				
Departures	149,330	146,272	-2.05%	16
Freight/Mail (lb.) (Scheduled and Non-Scheduled)				
Total	1,087m	1,099m	1.13%	6
Carriers				
Scheduled	30	28	-6.67%	

* Scheduled enplaned revenue passengers.
** 12 months ending June of each year.
*** Among 819 U.S. airports, 12 months ending June 2011

Carrier	Passengers	Share
Continental	10,952	50.73%
ExpressJet	2,731	12.65%
Delta	1,103	5.11%
JetBlue	1,057	4.90%
American	1,051	4.87%
Other	4,695	21.75%

Figure 10-4. High-quality aviation data is shared with the public on the Transtats website from the Bureau of Transportation Statistics. Source BTS

description of origins and destinations of vehicles using the highway system. Given the focus of this project on air and rail, the vexing lack of good long-distance highway flow data is beyond the scope of this report. In review of the present utility of either the 1995 American Travel Survey, or the 2001 National Household Travel Survey for the analysis of long-distance travel, proponents have suggested that both can supply valuable data about trip generation rates—and various characteristics of long-distance trip making. But there is general consensus that their direct use in determining the distribution of trip ends for trip tables is more problematic. Figure 10-6 (FHWA 2006) is presented here to give an example of how this kind of data can be used to understand fundamental characteristics of longer distance travel. In this case, data are organized at a high level of aggregation, showing how lower-income travelers have a higher propensity to stay with the private auto as the trip lengths become longer. As discussed in more detail herein, the FHWA is currently developing a nationwide long-distance trip table, whose vehicle flows are generated by a variety of variables, and whose trip distribution patterns are based on the best available data. This trip table will allow a common set of assumptions to be utilized in the analysis of longer distance highway travel, although it is not based on a recent original survey effort.

- Based on the research undertaken in the project the proponents of air and rail modes could support the further development of research efforts, possibly using newly developing technologies in which one's travel behavior is monitored on a voluntary basis, to create more accurate descriptions of long-distance, multi-state private vehicle travel. But, improved data resulting from methods will not be available for incorporation into the conclusions of this report.

Ground Access Data Surveys by Airport

In order to gain an understanding of the actual origins of passengers at an airport, available airport ground access surveys may be used in combination with T-100 data; this was demonstrated in Chapter 6, which examined the potential for new rail services to act in a feeder mode capacity at O'Hare. A good example of how ground access surveys can be merged with other data sources can be found in the Regional Plan Association's "Upgrading to World Class" study for the PANYNJ. As summarized in Table 3-1 of this report, for each major New York City airport, the reader could easily break out the number of people who access the airport from beyond the metropolitan area compared with the more traditional metropolitan markets. Although this data can be used to establish observations at a high level of aggregation (i.e., metro vs. beyond-metro market), issues of sample size constrain its use for further stratification. Strong traditions of consistent surveying exist at the PANYNJ, at the Metropolitan Washington Council of Governments, and in major MPOs in California. While most data collection happens within a metropolitan area (sometimes posing difficulties for merging of data), two major, multi-state exceptions to this pattern were the New England Regional Airport Systems Plan, and New York Region Plan of the FAA.

When examined on an airport-by-airport basis, good data often does exist to support decision making. In the prototypical study of Chicago O'Hare presented in Chapter 6, the number of air passengers going between the airport and

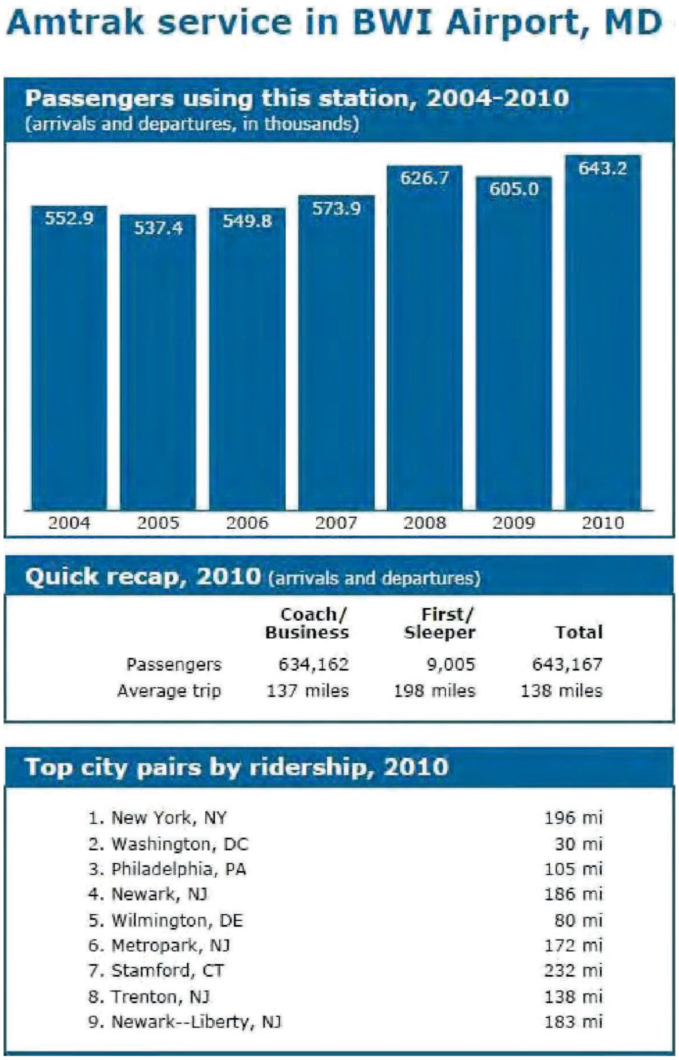


Figure 10-5. Amtrak provided ridership information in their station summaries.

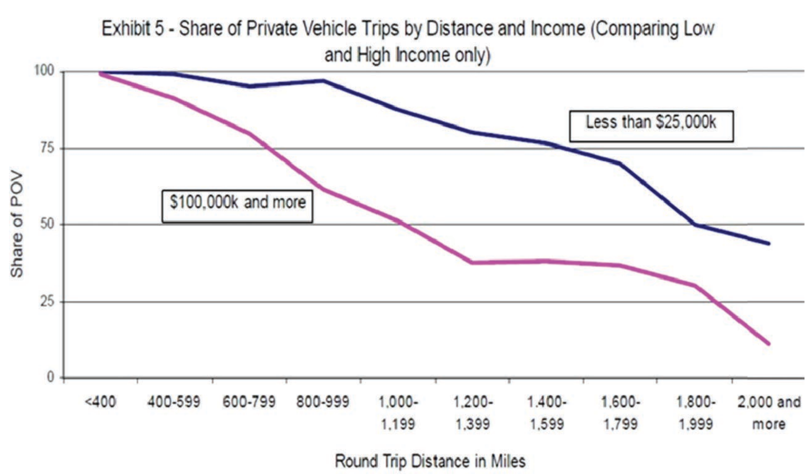


Figure 10-6. The Household Travel Survey was applied to the question of mode share as a function of distance in this analysis from FHWA. Source: FHWA Website.

destinations up to 300 miles away was defined. The percent of the airport's originating passengers that had destinations near the proposed rail lines was also defined, along with the proportion of those transferring at O'Hare who were using connecting flights. What was less clear in the case study was the ability to "predict" how many air passengers would choose rail as a feeder mode when competing air services were offered. This issue seems to require more data on which to calibrate any reasonable prediction model.

- *A conclusion from the analysis of market characteristics from one airport (as opposed to a corridor or a system) is that data collected describing ground access patterns can be combined with national aviation flow data to create valuable summaries of the potential markets that might be served by rail.*

American Sources of Information on Airport Access Issues

In addition to the raw data available from the survey processes, the literature in the United States has several sources of guidance on the question of the adequacy of the ground access modeling process in a more general context, including the characteristics of the models themselves. *ACRP Synthesis 5: Airport Ground Access Mode Choice Models* provides a valuable review of applied demand modeling, much of which is directly relevant to questions addressed in the case study interviews. Also relevant is *ACRP Report 26: Guidebook for Conducting Airport User Surveys.* As noted before, that Synthesis did cover regional planning applications of airport ground access patterns, but it did not explicitly deal with the interaction between aviation and long-distance rail. Other sources of value to the analyst (but, again not specifically aimed at this study issue) include *ACRP Report 4: Ground Access to Major Airports by Public Transportation* and *TCRP Report 83: Strategies for Improving Public Transportation Access to Large Airports* and *TCRP Report 62: Improving Public Transportation Access to Large Airports.*

Major Gaps Revealed in the Research

Analysts and scholars have addressed the issue of gaps in American data. Two experts in long-distance travel at Oak Ridge National Labs have noted,

> "By maintaining mode-specific datasets that are rarely combined, it is also a difficult and resource intensive activity to compare modal travel options with existing data sources. Rather, this information must be pieced together from a variety of sources with little or no consistency or coordination in the data collection methods being used" (Hu and Southworth 2010).

By contrast, the work program undertaken for Chapter 11 includes the use of newly structured aviation demand data, newly released and restructured rail data, and new national vehicle flow data organized to be consistent with the other two data formats. The decision by Amtrak to provide the Research Team with base data that can be expressed in traditional origin-to-destination format represents a major breakthrough in this area. The FHWA's ongoing Travel Analysis Framework project, designed to create an integrated package of trip tables with a highway component, a rail component, and an aviation component is similarly a major breakthrough (Jenkins and Vary 2010).

The Need for a "Quick Turn-around" Model of Air/Rail Mode Share

Earlier sections of this Chapter described a major difference between the European Union and the United States in the quality of publicly available information to be used in the public dialog about future investments in air and rail. Through their early investment in both the UIC study of long-distance travel demand, and the EU study of competition and complementarity in eight corridors served by air and HSR, policy makers have the benefit of a common set of terms and assumptions on which to frame the public debate. Alternative scenarios of various forms have already been analyzed, and the public debate continues.

Based on interviews in California, it is clear that models designed to produce extraordinary detail about such issues as sub-mode of access to and from stations were not designed to support quick turn-around planning-level analysis. Clearly, there is a trade-off between the level of detail of the analysis and the time required to develop and run the associated models, and for some purposes a simpler analysis that can be run more quickly has some attraction, even if it does not produce the same level of detailed results.

Aviation Response to Change in Competing Supply

The report illustrates that more research needs to be done concerning the market reaction from the airlines in response to a decrease in demand for air services in a corridor where high-quality HSR services have been introduced. In the corridors the Research Team examined, there were certain similarities in this pattern of response; with the exception of Frankfurt-Cologne (and portions of the Paris-Brussels market), most airlines responded by reducing flights to reflect the reduction in O-D traffic; however, these airlines still retained a market presence with flights needed to feed connecting traffic to their hub airport. Thus, while

Paris-Lyon was one of the original archetypes for a corridor in which the O-D market is virtually entirely served by rail, there are still seven flights a day between the two cities. Certain differences were also revealed; in general airlines in the Madrid-Barcelona corridor have responded with less service cuts that those in the Paris-Marseille corridor.

Within the pattern in which the airlines lower the number of flights, there remains significant variation in the extent to which the airlines ceded the O-D market to the competing rail (Figure 10-7). In particular, Chapter 4 shows that even after the opening of the HSR service between Madrid and Barcelona, the "air-bridge" shuttle service is still assertively marketed.

Between Madrid and Seville, about eight planes a day are operated, and the rail share of air plus rail is approximately 80%. Between Madrid and Barcelona (a much bigger and more important corridor for the airlines) the air operators have reacted in a fundamentally different way: the shuttle operations continue throughout the day, with a service frequency of three flights per hour in peak hours. Given this different reaction from the air industry, the rail share is markedly lower than experienced in other European corridors with rail service faster than three hours from terminal-to-terminal.

The market reaction to the HSR service from Madrid to Barcelona is similar to the market reaction to the Boston–NYC services; both attained just over a 50% share of O-D riders. This is important for this study, as the report documents that between Boston and NYC, the aviation industry responded by keeping the headways on critical Logan–LaGuardia services largely unchanged, while flying smaller aircraft.

- A major conclusion to be drawn from Chapter 4 is that an analysis process is needed that specifically incorporates various scenarios of service responses by the aviation sector. The work program described in Chapter 11 was designed to address this important issue.

The Need to Find New Methods to Better Understand Long-Distance Highway Flows

This Chapter has emphasized ways in which policy makers in the European Union have made investments in research methods to better understand the relationship between air and HSR; this pattern is not true for the subject of improving the understanding of long-distance auto vehicle flow on the highway system. At present, analysts of long-distance travel flows in Europe are not assuming any massive investment in comprehensive origin-destination surveying for users of private vehicles. They, too, are seeking ways to estimate these flows through methods not yet developed.

Given the dominance of the automobile in short and mid-distance travel there is clearly a larger market to be diverted from auto than from air. It is a concern that the scale of possible diversion from auto cannot be well understood in a setting in which long-distance highway demand is essentially undocumented. While a narrow definition of the role of air and rail would technically not need solid data about markets currently on the highway system, a more holistic approach would acknowledge this very significant gap in understanding the totality of the mid and longer distance market.

In this discussion of gaps in understanding, the need to solve the issue of better describing longer distance automobile travel

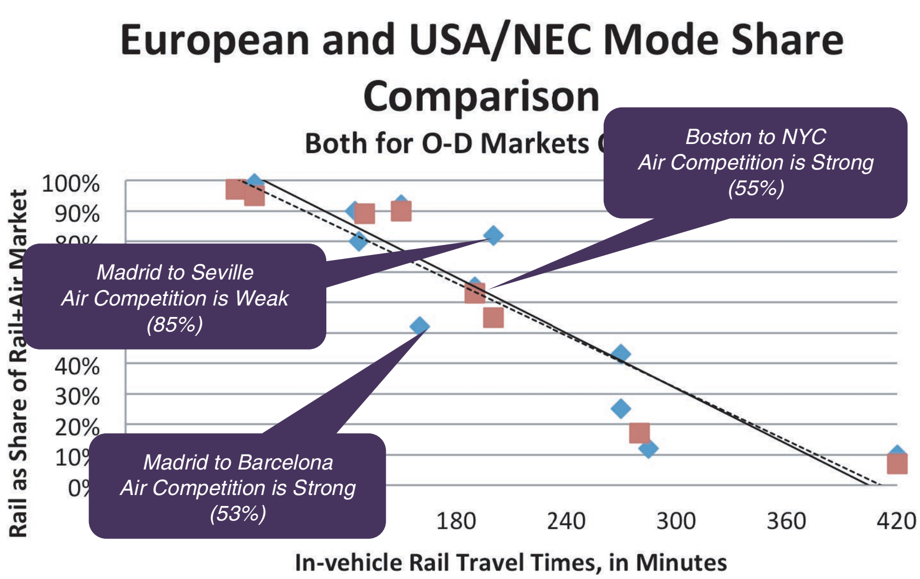


Figure 10-7. Market reactions of the aviation sector.

patterns (with emphasis on origins and destinations) needs to be flagged. Solutions would range from a full-scale replication of the 1995 American Travel Survey at one extreme, to incorporation of data originally collected for calibration of in-vehicle navigational devices at the other end of the technology spectrum—or some merging of various elements of several strategies at once. Importantly, the FHWA has addressed the problem of creating a standard reference for a national long-distance trip table, with the inauguration of its innovative Travel Analysis Framework (Part IIA) project (Jenkins and Vary 2010). That project will also create long-distance trip tables for air and rail as part of this unified effort to improve the quality of long-distance travel data.

Chapter 10 has sought to identify best practices and gaps. A lack of proper understanding of long-distance auto trip making must be reported as a major gap, a problem without any clear solution in sight. The information presented in this Chapter is now summarized in the form of a "Checklist" of available data and methods and their status in terms of further research from various programs (Table 10-2).

Table 10-2. Checklist of Available Tools and Methods.

A "Checklist" of Available Tools and Methods/Needs for Further Research			
Need for Data, Tool or Method	***Examples from the Case Studies of this Project***	***Concern***	***Implications for Present and Future Research***
Difficulty of application of demand model for rail competition with air to use in policy analysis.	Told by the MTC that model literally takes several days to be prepared and run.	Policy analysts need to test different scenarios in a transparent, and understandable way.	New modeling tool has been (Chapter 11) applied in the testing of alternative scenarios and hypotheses.
Difficulty in exploration of the role of the airline industry in response to competition.	Issue has been a concern for some time; what would the dominant airline in that corridor do?	Pricing and schedule characteristics are treated as exogenous in most modeling processes—not impacted by the change in competitive environment.	The relationship between level of rail service and amount of air service is addressed in Chapter 11, in a preliminary manner.
Lack of consistent method to predict the role of rail in a longer term scheme to have rail serve in a feeder mode to longer distance flights.	Chapters 2 and 3 present the most complete review yet of use of rail-as-feeder mode in Europe, and failure to do so in the United States, even with Continental/ Amtrak agreement in place in Newark.	Participants in Northern California were concerned that rail alignment decisions were being made under the assumption that rail could not work as feeder to air.	Further research examining European experience would be appropriate, lasting beyond the course of this ACRP project. In areas with existing patterns of rail reliance, use of long-distance rail to gain access to airports is high; efforts to "replace" feeder flights have mixed results. Issue needs to be understood in both California and NEC.
A nationwide forecast for rail volumes by corridor.	Work of the UIC, based on research methods from Germany and France.	There is very little agreement about the scale of ridership between corridors in the USA.	Since the FRA's publication of HSR in the United States Report (Volpe Center) there is probably a need to update national visions of ridership based on studies currently underway.
A nationwide forecast for highway-based long-distance trip making volumes expressed as zone to zone trip tables.	One of the major concerns expressed by NYC RPA research team—lack of long-distance trip making descriptions.	Lack of success with direct use of 1995 ATS and 2001 NHTS data has led researchers to downplay long-distance trip making by highway modes.	FHWA's presently ongoing project, Traffic Analysis Framework Part IIA, will build a county to county national trip table based on existing data resources. This will allow a common framework over which policy scenarios can be reviewed and analyzed.

(continued on next page)

Table 10-2. (Continued).

A "Checklist" of Available Tools and Methods/Needs for Further Research			
Need for Data, Tool or Method	***Examples from the Case Studies of this Project***	***Concern***	***Implications for Present and Future Research***
A nationwide forecast for aviation volumes expressed as county to county trip tables.	Most aviation forecasts have been done on a uni-modal basis, in a manner that makes integration with other modal data difficult.	The FAA's FACT 2 report introduced the FATE forecasts by the MITRE Corporation, which present data in county to county trip table format.	Aviation data prepared by/for FAA can now be integrated with new data development effort by FHWA Traffic Analysis Framework.
A nationwide description of present trip making on Amtrak, expressed as county to county trip tables.	Several case study participants noted that Amtrak considers most of its ridership data to be proprietary in nature, and used in its own business analysis	Need for openness and transparency in ongoing analysis and public debate.	The Research Team has formatted the Amtrak ridership data into a county to county trip table format, for use in the Chapter 11 work program, in a manner consistent with later integration with other modal data by FHWA.
A nationwide forecast of long-distance travel demand by highway, air and rail.	Given there is little consensus about present long-distance, participants in the case study interviews had very little optimism about longer term forecasts.	With separate projects around the nation making their own visions about future growth, it is extremely difficult to compare and contrast longer term visions.	The FHWA's Traffic Analysis Framework project is undertaking the expansion of the base year 2008 trip tables for highway, air, and rail to the forecast year 2040. This is being done in a method consistent with that of the FAA's FACT 2/FATE project and work undertaken for Chapter 11.
A full description of bus travel O-D patterns in Europe.	The Research Team found no examples where the private sector bus industry shares its "proprietary" ridership data with the governments.	It is difficult to understand how competition between air and rail is impacted by bus ridership, even where it is clearly occurring in the United Kingdom.	The Research Team is not aware of any effort in the UK to standardize, and make available to the public long-distance bus ridership data. (Swiss survey methods would capture short distance bus, but long-distance bus is not a major force in Switzerland.)
A full description of bus travel O-D patterns in the United States.	No one interviewed in the case study process believes that bus ridership is properly documented in the United States.	Anecdotal data suggests that in some sub-corridors in the Northeast, more people ride the long-distance bus than take the train.	Decision makers are concerned about the lack of systematic data about bus ridership. Episodic surveying may be undertaken in the Northeast Corridor, but these plans are not final. Issue remains unsolved.
A full description of air travel, by O-D pattern and by segment.	The US DOT's Bureau of Transportation Statistics has an unparalleled program for sharing highly detailed aviation data with the public	Consistently available information supports the ability of the public to engage in dialog and debate.	Data from US DOT's BTS is readily available for use by researchers, and by the public in general.
Publicly available descriptions of airport-specific ground access markets.	The Civil Aviation Authority (CAA) of the United Kingdom has a continuous program of data collection that is unmatched in its availability to the public.	Consistently available information supports the ability of the public to engage in dialog and debate.	No program in the United States compares with the kind of ground access market data commonly distributed by the UK's CAA. Some coordinated data collection has occurred in New England and in the New York region.
A standardized analysis tool to be applied over a wider variety of markets.	The "Competition and Complementarity" studies performed for the EU by SDG provide a consistent framework for scenario evaluation.	Strong emphasis on locally managed project development makes comparison across projects difficult.	FRA is aware of the difficulty of making comparisons across projects, and might continue tradition started with Volpe's HSR in the United States summary of corridor data.

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CHAPTER 11

The Air/Rail Diversion Model

Introduction and Structure

Highlights

The project has created a model to help improve understanding of the relationship among several key factors in the explanation of the choice of mode between air and rail, which, when seen in a scenario of improved rail services, is associated with the diversion from air to rail. The Air/Rail diversion model:

- Is a simplified forecasting tool strategically designed to address specific questions around consumer preferences and trade-offs in response to conventional rail/HSR and air service modifications.
- Is designed to be a quick-response tool, includes conventional rail/HSR and air service trade-offs.
- Is accessible and relatively easy for planners and analysts to use.
- Incorporates data on ground origin to ground destination air travel patterns, merging ground access patterns with airport-to-airport flows.
- Includes accurate data on existing intercity rail passenger flows (from Amtrak).
- Incorporates an airline response model to estimate the effects of rail/HSR services on flight volumes.
- Is built on an open-source code base in a scripted (non-compiled) programming language.

Structure

Chapter 11 is presented in two parts. Part One explores how the model fits into the context of the policy analysis, and the need for better tools discussed in Chapter 10. The Chapter explores the context and setting in which the model was developed and summarizes the purposes of the model. Several early examples of how the model could be used in policy analysis are presented. In the East Coast, the role of several conditions and service attributes are examined for both their incremental and cumulative effects on diversion to rail. In the West Coast, a different case study was developed, reflecting the very low speeds of the base case rail system, and the incremental steps that might be taken to improve the full system; the emphasis on the exercise is the understanding of the interaction of the separate policy variables, not the prediction of flows on an actual system. The scenario tests also serve as an introduction to how to use the model.

In Part Two, the Chapter reviews how the model works, and how it was developed, and summarizes the use of eight steps in model application. It presents a summary of the model at a level of detail appropriate for transportation managers, planners and analysts. At the same time, the project has created a Technical Appendix with documentation designed for those who are interested in demand models and the model development process. In addition, a free standing "Users Guide" to the application of the model has been created in PowerPoint format and can be found at the end of this report as well as on the accompanying CD. The Technical Appendix is available on the accompanying CD and could be utilized by all who want to apply the model in one way or other.

In short, the first half of this Chapter examines what the model does, and the second half examines how it does it. All of this is presented with the understanding that the mathematical model cannot indeed predict the future. No one can do that. As expressed to the Research Team by one expert, these models are,

> best used as a learning tool at an early concept stage of planning to determine basic impacts of a series of actions/investments so that a decision can be made on whether to engage in more detailed analysis. No one should believe this process can by itself support making a major investment decision. These kinds of models are ideally used to assess the comparative advantages among a group of alternatives of taking one action compared to some different action. Models can also offer wonderful kaleidoscopic effects allowing one to examine the same basic action/investment with different attributes. (Roberts, communication within the project panel.)

Part One: The Public Policy Context—What the Model Is Intended to Do

Model Overview

This Chapter presents the results of the development of a new modeling tool for the examination of the competition between air services and rail services. The Air/Rail Diversion model ("the model") is envisioned as a strategically designed forecasting tool to address specific questions about consumer preferences and trade-offs in response to conventional rail/HSR and air service modifications. The model was designed as an efficient, quick-response tool useful for realistic planning-level scenario analysis and it only includes trade-offs between air service and both conventional and HSR, omitting trade-offs with both auto travel and intercity bus.

As discussed in Chapter 10, several models presently exist concerning forecast travel behavior involving mode choice decisions between rail and air. In some cases, those models are considered proprietary, such as those used by Amtrak for detailed market research in its competitive environment. In the West Coast, an elaborate model of rail demand has been developed in order the meet the very exacting requirements for the CHSRA's project development and environmental documentation. While that model is extremely thorough in its approach, it was never designed to serve as an analysis tool for quick and cost effective analyses of public policy options.

Alternative settings, contexts, and potential future scenarios can be entered into the program in one of two ways. First, they can be established on a global scale, applied to all elements of the geographic network at once. Second, they can be entered on a geographically specific scale, with, say, major rail travel time improvements between San Jose and Bakersfield, but not in the rest of the corridor. Looking first at the process for entering global change, Figure 11-1 shows the settings established in the creation of a complex policy scenario developed for and described in this part of Chapter 11.

Inputs for Variation at the Global (System-wide) Level

The model has been designed to allow simplified access concerning seven kinds of network assumptions, labeled as "Scenario Input Factors" in Figure 11-1. The model can support the global (system-wide) alteration of data by the policy analyst concerning the following parameters:

- Speed of the rail system, called "Rail In-Vehicle Travel Time"
- Terminal-to-terminal time for the aircraft, called "Air In-Vehicle Travel Time"
- Travel time of the auto to gain access/egress for airport or rail station, "Auto IVTT"
- Rail fares
- Air fares
- Amount of rail service
- Amount of air service

Using these seven input variables, a wide variety of future conditions can be hypothesized, including variables over

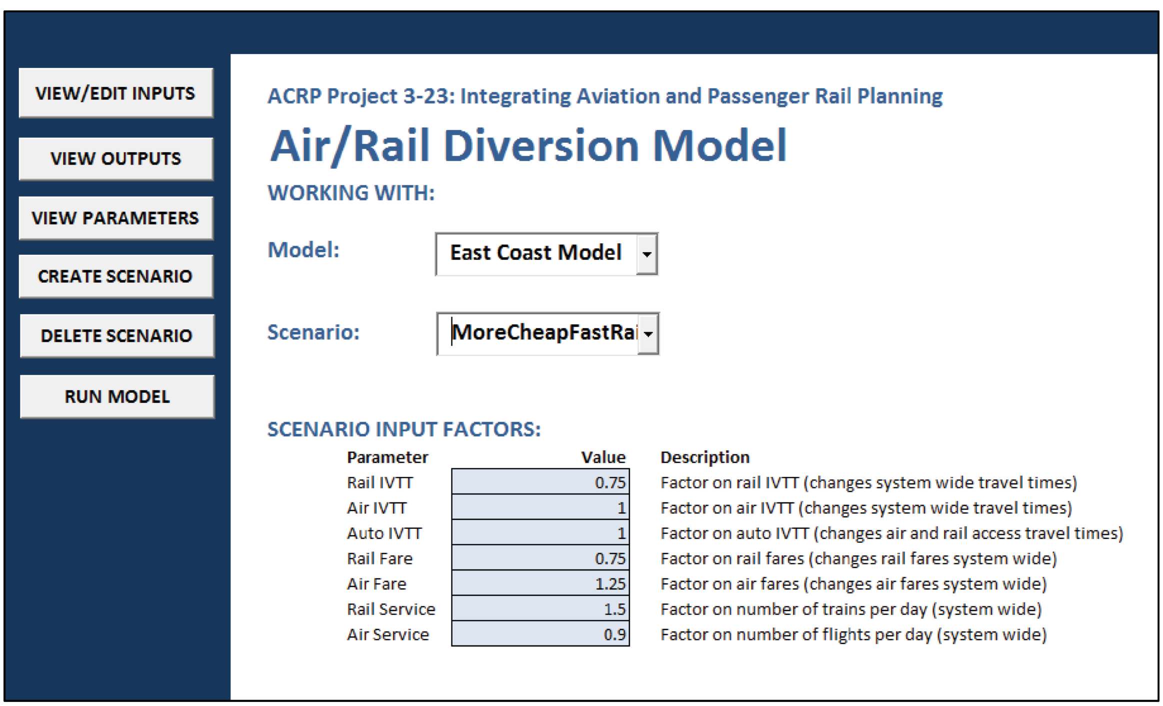

Figure 11-1. Scenario input screen for user interface, as used in this chapter.

which the policy maker might have direct control (e.g., setting the rail fares) and those over which the policy maker might have very little control, (e.g., congestion on the roadways leading to both airports and rail terminals.) For the East Coast, this Chapter will examine the use of one base case, and four hypothetical scenarios, cumulating in the composite scenario referenced in Figure 11-1.

Variables Which Can Be Altered at the Geographic Specific Level

In addition to the seven factors which can be varied as input for all the geographic coverage of the system, the Air/Rail Diversion Model contains a high number of data inputs, all of which could be altered and manipulated, if the analyst were to desire to do so. For each scenario, and for the present and the future, both system descriptions and demographic data are presented that could be considered as input variables for exploration, if such were warranted. Alteration of these variables can be done on the spreadsheet appropriate for the content.

There are five major categories of data input for each scenario, for the present and the future. They are

1. **Socioeconomic data.** This includes data about population household income, employment, all at the tract level. Also included here are total roundtrips by air and rail, organized on a county to county basis. Data on party size and party demographics are included here.
2. **Rail station access data.** This includes data about distance to candidate rail stations, including distance, highway travel time and transit travel time.
3. **Airport access data.** Same as for candidate rail stations.
4. **Rail service description data.** Includes schedules and distances for rail services.
5. **Air service description data.** Includes air passengers by airport pair, and various characteristics of the flight connections from the DB1B data base of BTS.

Because the source information is transparently presented in the model, the analysis could examine the manner in which input assumptions affect the resulting predictions of rail diversion from air by scenario. From the supply side, the analyst could create a hypothetical network with significantly improved overall rail travel time between New York and Washington, with no improvement in travel time between New York and Boston, if that were a policy question being addressed at some level.

Concerning the set of demographic assumptions made for the future case, the modeling process could be used to create a range of alternative futures for testing. By way of example, if the analyst was concerned that the established (e.g., Woods and Poole) forecasts might be under-predicting future income for a state (or set of states) alternative demographic assumptions could be manually inserted into model, by simply altering the contents of the Excel spreadsheets concerning household income.

The transparent presentation of input assumptions does indeed allow an exceptional level of policy exploration of the role of a wide variety of inputs assumptions; how much such exploration is justifiable is a question for further exploration. The reader is reminded that the model was not designed to predict change in rail ridership in total, only that change in rail ridership attributable to diversion to (or from) rail associated with air. Additionally, the model was not designed to predict air passenger volumes in total, only that change in air passengers attributable to change in competitive rail characteristics. The question of improved rail's ability to divert from auto and bus is simply not addressed in this ACRP study.

Definition of the Project Study Areas

The model has been applied in two North American study areas—the Northeast Corridor ("East Coast") and California ("West Coast")—where there is considerable availability of both air and rail modes, meaning that many long-distance travelers have a reasonable choice between the modes. Figure 11-2 and Figure 11-3 show the East and West coast study areas, respectively; they also show the county geography and the airport and rail station locations that are represented in the model. The input data summaries and model results presented in the remainder of this Chapter relate to these two study areas.

The geographic extent of the two study areas includes counties adjacent to the rail corridors since competition will be greatest for travelers starting and ending their trips near the rail line. Consideration was given to the definition of "adjacent" with the final study areas focused on defined corridors that follow the proposed HSR alignments without including counties that are unreasonably far away from the existing rail service.

Model Exercise for the East Coast

The fact that high-quality high-speed services already exist in the base case condition in the Northeast allows the analyst to examine four scenarios with relative modest scale of change in the input assumptions. Four such scenarios were developed for the Northeast Corridor, with only system-wide (global) changes utilized in this set of early explorations of the model. In each case, the analyst must first create the Scenario for testing with the Create Scenario command, save the results, and press the Run Model command, all shown on Figure 11-4. The model creates an elaborate set of input and output file folders with the creation of each new scenario; the user is encouraged to use the Delete Scenario command when any such file can be trimmed back out of the system.

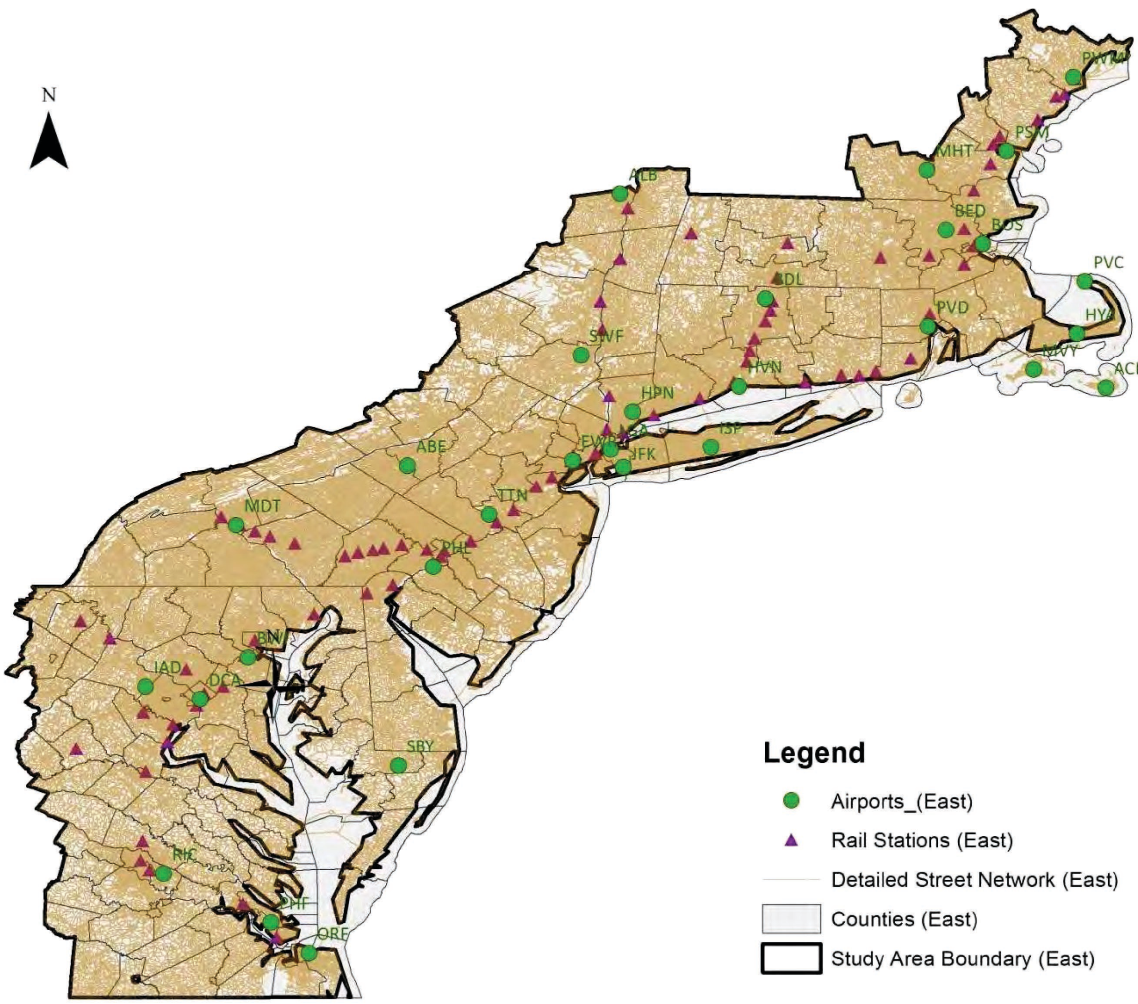

Figure 11-2. Definition of project study area, East Coast.

A Cumulative-Build Approach to Complex Scenario Testing

In this exercise the model was used to explore a set of future policies and contexts for the East Coast model applications. Each scenario is designed to allow the direct comparison with output from the previous (simpler) model, allowing for both an incremental and cumulative analysis.

East Coast Scenarios

- **Scenario #1** is the Base Case. The Air/Rail Diversion Model is structured to encourage the building of cumulative scenarios, with increasing levels of complexity. After the running of the Base Case in which all seven of the global factors remain set at 1.0 (strongly recommended), the "Create Scenario procedure" in the model asks the user to define an additional scenario, and queries which scenario it could be copied from.
- **Scenario #2** hypothesized that fares for rail would decrease by 25% and that the number of flights within the Study Area would decrease by 10%. This scenario was named "Cheaper Rail" for short. The model is run, and automatically creates a folder containing a set of spreadsheets summarizing the results. These spreadsheets can be copied to be used by the analyst for further refinement and presentation via whatever graphic formats are desired. The format of the spreadsheets (comma delimited) allows the immediate transfer to such programs as SPSS or PowerPoint.
- **Scenario #3.** The "Create Scenario" procedure was applied by copying it from Scenario #2, which appears on the screen. The Research Team's scenario #3 was based on this, with the addition of the hypothetical condition that additional trains were run on the system, with a 50% increase in number of trains (e.g., two trains an hour between Boston and New York changes to three trains per hour, with no change in speed assumed). This scenario was named "Cheaper and More Rail" and the model was run.
- **Scenario #4** was created in the Create Scenario process by taking the settings of Scenario #3 and adding the hypothetical assumption that all trains in the system would run

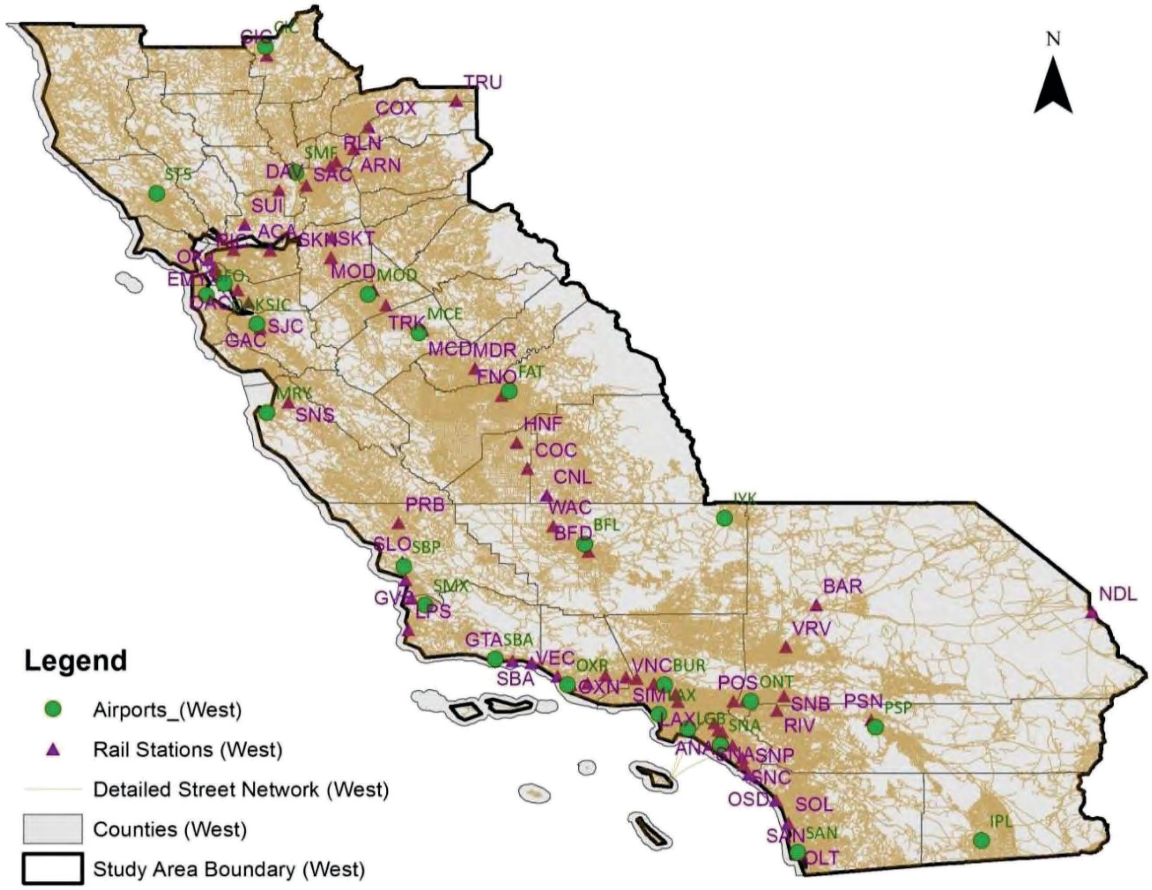

Figure 11-3. Definition of the project study area, West Coast.

