Airport Access via Rail Transit:
What Works and What Doesn't

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Abstract:

Despite their potential for providing efficient and reliable airport access, rail connections to U.S. airports have consistently had trouble attracting a significant percentage of airport passengers. This thesis attempts find out which characteristics of airport rail links most strongly influence mode share so that future rail link plans can be assessed. These findings are then applied to the current plans for an airport rail link in San Juan, Puerto Rico.

The thesis begins by examining current airport rail links in the U.S. Detailed case studies are performed for the following airports: John F. Kennedy, Philadelphia, Boston Logan, Washington National, Chicago O'Hare, Chicago Midway, and San Jose. Smaller case studies are performed for Atlanta, Cleveland, St Louis, Baltimore-Washington, Miami, and Oakland.

The data collected for these airports is compared by looking for relationships between characteristics of the rail links and their mode shares. Two variables, rail travel time and the difference between rail and auto travel time, are apparently related to rail link mode share. Several propositions are advanced about the characteristics of airport rail links that affect mode share, and the way in which they affect mode share. The strongest of these propositions are that the lower the travel time difference between rail and auto the greater the rail mode share, that on-airport rail stations are likely to increase mode share, and that effectively serving population and employment centers is likely to increase airport rail link mode share.

Some further analysis is then performed on two of the propositions advanced. First, the relevance of the airport rail station location is tested by looking at the effect on mode share at Washington National when the rail station was, in effect, moved closer to the airport terminal. This analysis indicates that it is likely that the location of an airport rail station is related to mode share. Second, an analysis of population and employment around airport rail link stations is performed for Boston, New York City, and Chicago. This analysis indicates that the rail links examined serve a very small percentage of the population and jobs in their respective metro areas. This makes sense since rail links in these cities all have relatively low mode shares.

Finally, a case study of San Juan is presented. This case study is different than the previous ones since the San Juan link is in the planning stages. After the San Juan plan is presented, each proposition developed earlier is applied to the San Juan case to determine the potential effect of that proposition on mode share for the San Juan link. This analysis and a model for calculating mode share based on rail/auto time difference help to predict mode share for San Juan. The mode share for San Juan is likely to be between 2% and 5%. The thesis concludes with potential changes to the plan that might help increase that figure.

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Chapter 1 – Introduction and Literature Review

Getting people to and from the airport would seem to be an ideal role for mass transit. Airports are such a significant destination in most cities that rail connections to them would seem to be good ideas. Yet airport rail links do not carry a significant percentage of airport passengers in this country, and traffic congestion en route to most U.S. airports continues to worsen. If rail is to play a role in improving airport access in the U.S., the experience with existing airport rail links needs to be understood, and lessons learned for future projects. This research will investigate the characteristics and performance of existing U.S. airport rail links to see what may be learned from them. The lessons learned from this investigation will then be applied to the city of San Juan, which is currently in the early stages of developing a rail system that may eventually include an airport link. Not only will this research address the likely effectiveness of a San Juan airport rail link, but it will also provide a framework for determining the future role of rail in U.S. airport access.

1.1 The Problem

Aviation is the swiftest mode of public transportation available on Earth. Unfortunately, airplanes cannot land at your home or office. The need for adequate landing space pushes airports well away from where people typically want to start and end their trips. For many inter-city trips, due to the high velocity of aircraft and relatively low velocity of ground vehicles, the airport access time can account for as much, if not more time than the actual flight time. Moreover, airport design makes pedestrian access to airports impracticable virtually everywhere. Therefore, almost every single airport passenger or worker must be transported by vehicle to and from the airport, and often during peak hours. This means that airport access and egress times grow ever larger with respect to the time devoted to actual flying. Traffic congestion, or the fear of its occurrence, can add large amounts of time to any air trip by causing passengers to leave extra slack time.

The value of this extra time is ver high. Air travel can be a stressful experience even without traffic. Passengers are especially anxious because the consequences of missing a flight can often be so large. Lateness due to traffic may not be welcome for any trip, but if one is late for a meeting or a baseball game, this may not be a serious problem. Easy remedies do not exist for the late air traveler, however. Passengers are also stressed out because they know that the majority of the time they will have to wait on lines, fight crowds, and generally feel uncomfortable before they get to what for some is the most stressful part of all- flying. Moreover, human beings are generally uncomfortable with any kind of long-distance travel, since it tends to displace them from their familiar, comfortable environment. People face high stress on any airport access or egress trip, and the value of their time on these trips is likely to be higher than on a typical ground transportation trip.

Besides being important to each individual, airport access and egress time is vital to the economic well being of a city and its metropolitan area. Imagine a fictitious city with the nearest airport 100 miles from the edge of the metropolitan area. This city would not survive in the modern world for very long, since it would be considered isolated. Although no major American city faces this kind of absurd physical setup, many of them face comparable access times due to traffic congestion. For example, traffic in the Callahan tunnel can occasionally force Bostonians to sit in traffic for an hour in order to travel the 3 miles from Logan to downtown. Since automobiles can usually average at least 50 miles per hour on the highway, Logan could be considered the equivalent of 50 miles away when the traffic is this bad. Taken to the extreme, we can see that worsening traffic could have the same isolating effect on a city as a distant airport.

This means that good airport access is important to the economic life of a city. But what exactly makes airport access "good"? Clearly there should be a limited distance, if possible, between the airport and points to which passengers are going on the ground, but this is very difficult to change. Speed could be important, but ground transportation modes do not vary greatly in their potential velocity. Most major airports already have expressways, the fastest available ground transportation (with the exception of high-speed rail, which is virtually non-existent in the U.S.) leading to them. Therefore, speed, unless high-speed rail is implemented, cannot be significantly changed either. Considering the importance of time to the air traveler, consistency in airport access is vital for people and cities alike. Even potential traffic congestion can lead to extra travel time. But if every traveler knew, for example, that it would never take more than 30 minutes to get to the airport, this would make travelers much more comfortable and potentially increase the economic viability of the city that the airport serves.

Therefore, airport rail access, or an exclusive right-of-way for a rubber-tired vehicle, could theoretically stabilize the airport access time for cities, ensuring a less stressful trip, and helping to preserve and increase economic vitality. Exclusive rights-of-way could ensure airport travelers a consistent, reliable connection to the airport via mass transit. With adequate rail or busway access in place, travelers could always count on a fast, consistent trip to the airport.

Unfortunately, this is not reality in this country. An overwhelming majority of Americans, both workers and passengers, use automobiles to access the airport. Rail links have been built at many major airports in this country, yet they have failed to garner significant mode share when compared to airport rail links in other countries, and airport access traffic continues to worsen. The consequences for travelers are continued stress. The long-term consequences for cities are potentially deeper and more detrimental. With landside congestion increasing and rail access ineffective, businesses and residences may continue to move away from congested cities towards less congested and smaller cities. These newer cities often have sprawling development patterns. Until larger and denser cities can provide effective access to the airport, small but sprawling cities will have a competitive advantage. These cities, which are heavily auto-dependent and land consuming, will continue to grow, damage our environment, and arguably promote societal isolation.

Any city that continues to grow will eventually have a landside capacity problem at its airport. Most airports in the U.S. were constructed without considering landside access as an important element. Moreover, the construction of a new runway can bring about a very large increase in airside capacity. The addition of a new lane onto an expressway leading to the airport provides a relatively small increase in landside capacity. Most major airports already have expressways leading to them, and after a point, adding lanes to these expressways becomes impractical or infeasible. Airline load factors and the number of flights are increasing, but the single occupancy vehicle that carries most passengers to the airport is becoming more dominant. The expandability of airside capacity relative to landside capacity implies that major landside congestion may await all airports that wish to grow.

Therefore, landside congestion is, or will eventually be, a problem for most U.S. airports. Rail, or a different high-occupancy mode with its own right-of-way, would seem to be a potential solution to the landside congestion problem. Rail should be able to make a significant contribution to solving this problem, but so far it has not. If the landside congestion issue is to be solved via rail, we must first figure out why previous attempts at solutions have failed, and whether or not we can achieve greater success with modified strategies.

1.2 The Approach

This research will investigate why airport rail links in the U.S. have failed to attract significant percentages of airport passengers, and will attempt to accomplish two important things. First, it will help to solve the problem outlined above by recognizing what it may take to create a viable airport rail link, as well as what makes most U.S. airport rail links unattractive. Second, the results of this research will be applied to a U.S. airport rail link currently in the planning stages. This proposed rail link would be part of the new Tren Urbano heavy rail system in San Juan, Puerto Rico. This research will attempt to address the question of whether it makes sense to build rail access into a future Tren Urbano extension, and if, so, how it should be done to ensure that such a link carries significant numbers of airport passengers.

Based on what is learned from researching U.S. airport rail links, a determination will be made as to the ability of a Tren Urbano airport rail link to attract significant numbers of airport passengers. This determination will be made for the existing airport rail link plan in San Juan. However, the research presented here should show the key characteristics necessary for an airport rail link to attract significant airport passengers. The characteristics that are applicable to San Juan will be identified, and modifications to the airport rail link plan, if they are necessary, will be suggested.

The positive and negative aspects of current U.S. airport rail links will be determined through a series of case studies. An airport rail link is defined to be any rail service that either provides a station within walking distance of an airport terminal, or where a designated airport shuttle vehicle connects the rail station to an airport terminal. The purpose of this definition is to exclude airports at which an airport rail link does not even have the advantage of offering consistency in the face of traffic congestion on airport access roadways. It is assumed that if rail gets close enough to an airport terminal for there to be a designated shuttle service, then this rail link may have a consistency advantage over the automobile. A good example of an excluded airport is LaGuardia Airport in New York, where a city bus connection to the subway is available. It is excluded because this bus is not designated as an airport shuttle, and must navigate through congested city streets for a significant distance. Although this definition might exclude a bus connection that was short but not designated as an airport shuttle, this is not a problem since such a connection is very unlikely (airports usually take the opportunity to promote rail links with free shuttles) and no such example is known. More importantly, this definition serves to include airport rail link connections that can clearly provide more consistent service than access roadways even if the airport train station is not inside the airport terminal.

The case studies examine the characteristics of all U.S. airport rail links that fall under this definition for the purpose of determining propositions about airport access that can then be applied to potential airport rail links. The conclusions drawn from the case studies and to some extent the information from the case studies represent the perspective of the airport, as opposed to the perspective of the city or the individual. The perspective of the city would draw in too many additional factors that could obscure the airport access problem. The individual's perspective is also too broad. An individual may prefer an airport rail link in order to have the option of using it, while he or she continues to take a taxi under most circumstances. An airport should have the main objectives of growth and improving landside access, which are the same objectives as this research. This is why this perspective is adopted.

The case studies analyze the characteristics of each city and airport in terms of factors that can be changed and those factors that cannot be changed. This way, the lessons from these case studies will not imply that proper planning can produce high ridership on any given airport rail link. The case studies will help to highlight the characteristics of certain cities and their airports that can make even the best airport rail links poorly used. They will also help realize the city and airport characteristics that are most amenable to airport rail link construction.

The major value of this overall approach is that it establishes a body of knowledge about airport rail links from which others can draw. Although this research is geared towards establishing the factors necessary to create a successful airport rail link in San

Juan, the information should help others in future American airport rail planning. A pure modeling approach focused only on San Juan might help to determine whether or not the San Juan link should be built, but it would not answer the more general question.

1.3 Literature Review

One of the stimuli for this research is that airport rail links in Europe often garner much greater mode shares than American airport rail links. Therefore, we know that high airport rail link ridership is possible. In theory, it should be possible to learn from the European experience and design an airport rail link that is comparable in San Juan. However, Coogan's research (1995) in this area showed that European airport rail links are more likely to attract significant mode shares due to the extensive public transit and rail network that exists independent of the airport rail link (see Table 1-1)[1]. Coogan explains that mode shares for European rail links are typically twice as high as those for American airport rail links due to the fact that European travelers are more likely to use rail to get to their final destination. In other words, since American travelers usually require an automobile at some point within a journey to/from the airport or during their stay, they have a lower probability of using an airport rail link. His research prompts the question of how high a mode share is achievable for an airport rail link in San Juan simply because of the lack of an extensive rail system there and high car ownership rates.

Coogan's research does not, however, provide a framework for determining whether or not a potential airport rail line in the U.S. will be able to improve on, or match the highest mode share figures of its peers. His research sought to explain the differences between European and American airport rail link mode share. He does not attempt to explain in detail whether this gap can be filled and if so how. In fact, he suggests working towards the closing of this gap by performing research such as that presented here; an attempt to build on the limited successes of U.S. airport rail links in order to increase mode share in future rail link plans. Coogan also stops short of making suggestions that might improve rail access in the U.S., which is the focus of this research.

Table 1-1 Coogan's Airport Rail Link Comparison (1995)

Europe	**Mode Share**	**U.S.**	**Mode Share**
Zurich	34%	Washington National	15%
Munich	30%	Atlanta Hartsfield	9%
Frankfurt	29%	Boston Logan	6%
London Gatwick	26%	Chicago O'Hare	5%
Amsterdam Schipol	25%	Philadelphia	5%

Harvey (1986) also performed significant work in the field of airport access. Harvey attempted to model airport access choice for departing passengers in the Bay Area[2]. He obtained survey data for these passengers, and then estimated a multinomial logit model to reflect the relative importance of factors that led to their decision about which mode to use to access the airport. The logit equation calculates the probability (P) that a decision-maker (i) will choose mode (j) given a utility (U) for each mode:

$$P[i, j] = \frac{\exp(U[i,j])}{\sum_{k=1}^{N} \exp(U[i,k])}$$

U[i,j] is defined as a linear function as follows:

$$U[i,j] = b_0 + b_1 + X_1[i,j] + \ldots + b_m * X_m[i,j]$$

Where m is the number of variables that affect utility, X's are relevant attributes of the alternative and the decision-maker, and *b's* are parameters to be estimated. Five utility functions were estimated for five distinct access modes: Drive, Drop-off, Transit, Airporter, and Taxi. Harvey estimated two different models, B1 and B2, for two samples: "business" (passengers indicating "business" or "convention" as their trip purpose) and "non-business" (all others) passengers. The sixteen variables used in the models are shown in Table 1-2. The difference between the two models is that B1 does not account for differences in airport access mode choice that may be associated with longer or shorter flight times. The variables TT(Short), TT(long), Cst(Short), and Cst(Long) appear only in model B2. B2 does not incorporate the variables TT or Cst. The "business" models do not use the Fem(DR,TX) variable.

Table 1-2: Variables in Harvey's Models of Airport Access Mode Choice

Name	Definition
Dum(DA)	Dummy variable for Drive alternative
Dum(DR)	Dummy variable for Drop-off alternative
Dum(TR)	Dummy variable for Transit alternative
Dum(AP)	Dummy variable for Airporter alternative
TT	Travel time for each mode (minutes)
TT(Short)	Travel time for short flights
TT(Long)	Travel time for long flights
AACC(TR)	Constant for auto access to transit
Cst	Travel cost for each mode(cents)
Cst(Short)	Travel cost for short trips
Cst(Long)	Travel cost for long trips
Time(DR)	Travel time for Drop-off passengers
Lug(TR)	Pieces of luggage per person for transit
HS>1(DR)	Constant in drop-off for household size
Home(DR)	Constant in drop-off for trips beginning at home
Fem(DR,TX)	Dummy variable for sex of passenger

Note that no dummy variable is listed for the Taxi alternative – this was considered as the base mode. Several additional variables are incorporated into the "non-business" model. Both non-business models use the dummy variable for sex of the passenger, and neither incorporates the Time(DR) variable. Several additional variables for cost (Cst (Low, Short), Cst (Low, Long), Cst(Mid, Short), Cst(Mid, Long), Cst(High, Short), Cst(High, Long)) are used in model B2 to highlight the greater cost sensitivity for this group. The estimation results for both models, using both the "business" and "non-business" samples, are presented in Tables 1-3 and 1-4.

Table 1-3: Harvey's Model Estimation Results - Business Travelers				
Variable	**Model B1**	**T-statistic**	**Model B2**	**T-statistic**
Dum(DA)	1.44	9.69	1.36	9.02
Dum(DR)	0.158	0.52	-0.086	-0.27
Dum(TR)	-1.17	-3.37	-1.43	-3.97
Dum(AP)	0.662	2.51	0.571	2.13
TT	-0.069	-3.73		
TT(Short)			-0.0493	-2.25
TT(Long)			-0.0987	-3.41
AACC(TR)	-1.42	-2.30	-1.36	-2.20
Cst	-0.000995	-8.52		
Cst(Short)			-0.001444	-7.31
Cst(Long)			-0.000897	-7.20
Time(DR)	-0.0159	-4.81	-0.0148	-4.40
Lug(TR)	-0.473	-1.03	-0.456	-1.00
HS>1(DR)	0.489	2.02	0.506	2.08
Home(DR)	0.794	4.35	0.806	4.40

Table 1.4: Harvey's Model Estimation Results - Non-Business Travelers				
Variable	**Model B1**	**T-statistic**	**Model B2**	**T-statistic**
Dum(DA)	2.03	11.49	2.00	11.35
Dum(DR)	0.323	1.38	0.086	0.36
Dum(TR)	0.088	0.31	-0.146	-0.50
Dum(AP)	1.38	5.72	1.40	5.72
TT	-0.0398	-3.27		
TT(Short)			-0.0238	-1.91
TT(Long)			-0.0841	-4.14
AACC(TR)	-0.388	-1.20	-0.388	-1.18
Cst	-0.001218	-9.38		
Cst(Low,Short)			-0.002006	-8.74
Cst(Low,Long)			-0.001116	-5.53
Cst(Mid,Short)			-0.001367	-4.92
Cst(Mid,Long)			-0.001331	-4.70
Cst(High,Short)			-0.000742	-3.59
Cst(High,Long)			-0.000773	-3.84
Lug(TR)	-1.36	-3.71	-1.34	-3.55
HS>1(DR)	1.33	7.88	1.51	8.55
Home(DR)	0.647	4.77	0.643	4.68

From these figures, Harvey reached several conclusions about airport access relevant to this research. First, he showed that travel time and travel cost are both strong explanatory variables in airport access mode choice. Second, time-sensitivity for airport access time was found to be high relative to typical travel time-sensitivities, especially for business travelers. This sensitivity was found to increase with the length of the flight travelers were trying to catch. Moreover, the value of time for air travelers accessing airports was found to be at least as high as the average wage, and often higher. Finally, travelers carrying more than one piece of luggage are substantially less likely to use transit.

Harvey's work, the most comprehensive available on the subject airport access, is helpful but not definitive in terms of looking at the potential for proposed airport rail links. First, his analysis used survey data from three airports in the San Francisco area. Of these three airports, at the time of Harvey's study, only one had a true rail link (Oakland), which had an off-airport train station. This may have made it difficult for Harvey to examine a potentially important variable: reliability. Since it does not take into account a potentially important advantage of rail (the transit alternative at several U.S. airports), his model may not be valid in analyzing airport rail links. This research, by contrast, focuses on rail in order to account for transit's potential comparative advantage. Furthermore, mode choice by passengers at Bay Area airports, though helpful, may not be applicable to all parts of the U.S. This research attempts to be more comprehensive, and therefore more useful for the planning of any U.S. airport rail link.

Second, Harvey looks at airport access only from the perspective of the individual. The survey he analyzed asked individuals to indicate the mode of transportation they used to access the airport. This method is valuable, but it misses some points that could help an airport authority and a metropolitan area determine whether or not and/or how to build an airport rail link, as described above. Harvey's perspective fails to account for the tendency of certain airport characteristics to affect transit mode share. He does examine long versus short flights, but this is not the whole picture. For example, airports with more low-cost carriers may tend to attract more transit riders. Since Harvey did not examine airport characteristics in detail, his study does not account for the potential influence of these factors. Airport characteristics may have an important effect on airport rail link mode share that will hopefully be uncovered in this work.

Mandalapu and Sproule (1995) performed more recent work on this topic[3]. In their paper (based on an unpublished Ph.D. dissertation[4]) on rail transit access, they sought to define when rail transit connections to airports make sense from a cost perspective. They examined three generic rail transit access alternatives: 1) An exclusive airport link to the CBD, 2) An extension of an existing line to the airport, and 3) A shuttle bus or people mover connection to a nearby rail line. The research used multi-criteria analysis with travel time, cost, reliability, baggage convenience, accessibility, and parking as the criteria. These criteria were assigned values and weights based on quantitative and qualitative data collected by the researchers. The values were multiplied by the weights to give final values for each alternative, which is really a measure of attractiveness on a relative scale. Each rail alternative was compared with bus, auto, and taxi using a range of distances, demands, business/vacation traveler ratios, and baggage handling facilities. The different ratios of business to leisure passengers used were 90/10, 50/50, and 10/90.

For each of these different ratios, based on demands for airport access at different distances, the relative "attractiveness" of different types of rail access was determined. The authors use "attractiveness" to refer to whether or not it makes sense to build a rail link from a cost perspective. For example, they concluded that if an airport attracts mostly vacationers, it must have passenger demand of over 50,000 passengers per day that wish to go where the link goes in order to make an exclusive rail link attractive. By contrast, for an airport with mostly business travelers, exclusive rail links become attractive at demands from 2,500 to 18,000 per day. At an airport with an equal mix of business and vacation travelers, demands of 15,000 passengers per day for a 10km distance, or 30,000 passengers at a 50km distance are required to make the link attractive. Some general conclusions were: 1) Rail alternatives are more attractive at lower demand levels if an airport has more business passengers, and 2) For low demands, rail extensions are more attractive than exclusive links, and shuttle buses are more attractive than people mover connections.

This analysis of when demand levels at an airport will make a rail link attractive does not attempt to address the issue of why many rail links at the nation's busiest airports do not carry significant numbers of passengers. Also, this analysis considers only one characteristic of airports: the ratio of business to leisure passengers. Although this is useful, it is but one of many airport characteristics that can influence rail link demand. Many differences between airports that may have more to do with airport rail links include long vs. short haul, domestic vs. international, and low-cost vs. major airlines, none of which are examined by Mandalapu and Sproule.

1.4 Thesis Structure

After this introduction, case studies of all American airport rail links (according to the definition presented previously) are presented in Chapter 2. First, an explanation of the case study information is given. Then in-depth case studies of some key cities are presented, followed by short summaries of the remaining rail links. Finally, some information is provided about airport rail links currently under construction.

Chapter 3 draws some preliminary conclusions from the case studies. First, the case studies are compared and analyzed to try to determine which factors in each of the case studies play a large role in determining mode share. Then propositions that can be proposed based on the comparison and the case studies are presented. Chapter 4 takes the propositions a step further. First, the notion that airport train station location is an important factor in rail link mode share is assessed. This is done through an analysis of Washington National Airport. Second, population and employment data for three cities is analyzed to determine the how much the ability of an airport rail link to serve population and employment centers affects mode share.

In Chapter 5 the focus shifts to San Juan. First the plans for the San Juan airport rail link are described, and then a case study of the San Juan airport is presented. Chapter 6 examines the San Juan airport rail link proposal in detail. First, the propositions developed in Chapter 3 are applied to San Juan. Secondly, from this analysis a mode share prediction for San Juan is developed. Third, conclusions about the San Juan rail link are discussed.

Chapter 7 is the final chapter where conclusions about the entire thesis are drawn. A summary and general conclusions from the thesis and the San Juan case study are presented.

Chapter 2 - Case Studies

This chapter contains the case studies that will provide a substantive look at the current state of U.S. airport rail access. In the first section, the procedure for analyzing each link is described. Following this are six detailed case studies of what are seen as some of the most interesting and significant airport rail links: John F. Kennedy Airport in New York City (JFK), Philadelphia International Airport (PHL), Washington National Airport (DCA), Boston Logan Airport (BOS), Chicago O'Hare (ORD), Chicago Midway (MDW), and San Jose International Airport (SJC). JFK was chosen for detailed analysis because New York City is the biggest public transit market in the U.S., and it is important to assess the role of such a market in determining airport rail link viability. Philadelphia was chosen because it is the only U.S. example of a commuter rail, in-terminal airport rail link. Washington National has the highest mode share of any U.S. airport rail link and thus deserves detailed analysis. Boston Logan was chosen because it was the first U.S. airport rail link, and because information about it is easily accessible. Chicago provides the only opportunity to analyze two airport rail links in one city, and thus could not be left out. Finally, San Jose allows an in-depth look at a new light rail system in an auto-dominated environment.

Following the detailed case studies are short summaries that provide limited information about every other U.S. airport rail link. For the purposes of this analysis, an airport rail link is defined as was described earlier: the rail service must provide a station within walking distance of an airport terminal, or a designated shuttle bus must connect the rail station to an airport terminal. All other U.S. rail links that fall under this definition are briefly described in this section. The last section in this chapter is a description of two airport rail links currently under construction: JFK (a new link) and San Francisco (SFO).

2.1 Case Study Introduction

In the analysis of all rail links, the factors describing each link are separated into two categories (see Table 2-1).

Table 2-1: Fixed and Design Factors

Fixed Factors	**Design Factors**
location of the airport relative to the city	speed and reliability relative to other access modes
productions and attractions along link	location of airport train station
local cultural factors	transit fare(s)
airport characteristics	parking rates
ease and availability of connections	
state of local transit	

Aspects of an airport rail link that are considered permanent or very difficult to change are termed *fixed factors*. These include the location of the airport relative to the city, the attractions and origins along the rail link, local cultural factors, airport characteristics, ease and availability of connections, and the state of local transit. Aspects that are, at least to some extent, controllable are termed *design factors*. These include speed and reliability relative to other access modes, location of the airport rail station, transit fares, and parking rates. The location of the airport rail station is usually reduced to either "on-airport" or "off-airport". In reality, however, there are some rail stations that have shuttle bus connections and also pedestrian access. For the purposes of this research, in order to qualify as "on-airport" a train station must provide pedestrian access to the airport terminal.

Most of these factors are self-explanatory, but "location of the airport relative to the city," "ease and availability of connections", and "productions and attractions along rail link" need further specification. **Location** can be measured in two separate ways: 1) Miles from the airport to the central business district(s) and 2) the location of the airport relative to the metropolitan area population and employment locations. The second of these ways is analyzed in more detail after the case studies are presented. **Ease and availability of connections** will be used to refer to the facility with which passengers can access points other than the downtown central business district. Since all airport rail links examined serve downtown directly, connections are only relevant to the extent that they serve other destinations. **Productions and attractions** are discussed in terms of the chances that airport passengers might use the airport rail link to access some other part of the city besides the central business district (or alternatively, the chances that local residents live on or near the airport rail line). In all cases, the major productions and attractions along the links are likely to be in the central business district.

Some quantitative data are also presented. The figure given for *airport passengers per year* is the total number of passengers handled at that airport[5]. A separate figure is given for *origin and destination passengers* at the airport per year, since this figure is more relevant when discussing access to the airport. *Transit Fare* is defined as the full one-way cost of off-peak travel by rail (including necessary bus connections) from the airport to the city center[6]. Peak fares (as in Washington D.C.) are ignored because airport passengers are not subject to the excessive peaking that typifies commuter patterns, and the peak fares only apply during small portions of the day. *Auto travel time* is the time that it takes, under typical daytime conditions, to drive from the airport to the center city area. This figure is especially relevant for comparison of taxi and rail. *Rail travel time* is indicated for the purposes of comparing it with auto travel time. It is an approximation of the time from the point the passenger begins waiting for an initial vehicle boarding at the airport terminal to the exit at a downtown station[7]. This means that any shuttle bus time and waiting time are included in this figure, but not walking time. The reason for this is that walking time at an airport is generally equivalent for auto (non-taxi) and rail passengers (where this is not the case, it is noted). Walking time within the downtown area is also excluded, because both auto and rail passengers may have to spend extra time after arrival within the downtown area before reaching a final destination. Whereas a rail passenger may need to walk from the station to an apartment or office, an auto passenger will also experience some supplemental time subsequent to entering downtown (traversing congested city streets, parking, etc…). This reasoning holds for trips in the opposite direction (city to airport) as well. Taxi travel time is typically 5 to 10 minutes shorter than the auto travel time.

The distance from the airport terminal(s) to the city center is reported as *miles to CBD*[8]. Three parking rates are reported. The first is for *short-term parking*, a dollar amount that corresponds to the cost of one-hour parking at the airport in a short-term lot. This is used as a measure of the parking cost for meeters and greeters. The cost reported for *mid-term parking* indicates the cost of one day of parking for those passengers least sensitive to price. These are drivers that chose to park in a more expensive, more convenient airport lot. A dollar amount for *long-term parking* indicates the lowest available long-term parking rate per day at the airport (rates at off-airport lots are not reported). This figure is meant to measure parking cost for local residents who drive to the airport and are price sensitive. At some airports, this figure may be the same as the mid-term parking rate.

The final figure reported for each case study is the *mode share*[9]. This indicates the percentage of travelers going to and from the airport who choose to use the available rail link. This figure does not include airport workers. It does, however, provide a good measure of the relative success of an airport rail link, and mode share figures are used to compare rail links with one another. Where available, other results of the latest passenger survey are also presented. These results usually indicate the mode share of every available access mode. The share garnered by public transportation is calculated where possible - this figure does not include taxis or private limousines, but it does include all access modes that are available to the general public. Where possible, different mode shares for residents and non-residents are also presented. The category termed "residents" refers to people who live within the metropolitan area that the airport serves.

Mode share figures are typically determined by conducting air passenger surveys, and are not precise. An awareness of the lack of precision of mode share figures is vital to understanding the case studies. These figures are used to make important determinations about rail link characteristics, but they are only estimations of the percentage of people using rail links. These estimates are generally accurate to within 2 percentage points.

2.2 Detailed Case Studies

2.2.1 John F. Kennedy Airport (JFK)

New York's largest airport is a fascinating piece of the American rail access puzzle. New York City has the greatest transit usage of any city in North America, and a vast subway and commuter rail system on par with any city in the world. Kennedy Airport is the largest international gateway in the country. Yet since most of the subway system was built well before JFK, Kennedy Airport is not effectively connected to it. Plans are currently well underway (see section 2.5.1) to make a much more effective airport connection with a light rail line. However, for years JFK has been weakly connected to the New York City subway system by a shuttle bus to the Howard Beach station. The failure of this line to attract significant numbers of the passengers traveling to JFK is a story from which we can learn much about rail access to U.S. airports. Many people would not consider the current JFK transit link to be a true airport rail link, since the subway station is so far from the airport. However, the lessons about rail access in the largest city in the country are important, even if it is not true airport rail access that is being analyzed. Table 2-2 summarizes the key attributes of JFK and its existing access characteristics.