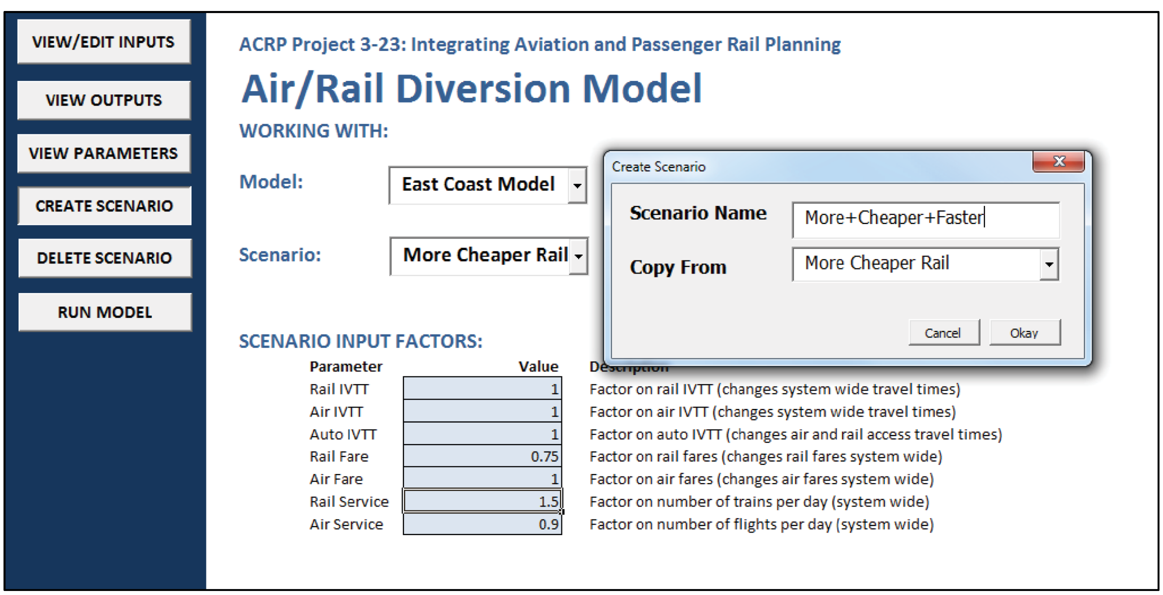

Figure 11-4. The program allows new scenarios to be built from existing scenarios, within the Create Scenario command.

with speeds resulting in a decrease in terminal-to-terminal travel time by 25% (e.g., a 4 hour travel time from Washington to Stamford would become a 3 hour travel time). This scenario was named "Cheaper, More, and Faster Rail" and is illustrated in Figure 11-4.

- **Scenario #5** was created from the input factors of Scenario #4, with the addition of the hypothetical assumption that air fares in the study area would increase by 25% (e.g., an airline fare of $200 is assumed to rise to a fare of $250).

Illustrative Examples of the Analysis Process

The output variables produced for this analysis were the total number of air trips and rail trips from all counties (and thus all SMSAs) combined. For this analysis, the model created output files for each scenario. Here the Research Team used one spreadsheet entitled "OriginCBSA" for each of the five scenarios. In this case study, the Research Team was interested in the change in the absolute number of rail trips in the region, not any set trips between specific origins and destinations. External to the model, the spreadsheets were grouped geographically and reorganized by sub-region in the study area. An example of the output spreadsheet produced in the model is shown in Figure 11-5. The model stores each spreadsheet in a file labeled with the name of the scenario created by the user (Figure 11-5).

East Coast Geographic Areas

Using MS Excel independently of the model, the metropolitan areas were restructured by geographic area for this particular analysis, based on the following definitions:

- All study area metro areas north of New Haven, CT, were aggregated into a category called "New England."
- All study area metro areas in New York State, and all between New Haven and north of Trenton, NJ, were aggregated into a category called "New York."
- All metro areas between Trenton and the Maryland border were aggregated into a category called "Mid-Atlantic."
- All study area metro areas in Maryland, the District of Columbia, and Virginia were aggregated into a category called "Baltimore/Washington."

As presented in the Table 11-1, volumes of rail origins by regional area were then summarized for each scenario, again outside of the model structure. From the summaries created from the "OriginCBSA" spreadsheets, as categorized by regional areas, total number of rail round trip origins was calculated; they are presented as Table 11-1. The data are expressed in terms of four regional geographic areas, and five hypothetical scenarios for service attributes and market conditions. The model output was then examined in terms of the impact of the five cumulative scenarios on the rail share of the air + rail market in the East Coast project study area, as shown in Figure 11-6.

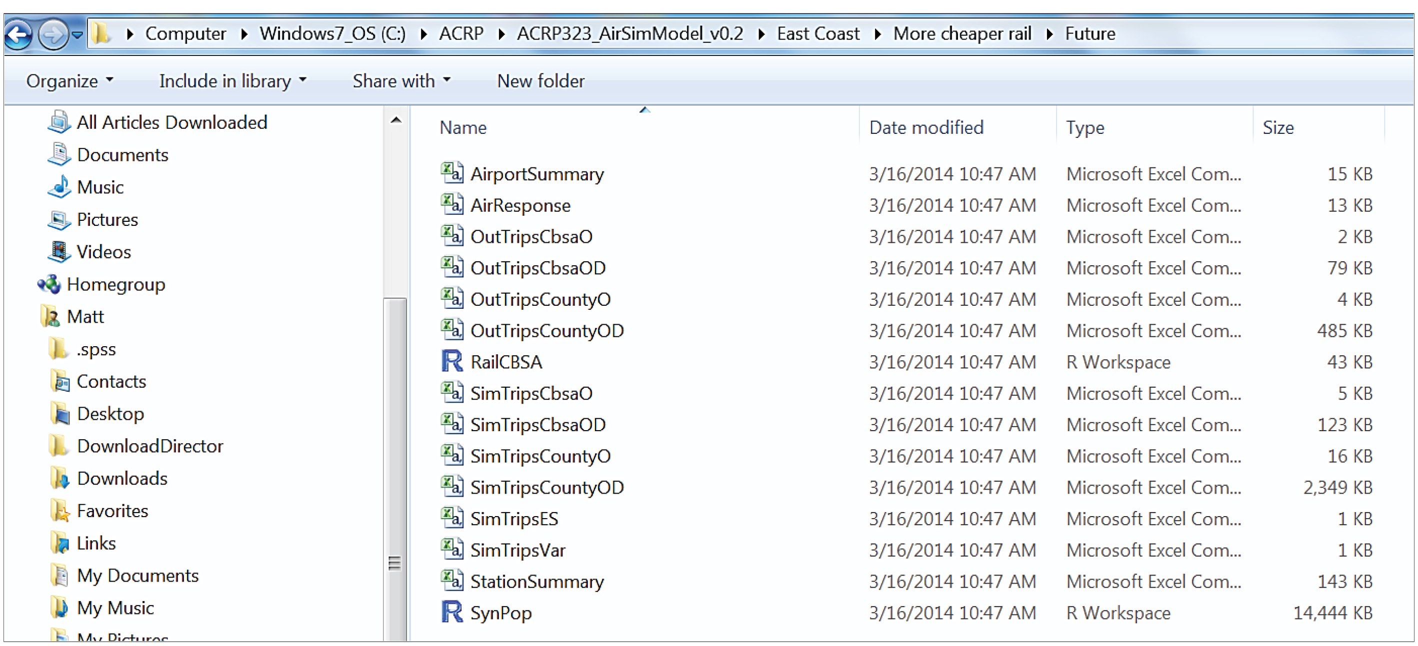

Figure 11-5. The model creates file folders for each scenario created; these can be deleted with the Delete Scenario Command.

Table 11-1. Number of rail trips including diversion from air, by scenario and region.

	Scenario #1 *Base condition*	*Scenario #2* *Scenario 1 plus cheaper rail*	*Scenario #3* *Scenario 2 plus more rail service*	*Scenario #4* *Scenario 3 plus faster rail service*	*Scenario #5* *Scenario 4 plus higher airline fares*
OriginCBSA					
New England	1,222,700	1,326,750	1,389,300	1,599,500	1,749,300
New York	2,465,550	2,573,900	2,640,100	2,869,750	3,006,400
Mid-Atlantic	1,580,500	1,627,000	1,673,600	1,721,000	1,743,950
Bal-Wash	1,714,500	1,850,200	1,917,250	2,162,100	2,329,800
Study Area	6,983,250	7,377,850	7,620,250	8,352,350	8,829,450

Figures 11-7 and 11-8 graphically portray these same results in terms of relative impacts of the scenarios. The results of the scenario testing are expressed from the vantage point of the rail analyst on Figure 11-7, which graphically portrays the data in Table 11-2 The rail volumes are set in the base case as 1.0, with growth in rail volume by scenario level expressed for each of the four geographic areas, and the total study area.

The same data is expressed from the vantage point of the air analyst in Figure 11-8. In this format, the number of air trips in the base case is set at 1.0 with decrease by scenario level expressed for each of the four geographic areas. Both figures were developed from the rail volumes summarized in Table 11-1, and reflect two different ways to look at the policy implications of the diversion patterns. The graphic format reflects the orientation of the modal manager (air or rail), who may be interested in the relative change in markets as much as the absolute values reflected in the status quo.

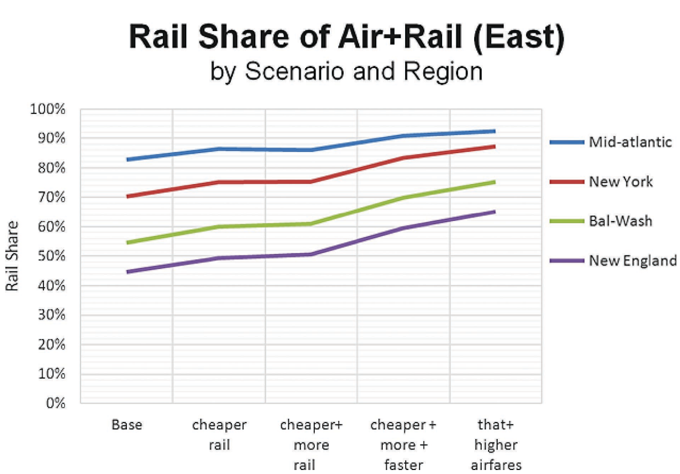

Figure 11-6. Change in rail mode share by diversion scenario and region.

Implications for the East Coast

Whether expressed as a loss to air ridership, or a gain to rail ridership, the results of this early policy exercise have interesting implications. First, when an analysis is undertaken on a cumulative basis, the analyst can explore both the combined impact of multiple factors (expressed as Scenario #5) and the increments of change associated with the addition of each

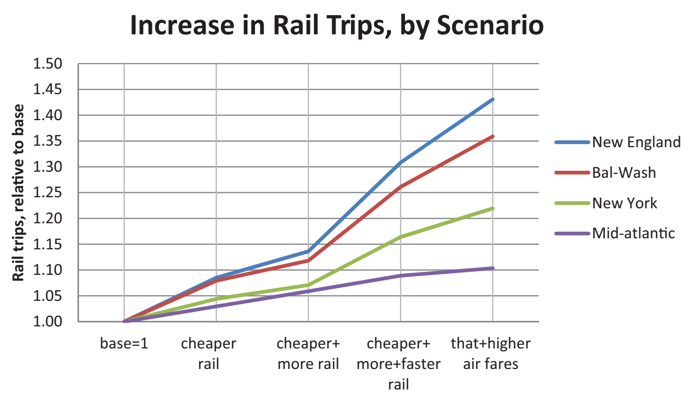

Figure 11-7. Relative increase in rail trips from diversion from air.

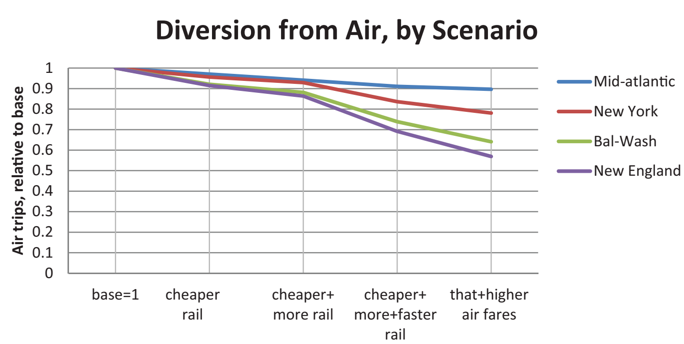

Figure 11-8. Relative change in air trips by diversion scenario.

Table 11-2. Increments of increase in rail trips due to diversion from air.

Region	*Scenario #1* Base Condition = 1	*Scenario #2* Scenario #1 plus cheaper rail	*Scenario #3* Scenario #2 plus more rail service	*Scenario #4* Scenario #3 plus faster rail service	*Scenario #5* Scenario #4 plus higher airline fares
New England	1.00	1.09	1.14	1.31	1.43
Bal-Wash	1.00	1.08	1.12	1.26	1.36
New York	1.00	1.04	1.07	1.16	1.22
Mid-Atlantic	1.00	1.03	1.06	1.09	1.10
Study Area	1.00	1.06	1.09	1.20	1.26
Increment for each scenario	Base	.06	.03	.11	.06

factor separately into the analysis. Of the four strategies of improvement over the base case, the largest NEC system-wide increment comes from the assumption that all travel times will improve by 25%. This is consistent with the present exploration by Amtrak and FRA of significantly improved travel times under various HSR futures, as is associated here with an 11% increase in the number of rail passengers solely attributable to increase in diversion from air on the basis of travel times. More relevant to policy makers is the increase attributable to many diverse factors together, as reflected in the Scenario #5 future in this analysis. Once again, the Research Team cautions that these increases in rail ridership do not include any increased diversion from auto and bus, which is not analyzed here.

When examined from the point of view of separate regions, several patterns are revealed. Most dominant is the simple fact that service levels in the Mid-Atlantic region are already high, such that incremental increase from more air diversion is simply less relevant here than it is in either New England or the southernmost region including Maryland, Virginia and the District of Columbia. Expressed differently, there are more air trips to be potentially diverted outside of the New York and Mid-Atlantic regions.

Explorations of Factors Separately—East Coast

The East Coast exercise described herein sought to allow the examination of several factors (both about the quality of the rail service and the competitive characteristics of the air service). The model can also be used to explore one variable at a time.

Change in Travel Times–East Coast

The model can be used to look at gradations in any given input variable, such as travel time. Models were run to explore the impact of new rail travel times which were (a) 70% of current times, and (b) 50% of current times. Looking first at the East Coast, the model predicts that, under the assumption of better rail travel times 70% of the present, impacted air travel might fall from a base case of 3.8 million trips, down to about 3.3 million trips. Under the scenario in which rail improves to provide travel times as low as 50% of present times, air volumes would decrease to 2.9 million trips. Expressed as mode share, the airlines' proportion of the air-plus rail would fall from 35% in the base case, to 30% and 26% under the two improved rail scenarios modeled for the East Coast.

Change in Air Fares: East Coast

At the same time, key policy variables are available to the airlines, particularly in the setting of fares. For the East Coast, a lowering of air fares to 70% of their present level results in an increase in predicted air travelers from 3.8 million trips in the base scenario to 4.5 million in the lowered-fare scenario. Expressed as mode share, the airlines' proportion of the air plus rail market would increase from 35% in the base scenario to 41% in the lowered-fare scenario in the East Coast.

Model Exercise for the West Coast

Setting and Context

The policy questions facing decision makers in the West Coast are fundamentally different from those presented herein, as the base case conditions for rail are so much worse than those faced in the East Coast.

Rail services in the West Coast take on a different form from those in the Northeast Corridor. Between the two dominant cities of California, the present rail system could more accurately be described as a rail and bus system. From Los Angeles

Union Station one train a day goes to the Bay Area, with a stop at the waterfront (Jack London Square) in Oakland. Six more services with a single transfer from rail to bus are provided by Amtrak. Accepting these definitions there are about seven bus + rail services a day. The 340 mile trip takes between 8.5 hours to 11 hours, with the slowest trip on the direct train. Thus, terminal-to-terminal speeds range from about 30 mph, to 40 mph.

Policy makers in California are now facing the concept of incremental upgrades to get to the final HSR at the scale system originally envisioned, including the idea of "blended service" where early investment in electrification can improve commuter services years earlier than previously contemplated. To better understand how the model might be applied in California, one scenario was created to reflect a major improvement in rail travel times, but one somewhat short of true high-speed rail, with an across the system assumption that travel times could be lowered by 50%. For example, to accomplish this, the average speed of (approximately) 33 mph between Los Angeles and the Bay Area would be assumed to be 66 mph in Scenario #2. Only in Scenario #4 is it assumed that the average rail speed would be 99 mph, which is associated with a higher level of infrastructure investment.

Defining the Scenarios and the Geographic Segments

Without question, the policy questions to be addressed will be different from those in the Northeast, as the rail service is poor. The model was tested with five scenarios, including the base case using actual schedules and timetables as input.

The West Coast Scenarios

- **Scenario #1** is the Base Case. All the service descriptions provided in the model were left intact, with all seven of the global input factors left at "1."
- **Scenario #2.** Double in-vehicle travel speeds (or more accurately cut terminal-to-terminal travel times by half for all areas now serviced by the rail-plus-bus network). For example, a 10-hour trip between LA and the Bay Area would now be a 5-hour trip. For model testing purposes, all trip times would be cut in half in this testing scenario. In cases where the average trip speed was 33 mph, it would now become 66 mph.
- **Scenario #3.** Double the speed of the train, and operate three times as many. Thus, the example trip between LA and Oakland would operate 21 times a day, better than hourly service, but still less than Amtrak operates in the Northeast Corridor. This scenario explores frequency of service as a separate factor from in-vehicle travel times.
- **Scenario #4** would simulate high-speed train service, with average speeds raised from the present 33 mph today to a very high average speed of about 100 miles per hour, for example. This is similar to average speeds between Paris and London for many years, and present HSR service between Paris and Amsterdam. The scenario is designed to test the upward limits of the model, and not to represent any assumptions about how many OD pairs could actually be provided with service this fast.
- **Scenario #5** takes the very high-quality train service assumed in Scenario #4, and hypothesizes that the cost of an air ticket has increased by 20% and that the number of planes operated has decreased by 20%. The purpose of this scenario is to observe the model's reaction to competing services, separate from the characteristics of the rail.

West Coast Geographic Areas

For this analysis, the California study area was divided into four geographic subareas.

1. **"North"** includes both the San Francisco and San Jose metropolitan areas and everything to the north.
2. **"Central"** includes areas to the South and immediately west of San Jose, including all areas to the south just short of Santa Barbara.
3. **"Los Angeles"** area includes everything south of San Louis Obispo, and north of San Diego.
4. **"San Diego"** includes San Diego and El Centro.

Results of the Scenario Testing

The model shows that the rail/bus system attains a share of the rail plus air market ranging from 19% in the North to 45% in the central area, which may reflect the relative paucity of within-study area flights in the Central Area, and their relative strength in the North. Figures 11-9 and 11-10 suggest that the travelers in the Central area of California do not rely on within-state airline services to the extent that the other three subareas do. (Arguably, this seems reasonable as trip lengths would tend to be less than half the length of the state.) This seems to result in a low mode share to air, compared to the other regions, in four of the scenarios; in the fifth scenario, the hypothetical increase in airfare tends to bring the other three regions up in rail share, closing the gap somewhat. How much of this pattern reflects geography, and how much reflects socioeconomic characteristics remains to be explored.

By contrast, residents of both San Francisco to the north, and Los Angeles are separated by about 340 miles, making the air an extremely attractive alternative to the rail-plus-bus network, reflected in the fact that the "rail" mode share for these two areas is one half of that simulated for the Central Area. Applying the

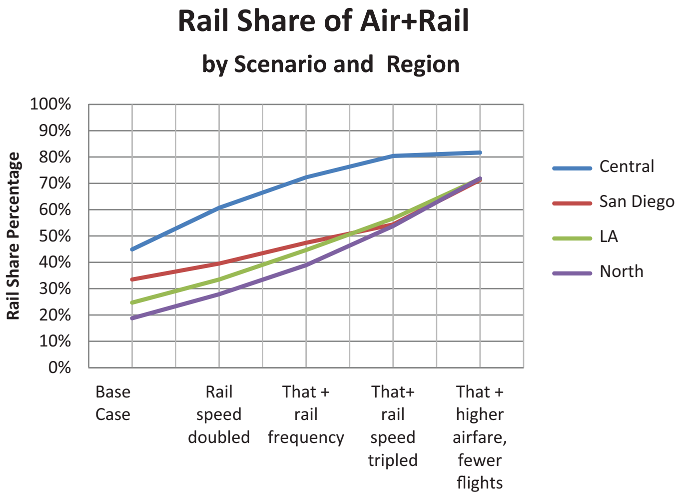

Figure 11-9. Change in rail mode share by diversion scenario and region.

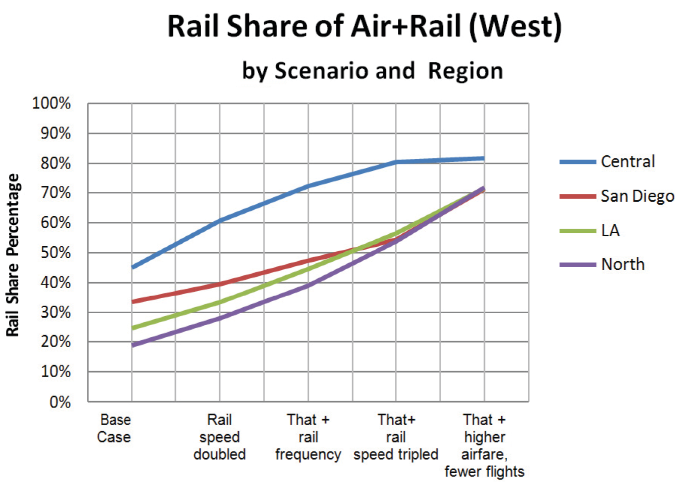

Figure 11-10. Relative change in air trips by diversion scenario.

scenarios to the modeling process, the differences among the four sub-regions tend to dissipate with the assumption of better rail services, such that all three become more and more similar to the mode share pattern of the Central Area.

All four groups are influenced by the incremental improvement attributable to high speed, but those living in the northernmost area seem to be most affected by this factor. This group experiences a 15 point increase in percentage to rail from the assumption of cutting travel times by one half in this increment (from Table 11-3). This is similar to the 12 point increase for the LA group, both of which are higher than the eight point increase for the Central area residents.

Once the higher quality rail is assumed, the residents of the study area as whole are sensitive to the change in assumptions about the strength of the air competition, with a 17 point increase attributable to the increment of change included in the final scenario. As noted, once the high-quality rail service is in place the Central area residents are not influenced by the costs and frequency changes in air services that may not serve them well in the first place, as reflected in their increase of only two points for this scenario (Table 11-3).

From the vantage point of the aviation manager, each of the scenario increments reflects a logically predicted decrease in air trips within the study area. Holding the base case as today's (e.g., 2008) air volumes, the pattern of decrease from the status quo is graphed in Figure 11-10. Interestingly, the geographic group with the weakest pattern of use of air for these intrastate trips is the group that loses air volumes most dramatically over the first four scenarios examined.

The model seems to be presenting a consistent pattern of response to the somewhat arbitrary details invented for the progression of scenarios in this exercise. In general, the results are consistent with working assumptions about the scale of impacts at major airports. If it is assumed that approximately 15% of those passengers boarding at SFO or LAX have actual

Table 11-3. Rail share of air plus rail market, including project study area (West).

	Scenario # 1	*Scenario # 2*	*Scenario # 3*	*Scenario # 4*	*Scenario # 5*
	Base Case	Rail speed doubled	That + rail frequency	That + rail speed tripled	That + higher airfare, fewer flights
Central	45%	61%	72%	80%	82%
San Diego	33%	40%	47%	54%	71%
LA	25%	33%	45%	57%	72%
North	19%	28%	39%	54%	72%
Project Study Area	*24%*	*33%*	*43.5%*	*56%*	*73%*

trip destinations within the State of California (*ACRP Report 31*), Figure 11-10 suggest that some 60% of such intra-state travelers would not be diverted to rail under Scenario #4, which reflects a robust rail but without any assumptions about change in air services. Thus, total boardings at the two airports might be expected to drop by about six percent, under the assumptions used in this early application of the model.

Limitations of the Scenario Test

The purposes of the exercises included in this Chapter are to explore the propensity of the new model to produce reasonable and logical results. While the general scale of diversions implied for California's major airports seems consistent with other published analyses, the results of the modeling process in this exercise are not meant be used for policy purposes. Specifically, the alteration of "global" or system-wide parameters is undertaken to better understand how the model factors interact, and work together. There is no underlying assumption in this work that every travel time in the system could be improved in this manner; the exercise examines what would happen if such qualitatively superior performances could be achieved.

As the process of developing and applying this model proceeds, the model will be used by altering input assumptions at the geographic specific level, a process through which actual physical plans could be described, inputted and analyzed. This was not attempted in this Chapter.

Results of the Scenario Testing (West Coast)

The West Coast exercise described herein sought to allow the examination of several factors (both about the quality of the rail service and the competitive characteristics of the air service); the model can also be used to explore one variable at a time.

Change in Rail Travel Times

Looking at the West Coast, the model predicts that, under the assumption of better rail times of 70% of those in the base case, air volumes would fall from 7.5 million trips in the base case, to 7.3 million trips in the moderate rail improvement scenario. Under the scenario in which rail improves to provide travel time only 50% of present times, air volumes would decrease to 6.9 million trips. Expressed as mode share, the airlines' proportion of the air plus rail market would fall from 80% in the base case, to 76% and 83% under the two improved rail scenarios for the West Coast.

Change in Airline Fares

Looking at the West Coast, a lowering of air fares to 70% of their present level results in an increase in predicted air travelers from 7.5 million trips in the base scenario to 7.8 million in the lowered-fare scenario. Expressed as mode share, the airlines' proportion of the air plus rail market would increase from 80% in the base scenario to 82% in the lowered-fare scenario in the West Coast.

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Looking at the West Coast, the model predicts that, under the assumption of better rail times of 70% of those in the base case, air volumes would fall from 7.5 million trips in the base case, to 7.3 million trips in the moderate rail improvement scenario. Under the scenario in which rail improves to provide travel time only 50% of present times, air volumes would decrease to 6.9 million trips. Expressed as mode share, the airlines' proportion of the air plus rail market would fall from 80% in the base case, to 76% and 83% under the two improved rail scenarios for the West Coast.

Part Two: Understanding How the Model Works

Model Structure

The model structure was designed to incorporate sufficient detail in both the models and input data. It does this by using as many of the attributes available in the transferred choice model specifications as possible and by using spatially detailed input data; as a result, the model is sensitive enough to capture the policy changes it is intended to evaluate. The general structure of the model is shown in Figure 11-11. This structure includes a set of data inputs; a set of policy inputs (future service descriptions); two primary statistical models, represented by the ovals; and two sets of outputs.

The model is implemented using commonly available software and is based on travel pattern data. The model has a simple graphical user interface (GUI), implemented in Microsoft's Excel spreadsheet application, which was selected as a familiar application that the vast majority of model users will have installed on their computers. The spreadsheet contains worksheets to manage scenarios, edit inputs (such as air and HSR service descriptions), and to view and compare outputs. The spreadsheet uses Visual Basic macros to provide additional functions for the model user, such as allowing selection of subsets of input data for viewing and editing and automating import of model results. The model computations are completed using "R," which is an open-source statistical programming language that is particularly useful for the type of database computation required for these models. The spreadsheet GUI means that model users do not need to use

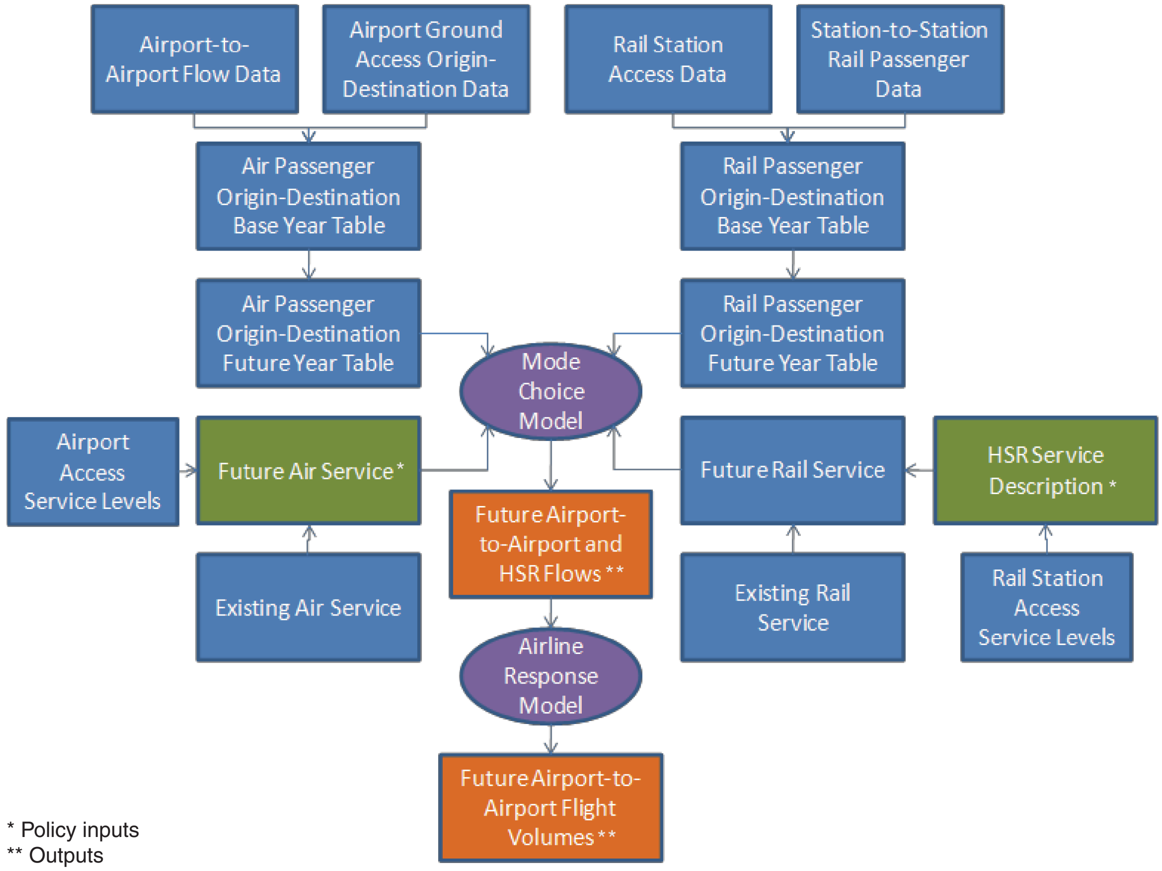

Figure 11-11. The component elements of the model.

the R language or interact with R directly to run the models, but merely have it installed on their computers by the ACRP Model installation package, working with Windows, Mac OS, or Linux computers.

Travel Demand

Input travel demand is provided at a county-level resolution, while much of the model's simulation uses a more detailed spatial resolution of Census Tracts. This represents a trade-off between the desire for additional resolution versus the reality of data availability. The observed travel demand data is currently only available at the county level for these large corridors. For example, in the output of the United States Department of Transportation's (U.S. DOT) Travel Analysis Framework project, modal OD tables for long-distance trips are at the county level, while certain model inputs are available at more detailed spatial resolutions.

The primary purpose of the model is to understand the competition between air and HSR. The largest market of interest, and the primary focus of the model, is the short-haul market with both an origin and destination in one of the corridors that form the study areas. A smaller market of interest is the short-haul market whereby a traveler might bypass one airport and use HSR to access another airport and make a long-distance flight outside the corridor (rather than an airport transfer). This transfer market is potentially relevant in both California and the northeast, given the recent policy interest in better long-distance service to JFK Airport on Long Island. However, the Research Team considers it a difficult market to understand let alone model and elected to focus solely on the primary short-haul market, implementing a model to compare one airport alternative with one rail alternative, for each OD pair with a choice.

The analysis years for the model are 2008 and 2040 (Tables 11-4–11-7). These years were chosen because they are consistent with the analysis years for the person-trip tables developed as part of the U.S. DOT Travel Analysis Framework project (Jenkins and Vary 2010). The 2008 trip tables by air and rail were combined to reflect overall travel demand by these two modes, and they are used as a basis for base year model calibration. The trip tables do not include any market segmentation (e.g., trip purpose or demographic data), and therefore the Research Team has used a simulation approach to characterize travel parties by drawing from observed distributions by trip purpose and demographics. While the trip tables are published in O-D format and do not explicitly identify the home end of the trip, the tables have been processed using assumptions described in later sections to infer the origin location and derive segmentation attributes based on the origin location.

Representation of Transportation Supply

The Research Team considered two options for representing the air and rail networks in the model. The first option is akin to a traditional travel model network depicting the physical linkages and service characteristics between stations and between airports. This first approach would have required that a network be included with the model that the model user could modify for scenario testing, and this network would represent the relative ease of traveling from place to place by each mode.

The second option, which the Research Team selected for model implementation, is a simpler approach whereby the network characteristics are embedded in the model in the form of predefined tabular inputs. In this approach, while it is clear what the travel time or cost is from place to place, there is no network included with the model. The predefined travel times and costs and frequencies by mode that are used as inputs to the model are viewable by the model user in the GUI; in addition, the model user has the ability to efficiently modify these inputs (rather than modifying networks) in order to develop and evaluate scenarios. This second approach was more straightforward because air networks are complex to represent and visualize, and although transit networks are clear when considering a single HSR line, the inclusion of local transit access adds an unmanageable amount of complexity given the intent of the model.

Travel time and cost data were derived from several available sources. Published Amtrak schedules were used for the base condition (i.e., rail frequencies and travel times). Auto access times were derived from national roadway networks available from FHWA. Transit access times to both rail and airports were identified as a particularly difficult detail to represent, primarily because there is no corridor-wide transit network to rely on for this purpose. Instead, the Research Team used data from the Census journey to work data program (now the American Community Survey) to develop a comprehensive representation of the quality of transit service at a Census Tract level of spatial detail.

Airport, Station, and Mode Choice Models

The model framework makes use of three choice models to select a preferred airport pair, a preferred station pair, and the main mode for the trip, comparing air versus rail. For the airport and station choice models, the Research Team used models developed for the West of Hudson Regional Transit Access Study, a study sponsored by the Port Authority of New York and New Jersey and MTA's Metro-North Railroad to evaluate improved transit connections to Stewart Airport. These models were applied to consider a set of possible airport pairs for the trip being modeled and a set of stations pairs. The model also permitted the selection of a preferred pair in each case, based on the characteristics of the access and egress trips from the airports and stations at either end of the trip and the

Table 11-4. Air, rail, and total roundtrips by state (2008).

State	Air	Rail	Total
CONNECTICUT	186,755	406,908	593,663
DELAWARE	12,737	104,874	117,611
DISTRICT OF COLUMBIA	154,698	853,280	1,007,978
MAINE	96,752	55,334	152,086
MARYLAND	596,054	606,369	1,202,423
MASSACHUSETTS	1,032,723	700,014	1,732,737
NEW HAMPSHIRE	150,059	56,536	206,595
NEW JERSEY	159,937	522,226	682,163
NEW YORK	735,790	1,856,841	2,592,631
PENNSYLVANIA	225,271	1,375,768	1,601,039
RHODE ISLAND	142,715	211,785	354,500
VIRGINIA	674,518	254,002	928,520
WEST VIRGINIA	3,123	1,979	5,102
CALIFORNIA	7,062,106	2,517,740	9,579,846

Source: FHWA Travel Analysis Framework.

Table 11-5. Air, rail, and total roundtrips by state (2040).

State	Air	Rail	Total
CONNECTICUT	268,048	562,465	830,513
DELAWARE	25,922	152,559	178,481
DISTRICT OF COLUMBIA	280,908	1,265,506	1,546,414
MAINE	157,657	79,027	236,684
MARYLAND	992,693	907,647	1,900,340
MASSACHUSETTS	2,046,045	968,468	3,014,513
NEW HAMPSHIRE	221,086	80,237	301,323
NEW JERSEY	311,659	737,029	1,048,688
NEW YORK	1,008,999	2,569,400	3,578,399
PENNSYLVANIA	424,709	1,933,877	2,358,586
RHODE ISLAND	192,162	291,717	483,879
VIRGINIA	1,074,605	413,035	1,487,640
WEST VIRGINIA	5,164	3,223	8,387
East Coast Total	**7,009,657**	**9,964,190**	**16,973,847**
CALIFORNIA	11,110,091	4,281,203	15,391,294
West Coast Total	**11,110,091**	**4,281,203**	**15,391,294**

Source: FHWA Travel Analysis Framework.

relative levels of service on the air or rail service between the airports and stations.

For the mode choice models, the team identified two existing models that have similar structures and whose coefficients have been estimated using recent data: a model developed by RSG for the most recent Toronto-Montreal-Quebec City corridor HSR study under contract to Transport Canada and the Ministries of Transport for Ontario and Quebec (2009/2010), and the California HSR model developed by Cambridge Systematics, modified to represent the air versus HSR trade-off elements. The mode choice model that was implemented is derived from the California HSR model.

Airline Response Model

The airline response model predicts how airline schedules will respond to the introduction of HSR service on the Northeast and California Corridors. The response may include several elements. First, to the extent that HSR captures traffic that previously traveled by air, airlines may reduce seat capacity on affected segments. Second, either as a result of offering reduced seat capacity or as a direct response to competition from HSR, the distribution of capacity among different types of airlines—mainline network carriers, regional affiliates, and low-cost carriers—may change. Finally, either as a direct response to HSR competition, or as a secondary response to diminished traffic, carriers may change their fleet mixes in corridors with HSR service.

Eight Steps in the Model Implementation Process

As noted in the previous sections, the model was developed and implemented using a combination of Microsoft Excel and custom scripts developed in the R open-source statistical analysis software. The following is a step-by-step sequence that describes the model flow as implemented in the model's code; each step is expanded upon in the Technical Appendix with discussion of data sources, model structure and specification, outputs, and sensitivity to changes in the inputs. For each scenario tested, the model will:

1. Combine the rail and air county to county flows (2008 and 2040 trip tables are preprocessed as round trips from county to county) to create total demand for rail and air service for each county pair (Figure 11-12).
2. Enumerate a population of travelers from the total demand data, sample a selection of travel parties to simulate in the remaining models, and simulate a trip purpose and party size for each traveler in the list.
3. Allocate each travel party to specific origin and destination Census tracts using an allocation model.
4. Simulate income category and vehicle availability for the travel party based on their trip purpose for the travel party and their origin Census Tract.
5. Choose the best airport and rail station for the origin and destination ends of the trip for each party using an airport choice and a station choice model.

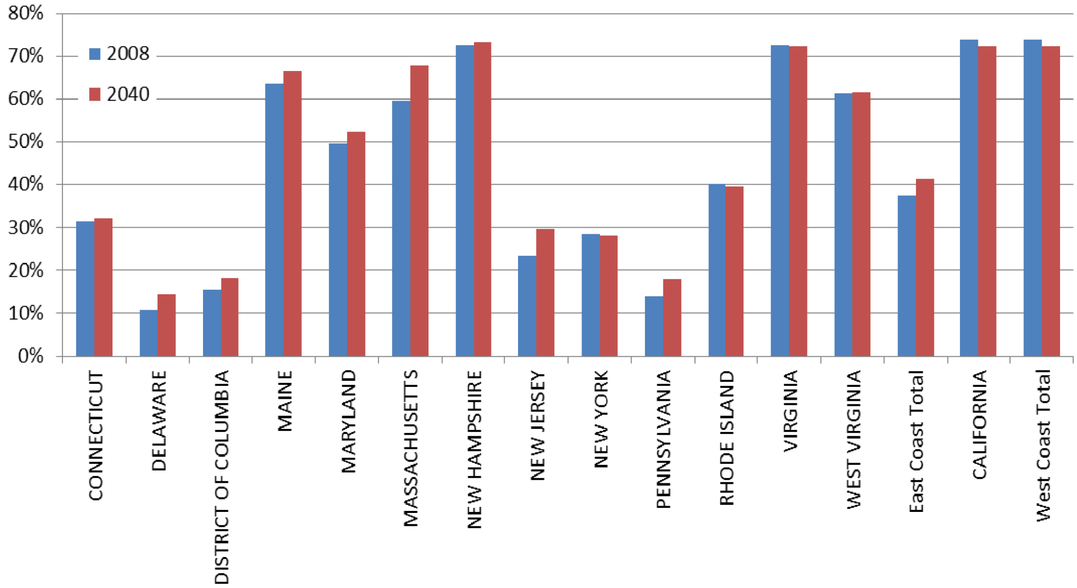

Figure 11-12. Air mode share by state for 2008 and 2040.

6. Apply the main mode choice model to choose between traveling by air or rail, based on the characteristics of the travel party, the accessibility of the airports and rail stations at the origin and destination end of the trip, and the level of air and rail service between them.
7. Apply the airline response model to calculate a likely response to the rail service scenario in terms of air service changes by the airlines.
8. Generate data in spreadsheet summary format.

Each of the eight steps undertaken within the model is summarized here.

Step 1. Combine Rail and Air County to County Flows

The model's first step is to import the preprocessed county to county OD flows for air and rail, which have been converted from one-way trips to round trips as described herein. The

Table 11.6. Air, rail, and total round trips by state (growth from 2008 to 2040).

State	Air	Rail	Total
CONNECTICUT	44%	38%	40%
DELAWARE	104%	45%	52%
DISTRICT OF COLUMBIA	82%	48%	53%
MAINE	63%	43%	56%
MARYLAND	67%	50%	58%
MASSACHUSETTS	98%	38%	74%
NEW HAMPSHIRE	47%	42%	46%
NEW JERSEY	95%	41%	54%
NEW YORK	37%	38%	38%
PENNSYLVANIA	89%	41%	47%
RHODE ISLAND	35%	38%	36%
VIRGINIA	59%	63%	60%
WEST VIRGINIA	65%	63%	64%
East Coast Total	**68%**	**42%**	**52%**
CALIFORNIA	57%	70%	61%
West Coast Total	**57%**	**70%**	**61%**

model then combines them to create the total demand for air and rail travel in the two study areas for both 2008 and 2040.

Step 2. Enumerate a Population of Travelers, Select a Sample and Simulate Trip Purpose and Party Size

This step of the model converts the summary of demand from each county to total trips and then to an enumerated list of travelers. The model then selects a sample of them for further simulation. For each selected traveler, the model simulates a trip purpose and party size by drawing from a joint distribution of trip purpose and party size derived from airport ground access survey data and rail survey data.

Step 3. Allocate to Census Tracts

The simulation sample that is produced by previous steps of the model and that is input into this step is comprised of a set of travel parties with roundtrip itineraries. The origin county at the start of the travel parties' outbound trips (and their final destination at the end of their return trip) is known, along with the destination county of their outbound trip (which is the origin county of their return trip). This model step then allocates each travel party in the simulation sample to specific origin and destination Census tracts within their origin counties and destination counties using an allocation model. The population data were obtained from the 2010 U.S. Census. The study areas comprise 13,273 tracts in the East Coast study area.

Step 4. Simulate Income Categories and Vehicle Availability

The simulation sample that is an input to the mode choice models is comprised of a set of travel parties with round trip itineraries whose origin county and Census tract at the start of their outbound trip (and their final destination at the end of their return trip) are known. Also know are their destination county, the Census tract of their outbound trip, and their trip purpose. This step in the model simulates the household income category and vehicle availability for the travel party given their trip purpose to allow the subsequent choice models to be applied correctly to each travel party.

The additional data used by this model step describes the distributions of household income and vehicle availability among air and rail travelers as well as the household income and vehicle ownership of households in the air and rail travelers home Census tracts. The data sources are as follows:

- Airport ground access surveys for the New York region, New England, the Baltimore-Washington area, Los Angeles, the Bay Area, and San Diego (FAA, MCOG, MTC)
- Travel survey data collected in California by California High-Speed Rail Authority. American Community Survey data for 2006–2010 at the Census Tract level describing household income and vehicle ownership, available from the U.S. Census Bureau (ACS).

Table 11.7. Population, employment, and hospitality employment by state.

State	Population	Total Employment	Hospitality Employment
CONNECTICUT	3,574,097	1,575,309	106,126
DELAWARE	897,934	392,294	31,489
DISTRICT OF COLUMBIA	601,723	621,524	54,762
MAINE	478,805	224,881	20,454
MARYLAND	5,668,368	2,383,588	184,822
MASSACHUSETTS	6,547,629	2,924,913*	232,603*
NEW HAMPSHIRE	819,087	372,312	28,024
NEW JERSEY	8,791,894	3,732,237	268,508
NEW YORK	13,874,816	6,025,444	398,364
PENNSYLVANIA	7,396,902	3,196,508	233,356
RHODE ISLAND	1,052,567	435,352	39,850
VIRGINIA	5,939,131	2,595,203	216,880
WEST VIRGINIA	175,208	46,465	5,041
East Coast Total	**55,818,161**	**24,526,030**	**1,820,279**
CALIFORNIA	36,689,600	14,285,120	1,251,945
West Coast Total	**36,689,600**	**14,285,120**	**1,251,945**

Source: 2010 U.S. Census.

Table 11-8. Most Flights per day–West

ORIGIN	DEST	Flights/Day
SFO	LAX	38
LAX	SFO	37
LAX	SAN	31
SAN	LAX	31
SJC	LAX	24
LAX	SJC	24
LAX	OAK	21
OAK	LAX	21
SAN	SFO	18
SFO	SAN	17
OAK	SAN	16
SAN	OAK	16
SMF	LAX	16
LAX	SMF	16
BUR	OAK	15
OAK	BUR	15

Source: BTS Transtats, 2008

Table 11-9. Most flights per day–East.

ORIGIN	DEST	Flights/Day
LGA	BOS	33
BOS	LGA	33
DCA	LGA	30
LGA	DCA	30
DCA	BOS	24
BOS	DCA	24
JFK	BOS	21
BOS	JFK	20
PHL	BOS	17
BOS	PHL	17
BOS	BWI	13
BWI	BOS	13
BOS	IAD	11
BWI	PVD	11
PVD	BWI	11
BOS	EWR	11

Step 5. Airport Choice and Station Choice

This step in the model applies airport and station choice models to each travel party to select likely airports and rail stations for their origins and destinations. The simulation sample that is input into this step is comprised of a set of travel parties with roundtrip itineraries where their origin county and Census Tract at the start of their outbound trip (and their final destination at the end of their return trip) are known, along with the destination county and Census Tract of their outbound trip. In addition, several characteristics of the party are known: party size, trip purpose (business versus nonbusiness), income category, and vehicle availability at the origin end of their trip. The additional data required by the airport and station choice models are as follows:

- Aviation data—flight availability and fares by airport pair and airport enplanements. These data were developed using publicly sourced aviation data, including T100, on-time performance data, and DB1B.
- Rail data—data items parallel to the aviation data using Amtrak OD data and Amtrak schedules (Amtrak).
- Transit accessibility measures for each Census Tract—derived from CTPP journey to work data.
- Highway accessibility to airports and stations—developed by applying shortest path algorithm from each Census Tract within 150 miles of each airport and station to a highway network built from a national street centerline geodatabase.

Tables 11-8 and 11-9 show the airport pairs in each study area with the highest levels of air service. The source for these data is the BTS Airline on-time performance data, which shows the service scheduled and actually operated, in this case for 2008. Unlike the Official Airline Guide, this is a publicly available source of airline LOS data; therefore, this is preferable as the data can be included in the model for distribution without licensing issues (BTS/Transtats).

Rail schedule data were developed using the published Amtrak schedule (Amtrak); these data incorporate Amtrak's connecting buses in California (this was also incorporated on the demand side into the development of the rail county to county trip tables). For the transit accessibility measure, 2000 CTPP data describing journey to work by mode was processed for all Census Tracts and counties in the study area to calculate transit mode shares for the journey to work. These data are used in the model as a proxy for transit accessibility from that Census Tract and county rather than attempting to develop transit network data, which is beyond the scope of the type of sketch planning model developed as part of this research.

While the primary choice model in the framework is the main mode choice between air and rail, the model incorporates a choice model to define the particular trade-off used in the main mode choice model for each travel party. The selection of particular airports and rail stations can be achieved using a simple algorithm, such as selecting the closest airport and rail stations. Instead of this approach, the model incorporates an airport choice and a station choice model into the framework. As a result, travel parties first choose between the available airports and then between the available rail stations at each end of their trip to select a preferred pair of airports and pair of rail stations for use in the main mode choice model.

The model that is being transferred is a joint multinomial logit airport choice and ground access mode choice model with alternatives specified for each combination of airport and mode choice. It was developed by members of the Research Team for the West of Hudson Regional Transit Access Study, WHRTAS (RSG 2010). This included airport choice between the airports in the New York region.

Step 6. Main Mode Choice

This step in the model applies the main mode choice model to choose between traveling by air or rail, based on the characteristics of the travel party, the accessibility of the airports and rail stations at origin and destination end of the trip, and the level of air and rail service between them.

The output produced by the airport and station choice step is comprised of a set of travel parties with round trip itineraries that include the origin and destination Census Tracts. Several characteristics of the party are known: party size, trip purpose (business vs. nonbusiness), their income category, and their vehicle availability at the origin end of their trip. Finally, the preferred airport pair for their trip and rail station pair for their trip are known, along with variables representing the accessibility of the preferred airport pairs and station pairs.

The data used in the airport and station choice models, describing the competing air and rail levels of service and fares, are used again in the main mode choice model.

Step 7. Airline Response

The airline response model predicts how airline schedules respond to the introduction of HSR service. Conceptually, that response includes several elements. First, to the extent that HSR captures traffic that previously traveled by air, airlines may reduce seat capacity on affected segments. Second, either as a result of offering reduced seat capacity or as a direct response to competition from HSR, the distribution of capacity among different types of airlines—mainline network carriers, regional affiliates, and low-cost carriers—may change. Finally, either as a direct response to HSR competition, or as a secondary response to diminished traffic, carriers may change their fleet mixes in corridors with HSR service.

To model these responses, the Research Team has performed econometric analyses on cross-sectional airline service data in order to isolate the direct and indirect effects of competition from existing rail services. This approach assumes that the impact of introducing HSR can be captured by the change in "rail competitiveness" that results; thus, the impact can be extrapolated by observing the effect of existing variation in that factor. Ways of measuring this factor are discussed further in the following section. An alternative would be to expand the geographic scope of the analysis to Europe and Japan, where HSR is already present. Limits on data availability and questions about the applicability of the results to the United States meant that the Research Team did not pursue this approach.

The input data used for estimation of this model are derived from the air and rail LOS data described in the Technical Appendix to this Report. The rail stations and airports in the East Coast and West Coast study areas were mapped to the common geographic regions of Metropolitan Statistical Areas (MSA). Figure 11-13 summarizes the implications of the model research concerning the relationship between the supply of rail service and the supply of air service. Data collected in the model building show rail travel times around one hour are associated with about 40% of the flights that would be expected without rail service. This effect attenuates so that a 7-hour rail service would be associated with 80% of the flights expected under a non-rail scenario. The effect disappears entirely at a rail travel time of around 11 hours. Although the coefficient estimates are significant, there remains considerable uncertainty about the actual coefficient values, and thus about the relationship shown in this diagram. As discussed in the section of Chapter 12 concerning further research, additional analysis will be required to reduce this uncertainty.

Step 8. Generate Data in Spreadsheet Summary Format

The ACRP Air/Rail Diversion Model creates a wide variety of output documentation, generally filed in the folder

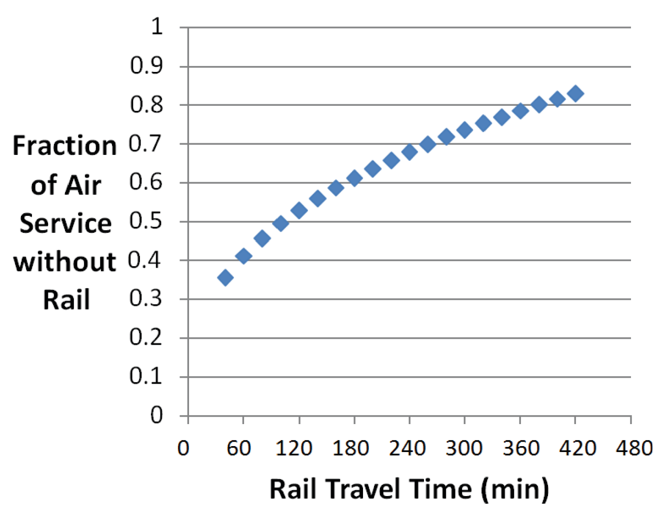

Figure 11-13. Relationship between rail travel time and air service without rail.

created for the specific scenario being modeled. Thus, for every model run undertaken for a specific scenario name, the model creates subfolders with spreadsheets concerning the information used and outputted in that model run. A partial list of the output for each model run includes:

1. Geographic assumptions.
2. Socioeconomic data.
3. Rail Station access data.
4. Airport access data.
5. Rail travel data.
6. Travel summaries for the present time frame.
7. Travel summaries for the future time frame.
8. For both the present time frame and future time frame output set, the model creates:
   - An airport-by-airport summary.
   - Results of the air response sub-procedure.
   - Total trips by county, by mode.
   - Total trips by SMSA, by mode.
   - Origin-destination summaries by county, by mode.
   - Origin-destination summaries by SMSA, by mode.

Validation of the Model: At the City Pair Level

A key element of the calibration of a model is the somewhat iterative process of "fitting" the results of the model to see how, at a given point of iteration or development, the model is replicating the conditions it was calibrated to represent. One of several examples of this validation process included in the Technical Appendix is reproduced here, in Figure 11-14. It shows a wide variety of cases in which the prediction comes close to the observed values, and suggests that some of these city pairs may have causal patterns that the general model has trouble dealing with, such as its propensity to under-predict volumes for the city pair between Los Angeles and San Jose. The interested reader is encouraged to explore the concept of validation more in the Technical Appendix.

Reasonableness of the Model at the Policy Level

The practitioner interested in the strengths and weaknesses of the model might also be interested in its more global application to the question of the importance of given attributes in the prediction of change in mode share for rail in the air + rail market. The Research Team undertook a series of analyses to cross check the basic level of "reasonableness" of the model for rail line haul times, the variable analyzed in Chapters 4 and 5 of this Report. Those two chapters presented a set of outcome mode shares together with total in-rail-vehicle trip times. The results of that test of reasonableness are described in the Technical Appendix. An example of the tests undertaken is here presented as Figure 11-15. The model tends to show that, when rail travel times are extremely short, the model tends to replicate the European experience of high rail share of the rail + air market.

However, the European data set had fewer observations about longer train travel times. Thus, the model tends to predict a mode share of about 5% to most rail trips of over 7.5 hours. The Research Team does not find this to be unreasonable (e.g., Boston to Washington, DC) as there evidently

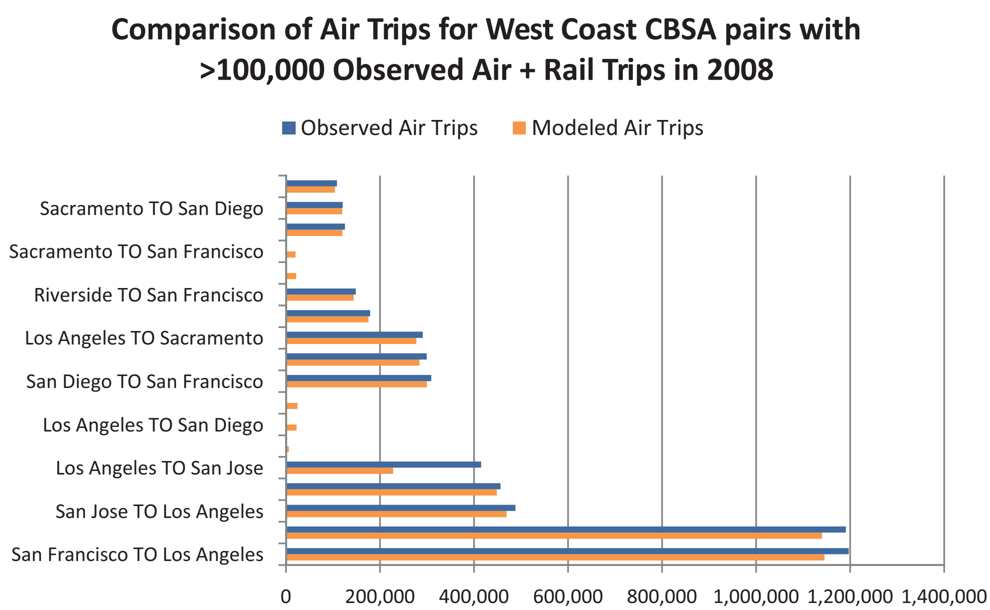

Figure 11-14. Results of the validation process.

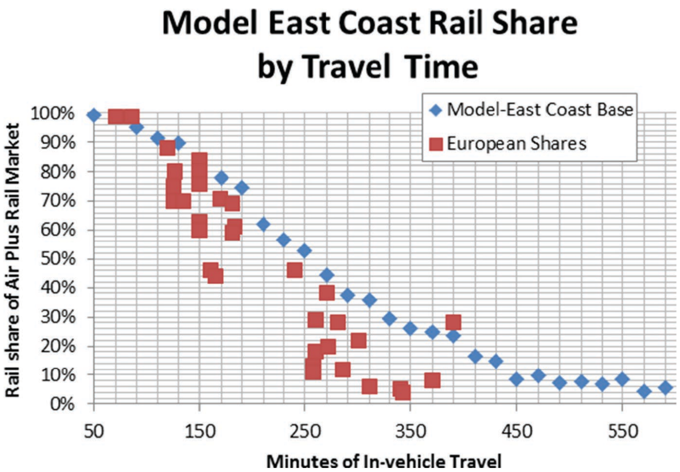

Figure 11-15. An example of a reasonableness test for global attributes of rail.

is a loyal residual market of travelers who do not choose to fly, and they are, by definition not very time-sensitive at these travel times. The reader might well conclude that the model is more relevantly applied to situations where the rail travel times are more competitive with air. In the important area around 3.5 hours of rail travel time, there is a considerable variation in the European experience for mode share. Within that category of rail travel times, the model tends to veer towards the higher range of the observed experience. The reader is cautioned that significant variations in these mode share calculations can arise from variation in assumptions about the geographic size of the market area of origin and of destination; the reader is encouraged to review the analysis included in the Appendix to the SDG report (2006) upon which the European shares are based. That analysis suggests that the larger the market zone size, the further a candidate traveler might be from the central business district and the lower the reported rail mode share will be. In short, a given reported mode share (from either continent) will be highly affected by assumptions made about the geographic scale of market shares considered. The level of variation in the accuracy of any reported mode share could be taken into consideration when comparing results.

Summary: Application of the Model

The ACRP Air/Rail Diversion Model was designed to provide a model that incorporates several improvements over the tools that are currently available to support integrated air and rail service planning:

- The model is accessible and relatively easy for planners and analysts to use, especially when compared to the much more detailed models that have been used for new rail service planning and environmental documentation.
- The model incorporates data on ground origin to ground destination air travel patterns, merging ground access patterns with airport-to-airport flows.
- The model includes accurate data on existing intercity rail passenger flows (from Amtrak).
- The model incorporates an airline response module that reflects the effects of rail/HSR services on flight volumes. This will also support HSR planners to estimate the corresponding benefits to airports of new rail service.
- The model produces output in a spreadsheet format (comma delimited from Excel) that is easily transferable to other programs for analysis (e.g., SPSS or SAS) or graphic presentation (PowerPoint or MS Publisher.) In the same process, the model produces spreadsheet summaries of the results of calculations made while running the submodules of the model.

Uses of the Model Presented in This Chapter

Chapter 11 has provided an overview of the model; it specifically illustrated how the model could be used for the examination of broad policy issues on a high level basis, and introduced the concept of tests for model validation and assessment of reasonableness of policy results. As described in much more detail in the Technical Appendix, the model can be further utilized by variation of many input parameters, including project specific alterations in speeds and travel times for geographically specific networks and segments of networks, down to the level of city-to-city pairs.

Further Development Possibilities

The model has been prepared using open-source software methods, and is specifically designed to make use of data that is provided by the agencies of the U.S. DOT. As such, practitioners can refine the model to change a wide variety of input assumptions, all of which are presented transparently the program's application. Different practitioners could take the model in different directions, based on these open-source characteristics. This further development work could be undertaken in later research projects, including possibly some within the Cooperative Research Programs. The purpose of Chapter 11 has been to explore the use of the model to better understand the inter-relationship between key factors in both the East and West Coast project study areas. The possible directions for later research are further discussed in Chapter 12.

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CHAPTER 12

Strategies for Integration of Air and Rail: Review and Further Research

Introduction and Structure

Chapter 12 is presented in two sections. In Part One, the Chapter examines key themes and strategies that emerge from the examination of the American and European projects and programs discussed in this report. The focus is on how the many themes and strategies must work together to bring about results. First, the section reviews major lessons learned concerning the competition between rail and air. Then it explores what combination of strategies might be needed to allow long-distance rail and longer distance air services to operate as a more complementary intermodal transportation system. Three component elements are reviewed: (1) quality of transportation services offered; (2) quality of physical infrastructure at the points of air/rail interconnection; and (3) integration of marketing, ticketing, and baggage management strategies.

Part Two then presents a review of the possible implications of these themes and practices for further research and policy development. It suggests several areas where additional research could improve the understanding of the major implications of the research undertaken in this ACRP research project.

Part One: Reviewing the Major Themes Revealed in this Research

Context

Rail systems and air systems interact and influence each other in several ways. For many, a rail station at an airport symbolizes rail and air working as part of a robust intermodal system—perhaps even an airport planned from conception to operate well with a central point of transfer for several kinds of rail services, such as the newest plan for an additional air terminal complex at Orlando International Airport (Figure 12-1). But, quality of the physical/architectural design is just one part of the puzzle. This report concludes that the relationship between an air system and a rail system should be conceived as a network of interconnected products—products that in some cases compete for customers' dollars and products that in other cases create seamless, unified services. For the latter in particular, the successful intermodal passenger product will only work if it produces positive business outcomes for the airlines, for the rail operator, and for the airport managers.

As revealed in Chapter 1, in the United States, the role of rail in a competitive mode to air simply dwarfs the scale of any activity where long-distance rail might feed major airports for long-distance flights. At the same time, Chapter 1 shows that in Europe the volume of travel undertaken by rail in a complementary mode is several times the scale of that diverted away from air and onto long-distance rail.

The meaning of this for planning of American intermodal systems is unclear and could be further explored. The empirical findings presented in Chapter 3 show that Americans do not use rail as a long-distance feeder to airports, with the possible exception of airports in America's most dense metropolitan areas. However, in general, American travelers have not been offered packages of services that would be expected to gain the kinds of market success reported in Chapter 2 for many airports in Europe. Therefore, while this report concludes that Americans do not currently use long-distance rail as a feeder to airports, the report is not concluding that Americans would never respond positively to well-presented services in the marketplace, were they ever to be offered.

Rethinking the Concept of Competition

In terms of data organization and data interpretation, this study has separately examined the role of rail in competing with, and its role in providing access to, air. Indeed, the decision by the rail provider to stop at an airport may be in direct conflict with the objective of allowing the rail to play its optimal role in an intermodal network (e.g., slow trains do not divert passengers from congested airports). Given these observations, this report emphasizes the concept that, in providing high-quality point-to-point service, long-distance passenger

Figure 12-1. Airport planners are working with rail planners at Orlando International Airport on an "Intermodal Terminal" for long distance rail, commuter rail, light rail, and an on-airport people-mover. Source: Greater Orlando Aviation Authority, 2013.

rail can be contributing to solving aviation system capacity problems. In interviews with airport managers in San Diego, officials stressed their disappointment that CHSRA plans would not divert more of the air market between the city of San Diego and LAX. Good competitive service to LAX was seen as having the greatest rail benefits for San Diego—supporting the theme that rail services not be portrayed to the public as either just feeder-to-airport or region-to-region services; sometimes they are both.

In the American experience, the interviews illustrated a consensus that the first responsibility of the rail system is to provide competitive terminal-to-terminal travel times with investment in HSR. Thus, any additional station stop must be justifiable in terms of the number of additional passengers (and thus revenues) gained to the system compared with the additional travel time inflicted on the through passengers. Consistent with the desirability of minimizing stops on the alignment, in some cases the optimal location of a long-distance airport rail station may not be on/near airport property; instead, the optimal alignment would be to connect airport riders back to a high-quality transfer point in the rail system. The concept of replacing the existing rail station at Newark Liberty International Airport with a greater focus on Newark Penn Station was actively explored by the PANYNJ through the RPA study, allowing for all Amtrak services to feed the airport, (n.b., The PANYNJ has more recently announced its intention to extend PATH to the airport rail station). This was the early direction taken in the San Diego Regional Airport Strategy Plan, although there is no local consensus that this is the optimal solution. Concerning SFO, this is consistent with the present plans for new, "blended" rail services to only stop at Millbrae, where BART trains, Caltrain services, feeder buses, and major parking will come together in one, unified intermodal transfer facility. Thus, in some cases desire of the rail operator to minimize the number of stops may be consistent with the needs of the airport to see high-quality feeder services provided. The two categories of air/rail relationship are separate, but not always in conflict.

The popular focus on the airport-based transfer facility is perhaps misplaced. The quality of transfer at the airport is only one piece of a bigger puzzle in which the analyst must first answer the question of why the traveler would select the several-mode trip in the first place. This research effort has observed that, before one gets to the questions of site planning and architecture, the basic logic of the long-distance rail feeder mode must be established within the context of the larger question of competing network combinations of services. A future expansion of the existing research field of "airport choice" might include high-quality ground access modes as a factor as important as travel times, ticket costs, and frequent flier loyalties.

Perhaps most importantly, the integration of aviation and passenger rail planning may require a basic acknowledgment of where each mode excels. As documented in Chapter 3, the rail manager may serve the intermodal system best by not stopping trains at an airport rail station. The airport manager may serve the intermodal system best by supporting high-quality connections to points on the rail system where the rail needs to stop, to deal with rail markets other than airport access markets. The airline manager may find that the marketing of a joint ticket may prove advantageous in some market conditions, but only for combinations where superior times are attainable. All of these anecdotal observations tend to support the conclusion that metaphors based on the inherent competition between modes could be replaced by new ones based on the idea that some elements of the intermodal system can be integrated for the greater good of the traveler. The resulting networks could maximize the potential of the travelers to make choices based on their own values expressed in a marketplace setting.

Competition: Considerations in the Diversion from Air to Rail

Lessons Learned About Rail Diversion from Air

This report has concluded that major diversions from air to rail have occurred in Europe, with about 7 million passengers reported in the corridors examined. In the NEC in the United States, roughly 1 million passengers were reported. The study of diversion from air to rail has strongly supported the long-believed "rule of thumb" that a travel time of 3.5 hours (or less) from rail terminal to rail terminal is a necessary precondition for the rail to capture the majority of the air plus rail market. Moreover, the conclusions of Chapter 5 suggest that American travelers respond to in-vehicle travel times similarly to European travelers. Figure 5-2 makes possible this comparison of rail market share for the two continents, using only origin-destination markets.

Diversion from a Corridor Perspective

Chapters 4 and 5 illustrated that the manner in which airlines alter service is difficult to predict. Rail systems and air systems operate in parallel; a given change in the economic supply characteristics of one mode will stimulate a market response from the competitive mode. The final service balance between modal services will be determined less by the characteristics of the segment, and more by the characteristics of the full network. While the amount of diversion from air tended to support initial assumptions, the change in the amount and nature of air service in an impacted corridor is harder to summarize. In several corridors in France, the pattern is summarized as a decision by the airline to retreat from the origin-destination markets while carefully retaining all the flights needed to maintain a competitive position with good feeder service to longer distance markets. By contrast, in the market between Barcelona and Madrid, Chapter 5 did not find any significant retreat in terms of traditional shuttle-quality service between the two cities, resulting in the air service gaining slightly more than 50% of the market when connecting air passengers are counted, and slightly less than 50% when the only origin-destination air passengers are counted.

The response of the aviation sector in the Madrid-Barcelona corridor was similar to that in the American experience between Boston and New York. Chapter 5 describes how a similar number of flights were undertaken with smaller aircraft, which are cheaper to operate for the airlines. These observations led to a reaffirmation of the original planned work program, which prioritized the project undertaking a new model of rail to air diversion, which would begin the task of incorporating possible responses by the airlines into the forecasting process.

The data presented in Chapter 4 concerning diversions from air to rail in Europe, and Chapter 5 in the Unites States document that high-quality rail services can, indeed, divert air passengers away from flights, and to a lesser extent, can lower the number of flights at impacted airports. The question of how the market factors interact together to bring this about was examined in some detail in Chapter 11, which presented the results of this ACRP project's Air/Rail Diversion Model. A quick summary of the manner in which market factors can combine and interact to result in diversion of air passengers to rail in a corridor is presented in graph form in Figure 12-2, reproduced from Chapter 11. Based on the structure of the chart, two separate sets of considerations can be observed together. First, as the rail is (or is not) able to compete in terms of competitive costs, amount of its scheduled services, and the speed of its services, its effect on lowering air volumes is graphed; second, the graphic format shows how the addition of these increments of competitive attributes vary by the geographic subarea of the Northeast Corridor. As noted in Chapter 11, there are simply more air trips left to be diverted from the geographic regions of the north of and to the south of the New York and Mid-Atlantic regions. Accepting the premise that the final scenario (right) represents a set of assumptions that are "optimistically" favorable to rail, decreases in air volumes between 10% and 40% for travel within the project East Coast study establish the scale of diversions for further discussion and analysis.

As also noted in Chapter 11, the reader must consider that these relationships concern only those between rail and air service; no modeling of diversion from auto or diversion from bus has been undertaken in this ACRP project.

Diversion from an Airport Perspective: O'Hare

Looking back at the major conclusion of Chapter 6, this research has not located many opportunities for rail to replace air services to and from Chicago O'Hare International Airport. As documented there, the Research Team analyzed both diversions from air for the O-D market, and diversions from other ground transportation modes for access to the airport.

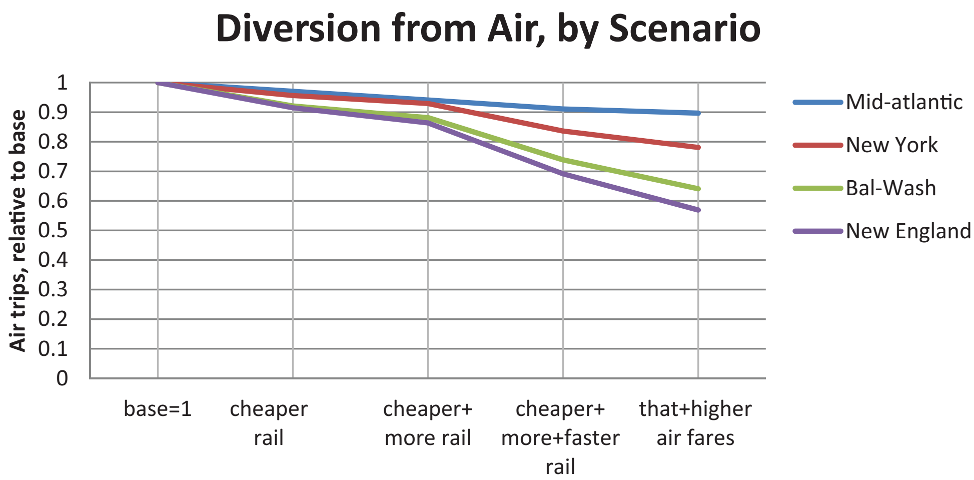

Figure 12-2. Factors influencing competitiveness of rail for diversion from air. Source: Chapter 11.

As shown in the tables from Chapter 6, and reproduced here as Table 12-1, the strongest market analyzed is comprised of diversions from air trips within the study area. Because these trips make up only 6% of the boardings at ORD, the potential for this diversion to reduce congestion seems to be highly limited. The Research Team's methods did not allow for an estimate of how many long-distance air passengers would select the long-distance rail mode as a substitute for feeder flights, which would continue to exist in this market. However, the data in Chapter 6 shows that the major markets choosing to fly to ORD to gain access to long-distance flights are from large cities at the periphery of a possible rail market area. The small amount of European data available regarding the choice between rail as a long-distance feeder versus air as a long-distance feeder suggests air services have the edge. Thus, there seems to be only a limited amount of "low-hanging fruit" for a possible rail market to lower the number of flights at ORD.

Complementarity: Three Components of a Successful Rail Feeder System

Turning to the report's conclusions concerning rail in the complementary mode, the market factors in play require a more nuanced analysis than applied in the previous paragraphs. It is unknown if exacting conditions must exist for an air/rail transfer system to work well. This report reviewed a series of attempts in the United States to add rail stations to existing long-distance lines to allow intercity rail service to serve as a feeder service to longer distance flights: in only one of them (Newark) does intercity rail make up at least 1% of the total embarking passengers at the airport. A unified strategy to make long-distance rail successfully feed airports would require three program elements. The following section explores each of those component elements.

The research for this report pointed to three component elements of a successful integrated air/rail system:

- First, the system includes intermodal services that are superior from a network perspective.
- Second, the system includes physical facilities that can provide seamless transfer.
- Finally, integrated institutional systems would logically benefit from support systems for integrated ticketing and service provision.

All of this could be set in the context of the existence of a national public policy: a strong public policy towards creating an efficiently unified system might influence decisions taken

Table 12-1. Diversions to HSR at Chicago O'Hare airport.

	Low Diversion	Medium Diversion	High Diversion
Trips within the study area (O-D Market)	298,576	522,508	746,440
Ground Access Market	124,547	217,958	311,369
Rail-as-Feeder Mode		(not quantified)	
Total	423,123	740,466	1,057,809

in all three levels of the hierarchy. Thus, the operation of a late-night rail service from an airport might be evaluated differently in Switzerland (where public policy is clear) than in the United States, where the mandate to the rail operator is less discernible.

Component One: Marketable Services from a Network Perspective

The most important factor governing the success of an integrated air/rail system is the role of the station within complex markets and networks that feed those markets; this will determine the outcome of the project. The first requirement is that air services at the host airport offer an aviation product that is sufficiently attractive to lure riders from outside its immediate market area. The second requirement is for the rail operator to provide a set of services to support this demanding market segment.

The Services Provided by the Air Companies

Consistent with the interview with Hans Fakiner of Fraport, the host airport must be offering some product characteristic not offered at an airport closer to the user's actual origin. Airport managers in Lyon (Figure 12-3) learned that people will not take a train to a distant airport in order to gain access to a set of services qualitatively similar to those offered at the airport closer to the traveler's point-of-origin. These basic market facts set in motion a spiral of consequences in which the long-distance train operator chooses not to stop many trains at the airport, making the combined product even less competitive. While this was happening in Lyon, the parallel decision by German Rail to stop fewer long-distance trains at the new Dusseldorf Airport stop had a similar market effect.

In the United States, the differentiating market characteristic may be price. Several interviews revealed that when Southwest Airlines was offering unusually low prices at BWI, and was not providing such services at PHL, air travelers took Amtrak south to BWI, a pattern which has decreased today. Similarly, the quick characterization of an airport as a "low-cost airport" is much less of a pattern today than it was a decade ago. Although the reasons for this are largely beyond the scope of this study, some "low-cost" carriers returned to (or developed in) traditional airports over this decade, which resulted in airports such as Boston Logan offering air service at a wider range of price points than a decade ago. This, in turn, would affect the number of Boston travelers desiring to take rail services to the Providence airport to access a low-cost carrier, for example.

In Europe, the differentiating market characteristic may be direct, non-stop airline service, particularly to destinations beyond the continent of Europe. A major challenge to the growth at Gatwick Airport (Figure 12-4) has been varying mix of flights offered from there over the decades; high-quality rail has been a given.

In Germany, the provision of many direct flights to Asia and America occurs primarily from one single hub, FRA. Thus, it makes sense to tolerate a relatively long train ride in Germany to get the non-stop service to Qatar, for example. This could be contrasted with a resident of Philadelphia, who, upon considering a long train trip to JFK or Newark, has a wide variety of direct flights from her/his own metro area, and sees no logic in a long feeder segment.

The market strategies in play must be examined in detail on a case-by-case basis. The managers of strategy at Amsterdam Schipol might conclude they had a better chance of pulling rail customers in from Belgium, where the traditional air carrier had ceased operation, rather than from areas to the east where competition is intense with German airports. Zurich might

Figure 12-3. The air/rail station platforms at Lyon are largely empty. Source: www.Shutterstock.com. Copyright: procasson Frederic.

Figure 12-4. Gatwick offered high quality rail connections from its inception in 1956. Source: www.pprune.org (image from original postcard).

conclude it would be more competitive to pull rail passengers down from southwestern Germany than from Italian-speaking markets within Switzerland itself, but located beyond mountain ranges difficult to traverse. In each case, rail either does or does not fill a market niche that positions the airport to compete with other airports all offering essentially the same network ability to provide services from airport of origin to airport of destination.

Examination of the importance of the host airport providing superior aviation services suggests that JFK, EWR, SFO, PHL, ORD, and LAX meet the criteria of provision of superior long-distance aviation services.

The Services Provided by the Rail Companies

Just as the airline services from the airport must be attractive, the scheduled ground mode to the airport must offer a schedule that mimics the actual operational patterns of the air network. It is common for arriving air passengers to be one or two hours late because of missed connections, etc. An Amtrak schedule with three or four services per day might be inadequate to be competitive in this element of the trip selection process. Fakiner sets one train per hour as the gold standard, which is usually met by German Rail services to FRA. On the West Coast in the United States, some peak departure hours occur around 7 a.m., making extraordinary time demands on a rail system. In short, the connecting rail service must offer a consistent set of services to accommodate both planned and unplanned air service schedule patterns. Most importantly, the business case for the rail company to provide these services must be strong enough to entice the rail managers to provide them.

Over 24 million long-distance rail trips to a sample of European airports were identified for this report. Each airport was designed to benefit from the long-distance rail infrastructure, with long-distance services designed to gain market share from airport passengers. In short, with supportive market conditions, rail companies can provide services that work.

At the same time in many other cities rail managers have opted not to send HSR directly to airports. In London the presently proposed initial HS2 system does not serve Heathrow directly. While a later airport spur is under debate, the Government does not intend to extend the present HS1 line further beyond London, ending speculation about a possible service from Heathrow to destinations on the Continent. The national rail system around Madrid received a massive investment in HSR; this investment did not attempt integration with airports. Additional cities well served by HSR, but not integrated with the airport, include Rome, Hamburg, and Munich.