Table 2-2: Summary of JFK Factors	
Airport Pax/Year (Millions)	31
Origin and Destination Pax	21
Transit Fare	$ 1.50
Rail Peak Headway (Minutes)	7
Rail Travel Time (Minutes)	65
Auto Travel Time (Minutes)	25
Rail/auto Difference	40
Miles to CBD	16
Station in terminal?	No
Short Term Parking Rate	$ 4.00
Mid Term Parking Rate	$24.00
Long Term Parking Rate	$ 6.00
Rail Link Speed (MPH)	15
Rail Mode Share	1.7%

Fixed Factors

Location relative to city:

Kennedy is located sixteen miles from lower Manhattan[10]. It is officially within the New York City limits, but it lies in the farthest reaches of Queens, the New York borough with the greatest area (see Appendix 2-A). However, Brooklyn (also very close to the airport) and Queens are home to more New York City residents than the other three boroughs combined, and the vast suburban area of Nassau County is immediately adjacent to the airport. Therefore, JFK is located quite close to a significant resident population. However, despite housing only one million of New York City's twenty million people, Manhattan is the center of commerce for the entire region. Many business travelers (especially international passengers) arriving in the New York area at JFK are heading to lower Manhattan.

Productions and Attractions along Rail Link:

The rail link to Kennedy is New York's famous "A" train (see Appendix 2-B). This train is the longest subway line in a vast subway system of 722 miles, and it passes through very dense population centers[11]. The line begins across Jamaica Bay in the Rockaways. It crosses over the bay and past the airport, winding its way towards downtown Brooklyn through some very low-income neighborhoods. It then passes through lower Manhattan, along Central Park through the Upper West Side and ends at the very northern tip of Manhattan. At different points on its journey, this line connects to every other subway line in the city, as well as to Penn Station, where most regional commuter trains arrive and depart.

State of Local Public Transit/Cultural Factors:

New York City is the most transit-oriented city in the United States. Owning and operating a car in Manhattan is prohibitively expensive and unnecessary for most residents, and even the outer boroughs have relatively low car ownership rates. However, the airport is far from Manhattan on the border between Nassau and Queens Counties. These two counties are heavily car dependent relative to Manhattan and Brooklyn. Therefore, most New York area residents close to JFK are likely to own vehicles, despite living in the most transit dependent city in the U.S.

There is probably no city in the world more culturally diverse than New York City. However, New Yorkers generally agree that time is limited, and are well-known for always being in a hurry. They are therefore very sensitive to the amount of time it takes to get anywhere, especially to the airport.

Ease and Availability of Connections:

The "A" train passes through so much of New York City that it connects with every other subway line and all Long Island Rail Road (LIRR) and New Jersey Transit trains through Penn Station. However, the New York subway system is designed such that most connections must be made in Manhattan. Since only one million of the twenty million people in the metropolitan area actually live in Manhattan, most of these connections typically do not allow effective paths between the airport and most residences. Residents of Long Island, for example, are very unlikely to take the "A" train towards Manhattan in order to transfer to the LIRR. Residents of Queens, the Bronx, and

Westchester County north of the city would also have to make circuitous journeys if they wanted to take rail to JFK.

Airport Characteristics:

Kennedy Airport serves primarily international passengers and long-haul destinations. The Port Authority of New York and New Jersey runs Kennedy and the two other airports in the region, Newark and LaGuardia. LaGuardia airport, which is also in Queens but much closer to Manhattan, serves most of New York's domestic passengers. Newark is slightly closer to downtown Manhattan than JFK, and has seen a recent surge in traffic, but does not handle nearly as many international passengers as JFK, or as many domestic passengers as LaGuardia. Kennedy is the premier international gateway in the United States, but it is also consistently ranked by travelers as one of the worst airports in the world due to its extreme congestion and outdated facilities.

<u>Design Factors</u>

Location of airport train station:

This is one of the factors which makes the "A" train an ineffective airport rail link. The closest station to the airport is the Howard Beach station, three miles from the airport, and it is connected to the airport terminals with a free shuttle bus. This bus is equipped with luggage racks, and timed to leave upon the arrival of a train. But the bus also serves the long-term parking facility, and is the means, apart from walking, to transfer between terminals at JFK. Travel on the bus takes approximately 15 minutes (including wait time).

Speed relative to Other Modes:

The "A" train is very slow. Although it runs on express tracks and makes many fewer stops than the corresponding local train, it still takes over an hour to get to lower Manhattan from JFK by subway. The train itself is scheduled for approximately 35 minutes to lower Manhattan, but the shuttle bus increases this time by fifteen minutes, and travel time to midtown is an additional 15 minutes[12]. Congestion on the highways leading to JFK is quite common, and at some times the subway may actually be faster than a taxi. However, the majority of the time, even traffic cannot make this rail connection look good. Since there are many different routes from JFK to Manhattan and traffic in the city is extremely variable, a passenger can never be certain that a trip to downtown via taxi will be slow. The same passenger knows for certain that the train will take more than an hour under the best possible conditions.

The speed of this link was temporarily altered in 1978, when a concept called the "JFK express" was introduced. This train ran every twenty minutes from 57th Street and 6th Avenue in Manhattan, with only seven stops to the airport. The run took 44 minutes end to end, which means running time was probably close to 25 minutes from lower Manhattan and 20 minutes from downtown Brooklyn (plus the shuttle bus ride of 15 minutes). The fare for this train was about five times the regular subway fare, and was payable upon boarding the train. The "train to the plane" was heavily marketed, had "first-class" service with four person crews, and was on time more than 90% of the time in an excellent display of reliability[13]. The experiment was a major financial loser however (due to poor ridership), and was eventually abandoned in the early 90's.

Mode Share Survey Results:

Table 2-3: JFK Ground Access Mode Split	Mode Shares		
Mode	**All Passengers**	**Local Residents**	**Non-residents**
Private Car - Drop-off Only	28.5%	39.1%	19.2%
Taxi	22.1%	15.3%	27.1%
Private Limo/Car Service	16.9%	19.6%	14.2%
Private Car - Daily Parking on Airport	8.7%	10.8%	6.8%
Scheduled Airport Bus/Van	4.8%	2.7%	6.5%
Charter Bus	3.7%	1.2%	5.6%
Shared Limo/Car Service	3.0%	2.6%	3.3%
Rental Car	2.9%	0.7%	4.7%
Private Car - Long Term Parking	2.6%	3.8%	1.7%
Private Car - Parked Off-Airport	2.3%	2.5%	2.1%
Hotel Courtesy Vehicle	1.8%	0.1%	3.1%
A Train	1.7%	1.2%	2.1%
Local City Bus	0.5%	0.2%	0.7%
Other	0.4%	0.2%	0.5%
Helicopter	0.0%	0.0%	0.1%

The mode shares calculated from the latest JFK passenger survey, taken between May 1997 and April 1998, are shown in Table 2-3. About 84% of all JFK origin/destination (O-D) passengers access the airport using some form of private automobile or taxi. Airport buses account for the largest portion of the remaining passengers, but charter buses account for a similar share. Public transportation's mode share is approximately 10% (taxis, charter buses and hotel vehicles are excluded from this figure).

Non-residents appear to be more likely than residents to use JFK's airport rail link, and non-residents are almost twice as likely to use public transportation to JFK (13% of residents vs. 7% of non-residents). Most of this difference is attributable to non-resident use of airport buses.

2.2.2 Philadelphia International Airport (PHL)

Philadelphia has the fifth largest metropolitan population in the United States[14], and is typical of several East Coast cities in the way its center city has declined. Philadelphia is analyzed in detail because it provides a good example of a commuter-rail airport connection. The airport is a major hub for US Airways, the nation's sixth largest air carrier. It is connected to the city center by an extension of the local commuter rail system. Table 2-4 summarizes the airport and access characteristics for Philadelphia.

Summary of PHL Factors	
Airport Pax/Year (Millions)	22
Origin and Destination Pax	17
Transit Fare	$ 5.00
Rail Peak Headway (Minutes)	30
Rail Travel Time (Minutes)	42
Auto Travel Time (Minutes)	17
Rail/Auto Difference	25
Miles to CBD	7
Station in Terminal?	Yes
Short Term Parking Rate	$ 5.00
Mid Term Parking Rate	$14.00
Long Term Parking Rate	$ 6.50
Rail Link Speed (MPH)	10
Rail Link Mode Share	2.0%

<u>Fixed Factors</u>

Location Relative to City:

The airport is located seven miles from the central business district,[15] south of the city, near the Delaware River. PHL is well located with respect to the metropolitan region and downtown.

Productions and Attractions along Rail Link:

Since the Philadelphia rail link is an express line to downtown, there is a very limited effective population along the link. The line makes two stops (Eastwick and

University City) outside the airport before reaching downtown, where it stops in five different locations. Downtown Philadelphia is not a major residential area, but is clearly a major business destination. At most times, the line continues past downtown into the northern suburbs just outside the city, where it terminates (not reaching as far into the suburbs as most local commuter lines). At other times, the line terminates downtown.

State of Local Transit/Ease of Connections:

Like other northeastern cities, Philadelphia has a solid public transportation system. The rail network includes seven commuter rail lines, two subway lines, and eight trolley lines (see Appendix 2-C). However, almost all commuter rail connections go through the three major downtown stations in the very center of the city, making suburb to suburb commuting very time consuming. The subway system is much less extensive, and covers only a part of the city.

Cultural Factors:

No significant cultural factors affect Philadelphia's airport rail link.

Airport Characteristics:

PHL handled more than 22 million passengers in 1997, but the since the airport serves as a major hub for US Airways, that figure is much higher than the actual number of passengers arriving and departing from the metropolitan area (17 million). It accommodates more than 25 carriers serving over 100 destinations. The airport is owned by the city, and operated by the Department of Commerce's Division of Aviation.

Terminal A is the international terminal, but the number of international carriers is quite limited and some domestic carriers also use the terminal. Terminals B and C are dominated by US Airways, with B handling domestic and commuter flights and C handling international flights. All major carriers along with some low-cost airlines fill out the rest of the airport. The airport is currently consolidating terminals B and C into one terminal.

Design Factors

Location of airport train station:

Philadelphia is unique in this category. Not only does the airport rail link take passengers straight to the terminals, but it even has three different stations within the airport (see Appendix 2-D). One station is between terminals A and B, one between terminals C and D, and the terminus is at terminal E. From the first airport train station to the third is a distance of three tenths of a mile[16].

Speed Relative to Other Modes:

The airport train takes forty-two minutes to get from the Market East station in downtown Philadelphia to the airport terminals[17]. It is a slightly shorter ride from the 30th Street station, the rail hub of Philadelphia. PHL is well connected to the local highway network, since it is directly off I-95 and close to the Pennsylvania Turnpike. Traffic along this corridor can slow travel times from the city center to below those of the rail link during peak hours.

The effective speed of this link is dramatically reduced by thirty-minute headways. However, unlike other rail links that are subject to the peak hours of non-airport travelers, since this line serves the airport almost exclusively, it has a schedule that is tailored to the needs of airport travelers. This is reflected in constant thirty-minute headways at all times (:09 and :39 past the hour) during which the link operates. In using these consistent headways, the line does not reflect the peaking of commuters. However, neither does it cater to the peaking of aircraft arrivals and departures.

Mode Share:

Table 2-5: PHL Mode Share Survey Results (1997 - Int'l Terminal Only)

Mode	Mode Share
Private Car	46.4%
Public Bus	0.0%
Train	9.2%
Taxi	2.0%
Tour Bus	0.0%
Limousine	14.3%
Hotel Courtesy Van	15.2%
Off-airport Parking Shuttle	0.7%
Rental Car	4.7%
Other	7.4%

The PHL survey results (presented in Table 2-5) are the most recent that are available, but should be analyzed cautiously. First, the results are from a survey taken over a period of two days, and only between 2:30pm and 7:30pm. This small time period may bias the results. Also, the survey is only for the international terminal at PHL, so the results are quite different from those for the entire airport.

According to this survey, 9.2% of all people accessed PHL by public transportation, and all public transportation mode share is assumed by rail. This is a questionable result since the rail mode share at PHL is known to be much lower (2.0%)

according to more rigorous surveys, and since some other form of public transportation would be expected to account for at least some mode share. The reliability of this survey is questionable.

2.2.3 Washington National (DCA)

Washington National is unparalleled on this continent in terms of its airport rail link mode share. Since it opened in 1977, metro-rail has carried up to 15% of all passengers traveling to and from National Airport[18], although it now carries closer to 9%[19]. From looking at DCA, we can learn what factors are necessary to attract significant numbers of passengers to an airport rail link. Table 2-6 summarizes the relevant access characteristics for Washington.

Table 2-6: Summary of DCA Factors	
Airport Pax/Year (Millions)	16
Origin and Destination Pax	15
Transit Fare	$ 1.10
Rail Peak Headway (Minutes)	3
Rail Travel Time (Minutes)	17
Auto Travel Time (Minutes)	10
Rail/auto Difference	(7)
Miles to CBD	4.5
Station in terminal?	Yes
Short Term Parking Rate	$ 4.00
Mid Term Parking Rate	$12.00
Long Term Parking Rate	$ 8.00
Rail Link Speed (MPH)	16
Rail Mode Share	9.0%

Fixed Factors

Location Relative to City:

National is located 4.5 miles south of Washington D.C.[20], just across the Potomac River in Virginia. Its proximity to downtown makes it well located with respect to both businesses and residences in the area.

Productions and Attractions along Rail Link:

Two rail lines - the Blue Line and the Yellow Line, serve the airport station. Both of these lines operate on the same track when they arrive at the airport (see Appendix 2-E). The Yellow Line is the direct connection to downtown. The Blue Line gets to downtown only after heading through Arlington Cemetery and the Northwest part of the city near George Washington University. It then parallels the Orange Line through downtown and out to the eastern Maryland suburbs. Both lines continue past the airport to Alexandria and other Virginia suburbs. This is the only airport in the country with two distinct subway lines directly serving it, which not only increases the number of people directly served by the rail link, but eases connections for others who may be close to major mass transit lines. For example, riders boarding in the Virginia suburbs along the Orange Line need not enter the city of Washington to access National Airport by rail because the Blue Line provides this connection. On the other hand, riders along the Green Line need not pass through the Western Virginia suburbs along the Blue Line, since the Yellow Line whisks them directly from downtown to the airport. The airport station accounts for approximately 1.3% of the ridership on the Yellow and Blue Lines combined[21].

State of Local Transit/Ease of Connections:

Washington's metro is a high quality, modern subway system. The system was built in the 1970's, and stations tend to be further apart than those on older rail systems, so that the subway functions almost like commuter rail service in the suburbs. A true commuter rail system (MARC) also extends out from Union Station in the heart of the city. The subway system has five lines, and since they were designed to coordinate, every line connects with every other line. These connections are mostly in the center of the city, which makes many airport to suburb trips via Metrorail circuitous. Furthermore, many Metrorail stations in suburban areas are not located in dense pedestrian centers, meaning another mode of transportation is almost always required to get from these stations to a final destination.

Airport Characteristics:

National Airport is one of three airports in the Washington area. Dulles Airport is a newer facility located in the Virginia suburbs and Baltimore – Washington International (BWI) is located northeast of the capital, in Maryland. Each of these airports plays a specific role. Dulles is primarily an international airport and a hub for United Airlines, BWI is Baltimore's airport and a hub for Southwest Airlines and USAirways, and National is for short-haul domestic departures. Flights over 1,500 miles from D.C. are not permitted from National, but due to the city's location along the most heavily populated corridor in the U.S., these shirt-haul flights represent an enormous amount of traffic – more than 16 million passengers per year. National dominates the local airport scene and can sustain much higher fares than those to neighboring airports[22].

Design Factors

Location of airport train station:

The train station is an elevated station with a pedestrian footbridge and elevated walkways connecting directly to the second level of the newest airport terminal. The older terminal is a longer walk, about 1/3 of a mile, and free shuttle buses run for those who desire them[23]. For years before the new terminal opened, this longer walk was one option for travelers – the other option was the shuttle bus that still runs today. Apparently the distance of 1/3[rd] of a mile was not long enough to deter potential metro riders, since mode share on this rail link has consistently been the highest in the U.S.

Speed Relative to Other Modes:

National is a very short ride by automobile to downtown in the absence of traffic - a rare occurrence in Washington. The Potomac limits the number of automobile access points between Virginia and D.C. Metrorail has a slight edge in speed and reliability during peak period, as it takes a passenger about 17 minutes to get downtown.

Mode Share Survey Results:

Table 2-7: DCA Mode Share Survey (1992)

Mode	**Share**
Taxi	36%
Auto	33%
Rental Car	11%
Rail	9%
Courtesy Bus	6%
Airport Bus and Limo	3%
Other	1%

The latest mode share survey from DCA (1992) is presented in Table 2-7. The automobile dominates, carrying almost 80% of all passengers. A sizeable portion (6%) of the remaining 20% is attributable to "Courtesy Buses." These are shuttle buses to hotels that are very close to the airport and cannot be accessed by rail[24]. Public transportation's mode share is approximately 12% according to this survey.

2.2.4 Boston Logan Airport

Boston created the very first rail-to-airport connection in the U.S. in 1952 when the Blue Line Airport station was opened. The city's extremely close airport, horrible traffic, high density, and extensive transit network make it a prime candidate for a successful airport rail link. Boston still has occasional traffic jams in the tunnels leading to the airport, but despite these characteristics it has a much lower rail link mode share than one might hope.

Table 2-8: Summary of BOS Factors	
Airport Pax/Year (Millions)	25
Origin and Destination Pax	18
Transit Fare	$ 0.85
Rail Peak Headway (Minutes)	4
Rail Travel Time (Minutes)	14
Auto Travel Time (Minutes)	8
Rail/auto Difference	6
Miles to CBD	2.5
Station in terminal?	No
Short Term Parking Rate	$ 4.00
Mid Term Parking Rate	$18.00
Long Term Parking Rate	$12.00
Rail Link Speed (MPH)	11
Rail Link Mode Share	5.7%

Fixed Factors

Location Relative to City

Logan Airport is located within the city limits of Boston in East Boston, about 2.5 miles from downtown[25]. East Boston is a collection of islands across the Boston Harbor that was mostly filled to create Logan Airport. The neighborhood of East Boston predated the airport and has fought many battles over the years with its noisy, land-consuming neighbor.

Productions and Attractions along Rail Link

Since Logan is so close to downtown, the Airport station on Boston's Blue Line is actually about halfway between the beginning and the end of the line. The line begins in the heart of Boston near Government Center, and after only a few stops, crosses under the harbor through a tunnel to East Boston. Only one stop in East Boston precedes the Airport station. Unlike many other airport rail links, this one was built well before the airport existed as a major trip attractor. The Blue Line is a rapid transit line, not purely an airport rail link, and it is by far the shortest of the Boston rapid transit lines. Moreover, it is the only line in the city that terminates in the downtown area instead of passing through it. The airport station accounts for approximately 6.9% of Blue Line ridership[26].

State of Local Transit

Boston has the oldest subway in the U.S. and continues to be heavily transit oriented. The city is famous for its bad drivers and impossible street network that makes transit an attractive alternative. As in the case of New York, the subway system was designed by private entities, and transfers are not well thought out for system coordination. For example, the Blue Line does not directly connect to the Red Line, so that passengers wishing to make such a transfer must use the Green Line as a shuttle between Park Street and Government Center (see Appendix 2-F). Furthermore, all such connections in Boston are made within a very small area. Six transfer stations connect the lines, and all of these stations are within walking distance of one another. Traveling from one part of the Boston area to another by rapid transit almost always means going through downtown.

Airport Characteristics:

Logan Airport is the major airport for Boston and the New England region. It is a major international and domestic gateway, with significant airside congestion. Certain weather conditions that occur frequently can make Logan close all but two of it runways, causing long delays[27]. Logan has five terminals that are all connected by pedestrian walkways. Logan is not a hub for any airline, but USAirways, an airline with a very strong northeastern network, has more flights out of Logan than any other carrier. Lately, American Airlines has been starting nonstop flights from Boston to several new destinations, prompting speculation of a possible hub. Logan is severely hampered in its development by its surrounding neighborhood. Local residents do not appreciate the noise generated by Logan, nor the desire of the airport to expand.

Design Factors

Location of Airport Train Station

The Airport station on the Blue Line is located approximately one mile from the airport terminals. This mile is virtually impossible to walk on foot, but free shuttle buses run frequently. To speed service and increase comfort, one shuttle bus picks up and drops off passengers for terminals A and B, while the other does the same for terminals C, D, and E (terminal D is very small and is used mostly for charter airlines, so this split distributes passengers quite evenly). Passengers board the shuttle bus one flight up from the rail platform. A separate bus route is responsible for inter-terminal passenger transfers, leaving these routes to serve rail passengers almost exclusively.

Speed Relative to Other Modes

Like many other airport rail links, this one can be faster than an automobile when there is highway congestion. For most downtown destinations, equivalent travel times can be obtained with the rail link and an automobile, even in the absence of congestion. Congestion in Boston can be overwhelming, but traffic to the airport and traffic from the airport are two very different issues. Traffic going to the airport can back up to some extent, but the Callahan tunnel is usually quite fast and if you can avoid getting delayed on one of the routes leading to the tunnel then the trip will usually be short. The only way back from the airport (until the connection between the new harbor tunnel and the Massachusetts Turnpike is complete) is via the Sumner Tunnel. This tunnel leads directly into the Central Artery, a highway that is usually congested even at off-peak hours. For this reason, the tunnel is very often backed up to a point on route 1A past

Logan Airport, and passengers from the airport must be diverted in the opposite direction in order to avoid clogging up the airport terminal access road. This problem can give the Blue Line a significant reliability and speed advantage.

Mode Share:

Table 2-9: BOS Ground Access Mode Split		**Mode Shares**	
Mode	**All Passengers**	**Residents**	**Non-Residents**
Private Car	35.3%	48.4%	16.4%
Taxicab	20.4%	16.3%	26.4%
Rental Car	13.3%	1.3%	30.8%
Limo: Door to Door	10.1%	13.5%	5.2%
Logan Express	6.1%	8.9%	1.9%
MBTA Subway	5.7%	5.5%	6.0%
Bus-limo: Fixed Schedule	5.6%	4.0%	7.9%
Courtesy Shuttle	2.2%	1.0%	3.9%
Water Shuttle/taxi	0.6%	0.3%	1.2%
Other	0.6%	0.7%	0.4%

The results of the latest (1996) BOS passenger survey (see Table 2.9) show that BOS garners an exceptionally high share of public transportation users (about 18%). Much of this is attributable to the popularity of Logan Express, suburban bus connections designed exclusively for people accessing the airport. However, about 79.2% of all persons accessing Logan do so by some form of private automobile.

Residents and non-residents are equally likely to use the MBTA to access BOS. However, residents are much more likely to use Logan Express, whereas non-residents are more likely to use some other fixed schedule public transportation, including the water shuttle. Both groups have similar public transportation mode shares overall.

2.2.5 Chicago: O'Hare (ORD) and Midway (MDW) Airports

The two Chicago airports are presented together in order to show how different rail links can be, even in the same general environment. O'Hare is the largest airport in the world, and a hub for both United and American Airlines. Midway is Chicago's oldest airport, and underwent a recent revival by luring several low-cost carriers. Chicago, as the nation's third largest metropolitan area, provides a showcase of airport rail links all by itself. Table 2-10 summarizes the access characteristics of both Chicago airports.

Table 2.10: Summary of Chicago Factors	**MDW**	**ORD**
Airport Pax/Year (Millions)	10	70
Origin and Destination Pax	9	35
Transit Fare	$ 1.50	$ 1.50
Rail Peak Headway (Minutes)	7	7
Rail Travel Time (Minutes)	29	44
Auto Travel Time (Minutes)	19	21
Rail/auto Difference	10	23
Miles to CBD	11	18
Station in terminal?	Yes	Yes
Short Term Parking Rate	$ 3.00	$ 3.00
Mid Term Parking Rate	$20.00	$ 18.00
Long Term Parking Rate	$10.00	$ 8.50
Rail Link Speed (MPH)	23	25
Rail Mode Share	8.1%	3.9%

<u>Fixed Factors</u>

Location relative to city:

O'Hare is officially located within the Chicago city limits, but it is really a pocket in the northwest suburbs that is the property of the city. It is 18 miles from downtown[28], which is typically known as "the loop." Chicago's heavily suburban population benefits greatly from this location, especially since half of all O'Hare traffic originates from that direction[29].

Midway is located on the Southwest side of Chicago, about 11 miles from downtown. This area is an older, more industrial Chicago neighborhood that has lost most of its population since World War II. Chicago is well known for being a very segregated city and the Southwest side is a predominantly Black and Hispanic area. Midway's location might make it more popular in another city, but it cannot hope to compete with the world's largest airport.

Productions and Attractions along Rail Link

The O'Hare Blue Line begins at the airport and passes through the northwest side of Chicago, a predominantly white and immigrant neighborhood. It travels in the median of the Kennedy Expressway (I-90 and I-94), which makes its stations relatively difficult to access and limits intensive development along the line. The line becomes a subway when it enters downtown, and makes a 45-degree turn to head towards the West Side of the city. Two stations after leaving downtown, the line splits into two branches. One branch follows the median of the Eisenhower Expressway (I-290) all the way to the western suburbs of Oak Park and Forest Park. The other branch turns slightly South but continues through the West side until it reaches Cicero, a working class suburb just outside the city limits (see Appendix 2-G).

The Midway Orange Line is a recent rapid transit addition to the Chicago system, and the shortest line in the city. Opened in 1993, the line starts along the historic elevated loop upon which three other rapid transit lines also operate. It heads directly South from the loop until about 18th Street, where it curves to the southwest. The route parallels the Stevenson Expressway (I-55) to some extent, and then winds its way to

Midway. The section of the city traversed by the Orange Line contains a significant population, though not a prosperous one nor one with extremely high density. Before the construction of the Orange Line, average travel time in this corridor was 50% higher than in other Chicago corridors[30].

State of Local Transit:

Chicago has many characteristics of older U.S. cities, but is much more spread out than the cities of the northeast. Like those cities, it is heavily dependent on a transit system designed to bring workers into downtown, and it has seen transit suffer from poor coordination. Virtually all transfers between rail lines in Chicago must be made in the downtown area. Moreover, although the city is of a geographical size similar to New York, the rapid transit system includes only 110 rail route miles[31] compared to 722 in New York. Chicago is well known for traffic and air quality problems, as well as an extensive system of expressways leading into and around the city. These expressways have not only damaged urban neighborhoods, but they have made the automobile a vastly superior alternative to transit for most Chicagoans. However, transit does benefit from Chicago's streets, which are generally wider than those found in older northeastern cities, and allow buses to reach higher average speeds. The bus system, which is quite extensive, is able to supplement the rapid transit system better than in many other cities.

Airport Characteristics:

Chicago O'Hare is the largest airport in the world, handling close to 70 million passengers per year[32]. Most of this traffic is due to the hub/transfer operations of

American and United. These are the two largest airlines in the U.S., and both have major domestic and international hubs at O'Hare. The airport has a people mover that connects its four terminals. Terminal 1 handles all United Airlines traffic, and terminal 3 handles all American Airlines and Delta Airlines flights. Terminal 2 handles all other domestic carriers, and Terminal 5 is the international terminal (Terminal 4 does not exist). Only 14 percent of O'Hare's origin and destination passengers travel to and from downtown[33].

Chicago Midway was built in the 1920's. It served 10 million passengers in 1959 – last year it served slightly less than that figure. It has a single terminal with three concourses. The airport serves only domestic flights, and the major carrier there is Southwest Airlines, which means that most of these flights are short-haul. Midway is served primarily by low-cost carriers, and typically is not viewed as the "closer domestic airport" (as in the cases of LaGuardia and National). Despite its low-cost, leisure traveler image, 19 to 21 percent of Midway's passengers are destined for the loop[34].

<u>Design Factors</u>

Location of Airport Train Station

Prior to the 7.9-mile extension from the Jefferson Park station, completed in 1984, shuttle buses ran between O'Hare and that station[35]. Now the O'Hare rail station is located directly underneath the central parking structure at the airport. The station is at the center of the main parking complex that is centrally located between terminals 1, 2 and 3. To get to terminal 5, passengers must transfer to the automated people mover that is adjacent to the terminals. Moving walkways connect passengers from the subway to the terminals, with a total walking time of about five minutes. The longest walk is for passengers on United Airlines using concourse C, which requires an underground walk over another set of moving walkways.

Midway's rail station is slightly depressed and outdoors. From the main terminal passengers climb stairs or use an escalator to access the pedestrian footbridge that crosses Cicero Avenue, and then descend into the station. The station is equidistant from the entrance to all gates, but is closest to the Southwest Airlines baggage claim area. There is some speculation that the relative unattractiveness of this station is due to budget concerns in construction as a result of cost overruns on the O'Hare extension.

Speed Relative to Other Modes:

Travel to and from O'Hare along the Kennedy Expressway is almost always subject to congestion, but under free-flow conditions the trip takes about 30 minutes. The same trip takes 44 minutes by rapid transit. This makes the line quite competitive in terms of speed. The O'Hare access road (I-190) often experiences congestion heading out to the airport. Traffic back from the airport is subject to delay as well, since the Kennedy (I-90) and Edens (I-94) Expressways merge at Irving Park Road, creating congestion.

Travel time to Midway from downtown takes about 15 minutes by car and 29 minutes via the Orange Line. The Stevenson expressway that connects the Southwest side to downtown is often congested, but the worst part about driving to Midway is that the airport is not directly connected to the highway. Midway is unusual in that it can only be accessed from arterial roads. Drivers must exit the expressway on to Cicero Avenue and drive South for two miles. Cicero is a six-lane road, but traffic lights and cross streets slow traffic significantly. Traffic can easily back up on Cicero, leading to major delays.

Mode Share:

There is no mode share data available for MDW. The most recent passenger survey for that airport was performed before the opening of the MDW airport rail link, and is not relevant to this analysis.