The Replacement of Air Feeder Services with Rail

The European interviews suggest that developing feeder rail services to the level where they replace feeder air services has seldom happened in Europe. Any air service that is a candidate for deletion will be reviewed critically both by the airline affected and the long-distance rail carrier. Clearly, the business case for deleting a feeder flight and substituting a rail connection must be beneficial to both air and rail companies before such a deletion will occur. As documented in Chapter 2, the air passenger from Boston to Cologne who, for one reason or another, does not like the train between FRA and Cologne is offered a robust set of competitive air service options via Paris, Amsterdam, and Munich. Seen in terms of network connections, no airport or rail company can conclude they have a monopoly position over any link or segment. A decision to eliminate a feeder air option has market implications for the airline and the airport. The European experience suggests that early successes at providing feeder services by rail in Frankfurt and Paris CDG airports may be difficult to replicate in Europe or elsewhere.

Concerning "Component One," the first question is whether the airport-to-airport aviation offerings at the rail-served airport make sense to the traveler. This is followed by a decision about the quality of rail access. In the home based trip, access options include possibly small feeder planes, scheduled rail or buses to the airport, or possibly unpleasantly long personal driving distances and associated high cost parking. However, in all cases, they must be accessing an airport that has appealing air service characteristics compared with a competing airport closer to the origin of the traveler. Assuming that these underlying market requirements have been met, the question can turn to the quality of transfer at the airport.

The Role of Good Design

The Research Team does recognize that high-quality architectural design of the rail/airport terminal/station does not solely guarantee, or result in, ridership success in bringing intercity, commuter, or even HSR services to an airport. However, if all other factors (e.g., rail service characteristics, frequencies and fares, airport and rail providers in full partnership, financial framework in place, and proximity to the terminal processing/check-in functions) are in the right synergistic state, then the architectural design of the rail/air terminal can make a meaningful contribution to the success of the integration. The architecture can enhance the sense of arrival, convenience/orientation, and the LOS for the air traveler using the rail mode and serve as a marketing/PR tool to reinforce the overall "experience" of this mode of access to the airport terminals (Figures 12-5 through 12-7). This concept is explored further herein.

Component Two: The Quality of Air/Rail Transfer Facilities Provided at the Airport

More conventional questions of site planning and design become relevant once both conditions of good aviation and rail service have been established. This section of Chapter 12

Figure 12-5. At Oslo Airport, the rail alignment under the terminal (center) *and under the airside area allows through-routed intercity service. Source: Oslo Airport.*

explores the lessons learned about optimal site planning attributes for a successful airport air/rail transfer.

In the review of existing conditions at case study airports, earlier chapters of this report defined three site planning concepts for locating the rail station relative to the airport:

- First, the long-distance rail alignment could be re-routed into the area of the main passenger check-in terminals.
- Second, the long-distance rail alignment could be brought as close to the passenger terminal as reasonable, with a minimized distance for a people-mover connection to the main terminal(s).
- Third, the transfer station could take place at a non-airport location, with high-quality transfer back to the airport passenger terminals.

What Functionality Would Be Required for an Optimal Transfer?

In the optimal system, the passenger emerging from the train would be processed at a reasonable walking distance from the rail platform, including the critically important security clearances. After this point, the psychology of the traveler suggests that he/she has "arrived" and will be served from that point forward. It is productive to examine two kinds of airports when looking at the design constraints influencing the physical quality of intermodal connections. First examined are airports built in the "greenfield" context, where the designer could specify connections to rail services from the earliest conceptualization of the airport master plan. Second to be reviewed are airports where extensive existing infrastructure must be retrofitted to adapt to the addition of a rail service to an already functioning airport.

Air/rail Connections at "Greenfield" Airports

Examples of where the airport site planner has had the luxury of designing an airport and rail as one integrated design include the European airport with the highest overall share to public transportation, Oslo (Figure 12-5), and new airports in

Figure 12-6. At Berlin Brandenburg Airport, the rail line is in a tunnel through the airport, allowing a through-routed rail station, shown by the symbol "S." Source: Berlin Brandenburg Airport.

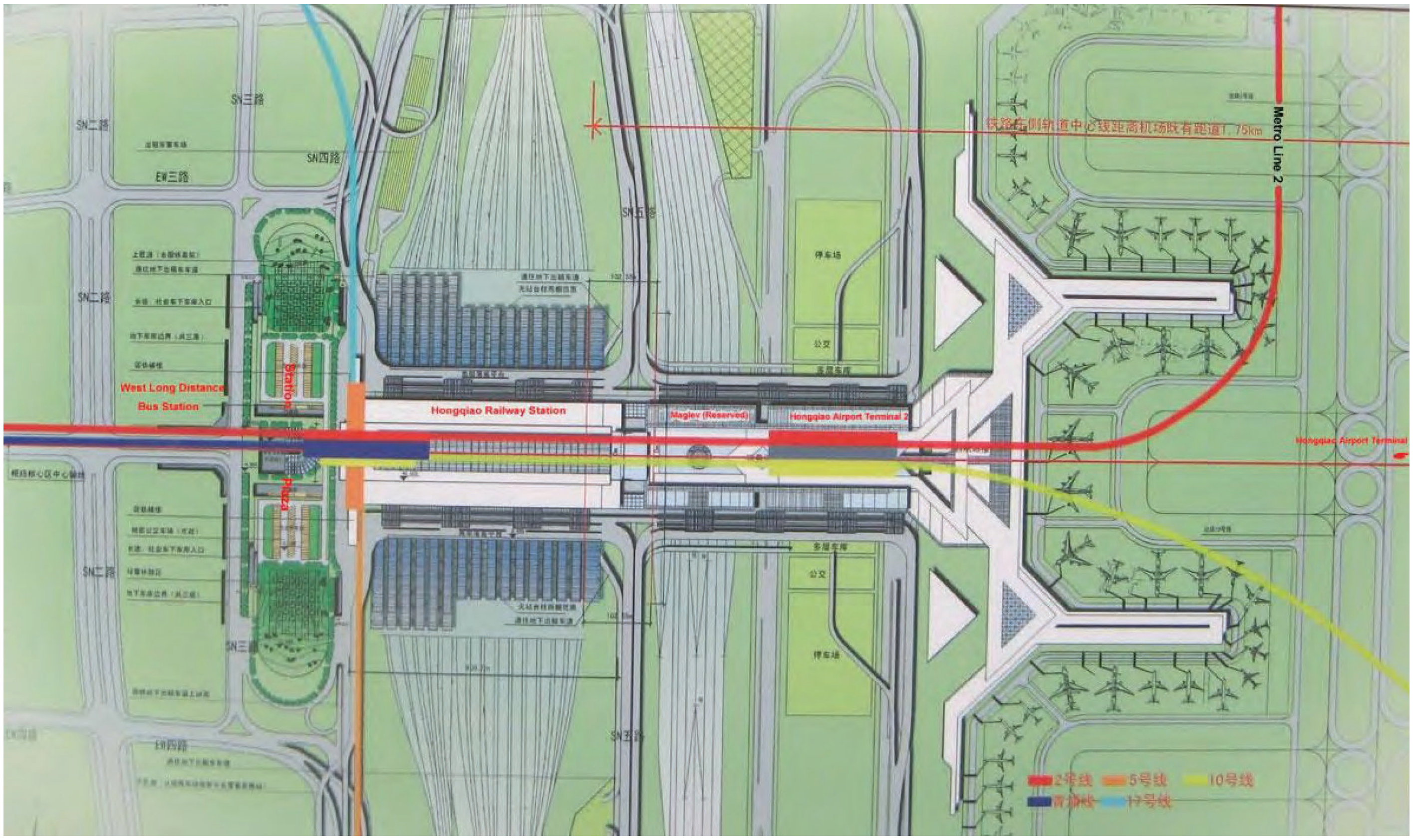

Figure 12-7. At Shanghai Hongqiao, inter-city bus (**left*****) connects to long distance rail, to Maglev (*****center*****), to the air passenger terminal, to the airplane gates (*****right*****). Source: Jiangsu Region Office of Travel and Tourism (2014).***

Berlin (Figure 12-6) and Shanghai (Figure 12-7). Similarly, the expansion of Orlando International Airport will take place on an empty parcel of land, allowing the designers considerable latitude in the integration of air and rail terminal facilities, providing, in effect, a "greenfield" addition to an older existing airport.

Greenfield Airport Designs Outside the United States

Shanghai. Figure 12-7 shows a good example of careful design integration of long-distance intercity rail with airport design in Shanghai. The airport complex shown is designed to deal with the considerable number of rail platforms integrated into the system. The need for multiple rail platforms is a particularly challenging design problem for the retrofitting of existing airports to add long-distance rail. The landside air terminal has been designed to provide passenger car drop off on both sides of the terminal, while minimizing walking distance from both the long-distance rail station (left) and the metropolitan rail station (center).

Functionally, the Shanghai intermodal complex forms the same set of functions as that in Oslo Airport, shown as Figure 12-5. Long-distance trains are provided with through service as the design routes the rail alignment through (and beyond) the airport, rather than using a stub-end terminal. In the case of Shanghai, the tracks are kept to the side of the airside portions of the airport; in the case of Oslo, the tracks use a tunnel under the taxiways, a design detail that allows the rail station to be located directly in the basement of the air terminal.

Berlin. The Oslo terminal concept, where the long-distance rail line is tunneled through the airport, with a major rail station under a central landside air terminal, has been adopted in Berlin Brandenburg Airport (Figure 12-6), scheduled for opening in 2016. The initial concourse will serve up to 30 million passengers per year; two satellite airside concourses connected by people-movers will be added later, increasing the build-out capacity to 50 million. The full build out is entirely served by the landside air terminal with the rail facilities in the basement.

Gatwick. Other examples where the airport designer accommodated through-operated intercity rail services for a newly built airport include London Gatwick (Figure 12-4), where the idea was first demonstrated in the 1950s. With the present consideration of doubling runway capacity at Gatwick, designers there are exploring the best way to connect new landside terminal facilities with the existing rail alignment. In other cases, designers have brought about integration with new air terminals by placing the rail station in a stub-end configuration, as was done at London-Stansted Airport, which offers rail service to regional locations in addition to its dominant rail market to London.

Greenfield Airport Designs in the United States

Existing American Airports. In the United States, only a few airports have been built without the need to adapt existing terminals, with completely new terminal facilities, and most of those were not designed to accommodate long-distance rail. Many of these newer American airports have been designed around a single, highly centralized landside "central processor" terminal including airports in Tampa, Orlando, Atlanta, Pittsburg, and Denver. Such a centralized landside configuration would be a positive factor in dealing with a rail service, if one were offered. Of these, only Atlanta is currently served by local rail, with Denver now building a local rail station; only Orlando has active plans to link to longer distance rail.

Orlando. The Greater Orlando Aviation Authority announced in 2013 an ambitious expansion plan for its Orlando International Airport. The expansion will occur in a now-empty parcel located just two miles south of the existing facility. The new complex is being designed from the ground up to deal with rail routes being planned by others to the airport. While Orlando International Airport was originally designed to operate out of a single landside terminal, now called the North Terminal, the Airport Authority has determined that a second, and somewhat independent terminal area complex will have to be built, called the South Terminal Complex. The airport believes the existing facility will accommodate about 45 million passengers per year in about year 2019, requiring a new approach to expansion. The master plan documents call for a multimodal strategy which includes:

- "Development of a viable Mass Transportation Commuter Rail System
- Regional Development of a viable Intercity Passenger Rail System
- Strategic Geographical Location as an opportunity for Multimodal Connectivity
- Seamless Integration of Multimodal Transit in the South Terminal Complex (STC) Master Plan Concept" (Greater Orlando 2013)

In terms of its site plan, the Orlando STC (Figure 12-8) can be compared with that in Shanghai (Figure 12-7). By placing the intermodal transfer terminal in the center of the complex (see Figure 12-1 for full site plan), a single rail terminal can serve one major air passenger terminal complex to the east, and one to the west. Looking only at partial build out (with the first terminal assumed to be on the east side in the diagram), the Orlando rail rider would emerge from the rail terminal area, proceed through a garage/hotel complex, and then to the air passenger terminal. After processing there, an airside people-mover would connect to all six STC airside concourse areas. This is similar to the path from the long-distance rail platforms to the airside concourses shown in the Shanghai diagram, except for the parking garage complex. The Orlando walking experience is similar to that existing today in Frankfurt (Figure 2-3), where the long-distance rail user proceeds through the hotel/commercial complex and then to the air terminal, after which an airside people-mover is available to get to the more distance concourses.

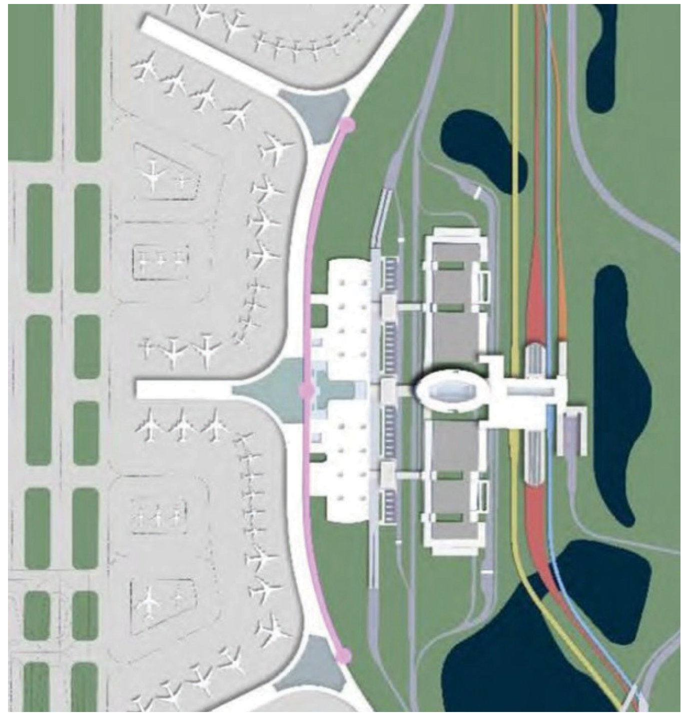

Figure 12-8. In Orlando's South Terminal Complex, the terminal for long distance and local rail is on the right, with a parking garage* (center) *and air terminal* (left). *Source: Greater Orlando Aviation Authority, 2013.

Air/rail Transfers at Adapted Older Airports

European Examples of Adapting Older Terminals

Most airports served by longer distance intercity rail were not designed for such connections. While Oslo and Berlin stand as optimal new European models for transfer between rail and a centralized landside passenger processing area, good examples of "best practice" for adapting older airports can be found in Amsterdam, Zurich, and Copenhagen. The ambitious construction process at Amsterdam Schipol took the through-routed rail line to the center of a complex with three passenger terminals, where baggage pick-up is highly centralized around the rail station. As documented in Chapter 2, each of these airports followed the strategy of bringing the rail line as close as possible to the actual airport facilities while minimizing the construction impact on a functioning airport. Each of these three airports links the train station by a short-distance walk to both check-in and baggage claim/customs clearance locations.

While some European airports with longer distance rail connections have been able to provide all landside terminal functions (check-in and baggage claim) adjacent to an air/rail station, the larger airports have not. Simply stated, as airport volumes get bigger, it becomes more difficult to process all passengers in one location. Consistent with the problems faced in Paris CDG, Terminal Two in Frankfurt is more than a mile from the intercity rail station, and expansion plans for the airport call for more terminals on the opposite side of the runways. This mirrors the dilemma faced by ground access planners at Heathrow, who found that they could not connect the Heathrow Express to both Terminal Four and Terminal Five; the layout of the multi-terminal airport was simply too complicated for the provision of direct rail service everywhere.

In short, best practices and lessons learned from European airports support the idea that the largest airports must accommodate some kind of passenger distribution system (usually an automated people-mover system) to connect the rail station(s) with a set of air passenger terminals. The design of these systems is often a challenge to the system designer. The new people-mover connection from Paris CDG's older Terminal One to the high-speed rail station is nearly two miles in length.

American Examples of Adapting Older Terminals for Rail Transfer

There are not many examples of favorable transfer conditions between long-distance rail and airport landside terminals at major North American airports. In terms of site planning theory, the people-mover connection from the Northeast Corridor (NEC) main line station to Newark Liberty Airport's three passenger terminals provides much of the functionality noted here. Its early designers strove to provide the traveler with the option of checking in to the "airport" at the train station (a service since abandoned). In practice, design limitations and general quality of service from the people-mover connection have been a concern (Zupan et al. 2011). Thus, this section focuses on several American examples of transfer facilities under design and development.

Miami Intermodal Center. As discussed in Chapter 9 (from the point of view of funding), any review of American best practices in the site planning design of transfers should include the recent developments at the MIC at the Miami International Airport (Figure 12-9). The airport has opened

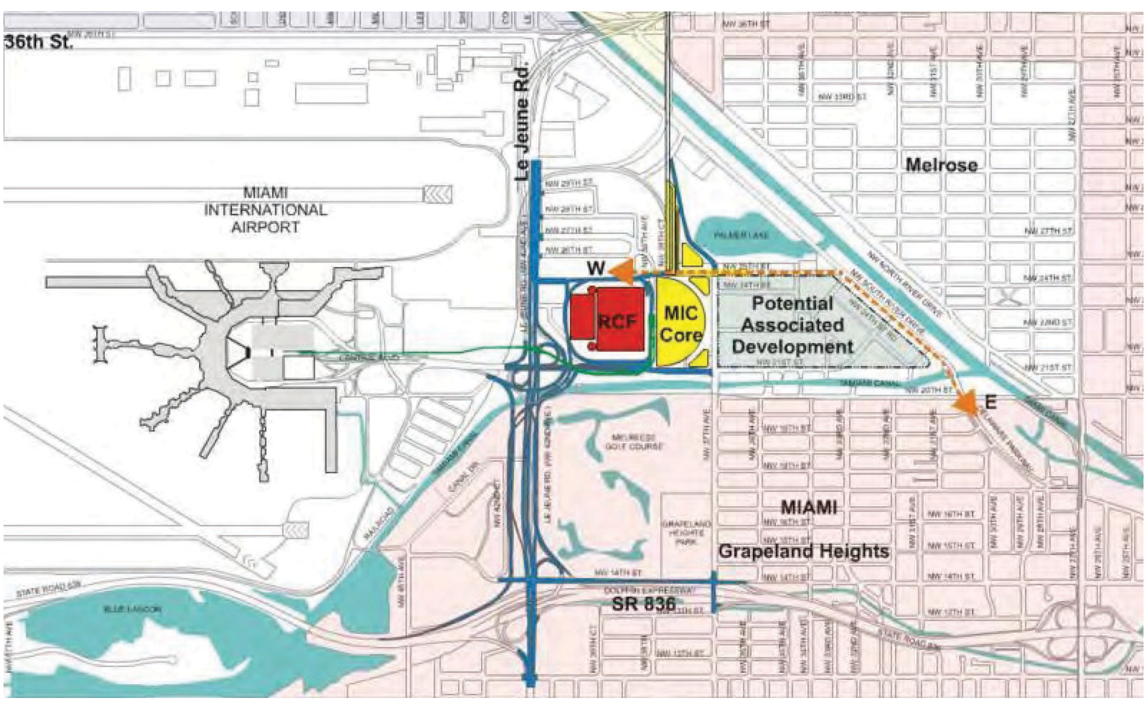

Figure 12-9. The "Miami Central Station," labeled "MIC Core," is located about 1.2 miles from the airport station of the MIA Mover. Source: Miami Intermodal Center, Florida DOT.

a people-mover, called the "MIA Mover" between the Miami Central Station and the central garage of the airport terminal area. At the Miami Central Station plans are being realized for a joint complex, including a new Metrorail rapid transit station, and a rebuilt rail station for both the local Tri-Rail service and two Amtrak trains per day, all adjacent to the Rental Car Facility (RCF in Figure 12-9). The users of all these access modes, plus some bus services, will now have a direct APM to the center of the main parking garage at the airport. From there, travelers use several bridges to cross the airport roadway, using elevators down to the five separate landside check-in areas and security clearance locations. From there, most concourse gate areas are accessed by foot (with some within-terminal people-movers in operation). An estimate of the distance from the MIA Mover station in the airport garage to the furthest airline gate in the North Terminal is somewhat more than 3,000 feet. The North Terminal's Concourse D is described by the airport as being a "mile-long concourse" (Miami Airport 2012).

Terminal 7 at Chicago O'Hare. Importantly, the functional concept of a rail terminal complex with good people-mover connections to the gates on the concourses, such as that in operation in Atlanta and planned for Denver, is similar to that developed for the Chicago Department of Aviation in the Terminal 7 project (detailed in Chapter 6). In the Chicago concept, rail services (both metropolitan and long distance) to the airport were to be consolidated at the new Terminal 7, where full check-in functions were proposed. Although the concept of a check-in service at the rail station is not new, the concept of a people-mover from this point to all the existing airside passenger pier/concourses was highly unusual, with some implications for construction impacts. In this site planning concept, the user of Terminal 7 approaches by a variety of modes (including a new highway connector), experiences full check-in and security clearance, and proceeds on a people-mover system that is entirely within the secure areas of the airport. Issues faced in retrofitting an older airport include the question of where the travelers pick up their bags, and how to get them back to the train platforms.

The experience at Chicago's O'Hare Airport (ORD) demonstrates the difficulty of providing a "seamless connection" by retrofitting a dispersed set of airside concourse piers that are already built, in operation, and unable to be moved. Unlike the luxury of having a greenfield setting, planners at most American airports must deal with the extensive infrastructure already in place which constrains the realistic options for locating a long-distance train station on the site, as was discussed in Chapter 7 concerning site planning options available at SFO.

Future Intercity Rail to JFK. Because JFK airport is connected to a commuter rail line, and not served by Amtrak, the AirTrain connection between the JFK terminals and Jamaica Station has been considered beyond the scope of this study of long-distance rail connections. However, it should be noted that several studies currently underway concerning the effectiveness of operational patterns at New York's Penn Station are exploring the logic of turning back fewer trains at New York's Penn Station and encouraging more through-routed operations eastward towards Jamaica Station. Under such a vision, trains traveling from New Jersey might serve Jamaica Station or other more distant destinations in the future. This "integrated" service concept is being further discussed in the NEC Future project now being undertaken by the FRA (NEC Future 2014).

Destination Lindbergh, San Diego. The site planning options for connecting rail to air in San Diego are harder to categorize here. In the mid phases of the Destination Lindbergh staging, some passengers would be processed in a central processing facility near the rail station and shuttled to concourses adapted from older terminals. In the final phase, all passengers would be processed near the rail station, then taken by people-movers to the airside concourses. Of all the American airports reviewed in this research, San Diego International Airport compares with Berlin Brandenburg as having the best opportunity to make a new, high-quality connection between long-distance rail and a newly configured air passenger terminal for all its passengers. The resulting SAN terminal facility could have a seamless transfer capability comparable to the best in Europe, as exemplified by the "greenfield" airports at Oslo and Berlin, or the adapted airports in Zurich, Amsterdam, or Copenhagen. In its final configuration the Destination Lindbergh concept would offer a single, centralized landside facility with APM access to airside concourses, functionally similar to those in Atlanta or Denver, but, for the first time, with long-distance rail as a feeder mode.

Component Three: Mechanisms for Ticketing and Integrated Services

This final Chapter emphasizes both market strategies and physical strategies that might require major improvements in the quality of institutional cooperation among the rail company, the airline, and the airport. A major conclusion of this ACRP study is that fully integrated ticketing mechanisms form an exceedingly small role in major European airports and only exist for a small number of destinations: Basel, Brussels, Cologne, and Stuttgart. Chapter 2 reported that, of all those accessing flights by HSR at Paris Charles de Gaulle, only about 4% used an integrated ticket. Chapter 2 also reported that of the 5 million persons accessing Frankfurt Airport by long-distance rail, only about 4% of them were using a rail ticket issued by an airline for a train with a flight number associated with it. Beyond this, an integrated air plus rail ticket, which provides for baggage check-in at the terminal of origin to baggage reclaim at the terminal of destination, no longer exists in Europe (n.b., the Swiss Railways provides a for-fee baggage transfer system offered independently of the airlines, and thus not incorporated into an airline ticket).

Two patterns are observed when looking at the future of institutions that could influence the attainment of the truly seamless (or at least less problematic) air/rail connection. First, in terms of stated policies, major aviation institutions are publicly advocating for an overarching "door-to-door" approach. Second, in terms of actual services offered to consumers, air and rail carriers alike are emphasizing just the opposite approach.

Categories of Air/Rail Agreements for Ticketing

A recent "think tank" study by IATA examined the need to provide the user with more integrated services on a "door-to-door" basis. The special study group, called Simplify the Business (StB), prepared a report titled, "A Road Map to Prepare for Tomorrow's Passenger." The authors noted that, "In a recent IBM survey, none of the respondents indicated that they were able to complete their travel booking needs in one website visit." In the report, they observed,

> "Customers cannot experience a seamless integrated journey with reduced stress if travel partners are not connected. When a flight is changed, for example, the airport pick-up service may not be notified. The changes in the travel distribution landscape have forced many customers to assume the role of travel agents responsible for finding schedules that work well across travel modes and also monitoring connections between modes in transit."

While the exact role of the airlines in dealing with this challenge is not prescribed in the document, they note:

> "If airlines had more information about the final destination of their passengers they would be in a better position to delight the customer with more information, better service, and choices on how to adjust when things change . . . by reaching agreement through cooperation with travel partners, the future could be a single travel wallet for the entire journey, with all travel segments talking to each other, to the passenger, and being able to exchange information with the consumer at different points during his trip" (IATA 2011).

This work of the IATA Task Force shows some policy interest by the airline industry in improving the integration of information over carriers and organizations. The question of the form of institutional cooperation between airlines and rail companies in Europe has been explored in the article "Air-rail Intermodal Agreements: Balancing the Competition and Environmental Effects" (Chiambaretto and Decker 2012). The authors divide the agreements into three categories, providing a worthwhile structure to support this discussion. The trend is clear: airlines will cooperate with rail operators using schemes that force the minimum amount of integration.

Highest Level of Integration—German AIRail

While Chiambaretto and Decker place the German AIRail product at the highest level of integration, it is only offered to two destinations, Stuttgart and Cologne/Bonn by Lufthansa. As discussed in Chapter 2, the airline buys a block of tickets on selected trains and sells them as airplane tickets. Lufthansa passengers are given separate compartments; first class air passengers are offered drinks and snacks, while economy passengers are given a voucher to use at the bar car. The ticket is sold as a product for which the airline assumes branding and bears responsibility consistent with the rules of an IATA ticket.

"Moderate" Level of Integration—TGVair, Swiss AirTrain

The article places the French National Railway's TGVair product, in the "moderate" integration category, with 10 airlines have opting to use it (see Figure 12-10). The system is sophisticated—on the Qatar Airlines website, the airline three-

Outbound: Nantes To Doha / Wed, 05 Sep 2012

Flight / Carrier	Departs / Arrives		Duration (Total Hours)	Fares: Economy restricted
QR5011 TGV (High Speed Train)	Nantes (QJZ) Paris (CDG) *Operated By SNCF	06:05 09:11	11:50 hrs	428.78 EUR 3 seats left
	Transit Time: 02:19 hrs			
QR022 A340-600	Paris (CDG) Doha (DOH)	11:30 18:55		
QR5053 TGV (High Speed Train)	Nantes (QJZ) Paris (CDG) *Operated By SNCF	10:05 13:11	12:25 hrs	503.78 EUR 4 seats left
	Transit Time: 02:54 hrs			
QR020 A340-600	Paris (CDG) Doha (DOH)	16:05 23:30		
QR5011 TGV (High Speed Train)	Nantes (QJZ) Paris (CDG) *Operated By SNCF	06:05 09:11	16:25 hrs	503.78 EUR 4 seats left
	Transit Time: 06:54 hrs			
QR020 A340-600	Paris (CDG) Doha (DOH)	16:05 23:30		
AZ7383 Embraer RJ145	Nantes (NTE) Milan (MXP) *Operated By Air France	10:25 11:55	17:40 hrs	No Availability
	Transit Time: 10:20 hrs			
QR038 A320-100/200	Milan (MXP) Doha (DOH) +1 day(s)	22:15 05:05		

Return: Doha To Nantes / Wed, 19 Sep 2012

Figure 12-10. The TGVair reservation system shows code-shared tickets from Nantes (France) to Doha (Qatar). Source: Qatar Airlines Website.

letter code for the airport at Nantes, France, was entered, but not for the Nantes train station. The system immediately recommended the connections via the train station, with some additional connections to fly to the airport, as shown in Figure 12-10. By comparison, the US Airways site did not recognize the word "Nantes," even for the airport itself, nor did it recognize the train stations at any French site served by the TGV ticketing program. Thus, passengers seeking information from websites of Qatar and Etihad Airways, for example, would be shown high-quality integrated ticketing options, and offered a through, code-shared ticket from the airline. Presumably, the ability to offer this product seamlessly could be of value to the airline competing in the marketplace with an airline that does not list the destination. The fact that only 10 airlines have bought into the project (see Chapter 2) is of concern to its managers, who are working to improve the quality of ticket integration.

The Swiss Federal Railways AirTrain service between Basel and Zurich Airport belongs in this middle category of integration, as the airline sells the rail ticket. The Swiss International Airlines website offers a ticket from Boston to Basel, via the AirTrain from Zurich Airport, at the same price as a ticket to Zurich alone. A barcode is provided that serves as a rail ticket once the ticket is printed out by the passenger; no airline personnel are involved in processing passengers at the Basel rail station or aboard the train. The ticket does not include any services for baggage check-in or reclaim; these can be arranged through a separate program from the railway, for a fee.

At present, there is no direct rail access between Heathrow Airport and cities to the west such as Bristol, Plymouth, and Cardiff. This notwithstanding, Singapore Airlines (Figure 12-11) has announced plans to offer unified ticketing from such cities in southwestern England by including First/Great Western Railway services to London's Paddington station, where the traveler can change platforms and proceed back towards the west on the Heathrow Express. Given that the Heathrow Express offers direct service from Paddington to Terminal 5 in about 21 minutes (with faster times to the Terminal 2 complex), the program offers reasonable levels of service to the passenger. Full implementation of the program was planned for 2014.

Figure 12-11. Singapore Airlines has formed a marketing alliance with First/Great Western Railway to sell integrated tickets. Source: Singapore Airlines.

Lowest Level of Integration—German Rail&Fly

Chiambaretto and Decker categorize the German Rail's Rail&Fly product in the 'low' category of integration. By far the biggest and most purchased of the integrated ticketing options, the Rail&Fly program is offered through any airline that chooses to market the service to the customer. To get a Rail&Fly ticket, the traveler must buy the airline ticket, not just inquire about it. With the purchase of the airline ticket, the traveler can click on a Rail&Fly link, which will transfer the date of origin and date of return flights into the system. The user then chooses his/her rail ticket (specific to city pair), good within one day before departure from Germany, and one day after arrival in Germany. After the conclusion of the process of purchasing both the air ticket and the rail ticket, a barcode confirmation e-mail is sent to the purchaser, who simply prints it at home and carries it during the trip; alternatively, the DB rail ticket kiosks can be used. As sold by Lufthansa, the ticket costs only 29 Euros, and is good for any train trip operated by DB. Although the program is for Lufthansa international trips, trips to the hubs of their competitors are not covered; thus, the product is not offered for flights between Germany and Amsterdam, Brussels, Paris, Salzburg, Vienna, Basel, or Zürich.

DB only sells the product through the airlines (and their related travel agents) and DB offers them great flexibility in the products they choose to sell. For example, American Airlines offers the product to any rail station in Germany for free on its flight from Dallas Fort Worth. Thus, a given airline can use the product in a manner responsive to their marketing needs. Rail&Fly represents something of a middle-level solution, positioned between the full code-share service offered in the program between FRA and Cologne and Stuttgart, and the lack of an integrated solution existing in most situations. Most importantly, the product offers the airlines a smoothly functioning system to offer marketing incentives they choose without creating new burdens of responsibility and liability into the air ticketing business. It has been reported in the literature that over 1.5 million such tickets are sold each year; these tickets are purchased primarily by residents of Germany (Grimme 2007).

The Question of Liability for the Missed Connection

Walking a fine line, Lufthansa helps the user buy a discounted train ticket from the train company, but it does not have any role in approving it or taking responsibility for it. The airline states, somewhat enigmatically,

> "The travel times for your train journey shown on your itinerary do not represent valid connections. Please choose the fitting connections for your journey by yourself. . . . When choosing your train connection, please consider the check-in deadlines for your flight, so you arrive at the airport in time" (Lufthansa 2012).

The question of how rail tickets can be sold through the airline-based ticket distribution system has been resolved. A private company, AccesRail, based in Montreal, has created a set of IATA-approved codes for its product. For example, "QYG—means 'Railway Germany' and it is IATA city code for any German Rail's railway station" (Access Rail 2011). For the Netherlands Railway and the Belgian Railway, the carrier code is "9B." In this manner, German Rail&Fly can be booked through Abacus, Amadeus, Apollo, Galileo, Infini, Sabre, Travel Sky, and Worldspan. The major ticket distribution channels accept these codes, and the travel agent can sell the ticket under conditions authorized by the airline selling the ticket. The travel agent creates a ticket code number, and any German Rail ticketing kiosk honors this code, which then generates a paper ticket up to 72 hours before the day of rail departure. About 75 airlines are listed as business partners with AccesRail, including American, Continental, and US Airways. A review of the US Airways booking site, however, found no mention of this product offering.

What Level of Integration in the Future?

The success of Rail&Fly suggests a new paradigm for integration. Such a paradigm includes the airline, which takes only minimal responsibility for the rail segment (i.e., no code-share), but would indeed facilitate the provision of all needed information to allow the customer to choose a subsidized rail ticket. Those wanting rail tickets can get them at the same time as the actual air ticket purchase, thus dealing with the issue reported by IBM that the customer must visit too many sites just to plan a trip. Functionally, there is a certain hierarchical logic here in terms of information provision; intensely detailed questions about the 5,000+ stations of the German Railway system are displayed on a screen managed entirely by the rail operator, not added onto a system designed to serve three-letter airport codes. Importantly, the organization issuing the ticket is the organization providing the rail service. The airline bypasses the issue of service problems, including that of missed connections.

Dealing with Missed Connections

Sweden has developed a compromise strategy. Although not currently well advertised, the traveler can work his way to a site jointly operated by SAS Airlines and the state railway, flyrail.se (as shown in Figure 12-12). The customer is informed at the beginning that use of the site will add 50 Swedish Kroner (about $7.45) to the cost of the ticket. However, this buys the traveler the "get you there guarantee." The program offers the traveler a series of itinerary options in which the only connecting times offered are of more than 45 minutes for domestic, 60 minutes for European, and 2 hours for intercontinental flights. The flyrail.se program states:

> The "get you there" guarantee will rebook, but not refund, your ticket. Passengers who miss a connecting flight due to a train delay will be booked onto the next flight at no extra cost. Passengers who miss a connecting train due to a flight delay will be booked onto the next train at no extra cost. If the delay time exceeds two hours, the passenger will be looked after and may, for example, be offered food, overnight accommodation or various types of transportation.

The system is not a code-share: tickets for rail services are provided by the rail company and tickets for the air services are provided by the airline. The explicit acknowledgment of the problem of liability associated with connections with separate tickets is unique, however. Interestingly, those leaving the Copenhagen Airport (Kastrup) and proceeding to Sweden can buy an integrated air/rail ticket, while those proceeding to a destination in Denmark cannot buy an integrated air/rail ticket. When the potential traveler on the Kastrup website clicks on the link to Danish Railways, she/he is immediately offered a local trip itinerary planner, which provides door-to-door trip plans from Kastrup airport to any address in Denmark, including all public transportation services. The Danish national railway

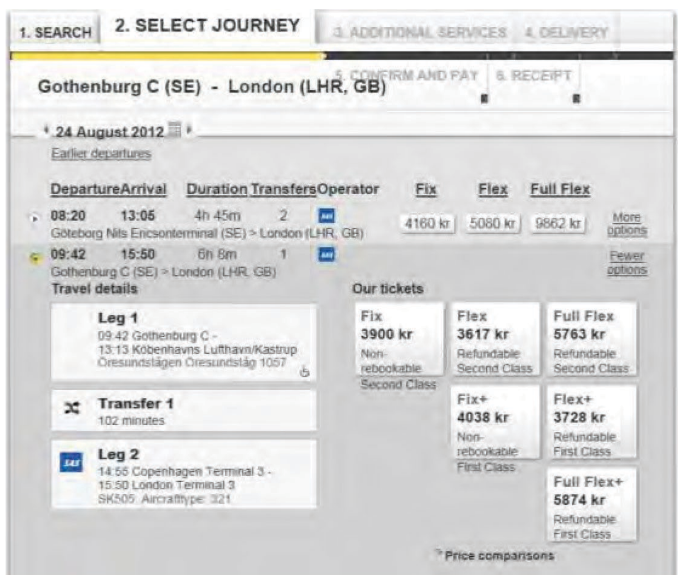

Figure 12-12. The Swedish system sells an air ticket and a rail ticket, with a guaranteed connection. Source: flyrail.se.

system does not emphasize the need for advance reservations; thus, the task of purchasing the intercity ground rail service can be left to the user upon arrival at the train station. The national rail system website does offer the option to purchase rail tickets and print them at home; currently, though, this feature exists only in the Danish and Swedish languages. Danish Railways does not offer an integrated air/rail ticket program.

The Future of Integrated Ticketing?

This report concludes that the institutional mechanisms needed to support the sale of integrated air and rail services to the consumer have not reached their full potential. The original concept, in which an airline would sell a specific rail ticket and guarantee a specific seat, has been replaced with a looser relationship, in which the airline subsidizes the rail ticket, but leaves all issues of trip planning to the customer and the railroad. Except for the new Swedish model, customers are on their own to plan a connecting rail trip.

Interviews with managers of these systems reveal that major improvements are now being implemented, particularly concerning the need to manage the difficulties associated with transforming a ticket number into a usable railroad ticket, which still can involve long lines at airport train stations. The common acceptance of bar-coding technology by railroads could improve the present system at Paris CDG, for example. However, this study concludes with the observation that universal offering of easily obtained railway tickets at the time of airline ticket purchase has not yet occurred, even though the technology to make it happen is readily available. In general, the traveler who has already decided to find a rail ticket through an airline website (or travel information system such as Expedia or Travelocity) can often explore the site and find the service. However, in most of the systems tested, users who do not enter the railroad station's three-letter code will not be shown existing service options, if they exist. In short, the potential for increased sales of rail connection tickets of all kinds may be being constrained by the disjointed nature of the present marketing efforts.

Part Two: Next Steps and Possible Further Research

Concerning the Adequacy of Tools and Information to Support Regional Decisions

As discussed in detail in Chapter 10 of this report, some of the problems concerning the adequacy of tools identified in the study process have been explored in the latter phases of the research effort, and some have not. Most obviously, the work program of ACRP Project 3-23 has addressed the need for a transparent and usable model of air rail competition—one which emphasizes policy sensitivity on a quick turn-around basis. Less visibly, the project has helped to address the question of availability of a national rail travel trip table, which is now available from FHWA, allowing the analyst to deal with national flows for air, rail, and auto from the same source. This responds to the concerns noted in New York interviews with the Regional Plan Association and the Port Authority. Similarly, the data presented in Chapters 2, 3, 4, and 5 makes possible a level of comparison between the European and American air/rail experiences, filling a gap in the availability of data for the American practitioner.

This research effort has identified the challenges to better-integrated inter-agency planning processes. As discussed in Chapter 10, decision makers in the New York region, the Midwest around Chicago, and throughout California are aware of the challenges stemming from poor data and lack of intermodal planning tools; however, they have also developed professional "workarounds" so that key decisions need not be delayed. That said, there remain areas where additional tools could be made available to the analyst, in order to follow up on the major themes revealed in Chapter 10.

- In the interview with NJ Transit, it became clear that many participants in the planning process do not understand the need for the stated preference modeling process (which is used in analyzing access to airports and diversions from air) to be grounded in experience with these modal circumstances and not simply lifted from the modeling process used in the metropolitan areas.
- Regional planners think they lack the tools to understand how passengers will divert from a specific airport. Planners in northern California wanted more attention to modeling needs when considering diversion from air to HSR. All organizations interviewed asserted a strong interest in evaluating air/rail complementarity. Clearly, predicting the propensity of the separate modal players in the marketplace in the creation of joint products will require tools that do not exist.
- The issue of rail as a feeder service to longer distance flights in North America remains unresolved. Technical work in the northern California RASPS study, based at MTC in Oakland, creatively applied models created for other purposes to provide an early estimate of change in air trips serving as a feeder mode to SFO. The FRA's NEC Future project plans to explore an expanded role for rail in support of JFK and Newark, but the quantitative analysis tools are weak.