Table 2-11 ORD Ground Access Mode Split	
Mode	**Mode Share**
Private Vehicle, as Driver	28.9%
Private Vehicle, as Passenger	27.7%
Livery/Limousine	10.3%
Rental Vehicle	8.8%
City Taxi	7.6%
CTA (rail)	3.9%
Suburban Taxi	2.9%
Airport Bus	2.8%
Hotel/Motel Courtesy Vehicle	2.2%
Regional Bus	1.9%
Charter Bus	1.4%
Other	1.1%
Metra/Pace/RTA Bus	0.6%

Table 2-11 shows the results of the latest passenger survey at O'Hare (1997). About 86% of all O'Hare ground passengers access the airport via some form of automobile. Public transportation garners about 9% of all passengers.

Table 2-12: ORD Mode Shares - Residents vs. Non-residents		
Mode	**Resident Mode Share**	**Non-resident Mode Share**
Private Vehicle, as Driver	45.1%	8.5%
Private Vehicle, as Passenger	27.9%	27.0%
Taxi/Livery/Limousine	20.1%	21.7%
Public Transit	4.6%	4.6%
All Other	1.4%	13.7%
Rental Vehicle	0.5%	19.8%
Hotel/Motel Courtesy Vehicle	0.3%	4.6%

Table 2-12 compares the mode shares for residents and non-residents. Both groups are equally likely to use public transportation. Unfortunately, many non-residents are lumped into the "All Other" category, and we cannot be sure of their exact mode choice. Much of this category likely includes charter buses and airport buses that were (mistakenly) not considered by the survey compilers to be public transportation.

2.2.6 San Jose International Airport (SJC)

San Jose is a sprawling city that has recently experienced tremendous growth due to the dawn of the computer age and a boom in Silicon Valley. The VTA (Valley Transportation Authority) operates a light rail system in San Jose (LRT), along with 34 connecting bus routes. There are no direct connections from the LRT to other regional transit systems in the San Francisco Bay area. Since its completion in 1991, the VTA light rail has shown modest growth in ridership with average weekly ridership increasing from 19,470 in 1991 to 22,690 in 1997. Table 2-13 summarizes the important access characteristics for San Jose.

Table 2-13: Summary of SJC Factors	
Airport Pax/Year (Millions)	11
Origin and Destination Pax	10
Transit Fare	$ 1.10
Rail Peak Headway (Minutes)	10
Rail Travel Time (Minutes)	29
Auto Travel Time (Minutes)	5
Rail/auto Difference	24
Miles to CBD	2
Station in terminal?	No
Short Term Parking Rate	$ 1.50
Mid Term Parking Rate	$10.00
Long Term Parking Rate	$10.00
Rail Link Speed (MPH)	5
Rail Mode Share	1%

Fixed Factors

Location Relative to the city:

San Jose International Airport is located 2 miles north of downtown San Jose, making it easily accessible for area residents.

Productions and Attractions along Rail Link:

The VTA is a single light rail line 20 miles long with 33 stations (see Appendix 2-I). It runs through the San Jose Civic Center, Downtown San Jose and some residential areas of South San Jose with many links to the local bus system. Other attractions along the line include an amusement park, a casino and a strip mall. Residential and commercial densities around the LRT are generally low. There are two LRT stops that have links to two separate Caltrain stations by shuttle bus.

The Light Rail does not have stations within walking distance of the Arena, the Junior College or the Valley Medical Center, all of which account for large volumes of traffic in the San Jose area. Moreover, the light rail system is very small relative to the geographic area of San Jose, and the vast majority of people in the area do not live within walking distance of the line.

State of Local Transit/Ease of Connections:

The VTA light rail consists of two tracks situated in the median of several major thoroughfares in San Jose. The location of the station platforms in the middle of the road requires transit users to cross one direction of travel lanes for access and egress. The stations themselves are of a split platform configuration and are non-staffed. Amenities include, waiting area shelters, benches and shade trees. Ticket vending machines are located on each platform as are maps of the transit system and other traveler information.

San Jose was never a transit dependent city, and it certainly is not one now. Recent attempts to develop the downtown area have been moderately successful, but San Jose is a product of the automobile age and lacks any serious downtown concentration. In viewing the city, many would not even notice that there was a city, as San Jose resembles a very large suburb.

Airport Characteristics:

Passenger totals for SJC in 1997 were 10.2 million, 48% of which were business passengers. It supports 16 commercial airlines, of which Southwest Airlines accounts for 36% of passenger volume. The popularity of Southwest Airlines has been a major boon for the airport and the region. Moreover, the airport represents a less congested, more convenient alternative to the other regional airports (OAK and SFO) for many people in the southern portion of the Bay Area.

<u>Design Factors</u>

Location of airport train station:

The link between the VTA and the airport is via shuttle bus that connects to the Metro/Airport light rail station. A special bus designated the *Airport Flyer* and equipped with luggage racks began service in April of 1998 in an effort to increase mode share significantly. The shuttle bus runs every 10 minutes and goes directly to each of the two terminals.

Speed Relative to other modes:

The VTA light rail provides efficient and reliable service to the airport for those it serves. It takes approximately 29 minutes to get from the CBD to the airport, including waiting and shuttle bus time. However, wide roads with little congestion make auto access to San Jose very easy - it takes a maximum of five minutes to reach downtown by automobile under normal driving conditions.

Mode Share:

Table 2-14 SJC Ground Access Mode Split		**Mode Shares**	
Mode	**All Passengers**	**Local Residents**	**Non-residents**
Private Car	65.0%	87.6%	43.1%
Rental Car	23.4%	2.1%	44.3%
Public Transit	0.7%	0.8%	0.6%
Door to Door Van	1.6%	2.1%	1.1%
Private Scheduled Operator	1.4%	1.2%	1.5%
Taxi	4.0%	4.8%	3.2%
Hotel Courtesy Shuttle	2.8%	0.2%	5.2%
Limousine	0.8%	1.1%	0.6%
Charter Group	0.1%	0.0%	0.2%
Other	0.2%	0.2%	0.3%

Table 2-14 shows the mode shares for access to SJC. The public transit listing here is solely the light rail option. This data is from a 1995 study (only one year after the light rail opened), and the transit mode share has improved somewhat since then. Nonetheless, some form of the private automobile accounts for about 93% of all trips to the airport according to this data. Public transportation accounts for barely 4% of airport access to SJC.

2.3 More Airport Rail Links – Short Summaries

2.3.1 Atlanta (ATL)

MARTA (Metropolitan Atlanta Rapid Transit Association) is a simple subway system with two lines that intersect in downtown Atlanta at Five Points station. The north-south line terminates at Atlanta Hartsfield, and service to the airport has existed since 1986[36]. The Atlanta airport is 9 miles from downtown, and the train takes only 21 minutes to make the trip. The fare is $1.50, and the headways for the trains are 4 to 5 minutes weekdays and 10 to 15 minutes on weekends[37].

The rail station is located within the airport, but the size of the airport adds significantly to walking/traveling times to that station[38]. Atlanta Hartsfield is an enormous airport relative to the local population. The Atlanta metro area is smaller than Boston in terms of population, but the airport is the nation's second busiest, with over 63 million passengers handled in 1996[39]. This is mostly due to the hub operations of Delta Airlines, the nation's third largest carrier. Atlanta is by far the airline's biggest hub.

About 6% of all passengers going to and from ATL use MARTA. This number is the third highest in the country, and all the more astounding considering the fact that Atlanta is a spread out, car dependent city with a relatively small downtown concentration. The density of the city is significantly lower than San Juan or New York, with only 1,154 persons per square kilometer[40]. The relative success of the rail link is probably aided by the hub operations at ATL of Air Tran airlines. Air Tran is the third largest low-cost carrier in the nation and tends to attract price sensitive passengers. The airline also has a competitive impact on some Delta Airlines routes.

2.3.2 Lambert - St. Louis International (STL)

The most recent airport rail connection in the U.S. is in St. Louis, Missouri. Opening in June of 1994, MetroLink is a light-rail line running from STL through downtown and on to East St. Louis, Illinois. The airport is 10 miles from downtown, and the trip via MetroLink takes approximately 39 minutes[41]. MetroLink is the only rail service available in St. Louis, with a fare of $1.00 or $1.10 with a bus transfer[42]. Since gambling is legal on Illinois riverboats, the train also carries significant traffic to that attraction directly from the airport[43].

The St. Louis airport is the major domestic hub of TWA, the nation's eighth largest airline. TWA uses St. Louis as the domestic feeder to its international hub at JFK, although it does also fly to London and Paris directly from STL[44]. Therefore, St. Louis is more of an international airport than it might initially appear. The airport is the 15th largest in the U.S., handling around 23 million passengers[45].

The airport train station is located inside the main terminal complex. Although the train is at grade for most of its journey, it is elevated when it reaches the airport. The line will be extended from its current terminus at the main terminal to Lambert's future Airport East Terminal currently under construction[46]. Ridership on MetroLink is higher than predicted levels[47], and the percentage of airport passengers using the link is 5%[48]. Considering St. Louis' suburban nature, this figure is quite high.

2.3.3 Cleveland Hopkins (CLE)

Cleveland has one of the oldest airport rail links in the U.S. The airport extension to the Cleveland Transit System opened in 1968, about thirteen years after the rapid transit system began service[49]. The line runs through downtown Cleveland from Windermere in the northeast suburbs, and then continues southwest until it terminates at the airport. The train takes 34 minutes to get to downtown Cleveland, which is ten miles from the airport, at a fare of $1.50[50]. The train station is located directly inside the airport terminal, and the airport is relatively small, making the connection very convenient[51]. The link carries only 3% of all airport passengers[52].

Cleveland Hopkins has suffered tremendously since deregulation. In 1979, United Airlines operated more than half of the flights out of Cleveland – their current presence there is severely diminished[53]. US Airways and Continental have partially replaced that service, and recent service by Southwest Airlines has contributed to the revival of CLE.

2.3.4 Oakland International Airport (OAK)

OAK is served by the BART rail system. BART (Bay Area Rapid Transit) is a heavy rail system that was built in the 1970's, although in some respects it is more like a commuter rail system. It connects the airport to Oakland and San Francisco, as well as other points south of the Bay Area. The bus service connecting the airport to the closest train station is called AirBart, operating every fifteen minutes and costing $2.00[54]. An additional fare of $1.10 must be paid to ride BART the eight miles to the center of Oakland, and it costs an additional $2.75 to travel the 19 miles to San Francisco[55]. Travel times to those cities are 30 minutes and 40 minutes respectively.

The Oakland Airport was long the step-child of the Bay Area compared to its better known neighbor (San Francisco International), which is slightly closer to San

Francisco and a major hub for United Airlines. Recently, Southwest Airlines has moved into the airport, and taken over terminal 2 (the airport only has two terminals). Southwest's fierce competition with United on domestic flights to the Bay area, especially the heavily traveled Los Angeles – San Francisco route, has largely been facilitated by the capacity available at OAK. Two other low-cost carriers serve OAK (Taesa and America West) and it tends towards domestic flights much more than its larger neighbor. Four out of the top ten U.S. airlines do not serve OAK.

Table 2-15 OAK Ground Access Mode Split		**Mode Shares**	
Mode	**All Passengers**	**Local Residents**	**Non-residents**
Private Car	69.5%	84.6%	51.1%
Rental Car	15.7%	1.4%	33.3%
Public Transit	5.0%	5.6%	4.3%
Door to Door Van	3.3%	3.4%	3.2%
Private Scheduled Operator	2.6%	2.5%	2.8%
Taxi	2.1%	1.3%	3.1%
Hotel Courtesy Shuttle	1.0%	0.3%	1.8%
Limousine	0.4%	0.6%	0.2%
Charter Group	0.1%	0.0%	0.1%
Other	0.1%	0.2%	0.1%

2.3.5 Miami International Airport (MIA)

MIA is loosely connected by rail to the sprawling South Florida metropolitan area by a free shuttle bus that takes passengers to the nearest commuter rail (Tri-rail) station. The Tri-rail network consists of one line running from the airport station 66 miles north to the edge of the metropolitan area in West Palm Beach[56]. A transfer is available to the Miami Metrorail, an elevated heavy rail line, which is two stations north of the airport. This line makes frequent stops as it goes through downtown Miami and on to the southern tip of the county. The entire trip from the airport to downtown by rail takes about 75 minutes[57]. The airport is six miles from downtown[58], a distance easily driven in

12 minutes without traffic. The total fare, combining Metrorail and Tri-rail, is approximately $3.25[59].

MIA is a major international hub for American Airlines. Almost all South American flights from the U.S. go through Miami, most of them on American. Two nearby airports within the metro area, Ft. Lauderdale and West Palm Beach, are much smaller and handle more domestic traffic (these airports are also connected to the Tri-rail line by shuttle buses – they are not analyzed further because there is no rail service to downtown areas besides Miami from these airports). The nature of MIA as an international gateway and the nature of Miami as a sprawling pedestrian-unfriendly area make this poor rail connection a virtual unknown. Many people who work at the airport are oblivious to the existence of this connection. However, a new East – West rail link is planned that will connect the airport directly to downtown. The station for the new rail link will be at the same location as the current Tri-rail station, but a new people mover will connect that station with the airport[60].

Access to MIA is particularly interesting relative to San Juan because of the local cultural factors. Miami is dominated by a large Cuban population that unlike many other immigrant groups has achieved relative financial success without assimilation[61]. This means that a strong Cuban culture has prevailed and probably will prevail in the city for a long time. Part of Cuban and Latin American culture is a strong family structure that encourages the seeing off and meeting of family and friends at the airport. Large groups of people are less likely to use mass transit, which is most cost-effective for a single traveler.

Table 2-16 MIA Ground Access Mode Split	
Mode	**Mode Share**
Private Vehicle	71.7%
Taxi	11.7%
Hotel Courtesy Shuttle	6.2%
On-Airport Buses	3.7%
Other	3.0%
Off-Airport Buses	1.5%
Tour Vans	1.2%
Super Shuttle	0.9%
Couriers	0.1%

2.3.6 Baltimore Washington International (BWI)

Baltimore Washington is connected to both Baltimore and Washington by rail. The Washington connection is an off-airport commuter rail and Amtrak station. Passengers can catch a shuttle bus provided by MARC (the commuter rail) and Amtrak to access the station. MARC trains leave with varying frequency, from every hour to every half-hour depending on time of day[62]. The trains take about 40 minutes to reach Union Station in D.C., and total trip time (including shuttle bus and waiting times) is around 73 minutes. Amtrak trains are even less frequent, but are slightly faster. The Baltimore connection is a new light rail service that connects directly into BWI's new international terminal. The light rail system takes about 40 minutes to make the eight-mile trip to downtown Baltimore.

BWI is second fiddle to Washington National in the local domestic market, but has seen tremendous growth of late. Both Southwest Airlines and USAirways have located hub operations at the airport, which provides uncongested airspace and cheaper fares for those traveling to the nation's capital. Expensive taxi service to travel the 30 miles to downtown Washington makes the MARC connection a very affordable alternative at $6.00, but its off-airport location and low frequency make for a long door-to-door trip time. The light rail system serves downtown Baltimore rather quickly, but since the service is so new (opening last December), the mode share is unknown. It does connect directly into Baltimore's Penn Station, providing easy connections to the MARC and Amtrak trains there[63].

2.4 Airport Worker Mode Shares

Airport workers are obviously some of the most frequent airport visitors. Unlike air passengers, workers make the trip to the airport every day, and can thus account for a large percentage of airport rail link ridership. Unfortunately, little data exists concerning airport worker mode choice. The available mode share data is shown in Table 2-16 and compared with passenger mode share[64].

Table 2-16: Airport Worker Mode Shares

Airport	Passenger Mode Share	Worker Mode Share
BOS	5.7%	10.7%
STL	5.0%	8.0%
ORD	3.9%	7.4%
JFK	1.7%	2.5%

Despite limited data, some important observations can be made about airport workers:

1) At all four airports, workers are more likely than passengers to use available rail links. This can be explained in four important ways. First, employees go to the airport every day, eliminating some expensive options such as taxis, rental cars and limousines. Second, employees are more likely to live near a station on the airport rail link, since it is possible that they considered their commuting options when determining their residential location. Passengers are more likely to come from areas that are not accessible by rail. Third, airport employees are likely to have incomes

that are lower than those of the typical air passenger. This makes them more likely to use public transportation due to the inexpensive nature of that mode. Finally, the lack of available parking for employees at some airports makes it more likely that they will use transit.

2) In each case, employee mode share data is between 1.5 and 2 times the figure for passenger mode share. Passenger mode share appears to be a good proxy for worker mode share, at least in terms of comparing airports.

2.5 Planned Airport Rail Links

2.5.1 John F. Kennedy Airport

As described above, the current rail link to JFK airport is ineffective as a means of bringing passengers to and from Manhattan, and even less effective in providing good access to JFK for most New Yorkers. The latest attempt to bring decent rail service to the busiest airport in the biggest city in the United States is a light rail line that is currently under construction. The 8.4-mile link will start at the Jamaica train station in Queens[65]. This station is a major hub for the Long Island Rail Road (LIRR), and almost every train from Manhattan to Long Island passes through it. Two subway lines also terminate in Jamaica; one goes through Brooklyn to Manhattan and the other operates along the Queens Boulevard trunk line, which also leads to Manhattan. From Jamaica, the line will make one stop (Federal Circle) before entering the terminal area, where it will make a loop with six stops. The line will have a spur from Federal Circle that stops at the long-term parking lot before terminating at the Howard Beach subway station.

The estimated travel time will be eight minutes to Howard Beach, and eight minutes to Jamaica from the last stop at JFK. This means that travel time to Manhattan through Howard Beach will be reduced by at most seven minutes, since the shuttle bus currently running on that route takes about fifteen minutes. Travel time through Jamaica will be the new premium service, since LIRR trains from Jamaica to Penn Station in Manhattan have a travel time of approximately eighteen minutes and leave with very high frequency.

The project will be built at a cost of $1.5 billion[66]. It will be financed through passenger facility charges (PFCs) at JFK as well as capital funding from the Port Authority of New York and New Jersey[67]. The new line faces several engineering challenges. It will require a tunnel under two JFK taxiways, and construction right next to operating aircraft. Part of the link will be constructed in the median of the Van Wyck expressway, which will mean increases in congestion along with the task of building a light rail line on a four-foot median. Furthermore, much of the link will be elevated but built on soil that is "prone to liquefy during seismic activity[68]." The procurement for the project is design-build-operate-maintain, with a contract of fifteen years.

2.5.2 San Francisco International (SFO)

The heavy rail system in the San Francisco area, or BART (Bay Area Rapid Transit), is a part subway, part elevated line that has distances between stations that make it more like a commuter rail system than typical rapid transit. BART is a 71.5-mile system in the midst of an expansion program that will include a line with service to SFO[69] (another route currently under construction is on the opposite side of the bay). The new line will be an extension of the main trunk line from Daly City, down past the airport to Millbrae. Ground was broken for the extension in December of 1997[70].

The BART expansion is part of the FTA's turnkey demonstration program, and uses a design-build approach. The project will cost approximately $1.2 billion. $750 million comes from the FTA, $200 million from SFO (not from passenger facility charges), $108 million from California, $99 million from SamTrans (San Mateo County Transit District), and $10 million from the Metropolitan Transportation Commission (the region's MPO which includes nine counties)[71].

Although most of the new line is subway, the airport train station will be an elevated station. It will be located next to the new international terminal currently under construction at SFO. Passengers bound for other terminals must transfer to the planned Airport Rail Transit System (ARTS), or walk to their flights. The airport station will be a spur off the planned line – not a station directly on the line. Passengers coming from the one station south of the airport will have to transfer back in the opposite direction[72]. Also, the frequency of trains to the airport will be less than the frequency of trains on the BART main line.

Chapter 3 - Case Study Analysis

This chapter analyzes the information presented in Chapter 2. First, quantitative data from the case studies are compared in section 3.1. Then, the results of this comparison and the remaining data from the case studies are combined to produce some propositions about the role for rail in airport access.

3.1 Case Study Comparison

This section compares the basic information about each rail link studied. Table 3-1 summarizes the most important information with each airport listed by declining rail mode share and indicated by its three-letter code[73]. Putting all of these factors together shows the sheer number of different characteristics that can strongly influence an airport rail link's viability. It shows that the best rail links do not necessarily have favorable characteristics across the board, and that rail links with low mode share can have some exceptionally good qualities that are dominated by other negative characteristics. Since no airport rail link in this country has a substantial share of passengers when compared to European rail links, it is likely that a new link should meet some minimum level for most factors, and provide exceptional levels for others if it is to produce a superior mode share.

Table 3-1: Comparison of Major Rail Links												
		Time to CBD			Rail Peak	Miles	Parking Rates		Terminal in	Speed	Mode
Airport	Fare	Rail	Auto	Diff.	Headway	to CBD	short	long	Airport?	(Mph)	Share
DCA	$1.10	17	10	7	3	4.5	$4.00	$ 8.00	Yes	16	9.0%
MDW	$1.50	29	19	10	7	11	$3.00	$10.00	Yes	23	8.1%
ATL	$1.50	21	10	11	8	9	$1.00	$ 5.00	Yes	26	6.0%
BOS	$0.85	14	8	6	4	3	$4.00	$12.00	No	13	5.7%
STL	$3.00	39	30	9	7	10	$1.50	$ 5.00	Yes	16	5.0%
OAK	$3.10	30	14	16	10	8	$2.00	$ 8.00	No	16	4.1%
OAK - to SF	$4.75	40	29	11	10	19	$2.00	$ 8.00	No	29	4.1%
ORD	$1.50	44	21	23	7	18	$3.00	$ 8.50	Yes	25	3.9%
CLE	$1.50	34	20	14	12	10	$3.00	$11.00	Yes	18	3.0%
PHL	$5.00	42	17	25	30	7	$5.00	$ 6.50	Yes	10	2.0%
JFK	$1.50	65	25	40	10	16	$4.00	$ 6.00	No	15	1.7%
BWI - to DC	$6.00	73	38	35	45	30	$4.00	$ 6.00	No	25	1.0%
MIA	$3.25	75	12	63	60	7	$3.00	$10.00	No	6	1.0%
SJC	$1.10	29	5	24	10	2	$1.50	$10.00	No	4	1.0%
BWI - to Balt	$1.35	40	15	25	30	8	$4.00	$ 6.00	Yes	12	n/a

Looking at this data, it is difficult, if not impossible to determine the factors that play the strongest role in influencing rail mode share. Each factor was examined separately using regression analysis to determine whether or not there was a strong relationship between it and mode share. Two factors showed a strong correlation with mode share: rail link travel time, and rail/auto time difference.

Table 3-2: Rail Link Time Comparison				
Airport	Miles to CBD	Time to CBD	Speed (MPH)	Mode Share
BOS	3	14	13	5.7%
DCA	4.5	17	16	9.0%
ATL	9	21	26	6.0%
MDW	11	29	23	8.1%
SJC	2	29	4	1.0%
OAK	8	30	16	4.1%
CLE	10	34	18	3.0%
STL	10	39	16	5.0%
OAK - to San Fran	19	40	29	4.1%
BWI - to Baltimore	8	40	12	n/a
PHL	7	42	10	2.0%
ORD	18	44	25	3.9%
JFK	16	65	15	1.7%
BWI - to DC	30	73	25	1.0%
MIA	7	75	6	1.0%

Table 3-2 and shows a strong relationship between the time that it takes to get to the downtown area and the popularity of rail links. With the exception of San Jose, the links with the shortest times have the highest mode share. San Jose is explained by the fact that that link covers a miniscule portion of the metro area, and operates in an environment where the automobile is dominant. At a minimum, we can say that the top four airport links in terms of mode share have the shortest times to the CBD, and the bottom two airport links in terms of mode share have the longest times to the CBD. The table also shows that links connecting distant airports have very low patronage. Generally, people tend to avoid rail for airport trips over 45 minutes. The converse is not true, as airports close to the city can have very low mode shares (MIA and SJC).

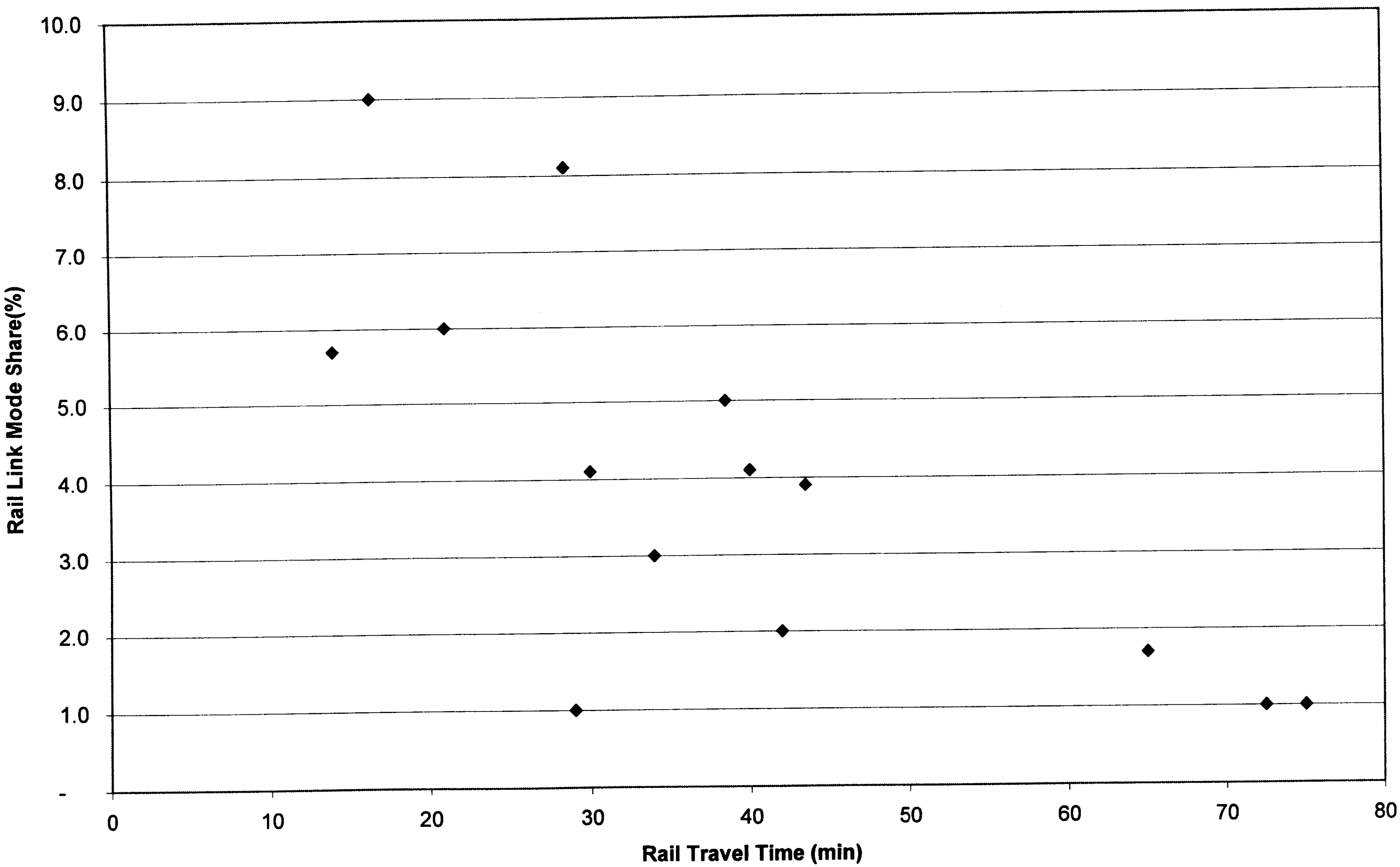
Furthermore, Table 3-2 demonstrates that speed is not as important as time. One might expect passengers to prefer a rail trip that does not stop as often, or travels at high speeds, since this might make them feel more secure about getting to the airport on time. Yet this cannot be seen in this data. Even though the BWI rail link is very fast, the distance is too great for speed to have a strong effect (although mode share on this link to Washington may be low in part because BWI primarily serves Baltimore). Conversely, Boston and D.C. are relatively slow, yet they have very high mode shares. The table also shows that distance from the CBD is not as important as travel time.

Table 3-3: Rail Travel Time Regression Results

Adjusted R Square	0.491
Independent Variable T-statistic	-3.676
Y-intercept	7.780
X-coefficient	-0.097

Figure 3-1 shows a scattergram plot of the rail travel time versus mode share. Table 3-3 shows the results of a corresponding regression analysis (full regression results

Figure 3-1: Rail Travel Time



appear in Appendix 3-A). There is clearly a relationship between rail travel time and mode share, as indicated by a strong t-statistic and a moderate adjusted R squared. However, an even clearer relationship became evident when a similar analysis was performed for travel time difference.

Table 3-4 compares airports in terms of the travel time difference between automobiles and rail links. Both times represent about how long it takes the average traveler to get to the general downtown area during off-peak hours; auto travel times in the peak periods may be much longer.

Table 3-4: Time to CBD Comparison

Airport	**Rail**	**Auto**	**Difference Between Rail and Auto**	**Mode Share**
BOS	14	8	6	5.7%
DCA	17	10	7	9.0%
STL	39	30	9	5.0%
MDW	29	19	10	8.1%
ATL	21	10	11	6.0%
OAK - to SF	40	29	11	4.1%
CLE	34	20	14	3.0%
OAK	30	14	16	4.1%
ORD	44	21	23	3.9%
SJC	29	5	24	1.0%
BWI - to Balt	40	15	25	n/a
PHL	42	17	25	2.0%
BWI - to DC	73	38	35	1.0%
JFK	65	25	40	1.7%
MIA	75	12	63	1.0%

Table 3-5: Travel Time Difference Regression Results

Adjusted R Square	0.513
Independent Variable T-statistic	-3.835
Y-intercept	6.468
X-coefficient	-0.120

The rail links with times most comparable to auto have the highest mode shares. When the difference between auto and rail is around ten minutes or less, it may not affect mode share significantly. However, when the difference is greater than 20 minutes, mode share plummets. Figure 3-2 shows the scattergram plot for this data, and Table 3-5 shows the results of a regression analysis performed on the data (full regression results appear in Appendix 3-B). The moderate adjusted R-squared and strong t-statistic indicate a strong relationship between rail/auto time difference and mode share. The regression results in the following equation for a line:

$$Y = 6.469 - 0.120X$$

Table 3-6: ln (Time Difference) Regression Results	
Adjusted R Square	0.699
Independent Variable T-statistic	-5.590
Y-intercept	12.651
X-coefficient	-3.104

The scattergram in Figure 3-2 suggests that it might be useful to fit a curve to this data rather than a straight line. In order to do this, the natural logarithm of the rail/auto time difference was calculated for each airport. A new regression analysis was then performed with the natural logarithm calculations as the new x-variable. The results of this analysis appear in Table 3-6 (full regression results appear in Appendix 3-C). The equation resulting from this regression is as follows:

$$Y = 12.651 - 3.104 \ln X$$

This equation for a curve is plotted in Figure 3-3, which also shows the original data for purposes of comparison. The curve is a good fit, indicating that the travel time difference between rail and auto may be a good indicator of mode share.