Further Research Needs and Potentials

Competition with Low-Cost Carriers?

There are many possible areas for further research into the way air and rail services compete over time. Major shifts in the services provided by either mode would logically impact not only the mode of the future trip, but also the destination terminal of the future trip. Use of the concept of a "corridor" might tend to oversimplify what happens to long-distance travel behavior over time, as traffic may shift within corridors. The major study on these issues by the European Union (SDG 2006) was based on the concept that the relationship between the long-distance mode industries exists as three phases. First, the rail sector makes a vast improvement in travel time, which lowers the amount of O-D traffic between the major airports in the corridor. Second, the legacy airlines react with an initial lowering of the amount of service offered. Third, the aviation industry refines its response, with new lower cost services in a general corridor of influence, but not necessarily between the original hub airports in the corridor.

In Europe, arrival of the high-speed train network occurred at a time of rapid development of the so-called low-cost carriers. Without question, the low-cost carriers have eroded rail market share on longer trips; in a recent paper, Grimme concluded, "The analysis indicated that there is robust evidence for effective competition between low-cost airlines and rail operators." Jorritsma (2009) noted, "Unfortunately, hardly any research is available about the impact of low-cost carriers on the substitution rate. Eisenkopf (2006) estimates a substitution rate from rail to air ranging from 5 per cent (Cologne—Hamburg) to 13 per cent (Cologne-Munich)." While Grimme has noted the impact of the low-cost air carriers on existing rail ridership patterns, the competition is not one-sided; in January of 2014, Ryanair announced it would no longer compete with rail in the corridor between Milan and Rome (*Business Traveler* 2014).

In cases where the new HSR dramatically altered the network at one point in time (e.g., Madrid-Seville) it is straightforward to calculate the number of riders diverted from air. Further research could better document the role of situations in which strong rail shares have been built up incrementally by staged investments over a multi-decade period, as is often the case in German corridors served by air and rail. Often, it is difficult to examine a given corridor mode share and estimate how many were diverted from air, and how many from auto, as some of the diversion may have occurred years ago—further complicating the role of induced demand. In a mature market like New York to Washington, DC, it is harder to calculate the number of passengers "diverted" from air, and the process of incremental market development has occurred over several decades.

Further Research on Ground Access and Airport Choice

Further research might emphasize a closer integration between air/rail competition studies and those of airport choice. The connection between the two research areas was flagged by a timely paper by two Dutch economic geographers, Terpstra and Lijesen, in their article titled, "High-Speed Train as a Feeder for Air Transport" (2011).

> "Several empirical studies have studied airport choice in multiple airport regions, with the majority focusing on the San Francisco Bay Area (Harvey, 1987; Basar and Bhat, 2004; Pels et al., 1998; Suzuki, 2005) and the Greater London area (Bencheman and Ashford, 1987; Hess and Polak, 2006). The general picture from those studies is that airport choice depends on airport access time, flight frequency, fare, flight time and frequent flier program membership."

While most of the research referenced in the previous quote is not about longer distance rail in any role, there is a need for research that better explores the role of all ground access service quality as an input to airport choice. The research question might turn to, "Given that the traveler chose airport Y over airport X with its present access services, might the traveler chose airport X if high-quality rail services were offered?" Early explorations of this research question were undertaken in a series of studies done for the PANYNJ and Metro-North Railroad concerning the possibility of attracting more air passengers to Stewart Airport in a far suburban location of New York (RSG 2010).

ACRP Report 98: Understanding Airline and Passenger Choice in Regions with Multiple Airports, seeks "to help airports and their stakeholders understand the dynamics of airline and passenger decision making in multi-airport regions" (Parella 2013). While the report was designed to fill a gap in the study of airline decisions about which airports to serve, it contains a strong Literature Review appendix which covers the extensive literature about airport choice from the passenger perspective. While its several case studies did not include any in which rail might be expected to play a role in airport choice, the role of auto travel times in airport choice was noted.

Modeling the Impact of Improved Rail Service on Air Markets

Further research could well build upon the very early results of the new policy-sensitive model of the relationship between air and rail, whose development was described in Chapter 11. The component elements of that research effort are summarized in the chart reproduced here as Figure 12-13. With this model, policy makers can directly input a wide variety of assumptions about determinants of market behavior into its spreadsheet format, as the model operates on the widely used MS Excel program. Users are provided with the implications of those assumptions for modeling predicted change in market behavior. Researchers and practitioners concerned with integrated transportation policy would benefit if such a modeling process could be expanded to better reflect the reality

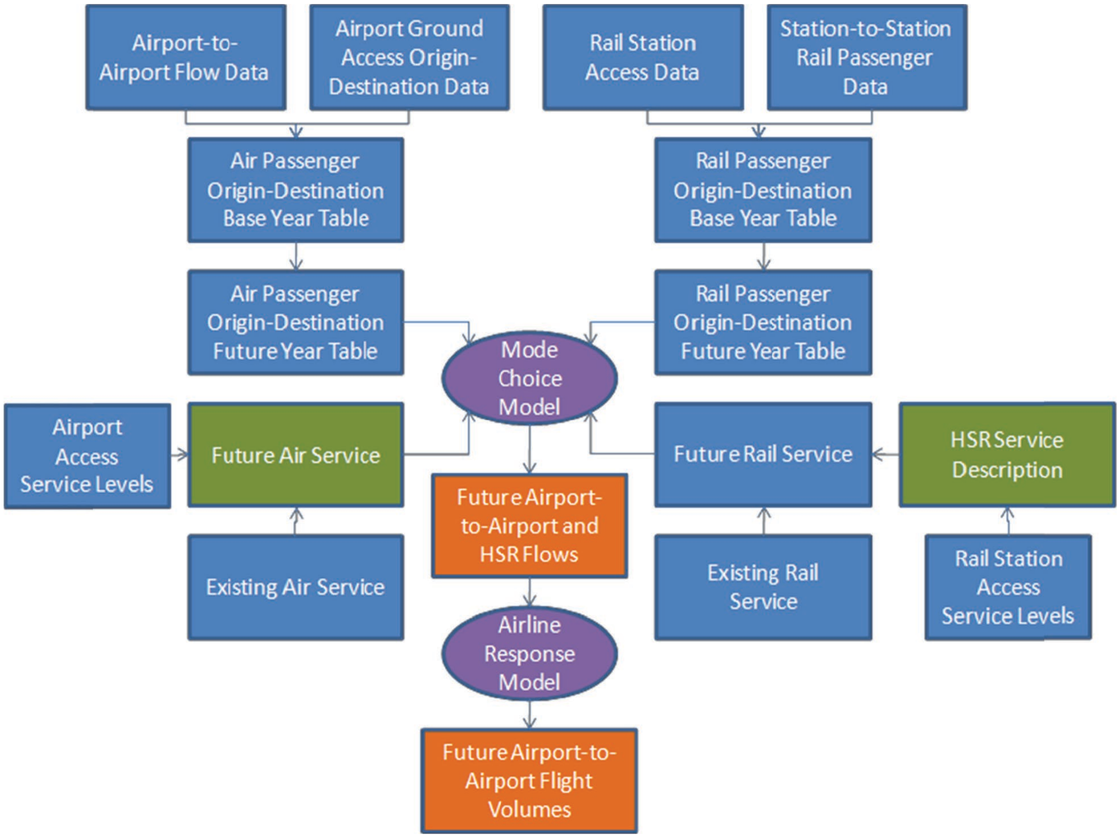

Figure 12-13. Component elements of the ACRP diversion model could be further developed.

that choice of any one mode for the medium-distance trip is impacted by competitive conditions from all modes, not just the air vs. rail scenario explored in the present study. Both air and rail ridership patterns need to be analyzed in terms of competition from auto and intercity bus to meaningfully support public policy analysis.

Modeling of Specific Networks

As noted in Chapter 11, this project has included the creation of a policy-sensitive model to explore the relationships between and among major policy factors including both the direct impact of variation in times and costs of the subject mode, and the cross elasticities associated with variation in competing modal characteristics. To provide an early illustration of how the model could be applied in scenario analysis, the model was applied to a set of scenarios in both the East and West Coasts. Much remains to be explored in further research, however, concerning the ability of the model to deal with highly specific variations in network characteristics, including, in theory, full simulation of alternative rail networks and air service characteristics. A wide variety of further research efforts could be based on the existing Air/Rail Diversion model, and its several component model elements.

Expanding the Modeling Process Beyond Times and Costs

As exemplified by the times of input variables used in the ACRP Air/Rail Diversion model, most predictions of future mode choice are made through the examination of travel times and travel costs. An alternative theme explored in the existing literature is the idea that, in addition to the analysis of times and costs, issues associated with attitudes, values and cultural preferences could also be included in the travel forecasting process. The approved Amplified Work Plan of NCHRP Project 03-02 of the National Cooperative Rail Research Program, entitled "Intercity Passenger Rail in the Context of Dynamic Travel Markets," calls for further research into the competition between air and rail, incorporating these additional sets of market conditions. At the conclusion of that research project, suggestions can be made about the need for further research of more detailed modeling of these factors in the subject area.

Understanding the Relationship Between Rail Supply and Air Supply

Chapter 11 (as well as the Technical Appendix) summarizes the implications of the model research concerning the relationship between the supply of rail service and the supply of air service. As discussed, rail travel times around one hour are associated with about 40% of the flights that would be expected without rail service. This effect attenuates so that a 7-hour rail service would be associated with 80% of the flights expected under a non-rail scenario. The effect disappears entirely at a rail travel time of around 11 hours. Chapter 11 notes that although the coefficient estimates are significant, there remains considerable uncertainty about the actual coefficient values, and thus about the relationship shown in this diagram. Further analysis is required to reduce this uncertainty.

The work of the project team shows varied airline responses to rail service. The Research Team does find evidence that in some markets, rail service is correlated with lower air service. While this correlation does not prove rail service directly reduces air service, it does indicate the possibility that new rail routes will interact with, and possible reduce, certain aviation service. The Research Team also finds a correlation between the introduction of rail service and airlines preserving frequency and augmenting aircraft size due to passenger loss. The variety of airline responses to rail calls for a suite of models to, in detail, document the air/rail competitive feedback loop. Such models would capture how passengers shift from air to rail due to the introduction of rail, how airlines respond to this new competitor and passenger loss, and the feedback loop of passengers responding to these further modifications in air service. Such work could also consider how passengers choose between air and rail in both competitive and collaborative configurations.

Further Research on Ticketing and Product Integration

Further research could probe what attributes of integrated air/rail services are valued by customers in various market segments. Are there some market segments who, when confronted by feeder air vs. rail in a feeder mode, would always prefer the air mode? Are there other segments that would always prefer the rail mode? Beyond the factor of simple geography (proximity to terminal of mode X vs. proximity to terminal of mode Y) are there some market segments who value the reliability of the rail mode in bad weather? Are there other segments that prefer the simplicity of airline check-in/security clearance at the earliest possible time? What is the trade-off between the security of a seat reservation on a short connecting rail segment compared to the spontaneity of being able to board the first train out, no matter when the flight arrived? Do travelers really want to part with their bags early, compared to keeping them nearby? These hypotheticals illustrate the diversity of questions left for future research, but they do not represent an exclusive list of questions.

Finally, the Swedish model is particularly noteworthy. This program could provide for a nearly "experimental" research context in which most variables are held constant, but variation occurs concerning the treatment of the liability for the failed connecting trip. Arguably, the additional cost of $7 buys the insurance policy for the failed connection; this is assuming that the trip maker could buy an air ticket and a rail ticket separately with minimal additional effort given that reservations for seats are not mandatory on the national rail systems. By offering the connection guarantee, the two carriers deal with one of the most vexing issues in intermodal service design—and this could be the subject of meaningful future research.

Further Research: Conclusion

Further research concerning market preferences towards the details of integrated services could help to set priorities where there is insufficient understanding of what factors really influence the choice of mode. Clearly, the development of a national research program based on the analysis of the needs of the passenger intermodal system will require contributions from all of the modal communities, with emphasis on cooperation across disciplines, and modal preferences.

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APPENDIX

ACRP 03-23 Air/Rail Diversion Model: User's Guide

Outline

This user's guide for the ACRP 03-23 Air/Rail Diversion Model providers instructions on how to install and use the model to evaluate scenarios. The input files are described in detail in the input files specification section, while the final section of the user's guide provides an overview of the code structure of the model for advanced users who might wish to edit the model.

- **Introduction**
- **Model files and Installation**
- **Creating Scenarios**
- **Editing Inputs**
- **Running the Model**
- **Viewing Output**
- **Input File Specifications**
- **Code Guide**

Introduction

The ACRP 03-23 Air/Rail Diversion Model is a sketch planning model to provide model users with a quick response tool capable of evaluating a range of policy interventions that affect choice of air or rail for long distance travel in a mega region sized corridor.

The model is intended to provide a framework for managing scenarios, editing inputs, running the model, and viewing outputs. All inputs and outputs are in .csv format to also allow viewing and analysis in software other than the ACRP 03-23 Air/Rail Diversion Model.

This users' guide does not describe the model structure; this is covered in the technical appendix to the project report found on the enclosed CD.

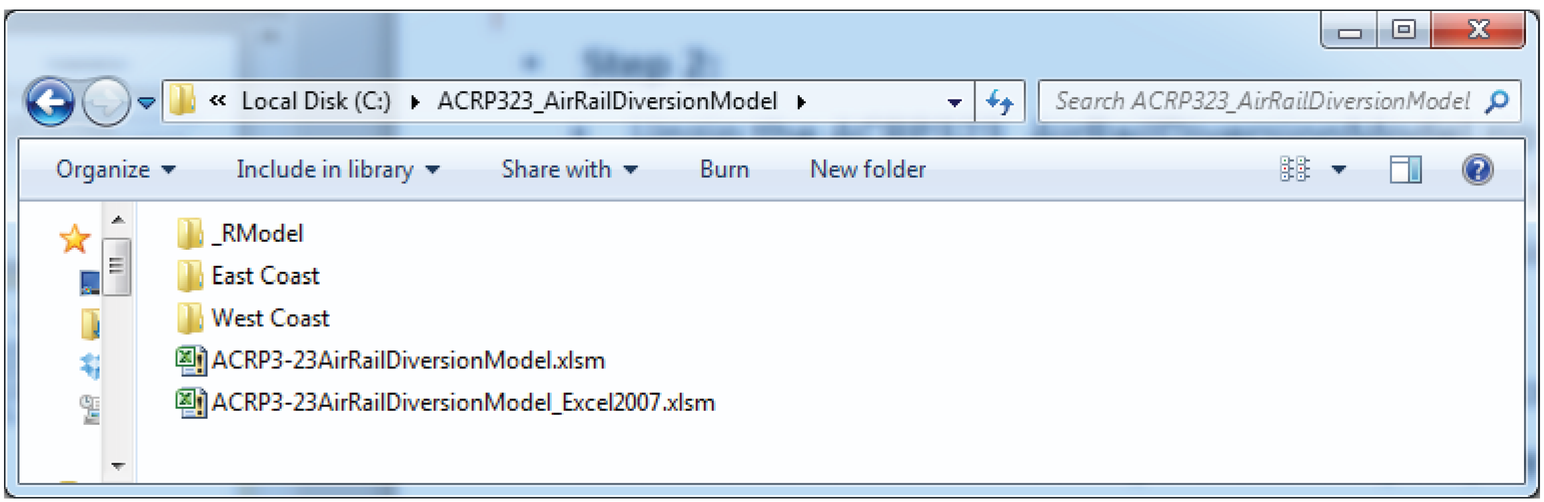
Model Files and Installation

Installation

- **Requirements**
  - The ACRP 03-23 Air/Rail Diversion Model is designed to work on a PC computer that has a recent version of Microsoft Excel installed (2007 or later).
- **Step 1: Save ZIP folder to Computer**
  - The **ACRP323_AirRailDiversionModel.zip** folder includes all of the necessary files to run the model. To install the model, click on the Air/Rail Diversion Model menu button. Save the zip folder labeled ACRP323_AirRailDiversionModel.zip to the appropriate location by clicking “ok.”

Installation (Contd.)

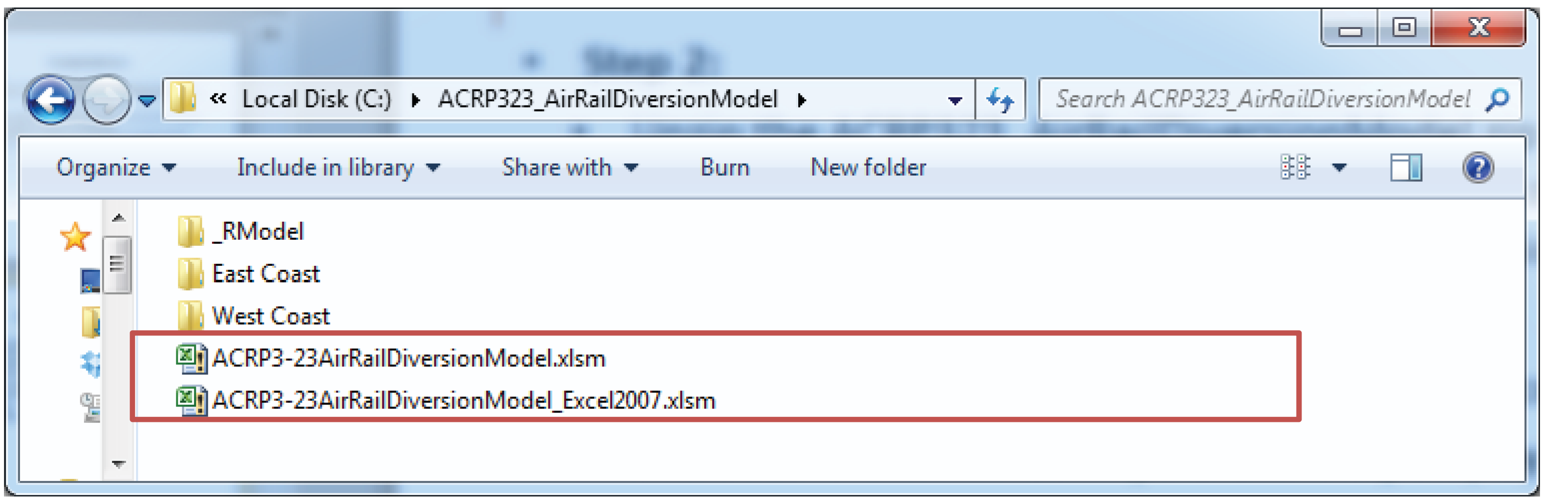
- **Step 2: Unzip the ZIP folder**
  - Unzip the ACRP323_AirRailDiversionModel.zip using a zip utility installed on your computer (e.g., WinZIP). The zip file's contents are inside a directory call "ACRP323_AirRailDiversionModel"
  - That directory contains:
    - R model scripts and R application in the "_RModel" folder
    - File structure with model inputs and outputs, by scenario, in the "East Coast" and "West Coast" folders
    - Two spreadsheets: Excel spreadsheet graphical user interface (GUI) for current versions of Excel, and also Excel 2007



Open the Excel GUI

- **Step 3: Open the Excel GUI**

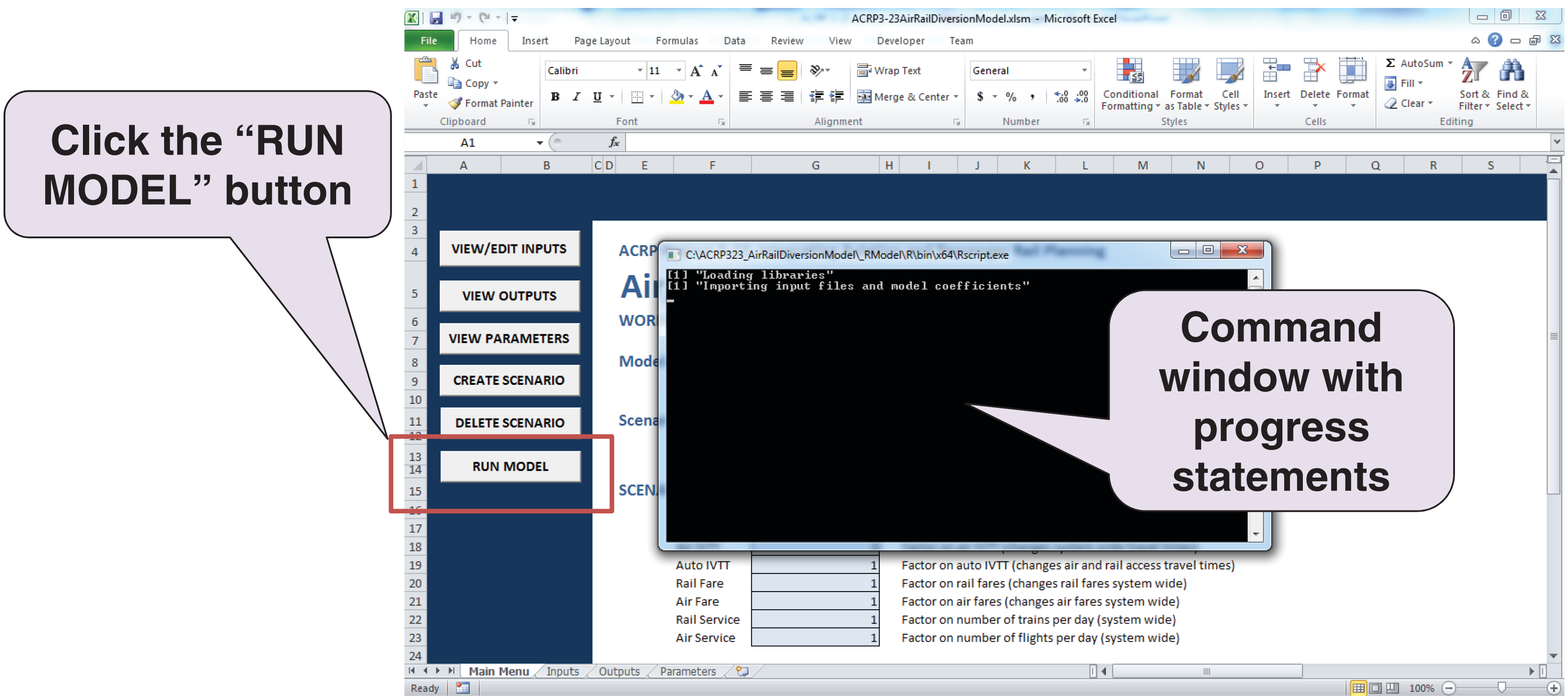
  There are two versions of the excel GUI, one for Excel 2007 and one for more recent versions of Excel. Open the one that conforms to the version of Excel on your computer.



Test the installation

Step 4: Test the Installation

Test the installation and connection between the Excel GUI and R (open source software that runs the model's simulation and is included with the model zip file). On the Main Menu sheet in the excel GUI, click on the Run Model button to launch a run. A command window will launch and the model's progress statements will start to appear.

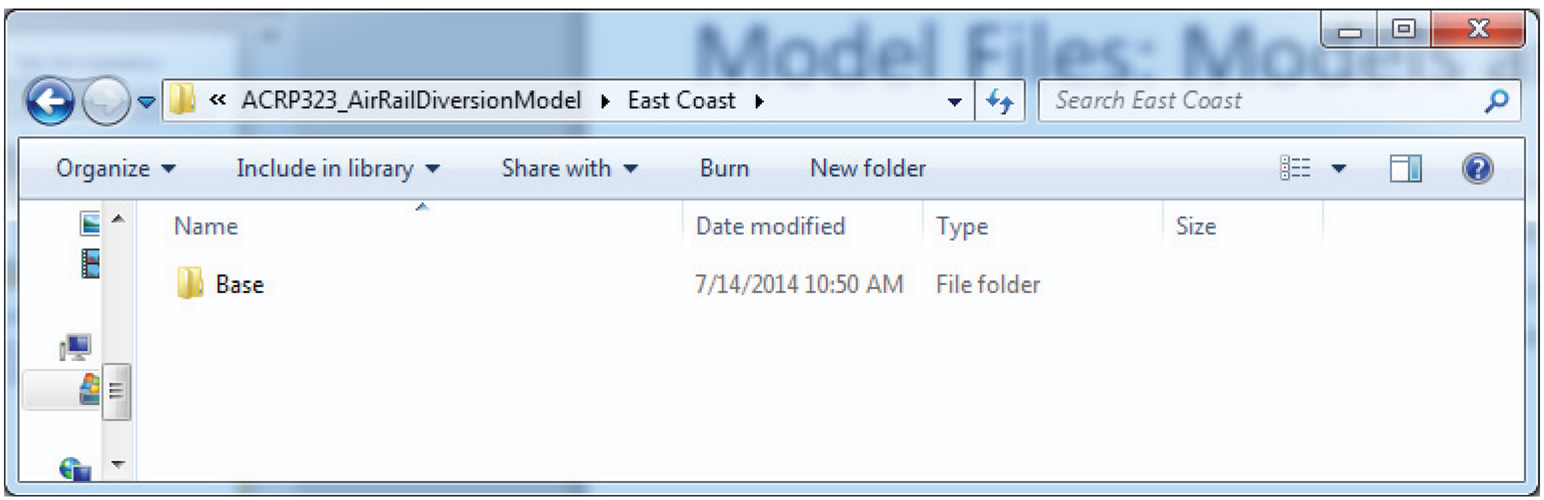


Model Files: Models and Scenarios

The model comes with two pre-developed models, for the East Coast and West Coast regions, which are contained in the "East Coast" and "West Coast" folders, respectively.

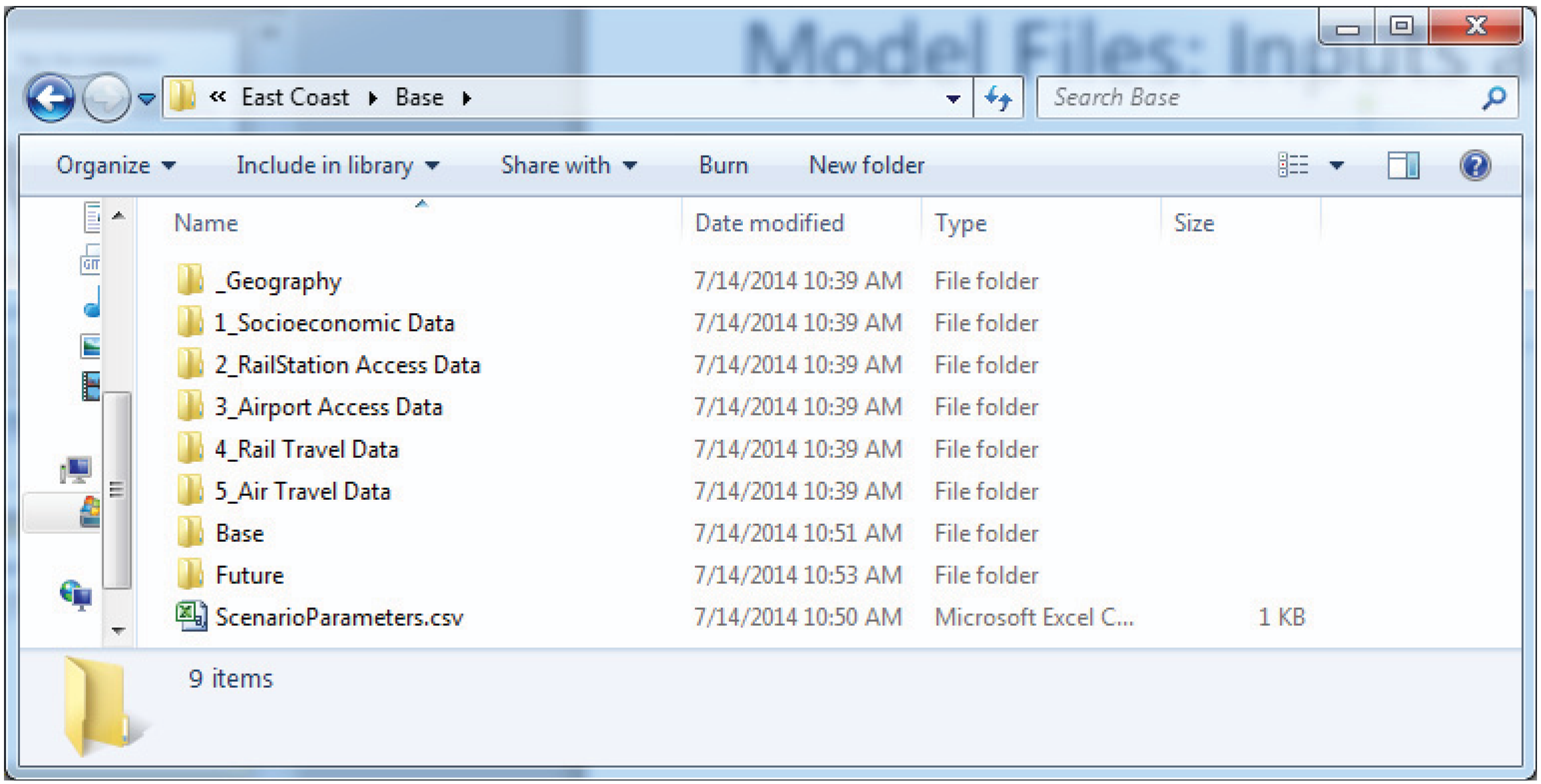
Within each of those two folders are a list of scenarios. Initially, there is only a "Base" scenario folder, but as scenarios are created (described in the following pages), additional scenario folders will appear here.

The screenshot below shows the contents of the "East Coast" folder – just the "Base" scenario folder at the moment.



Model Files: Inputs and Outputs

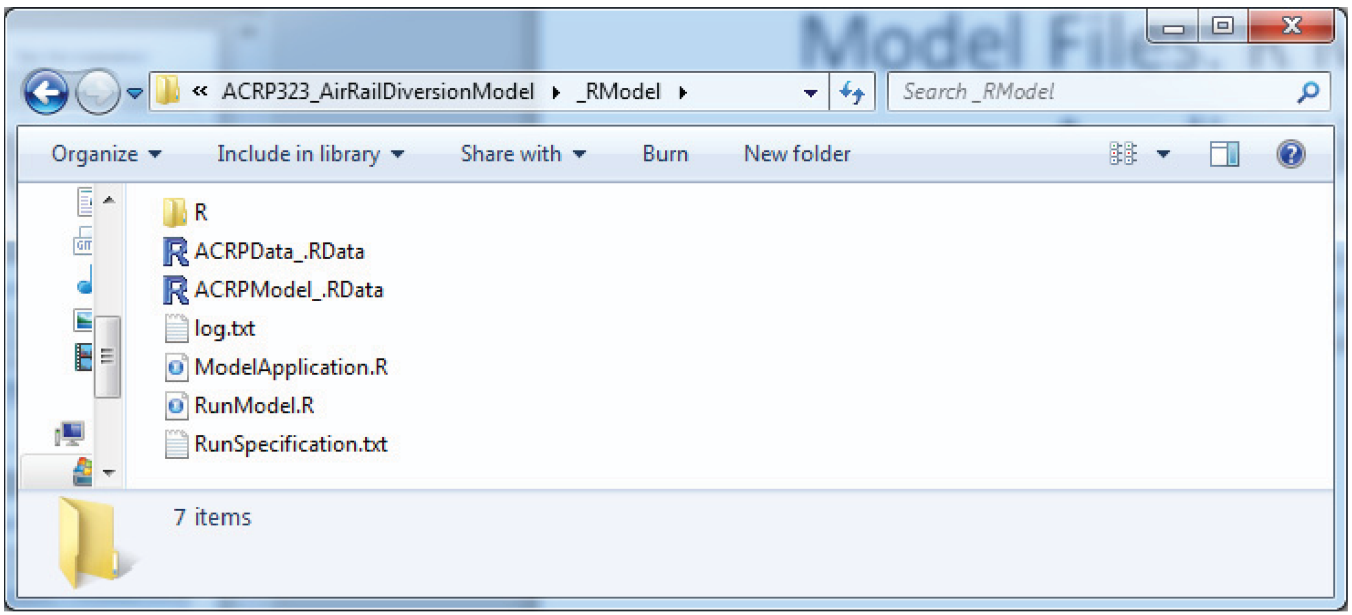
Each scenario folder, for example, with in the East Coast/Base folder as shown here, contains folders containing .csv files for several different categories of inputs, and the "Base" and "Future" folders which contain outputs (once the scenario has been run). The ScenarioParameters.csv file contains several top level policy variables (described later in the user's guide)



Model Files: R Model, Application

The _RModel folder contains the R folder, which is a version of the R application that is used to run the model. The files in that folder are as follows:

- ACRPData_.Rdata – R binary folder containing several input tabulations
- ACRPModel_.Rdata – R binary folder containing model coefficients
- Log.txt – log file from a model run (added when the model is run in installation)
- ModelApplication.R – R script containing the model code
- RunModel.R – R script to run the model (added when the model is run in installation)
- RunSpecification.txt – text file written by the Excel GUI providing variables to R (added when the model is run in installation)



The Model’s GUI

GUI Workflow

As noted above, the ACRP 03-23 Air/Rail Diversion Model is a sketch planning model to provide model users with a quick response tool capable of evaluating a range of policy interventions that affect choice of air or rail for long distance travel in a mega region sized corridor.

Model users do this by running different scenarios. A typical workflow is as follows:

1. Run the base scenario (This represents the current situation – the business as usual case or reference case)
2. Create an alternative scenario
3. Edit the alternative scenario's inputs to represent the policy to be tested
4. Run the alternative scenario
5. View the alternative scenario's results
6. Repeat steps 2-5 for all of the policies to be tested
7. Compare the results of the policy runs

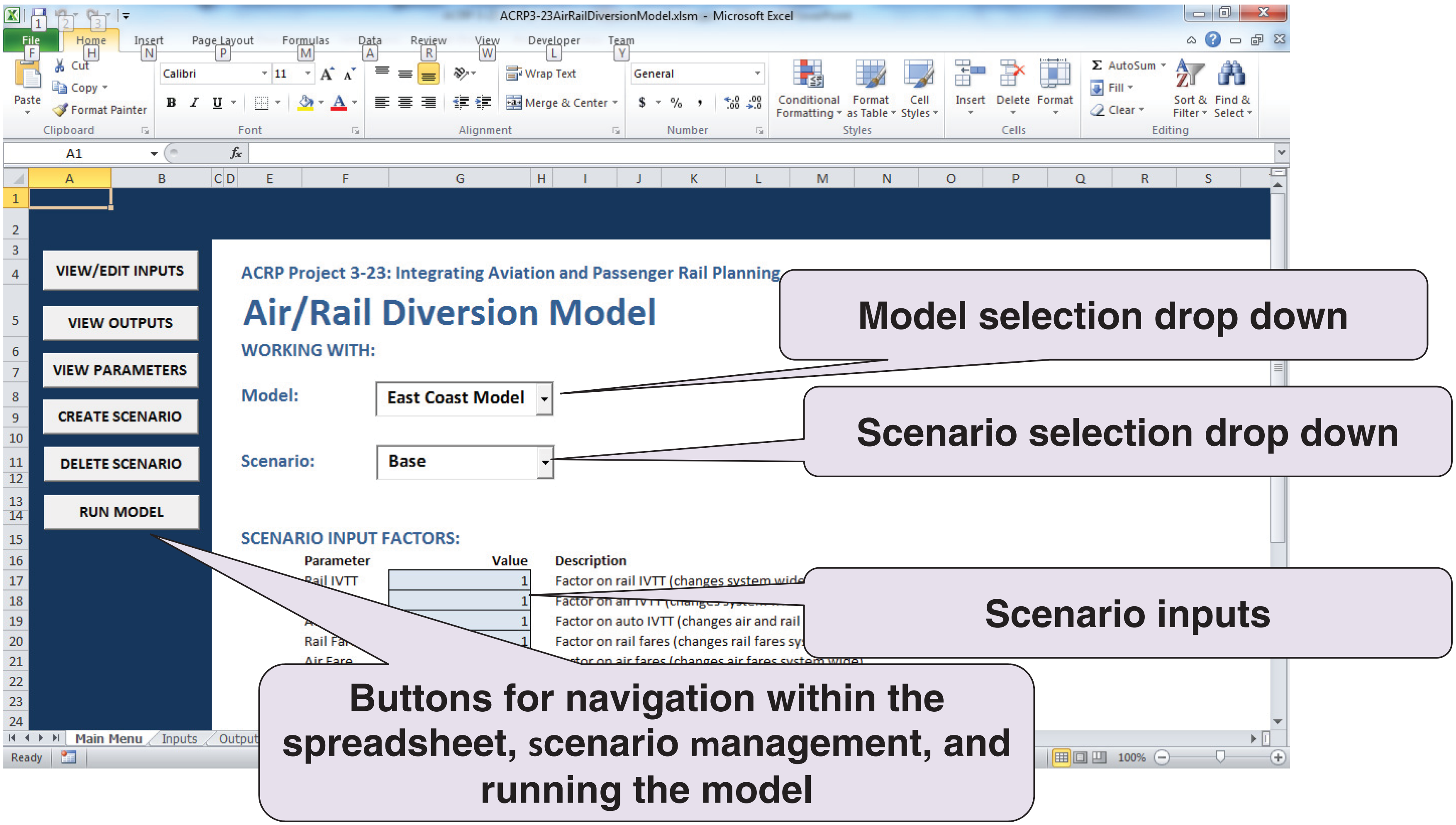
Elements of the GUI

The following pages show screenshots from different components of the GUI and demonstrate the functionality of the GUI, following the workflow described above:

- Main Menu
- Creating Scenarios
- Viewing and Editing Inputs
- Running the Model
- Reviewing Results

Main Menu: GUI on Opening

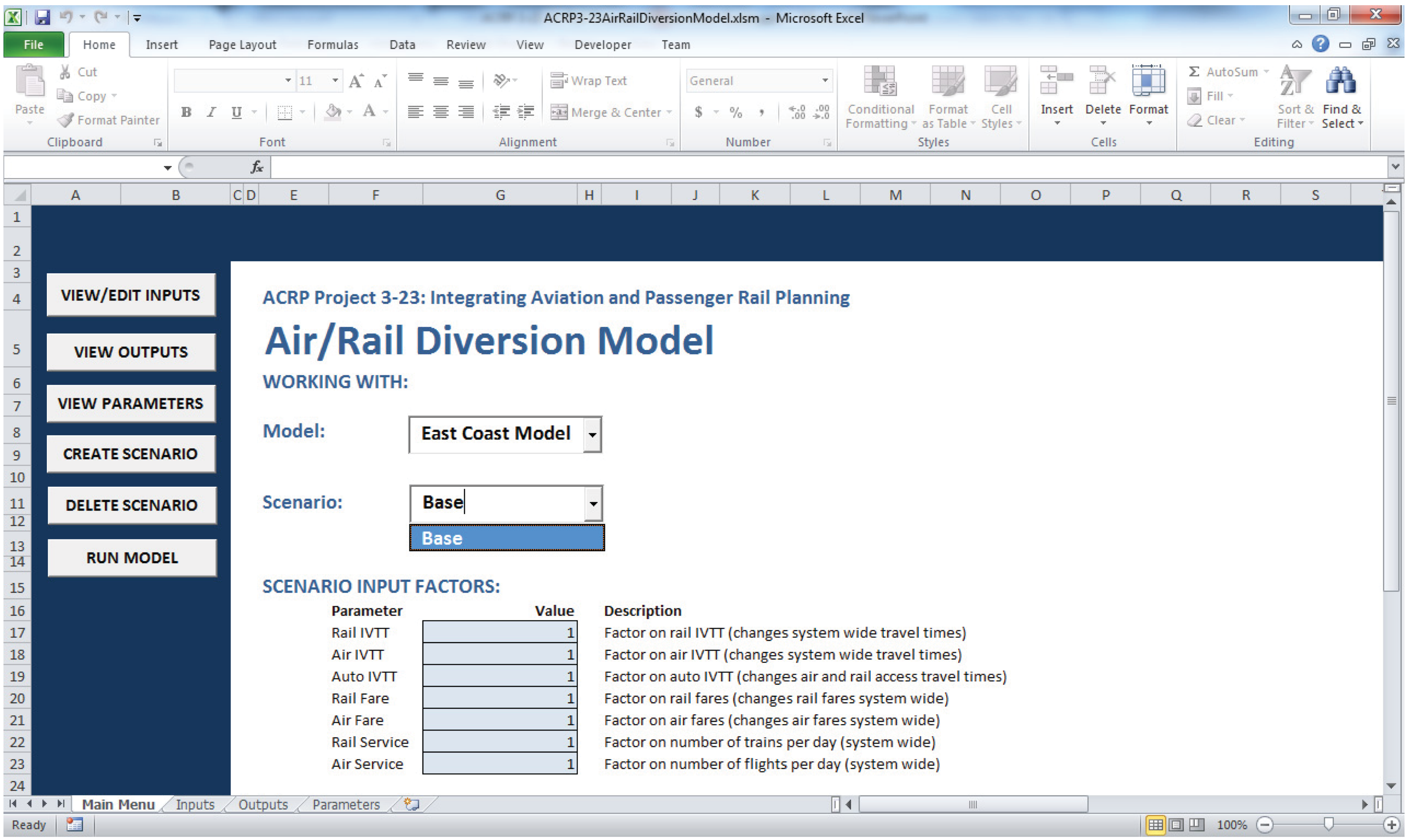
The GUI is a macro-enabled spreadsheet (an .xlsm file) and opens to a simple Main Menu



Creating Scenarios

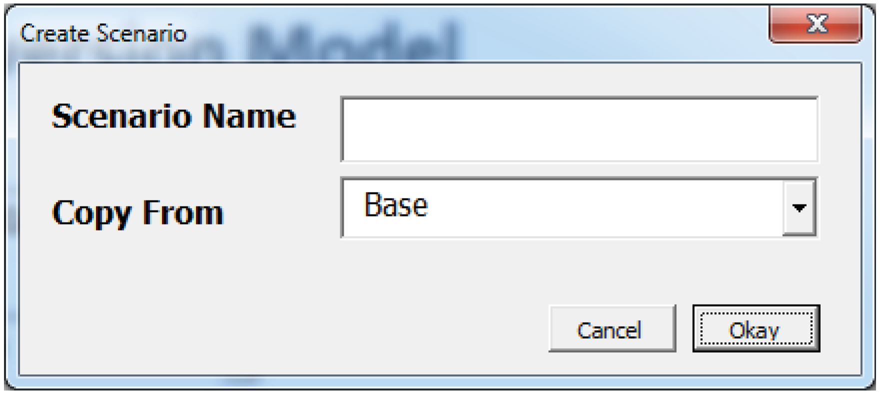
Creating a Scenario

The scenario drop down list on the Main Menu shows the current list of scenarios for the selected model. At first, just the Base scenario exists

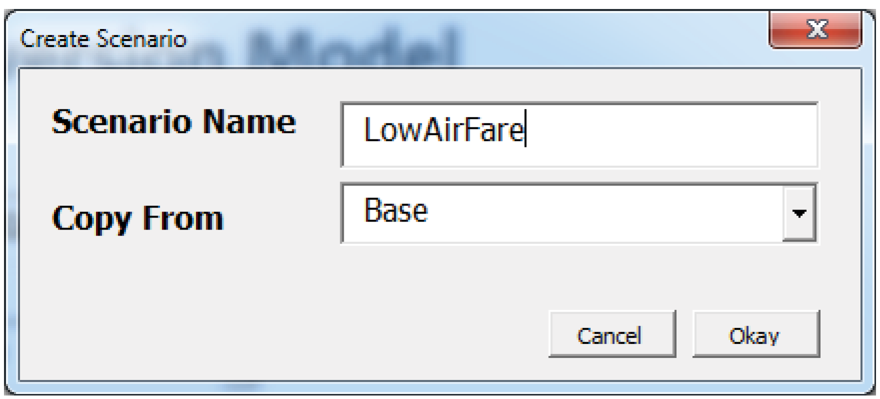


Creating a Scenario

Clicking the "Create Scenario" button launches the Create Scenario Dialog.