Figure 3-2: Time Difference

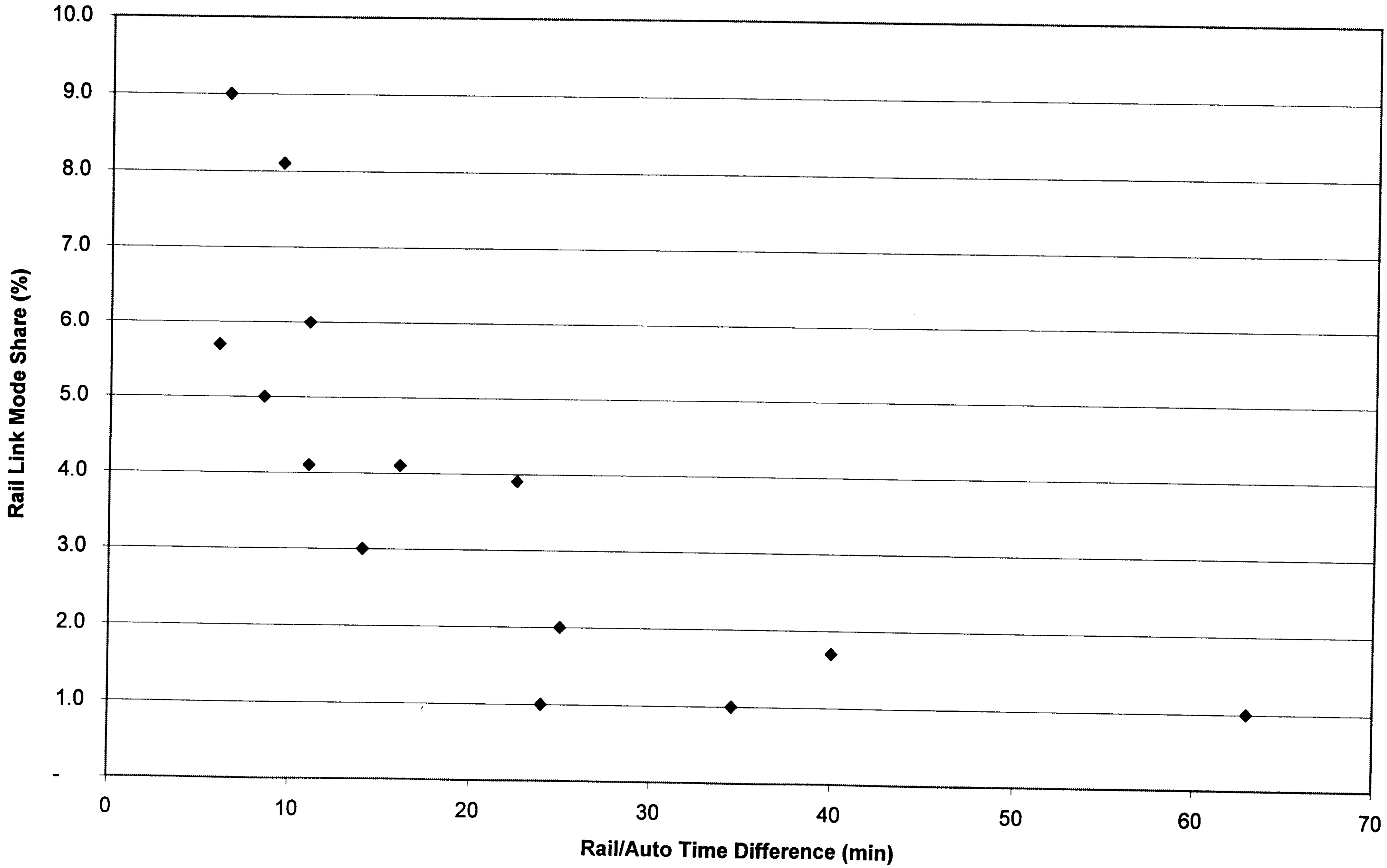
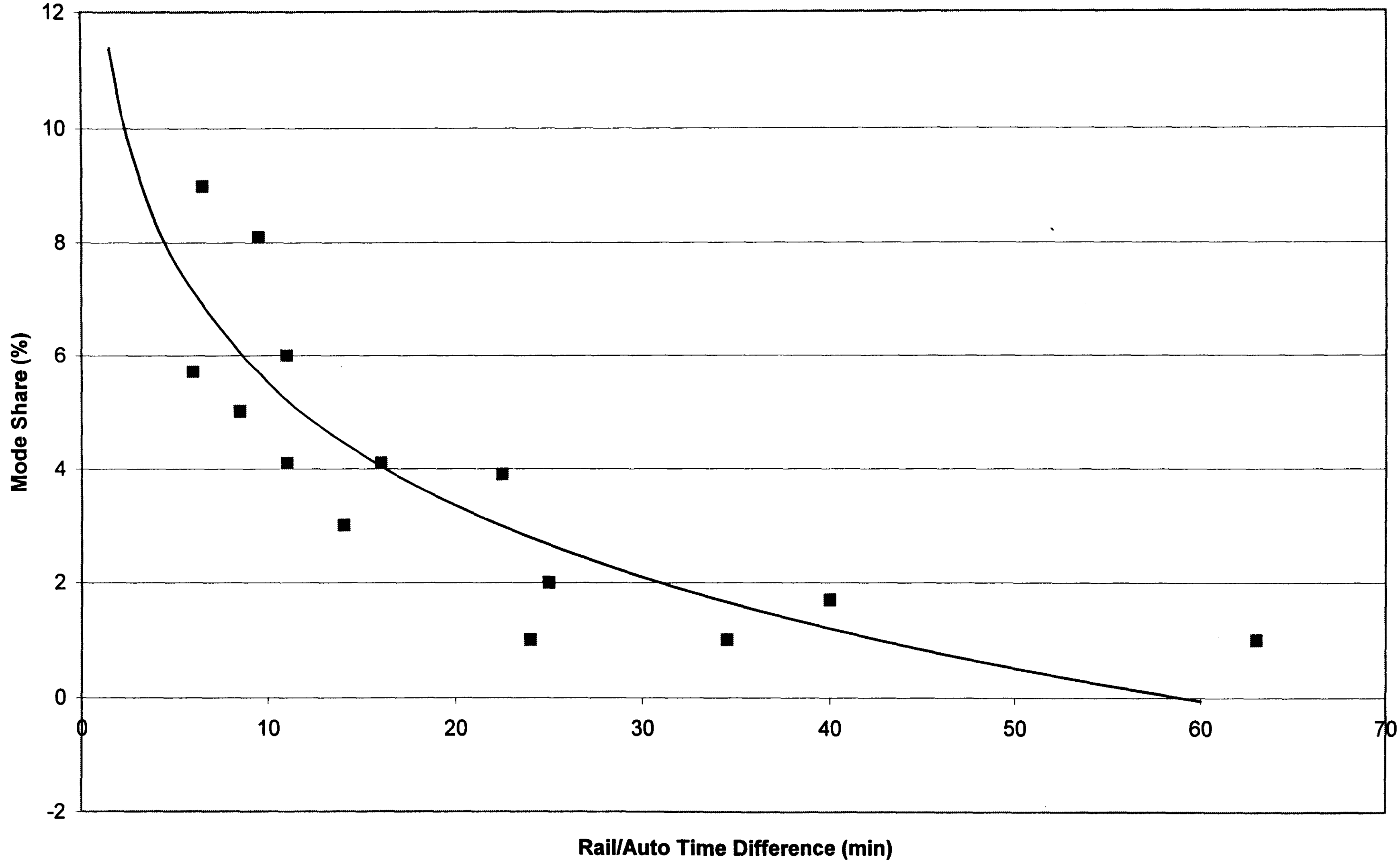


Figure 3-3: Time Difference/Mode Share Curve



3.2 Propositions

Some general propositions about airport rail links can be constructed from the case studies and subsequent analysis. They are ordered by their relative strength:

1) *A high rail/auto travel time difference is likely to significantly decrease rail mode share. A low rail/auto time difference is likely to significantly increase rail mode share.*

The data and analysis presented in section 3.1 showed that there is a strong relationship between rail/auto time difference and rail link mode share. This proposition makes intuitive sense, since airport passengers choosing between rail and auto are much more likely to use rail if they know that it will not take them much longer to make the trip. Airport travelers usually have high incomes and high values of time. This may explain why most of them will not use airport rail links that are dramatically slower than typical automobile travel times.

2) *Off-airport rail stations decrease airport rail mode share.*

The data show that of the top five airports in terms of mode share, four have on-airport stations. Moreover, of the bottom five airports in terms of mode share, four have off-airport stations. Rail links with off-airport stations must have many other positive characteristics in order to compensate for the reduction in travel time and other negative characteristics caused by off-airport stations, or else one cannot expect a significant rail mode share. Off-airport stations from which a shuttle bus is required have two effects on airport rail link characteristics. First, they increase the total travel time. Transferring to a shuttle bus requires additional wait and travel time. Since rail travel time is vital to the success of an airport rail link (see section 3.1), this is a major liability. Second, off-airport stations create a psychological and physical disconnect between plane and train that may deter passengers. Transferring modes means increased anxiety due to uncertain waiting time, moving baggage from one mode to another, and a general feeling that the trip is taking longer than it should. These two effects seem to make it very difficult for an airport rail link to capture significant mode share with an off-airport station.

The only off-airport stations in the U.S. with significant mode shares are Boston and Oakland. Both of these rail links have many other characteristics that make them viable despite the station locations. Boston is very close to the center city and automobiles travelling to and from the airport can face extreme congestion, making rail travel time comparable to auto travel time despite the off-airport station location. Also, Boston is a relatively transit-oriented city with a strong CBD. Oakland also carries significant passengers on its airport rail link. This airport is very close to the CBD and has a high proportion of low-cost carriers.

All other airports with off-airport stations have difficulty attracting passengers. Even JFK, an airport in the most transit dependent city in the U.S., cannot attract many passengers to its airport rail link partly because the off-airport station on that link creates significant additional travel time. It is possible that people movers, or other fixed right of way transit can compensate for the drawbacks of off-airport stations to some extent. When the new JFK link opens, this effect will be observable.

3) Airport rail links that effectively serve population and employment centers are likely to have higher mode shares.

U.S. airport rail links do not effectively serve metropolitan area population or employment centers, and this may partially explain their inability to capture significant mode share. No airport rail link examined is part of a rail system that provides convenient service to a significant portion of the metropolitan population. The link that comes closest is in New York City, but even there suburbanites outnumber city dwellers such that the New York City subway (which is entirely within city limits) does not cover even half of the metro area population. Most rail links do not even approximate the population coverage of New York, with links such as Atlanta, Oakland, San Jose, St. Louis, Cleveland, Miami, and Baltimore covering only a small fraction of the area population.

4) *A large concentration of international or long haul traffic at an airport is likely to decrease rail mode share. On the other hand, a prevalence of short haul traffic and/or low-cost carriers is likely to increase rail link mode share.*

The difference between Chicago's two airports is a perfect example to support this proposition. The two links are almost identical in their characteristics, but the two airports have very different kinds of passengers, which creates a significant difference in mode share. Midway serves only domestic and short-haul routes, and has a higher mode share. O'Hare serves many domestic routes, but also provides long-distance domestic departures as well as international traffic. Airports specializing in long-haul traffic are likely to have more passengers making overnight trips with baggage, which makes rail and transit in general less attractive. JFK is another good example of this problem, as it handles almost exclusively long-haul traffic. Even though New York has higher transit ridership than the Bay Area, JFK's mode share is well below that of Oakland. Distant shuttle buses serve both airports, but Oakland's primarily domestic traffic (and proximity to CBDs) gives it a higher rail link mode share.

Moreover, low-fare domestic airlines can attract significant numbers of passengers who are cost sensitive and who may be willing to switch to transit for their access mode. Atlanta, Oakland, and Midway have high rail mode shares compared to other similar U.S. links, and this is due in part to the presence of Air Tran at Atlanta, and Southwest/America West at Oakland and Southwest/Air Tran/Kiwi/America West at Midway. Comparing Oakland with Boston illustrates this point. Oakland's mode share is only slightly less than Boston's (4.1% vs. 5.7%), and both airports handle similar amounts of domestic and international traffic. Yet Oakland is further from the city (especially from San Francisco), has a higher headway (10 minutes vs. 4 minutes) and requires a longer shuttle bus than Boston. The mode share for Oakland may be higher than it would be without a major low-cost presence. San Jose is an exception to this proposition.

5) *A good airport location, one close to downtown and other major trip generators, is likely to increase rail mode share.*

Airports located at central points within the metropolitan region or near downtown are much more likely to have successful airport rail links. However, good location is not a guarantee of success. For example, the Oakland airport is very close to major trip generators, but it is weakly connected by rail and has a relatively low mode share. It is very difficult for rail to compete with the automobile at long distances, in a country where the automobile dominates virtually every city. The rail link must either stop frequently, thus making the trip much longer than by auto, or not stop at all, thus providing poor connections to points outside downtown. A short airport rail link avoids these problems.

6) High service frequency is likely to increase airport rail link mode share.

Airport rail links, as they are usually extensions of transit systems, are typically scheduled for city commuters rather than airport passengers. Airport passenger flow often peaks at different times from commuter peaks. For example, late Sunday is a peak travel time for air passengers, whereas transit experiences its lowest ridership on Sundays and offers low frequency as a result. SEPTA in Philadelphia tries to address this problem to some extent by scheduling its airport rail link on thirty-minute clock-face intervals at all times. This low frequency, however, is not more favorable to airport travelers, and results in low mode share for the PHL link. To date, no U.S. airport rail offer frequencies in accordance with airport passenger demand and no link provides consistent headways throughout the day with high frequency.

7) If an airport rail link is part of a modern, well-designed rail system, this is likely to increase mode share.

The DCA experience shows us what a difference a modern system can make, and the Boston system demonstrates the problems with rail lines that pre-date the airports they serve. In Washington, every line connects to every other line, and the airport train station is directly in front of the airport terminal. In Boston, some rapid transit lines (notably the line to the airport) do not connect with certain other rail transit lines at any point, and the airport station is a mile from the airport terminal. Creating an airport rail link from a previously constructed rail line, as was done in Boston and New York, is not likely to be as effective as designing the line from scratch.

Two different lines meeting at the airport is an especially valuable design feature, as demonstrated in Washington. It increases the number of people who have direct access to an airport rail link. More residences and more places of employment are within walking distance, or one transfer of the airport rail link. Fewer people have to go out of their way in the wrong direction to use the link. This feature is also evident to some extent in Oakland, where passengers from the airport can get one-seat rides to several different destinations. Although the potential for rail to offer this kind of feature may be limited, the rewards are great. Moreover, buses may be able to offer such a feature at a lower cost.

8) Airport rail links that do not effectively serve other areas besides downtown are likely to have low mode shares.

Contrasting Philadelphia and Washington best supports this proposition. PHL has a fast rail link, but it provides direct access only to downtown. Passengers heading for other destinations besides downtown via rapid transit have a circuitous journey. On the other hand, DCA is connected to Metro by two rail lines. These lines offer many destinations with reasonably direct service. The mode share at DCA is significantly higher.

Admittedly there are other factors involved, but only Philadelphia has a rail link that makes so few stops en route to downtown, and Philadelphia has a very low mode share considering its relatively positive characteristics in terms of rail time to CBD, and transit orientation.

9) *A vast transit network does not guarantee high airport rail link ridership - the transit network must work to the advantage of airport passengers.*

New York City has the best transit network and by far the highest transit ridership in the U.S., but the JFK rail link mode share is among the lowest. Although there are many contributing factors, one key reason is that the rapid transit network in New York is designed for commuting, not for efficient travel from a single non-central location, JFK, to other points in the city. Philadelphia also has a substantial rail transit network, but a low airport rail link mode share. Simply having an extensive transit network is not sufficient to induce high airport rail link mode share.

10) *Residents and non-residents appear equally likely to use airport rail links or public transportation to access the airport.*

Although the data on this subject is not complete, the small sample available indicates that there is little difference between resident and non-resident use of airport rail links. This proposition can potentially be explained by an interesting phenomenon. Residents are more likely to use the links because they are more likely to be aware of them. However, residents are also more likely to be able to secure a ride to the airport from a friend or family member, or to drive themselves to the airport. A non-resident might be picked up, but if not, the other options such as taxi, rental car, and airport limo are all significantly more expensive than public transportation. This could explain why residents and non-residents are equally likely to use public transportation to the airport.

11) Airport workers are more likely to use airport rail links than airport passengers.

The data are not complete on this topic, but judging from the four airports examined (St. Louis, Boston, New York, and Chicago), airport workers seem more likely than passengers to use rail links. Intuition supports this proposition, since airport workers are more likely to be able to align their place of residence with an airport rail link, and the regularity of their airport trips eliminates other popular options among passengers such as taxis and rental cars. Moreover, the limited availability of parking at airports is likely to limit the number of airport workers who have the option of driving to work.

Chapter 4 – Further Analysis

The propositions presented in Chapter 3 are based on the limited data available from the case studies. However, it is useful to perform some further exploratory analysis on them in order to determine how strong they are. The first part of this chapter is just such an analysis, made possible by the existence of a natural before and after experiment. The second part of this chapter further analyzes the relationship between population, employment and airport rail link mode share.

The case studies suggested that off-airport stations are associated with reduced rail link mode share. Since San Juan is considering an off-airport station, this proposition is an important element in this research. It is also, fortunately, somewhat testable due to the natural experimental design setup provided by DCA. Washington National airport recently opened a new terminal that is significantly closer to the Metro airport rail station than was the old terminal. Whereas the old terminal (which is still in operation) requires a 1/3rd of a mile walk (or use of a free shuttle bus), the new terminal is directly connected to the rail station by a short pedestrian bridge. Since most air passengers at National use the new terminal, the airport rail station has, in effect, been "moved" closer to the air passenger terminal for most travelers. This makes it possible to examine the effect of this "move" on airport rail traffic and thus to draw some conclusions about the relative importance of an on-airport rail station at least in one instance.

The second proposition pegged for further analysis is the idea that rail link mode share is dependent to some extent upon how many residences and places of employment are effectively served by the link. To test this proposition in reality, the population living within a quarter-mile and half-mile radius of certain rail links will be calculated and compared. Ideally, a similar analysis would be performed for employment. Since it was found to be very difficult to get geographic data on job locations, instead the relative strength of the CBDs of these cities will be compared. Since all airport rail links in the U.S. are designed to serve the CBD, this measure is an effective proxy for how well the link serves places of employment, and it is much easier to estimate.

4.1 Washington National Case Study Extension

Washington National has long been the king of airport rail links in the U.S. However, until its brand new airport terminal opened in July 1997, the walk from the train station to the airport terminal was significant. Many riders used a shuttle bus to travel that distance of 1/3rd of a mile, and often wound up stuck in internal airport traffic. The train station was built next to the site of the planned new terminal, long before the new terminal opened. Now that the new terminal is open, most passengers (about 80% fly out of the new terminal[74]) can make an easy indoor transfer via a pedestrian bridge from train to plane, while very few passengers still must walk or take a shuttle bus to the old terminal. National Airport officials predicted that rail mode share would increase from less than 10% to 20% with the opening of the new terminal[75].

This recent change provides a unique opportunity to study the effect of "moving" an airport train station closer to the airport terminal. Hopefully, this will provide some insight as to the effect of the distance from an airport terminal to the rail station on rail link mode share. If a very significant effect is detected, this will serve to support the importance of on-airport rail stations. If little or no effect is detected, the importance of airport rail station location must be questioned.

The Washington case is not directly analogous to San Juan, nor to the rest of the country and this limits the applicability of this analysis somewhat. Washington Metro is a well-established rail system (compared to Tren Urbano, which is not yet in operation). Washington D.C. is located quite close to other major metropolitan areas, allowing business travelers to fly in for the day or a short trip, thus reducing the number of passengers with large baggage. The city of Washington has a more established center and is a much larger city than San Juan. However, while all of these factors may influence airport rail link ridership, they may not influence on the relative effect of "moving" an airport rail station closer to an airport terminal.

4.1.1 The Case Study Revisited

Before beginning this analysis, it is useful to review for DCA all of the factors that are thought to influence airport rail link mode share. Some of these factors are known to have remained constant since just before the new terminal opened, while others may have changed and therefore may have influenced airport rail link ridership. In order to determine the true effect of "moving" the airport train station, it is important to see if changes in these factors in the recent past may have affected airport rail link mode share. For the purposes of this analysis, the recent past is considered to be the last five years. Each factor analyzed in the original DCA case study will now be revisited.

Location relative to city:

Unchanged. Neither the city nor the airport has moved in the past five years.

Productions and Attractions along Rail Link:

Although this factor has not remained unchanged in the past five years, it can be assumed that no significant change occurred that would have impacted airport rail link mode share, since cities typically do not experience significant changes so rapidly.

State of Local Public Transit/Cultural Factors:

The Metro system has undergone some changes during the past five years that could have impacted rail link mode share. Most significantly, two new stations were opened. One of these is the Glenmont station on the Red Line (opened 7/25/98), which is a distant suburban station that is the new terminus for that line. The other is the Franconia-Springfield station (opened 6/29/97), which is also a suburban terminus, but for the Blue Line. Both of these station openings could have helped to increase rail link mode share, although the Franconia-Springfield station is likely to have had a greater impact since it is on one of the airport lines.

Overall, Metro has experienced a modest system-wide ridership increase in the past five years. The month of May is often used as a proxy for yearly ridership figures. In May 1994, Metro has 517,256 riders, whereas in May 1998, there were 527,986 riders. This increase of 10,730 shows that the popularity of the Metro system is rising. The fare for riding the Metro, which is based on distance and time of day, increased once during the past five years. This increase (6/24/95) made the minimum peak fare $1.10 (up 10 cents) and the maximum peak fare (over 10 miles) $3.15 (up 30 cents). The off-peak 7 to 10 mile fare was increased to $1.50 (up 25 cents), and the maximum off-peak fare was raised to $2.00 (up 50 cents). However, many fares were not increased and thus experienced a decrease in real terms due to inflation (approximately 10% between 1994 and 1998[76]). Of the fares that were increased, only the off-peak fares show an increase after accounting for inflation. Peak fares increased at about the same rate as inflation.

Ease and Availability of Connections:

No change. The Metro system layout has not changed significantly in the past five years.

Airport characteristics:

Although National now has a new terminal and a new name, the basic characteristics of the airport have gone virtually unchanged in recent years. Low-cost carriers continue to be unable to obtain slots at National, and the perimeter rule (not permitting flights over 1,500 miles) is still in effect, so there has been no significant change in the type of air service available at the airport.

The parking rates at National Airport have not changed since July of 1995 (when they were increased). At that time, the Mid Term parking rate was increased from $10 to $12. This rate increase was so slight that it barely counteracted inflation and can be ignored.

One thing at the airport that may have been affecting mode share during the past five years is the ongoing construction of the new terminal. Although this construction began more than five years ago, it is likely to have impacted mode share. Whereas rail link mode share at National was close to 15% before construction started, mode shares during construction were around 9%. Therefore, any rise in airport station ridership since the opening of the new terminal may be due to the end of construction, as well as (or rather than) the improved rail station location.

Speed Relative to Other Modes:

No change other than the new terminal opening and its impact on speed. No major track improvements or speed increases occurred in the last five years. It is safe to assume that traffic in the Washington area has continued to worsen, however, and that the speed of Metro relative to other modes has increased as a result.

Table 4-1: Changed and Unchanged Factors at Washington National (1994 to 1998)

Factor	Change	Possible Mode Share Effect
parking rates	slight decrease	slight decrease
state of local transit	slight increase	slight increase
transit fare(s)	increase/decrease/unchanged	none
airport characteristics	None	none
speed and reliability relative to other access modes	slight increase	slight increase
ease and availability of connections	None	none
location of the airport relative to the city	None	none
local cultural factors	None	none
productions and attractions along link	None	none

The changes to relevant factors and their possible impact on airport rail link mode share are summarized in Table 4-1. As the table shows, very few of these factors have changed, and those that have are likely to have had minimal impact on mode share at DCA. The improvements to the state of local transit (increased ridership) could be part of an increase in mode share, but on the other hand, an increase in mode share due to the new terminal opening could be responsible for part of those ridership figures. Although new station openings on Metro might have some impact on mode share this impact is limited since those stations are in suburban areas.

Table 4-2: Summary of DCA Factors	1995	1998
Airport Pax/Year (Millions)	16	16
Origin and Destination Pax	15	15
Transit Fare	$ 1.10	$ 1.10
Rail Peak Headway (Minutes)	3	3
Rail Travel Time (Minutes)	18	17
Auto Travel Time (Minutes)	10	10
Rail/auto Difference	7	7
Miles to CBD	4.5	4.5
Station in terminal?	No	Yes
Short Term Parking Rate	$ 4.41	$ 4.00
Mid Term Parking Rate	$ 13.22	$ 12.00
Long Term Parking Rate	$ 8.81	$ 8.00
Rail Link Speed (MPH)	16	16
Rail Link Mode Share	9.0%	n.a

Table 4-2 summarizes the relevant factors for DCA and how they have changed since 1994. All dollar amounts are in 1998 dollars. According to this table, no significant change has occurred at DCA that might have influenced rail link mode share, aside from the obvious terminal move. It is now possible to examine ridership figures for the airport station at DCA in recent years with the knowledge that any increase in passengers is most likely due to the opening of the new terminal and its preferred location with respect to the Metro station.

4.1.2 Time Series Analysis

Table 4-3: Activity at Metro Airport Station Before and After New Terminal Opening of July 27, 1997

	Boardings	**Alightings**	**Total**
12 Months Prior	1,270,344	1,200,715	2,471,059
12 Months Following	1,603,075	1,473,800	3,076,875
Total Increase	332,731	273,085	605,816
Percent Increase	26%	23%	25%

Table 4-3 shows that there has been a substantial increase in the number of passengers using the airport Metro station since the opening of the new terminal. Boardings show a slightly greater increase than alightings, perhaps indicating that more passengers arriving at National were enticed to use the more convenient link. However, as Figure 4-1 shows, the major surge in passengers at the airport train station actually occurred slightly before the opening of the new terminal, during July 1997. A closer look at the daily data is necessary.

Figure 4-2 shows the daily ridership figures at the airport station during July and August of 1997. It is clear from this data that the apparent July ridership boost is really the result of two anomalous days (July 19 and 20). However, whether or not those days are ignored, Figure 4-2 shows that there was a general ridership increase after the new terminal opened. The chart shows that there was a steady decline in ridership after the new terminal opened, but that this decline was from a higher ridership level. Whereas before the terminal opening, ridership figures fluctuated between 5,000 and 10,000, after the opening they fluctuated between 7,500 and 15,000.

Table 4-4: Boardings at National Airport Station

	Average Daily Boardings	Daily OD Enplanements	Percentage
May-90	5,657	20,611	27.4%
May-91	4,548	19,640	23.2%
May-92	4,603	20,289	22.7%
May-93	4,699	21,187	22.2%
May-94	3,997	20,387	19.6%
May-95	4,094	20,159	20.3%
May-96	4,192	19,834	21.1%
May-97	3,956	20,677	19.1%
May-98	4,876	20,557	23.7%

The analysis presented in Table 4-4 attempts to account for the obvious link between Metro airport station boardings and passenger enplanements at National airport. The "Daily OD Enplanements" column refers to 95% of the total enplanements for that year (5% are assumed to be transfer traffic[77]) divided by 365.25. The percentages show a significant increase since the terminal opened (July 1997). Unfortunately, we only have one year of data available since the terminal opened, but this analysis makes it clear that

Figure 4-1: Activity at Metro Airport Station

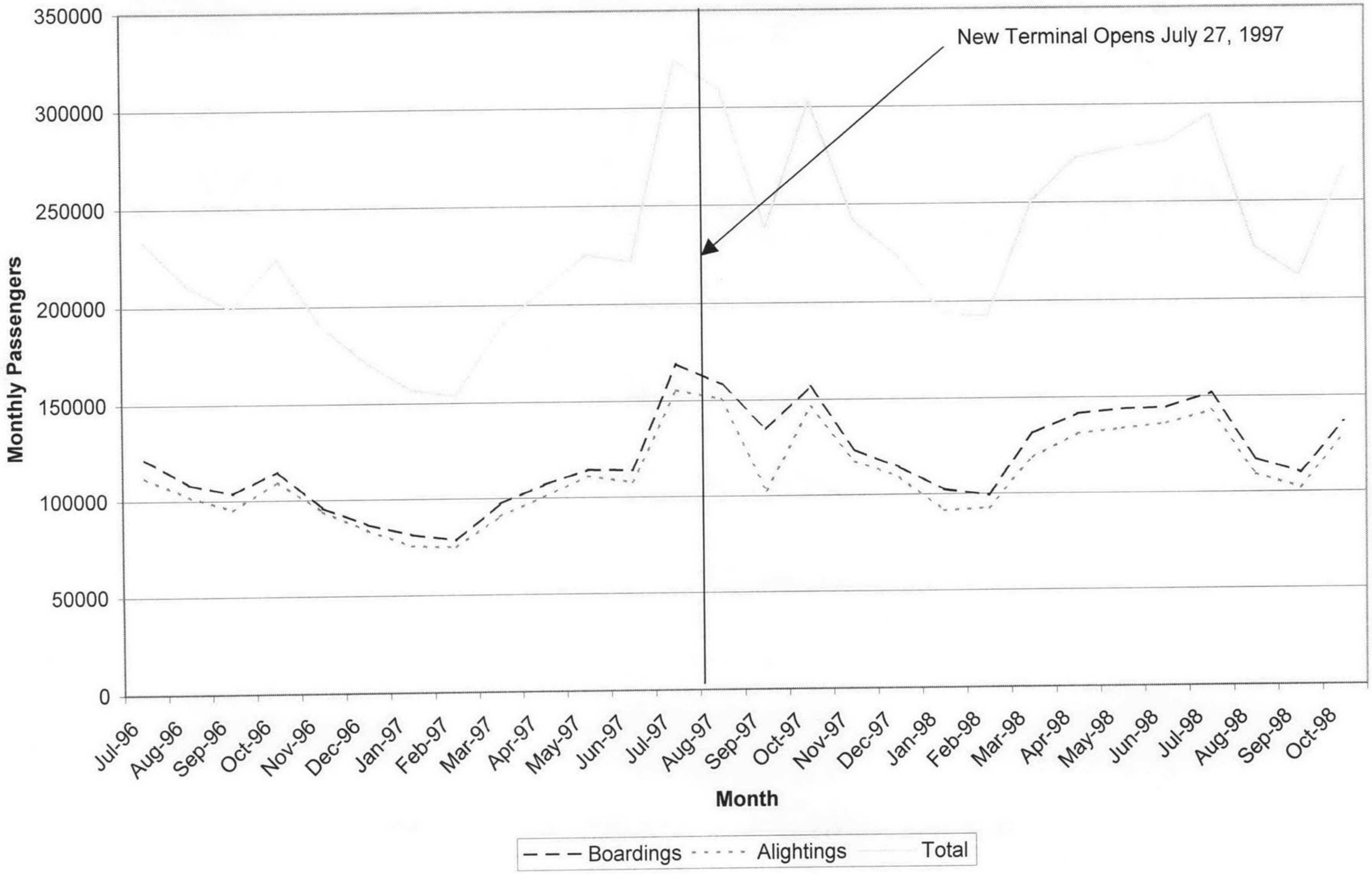
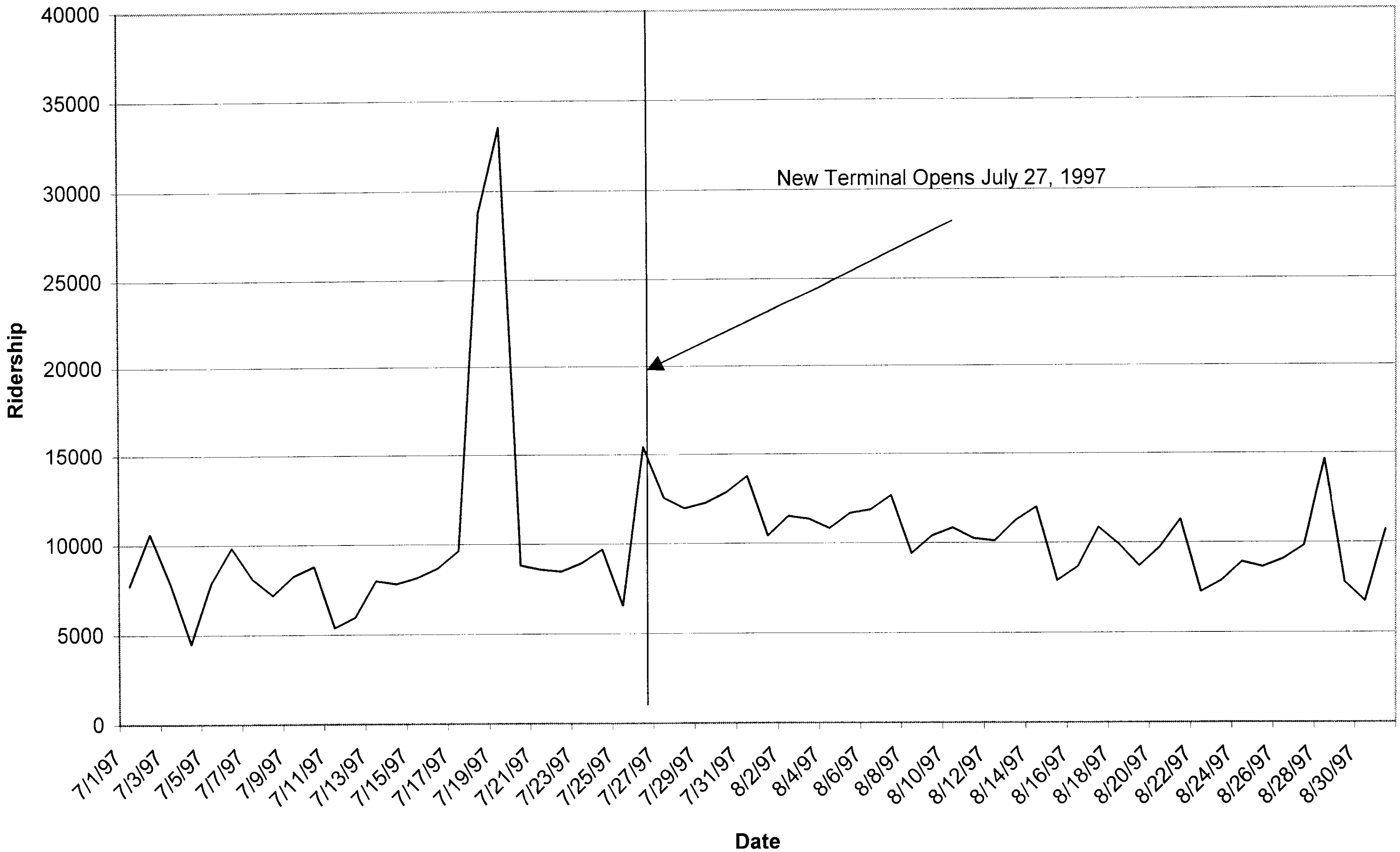


Figure 4-2: July/August Metro Airport Station Ridership



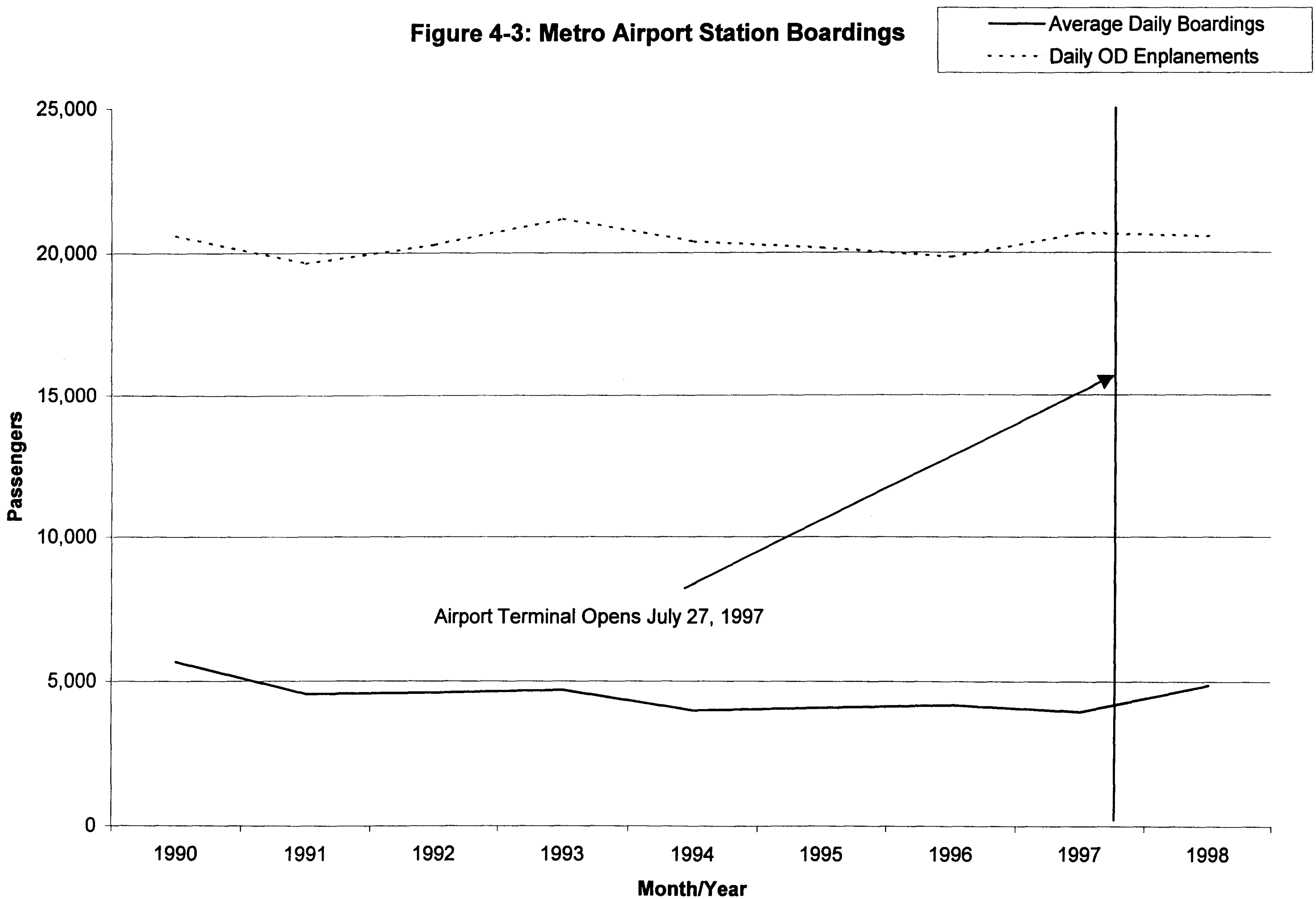
even accounting for the increase in travel, there has been an increase in passengers using the airport Metro station in the past year. However, it also shows that the percentage of passengers accessing the airport by rail still has not reached the level it attained back in 1990, before construction. Figure 4-3 displays these data graphically. The graph shows that despite a slight decrease in the total number of passengers using National airport since the new terminal opened, Metro airport station passengers have increased.

4.1.3 Extended Case Study Conclusions

The real cause of a ridership increase cannot be determined with absolute certainty. However, the ridership increase at the Washington National airport station seems attributable to the opening of a new terminal. The new terminal opening signaled the end of construction, and the "moving" of an airport rail station to a point that is much closer to where the majority of air passengers are going. It is not known how much of the ridership increase is attributable to a closer airport station, and how much is attributable to the ending of construction, but it is likely that both of these changes have had an impact.

The most convincing evidence that such an increase occurred is Figure 4-1, which shows greater ridership figures for the Metro airport station for every month since the new terminal opened. This information coupled with the knowledge that airport passengers at National have not been increasing makes it clear that the increase in station ridership was not due to increased air traffic. We can therefore conclude that "moving" the airport train station closer to the airport terminal, and/or the ending of construction, was the likely cause of increased mode share for the airport rail link at National.

Figure 4-3: Metro Airport Station Boardings



The applicability of this analysis to other airport rail links is admittedly limited. The link at National has consistently had the highest mode share of any link in the country. We cannot assume that "moving" airport train stations closer to airport terminals at other airports with less successful airport rail links would have a similar effect. However, considering the magnitude of improvement evident at National, it is likely that even poorly patronized airport rail links would realize some benefit from improved rail station location.

4.2 Population and Employment Data

One potential explanation for the ineffectiveness of airport rail links in the U.S. is that in cities with such links, only a small percentage of the population lives near the link or a rail station along a line that connects to the link. If very few people can easily get from their home to the airport by rail, this would certainly explain why rail links have poor mode shares. Furthermore, the people served by airport rail links may not all be likely air passengers. Rail links that serve people with incomes comparable to those of air passengers are more likely to attract high mode shares. Moreover, residences are only half of the total picture. Many travelers need to access the airport from work, and many visitors need to access employment areas to conduct business. Airport rail link mode share might also be explained, in part, by the number of jobs that are effectively served by the link.

Four airports were selected for population and employment analysis. The airports were divided into two pairs that make for effective comparisons. The first pair is BOS and JFK. These airport both have off-airport stations, and they are both located in older, northeastern metropolitan areas. The second pair is ORD and MDW. Since these airports are in the same city, they provide an ideal way to see population and employment characteristics significantly influence mode share.

4.2.1 Population Analysis

This section contains the results of research that seeks to determine approximately how many people live within walking distance of airport rail links in Chicago, Boston and New York. A description of the method that was used is followed by the results for each city/airport combination.

For each link, two population figures based on 1990 census data are presented. The "direct" figure represents an estimate of how many people live within a quarter mile radius of a station on the airport rail link. This does not include any transferring passengers except in New York, where those passengers transferring from local to express trains on the same line are included. The figure also excludes people for whom a trip to the airport via rail is implausible. For example, a person may live along the airport line, but live so far away from the airport that rail is an unrealistic alternative. The second population estimate is called "transfer" and refers to those people who live within a quarter mile radius of a rail station that allows them to access the airport by transferring to the airport rail link. Excluded from this estimate are people who must transfer from local to express trains, and those for whom a rail trip to the airport is unrealistic due to a long trip time or other available transit options.

The population estimates were made as follows. First, it was determined which rail stations to include in the data set. This was strictly a judgement call, but it was based on the estimated time for an airport trip from that station, whether or not other more realistic transit options exist, and whether or not a trip to the airport from that station would require extensive travel in the wrong direction. Second, these transit stations were plotted on a map of census tracts in TransCAD. This was done by determining exactly where each station was with respect to city streets using recent transit maps. Then these same streets were found on the census tract map, and a point was placed to indicate the station location. The station was located as precisely as possible, but nonetheless, it is sometimes very difficult to determine the exact location of a station from a map. However, there were no cases where the error in station location could have been great enough to significantly skew the analysis.

Once the stations were located, quarter mile bands were drawn around each. The bands are circles (radius of a quarter mile) with the station at the center. TransCAD was then employed to calculate selected 1990 census statistics for population within each band. In cases where bands overlapped, statistics were not double counted. TransCAD calculates band statistics by calculating the percentage of each census tract that lies within each band. These percentages are then used to estimate the statistics for the band by adding together the percentages multiplied by the totals for each tract.

For each city, the results are presented in a table. For both direct and transfer stations, tables show the "station area population" indicating how many people lived within walking distance of those stations in 1990. The "percentage of CMSA" column shows what percentage of the metropolitan population is covered by the link. For New York and Chicago, where the rail links and realistic transfers to them do not include points outside the city proper, a "percentage of city" column is also listed. Finally, the average median household income for the population near the stations is shown.

Boston:

All stations on Boston's Blue Line are included in the "direct" population calculation due to the short length of that line. For the "transfer" population, all stations on the Orange Line are included since this line connects easily with the Blue Line and is relatively short. The only Red Line stations included are those between Harvard and JFK, since accessing the Red Line from the Blue Line requires two transfers. All Green Line trunk stations are included. The B line stations are included as far as Chestnut Hill Road, all C and E line stations are included, and the D line stations are included up to Newton Highlands (see Appendix 2-F).

Table 4-5: BOS Link Population

	Station Area Population	Percentage of CMSA	Average Median Income
Direct	18,759	0.45%	$28,700
Transfer	199,056	4.77%	$31,763

Table 4-5 shows that the Blue Line and connecting lines effectively serve less than 5% of the metropolitan area residents. The Blue Line itself serves less than 1 percent of the area population, which is not surprising since the line is so short. The median household income for Boston area residents in 1990 was $40,647, and the median household income for the average Logan passenger was $88,970 in 1996, or $72,609 in 1990 dollars. The average passenger for whom the BOS airport rail link is convenient has a below average income for the area, and well below the average for airport passengers. This means that population served by the link that is likely to need to access Logan is even smaller than the percentage served by the link.

New York:

All stations on the "A" train outbound from JFK are included in the "direct" population calculation for New York City. Inbound stations are included until 125th street in Manhattan. Many stations on the "C" line, the local partner to the "A" train, are included in the "direct" calculation because psychologically, transferring from local to express in New York does not seem like a true transfer (one can often see the express train while in transit, thus reducing waiting time). "C" train stations within Brooklyn and Queens are included in this calculation. There are many stations included in the "transfer" population are due to the large number of reasonable connection possibilities. They are listed in Table 4-6.

Table 4-6: New York City Transfer Stations

Line	**Stations Included**
J/Z	Woodhaven - Marcy Avenue in Queens/Brooklyn Broad Street - The Bowery in Manhattan
L	Bedford Avenue - East New York
G	Smith/9th Street - Broadway/Union Avenue
S (Brooklyn)	All
F	Church Avenue - Broadway Lafayette
D/Q	Local: Prospect Park - Church Avenue Express: Prospect Park - Kings Highway
M	All
1	Chambers Street - Christopher Street
2,3	Wall Street - 42nd Street
B/D/F/Q (6th Avenue)	Local: West 4th Street and 34th Street Express: West 4th Street and 42nd Street

Table 4-7: JFK Link Population				
	Station Area Population	**Percentage of City Pop**	**Percentage of CMSA**	**Average Median Income**
Direct	238,274	3.25%	1.32%	$28,021
Transfer	835,049	11.40%	4.62%	$26,638

Table 4-7 shows that a very small percentage of New Yorkers live within walking distance of a stop along the JFK rail link. Even the percentage of city residents living near a transfer station (11.40%) seems low for a city that is very well covered by rapid rail transit. The median income for the New York area in 1990 was $37,869, much higher than the median income for residents near the rail link, and even higher than the median income for transfer passengers. The median income for the average JFK traveler is currently $79,000, or $61,548 in 1990 dollars. Therefore, the figure for the percentage of the area population served by the JFK link is probably higher than the percentage who actually need to access the airport as passengers.

Chicago Midway:

All stations along the MDW airport rail link (the Orange Line) are included in the calculation of the "direct" population. Transfer stations include those on the Green Line between 35th Street and Ashland Avenue, Red Line stations between Chicago Avenue and Roosevelt Avenue, Brown Line stations between Chicago Avenue and the Loop, and Blue Line stations between Chicago Avenue and Clinton St.

An important caveat should be considered while examining the data for MDW. When the 1990 census was conducted, the Midway Orange Line had not yet opened. In fact, it did not open until three years later. Therefore, it is quite possible that the population around the line has increased more dramatically since 1990 than those of the other links.

Table 4-8: MDW Link Population				
	Station Area Population	**Percentage of City Pop**	**Percentage of CMSA**	**Average Median Income**
Direct	15,276	0.55%	0.19%	$30,034
Transfer	35,619	1.28%	0.44%	$27,764

The number of Chicagoans within walking distance of an Orange Line station or a potential transfer station is again extremely small. Moreover, the median income in the Chicago area was $35,916 in 1990, higher than the income for the average resident near the Orange Line or transfer stations. Furthermore, the median household income for Midway passengers in 1990 was $60,995. Therefore, the percentages include many people who rarely, if ever, need to access the airport.

Chicago O'Hare:

All stations on the Blue Line were included in the calculations of the "direct" population except for those stations West of Cicero Avenue. Transfer stations include all Loop stations, the Orange Line to Halsted St., the Brown Line to Chicago Avenue, the Red Line between 35th Street and Chicago Avenue, and the Green Line between Halsted St. and 35th St.

Table 4-9: ORD Link Population				
	Station Area Population	**Percentage of City Pop**	**Percentage of CMSA**	**Average Median Income**
Direct	103,881	3.73%	1.29%	$24,695
Transfer	123,590	4.44%	1.53%	$25,826

The O'Hare rail link effectively captures a very small percentage of the metropolitan and city population. The median income captured is not only less than the Chicago area median, but also drastically lower than the average for O'Hare passengers of $76,000, or $60,217 in 1990 dollars. Therefore, even people that do live close to the ORD link are not very likely to be airport travelers.

4.2.2 Population Comparison

Table 4-10: Population Access for MDW and ORD

	Airport	Station Area Population	Percentage of CMSA	Income Differential	Mode Share
Direct	MDW	15,276	0.19%	$30,961	8.1%
	ORD	103,881	1.29%	$35,522	3.9%
Transfer	MDW	35,619	0.44%	$33,231	8.1%
	ORD	123,590	1.53%	$34,391	3.9%

Table 4-10 compares the two airports with on-airport stations (MDW and ORD). The "income differential" column refers to the difference between the median household income of passengers at the airport and the average median income of households near direct or transfer stations (as the case may be). There is no major difference between the airports in terms of the percentage of the population that they capture or the median incomes of those populations, even though there is a large difference in mode share. Moreover, the ORD link serves many more people, yet has the lower mode share. This suggests that it is likely that the difference in mode share between these two airports is unrelated to the resident population that they serve.

Table 4-11: Population Access for BOS and JFK					
	Airport	**Station Area Population**	**Percentage of CMSA**	**Income Differential**	**Mode Share**
Direct	BOS	18,759	0.45%	$43,909	5.7%
	JFK	238,274	1.32%	$33,527	1.7%
Transfer	BOS	199,056	4.77%	$40,846	5.7%
	JFK	835,049	4.62%	$34,910	1.7%

Table 4-11 compares the two airports with off-airport stations (BOS and JFK). Surprisingly, they serve similar population percentages despite the vast size of New York's rail network. However, Boston's airport line serves a very small number of residents on its own. Yet despite this problem and a higher income differential than JFK, the BOS rail link garners a significantly higher mode share. This suggests that the mode share of these two links is not strongly related to their ability to serve the residential population.

The analysis above shows that, for the cities examined, a very small percentage of the metropolitan area population lives near a rail link or a rail station on a line that connects to the link. It was then hypothesized that perhaps a quarter-mile radius is too small, and more significant populations live within a half-mile of the appropriate stations. The program was run again with half-mile bands around each station. The results can be seen in Tables 4-12 and 4-13.

Table 4-12: Adjusted Population Access for MDW and ORD					
	Airport	**Station Area Population**	**Percentage of CMSA**	**Income Differential**	**Mode Share**
Direct	MDW	59,874	0.74%	$34,254	8.1%
	ORD	312,724	3.88%	$35,662	3.9%
Transfer	MDW	115,119	1.43%	$36,233	8.1%
	ORD	356,301	4.42%	$35,703	3.9%

Table 4-13: Adjusted Population Access for BOS and JFK					
	Airport	**Station Area Population**	**Percentage of CMSA**	**Income Differential**	**Mode Share**
Direct	BOS	52,275	1.25%	$44,389	5.7%
	JFK	705,753	3.90%	$34,035	1.7%
Transfer	BOS	381,331	9.14%	$39,248	5.7%
	JFK	1,646,639	9.10%	$35,828	1.7%

The tables with adjusted figures show that even with a half-mile radius around stations, very few people live within walking distance of airport rail links in Boston, New York, and Chicago. New York's link is superior in this category, serving almost 10 percent of the population via transfers. However, this is probably unrelated to mode share as JFK has the lowest mode share of any airports studied. All of the data shows that the airport rail links studied are not convenient for most metropolitan area residents and that their relative convenience seems unrelated to mode share.

This analysis suggests that American rail links do such an ineffective job of serving the population that their relative strength in this area is irrelevant. Logically, one would expect accessibility to affect mode share. Unfortunately, in the cases examined here, this effect is not apparent. This may be due to the strong differences in quality between the links examined. The effect may also be obscured by the fact that no U.S. airport rail link attracts a high mode share. Perhaps with higher mode shares, the effect of accessibility becomes more readily apparent. Similar studies of European airports, where mode shares tend to be in the 30% range, might help determine the role that effectively serving a population plays in mode share.

4.2.3 Employment Analysis

For the purposes of comparison, the same rail links used in the population analysis will be studied in this employment analysis. Virtually all U.S. airport rail links are designed to serve the CBD directly. Therefore, one measure of how well an airport rail link serves places of employment is a measure of the employment in that center city. A rail link serving a city with a very low center city employment is likely to have trouble capturing significant business passengers, since airport rail links rarely serve suburban office parks.

Since data for this analysis was collected from local MPOs, the CBD definition in each case was the one used by that particular MPO. In New York the CBD is Manhattan below 60th Street. For Chicago, the northern boundary is Chicago Avenue, the eastern boundary is Lake Michigan, the southern boundary is Roosevelt Avenue, and the western boundary is Halsted Street. In Boston all areas north and east of Massachusetts Avenue (except South Boston) on the downtown side of the harbor are considered to be part of the CBD.

The definitions for all three cities serve this analysis well. Some sections that are not directly connected to the airport rail link are included for all cities, but in general, any area within the defined CBD can be easily accessed by rail from the airport. The figures for all three cities are the most recent available. Both the Boston and New York employment figures are from 1996, while the Chicago figure is from 1995.

Table 4-14: CBD Strength

City	CBD Employment	MSA Employment	CBD Strength
New York	1,850,000	8,445,500	21.9%
Chicago	525,200	3,801,800	13.8%
Boston	315,430	2,160,094	14.6%

Table 4-14 shows that New York has a stronger CBD than Chicago or Boston, which both have similar CBD strengths. This would seem to indicate that New York would have a better chance of attracting significant airport rail link mode share, but this has not happened. Both Chicago links and the Boston link have higher mode shares than the link to JFK. The percentages show that, for these particular cases, CBD strength is not a good indication of mode share. However, it is possible that if the airports and links being compared were more similar, the effect of CBD strength on mode share would be more apparent.

The percentages also show that airport rail links serving downtown exclusively are not bringing people to a large share of jobs. If anything, these numbers are over-representing CBD strength and the number of jobs served by airport rail links. This means that the vast majority of airport passengers traveling to and from work are unlikely to be able to use an airport rail link easily.

4.2.4 Conclusions from Population and Employment Analysis

None of this analysis has shown any correlation between population captured by an airport rail link and mode share, or strength of CBD and mode share. JFK and BOS both have off-airport stations and similar population captured by their airport rail links. New York has a stronger CBD. Regardless, BOS has a much higher mode share than JFK. This indicates that population and employment locations may not play as large a role in determining the rail link mode shares of these two airports as do other factors. Both Chicago airports have on-airport stations, a small population percentage served by their rail links, and the exact same CBD strength. Yet MDW has a much greater mode share than ORD. The ORD rail link actually serves slightly more residents than the MDW link. Clearly this does not impact mode share significantly in this particular case.

The results from this analysis are by no means definitive. The population distribution of these metropolitan areas has probably changed significantly since 1990. Moreover, the number of businesses effectively served by each link may not be accurately represented in the employment analysis above. Finally, it may be that these airport rail links all do such a poor job of effectively serving population and employment centers that this is an important reason why their rail mode shares are very low. Perhaps if any of them effectively served more of the population, we would see a difference in mode share based upon how well they did so. It is possible that the mode share of an airport rail link is strongly correlated with the percentage of metropolitan area population and jobs served by the link, but that this correlation is obscured by low mode shares in the cities examined.

Chapter 5 - The San Juan Case

This chapter will explore the city of San Juan as a case study. Section 5.1 presents the various plans for potential airport rail links in San Juan that are currently under consideration. Section 5.2 presents the basic data about San Juan relevant to the study of airport rail links, in a manner comparable to the detailed case studies of the second chapter.

San Juan is a very different city than those found on the mainland U.S. A Latin culture and hot climate unlike virtually any city examined in this research make San Juan quite distinct. Moreover, the city does not have a downtown like those found in the other cities discussed previously. There is no clear way to define the central business district in San Juan. The closest thing San Juan has to a CBD is the Hato Rey area, which contains large office buildings for several banks. Although Hato Rey is considered to be the CBD in this analysis, it does not have the concentration of jobs that characterizes most mainland CBDs.

It is also important to recognize that there is currently no passenger rail service at all in San Juan or on the entire island of Puerto Rico. Construction on the Tren Urbano trunk line (Appendix 5-E), phase 1 of the system, began in September 1997. When completed, the trunk line will run in a J-shape from the suburbs of Bayamon to the edge of Santurce. Aside from a small underground section, most of the line will be elevated or at-grade. The first extension, phase 1-A, is well into planning will create an additional subway portion under Avenue Ponce de Leon. A long history of development without any kind of dedicated transit ways has created a level of auto dependence in San Juan that is much greater than those in other cities of comparable density.

5.1 Current Plans for San Juan

Plans for a San Juan airport rail link are detailed in a report by the General Management Architecture and Engineering Consultant (GMAEC) for Tren Urbano[78]. Although this report is by no means a final plan for the corridor, it is the closest thing available at this time. The report, referred to here as the "Airport Corridor Study", was conducted for the PRHTA (Puerto Rico Highway and Transportation Authority) for the purpose of providing that agency information on the options for possible Tren Urbano extensions. As a result, the report does not thoroughly consider other modal options besides heavy rail, and it focuses heavily on cost/ridership forecasts for each option. Furthermore, the report assumes that the airport extension would be built before other extensions. One other proposed extension, along PR-3 to Carolina, could reduce ridership on the airport line due to overlapping catchment areas.

The general plan for the airport corridor is shown in Appendix 5-A. Phase 1-A of Tren Urbano calls for the extension of the original Tren Urbano trunk line from Sagrado Corazon to the Minillas station. It is expected that later extensions of Tren Urbano to Old San Juan and to the airport will begin at either the Minillas or R.H. Todd stations, but current plans show the line beginning at Minillas. Due to the recent recommendation of an underground alignment alternative for phase 1-A, it is now a virtual certainty that riders will not be able to advantage of a one-seat ride from stations along the original Tren Urbano trunk line to the airport. The nature of this alignment makes it impossible to run trains from anywhere along the original Tren Urbano alignment to the airport. Trains could eventually be sent from the airport through the Minillas station to points beyond, but this would necessitate a new right-of-way and is not currently planned. Therefore, all plans for airport rail links begin at the Minillas or R.H. Todd station.

Current plans for a San Juan airport rail link include three alternative methods of connecting the airport to Tren Urbano. All three methods follow the same alignment from Minillas along PR-26 with five stations before the airport. The PR-26 alignment was found to be the most cost-effective, as models did not show increases in ridership from alternative alignments that would warrant their higher cost. The airport line shows the highest cost/rider of any Tren Urbano extension under consideration, and thus any alternatives showing high costs without compensating ridership increases were rejected.

As mentioned above, the plans for an airport rail link assume that the link will use heavy rail technology. Although a busway is considered in the plan, and recommended for further examination, it is generally assumed that this link will use the same technology as the original Tren Urbano trunk line. Light rail transit and automated guideway transit technologies were examined and rejected because they did not provide significant cost or operational advantages.

For each airport rail connection, there are two different alignments considered for the right-of-way beyond the airport. The first terminates just two stations beyond the airport at the Iturregui transit center. The second possibility is a much longer extension that terminates in the center of Carolina, a suburb southeast of San Juan. This means that six possible alternatives are considered in-depth (three airport terminal connections and two line termini). No airport corridor alignment includes either a station in the air terminal itself or an airport station on airport grounds as a station along the *main portion* of the alignment, either as a terminus or a regular stop. Early on it was determined that doing either would be prohibitively expensive due to the necessity of tunneling underneath runways. The disruption of air traffic, or alternatively, the expense of avoiding such disruption, was determined to be too much of a cost to bear for this project.

5.1.1 Rail Spur into Airport

Appendix 5-B shows the rail spur alternative, which includes a spur off the planned airport corridor alignment that will get a train as close to the airport terminal as possible. Plans call for a people mover to cover the distance from the spur (which ends just before a new parking garage) to the terminal even though the distance is only 400 meters. The thinking behind this is that 400 meters is too far to walk with luggage given the hot San Juan climate.

This rail spur would be a single track off the main line. Tren Urbano headways will be 4 minutes. Every third train could terminate at the airport via this spur, meaning that airport passengers from Minillas would experience 12-minute headways while passengers traveling from Minillas to points beyond the airport would experience 6-minute headways on average. Passengers wishing to access the airport from points east would have to travel to the Isla Verde station west of the airport, and then switch to the other side of the platform to catch an airport train. This alignment includes an at-grade crossover for the rail spur, which poses potential safety and operational hazards. Ridership and cost estimates for the rail spur alternative are presented in Table 5-1.

Table 5-1: Rail Spur Projected Ridership and Costs

	Systemwide Ridership	Line Ridership	New Riders	Capital Costs	Operating Cost
Direct Spur/Iturregui	174,700	38,800	23,600	$ 1,144,200,000	$ 18,500,000
Direct Spur/Carolina	204,800	82,200	53,700	$ 1,450,800,000	$ 22,200,000

5.1.2 Bus Connection

Appendix 5-C shows a map of the bus connection alternative. This alternative does not include a specific station just for airport passengers. Instead, rail passengers wishing to access the airport would board a shuttle bus operating on 4-minute headways at the Laguna Gardens station. Unlike the rail alternative, the bus (and people mover) alternative allows for uninterrupted 4-minute headways for all passengers along the airport corridor. Current plans do not state how long the trip would take, however, the distance involved is nominal. Ridership and cost projections for the bus connection alternative are presented in Table 5-2.

Table 5-2: Bus Connection Projected Ridership and Costs

	Systemwide Ridership	Line Ridership	New Riders	Capital Costs	Operating Cost
Bus Connection/Iturregui	177,300	41,900	26,200	$ 1,008,400,000	$ 17,500,000
Bus Connection/Carolina	212,000	89,300	60,900	$ 1,321,200,000	$ 22,200,000

5.1.3 People Mover Connection

Appendix 5-D shows the people mover connection alternative. This alternative is similar to the bus connection alternative, except that instead of a bus, a people mover is used to shuttle passengers between the Laguna Gardens station and the airport. The term "people mover" typically refers to fully automated operation on a guideway[79]. In this case, the plans call for a two-track system, with tracks diverging and looping around the airport parking complex to meet at the terminal. Time for the people mover to make this run is assumed to be nominal. Ridership and cost projections for the people mover connection alternative are presented in Table 5-3.

Table 5-3: People Mover Connection Projected Ridership and Costs					
	Systemwide Ridership	**Line Ridership**	**New Riders**	**Capital Costs**	**Operating Cost**
PM Connection/Iturregui	177,300	41,900	26,200	$ 1,213,300,000	$ 19,100,000
PM Connection/Carolina	212,000	89,300	60,900	$ 1,526,100,000	$ 23,800,000

Table 5-4: Cost/Ridership Ratios						
	Capital Cost/System wide Rider	**Operating Cost/System wide Rider**	**Capital Cost/Line Rider**	**Operating Cost/Line Rider**	**Capital Cost/New Rider**	**Operating Cost/New Rider**
Direct Spur/Iturregui	$6,550	$106	$29,490	$477	$48,483	$784
PM Connection/Iturregui	$6,843	$108	$28,957	$456	$46,309	$729
Bus Connection/Iturregui	**$5,688**	**$99**	$24,067	$418	$38,489	$668
Direct Spur/Carolina	$7,084	$108	$17,650	$270	$27,017	$413
PM Connection/Carolina	$7,199	$112	$17,090	$267	$25,059	$391
Bus Connection/Carolina	$6,232	$105	**$14,795**	**$249**	**$21,695**	**$365**

Table 5-4 shows a quantitative analysis of each alternative as presented in the airport corridor study. The table shows that the bus alternative provides the least investment per rider (the lowest cost in each category is shown in bold). Whether the new line is extended to Carolina or not, in terms of costs and benefits, the bus alternative makes the most sense based on the airport corridor study. The bus alternative is the implicit recommendation of the study.

5.2 Luis Munoz Marin International Airport

Unlike the other case studies, this one deals with an airport rail link that does not yet exist. Therefore, both the airport bus service currently in operation, and the plan for a future airport rail link are examined. Some of the data for the airport line, most notably the travel time, is merely an approximation since the line has not yet been built. Moreover, since there are really six different plans for an airport rail link, different plans have different characteristics. Only the rail spur and shuttle-bus options are explicitly examined here as separate plans. Whether or not the line extends to Carolina, or utilizes a people mover instead of a bus should not dramatically affect the factors relevant to this link. Where they do, it is so noted.

Other case studies have focused on the ability of a link to serve downtown. As mentioned before, San Juan does not have a particularly distinct downtown area, but Hato Rey, or the golden mile, is generally considered to be the closest thing San Juan has to a central business district. In this case study, Hato Rey is considered to be the downtown.

Table 5-5: Summary of San Juan Factors	**Bus (Current)**	**Rail Spur**	**Shuttle Bus**
Airport Pax/Year (Millions)	13	13	13
Origin and Destination Pax	9	9	9
Transit Fare	$0.75	$1.00	$1.00
Peak Headway (Minutes)	20	8	4
Travel Time (Minutes)	40	29	32
Auto Travel Time (Minutes)	10	10	10
Transit/Auto Difference	30	19	24
Miles to CBD	4	4	4
Terminal in Airport?	Yes	Yes	No
Short Term Parking Rate	$1.35	$1.35	$1.35
Mid Term Parking Rate	$18.00	$18.00	$18.00
Long Term Parking Rate	$12.00	$12.00	$12.00
Speed (MPH)	6	8	7
Mode Share	n/a	n/a	n/a

Fixed Factors

Location relative to city:

Luis Munoz is located a mere 4 miles from downtown San Juan, just over the San Juan border in the neighboring city of Carolina. However, ground access to the airport is inhibited by the fact that a relatively small sliver of land between the Atlantic Ocean and the San Jose Lagoon is the most direct connection to the rest of the city. The Teodoro Moscoso Bridge traverses the Lagoon, but unlike the land connection, the bridge is tolled. Luis Munoz is especially well located with respect to the tourist areas of Isla Verde, the Condado, and Old San Juan.

On the other hand, the airport is relatively far from many residents who depend on it. The airport is close to the northeast corner of the metropolitan San Juan area, which means that it is quite far from certain populous areas such as Guaynabo and Bayamon. Although there are other airports on the island, Luis Munoz is by far the largest one. Virtually all residents and visitors to Puerto Rico must traverse the San Juan airport in order to get to their final destination. Other island cities such as Ponce and Mayaguez have their own airports, but are within driving distance of San Juan (under 2 hours).

Productions and Attractions along Rail Link:

The current bus route serving the airport, the B40 (fare: 25 cents), travels a route that is completely different from the proposed rail link. Instead of passing through Carolina and Isla Verde, the bus goes directly over the Teodoro Moscoso Bridge into San Juan. It leads to the Rio Piedras transit center, where it is possible to change for a Metrobus 1 (fare: 50 cents) to Hato Rey. Service to Rio Piedras, a neighborhood with both business and residential areas, is useful. However, very few other productions or attractions are served by the link. Another bus route, the C45, passes through the airport and some of the airport corridor on its way to Iturregui. However, this route is not analyzed here because it does not serve downtown efficiently.

The proposed link will cover different portions of Carolina depending upon how far it is extended (see section 5.1). Regardless, the line will traverse the tourist-laden Isla Verde and Condado area for some portion of its journey, as well as the poorer neighborhoods that lie between them and the airport. Most of the line to the airport will be along PR-26, a highway connecting Old San Juan and Carolina.

State of Local Public Transit:

Despite being one of the poorest U.S. cities, San Juan has remarkably high car ownership rates. The sprawling nature of the city and its lack of any high quality public transportation system for many years have made the automobile a virtual necessity. Buses are inexpensive (ranging from 25 to 50 cents), but often unreliable. The bus network was recently restructured, and ridership increased, but most buses operate in mixed traffic, making their journey through congested San Juan traffic very slow. Buses stop running very early at night, and often run with low frequency.

San Juan also has much lower parking rates and poorer parking enforcement than most major U.S. cities. This makes driving much more attractive than transit. Notably, the short term parking rates at the airport are low relative to many others.

Cultural Factors:

San Juan is unlike most American cities in that it consists of a predominantly Spanish-speaking population with some distinctive cultural and social attributes that might affect an airport rail link. First, many Puerto Ricans enjoy a strong familial structure. This means that many locally originating passengers accessing the airport will be accompanied by family members and lots of baggage (due to relatives' gifts), which may make rail an unattractive option for them. Second, San Juan has a very strong car culture. Given relatively high crime rates and extensive poverty, the automobile serves as a shield and status symbol for much of the population. Riding transit is not only considered to be an indication of lower social class, but is often perceived as dangerous by those who drive.

Ease and Availability of Connections:

The B40 bus provides excellent connections from the transit center at Rio Piedras. Unfortunately, this is only a realistic option for the transit dependent or airport workers, as any person who could avoid waiting for a bus with twenty-minute headways only to make a change at Rio Piedras for another bus would probably do so.

The San Juan rail link will connect to the Tren Urbano trunk line at either the Minillas or R.H. Todd station. This means that most Tren Urbano passengers, and specifically those originating and terminating downtown, will have to change trains to get to the airport. This is a potential problem in a city without an extensive rail system. If the airport link terminates at Iturregui, it will connect there to a bus and *publico* transit center. A similar center exists in Carolina Centro.

Airport Characteristics:

Luis Munoz Marin serves as the Caribbean hub for American Airlines. Many U.S. passengers destined for other Caribbean islands are funneled through the airport, which means that there is direct service to many major U.S. cities that are not necessarily airline hubs. The airport serves as the major access point between Puerto Rico and the rest of the world, as passenger boat service is virtually non-existent. However, the shortest flight to the mainland is a two-hour flight to Miami, and cities such as New York and Chicago are over three hours away. This means that most passengers arriving from the mainland and San Juan business travelers accessing the mainland are likely to stay at their destinations for longer than a day or two, making extra baggage likely.

Design Factors

Location of the airport train station:

The bus serves the airport terminal directly. For the rail link, as discussed in section 5.1, this is yet to be determined. However, it appears that the only potential location for a train station within walking distance of the airport terminal would still be some distance away (about 400 meters). No details about shuttle-bus or people mover services are available at this time, but traffic on the inner airport roadway is notoriously congested, and it is probable that a people mover would have a slight time advantage.

Speed Relative to Other Modes:

The bus is very slow relative to other modes. Whereas a car under free-flow driving conditions could easily make the trip from the airport to Hato Rey in ten minutes, by bus it takes at least 40 minutes to make the same trip.

For rail, this is very difficult to predict, but it should be approximately 29 minutes for the spur option, and 32 minutes for the shuttle bus option. One thing that is known is that traffic in San Juan, and on PR-26, is very congested during peak times. When this roadway is congested, auto travel time rise to as high as 1 hour from downtown to the airport. Under these conditions, rail would have a significant travel time advantage.

Effective Population Coverage:

Earlier, the New York, Boston, and Chicago links were examined to determine how well each of them served the metropolitan population. A similar study was performed for San Juan. Populations within a quarter mile of every planned airport station were calculated using block group data from the 1990 census. Since this is block group data, it is slightly more accurate than the census tract data used for the other studies. However, for this reason it is also not exactly comparable.

A similar methodology was followed for calculating populations. First "direct" population - those living within walking distance of an airport rail link station were counted. Then "transfer" passengers were included. All Tren Urbano trunk line stations were considered as potential places where airport passengers could originate or terminate. Direct and transfer passengers were calculated with and without the extension of the airport line to Carolina. Both quarter-mile and half-mile radii were used.

Table 5-6a SJU Link Population - 1/4 Mile Radius

	Station Area Population	Percentage of CMSA	Average Median Income
Direct - Iturregui	14,848	1.24%	$15,835
Transfer - Iturregui	49,543	4.15%	$15,091
Direct - Carolina	23,539	1.97%	$15,007
Transfer - Carolina	58,265	4.88%	$14,985

Table 5-6b SJU Link Population - 1/2 Mile Radius

	Station Area Population	Percentage of CMSA	Average Median Income
Direct - Iturregui	50,247	4.21%	$17,180
Transfer - Iturregui	159,017	13.32%	$16,281
Direct - Carolina	84,753	7.10%	$15,612
Transfer - Carolina	193,523	16.21%	$15,755

The results in Table 5-6a show that the San Juan link will about as well as current U.S. rail links in its attempt to serve the population directly. Most potential passengers would come from the Tren Urbano trunk line, and these would have to be transfer passengers. Even with these passengers included, a very small percentage of the population will live within walking distance of rail in San Juan.

On the other hand, Table 5-6b shows that when the radius is extended to one-half mile, high percentages of people are indirectly served by the link. Apparently, populations within one-half mile of the Tren Urbano trunk line are very significant. The percentage of area residents within one-half mile of transfer service is higher in San Juan than in New York City, which has a much more extensive rail system. This indicates that San Juan could potentially serve a very significant population with an airport rail link. A half-mile in San Juan, however, due to the hot climate, may be more difficult to traverse than a half-mile elsewhere. However, future Tren Urbano extensions will probably beef up both the half and quarter mile percentages, as may future development along Tren Urbano.

Chapter 6 – San Juan Analysis

This chapter consists of three parts that together analyze the plan for the San Juan airport rail link as described in the previous chapter. Section 6.1 places the plan within the context of the propositions developed in Chapter 3. Each proposition is revisited to determine how the San Juan plan is likely to be affected by its ramifications. Section 6.2 predicts the mode share that the San Juan plan will garner. Finally, section 6.3 draws some final conclusions about San Juan.

6.1 Analysis of the San Juan Plans

Each relevant proposition developed in Chapter 3 will be revisited in this section. Propositions that do not apply to San Juan are left out. All three variations on the current San Juan plan will be evaluated against the criteria implicit within the propositions. This will help to develop a mode share prediction for the link, and ultimately, determine whether or not the link will make sense from an airport access perspective. Each proposition is evaluated to determine how, if it is true, mode share in San Juan will be affected. A proposition will be placed in one of five categories based upon how it is likely to affect mode share in San Juan: 1) Strongly Negative, 2) Negative, 3) Neutral, 4) Positive, 5) Strongly Positive.

Proposition 1: A high rail/auto travel time difference is likely to significantly decrease mode share. A low rail/auto time difference is likely to increase mode share.

The rail travel time between Hato Rey and the airport is still relatively uncertain. The current estimates are 29 minutes with the rail spur alternative, and 32 minutes with the shuttle bus or people mover alternative. Auto travel time in San Juan is very short (10 minutes). With a rail-auto difference of 19 to 22 minutes, the San Juan link may have trouble being competitive. No rail link with a rail-auto time difference greater than 14 minutes carries more than a 2% mode share. On the other hand, congestion on PR-26 may be worse than the congestion on roads to other airports. This may mean higher mode shares in San Juan despite a high rail/auto time difference during free-flow traffic conditions.

The San Juan link will not have a low rail/auto time difference primarily because traveling to downtown via Tren Urbano will require a transfer at R.H. Todd station under the current plan. If San Juan wishes to have an effective airport rail link, it may need to consider other alternatives that link the airport directly to Hato Rey. This proposition, if true, has strong negative implications for San Juan.

Proposition 2: Off-airport rail stations decrease airport rail link mode share.

The current San Juan plan is certainly on the wrong end of this proposition. There is a continuum of airport train stations, with the best possible option being a station inside the airport terminal (DCA) and the worst option being a long shuttle bus ride (JFK). The San Juan options fall somewhere in the middle of this continuum, with the best possible option being a station 400 meters from the air terminal, connected by a people mover. Not only is this option inconvenient because of the longer headways it necessitates, it is also the most expensive option and is the least likely option to be built. San Juan will most likely have an off-airport train station comparable to Boston, with a short shuttle bus or people mover bringing passengers to the airport terminal.

This means that according to proposition 1, San Juan must should many other characteristics beneficial to an airport rail link to compensate for this problem. Unfortunately, San Juan does not have these characteristics. Fixed factors such as poor local transit and connections, negative airport characteristics, and local culture are all unchangeable and likely to negatively impact rail link mode share. An airport close to the city compensates slightly, but overall the off-airport plan is probably too much to overcome.

This proposition was reinforced by data collected at Washington National's rail station. The difference between the current San Juan plans and a station like the one at Washington National is significant and will deter riders. This proposition has strong negative implications for mode share in San Juan.

Proposition 3: *Airport rail links that effectively serve population and employment centers are likely to have higher mode shares.*

Further analysis of this proposition showed that some of the most transit dependent cities in the U.S. have airport rail links that, together with the local rail system, fail to serve a significant portion of the metropolitan population effectively. A similar analysis conducted in San Juan confirmed that the San Juan link would be no different (no employment analysis was performed). Even with significant Tren Urbano expansion, San Juan will still have trouble serving much of its population directly by rail due to the sprawling nature of the metropolis. This proposition, which was supported by further analysis, is negative for San Juan.

Proposition 4: A large concentration of international or long haul traffic at an airport is likely to decrease rail mode share. On the other hand, a prevalence of short haul traffic and/or low-cost carriers is likely to increase rail link mode share.

This proposition also paints a bleak picture for the San Juan link prospects. Luis Munoz Marin does not have a preponderance of low-cost carriers, and the geographic location of San Juan means that most flights out of the airport are long-haul flights. Although there are several flights out of San Juan that are short in duration, most major American cities are more than two hours away. This means that the average air passenger traveling to the San Juan airport is likely to carry significant luggage and therefore is less likely to use a rail access.

The dominance of long-haul flights from San Juan does not mean that no rail link could possibly serve the airport effectively. It does mean that other rail link characteristics must compensate. San Juan has some characteristics that could help to compensate, such as a short distance to the CBD, but most others such as location of the airport train station and rail/auto time difference will mean difficulty attracting mode share. The rail link features in the San Juan plan may not be sufficient to counteract the nature of flights from the San Juan airport. This proposition also suggests negative implications for San Juan.

Proposition 5: A good airport location, one close to downtown and other major trip generators, is likely to increase mode share.

This proposition bodes well for San Juan. The San Juan airport may be relatively far from some significant population centers, but it is also very close to downtown and well located with respect to Carolina and most of San Juan itself. The airport's location is very important because it is a fixed factor that is favorable for San Juan. If this proposition holds, it is strongly positive for San Juan.

Proposition 7: If an airport rail link is part of a modern, well-designed rail system, this is likely to increase mode share.

This proposition also bodes well for San Juan since Tren Urbano will be a modern system. However, one of the main benefits of a modern system is that we know that the airport is an important production and attraction to connect by rail. In Boston and New York, where rail systems predated the importance of the airports, the rail links do not connect directly into the terminal. Designing a rail system when the importance of a direct terminal connection is known provides an advantage. Unfortunately, the San Juan plans do not fully utilize this advantage. Therefore, although this could be strongly positive for San Juan, it is now only positive.

Proposition 8: Airport rail links that do not effectively serve other areas besides downtown are likely to have low mode shares.

If the San Juan airport line is extended to Carolina, then this need not be of concern. A line from Carolina to R.H. Todd would certainly serve many areas besides downtown. However, another proposed Tren Urbano extension to Carolina via PR-3 shows a greater potential for attracting riders due to the more direct route that it would provide from Carolina to downtown[80]. If the rail link terminates at Iturregui, there will be only seven stations on the entire line. Moreover, many of these stations will be along

PR-26, which means less potential for future development and population density increases around stations. The link would effectively serve other areas besides downtown, but not nearly as many of them.

If the airport line is not extended to Carolina, it might be worth considering extending the line beyond R.H. Todd station on the other end. First of all, this would extend the area effectively served by the link. Secondly, if a yards and shops location were found along this extension, it might make it possible to terminate the airport line at the airport. This would allow consistent headways and eliminate the problems associated with the rail spur option, while providing an improved train station location. As it stands now, with the Carolina extension, this proposition is a positive. Without the Carolina extension, this proposition is neutral.

Proposition 10: Residents and non-residents appear equally as likely to use airport rail links or public transportation to access the airport.

If this is true, it could be a very beneficial finding for San Juan. Normally, one would expect that visitors would be less likely to use airport rail links, but this does not appear to be the case at most U.S. airports. The San Juan airport has a high proportion of visitors to the area. If these people are equally as likely as residents to take Tren Urbano to and from the airport, then a rail link in San Juan has a better chance of attracting significant mode share. The Tren Urbano airport line will pass through Isla Verde and Condado, two popular tourist areas.

However, it is possible that this proposition will not hold in San Juan. Americans visiting San Juan may be scared of riding Tren Urbano, and could potentially be worried about following signs in Spanish, and many tourists arrive in San Juan on package tours that include transportation to and from the airport. Moreover, residents of San Juan are probably less likely to use airport rail links due to the cultural factors mentioned previously. This loss of residential passengers may negate any gain in non-resident traffic in San Juan. Nevertheless, overall, this proposition is positive for San Juan.

Table 6-1: Proposition Effects

Proposition	Summary	In San Juan	Fixed or Design?
1	Rail travel time	Strong Negative	Design
2	Off-airport terminals	Strong Negative	Design
3	Serve populations	Negative	Design
4	Airport service	Negative	Fixed
5	Airport location	Strong Positive	Fixed
7	Modern link	Positive	Design
8	Serve areas outside downtown	Neutral/Positive	Design
10	Residents/Non-residents	Positive	Fixed

Table 6-1 shows a summary of the relevant propositions and their potential implications for San Juan. The prevalence of negatives indicates potential problems with the San Juan link. The most important of these are a poorly located airport train station, and slow travel time relative to the automobile. These problems are significant and strongly supported by case study data and further analysis. The San Juan link cannot hope to garner a mode share comparable with the best American links with these two flaws, much less a mode share comparable to European links.

Fortunately, these and other problems with the San Juan link are design problems, not fixed problems. An in-terminal train station could be considered, although it would probably mean much greater expense. Faster rail travel time would be possible if the airport line were extended south, past R.H. Todd station and into downtown. Moreover, the fixed factors about San Juan are generally positive, and the number of people living within a half-mile of future rail stations is very high. The type of air service that is offered from San Juan airport is really the only fixed, negative factor. With an improved plan, the San Juan link could potentially carry significant numbers of passengers.

6.2 Mode Share Predictions for a San Juan Link

The airport corridor study does not predict mode share, nor reveal estimates for boardings at particular stations. However, daily boardings at the airport station were predicted for each alternative by the consulting firm performing the modeling for Tren Urbano. Based on these boardings, mode share can be estimated. First, we assume double boardings to account for alightings as well (we can assume that the numbers are similar). Second, we subtract 13% for airport workers (this is what is predicted by the models for airport workers mode share). Next, an additional 10% is subtracted for "other" passengers such as meeters and greeters. The final figure is an approximation of daily station activity by airport passengers. This is then divided by the daily number of air passengers requiring ground access to determine approximate mode share.

Table 6-2: Mode Share in San Juan

Alternative	Boardings	Air Pax Activity	Mode Share
Iturregui - Rail Spur	974	1500	6.4%
Iturregui - Shuttle	930	1432	6.1%
Carolina - Rail Spur	1322	2036	8.7%
Carolina - Shuttle	1171	1803	7.7%

Table 6-2 shows the estimated mode shares in San Juan. The people mover and shuttle-bus alternatives are assumed to have identical mode shares. Not surprisingly, the highest mode share results from the alternative with the greatest population coverage and the closest train station.

In chapter 3, an equation relating mode share and rail/auto travel time difference was developed. This equation may be helpful in estimating mode share in San Juan. Although this equation is based on data from mainland airports, it will at the very least provide a starting point for a mode share prediction based on the case study information. The equation is:

$$Y = 12.651 - 3.104 \ln X$$

The equation predicts a mode share of 3.5% for the San Juan link under the rail spur alternative (X=19). It predicts a mode share of 3.1% under the shuttle bus/people mover alternative (X=22). This indicates that the range of a mode share prediction in San Juan might be between 2% and 5%. These predictions are much lower than those of Cambridge Systematics.

Based on the results of this model, and information from the case studies, it is likely that the mode share in San Juan will be less than 5.0%. This can best be illustrated by comparing the planned San Juan link with Boston's airport rail link. Boston also has a short airport rail link that covers a very small portion of the metropolitan area, a similar type of off-airport connection, and an airport very close to the city. The rail mode share for Boston is approximately 5.7%. Unfortunately, San Juan cannot hope to capture even that percentage. Unlike Boston, San Juan does not have an extremely concentrated downtown with expensive and limited parking. Unlike San Juan, Boston is within two hours flying time of other major metropolitan areas, namely Chicago, New York, Washington, and Philadelphia. San Juan does not now have the level of transit orientation seen in Boston, and lacks the extensive transit network enjoyed by Bostonians (this is subject to change). Boston's airport rail link is not built along an expressway, and has been around for a very long time, fostering development. Finally, San Juan has lower short-term parking rates than Logan does or any other major airport. This is important due to the high numbers of meeters and greeters in San Juan that are encouraged by the local culture.

It is very difficult to predict a mode share for the rail spur alternative, since no current U.S. system has a comparable rail link design. The rail spur will present some interesting frequency issues, and the location of the airport train station is unlike any other. However, since even the rail spur alternative will not provide a one-seat ride to downtown, these mode share predictions may still be too high. The mode shares predicted for the rail spur (6.4% and 8.7%) are comparable to Atlanta (6.0%), Chicago Midway (8.1%), and Washington (9.0%). Yet, although these airports may not suffer the same level of congestion on their access roads as that seen on PR-26, all three of these systems provide rail travel times that are much closer to auto travel times under normal conditions. Washington and Chicago Midway have stronger downtowns and more extensive rail systems than San Juan. Chicago Midway has a high percentage of low-cost carriers, and Washington National only has flights that are under 1,500 miles in length. San Juan, with the rail spur alternative, will probably have a mode share under 5%.

6.3 San Juan Conclusions

The current San Juan rail access plan will not capture a significant air passenger mode share. However, the airport corridor study is a plan for an entire rail line, not just for an airport rail link. The airport station on a heavy rail line is unlikely to account for a significant percentage of the traffic on that line, as station percentages of 1.3% in

Washington and 6.9% in Boston show. Therefore, simply because the rail link mode share would be poor does not mean that the airport line should not be built.

On the other hand, if the airport line in San Juan is built as outlined in the airport corridor study, this will be the permanent airport rail link in San Juan. The costs of an inadequate airport rail link should not be underestimated. A city that wishes to compete in the global economic environment will need fast and reliable airport access, and the current plan does not provide it.

Other alternatives to the plan in the airport corridor study should be strongly considered. The cost of tunneling underneath runways is very high, but it might be worthwhile in the long term. Even though the cost per new rider in the short term may be extremely high for a link that goes directly into the airport terminal, in the long term it could produce many benefits. Similarly, the cost of an underground alignment, or an alignment away from PR-26 may be very high, but the increased development and improved pedestrian access that would occur as a result of this investment might be worth it for the city.

Terminating the airport line at the airport is another alternative that may produce more benefits. This could mean avoiding expensive tunneling underneath runways. It would also eliminate the headway reductions that would result from the rail spur option. A new yards and shops location would have to be found with this alternative. This might be found south of the R.H. Todd station. An alignment that continued after crossing the extended Phase I-A alignment could potentially solve the yards and shops problem and improve airport rail access at the same time. More people would have direct access to the airport, including the numerous workers in the Hato Rey area west of the Phase I alignment.

Finally, the use of a busway instead of heavy rail might also solve some of the problems in the airport corridor study. By taking two lanes from PR-26, or from a main arterial road, a busway could be created with little cost. Bus service could go directly into the airport terminal at a low cost, while maintaining the speed and reliability of rail service. Moreover, a busway would offer flexibility in the type of service offered that would allow more one seat rides to the airport. Such a busway would be more realistic if trucks, taxis, and *publicos* were also permitted to use the right-of-way, since all of these vehicles have an interest in improving their own travel times on PR-26. Furthermore, running buses over the Theodoro Moscoso Bridge and onto the existing busway that runs between Rio Piedras and Old San Juan might be another low-cost alternative to rail that is worth consideration.

Chapter 7 – Thesis Conclusions

This research has focused on two main issues. One is the general issue of airport rail access in the U.S. This was analyzed in detail using case studies, drawing propositions from them, and testing the validity of two of these propositions. The second issue is the potential for an airport rail link in San Juan specifically. The general information and propositions gathered from the general airport access analysis were applied to San Juan. This section reviews both parts. First, each part is briefly summarized and the conclusions from it are reviewed. Second, recommendations are made for future work that might help resolve some of the uncertainties about airport access via rail transit that remain after conducting this research.

7.1 Airport Rail Access – Summary and Conclusions

The foundation for this research is the information gathered through several case studies. Airport rail links in New York, Philadelphia, Washington, Boston, Chicago, and San Jose were analyzed in detail. Characteristics of each link in the detailed case studies were divided into fixed and design factors. Fixed factors are those that are considered given and unchangeable, while design factors are those over which some control may be exercised. Information was collected on each factor for the purposes of determining which played the greatest role in the success or failure of airport rail link.

Basic information was gathered about links in Atlanta, St. Louis, Oakland, Miami, Cleveland, and Baltimore. Future rail links in New York and San Francisco were also examined. The role of airport workers in the success of a rail link was examined briefly, but the focus for the case studies was how well each link attracted airport passengers.

The mode share, or the percentage of passengers using rail to access the airport, was the key factor in determining success or failure. Rail links were compared with one another based on the factors identified, and it was determined which factors play the strongest role in determining rail mode share. Following this, propositions about airport rail access were created. One proposition concerning the role of airport train station location was then tested using before and after data at Washington National airport. The role that the population and employment near airport rail links plays in determining mode share was also examined by looking at the number of people living and working within walking distance of airport rail links in Boston, New York, and Chicago.

The comparison of the case studies produced some important results. It was found that both rail travel time to the airport, and the difference between auto and rail travel time to the airport, strongly influence the mode share of an airport rail link. Regression and scattergram analysis showed that rail/auto has a stronger relationship with mode share for U.S airports than does rail travel time alone. An equation for a curve based on case study data for rail/auto travel time difference was developed and later used to help predict mode share in San Juan.

From the comparisons and case study information, some propositions were developed. Some of the most important propositions are reviewed here. First, on-airport stations are strongly associated with higher rail mode shares for airport rail links. The select few airports with off-airport stations and significant mode share also have several other factors that make for viable airport rail links. Second, travel time between the airport and downtown on an airport rail link must be comparable to auto travel time in order for passengers to use the link. Third, airport rail links must also be credible options for passengers outside the downtown area – nonstop links to the CBD are unlikely to attract high mode shares. Generally, central business districts are not strong enough in and of themselves to provide sufficient passengers for an airport rail link. Fourth, it was found that commuter rail does not work well as an airport rail link. Fifth, airport location is vital to the success of an airport rail link. Since rail becomes less competitive with greater distance, an airport close to the city has a much greater chance of attracting rail passengers. Finally, airport rail service should be scheduled to fit the travel peaks of airport passengers, with high train frequency corresponding to increased air traffic.

Washington National was ideal for studying the importance of airport rail station location, since it was effectively "moved" in 1997 when the new airport terminal opened right next to it. The results of this experiment showed that ridership at the Metro Airport station increased significantly after the new terminal opening, and that this increase was likely to be attributable to the new terminal opening. However, it is not clear whether the shortened distance between rail station and train terminal is responsible for this increase. It is possible that it was simply the end of construction that induced more people to use the rail link at Washington National.

The analysis of populations within walking distance of airport rail links showed that even moderately successful links such as Boston and Midway do not directly serve significant percentages of the metropolitan population. In three dense, transit dependent cities (New York, Boston and Chicago) rail links do not have very many people within walking distance of them, and those that can walk to the links have incomes well below the median for airport travelers in those cities. If this is the case for these cities, it is likely that other cities have similar, if not worse problems in this department. Moreover, these three cities show a small proportion of jobs in their Central Business Districts. Although connecting to the CBD effectively is vital for airport rail links, many U.S. links may have difficulty attracting high mode share due to the high percentage of residences and jobs outside their CBDs.

7.2 Airport Rail Access – Recommendations for Future Work

European Links. This research has focused exclusively on U.S. airport rail links. The most successful airport rail links in the world are in Europe, and it is likely that there is much that can be learned from studying these links in more detail. Although the applicability of such an analysis to the U.S. might be limited, it would undoubtedly have some value.

Further Proposition Testing. Only two of the propositions about airport access posed in this research were seriously tested. Further testing that might result in concrete lessons about airport access planning would be extremely valuable for planners.

Other modes. This research has focused exclusively on rail. However, other modes may offer potential airport access solutions, especially in the U.S. Research that focused on proper mode selection for airport access or simply an analysis of public transportation to airports in general would be helpful.

More analysis of airport workers. Airport workers make trips to the airport every day. They are a large part of the airport access problem. Before airport rail access can be fully understood, a study similar to this one that focuses on workers would be extremely valuable.

7.3 San Juan – Summary and Conclusions

Information gathered about U.S. airport rail access was applied to the San Juan case. First, the plans for airport rail links in San Juan were explained in detail. This meant a description of the plans, and a case study in a format similar to those performed for other cities. A study of population levels surrounding future stations was also performed. Second, the plans for the link were assessed in the context of the propositions generated in Chapter 3. A prediction on mode share and conclusions about the San Juan situation were drawn from this evaluation.

The planned rail link in San Juan involves a separate line connecting to the Tren Urbano trunk line at Minillas or R.H. Todd Station. The line is either at-grade or elevated throughout the entire alignment, which travels through Isla Verde and Condado to the airport along PR-26. After this point, it may terminate at the transit center, or it may bypass the center and proceed to Carolina Centro, making stops along the way. The proposed alignment will connect to the airport either with a shuttle bus or people mover from the Laguna Gardens station, or with a rail spur directly into the airport with a train station 400 feet from the airport terminal connected by a people mover.

If the propositions posed in Chapter 3 are true, the San Juan airport rail link will not attract a significant share of air passengers. Overall, the propositions point to significant flaws in the plan. The two most significant flaws are the lack of an on-airport train station, and slow rail travel time to Hato Rey caused by a necessary transfer. San Juan has some characteristics that could help increase rail mode share, such as a well-located airport, the fact that it is a modern system, and a large percentage of area residents within walking distance of future rail stations. However, the current plans for a

San Juan link do not have the design factors necessary to attract significant air passengers.

The possibility of revising the airport access plan to improve these design factors should be considered. Some possible revisions include running the airport line underneath the runways into the terminal, terminating the airport line at the airport and extending it past R.H. Todd station to the south, and creating a busway that could substitute for heavy rail in this corridor. These ideas, whether combined or implemented separately, could attract significant passengers to a San Juan airport access link.

Notes

[1] Coogan, Mathew A. "Comparing Airport Ground Access: A Transatlantic Look at an Intermodal Issue" in *TR NEWS 181*, November-December, 1995.
[2] Harvey, Greig. "Study of Airport Access Mode Choice" in *Journal of Transportation Engineering*, September, 1986.
[3] Mandalapalu S.R. and W.J. Sproule. Airport Ground Access: Rail Transit Alternatives. In Transportation Research Record 1503, TRB, National Research Council, Washington D.C., 1995.
[4] Mandalapu, Srinivasa R. *Multicriteria Evaluation of Rail Transit Connections to Airports*. Department of Civil Engineering, University of Alberta, 1994.
[5] Passengers is abbreviated as "Pax"
[6] Fare information was collected from a variety of sources, mostly airport and transit web sites, sometimes from phone interviews at airports. Fare shown is the off-peak fare for travel to the nearest downtown destination. Higher peak fares are charged in Oakland, Washington and Miami.
[7] This approximation was made by adding half of the scheduled headway to the scheduled running time of the train.
[8] Airport web sites usually gave the distance of the airports from their central business districts. If not, a call to the airport gave reasonably accurate data that could often be checked with distances listed in articles.
[9] Mode share was collected from a variety of sources. For most airports, Bill Craven (Associate, Cambridge Systematics) provided mode share information from a similar but unpublished study. The exceptions are Oakland, Kennedy, and Baltimore Washington (Anis, Zale. *Compiling Cross-sectional Data on Ground Access to Airports*, U.S. DOT, June 15, 1994). The figure for Miami is from an interview with Larry Coleman, a consultant on the current ground access project at MIA. This figure includes all public transit modes, as do the figures for JFK and BWI. Therefore, the actual mode shares for rail are less than 1% in these cases. Mode share for the new rail link to downtown Baltimore is not yet available.
[10] Cracchiolo, Anthony. "Light rail to 'the' Airport – JFK Light Rail System Poised to go" in *LRT News*, vol. 12, no. 1., p. 1.
[11] Hood, Clifton. *722 Miles: The Building of the Subways and How They Transformed New York*. Simon and Schuster, 1993.
[12] http://www.mta.nyc.ny.us/nyct/service/a-jfknb.htm
[13] Anonymous. "NYMTA: 'Train to the Plane" in *Railway Age*, vol. 180, no. 1, p. 10.
[14] www.phl.org
[15] Ibid.
[16] Anonymous. "Philadelphia Opens High Speed Airport Line" in *Passenger Transport*, May 1985, p. 27.
[17] Ibid.
[18] Martindale, David. "Travelers Attracted to Rail-to-Airport Connections" in Passenger Transport, v. 39, no.41, p. 28.
[19] Spade, Bill. Metropolitan Washington Airports Authority, March 8, 1999.
[20] www.mwaa.com

[21] This was calculated using ridership figures from May 1998. Total ridership for that month at the airport station was divided by the total ridership at all Blue and Yellow Line stations for the month. The data was received from the WMATA transit database.
[22] www.easysabre.com
[23] Young, David. "The Trains to the Planes" in *Mass Transit*, vol. 8, no. 8, p. 21. MWAA: Ground Transportation.
[24] Spade.
[25] www.airwise.com
[26] Harrington, Ian. Central Transportation Planning Staff, Boston.
[27] Odoni, Amadeo. Course 1.231: Airport Planning and Design, Massachusetts Institute of Technology.
[28] Newmark, Greg. Memo to Bill Craven, April 21, 1999.
[29] Gellman, Aaron. Director of Northwestern University Transportation Center, Evanston, IL.
[30] Anonymous. "Chicago's Second Airport Rail Line" in *Progressive Railroading*, v. 31, no. 12, p. 44.
[31] Ibid: p. 45.
[32] www.airwise.com
[33] Footi, LaBelle, and Stuart. "Increasing Rail Transit Access to Airports in Chicago" in *Transportation Research Record*, p. 4.
[34] Footi, LaBelle, and Stuart: p. 4.
[35] Chicago Transit Authority. "Kennedy Rapid Transit Service Extended to O'Hare" in *CTA Transit News*, v. 37, no. 9/10, p. 2.
[36] Bremer, Karl. "Intermodalism – it's all coming together" in *Airport Magazine*, vol. 5, no. 2, p. 12.
[37] www.airwise.com
[38] Ibid.
[39] www.airwise.com
[40] Newmark.
[41] Russell, Bruce J. "Trains Meet Planes in St. Louis" in *Rail Travel News*, vol. 24, no. 16, p. 12.
[42] www.stlouis.missouri.org
[43] Russell: p. 12.
[44] www.twa.com
[45] www.st-louis.com
[46] Young, Andrew D. "MetroLink Update" in *The New Electric Railway Journal*, vol. 7, no. 1.
[47] Russell: p. 11.
[48] Newmark.
[49] Kunz, Richard. "The Rapid at 30" in *Passenger Train Journal*, vol. 16, no. 5, p. 26.
[50] Cleveland Hopkins Information.
[51] Martindale: p. 29.
[52] Newmark.
[53] Martindale, David. "Who the Joke's on Now: Travelers to Cleveland Won't Laugh Anymore at the City That Everyone Loves to Hate" in *Frequent Flyer*, May 1989, p. 28.

[54] www.flyoakland.com
[55] www.bart.com
[56] Ball, William L., and Polzin, Steve. "Lessons to be Learned from a New Commuter Rail System" in *ITE Journal*, December 1992.
[57] Trip time was calculated using a combination of the Tri-rail schedule and an estimation of the Metrorail time based on trip time from end to end.
[58] www.airwise.com
[59] www.Tri-rail.com , www.metro-dade.com
[60] Florida DOT. *East – West Multimodal Corridor: Description of Project*, Dade County FL, May 1997.
[61] Portes, Alejandro and Stepick, Alex. *City on the Edge: The Transformation of Miami*, University of California Press, 1993.
[62] www.bwi.com
[63] Anonymous. "Md. Light Rail Extension Adds Intermodal Links" *in Passenger Transport*, vol. 55, no. 49, p. 1.
[64] St. Louis mode share from Craven. JFK, O'Hare, and Logan mode shares are from the latest employee surveys at those airports. They are from 1993, 1990, and 1996 respectively.
[65] www.panynj.com
[66] Cracchiolo: p. 2. Ibid.
[67] www.panynj.com
[68] Cracchiolo: p. 3.
[69] Middleton, William D. "BART Heads for the Airport" in *Railway Age*, vol. 197, no. 8, p. 52.
[70] Anonymous. "BART Breaks Ground for Airport Extension" in *Passenger Transport*, vol. 55, no. 47, p. 4.
[71] Ibid.
[72] Middleton: p. 53.
[73] ATL = Atlanta Hartsfield, BWI = Baltimore Washington International, BOS = Boston Logan, CLE = Cleveland Hopkins International, DCA = Washington National, JFK = John F. Kennedy International (New York), MDW = Chicago Midway Airport, MIA = Miami International, OAK = Oakland International, ORD = Chicago O'Hare, PHL = Philadelphia International, SJC = San Jose International, STL = Lambert St. Louis International.
[74] Yedinak, Mark. Metropolitan Washington Airports Authority.
[75] Fehr, Stephen C. "Metro Terminal Link to Reduce Some Preflight Turbulence" in *The Washington Post*, July 16, 1997.
[76] From inflation calculator at www.westegg.com/inflation
[77] Yedinak, Mark. Contract Administrator, Metropolitan Washington Airports Authority.
[78] *Draft Airport Corridor Study*. Tren Urbano/GMAEC, May 1998.
[79] G.E. Gray and L.A. Hoel. *Public Transportation (2nd Edition)*. Prentice Hall, Englewood Cliffs, NJ, 1992, Chapter 4, p. 97.
[80] Craven.

Bibliography:

Anis, Zale. *Compiling Cross-sectional Data on Ground Access to Airports*, U.S. DOT, June 15, 1994

Ball, William L., and Polzin, Steve. "Lessons to be Learned from a New Commuter Rail System" in *ITE Journal*, December 1992.

Bremer, Karl. "Intermodalism – it's all coming together" in *Airport Magazine*, vol. 5, no. 2.

Chicago Transit Authority. "Kennedy Rapid Transit Service Extended to O'Hare" in *CTA Transit News*, v. 37, no. 9/10.

Coogan, Mathew A. "Comparing Airport Ground Access: A Transatlantic Look at an Intermodal Issue" in *TR NEWS 181*, November-December, 1995.

Cracchiolo, Anthony. "Light rail to 'the' Airport – JFK Light Rail System Poised to go" in *LRT News*, vol. 12, no. 1.

Fehr, Stephen C. "Metro Terminal Link to Reduce Some Preflight Turbulence" in *The Washington Post*, July 16, 1997.

Florida DOT. *East – West Multimodal Corridor: Description of Project*, Dade County FL, May 1997.

Footi, LaBelle, and Stuart. "Increasing Rail Transit Access to Airports in Chicago" in *Transportation Research Record.*

G.E. Gray and L.A. Hoel. *Public Transportation (2nd Edition).* Prentice Hall, Englewood Cliffs, NJ, 1992.

Harvey, Greig. "Study of Airport Access Mode Choice" in *Journal of Transportation Engineering*, September, 1986.

Hood, Clifton. *722 Miles: The Building of the Subways and How They Transformed New York.* Simon and Schuster, 1993.

Kunz, Richard. "The Rapid at 30" in *Passenger Train Journal*, vol. 16, no. 5.

Mandalapu, Srinivasa R. *Multicriteria Evaluation of Rail Transit Connections to Airports*. Department of Civil Engineering, University of Alberta, 1994.

Mandalapalu S.R. and W.J. Sproule. Airport Ground Access: Rail Transit Alternatives. In Transportation Research Record 1503, TRB, National Research Council, Washington D.C., 1995.

Martindale, David. "Travelers Attracted to Rail-to-Airport Connections" in Passenger Transport, v. 39, no.41.

Middleton, William D. "BART Heads for the Airport" in *Railway Age*, vol. 197, no. 8.

Newmark, Greg (Cambridge Systematics). Memo to Bill Craven, April 21, 1999.

Portes, Alejandro and Stepick, Alex. *City on the Edge: The Transformation of Miami.* University of California Press, 1993.

Russell, Bruce J. "Trains Meet Planes in St. Louis" in *Rail Travel News*, vol. 24, no. 16.

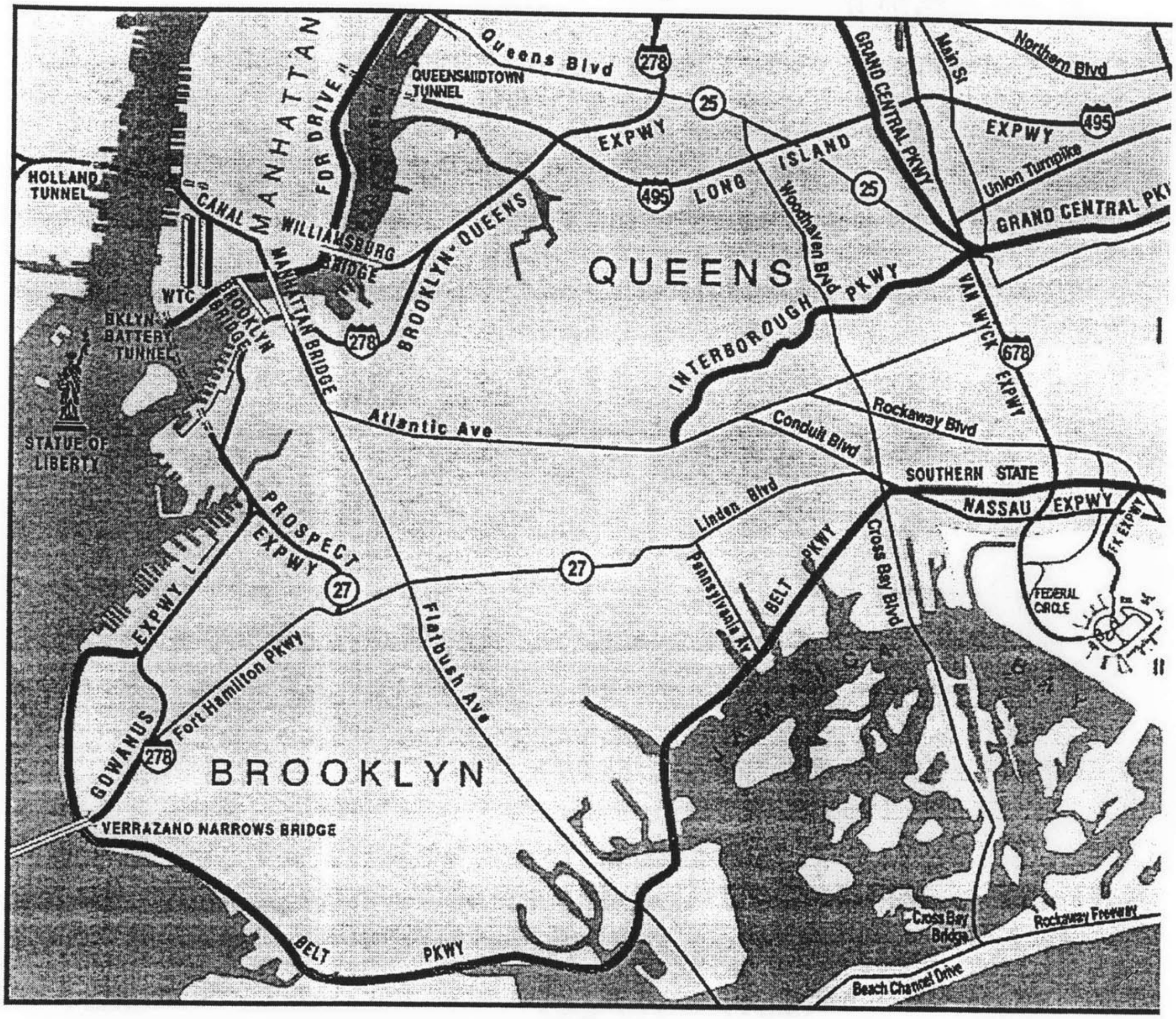
Tren Urbano/GMAEC. *Draft Airport Corridor Study.* May 1998.

Young, Andrew D. "MetroLink Update" in *The New Electric Railway Journal*, vol. 7, no. 1.

Young, David. "The Trains to the Planes" in *Mass Transit*, vol. 8, no. 8, p. 21.

Appendix 2-A: Kennedy Airport Location

DRIVING TO KENNEDY AIRPORT



Major Roadway Access Routes to JFK:

Printable PDF of major highways routes (Print in landscape mode)

FROM MANHATTAN

Van Wyck Expressway to Airport Exit
Belt Parkway East to Exit 19/Van Wyck Expressway (678)

FROM EASTERN LONG ISLAND

Belt Parkway West to Exit 20/JFK Expressway

FROM NEW JERSEY

NJ Turnpike to Exit 14C (Holland Tunnel), then South on West St. to Belt Pkwy

FROM UPSTATE NEW YORK

87 South to 278
278 South to 495

Appendix 2-B: New York's A-Train

MTA New York City Transit ONLINE

● NYC Transit ● Long Island Rail Road ● Long Island Bus ● Metro-North Railroad ● Bridges & Tunnels

- MTA Home
- NYC Transit Home
- Subways Main Page
- Buses Main Page

Subway Service Notices
Subway Schedules

(A) 8 Av Express

The A train schedule is divided into segments for easier use. Please choose one of the following sets of tables: between 207 St.and Jay St., between Jay St. and Lefferts Boulevard or Far Rockaway, or the A/S branch running between Broad Channel and Rockaway Park.

Rush Hours 6:30-9:30 am, 3:30-8 pm Monday-Friday:
207 St, Manhattan-Lefferts Blvd or Far Rockaway or Rockaway Park, Queens
Express in Manhattan and Brooklyn

Middays 9:30 am-3:30 pm Monday-Friday:
207 St, Manhattan-Lefferts Blvd or Far Rockaway, Queens
Express in Manhattan and Brooklyn

Evenings 8 pm-12 midnight Monday-Friday:
207 St, Manhattan-Lefferts Blvd or Far Rockaway, Queens
Express in Manhattan (145 St-Canal St), Local in Brooklyn after 9pm

Weekends 6:30 am-12 midnight Saturday and Sunday:

207 St, Manhattan-Lefferts Blvd or Far Rockaway, Queens
Express in

Line Manager: Dennis Ulrich (212) 645-6312

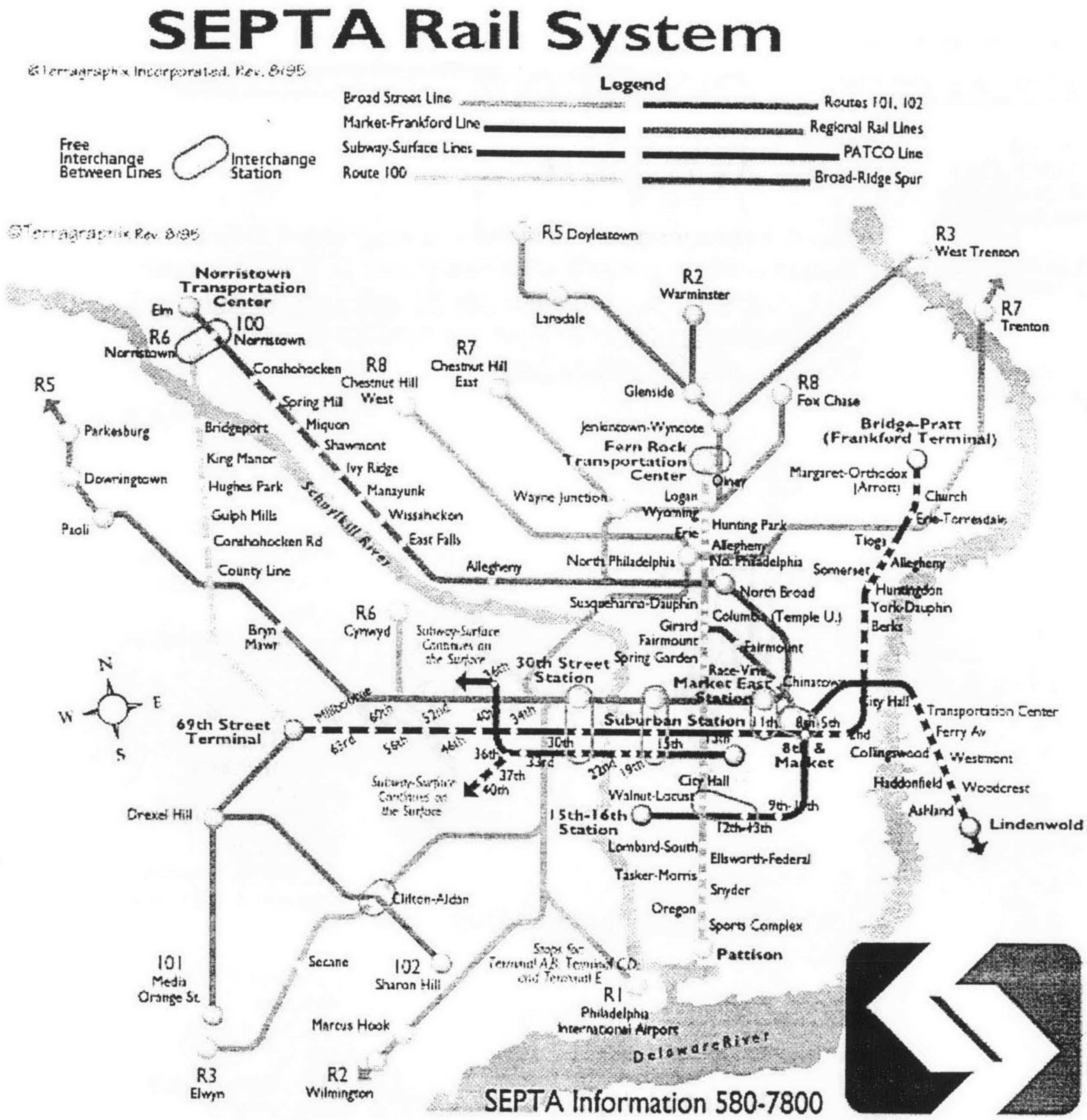
Schedule information

207th St and Jay St • Northbound Weekday Service
- Southbound Weekday Service
- Northbound Saturday Service
- Southbound Saturday Service
- Northbound Sunday Service
- Southbound Sunday Service

Back to top

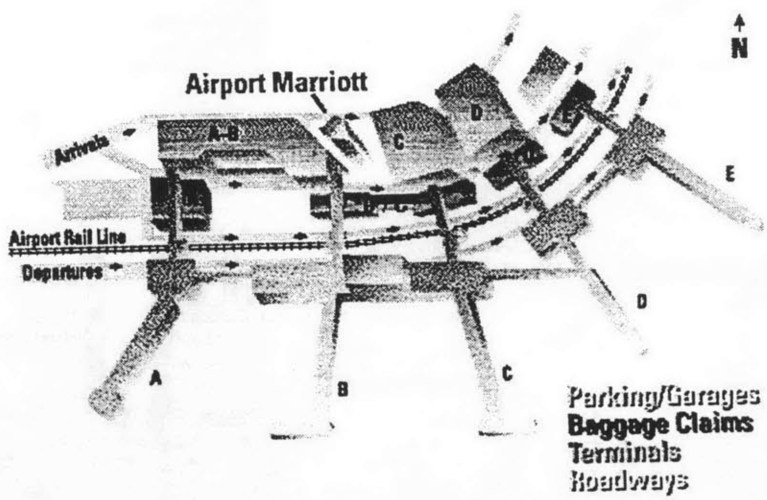
Jay St. and Lefferts Blvd or Far Rockaway • Northbound Weekday Service
- Southbound Weekday Service

Appendix 2-C: Philadelphia Rail System



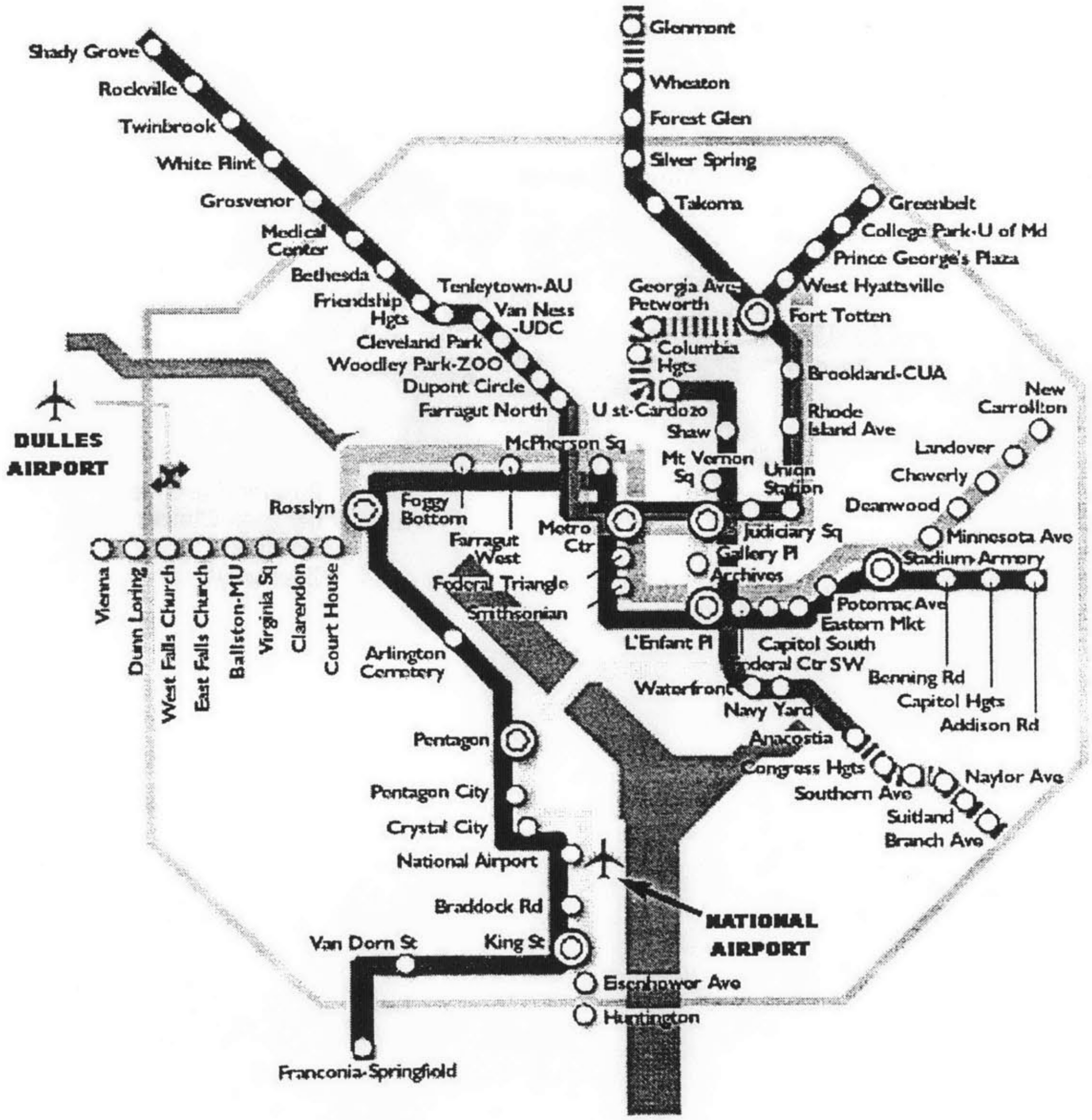
home
Return to LibertyNet's
Movies, Maps, and Photos of the Philadelphia Area

ıpendix 2-D: Philadelphia Airport



Appendix 2-E: Washington Metro

Washington DC Metrorail System Map



Subway Service

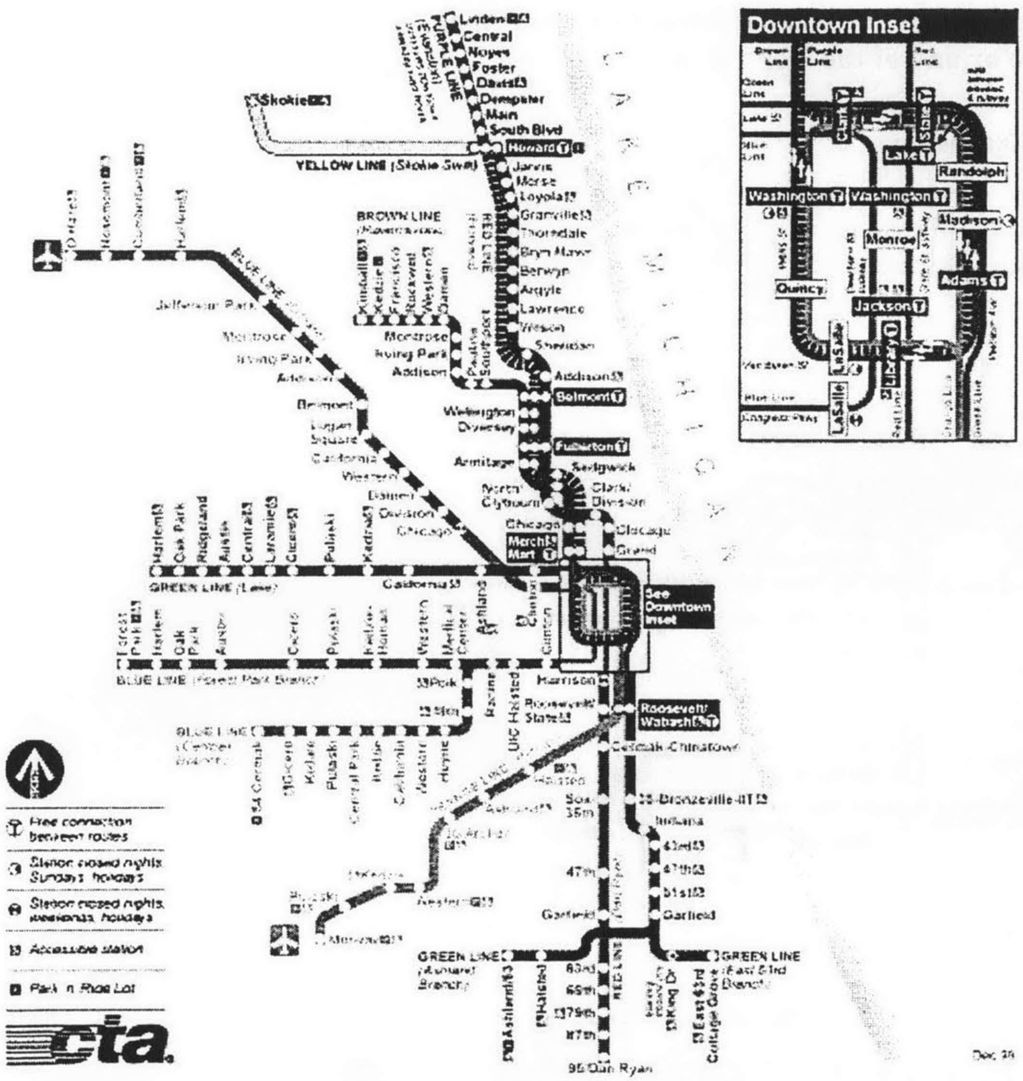
Schedules | PDF Formatted Schedule | Fares

Please click on a subway line for more information about that line or any of the stops on it.

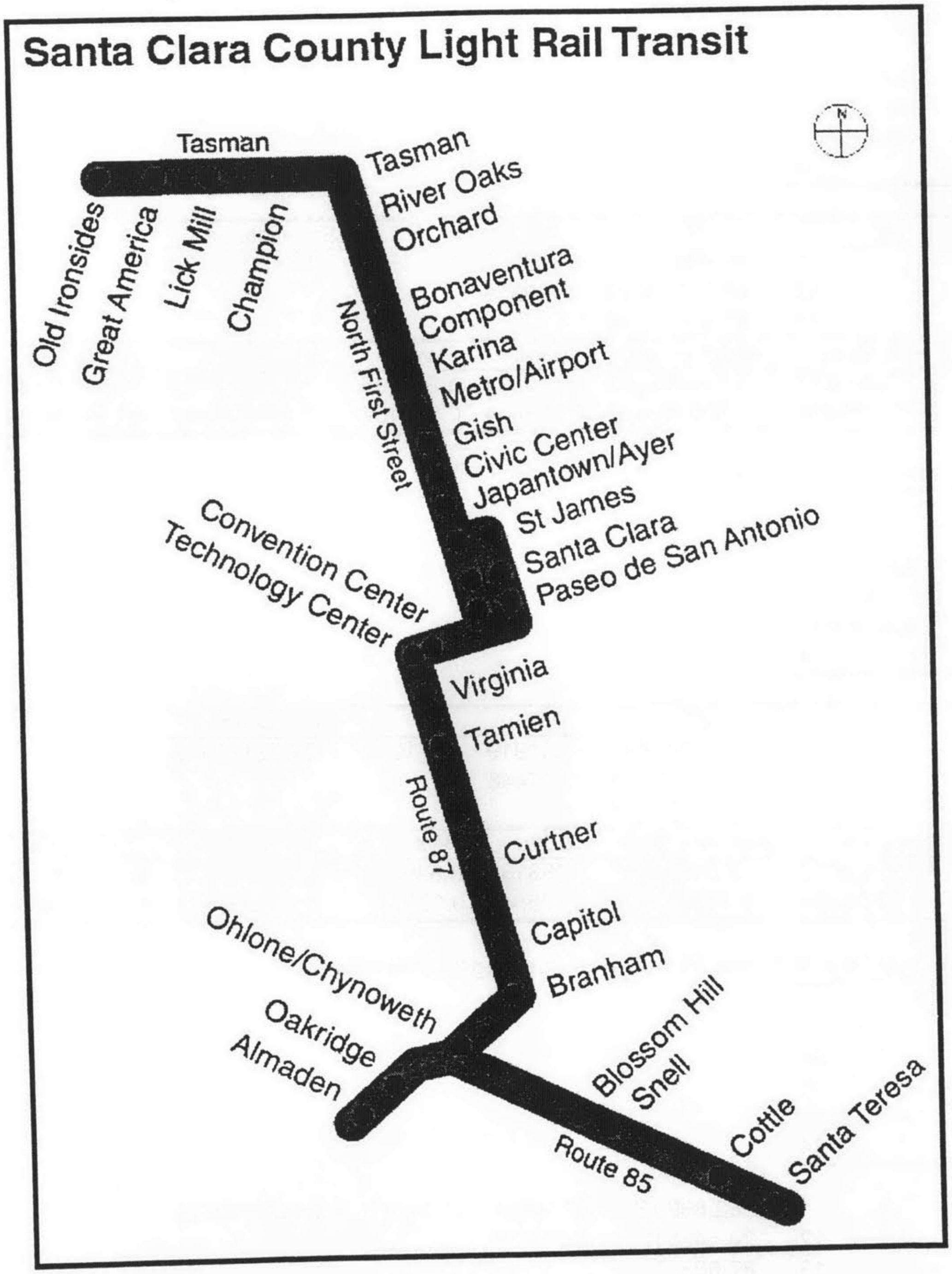
Red Line | Green Line | Orange Line | Blue Line

INTERNET

Appendix 2-G: Chicago Rail Map



dix 2-H: San Jose Light Rail



Appendix 3-A: Rail Travel Time Regression

Regression Statistics	
Multiple R	0.727812663
R Square	0.529711273
Adjusted R Square	0.490520546
Standard Error	1.846599359
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	46.08942114	46.08942	13.51624	0.003169378	
Residual	12	40.91915029	3.409929			
Total	13	87.00857143				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	7.779870213	1.147459245	6.780084	1.96E-05	5.27977133	10.2799691
X Variable 1	-0.09703036	0.026392449	-3.676444	0.003169	-0.154534567	-0.039526154

Appendix 3-B: Travel Time Difference Regression

Regression Statistics	
Multiple R	0.742119277
R Square	0.550741021
Adjusted R Square	0.513302773
Standard Error	1.804840297
Observations	14

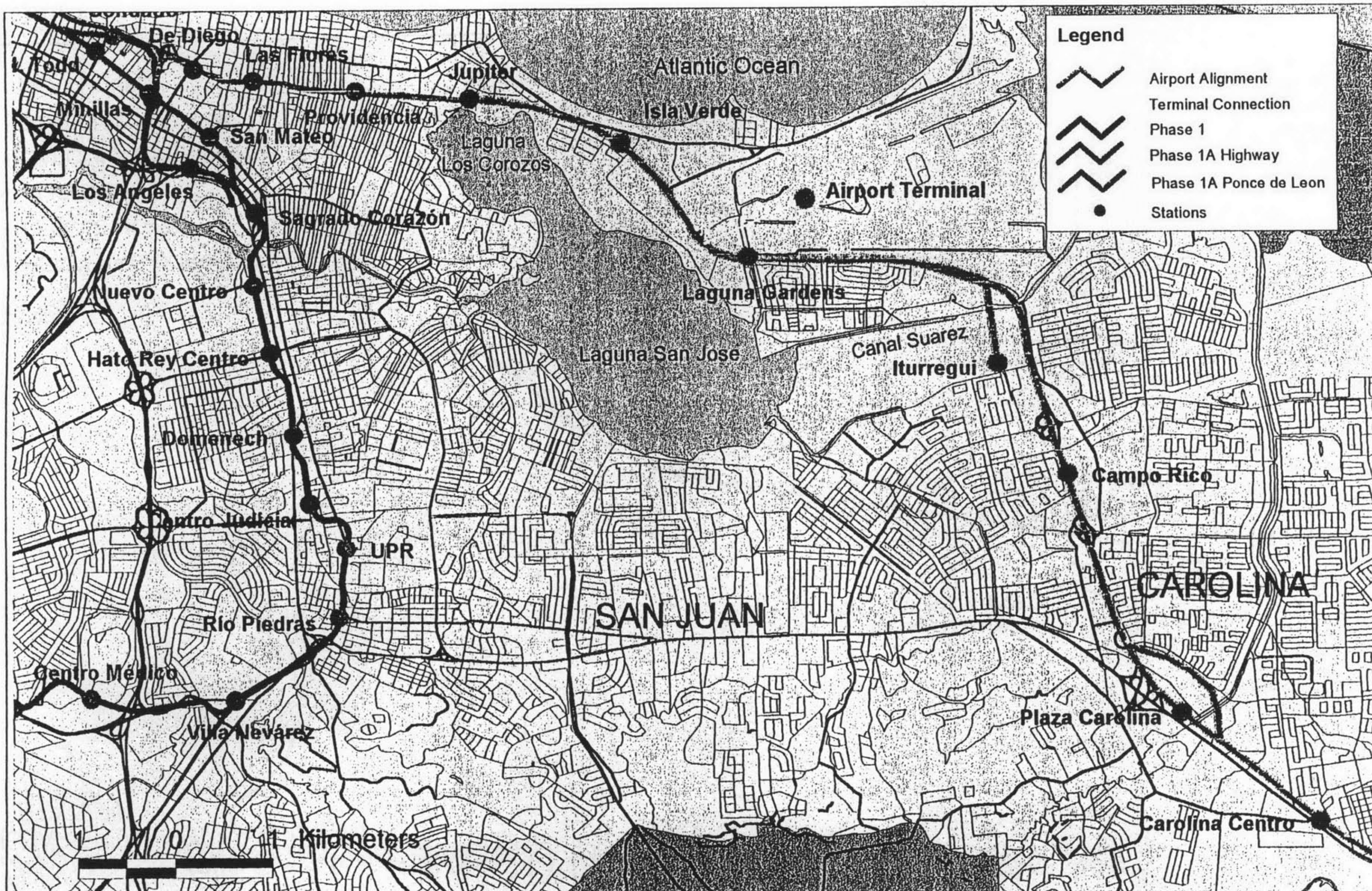
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	47.91918944	47.91919	14.71065	0.002371992	
Residual	12	39.08938198	3.257448			
Total	13	87.00857143				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.468468922	0.81026647	7.983138	3.84E-06	4.703049973	8.233887872
X Variable 1	-0.119926466	0.031267927	-3.835447	0.002372	-0.188053425	-0.051799508

Appendix 3-C: Natural Logarithm of Travel Time Difference Regression Results

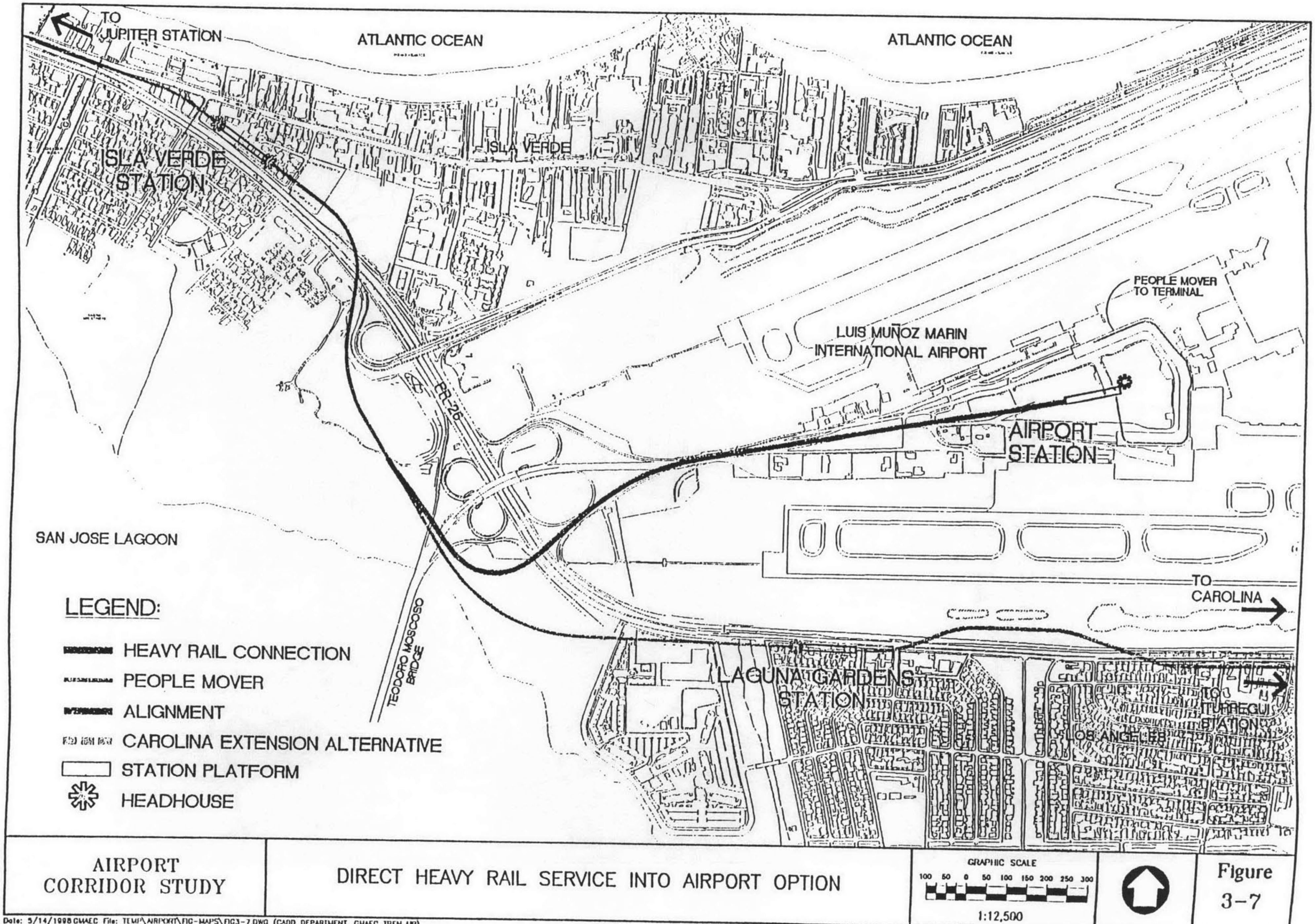
Regression Statistics	
Multiple R	0.850015955
R Square	0.722527124
Adjusted R Square	0.699404385
Standard Error	1.41840634
Observations	14

ANOVA						
Regression	1	62.8660529	62.86605	31.24747	0.000118012	
Residual	12	24.14251853	2.011877			
Total	13	87.00857143				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	12.65097715	1.59831369	7.915203	4.19E-06	9.168550838	16.13340347
X Variable 1	-3.104132723	0.555306617	-5.589944	0.000118	-4.314041885	-1.894223561



AIRPORT CORRIDOR STUDY	AIRPORT CORRIDOR		Figure ES-1

Appendix 5-A: Airport Corridor Plan



AIRPORT CORRIDOR STUDY	DIRECT HEAVY RAIL SERVICE INTO AIRPORT OPTION	Figure 3-7

Date: 5/14/1998 GMAEC File: TEMP\AIRPORT\FIG-MAPS\FIG3-7.DWG (CADD DEPARTMENT, GMAEC TREN UR)
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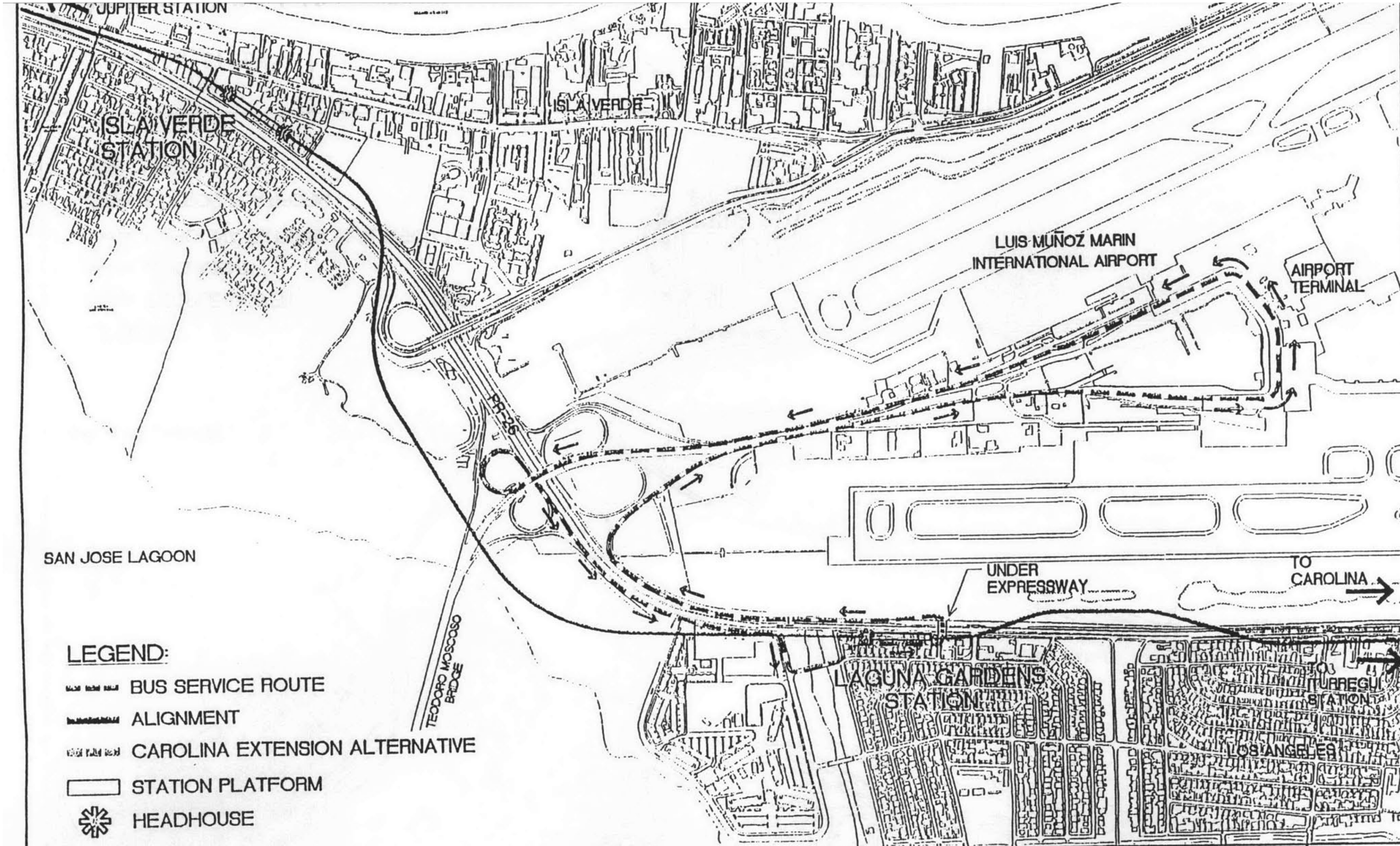
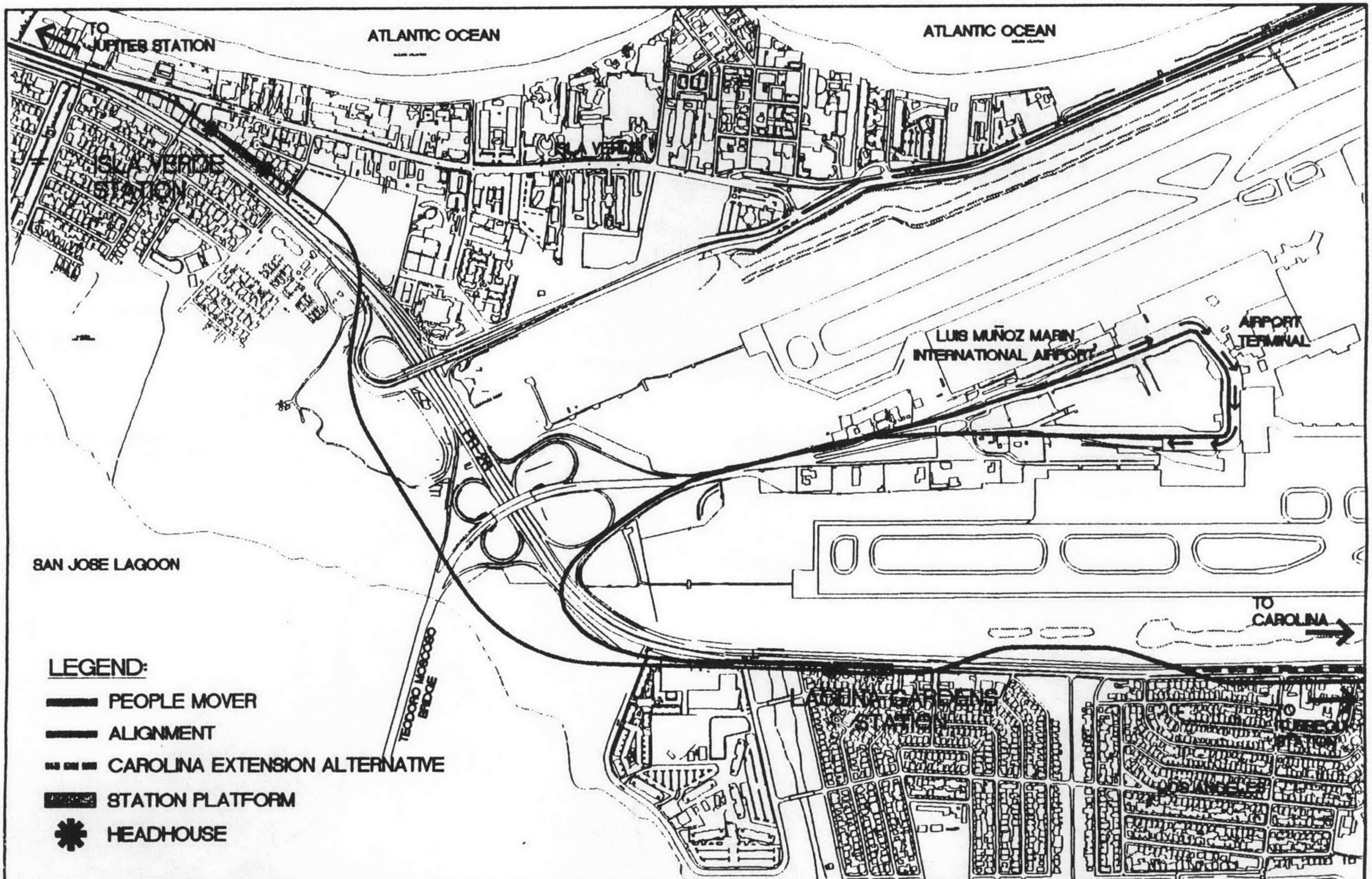
Appendix 5-B: Rail Spur Alternative



AIRPORT CORRIDOR STUDY	BUS SERVICE FROM LAGUNA GARDENS OPTION	GRAPHIC SCALE 100 50 0 50 100 150 200 250 300 1:12,500		Figure 3-9

Date: 5/18/1998 CMAEC File: TEMP\AIRPORT\FIG-MAPS\FIG3-9.DWG (CADD DEPARTMENT, CMAEC TIEN UR)
Time: 13.15.13 Xrefs: AL-INT, CARO48, CARO56, CARO55

Appendix 5-C: Shuttle Bus Alternative



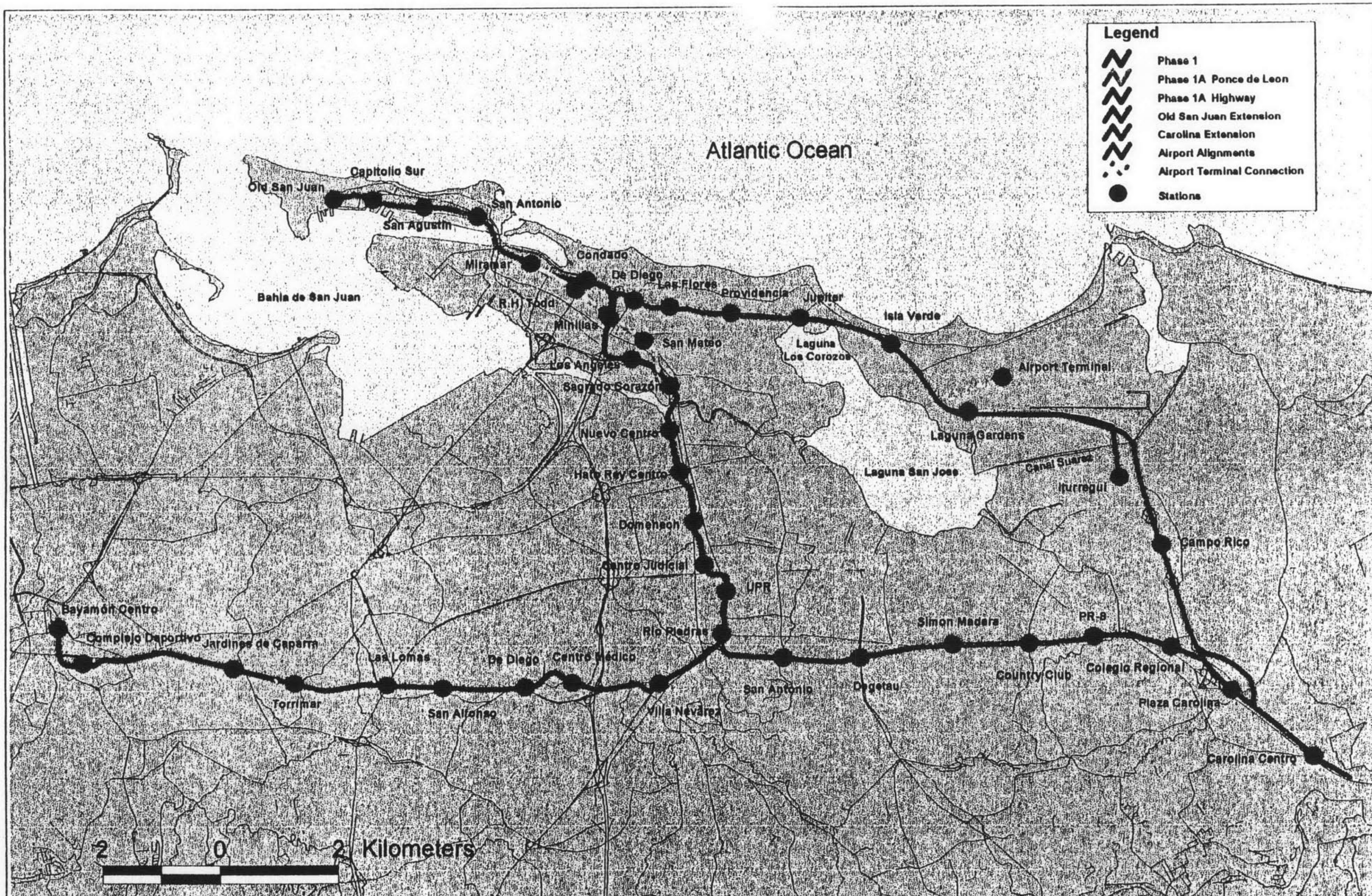
AIRPORT CORRIDOR STUDY

PEOPLE MOVER FROM LAGUNA GARDENS OPTION

GRAPHIC SCALE

1:12,500

Figure 3-8



AIRPORT CORRIDOR STUDY	TREN URBANO FULL "H" PATTERN SYSTEM	Figure 1-1

Appendix 5-E: Tren Urbano System Plan