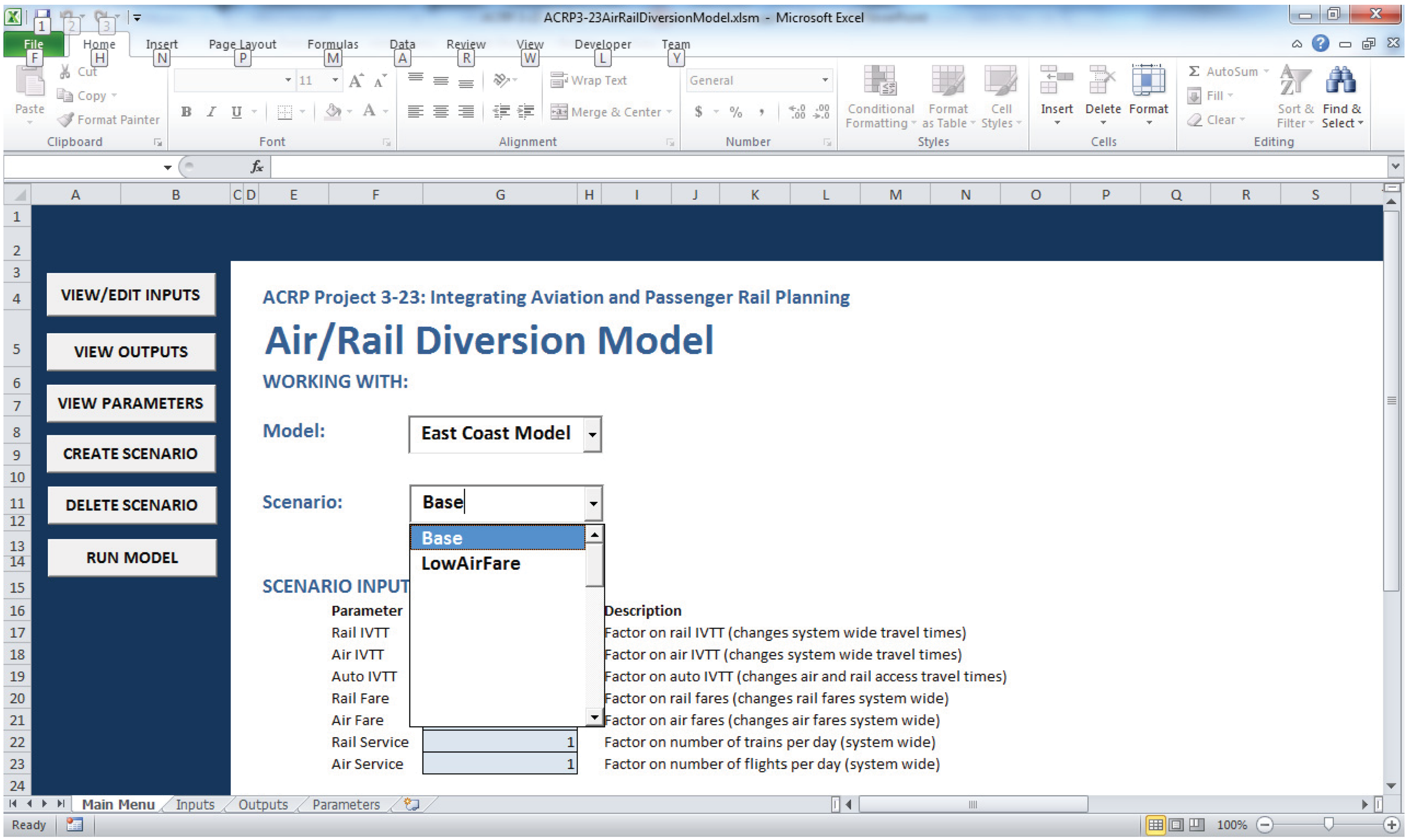


The model user names their scenario in the "Scenario Name" box. They can also specify which existing scenario to use as a template for the new scenario using the "Copy From" drop down. In this case, the Base scenario will be copied and, until the user edits the inputs to their new scenario, it will be identical to the Base scenario.



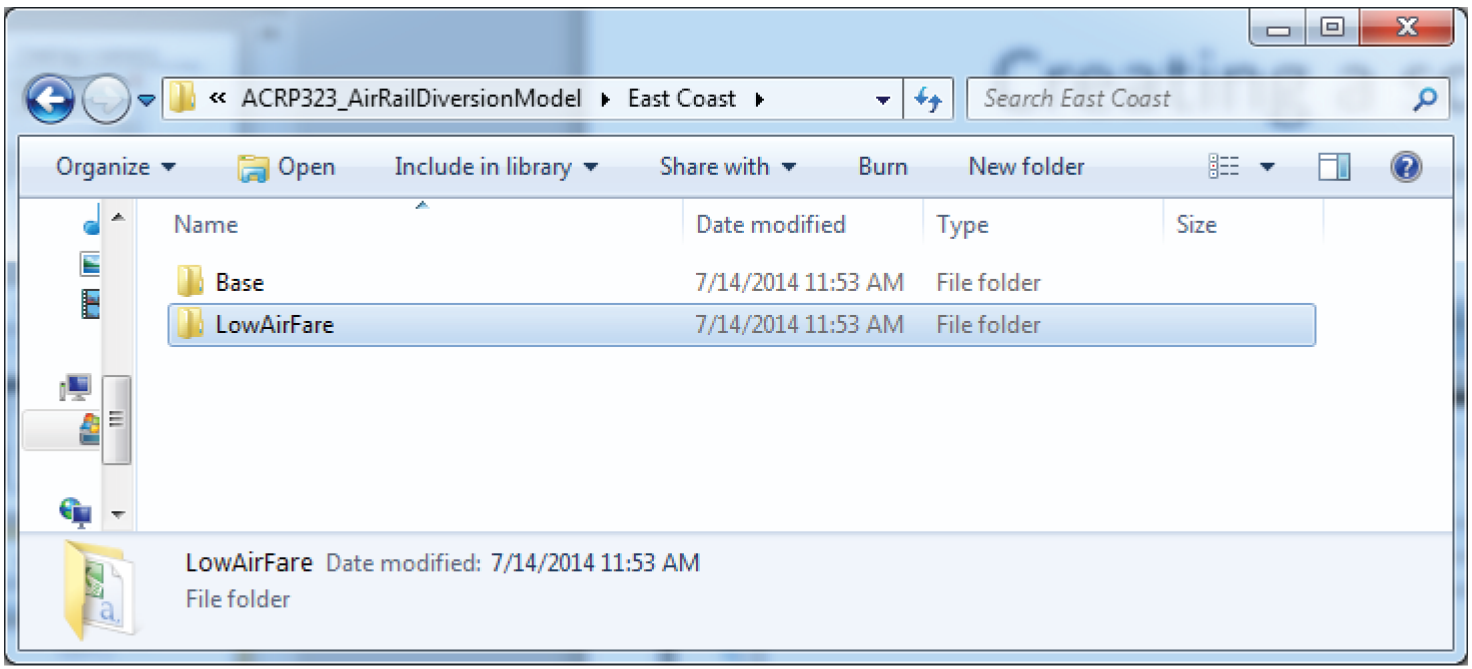
Creating a Scenario

The model user then clicks "okay" to create the new scenario. It is added to the scenario drop down as shown.



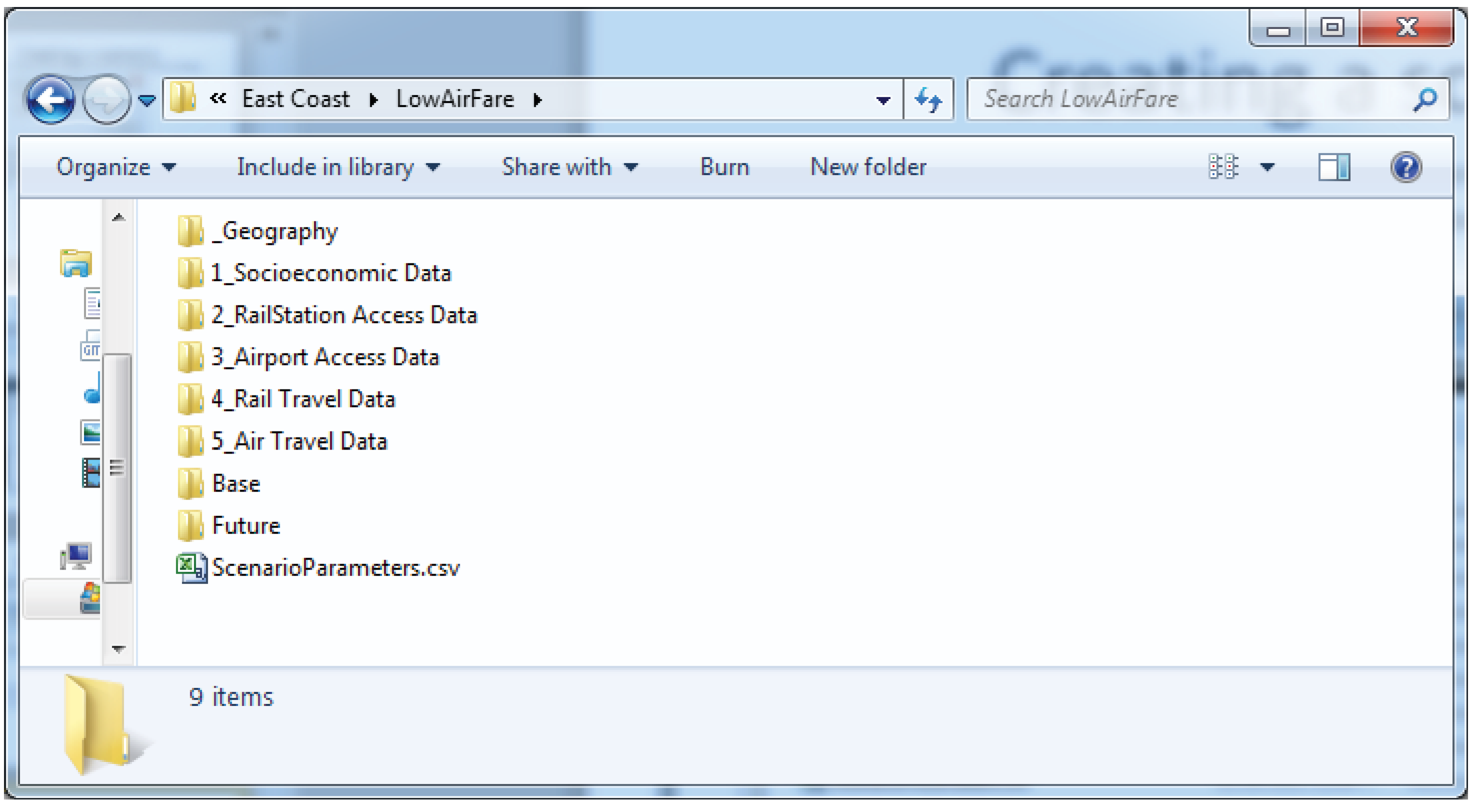
Creating a Scenario

In addition, the new scenario folder is also added to the file system, in this case to \East Coast\LowAirFare.



Creating a scenario

The file structure within the new scenario folder is identical to that within the Base scenario folder (shown earlier in the user's guide).



Editing Inputs

Editing Inputs

The GUI provides access to two types of scenario inputs

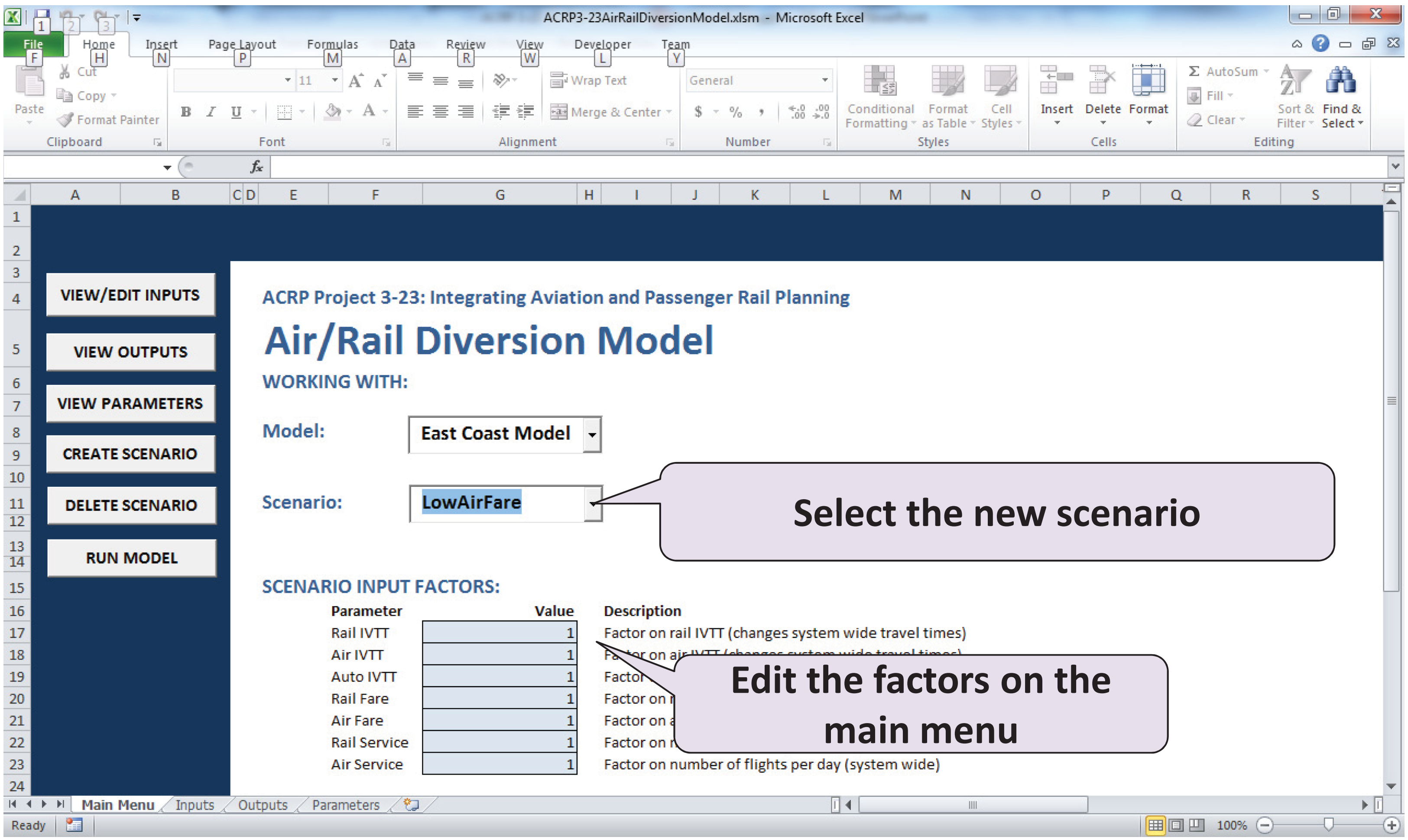
- Main scenario assumptions that can be set on the Main Menu tab
- More detailed inputs that can viewed and edited on the Inputs tab

These are described in turn on the following pages.

It is these edits to inputs that allow a model user to distinguish their new scenario from the base and other scenarios that they have already evaluated.

Editing Main Scenario Assumptions

The GUI contains 7 scenario input factors on the main menu. These allow the model user to make system level changes quickly in order to create the inputs for new scenarios quickly.



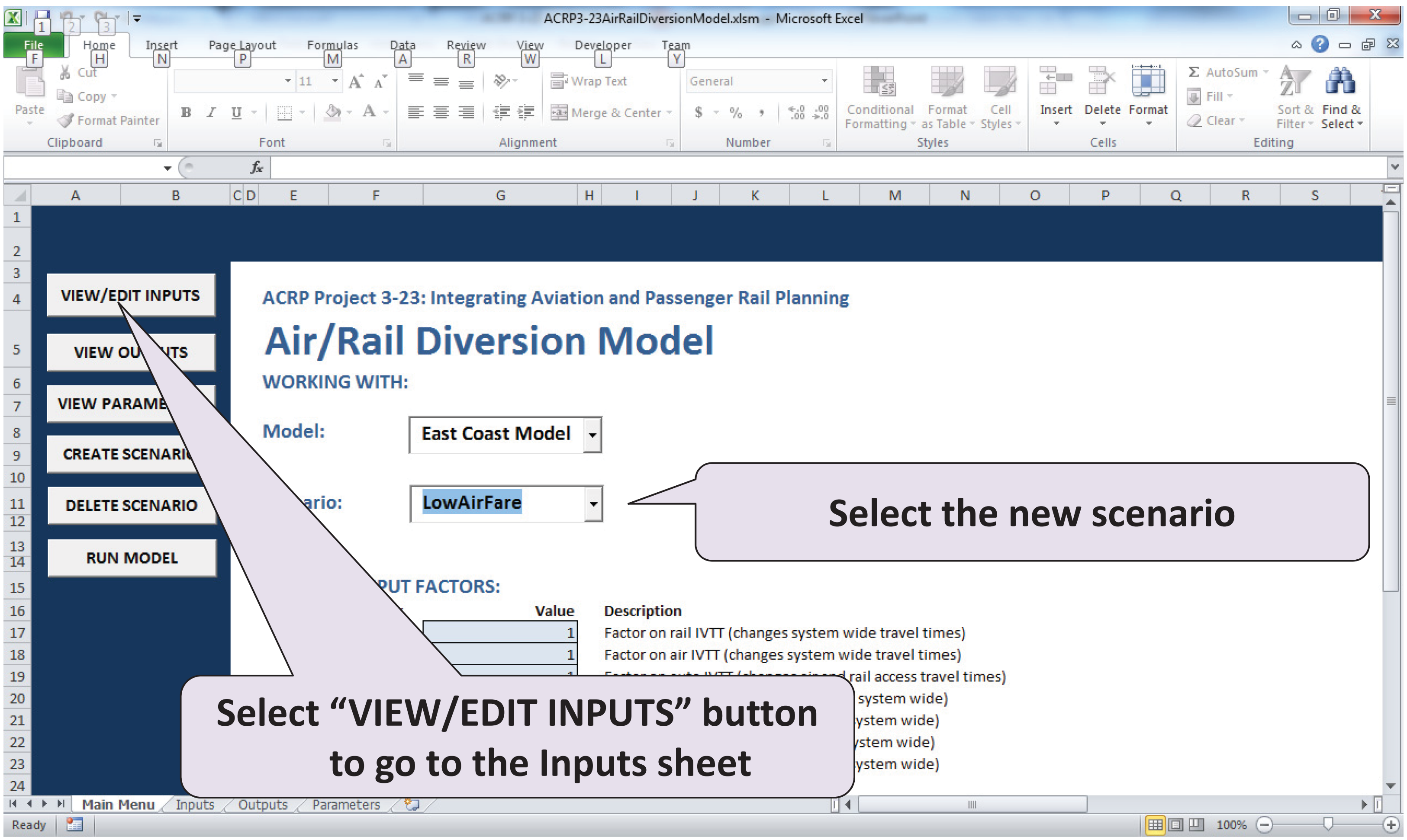
Editing Main Scenario Assumptions

The scenario inputs factors are all system wide effects that factor up or down proportionally a particular input.
For example, setting Rail Fare to a value higher than 1, such as 1.2, increases all rail fares by that factor. So 1.2 multiplies all rail fares by 1.2, resulting in a 20% increase.

Parameter	Description
Rail IVTT	Factor on rail in vehicle travel time (changes system wide travel times)
Air IVTT	Factor on air in vehicle travel time (changes system wide travel times)
Auto IVTT	Factor on auto in vehicle travel time (changes air and rail access travel times)
Rail Fare	Factor on rail fares (changes rail fares system wide)
Air Fare	Factor on air fares (changes air fares system wide)
Rail Service	Factor on number of trains per day (system wide)
Air Service	Factor on number of flights per day (system wide)

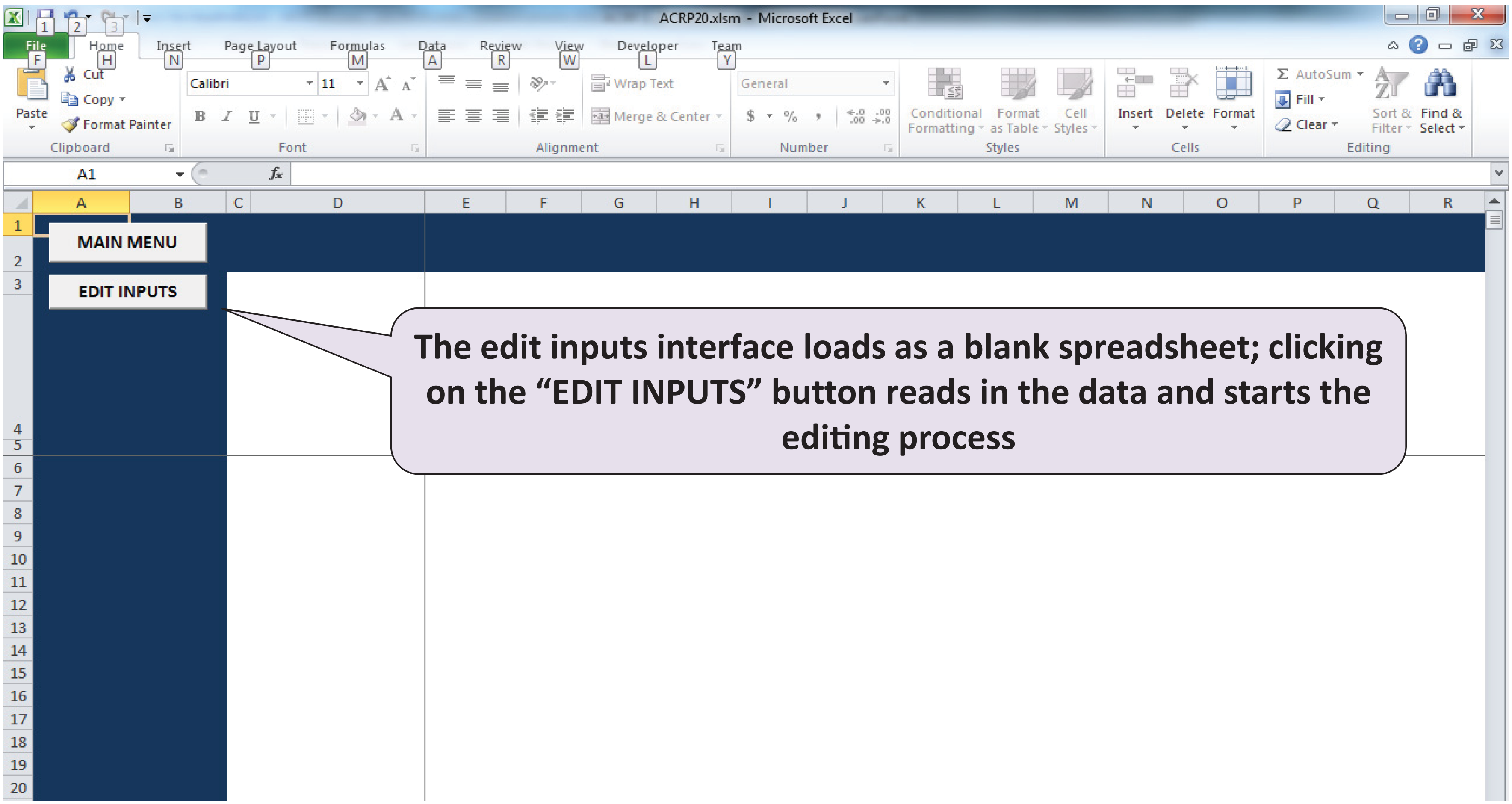
Editing Inputs

The GUI also includes the capability to edit the more detailed input files to a scenario, specifically the various inputs describing the rail services.



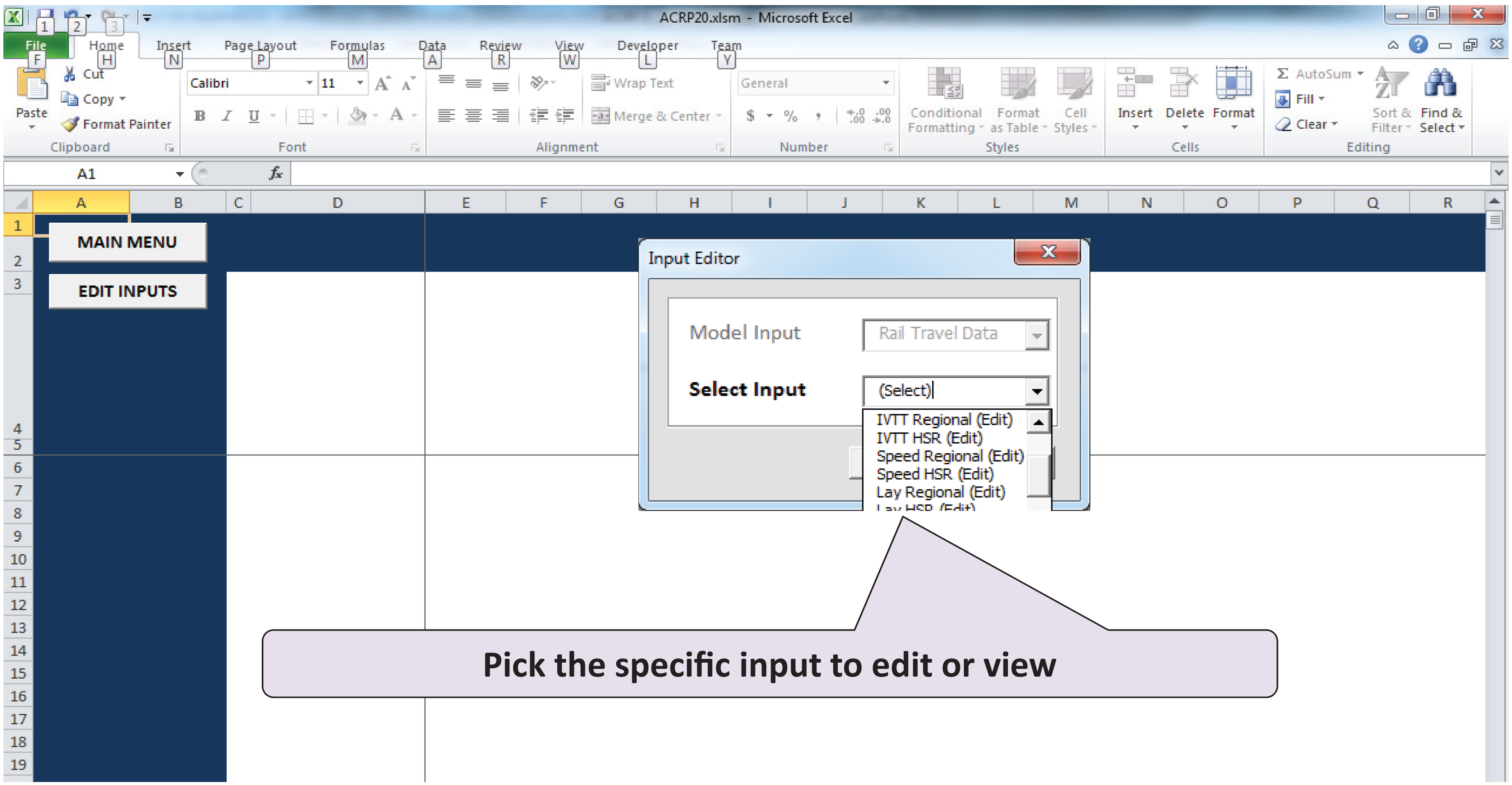
Editing Inputs

The Inputs sheet is a standard interface that allows the model user to load inputs for the scenario into memory and then view and edit specific inputs using dialog boxes and the spreadsheet.



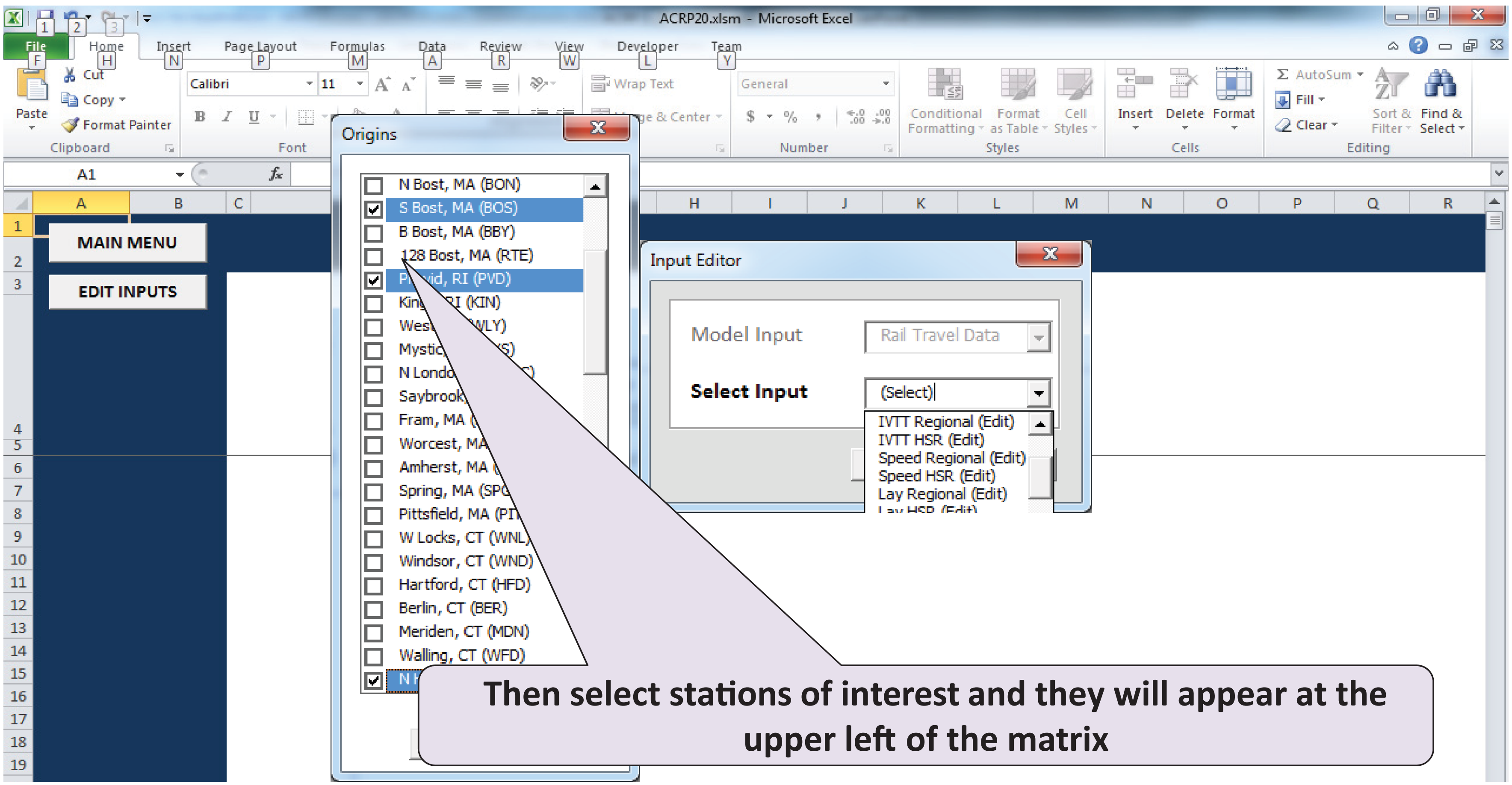
Editing Inputs

Once the Edit Inputs button has been clicked, a wizard takes the model user through the process of picking which particular input they wish to view or edit



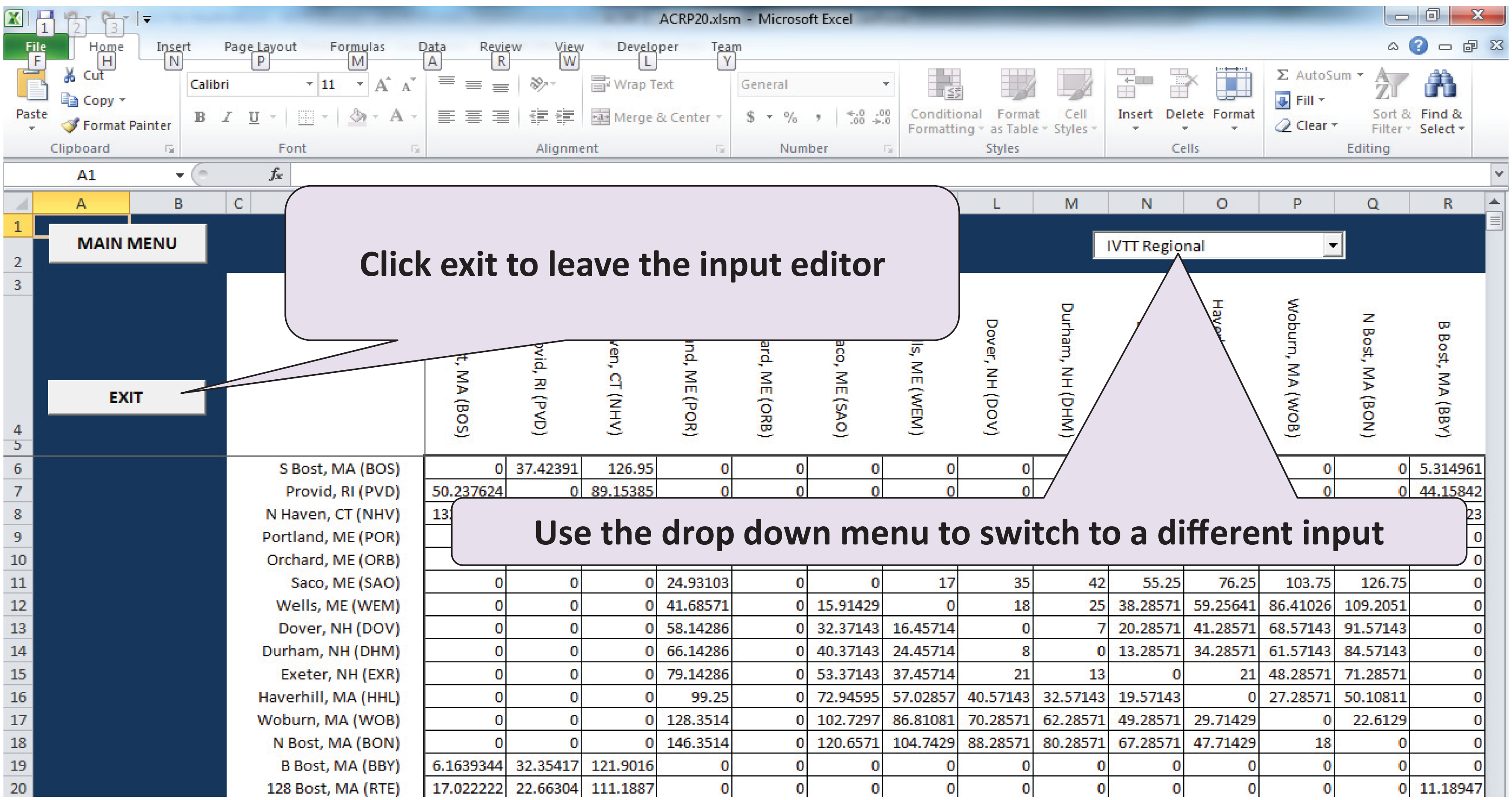
Editing Inputs

The model user can choose particular stations to appear at the upper left of the viewing/editing matrix, so they are easy to find.



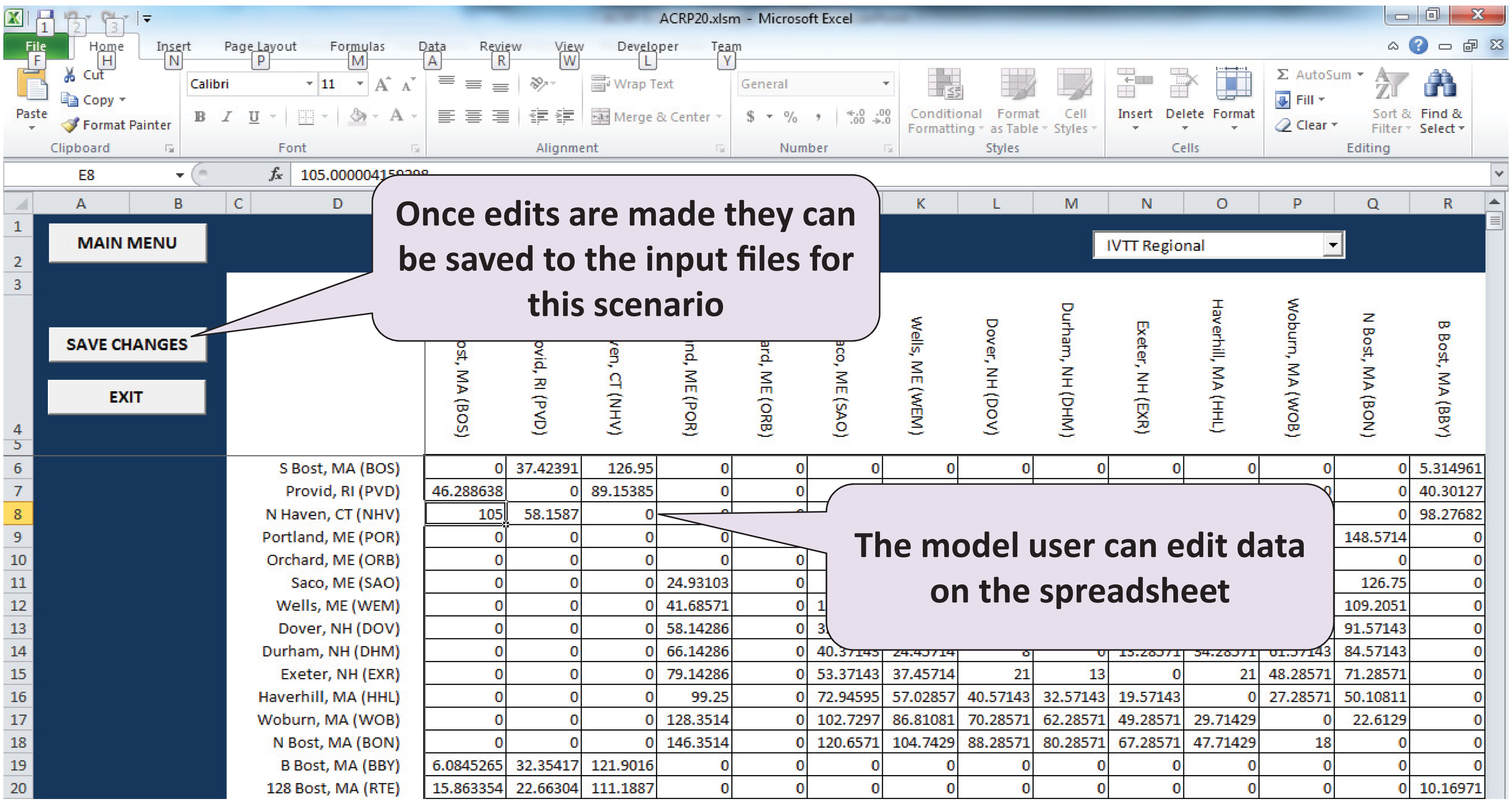
Editing inputs

Model users can use the buttons and drop downs to switch to different inputs or exit if they have finishing viewing files.



Editing inputs

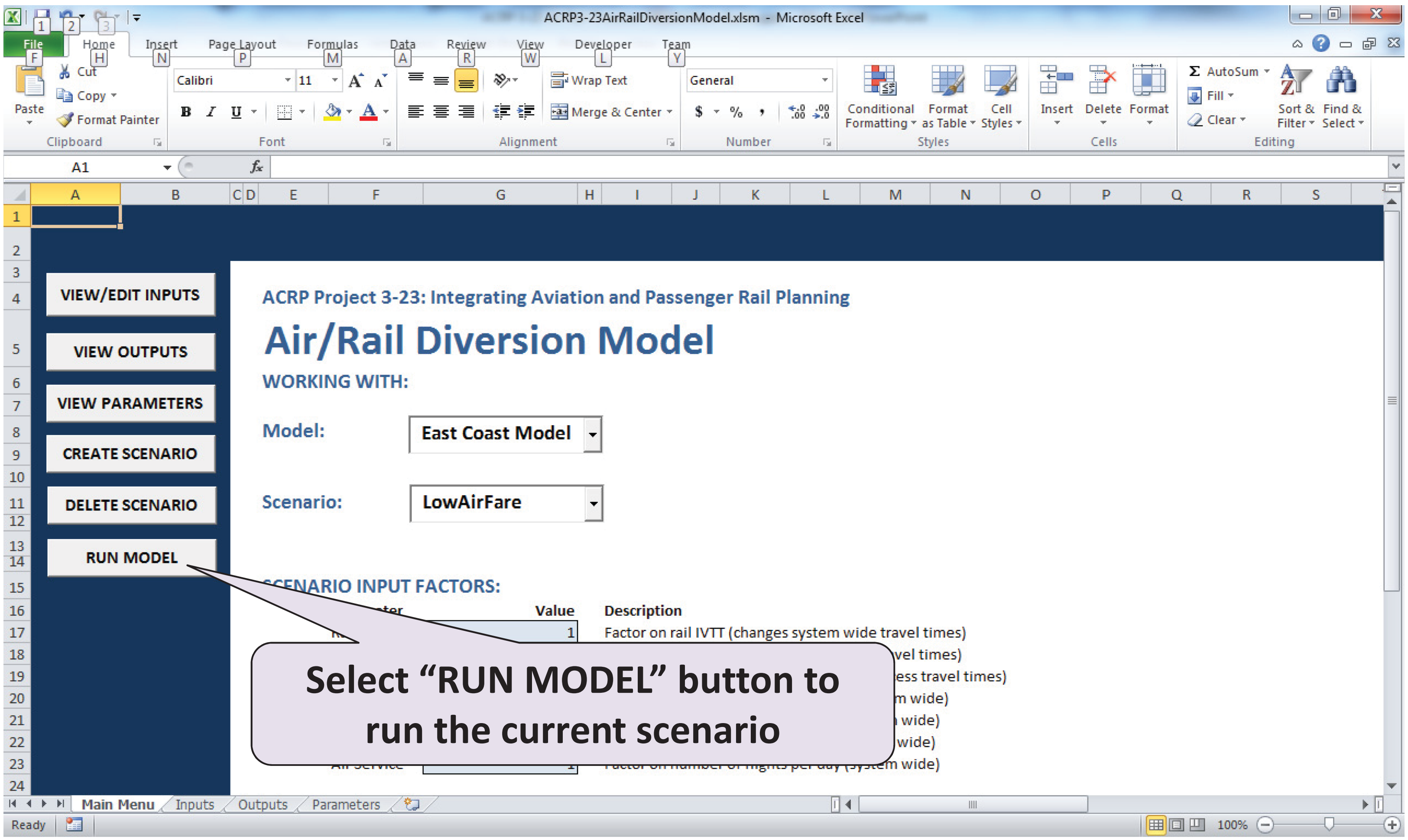
Once the data are loaded, the model user can edit them directly on the spreadsheet and then save the changes using the SAVE CHANGES button. The model user can then return to the main menu by clicking on MAIN MENU.



Running a Scenario

Running a Scenario

Once any file editing is done, the model user can run a scenario. A model run is started by clicking on the "RUN MODEL" button.



Running a scenario

When the model user clicks on the “RUN MODEL” button, several steps are initiated:

1. Creation of the “RunSpecification.txt” file, which describes the model and scenario to run.

2. R is launched via a command shell and the main R script containing the model application code, ModelApplication.R, is executed.

3. The simulation is carried out with logging of progress to a log file (“log.txt”).

RunSpecification.txt - Notepad

File Edit Format View Help

```
#This is the current Run Specification
#Written at run time by the excel application prior to
starting R and executing the model
#Read in by the R script so that the R script knows which
model scenario to run, which other important assumptions to
use

#The name of the model to run
#This is a character string which should be the same as the
name of the directory the model is stored in
RunModel = "East Coast"

#The name of the scenario to run
#This is a character string which should be the same as the
name of the directory the scenario is stored in
RunScenario = "Base"

#Sample fraction: 1-100 value indicating the percentage of
the demand to simulate (100 = all, every trip for the year)
SampleFraction =  2
```

log.txt - Notepad

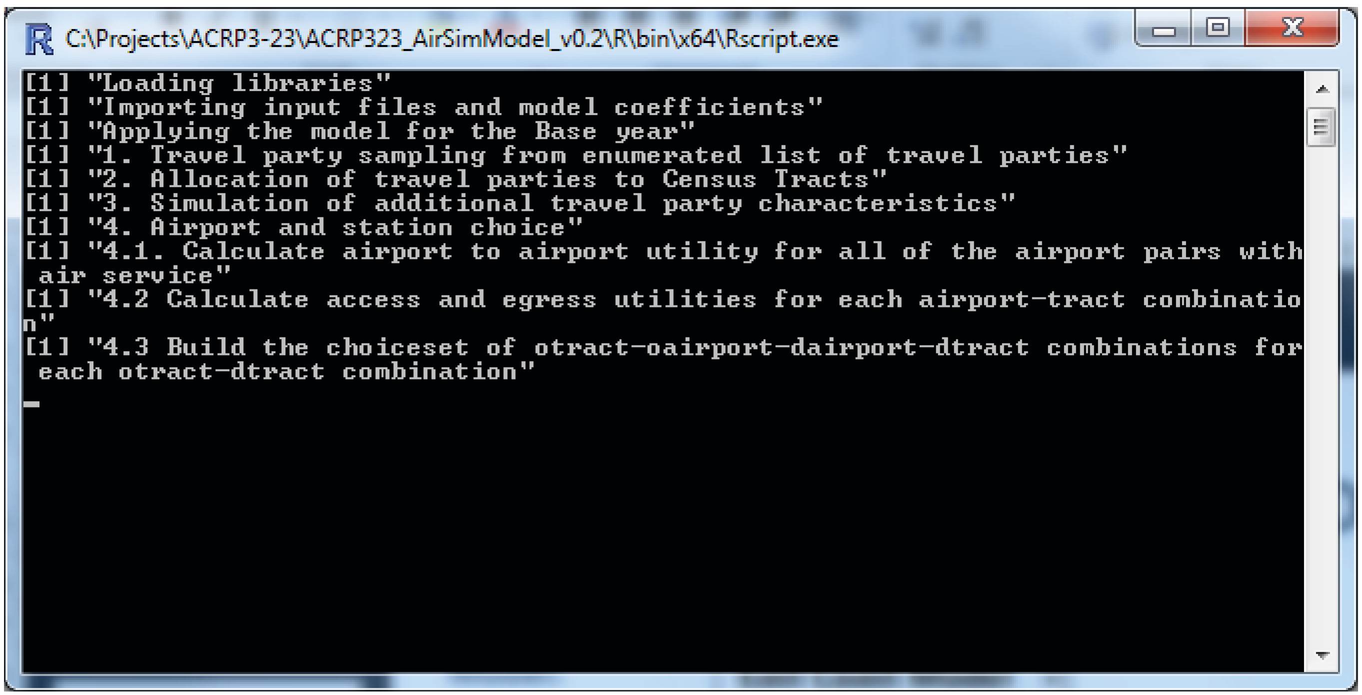
File Edit Format View Help

```
[1] "4.2 Calculate access and egress utilities for each
airport-tract combination"
[1] "4.3 Build the choiceset of otract-oairport-dairport-
dtract combinations for each otract-dtract combination"
[1] "4.4 Apply the airport choice model for each travel party"
[1] "4.5 Apply the rail station choice model"
[1] "5. Main mode choice model"
[1] "6. Airline Response Model"
[1] "7. Save large model output files"
[1] "Applying the model for the Future year"
[1] "1. Travel party sampling from enumerated list of travel
parties"
[1] "2. Allocation of travel parties to Census Tracts"
[1] "3. Simulation of additional travel party characteristics"
[1] "4. Airport and station choice"
[1] "4.1. Calculate airport to airport utility for all of the
airport pairs with air service"
[1] "4.2 Calculate access and egress utilities for each
airport-tract combination"
[1] "4.3 Build the choiceset of otract-oairport-dairport-
dtract combinations for each otract-dtract combination"
[1] "4.4 Apply the airport choice model for each travel party"
[1] "4.5 Apply the rail station choice model"
[1] "5. Main mode choice model"
[1] "6. Airline Response Model"
```

Running a scenario

During a scenario run the command shell window also shows and prints progress to the screen so that the user can see how the simulation is progressing.

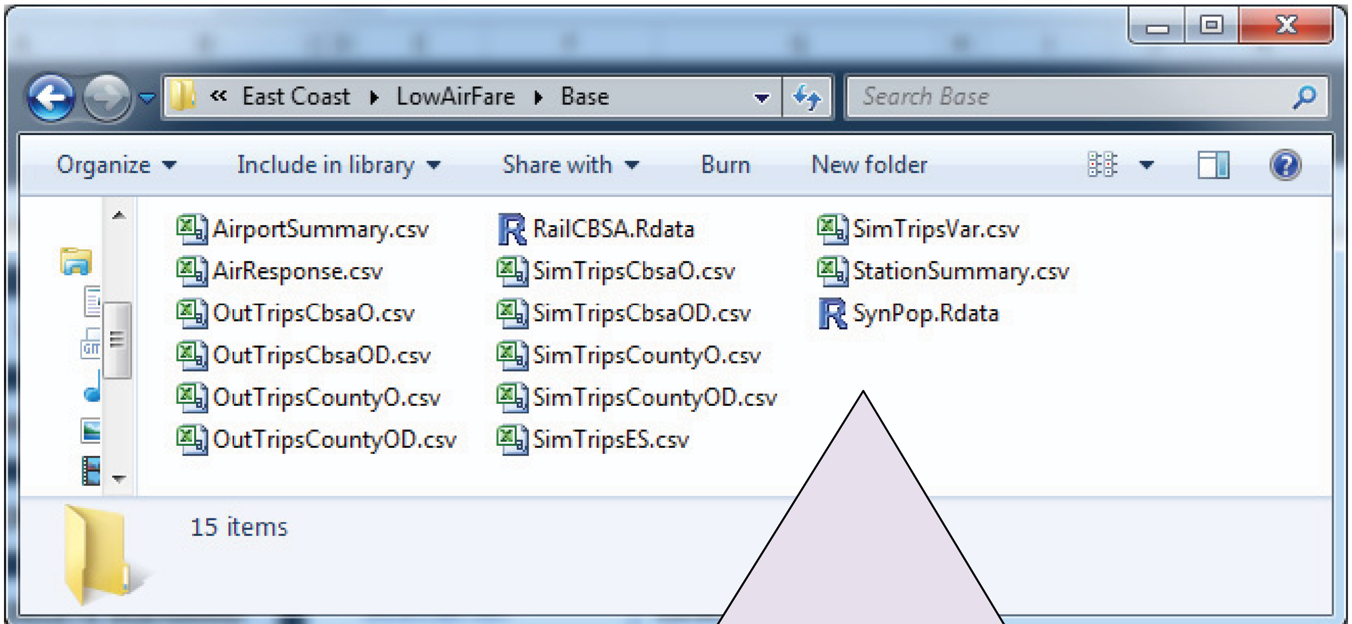
Once command shell window closes, the run is complete and the mode user can processed to view the results.



Viewing Results

Reviewing Results

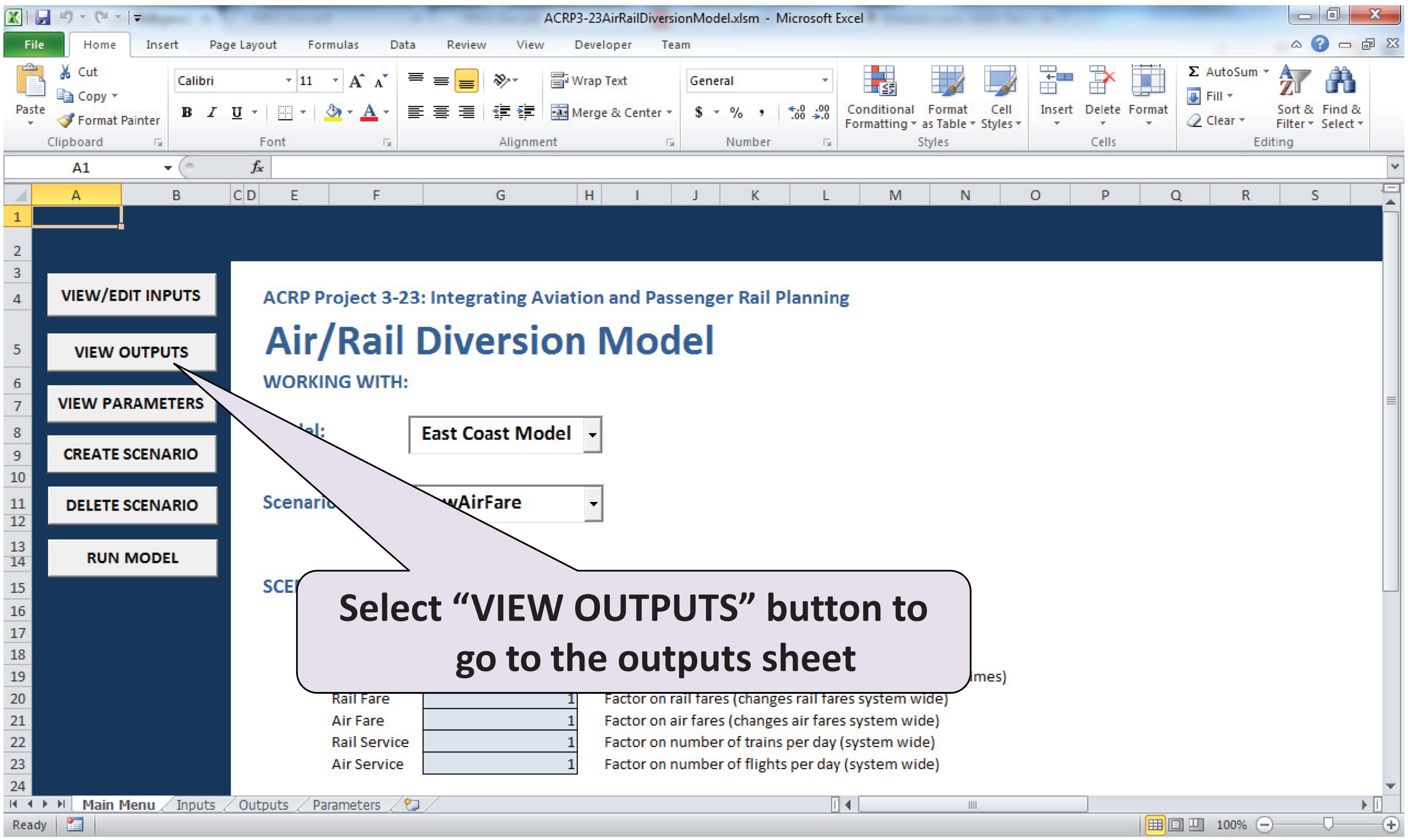
At the end of a run the results are written into the Base and Future folders within the scenario.



The model writes a complete set of outputs including the full simulation results into an R binary file and exports key summary tabulations into .csv files

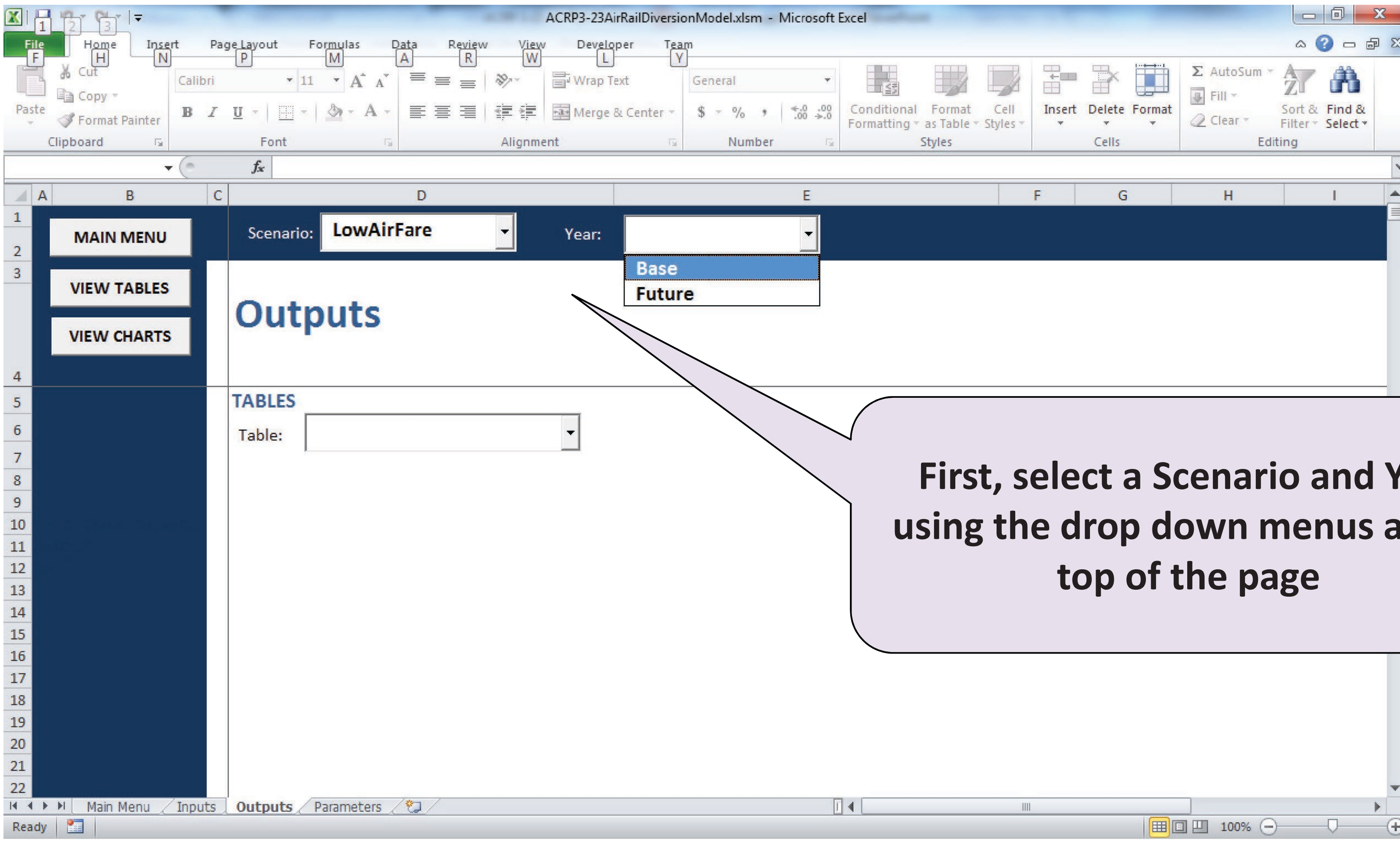
Reviewing Results

Click on the “VIEW OUTPUTS” button on the main menu to navigate to the outputs page.



Reviewing Results

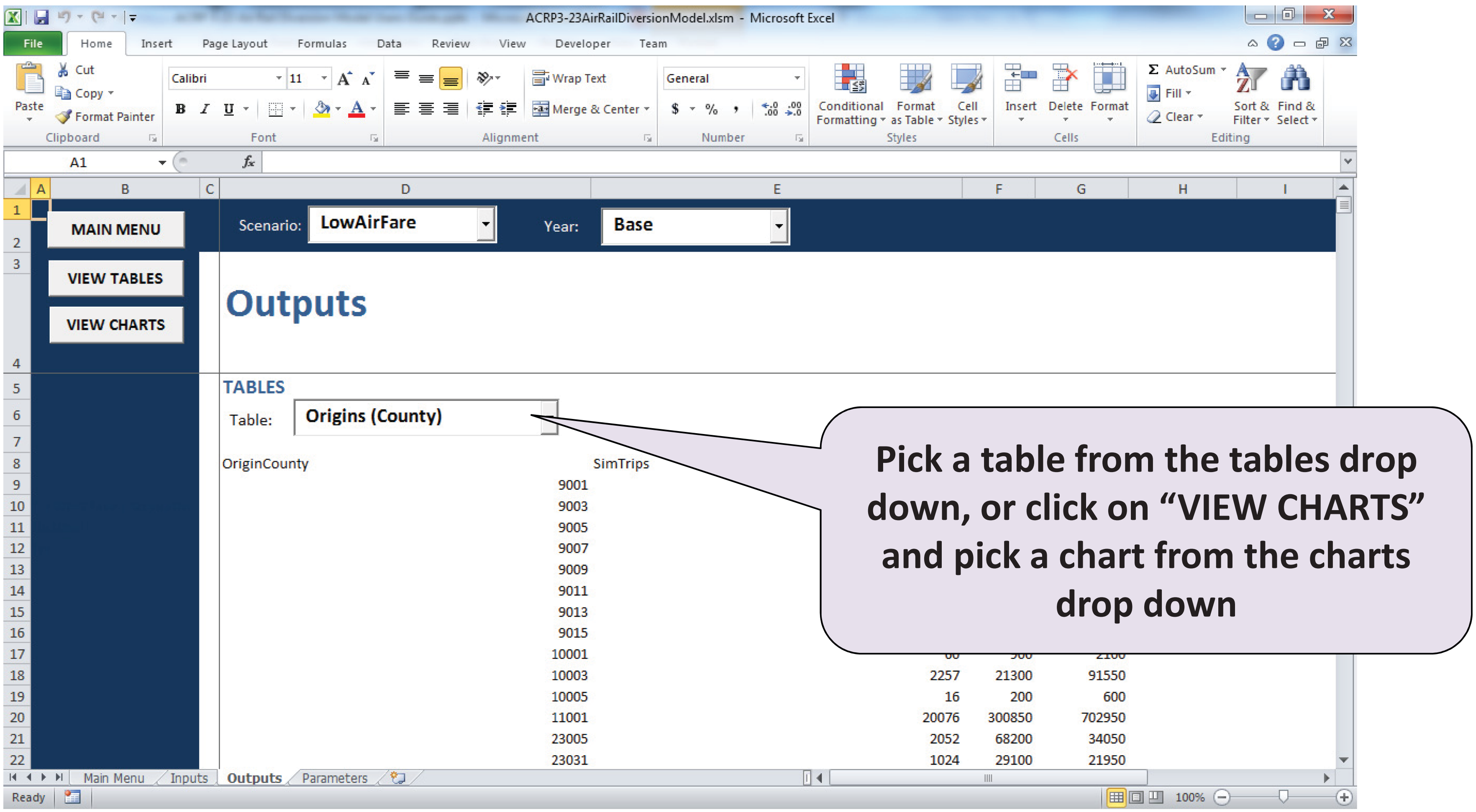
The outputs page allows the user to open results from any scenario that has been run, to view base and future results, and to view various tabulations and charts.



First, select a Scenario and Year using the drop down menus at the top of the page

Reviewing Results

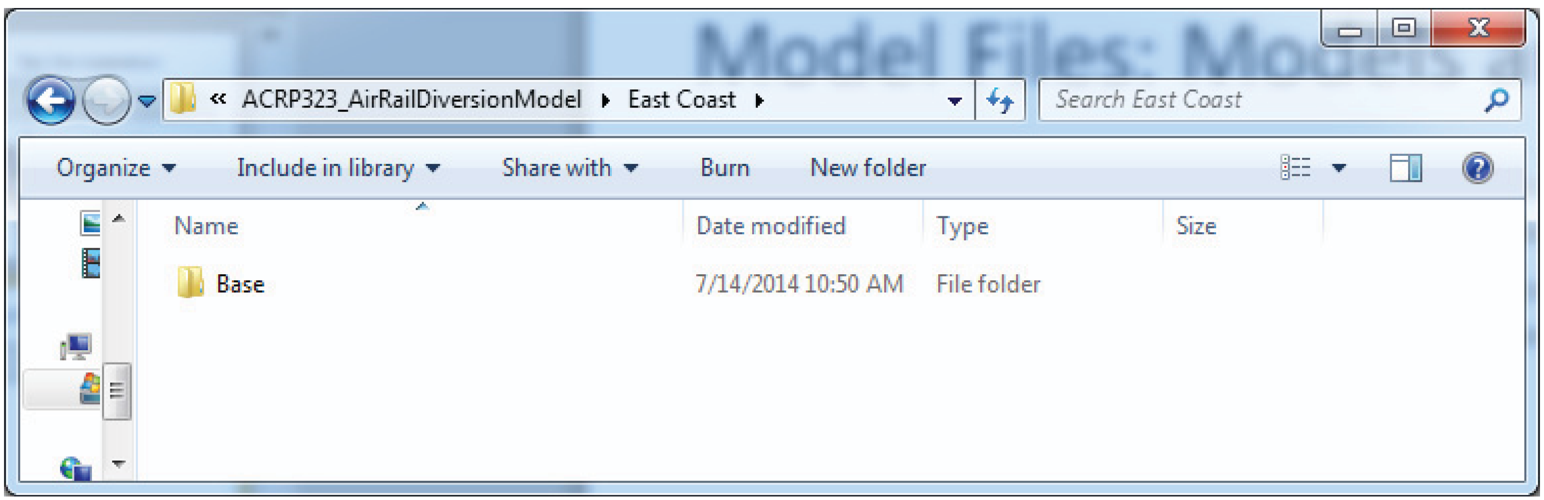
Once the user selects a table or chart to view the results are loaded and the data are displayed. Additional results including very detailed outputs are available via the file system.



Input File Specifications

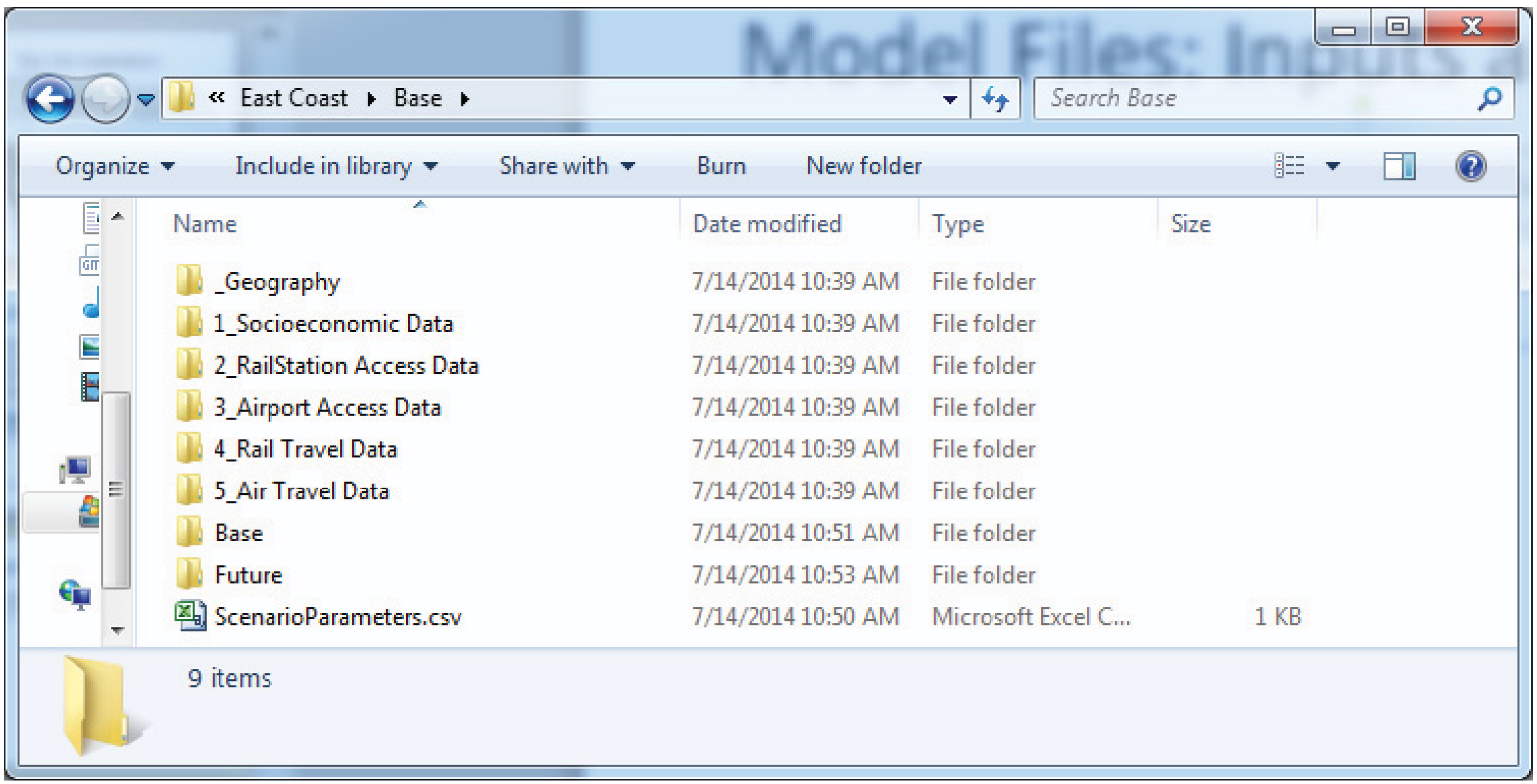
Input File Specifications

This section of the user's guides provides a complete description of the input files for the model. As noted above, the model comes with two pre-developed models, for the East Coast and West Coast regions, which are contained in the "East Coast" and "West Coast" folders, respectively. Within each of those two folders are a list of scenarios. Initially, there is only a "Base" scenario folder, but as scenarios are created, additional scenario folders will appear here. The screenshot below shows the contents of the "East Coast" folder – just the "Base" scenario folder when the model is installed.



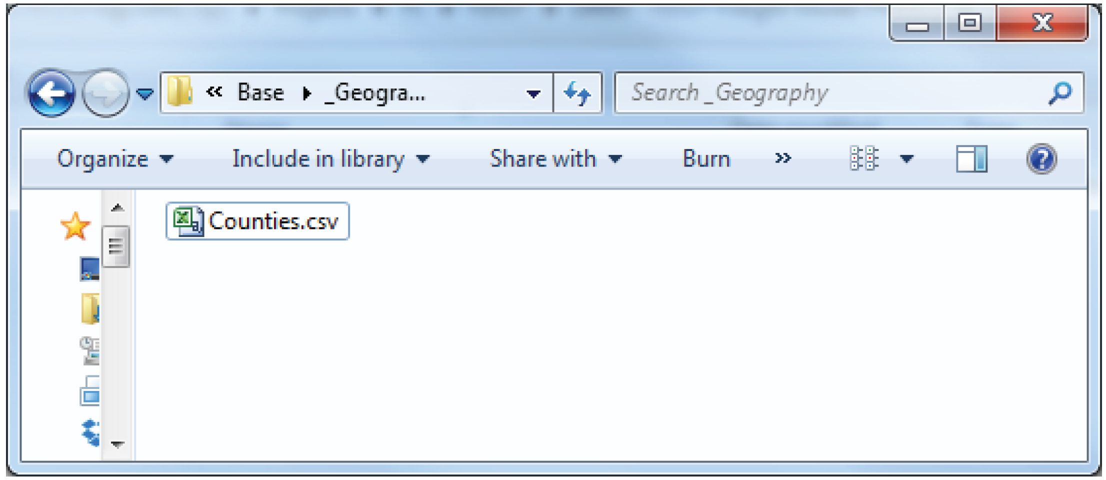
Model Files: Inputs and Outputs

Each scenario folder--for example, within the East Coast/Base folder as shown here--contains folders containing .csv files for several different categories of inputs, and the “Base” and “Future” folder which contain outputs (once the scenario has been run). The ScenarioParameters.csv file contains several top level policy variables and is edited using the GUI’s main menu.



Model Files: _Geography

The geography folder contains one file, Counties.csv. This file describes the extent of the study area for this model and is simply a list of county and state names. The first 10 rows are shown in the table below.



Counties.csv

Describes the extent of the study area

Field Descriptions:

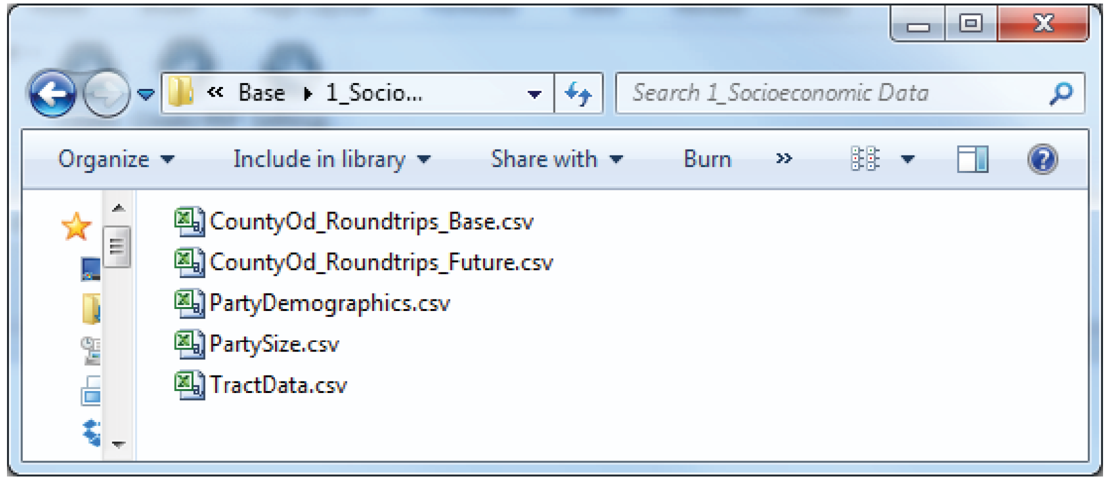
NAME – county name in text

STATE_NAME – state name in text

NAME	STATE_NAME
fairfield	connecticut
hartford	connecticut
litchfield	connecticut
middlesex	connecticut
new haven	connecticut
new london	connecticut
tolland	connecticut
windham	connecticut
kent	delaware
new castle	delaware

Model Files: 1_Socioeconomic Data (1)

The 1_Socioeconomic Data folder contains 5 files describing total air and rail travel and the demographics of travelers and more detailed spatial information about the study area.



CountyOd_Roundtrips_Base.csv
Describes existing OD travel in the study area
Field Descriptions:
orgfips – FIPS code for the origin county
desfips – FIPS code for the destination county
air_trips – annual air passenger trips in 2008 between the counties
rail_trips – annual rail passenger trips in 2008 between the counties
GCD – great circle distance between the counties
hwydist – distance over the highway network between the counties

orgfips	desfips	air_trips	rail_trips	GCD	hwydist
9001	9001	0	13	0	23.8
9001	9003	0	1142	50.8	88.6
9001	9005	0	96	38.1	74.4
9001	9007	0	223	45.4	82.6
9001	9009	0	1209	24.8	65.8
9001	9011	0	810	67.6	94.4
9001	9013	0	276	68	102.6
9001	9015	0	124	82.8	131.5
9001	10001	8	47	187.3	276.6
9001	10003	67	2636	158.5	228.1

Model Files: 1_Socioeconomic Data (2)

CountyOd_Roundtrips_Future.csv
Describes future year OD travel in the study area
Field Descriptions:
orgfips – FIPS code for the origin county
desfips – FIPS code for the destination county
air_trips – annual air passenger trips in 2040 between the counties
rail_trips – annual rail passenger trips in 2040 between the counties
GCD – great circle distance between the counties
hwydist – distance over the highway network between the counties

orgfips	desfips	air_trips	rail_trips	GCD	hwydist
9001	9001	0	18	0	23.8
9001	9003	0	1516	50.8	88.6
9001	9005	0	132	38.1	74.4
9001	9007	0	317	45.4	82.6
9001	9009	0	1608	24.8	65.8
9001	9011	0	1097	67.6	94.4
9001	9013	0	404	68	102.6
9001	9015	0	179	82.8	131.5
9001	10001	8	76	187.3	276.6
9001	10003	64	3700	158.5	228.1

Model Files: 1_Socioeconomic Data (3)

PartyDemographics.csv
Describes the joint income, vehicle availability and trip purpose distributions for air and rail travel parties

Field Descriptions:
Purpose – trip purpose groups (Business and NonBusiness)
Income – household income groups (<$25,000, $25,000 to $75,000, $75,000 to $125,000, and $125,000 or more)
VehicleAvailability – whether the travel party has a vehicle available or not (No, Yes)
AirProp – the proportion of air travel parties in each joint category of Purpose, Income, and Vehicle Availability. Sums to 1.0
RailProp – the proportion of rail travel parties in each joint category of Purpose, Income, and Vehicle Availability. Sums to 1.0

Purpose	Income	VehicleAvailability	AirProp	RailProp
Business	$125,000 or more	No	0	0
Business	$125,000 or more	Yes	0.22	0.12
Business	$75,000 to $125,000	No	0	0
Business	$75,000 to $125,000	Yes	0.11	0.18
Business	$25,000 to $75,000	No	0	0
Business	$25,000 to $75,000	Yes	0.09	0.09
Business	<$25,000	No	0	0
Business	<$25,000	Yes	0.01	0
NonBusiness	$125,000 or more	No	0	0
NonBusiness	$125,000 or more	Yes	0.17	0.07
NonBusiness	$75,000 to $125,000	No	0	0.01
NonBusiness	$75,000 to $125,000	Yes	0.13	0.21
NonBusiness	$25,000 to $75,000	No	0.01	0.01
NonBusiness	$25,000 to $75,000	Yes	0.21	0.25
NonBusiness	<$25,000	No	0.01	0
NonBusiness	<$25,000	Yes	0.03	0.06

Model Files: 1_Socioeconomic Data (4)

PartySize.csv
Describes the party size distribution for air and rail travel parties by trip purpose

Field Descriptions:
Purpose – trip purpose groups (Business and NonBusiness)
PartySize – party size of the travel party (1, 2, 3, 4, 5 or more)
AirProp – the proportion of air travel parties in each party size category. Sums to 1.0 for each purpose group, 2.0 overall.
RailProp – the proportion of rail travel parties in each party size category. Sums to 1.0 for each purpose group, 2.0 overall.

Purpose	PartySize	AirProp	RailProp
Business	1	0.8	0.75
Business	2	0.14	0.17
Business	3	0.03	0.05
Business	4	0.02	0.02
Business	5 or more	0.02	0.02
NonBusiness	1	0.49	0.29
NonBusiness	2	0.37	0.34
NonBusiness	3	0.06	0.13
NonBusiness	4	0.04	0.15
NonBusiness	5 or more	0.04	0.1

Model Files: 1_Socioeconomic Data (5)

TractData.csv
Describes the characteristics of each Census tract in the study area

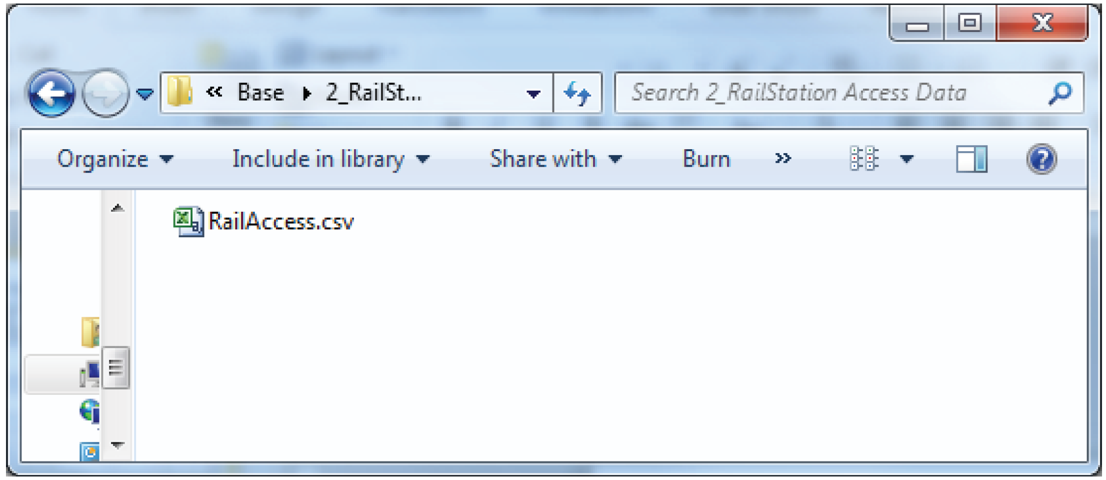
Field Descriptions:

TractNum – Census Bureau tract identification number
TractID – sequential tract identification number used in the model, 1:n tracts
CtyNum – county FIPS code
CtyName – text county name
StNum – state FIPS code
StName – text state name
Pop – tract population
HHMedInc – tract household median income ($)
AveHHVeh – tract average household vehicle availability
Emp_Tot – tract total employment
Emp_Hosp – tract employment in the hospitality industry

TractNum	TractID	CtyNum	CtyName	StNum	StName	Pop	HHMedInc	AvgHHVeh	Emp_Tot	Emp_Hosp
9001010101	1	9001	fairfield county	9	connecticut	4476	154421	2.342049	2913	147
9001010102	2	9001	fairfield county	9	connecticut	4330	241944	2.293716	913	13
9001010201	3	9001	fairfield county	9	connecticut	3421	250001	2.537137	839	10
9001010202	4	9001	fairfield county	9	connecticut	5359	175625	2.202524	414	0
9001010300	5	9001	fairfield county	9	connecticut	4010	152321	2.084577	4952	191
9001010400	6	9001	fairfield county	9	connecticut	5290	83036	1.78829	2198	170
9001010500	7	9001	fairfield county	9	connecticut	5494	88750	1.548553	2848	129
9001010600	8	9001	fairfield county	9	connecticut	1845	90909	1.331522	10852	699
9001010700	9	9001	fairfield county	9	connecticut	3579	65682	1.34878	336	7
9001010800	10	9001	fairfield county	9	connecticut	3388	135204	1.885401	1230	150

Model Files: 2_RailStation Access Data

The 2_RailStation Access Data folder contains one file, RailAccess.csv. This file describes the accessibility of each station to each tract in the study area.



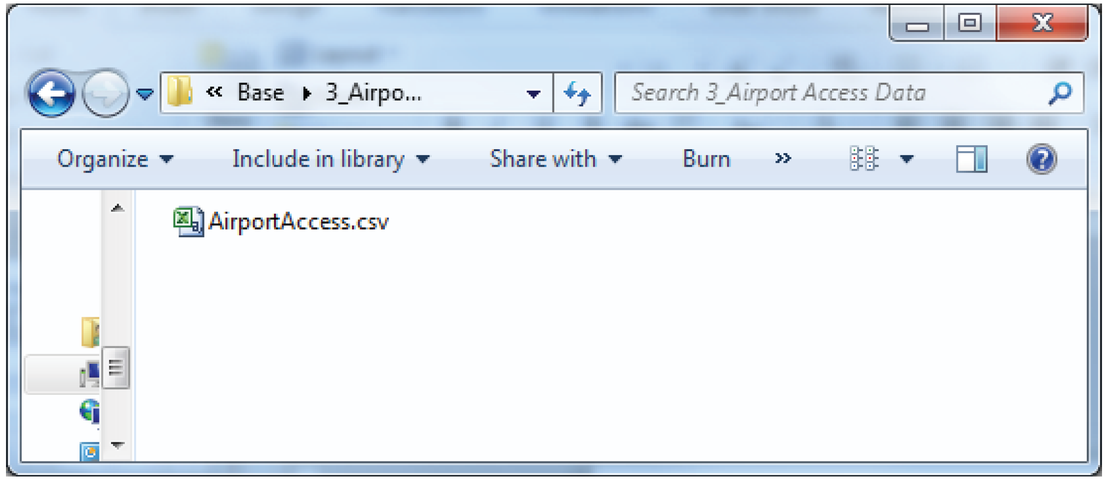
RailAccess.csv
Describes the accessibility of each rail station to each tract in the study area

Field Descriptions:
RailAccInd – unique identifier for the combination of tract and station, 1:n
TractInd – sequential tract identification number used in the model, 1:n tracts
StationInd - sequential rail station identification number used in the model, 1:n stations
AutoTT – auto travel time from tract to station
HwyDist – highway distance from tract to station
Transit – transit accessibility index, tract station combination

RailAccInd	TractInd	StationInd	AutoTT	HwyDist	Transit
1	1	1	256.38	270.59	0.011
2	1	2	251.63	262.24	0.008
3	1	3	247.9	258.44	0.008
4	1	4	233.1	243.79	0.01
5	1	5	222.25	228.7	0.012
6	1	6	223.4	224.22	0.008
7	1	7	209.77	212.32	0.008
8	1	8	188.21	194.96	0.024
9	1	9	173.29	178.7	0.018
10	1	10	169.36	178.2	0.008

Model Files: 3_Airport Access Data

The 3_Airport Access Data folder contains one file, AirportAccess.csv. This file describes the accessibility of each airport to each tract in the study area.



AirAccess.csv
Describes the accessibility of each airport station to each tract in the study area

Field Descriptions:
AccInd – unique identifier for the combination of tract and airport, 1:n
TractInd – sequential tract identification number used in the model, 1:n tracts
AirportInd - sequential airport identification number used in the model, 1:n airports
AutoTT – auto travel time from tract to airport
HwyDist – highway distance from tract to airport
Transit – transit accessibility index, tract airport combination

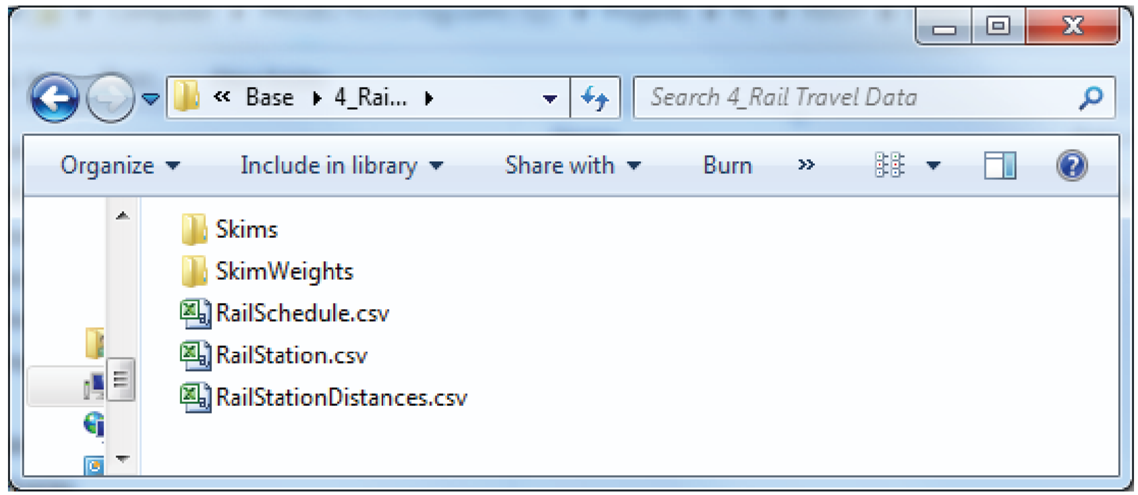
AccInd	TractInd	AirportInd	AutoTT	HwyDist	Transit
1	1	1	51.54	50.31	0.014
2	1	2	96.52	94.39	0.008
3	1	3	245.38	253.24	0.008
4	1	4	260.57	270.68	0.008
5	1	5	174.11	172.43	0.011
6	1	6	171.36	180.94	0.008
7	1	7	207.76	209.67	0.008
8	1	8	330.13	246.89	0.008
9	1	9	263.96	255.02	0.008
10	1	10	242.49	219.75	0.011

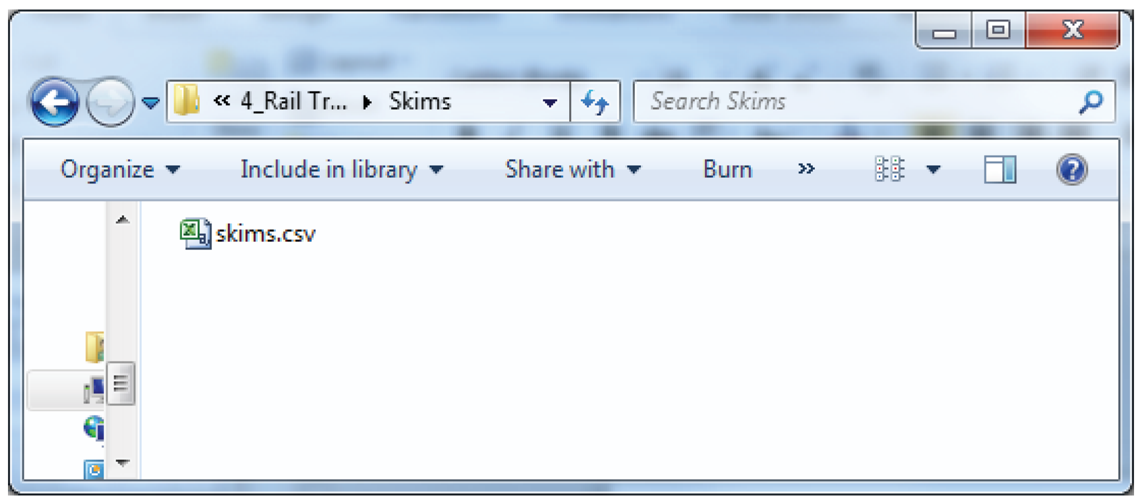
Model Files: 4_Rail Travel Data (1)

The 4_Rail Travel Data folder contains three files and two subfolders that contain files describing the rail station locations and rail service between them.

The Skims folder contains a single file, skims.csv.

The SkimWeights folder contains a set of files used by the model to support adjustments to the station to station travel times and should not be edited by the model user.





Model Files: 4_Rail Travel Data (2)

RailStation.csv
Describes the location of rail stations in the study area

Field Descriptions:
StationInd – sequential station identification number used in the model, 1:n stations
StationCod – 3 letter code for the station
StationName – text name for the station
TractID – sequential tract identification number used in the model, 1:n tracts; this is the tract containing the station
NAME – Name of the county the station is located in
STATE_NAME – Name of the state the station is located in
Latitude – latitude of the station
Longitude – longitude of the station
KeyStation - * identifying major stations (e.g., South Boston Station)

StationInd	StationCod	StationName	TractID	NAME	STATE_NAME	Latitude	Longitude	KeyStation
1	POR	Portland, ME (POR)	1257	Cumberland	Maine	43.63549	-70.2949	
2	ORB	Orchard, ME (ORB)	1303	York	Maine	43.51731	-70.3776	
3	SAO	Saco, ME (SAO)	1299	York	Maine	43.50092	-70.4428	
4	WEM	Wells, ME (WEM)	1330	York	Maine	43.32203	-70.5809	
5	DOV	Dover, NH (DOV)	4353	Strafford	New Hampshire	43.19786	-70.8737	
6	DHM	Durham, NH (DHM)	4347	Strafford	New Hampshire	43.13397	-70.9265	
7	EXR	Exeter, NH (EXR)	4337	Rockingham	New Hampshire	42.98148	-70.9478	
8	HHL	Haverhill, MA (HHL)	3073	Essex	Massachusetts	42.7762	-71.0773	
9	WOB	Woburn, MA (WOB)	3355	Middlesex	Massachusetts	42.47926	-71.1523	
10	BON	N Bost, MA (BON)	3853	Suffolk	Massachusetts	42.36558	-71.0613	
11	BOS	S Bost, MA (BOS)	3887	Suffolk	Massachusetts	42.35152	-71.0553	*

Model Files: 4_Rail Travel Data (3)

Skims.csv

Describes the rail level of service between station pairs in the study area (each of these fields can be edited in the GUI as described earlier in the user's guide)

Field Descriptions:

From – StationInd (station identification number used in the model, 1:n stations) for the origin station

To – StationInd (station identification number used in the model, 1:n stations) for the destination station

Time – average rail travel time (minutes)

Speed – average rail speed (mph)

Cost – average ticket cost ($)

Distance – average rail distance (miles)

Regional IVTT – regional rail service in vehicle travel time (minutes)

HSR IVTT – high speed rail in vehicle travel time (minutes)

Regional Speed – regional rail service average speed (mph)

HSR Speed – high speed rail average speed (mph)

Regional Layover – time transferring on regional rail services (minutes)

HSR Layover - time transferring on high speed rail services (minutes)

Regional Cost – average ticket cost on regional rail service ($)

HSR Cost – average ticket cost on high speed rail service ($)

Regional Distance – distance on regional rail service (miles)

HSR Distance – distance on high speed rail service (miles)

Transfers – average number of transfers for service between origin and destination station

nPaths – number of alternative itineraries per week

nRegPaths – number of alternative regional rail service itineraries per week

nHSRPaths – number of alternative high speed rail service itineraries per week

Model Files: 4_Rail Travel Data (4)

RailSchedule.csv
Matrix describing each train service and its schedule, with one column describing the schedule for each service. This file is processed into Skims.csv by the model in conjunction with RailStationDistances.csv

Field and row Descriptions:
Mode (row) – code for service type, 1-Regional Rail, 2-Existing Higher Speed Rail, 3-High Speed Rail, 4-Bus
Distance Group (row) – code to identify service groups (e.g., Northeast Regional service)
Bound (row) – direction of travel (N,S)
TrainName (row) - name of the train service (Amtrak)
TrainNumber (row) - Amtrak train number
Operation (row) – string describing the days the train operates (e.g., 1_2_3_4_5_6_7 operates every day, 6_7 operates on weekends only)
StationNum (column) - StationInd (station identification number used in the model, 1:n stations) for the station
StationCod - 3 letter code for the station
StationName – text name for the station

Cell values:
Each cell in the table encodes information about the rail service, including sequence for that train, whether passengers can board, alight, or both, and the time of arrival and departure

01--R--0930P—0
01 indicates that this is the first station for this train
R indicates boarding only (B is both boarding and alighting, D is alighting only)
0930P is the arrival time at the station, 9:30 PM
0 is the time that that station stops at the station, i.e., the scheduled departure time at the station is also 9:30 PM

Model Files: 4_Rail Travel Data (5)

RailStationDistances.csv
Matrix describing the station to station distances for each train service group, with one column describing the distances for each service group. This file is processed into Skims.csv by the model in conjunction with RailSchedule.csv

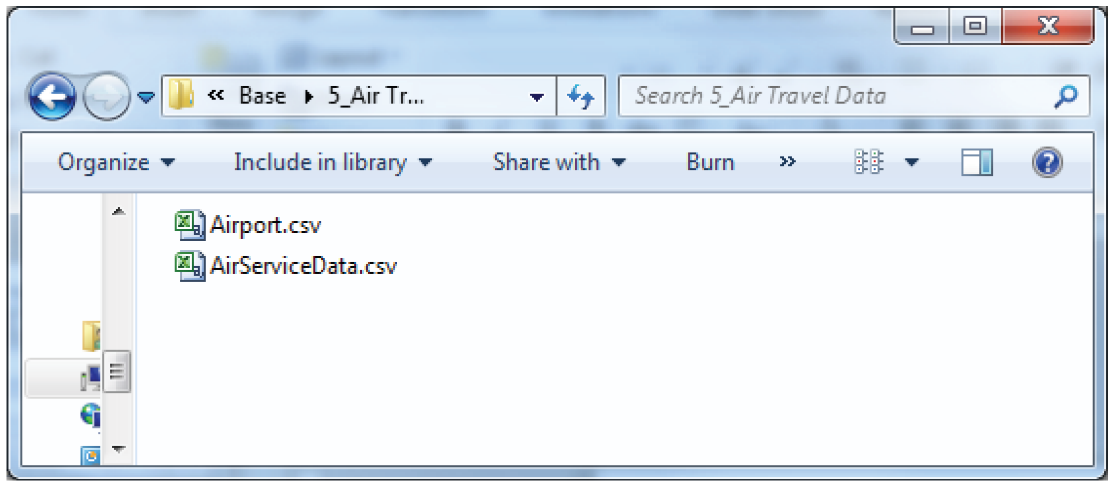
Field and row Descriptions:
Service (row) – name of the train service group (services with similar stopping pattern)
Group (row) – code to identify service groups
StationNum (column) - StationInd (station identification number used in the model, 1:n stations) for the station
StationCode 3 letter code for the station
StationName – text name for the station

Cell values:
Each cell value represents the train distance travelled for that service. The value is 0 at the first station and increases with each subsequent station in the sequence of stops

-	-	-	Service	Northeast Regional SB
StationInd	StationCode	StationName	Group	1
1	POR	Portland, ME		
2	ORB	Old Orchard Beach, ME		
3	SAO	Saco, ME		
4	WEM	Wells, ME		
5	DOV	Dover, NH		
6	DHM	Durham-UNH, NH		
7	EXR	Exeter, NH		
8	HHL	Haverhill, MA		
9	WOB	Woburn, MA		
10	BON	Boston, MA-North Station		
11	BOS	Boston, MA-South Station		0
12	BBY	Boston, MA-Back Bay Station		1
13	RTE	Route 128, MA		11
14	PVD	Providence, RI		43
15	KIN	Kingston, RI		70
16	WLY	Westerly, RI		87
17	MYS	Mystic, CT		96
18	NLC	New London, CT (Casino)		105
19	OSB	Old Saybrook, CT		123

Model Files: 5_Air Travel Data (1)

The 5_Air Travel Data folder contains two files that describe airport location and air service.



Model Files: 5_Air Travel Data (2)

Airport.csv
Describes the location of airports in the study area

Field Descriptions:
AirportInd – sequential airport identification number used in the model, 1:n airports
AirportCod – 3 letter code for the airport
AirportName – text name for the airport
TractID – sequential tract identification number used in the model, 1:n tracts; this is the tract containing the airport
NAME – Name of the county the airport is located in
STATE_NAME – Name of the state the airport is located in
Latitude – latitude of the airport
Longitude – longitude of the airport

AirportInd	AirportCod	AirportName	TractID	NAME	STATE_NAME	Latitude	Longitude
1	HVN	TWEED-NEW HAVEN	634	New Haven	CONNECTICUT	41.26375	-72.8868
2	BDL	BRADLEY INTL	435	Hartford	CONNECTICUT	41.93889	-72.6832
3	DCA	RONALD REAGAN WASHINGTON NATIONAL	11888	Arlington	DIST. OF COLUMBIA	38.85208	-77.0377
4	IAD	WASHINGTON DULLES INTL	12486	Loudoun	DIST. OF COLUMBIA	38.94744	-77.4599
5	BED	LAURENCE G HANSCOM FLD	3489	Middlesex	MASSACHUSETTS	42.46995	-71.289
6	BOS	GENERAL EDWARD LAWRENCE LOGAN INTL	4014	Suffolk	MASSACHUSETTS	42.36297	-71.0064
7	HYA	BARNSTABLE MUNI-BOARDMAN/POLANDO FIELD	2770	Barnstable	MASSACHUSETTS	41.66933	-70.2804
8	ACK	NANTUCKET MEMORIAL	3583	Nantucket	MASSACHUSETTS	41.25311	-70.0603
9	PVC	PROVINCETOWN MUNI	2715	Barnstable	MASSACHUSETTS	42.07228	-70.2207
10	MVY	MARTHAS VINEYARD	2940	Dukes	MASSACHUSETTS	41.39342	-70.6139

Model Files: 5_Air Travel Data (3)

Airport.csv
Describes the location of airports in the study area

Field Descriptions:
ORIGIN – origin airport code (3 letter)
DEST – destination airport code (3 letter)
Numpersons – number of persons traveling between airports (from DB1B)
N_direct – number of persons traveling direct between the two airports (from DB1B)
N_transfer – number of persons traveling between the airports with one or more transfers in between (from DB1B)
N_oneway – number of one way itineraries (from DB1B)
N_round – number of round trip itineraries (from DB1B)
Numdays – number of day reported for this airport pair in the on time performance data (OTP)
Numflights – number of flights (OTP)
Cancelled - number of cancelled flights (OTP)
Dep_delay – average departure delay in minutes (OTP)
Arr_delay – average arrival delay in minutes (OTP)
Sche_time – scheduled travel time in minutes (OTP)
Actual_time - actual travel time in minutes (OTP)
Distance - distance between airports (OTP)
Tran_days – days reported for transfer flight routes in the OTP
Tran_flight – number of transfer flights reported (OTP)
Tran_cancelled – number of transfer flights cancelled (OTP)
Tran_flight_time – tranfer flight travel time in minutes (OTP)
Tran_layover – layover time in minutes (OTP)
Mean_cost – average ticket cost (from DB1B, in $)
p0:p100 – 0 percentile to 100 percentile ticket costs in 10 percentile increments (from DB1B, in $)

Code Guide

Code Guide

This section of the user's guide provides a guide to the code of the model and the files containing model parameters.

The information in this section of the user's guide is intended for advanced users of the model who wish to modify the model – from making adjustments to individual parameters, to making fundamental changes to the structure of individual model components or the overall model framework.

R Resources

The R application comes packaged with the ACRP 3-23 Air/Rail Diversion Model. To work with the R scripts and R binary files outside of the model's GUI, using an integrated development environment (IDE), such as R Studio, is recommended.

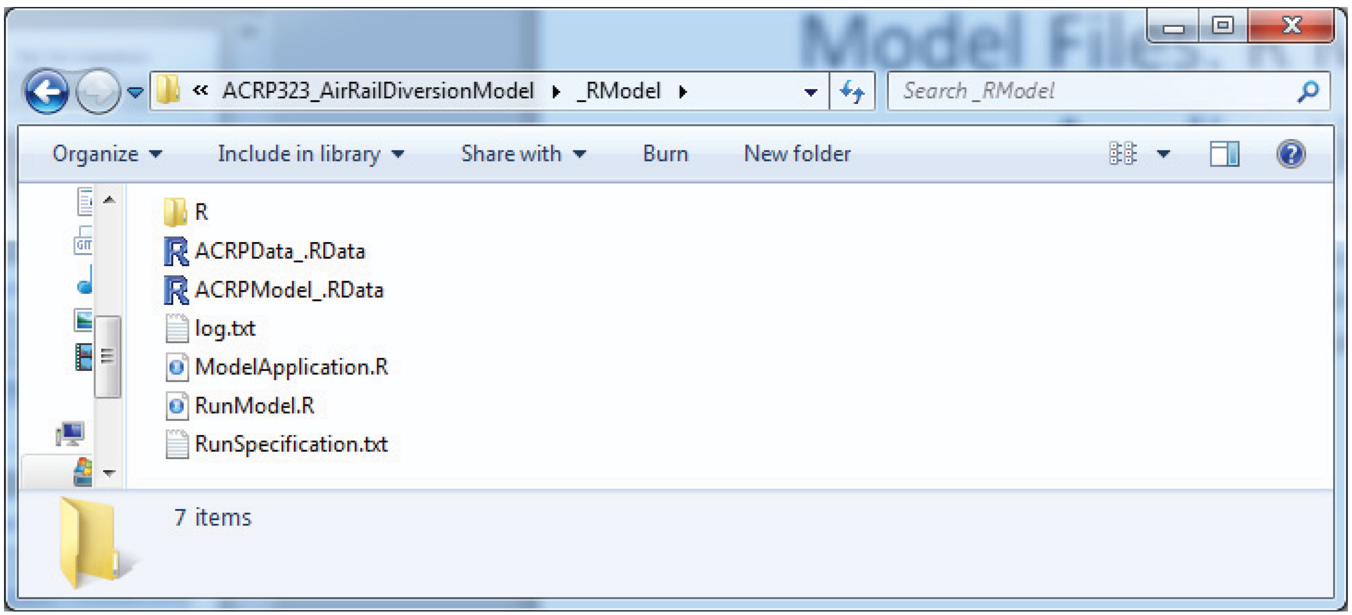
R Studio is an open source application and can be downloaded at http://www.rstudio.com/.

For new R users, model users are recommended to familiarize themselves with the R language prior to attempting to edit the model's R scripts. Resources such as http://www.r-project.org/ and http://www.r-bloggers.com/ are good places to start.

Model Files: R Model, Application

The _RModel folder contains the R folder, which is a version of the R application that is used to run the model. The files in that folder are as follows:

- ACRPData_.Rdata – R binary folder containing several input tabulations.
- ACRPModel_.Rdata – R binary folder containing model coefficients.
- Log.txt – log file from a model run (added when the model is run in installation).
- ModelApplication.R – R script containing the model code.
- RunModel.R – R script to run the model (added when the model is run in installation).
- RunSpecification.txt – text file written by the Excel GUI providing variables to R (added when the model is run in installation).



Model Files: ModelApplication.R (1)

ModelApplication.R is the R script containing the model code and encompasses all of the R code to run the model. Editing this script will allow the structure of individual model components or the overall model structure to be changed.

The overall structure of the file is as follows:

- Header (Lines 1-14): file meta data (e.g., author, version), and code to begin logging and timing.
- Functions (Lines 15-58): defined functions used later in the script to load R packages and to simulate logit models give a data set and model specification/coefficients.
- Libraries (Line 59-67): load R packages required by the model (note: R packages are separate libraries of additional functions).
- Directories, input files, output files, models (Lines 68-226): loads in the input data, model coefficients, and creates directories for the outputs.
    - Make a list to store the directory references (Lines 73-111): creates a list structure to hold the directory references for inputs and outputs.
    - Read in input data (Lines 112 – 167): reads into memory all of the input data for the model being executed.
    - Load the tabulations of model coefficients (Lines 168-200): loads the model coefficients and applies calibration adjustments to them.

Model Files: ModelApplication.R (2)

- Directories, input files, output files, models (Lines 68-226): loads in the input data, model coefficients, and creates directories for the outputs
  - Load validation/general correspondence data (Lines 201-226): loads in tables of correspondences, and also applies the parameters from the run specification to the inputs data.
- Model Simulation (Lines 228-881): The simulation applies the 6 model steps.
  - Line 243 start the loop on years: the model is sequentially applied first for the base year and then for the future year. This loop runs until line 1031 and includes the next main section of code from line 882 to 1031 where summary model outputs are produced.
  - 1. Travel party sampling from enumerated list of travel parties (Lines 247-313) produces a travel party sampling from enumerated list of travel parties.
  - 2. Allocation of travel parties to Census Tracts (Lines 314-338) assigns each travel party to a census origin and destination tract.
  - 3. Simulation of additional travel party characteristics (Lines 339-354) adds income category and vehicle availability for each travel party.
  - 4. Airport and station choice and access and egress mode choice model (Lines 355-661) applies in turn the airport and station choice models:
    - Calculate airport to airport utility for all of the airport pairs with air service (Lines 360-402).

Model Files: ModelApplication.R (3)

- Model Simulation (Lines 228-881): The simulation applies the 6 model steps.
  - 4. Airport and station choice and access and egress mode choice model (Lines 355-661) applies in turn the airport and station choice models:
    - Calculate access and egress utilities for each airport-tract combination (Lines 403-413).
    - Builds the choiceset of otract-oairport-dairport-dtract combinations for each otract-dtract combination (Lines 414-442).
    - Apply the choice model for each party in the SynPop.. (Lines 443-490)
    - Station Choice (Lines 491-574).
    - HSR Station Choice (Lines 575-660).
  - 5. Main mode choice model (Lines 661-783) applies the main mode choice model between air and rail.
  - 6. Airline Response Model (Lines 784-871) applies the airline response model including reapplying the main mode choice model.
  - Save large model output files (Lines 872-876) . Save R binary files containing the detailed tables of results for each travel party.
- Produce Summary Model Outputs (Lines 882-1031) writes summary results.
  - County Summaries (Lines 896-960) are produced in memory.
  - Airport and Station summaries (Lines 961-990) are produced in memory.
  - Airline Response Summaries (Lines 991-1001) are produced in memory.
  - Results, including summaries for GUI are written to file (Line 1001-1031).

Model Files: ACRPData_.Rdata

ACRPData_.Rdata is an R binary folder containing several input tabulations that include geographical correspondence and validation data. It is loaded into memory in the Load validation/general correspondence data section of the simulation at line 203:

- Apeast is a table of observed passenger trips in 2008 between airports in the East coast study area.
- Apwest is a table of observed passenger trips in 2008 between airports in the West coast study area
- Countymsa is a correspondence table between counties and metropolitan statistical areas.
- Steast is a table of observed passenger trips in 2008 between rail stations in the east coast study area.
- Stwest is a table of observed passenger trips in 2008 between rail stations in the west coast study area.

Model Files: R Model, Application

ACRPModel_.Rdata is an R binary folder containing model coefficients. It is loaded into memory in the Load the tabulations of model coefficients section of the simulation at line 170. The file contains an R list object that contains 5 elements:

- MainModeChoiceBusiness: a table of coefficients for the business segment in the main mode choice model
- MainModeChoiceNonBusiness: a table of coefficients for the non-business segment in the main mode choice model
- AirportAccessChoice: a table of coefficients for the airport choice model
- CensusTractAllocation: a list of coefficients of the census tract allocation model
- AirlineResponse: a table of coefficients for the airline response model

List of Abbreviations

Rail Stations

ALB	Albany, New York
BAL	Baltimore, Maryland Penn Station
BBY	Boston, Massachusetts Back Bay
BOS	Boston, Massachusetts South Station
BUR	Burbank, California Airport
BWI	BWI Airport Rail Station, Maryland
DAV	Davis, California
EMY	Emeryville, California
EWR	Newark Liberty International Airport Rail Station, New Jersey
FUL	Fullerton, California
LAX	Los Angles, California
MET	Metropark, New Jersey
MKE	Milwaukee, Wisconsin Airport Rail Station
MTZ	Martinez, California
NHV	New Haven, Connecticut
NLC	New London, Connecticut
NWK	Newark, New Jersey Penn Station
NYP	New York Penn Station
OKJ	Oakland, California—Jack London Square
OSD	Oceanside, California
PHL	Philadelphia 30th Street Station
PJC	Princeton Junction, New Jersey
PVD	Providence, Rhode Island
RIC	Richmond, California
RTE	Boston, Massachusetts Route 128 Station
SAC	Sacramento, California
SAN	San Diego, California
SNC	San Juan Capistrano, California
SOL	Solana Beach, California
STM	Stamford, Connecticut
TRE	Trenton, New Jersey
WAS	Washington, DC Union Station
WIL	Wilmington, Delaware

Airports

AMS	Schiphol Airport (Amsterdam, Netherlands)
BOS	Logan International Airport (Boston, MA)
BUR	Bob Hope Airport (Burbank, CA)
BWI	Baltimore/Washington International Thurgood Marshall Airport
CDG	Charles De Gaulle Airport (Paris, France)
CMH	Port Columbus International Airport (Columbus, OH)
CPH	Kastrup Airport (Copenhagen, Denmark)
DCA	Ronald Reagan Washington National Airport
DFW	Dallas/Fort Worth International Airport
DIA	Denver International Airport
DTW	Detroit Metropolitan Wayne County Airport
DUS	Dusseldorf International Airport (Germany)
EWR	Newark Liberty International Airport
FRA	Frankfurt International Airport (Germany)
FWA	Fort Wayne International Airport (Indiana)
GVA	Cointrin International Airport (Geneva, Switzerland)
IAD	Washington Dulles International Airport
JFK	John F. Kennedy International Airport (New York)
LAX	Los Angeles International Airport
LGA	LaGuardia Airport (New York)
LYS	Lyon-Saint Exupery Airport (France)
MAN	Manchester Airport (UK)
MDW	Midway International Airport (Chicago)
MHT	Manchester-Boston Regional Airport
MIA	Miami International Airport
MKE	General Mitchell International Airport, Milwaukee Wisconsin
OAK	Oakland International Airport (California)
ONT	Ontario International Airport (California)
ORD	O'Hare International (Chicago)
PHL	Philadelphia International Airport
PVD	T. F. Green State Airport (Providence)
SAN	San Diego International Airport
SDF	Louisville International Airport
SFO	San Francisco International Airport
SJC	Norman Mineta San Jose International Airport
STL	Lambert-St. Louis International Airport
ZRH	Zurich Airport (Switzerland)

Other Abbreviations

ABAG	Association of Bay Area Governments
AC	Available Costs
ACRP	Airport Cooperative Research Program
ACS	American Community Survey
AMAP	Airport Multimodal Accessibility Plan
APM	Airport People-Mover or Automated People-Mover
ATC	Air Traffic Control
ATOC	Association of Train Operating Companies
ATS	Air Traffic Service

BART	Bay Area Rapid Transit (San Francisco)
BCDC	San Francisco Bay Conservation and Development Commission
BRT	Bus Rapid Transit
CAA	Civil Aviation Authority (UK)
CBD	Central Business District
CHSRA	California High-speed Rail Authority
CHSRRM	California High-speed Rail Ridership Model
ConnDot	Connecticut Department of Transportation
CONRAC	Consolidated Rental Auto Center
CRS	Computer Reservation System
CTPP	Census Transportation Planning Package
DB	Deutsche Bahn (German Railway Company)
DGAC	Direction Generale de l'Aviation Civile (French Civil Aviation Authority)
DOD	Department of Defense
EIS	Environmental Impact Statement
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration
FAC	Fully Allocated Costs
FATE	Future Air Traffic Estimator
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GTC	Ground Transportation Center
HS2	High-speed Rail System
HSIPR	High-speed Intercity Passenger Rail
HSR	High-speed Rail
HSRRM	High-speed Rail Ridership Model
HST	High-speed train
I/O	Input/Output
IARO	International Air/Rail Organization
IATA	International Air Transport Association
IIA	Independence from Irrelevant Alternatives
INRETS	Institut National de Recherche sur les Transports et leur Securitie
ITC	Intermodal Transit Center/Intermodal Terminal Complex
KITE	Knowledge Base for Intermodal Transportation in Europe
LCC	Low Cost Carrier
LIRR	Long Island Rail Road
LOS	Level of Service
MARC	Maryland Area Regional Commuter train service
MBTA	Massachusetts Bay Transportation Agency
MHSRA	Midwest High Speed Rail Association
MIC	Miami Intermodal Center
MPO	Metropolitan Planning Organization
MPR	Monthly Performance Report
MTA	Metropolitan Transportation Authority
MTC	Metropolitan Transportation Commission
MTS	Metropolitan Transit System
MWCOG	Metropolitan Washington Council of Governments
MWRRI	Midwest Regional Rail Initiative
MWRRS	Midwest Regional Rail System
NEC	Northeast Corridor

NERASP	New England Regional Airport System Plan
NJT	New Jersey Transit
NS	Netherlands Railway
NYC	New York City
O-D	Origin-Destination
OIG	Office of the Inspector General
OLDA	Orange Line Development Authority
OPM	O'Hare Modernization Program
OTP	On-time Performance
PANYNJ	Port Authority of New York and New Jersey
PATH	Port Authority Trans-Hudson (Rail System)
PAX	Passengers
RAPC	Regional Airport Planning Committee
RASP	Regional Airport/Aviation Strategic/System Plan
RASPA	Regional Airport System Plan Analysis
RENFE	Red Nacional de Ferrocarriles Espanoles (Spanish Railway)
RITC	Regional Intermodal Transportation Center
ROW	Right of Way
RPA	Regional Plan Association
RSG	Resource Systems Group Inc.
RTP	Regional Transportation Plan
SANDAG	San Diego Association of Governments
SBB	Schweizerische Bundesbahnen (Swiss Railway)
SDCRAA	San Diego County Regional Airport Authority
SDG	Steer Davies Gleave
SKM	Sinclair Knight Mertz
SNCF	Societe National de Chemin de Fer (French National Railway)
StB	Simplify the Business
SWISS	Swiss International Airlines
TCRP	Transit Cooperative Research Program
TGV	French High Speed Rail
TSA	Transportation Security Administration
TTI	Texas Transportation Institute
UIC	Union Internationale des Chemins de Fer (International Union of Railways)
U.S. DOT	U.S. Department of Transportation
WMATA	Washington Metropolitan Transit Authority

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation