CalSpeed

California High Speed Rail Series

Revenue and Ridership Potential for a High-Speed Rail Service in the San Francisco/Sacramento-Los Angeles Corridor

Daniel Leavitt
Erin Vaca
Peter Hall

Working Paper
UCTC No 185

The University of California Transportation Center

University of California
Berkeley, CA 94720

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PREFACE

This report is part of IURD's study of the potential for a high-speed passenger train service in California Building upon previous work in the series, this report presents a preliminary estimate of the ridership and revenue that might be generated by the high-speed rail system described in Working Paper 564, *High Speed Trains for California*

The researchers gratefully acknowledge the support provided by the United States Department of Transportation and the California Department of Transportation through the University of California Transportation Center Any errors of fact or interpretation should, of course, be assigned to the researchers and not to our sponsors

Our thanks also goes to the many individuals at public agencies and private firms who provided information, assistance, and advice over the course of the study Special thanks goes to Tom Bordeaux, Peter Cheng, Sean Ennis, and Joel Tranter for their invaluable assistance in preparation of the report, and to Kevin Keck for excellent graphics services As always, thanks must also go to the staff at IURD, who have shown much patience with the study team over the past two and a half years

EXECUTIVE SUMMARY

This study documents an investigation into the potential for high-speed rail (HSR) service in California between Los Angeles and San Francisco/Sacramento via a new alignment in the Central Valley. An earlier report, IURD Working Paper 564, reviewed technology and alignment issues, recommended a steel-wheel-on-steel rail option, and identified a preferred corridor for further analysis. This report presents the results of further analysis, including demand and revenue projections.

This Caltrans-funded study has been conducted under the direction of Professor Peter Hall of the Institute of Urban and Regional Development at the University of California at Berkeley. Two main objectives were met in the study.

1. Prepare an initial set of demand forecasts and revenue projections for HSR service in the corridor.
2. Establish a solid analytical framework for further study and input to decision-making on HSR implementation.

Key findings from the study are summarized below:

- Steel-wheel-on-steel-rail technology is the only practicable option for high-speed ground transportation in California for the immediate and foreseeable future. In order to compete with existing modes of transportation and justify the considerable investment involved, the HSR mainline should allow for sustained operation of at least 200 mph.
- A new Central Valley corridor running west of Route 99 is suitable for HSR, would provide competitive travel times between the San Francisco Bay Area and the Los Angeles Metropolitan area, and would also serve important growing urban areas in the Central Valley. With the technology assumed, travel times of under three hours from downtown San Francisco to downtown Los Angeles are possible.
- There were an estimated 16 million auto passenger trips of at least 200 miles within the study area in 1987. By 2010, this number is expected to increase by 44 percent to 23 million passenger-trips.
- About 9.23 million non-connecting air passengers travelled in the corridor in 1992. An estimated 1 million of these trips began or ended in the Downtown San Francisco zone. Assuming a 3 percent annual growth rate, air passenger traffic should increase to 15.7 million passengers by 2010, a 70 percent increase from 1992 levels.
- High-speed rail could divert approximately 12.5 million passengers from the air and automobile travel markets in the year 2010 under a baseline service scenario. Higher fares and slightly lower frequencies than the baseline scenario would result in 10.3 million and 12.1 million diverted passengers respectively. The longer travel times involved in 125 mph operation would result in the diversion of only about 7.1 million passengers in the year 2010.

- Well over half the projected ridership comes from travel between the Los Angeles region and the Bay Area/Sacramento/San Joaquin County region under all scenarios Ridership between the downtown Los Angeles and San Francisco stations accounts for about one quarter of the total
- The estimated capital cost for the proposed HSR system, including trainsets and an extension to Sacramento, totals over $13 billion Annual operating and maintenance costs are estimated at $340 million and $376 million, depending upon the frequency of service offered
- The proposed HSR system operating at 200 mph would need to attract between 7 5 to 8 5 million annual passengers, depending upon the service scenario, to break even or just cover annual operating costs Total (capital and operating expense) cost recovery would require a ridership approaching or exceeding the system's capacity
- Revenue from ticket sales for a 200-mph system could cover all of the operating and maintenance costs and a portion of the capital costs If the system were operated at 125 mph, the lower resulting ridership would not generate enough revenue to cover operating and maintenance costs, however
- Due to the lack of total cost recovery and the high level of risk involved, a totally privately financed system is not feasible Since the 200-mph services could more than recover operating and maintenance expenses, however, operation of high-speed train services and stations may provide a more practicable opportunity for private participation
- These ridership figures reflect the analysis of the HSR mainline as a stand-alone corridor, without the network effects of feeder services and without induced ridership
- The ridership estimates and associated revenue projections are, by necessity, preliminary because of the current lack of knowledge regarding intercity travel patterns in California Investment grade studies will require a significant data collection effort

These first-look findings are promising, illustrating tremendous potential for HSR in the corridor Including only diverted demand from the air and auto modes, these forecasts are preliminary and should be used as the basis for further study. In conclusion, several recommendations are made, including develop specific policy goals for HSR, conduct a major origin/destination survey on all intercity travel modes in the corridor, investigate the potential for induced demand for HSR, evaluate the economic costs and benefits associated with HSR; and study potential sources of public and private financing

INTRODUCTION

This report represents the culmination of IURD's study of the market potential for a high-speed passenger mainline in California The first seven studies in the series dealt with specific high-speed train technologies, assessing their economic and technical viability. Next in the series is IURD Working Paper 564, *High-Speed Trains for California*, which discussed various technical issues, analyzed potential routes, and estimated capital costs for a high-speed passenger rail system A careful revisiting of the likely capital costs (Working Paper 567, *The Cost Escalation of Rail Projects: Using Previous Experience to Re-Evaluate the CalSpeed Estimates)* and an assessment of previous rail forecasting exercises (Working Paper 568, *Intercity Rail Ridership Forecasting and the Implementation of High-Speed Rail in California)* followed This report presents the findings of a preliminary revenue and ridership study for the high-speed rail system described in Working Paper 564.[1]

The first chapter, which relies most heavily upon *High-Speed Trains for California,* defines the high-speed rail supply assumptions, including the proposed alignment, the location of stations, the schedule of service, and the linehaul times and fares between stations The second chapter presents the best information currently available on the supply and demand characteristics of the current and future intercity travel market in California Although the second chapter focuses on the two presently dominant intercity transportation modes, automobile and air, some information is also included on intercity rail and bus travel. The next chapter contains preliminary estimates of high-speed rail ridership for the year 2010 This third chapter includes a brief discussion of the methodology (described in greater detail in the *Technical Appendix),* assumptions behind the ridership estimates, and recommendations for future ridership studies The fourth chapter reviews the likely costs of the system against potential revenue generation and discusses the financial and institutional implications The report concludes with a summary of findings and recommendations in the final chapter

1. THE CALSPEED HSR PROPOSAL

This chapter reviews the principal findings of *High-Speed Trains for California* (Institute of Urban and Regional Development Working Paper No 564) and describes the proposed high-speed rail (HSR) mainline that is the focus of this study. This chapter also presents the level-of-service attributes (frequency of service, travel time, and fare) and station locations used to determine market potential

The CalSpeed Vision for HSR in California

> The first priority for a California HSGT (High Speed Ground Transportation) system must be to provide for the fastest times between the state's two major urban areas and transportation markets, Greater Los Angeles and the San Francisco Bay Area A second priority should be to provide the best possible level of service to the next level of urban areas, including San Diego, Sacramento, and the major cities of the Central Valley Reconciling these objectives requires some degree of compromise [2]

With the above goals in mind, the proposed HSR network was designed to best serve the inter-city travel needs of the state of California. The segments of the network (Figure 1 1) are described below

(1) Greater Los Angeles and the San Francisco Bay Area would be connected by a new high-speed "mainline" through the Central Valley Once these two metropolitan areas are connected, an additional mainline branch could be added to provide service to Sacramento relatively easily

(2) The existing rail corridors between the Bay Area and Sacramento and between Los Angeles and San Diego would be upgraded to the highest possible level of service (maximum speeds between 100 and 125 mph) These corridors would ultimately be integrated with the high-speed mainline

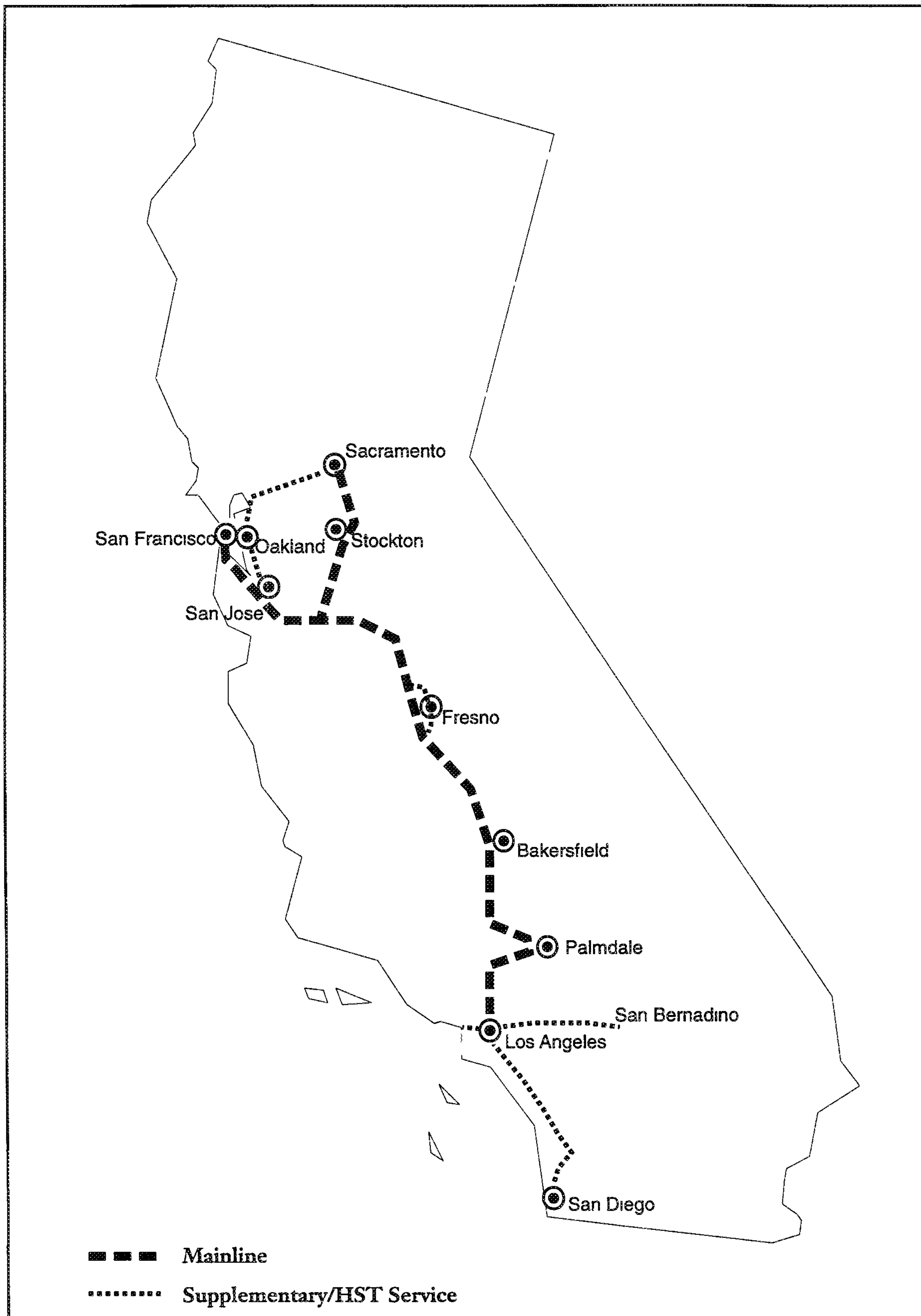
(3) The existing commuter rail corridors in the Greater Los Angeles Area would provide a feeder service to this widely dispersed region While commuter trains would initially provide this service, these corridors have the long-term potential for direct HSR service at reduced speeds to outlying points

The Los Angeles-San Francisco/Sacramento mainline is the subject of this market analysis, since this mainline represents "by far the biggest single market, and should be planned and built first, as the core of the entire future system "[3] Furthermore, while service in the existing rail corridors can be incrementally improved, the mainline should be planned and constructed as a whole Thus, while the network ultimately envisioned includes well-integrated feeder services, branch lines, and further extensions, the focus of this report is only the mainline core of that system

Technology

The choice for high-speed ground transportation (HSGT) in California is between steel-wheel-on-steel-rail and magnetic levitation (maglev) technology. In the first year of the CalSpeed study, six

FIGURE 1.1: THE CALSPEED NETWORK



steel-wheel-on-steel-rail technologies (the Japanese Shinkansen, the French TGV, the German ICE, the Italian ETR-450, the Swedish X-2000, and the British IC125/225) and two magnetic levitation technologies (the German Transrapid and the Japanese LMC) were evaluated, and separate working papers on each technology published This research led to the conclusion that steel-wheel-on-steel-rail technology is "strongly to be preferred," primarily on the basis of proven revenue performance and compatibility with existing rail systems

For an HSR mainline connecting Greater Los Angeles with the San Francisco Bay Area, the technology must be capable of sustaining very high speeds (200 mph or more) to compete with the existing modes of transportation (in order to accommodate such speeds, most of the route must consist of dedicated track through a new high-speed corridor). Only the Shinkansen, TGV, and ICE technologies are capable of meeting this very high-speed standard within the next few years. Presently, the TGV is clearly the leader of these three technologies, holding the current world speed record for ground transportation, the record for regular speed in revenue service, and a safe operation record for millions of miles of service Moreover, further TGV trainset improvements are scheduled for the near future Therefore, while the actual choice of operating system should be subject to competitive bidding between the leading technologies, the HSR supply attributes in this study are based on the "next-generation" TGV technology

Performance Characteristics and Types of Service

The HSR mainline will be a steel-wheel-on-steel-rail system powered by electric traction The mainline will be double-tracked, completely grade-separated, and fenced along its entirety Trainsets will maintain an operational speed of 200 mph through high-speed segments and be capable of sustaining grades of up to 5 percent. Table 1 1 summarizes selected performance characteristics for high-speed segments.

While special rolling stock could carry high-value or time-sensitive freight on the mainline tracks, passenger services would predominate on the HSR mainline Because of the high speeds and frequency of service envisioned, only high-speed passenger trains would run on the high-speed segments of the route during periods of passenger service operation Aside from freight services, commuter services could also potentially use parts of the high-speed mainline Although not the focus of this study, specially designed commuter trainsets could provide express commuter services on the mainline in urban areas.

Mainline Routing

In order to serve the major markets competitively, a mainline connecting Greater Los Angeles and the San Francisco Bay Area is necessary This mainline, with an additional branch to serve Sacramento, forms the foundation of the high-speed rail network envisioned for California

Table 1.1

High-Speed Segment: Performance Characteristics

Trainset Performance[1]	
Acceleration	
from 0 to 50 mph	0.4 miles
from 0 to 100 mph	1.9 miles
from 0 to 200 mph	14.8 miles
Maximum Emergency Braking	
from 200 to 0 mph	2.72 miles
Operational Deceleration	
from 200 to 0 mph	7.4 miles
Maximum Operational Speed	200 mph
Track Specifications	
Minimum Horizontal Curve Radius[2]	19,680 feet
Maximum Gradient (Preferred)	3.5%
Maximum Gradient (Absolute)	5.0%

[1]Trainset performance characteristics were based on the FRA report, *Safety Relevant Observations on the TGV High Speed Train* and are comparable to the Texas TGV specifications.
[2]The radius applies to high-speed sections (design speed 220 mph).

Route Considerations

Through each of the two metropolitan regions, the practical choice of route is limited to existing transportation corridors, in particular, existing rail rights-of-way. Speed through urban areas will be restricted by the geometry of the existing corridor, noise impact concerns, and energy efficiency constraints. Previous experience in Europe and Japan indicates that through urban areas, maximum practical speeds vary between 100 to 125 mph. Since the Los Angeles and Bay Area metropolitan areas represent nearly one-fourth of the entire mainline route connecting these two regions, urban speed limitations are a considerable constraint.

To divert traffic from existing modes, particularly air, the HSR mainline must offer competitive city-center-to-city-center travel times. To deliver this performance, very high-speed operation (200 mph or greater) must be sustained throughout the Central Valley and mountain passes. Thus, any new HSR corridor constructed through these regions should not pass through developed areas. While this corridor would be designed for operational speeds of at least 220 mph, the corridor should be built as straight as possible to accommodate the eventual improvement of technology and speed.

Alignment

The proposed HSR mainline (Figure 1.2) begins at Union Station in downtown Los Angeles. After running on reconstructed SP right-of-way north to the San Fernando Pass, the line veers east and a

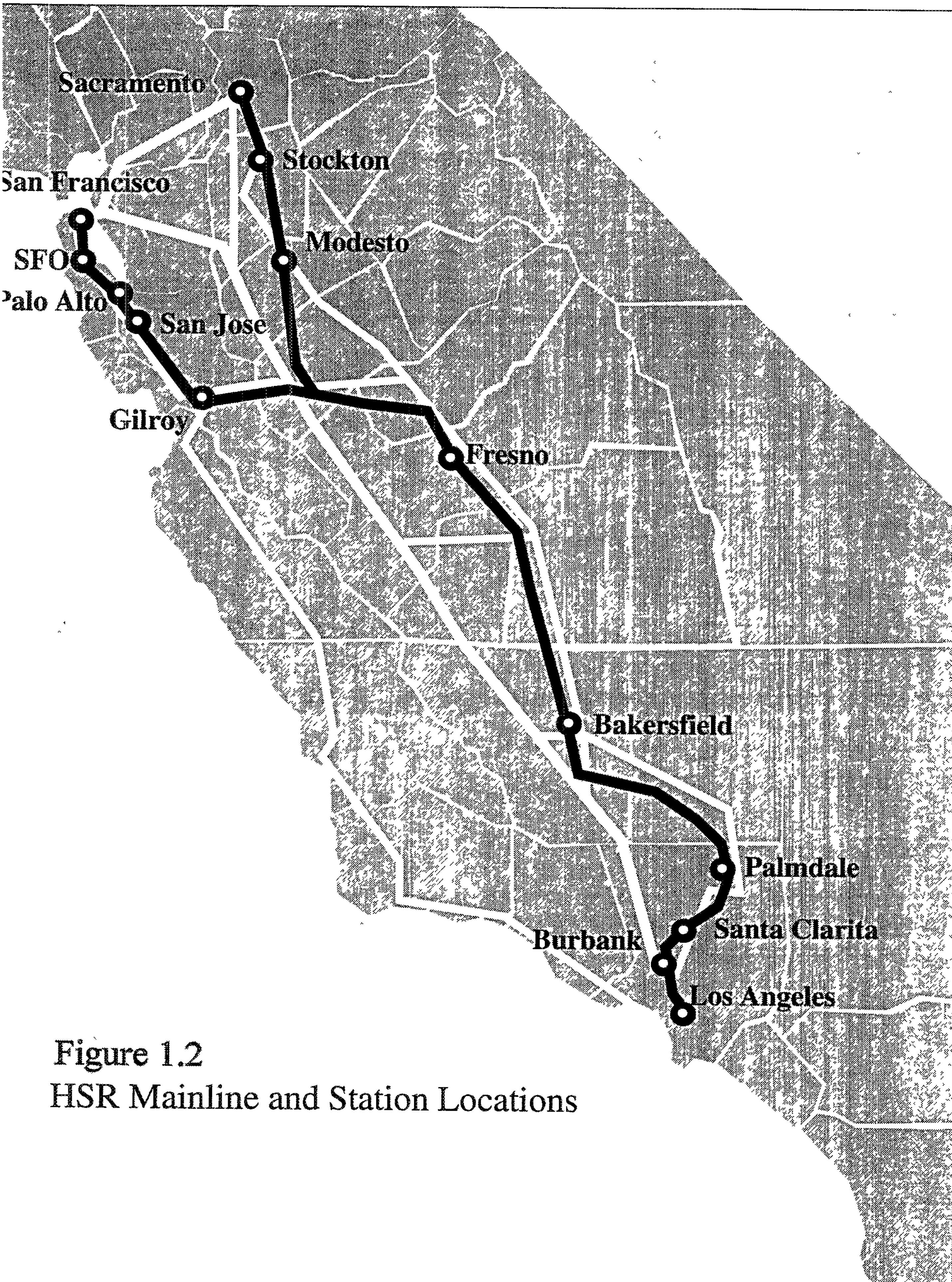


Figure 1.2
HSR Mainline and Station Locations

new alignment follows the Soledad Canyon to Palmdale. From Palmdale, this alignment heads north through the Antelope Valley and the Tehachapi mountains to the Central Valley. Reaching the Central Valley, the mainline continues north serving Bakersfield and Fresno on new right-of-way just west of these cities. Northwest of Fresno, near Los Banos, the mainline would split, with one branch going to the San Francisco Bay Area and the other to Sacramento.

To the Bay Area, the new alignment traverses the Pacheco Pass west to Gilroy at the southern end of the Santa Clara Valley. From Gilroy, the Highway 101 median strip brings the mainline north to San Jose. Southern Pacific (CalTrain) right-of-way is utilized up the peninsula to San Francisco. This segment of the mainline terminates in downtown San Francisco at a new Transbay Terminal.

The second branch of the mainline continues on a new alignment north through the Central Valley to Sacramento. This branch of the mainline terminates downtown at the Sacramento Amtrak station.

The Palmdale Alternative

The preferred mainline alignment described in *High Speed Trains for California* was used in this report with one exception: a Palmdale alignment replaced the Grapevine alignment for the Southern California mountain-crossing segment. Although use of a route through Palmdale rather than the Grapevine adds an estimated five minutes to travel times to and from the Los Angeles region, the benefits of such a routing appear to outweigh the costs.

A southern crossing alignment via Palmdale serves the widely dispersed population of the Los Angeles Metropolitan Region better than a Grapevine alternative for several reasons. Most notably, this alternative provides direct service for the rapidly growing population in the Palmdale/Lancaster area. The Southern California Association of Governments (SCAG) projects that the population for the Palmdale/Lancaster area (currently about 240,600) will increase to nearly 655,000 by the year 2010.[4] In effect, Palmdale/Lancaster will become a major new subsection of Greater Los Angeles, just as the San Fernando Valley did in the 1960s and 70s.

A Palmdale route also better serves the Santa Clarita/Newhall area. SCAG projects the population of this area (currently 151,000) to increase to about 483,000 by the year 2010. Although Grapevine alternatives pass through this area, alignment restrictions make service to Santa Clarita/Newhall virtually impossible.[5] Neither the Palmdale/Lancaster or Santa Clarita/Newhall areas are well served by current air service.

In addition, although considerably longer than the Grapevine route, the Palmdale alternative would be less expensive to construct assuming a maximum grade of 3.5 percent. Since the Palmdale alternative would need fewer miles of tunnel and viaduct, this alternative would cost between $365-$985 million less than a 3.5 percent Grapevine alternative. While a 5.0 percent Grapevine alternative would cost about the same as the 3.5 percent Palmdale alternative, the steeper gradient would significantly increase operational and maintenance costs through the mountain crossing.

Finally, the Palmdale alternative offers the prospect of shared infrastructure with two other HSGT proposals Las Vegas to Los Angeles, and Los Angeles International Airport to a future International Airport at Palmdale The 56 miles from downtown Los Angeles to Palmdale would represent the most costly (approximately $2 billion) and difficult-to-construct segment of an alignment from Los Angeles to Las Vegas Moreover, this segment would certainly represent the majority of the costs for an LAX to Palmdale connection

Stations

For the purpose of modeling ridership, 14 station locations were identified along the HSR mainline, assuming a southern mountain crossing via Palmdale[6] Figure 1 2 schematically illustrates station locations (distances between station pairs are presented in the *Technical Appendix*) Following is a list of the stations and a description of their likely locations

1 *Los Angeles Downtown Station:* The southern terminus of the HSR mainline would be located at Union Station in downtown Los Angeles This implies a major reconfiguration of Union Station's general layout to accommodate the tremendous increase in both train and passenger activity at this location[7] Union Station would not only serve as the hub of the HSR network, but also as the hub of an extensive urban rail network serving the Los Angeles Metropolitan Region

2 *Burbank Station:* An urban station to be constructed along the existing Southern Pacific right-of-way in the general vicinity of the Burbank International Airport.

3. *Santa Clarita Station:* An outlying[8] suburban station in the Santa Clarita/Newhall area, adjacent to Highway 14

4 *Palmdale Station:* An outlying suburban station on the outskirts of Palmdale near the California Aqueduct and Palmdale Boulevard.

5 *Bakersfield Station* An outlying station just west of Bakersfield along the Stockdale Highway

6 *Fresno Downtown Station* A downtown station in Fresno located on a loop line from the HSR mainline through Fresno on existing Southern Pacific right-of-way The most likely location is the site chosen by the Fresno Council of Governments in the Fresno Rail Consolidation Study, just north of Route 41.

7. *Gilroy Station* A suburban station near the junction of Highway 101 and Route 152

8 *San Jose Downtown Station.* An urban station would be constructed at the San Jose CalTrain station site at Cahill to serve as the hub of rail services in the San Jose region The San Jose station would connect HSR, CalTrain, and a future Vasona light rail extension

9 *Palo Alto Station* The CalTrain station at Palo Alto would be reconstructed to allow for HSR service at this location

10 *San Francisco International Airport Station:* A new suburban station to be built along the Southern Pacific right-of-way as close to the airport terminal as possible This station should be incorporated

with plans to bring future BART service to the airport terminal. Ideally, a people-mover would connect the three modes

11 *San Francisco Downtown Station:* A new Transbay Terminal would replace the existing facility. This terminal would serve both HSR and CalTrain services and connect to the existing Montgomery Street BART/Muni station. The downtown San Francisco station would be the Bay Area terminus of the HSR mainline.

12 *Modesto Station:* An outlying suburban station just north of Modesto, near Route 99

13. *Stockton Station:* An outlying suburban station just west of Stockton, near Highway 26.

14 *Sacramento Downtown Station:* The existing Amtrak station in Downtown Sacramento would be reconfigured as the terminal station of the Central Valley HSR mainline branch. A future light rail extension could ultimately provide a direct connection at this facility to the existing Sacramento light rail system.

Because route constraints, the availability of land, and population concentrations largely determine the most likely locations for stations, the choice of location is simpler than might be expected In urban areas, the HSR routing is generally confined to use of existing rail right-of-way Existing rail station sites then become obvious locations for potential HSR stations. Existing stations are generally located very near or actually within downtown core areas, are usually well-connected to the highway network, and are on relatively large plots of land that can accommodate multi-modal terminal uses Furthermore, most cities have long-range revitalization or redevelopment plans focused around their existing downtown rail sites and the surrounding land. Often, existing station sites are the only politically acceptable locations

In rural or suburban areas, locations for outlying stations should be as near as possible to the major population centers. Good access to the highway network and undeveloped land for the facilities are critical factors in choosing these station sites.

The 14 station locations represent an attempt to best serve the population along the HSR mainline Each major population center would have at least one station. More stations along the route would reduce the level of service of the overall system without necessarily providing much additional ridership potential Nevertheless, additional station locations might eventually be desirable, particularly in the Central Valley Consequently, the alignment should be planned to allow for the development of future stations.

Service Attributes

Several service scenarios were defined for the mainline ridership forecasts The basic scenario, summarized in Table 1.2, assumed an ambitious service frequency with HSR fares set at 75 percent of the comparable market air fare.[9] The HSR schedule envisioned reflects a mature system (the forecast year is 2010) and includes both express and skip-stop trains Forty-five trains per day in each direction (for a total of 90 trains) were scheduled between Los Angeles to San Francisco. Of these, 30 would be skip-

Table 1.2

HSR Mainline, Selected Station Pairs: Baseline Assumption Service Attributes

Stations From/To	Distance (miles)	Travel Time (min.)	Avg Speed (mph)	Fare ($)	Service Frequency	Number of Stops
Downtown Los Angeles - Downtown SF*	428	177	145	56	15	1
Downtown Los Angeles - Sacramento *	421	158	160	50	5	1
Downtown Los Angeles - San Jose *	381	138	166	56	8	0
Downtown Los Angeles - Fresno	244	97	151	30	12	1
Downtown Los Angeles - Bakersfield	136	61	134	25	12	1
Fresno - Downtown San Francisco	184	95	116	30	12	1
Fresno - San Jose	136	55	148	25	6	0
Fresno - Sacramento	177	75	142	25	5	1
Fresno - Bakersfield	108	39	166	18	4	0
Bakersfield - Downtown San Francisco	292	128	137	40	12	1
Bakersfield - San Jose	244	89	164	35	6	0
Bakersfield - Sacramento	285	109	157	40	5	1

Notes
* Attributes for Express Service
** One-way fare, 1992 $ (75 percent Air Fare for End-to-End market Alternative)
Frequency One-direction

stop trains and 15 would be express trains making only one stop between terminal stations. Fifteen trains per day in each direction were scheduled between Los Angeles and Sacramento ten skip-stop trains and five express trains.

Additional service scenarios were defined from the initial "basic" scenario by varying one attribute (fare, frequency, and linehaul time) in each. Note that these additional scenarios all assume the same HSR mainline alignment and station locations but vary only in frequency of service to each station, fare, or travel time The "reduced frequency" scenario simply assumed five fewer express trains and four fewer skip-stop trains per day in each direction between Los Angeles and San Francisco and two fewer express trains per day between Los Angeles and Sacramento. The "higher fare" scenario assumed that HSR fares would be equal to air fares in the comparable market Lastly, the "125 mph" scenario assumed maximum operating speeds of 125 mph rather than 200 mph and travel times were recalculated accordingly.

A complete listing of terminal times, linehaul times, fares, and frequency of service for all station pairs and the methodologies used to determine these attributes may be found in the Technical Appendix of this report. Note that while the HSR attributes presented in this report accurately reflect the technology's potential, they are by no means definitive. Countless possible configurations of HSR service attributes exist and the ultimate configuration will depend, in part, on public policy considerations

The Potential for Additional Passenger Services

Modern signaling systems for HSR systems permit three-minute headways Thus, in addition to the skip-stop and express intercity services described in this study, the mainline has the capacity to support other types of service. While not the focus of this study, two additional types of service warrant mention. local intercity operations and commuter services.

For the purposes of this study, an attempt was made to minimize travel times yet provide a high service frequency between station pairs Although not considered here, some demand would arise for trains making several stops or even stopping at all stations Since the mainline can accommodate many different levels of service, the mainline should be carefully planned to allow for as great of flexibility in scheduling as possible.

Throughout the Los Angeles Metropolitan Region and the San Francisco Bay Area, express commuter services could operate on the HSR mainline (the trainsets used for these special commuter services would need to be compatible with the high-speed trainsets) While commuter trains would not operate throughout the high-speed segments, maximum speed capabilities up to 125 mph would be realistic.

Additionally, existing passenger rail services such as the San Joaquins, the Capitol Corridor, and the San Diegans will act as feeder services to the HSR mainline Eventually, these lines may be upgraded to the point where high-speed trainsets may run at lower speeds directly to points along these lines Alternatively, compatible trainsets serving these routes may run on portions of the high-speed mainline

The Potential for Freight Services

Although passenger service is the focus of the CalSpeed study, some potential exists for high-speed freight operations[10] on the mainline In Germany, for example, new high-speed alignments accommodate special freight rolling stock carrying high-value and time-sensitive goods at speeds up to 100 mph during off-peak hours (the German Intercity Express passenger trains maintain a top speed of 155 mph). In a similar manner, high-speed freight could run on the mainline during late night and early morning hours in California

Building and operating a mixed-use high-speed mainline would present some difficulties Overnight high-speed freight operations would have to coexist with nightly maintenance operations, leading to delays and increased maintenance costs Moreover, the freight facilities required for loading and unloading would add a considerable cost to stations. Whether freight rolling stock capable of carrying time-sensitive goods such as agricultural products can operate efficiently over relatively steep grades remains open to question[11] In summary, the freight question deserves further study to determine the potential costs, benefits, and markets for high-speed rail freight in California.

Summary

The goal of the CalSpeed study has been to identify an HSR system which best serves the interests of the people and businesses of California. The study has identified a steel-wheel-on-steel-rail high-speed network predominantly serving passenger service along a mainline from Los Angeles to San Francisco and Sacramento This mainline simultaneously provides for fast through service between California's two major metropolitan regions while delivering high-quality direct connections between all medium-sized communities along the route The demand diverted from other modes to this mainline is the subject of the market and ridership study presented in subsequent chapters of this report

2. INTERCITY TRANSPORTATION IN CALIFORNIA

The transportation network connecting the San Francisco Bay Area/Sacramento region with the Los Angeles region is one of the most heavily traveled in the nation This corridor connects the Bay Area, with its population base of six million, to the fourteen million people living in the Los Angeles region as well as the Sacramento area and the rapidly growing Central Valley In the absence of high-speed ground transportation, intercity travel within the San Francisco Bay Area/Sacramento to Los Angeles corridor relies primarily on four travel modes— air, private automobiles, commercial and chartered buses, and conventional rail. This chapter analyzes the characteristics of these modes, which will compete with high-speed rail for passengers in this corridor.

Of the four modes, air and automobile carry the great majority of passengers, particularly those traveling more than 200 miles In terms of total passengers, the combination of the air and auto modes constitutes over 90 percent of the intercity travel market (see Figure 2.1) Because of the dominance of these two modes and due to limited time and resources, the study focused on air and automobile traffic rather than bus and conventional rail. Buses and conventional rail provide more limited service and carry considerably fewer passengers than either air or private auto travel However, these two modes provide service for trips, predominantly 200 miles or less in length, where air service is either nonexistent, inadequate, or expensive

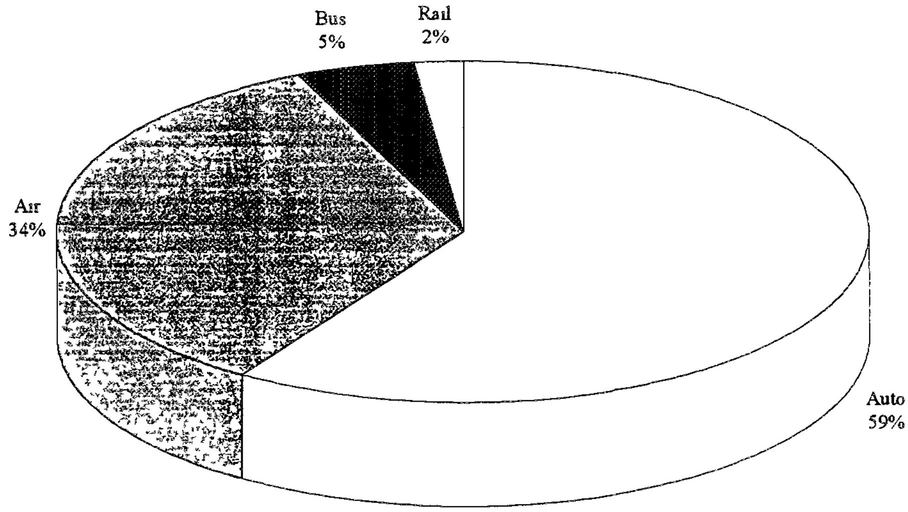
Data is most readily available on air and auto travel patterns. Due to federal reporting requirements, air traffic data is quite extensive In contrast, detailed information on annual Greyhound bus line ridership is difficult to attain since Greyhound has no reporting requirements For automobile travel, the Caltrans statewide trip model provides estimates for intercity trips However, this source is considerably less precise than the air traffic information, as the statewide model is based on somewhat dated survey data and has not been re-calibrated recently. The most recent base year calibration of the Statewide Traffic Model available is for 1987

The remainder of this chapter examines the existing supply and demand conditions for air and automobile travel and projects possible future conditions, in particular, market characteristics and facility capacity The essential features of Greyhound bus and Amtrak rail service are also summarized.

Air Travel

With its large population base, the air network between the San Francisco Bay Area and Greater Los Angeles carries more passengers than any other U.S air corridor under 500 miles (see Table 2.1) Historically, the California corridor has ranked among the most competitive air markets in the United States Unlike most domestic markets, the California corridor was never regulated by the Civil Aviation Board since the corridor constituted an intrastate market. Thus, low airfares in California predate dereg-

Figure 2.1 Intercity Travel in California



Note For passenger numbers by mode refer to Table 2 10

Table 2.1

Largest Domestic US Air Markets Less than 500 miles

	Distance (miles)	Annual Passenger Trips in 1988 (millions)
Los Angeles-San Francisco *	347	6 6
New York-Boston	191	3 4
New York-Washington	214	3 3
Los Angeles-Phoenix	248	2 6
Dallas-Houston	222	2 0
San Diego-San Francisco	447	1 8

* includes only the three major Bay Area airports (OAK, SFO, & SJC) and five major L A region airports (BUR, LAX, LGB, ONT, & SNA)

Source OTA, 1991

ulation of the domestic airline industry, and Californians have long been used to air travel as a relatively inexpensive means of travel.

Today, the corridor remains a highly competitive and rapidly changing market. In 1989, the low-cost, "no-frills" air carrier Southwest Airlines entered the market and began a round of aggressive competition and consolidation that continued into 1993. Another low-cost air carrier, Reno Air, initiated service from San Jose Airport to the Los Angeles region in July of 1993. As a result, previously dominant air carriers such as American Airlines and USAir have reduced their service in the corridor. Based on this recent experience, the prospects for intense competition in this market over the next 20 years remain strong.

However, the Los-Angeles-to-Bay-Area route is not the only intrastate air market within the California corridor that has changed since deregulation in 1977. In the Central Valley, the federal government reduced or eliminated subsidies to airlines operating on routes otherwise not profitable. The air carriers serving Central Valley airports have changed frequently, although discontinued air service has often reappeared through code-sharing carriers.[12] Nevertheless, the net effect for the Central Valley markets was higher fares and lower frequencies.

Existing Conditions

Although continuous change has characterized the California air market since deregulation, the starting point for any analysis requires an understanding of the current intrastate air market. For this purpose, the study relies on three sources: the Federal Aviation Administration (FAA) ten percent ticket sample, the Official Airline Guide, and a survey of air passengers conducted by the CalSpeed researchers.

The FAA data consists of a ten percent sampling of all domestic tickets sold and contains information on actual fares and route.[13] By law, airlines are responsible for submitting this fare and route information to the FAA. Although reporting problems have been known to exist, this problem is more typical of smaller airlines and less so for the major airlines operating in the California corridor. Thus, the ten percent ticket sample seemed a fairly reliable source of total air passenger numbers and air fares.

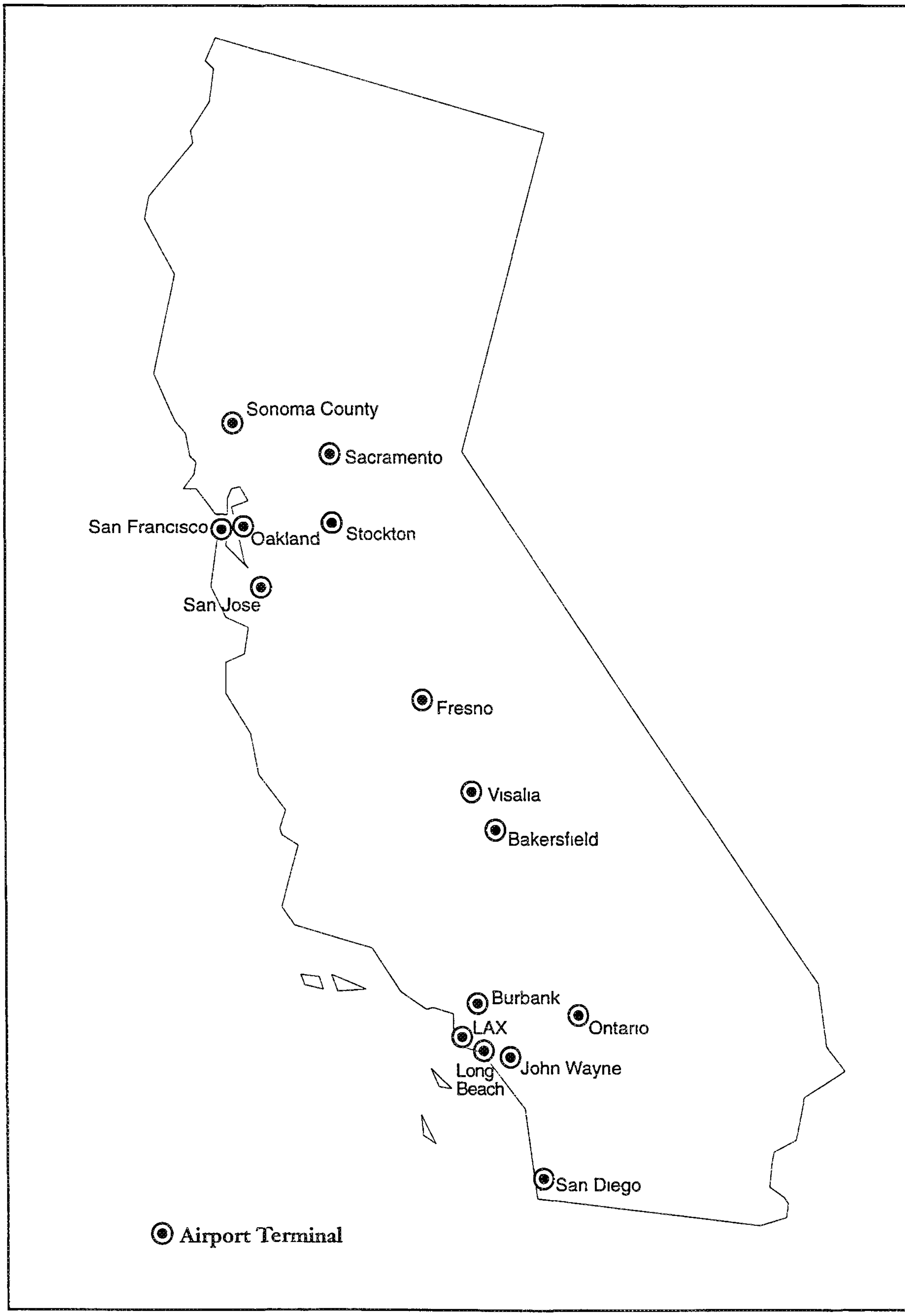
The Official Airline Guide (OAG) lists the schedules of airlines and is published every other week to update airline schedules. The OAG served as the main source for calculating frequency of service between airports. The OAG was not used as a source of airfares since it does not reflect special fares available to certain business customers or the breakdown of passengers paying the different available fares.

Finally, the CalSpeed 1993 Air Passenger Survey collected information from more than 3,000 California corridor air passengers. This extensive survey provided precise information on passenger origins and destinations unavailable from other sources.

To analyze the air market, the study first identified those airports which would compete with the proposed high-speed rail service. These airports include the main Bay Area airports (San Francisco International or SFO, Oakland, and San Jose), the main Los Angeles region airports (Los Angeles International or LAX, Ontario, Burbank, Orange County/John Wayne, and Long Beach), the Sacramento Airport, the Sonoma Airport, and intermediate airports in Bakersfield, Fresno, Merced, Modesto, Stockton, and Visalia (see Figure 2.2). The data gathered for these 16 airports included passenger trips, fares, and flight frequency.

As expected, the flights between the main Los Angeles and Bay Area airports carried the majority of the passengers in the study area (see Table 2.2). In 1992, 9.2 million passengers flew within the study area. Of these, 7.2 million or 78 percent flew between the five Los Angeles and three Bay Area airports; 1.7 million passengers or 19 percent began or ended their journey in Sacramento, and 194,480

Figure 2.2 Airport Locations: San Francisco to Los Angeles Corridor



passengers traveled to or from the Central Valley [14] These numbers include commercial and commuter airlines, *and exclude connecting and non-paying passengers* [15]

Note that connecting passengers are defined as those who have a trip end outside the study area Thus, passengers with flight itineraries such as Los Angeles-San Francisco-Tokyo or San Francisco-Los Angeles-Phoenix would be excluded from the count for the purposes of this study. Note also that a large percentage of the traffic between LAX and SFO is classified as "connecting" under this definition (41 percent in 1992) In contrast, a greater percentage of traffic between airport pairs such as Oakland-Burbank is intrastate or "local" traffic (90 percent in 1992, refer to Table 2.3) This phenomenon would explain the low number of passengers shown in Table 2 2 between LAX and SFO relative to the high number of flights offered

The price of the average one-way air fare varied considerably. For most flights between the Los Angeles and Bay Areas, the fares were relatively modest. For example, on average, flying between Oakland and Los Angeles cost $50 and one-way fares for flights between San Francisco and Burbank averaged $78 (see Table 2 4) However, passengers at the smaller airports, such as Fresno or Bakersfield, faced considerably higher fares even though those flights usually traversed shorter distances. Most of the other flights that required higher fares were either operated with smaller commuter aircraft or made stopovers along the way.

Table 2.2

Selected 1992 Passenger Traffic Between Airports (excluding connecting passengers)

	Oakland	San Francisco	San Jose	Sacramento	Bakersfield	Fresno
Burbank	765,910	470,630	207,290	454,810	***	1,330
Long Beach	116,640	132,930	2,180	810	***	***
Los Angeles	1,033,600	1,684,850	552,039	443,590	4,250	49,840
Ontario	650,630	268,160	196,580	492,710	160	17,560
Orange County	88,470	629,650	440,330	331,700	470	20,690
Oakland	***	***	***	***	***	4,130
San Francisco	***	***	1,810	16,860	17,150	29,990
San Jose	***	1,810	***	8,350	910	3,760
Sacramento	***	16,860	8,350	***	2,670	6,760

Note Refer to the Technical Appendix for passenger traffic information on all other airport pairs

Source FAA 10 percent Ticket Sample, 1992

Table 2.3

Categories of Air Traffic Between Airports

Passenger Traffic Between Los Angeles (LAX) and San Francisco (SFO) Airports

Year/Quarter	(A) "Onboard Pax "	(B) "Enplaned Pax "	(C) "Total Traffic"	(A-C)/A Percentage Connecting
1991/all	3,899,941	3,637,509	2,425,780	0 38
1992/1st quarter	751,292	716,537	454,260	
1992/2nd quarter	786,303	741,691	449,920	
1992/Quarter 1 & 2	1,537,595	1,458,228	904,180	0 41

Passenger Traffic Between Oakland and Burbank Airports

Year/Quarter	(A) "Onboard Pax "	(B) "Enplaned Pax "	(C) "Total Traffic"	(A-C)/A Percentage Connecting
1991/all	914,345	816,728	812,090	0 11
1992/1st quarter	215,658	192,113	190,900	
1992/2nd quarter	237,664	216,418	216,360	
1992/Quarter 1 & 2	453,322	408,531	407,260	0 10

Notes
(A) Onboard Passengers Passengers transported in the non-stop market from origin airport to destination airport (Onboard Database)
(B) Enplaned Passengers Passengers enplaned at origin airport and continuing to an on-flight destination (Onboard Database)
(C) Local Traffic passengers who made the entire trip on a single carrier (O&D Plus Database [reflects passenger's true origin and destination])

Based on OAG data, HSR would compete with an average of 845 flights per day if current conditions persist Of these flights, 123 are between SFO and LAX. In addition, the main airports for the Bay Area and the Los Angeles region together account for well over half of the total flights in the study area, and the total capacity for these airports is proportionately larger because many of the Central Valley airports only utilize low capacity commuter aircraft

In recent years, several agencies have conducted surveys of California air passengers, including the 1987/88 Los Angeles and Ontario Air Passenger Surveys and the 1991 Metropolitan Transportation Commission (MTC) Air Passenger Survey at San Francisco, San Jose, and Oakland airports However, the existing surveys lack complete origin to destination information, since the purpose of those surveys was to study not only the California corridor but a combination of intrastate, interstate, and international travel patterns as well None of these surveys requested information on passenger destinations after disembarking from the aircraft

The CalSpeed study conducted an air passenger survey to remedy this shortcoming The survey was administered at the three main Bay Area airports (SFO, Oakland, and San Jose), as well as at four of the Los Angeles region airports (LAX, Ontario, Burbank, and Orange Country/John Wayne [SNA]) (see Table 2.5) Passengers waiting for flights bound for the Bay Area or Los Angeles were targeted during

Table 2.4

Air Travel Characteristics, 1992

Average One-Way Fares Between Airports (1992 dollars)

	Oakland	San Francisco	San Jose	Sacramento	Bakersfield	Fresno
Burbank	48	78	79	47	***	89
Long Beach	73	64	59	169	***	***
Los Angeles	50	70	74	66	93	95
Ontario	46	71	71	49	124	76
Orange County	120	77	82	66	116	118
Oakland	***	***	***	***	48	101
San Francisco	***	***	36	76	100	88
San Jose	***	36	***	106	130	106
Sacramento	***	76	106	***	138	130

Source FAA 10 percent Ticket Sample, 1992

Average Daily Flight Frequency

	Oakland	San Francisco	San Jose	Sacramento	Bakersfield	Fresno
Burbank	18	16	15	14	***	7
Long Beach	8	6	***	***	***	***
Los Angeles	30	123	33	21	32	55
Ontario	21	14	17	19	***	11
Orange County	17	31	18	13	***	7
Oakland	***	***	***	***	***	7
San Francisco	***	***	13	52	13	33
San Jose	***	13	***	14	***	8
Sacramento	***	52	14	***	4	5

Source OAG

Table 2.5

Airport Pairs and Passenger Survey Numbers

	BUR	LAX	ONT	SNA	OAK	SFO	SJC
No of passengers surveyed*	479	616	121	534	467	534	424
Valid survey responses	434	418	100	420	363	318	282
Connecting passengers	45	208	21	114	104	216	142
Valid response percentage	90 6%	66 7%	82 6%	78 7%	77 7%	59 6%	66 5%
Connecting passenger %	9 4%	33 2%	17 4%	21 3%	22 3%	40 4%	33 5%

* Includes connecting passengers, which are excluded from all other survey results

April and May of 1993 (excluding the Easter holiday) A total of 3,174 passengers were interviewed, of whom 849 were connecting passengers [15]

To record passenger origins and destinations, the nine-county Bay Area region was divided into 34 zones and the Greater Los Angeles region was divided into 43 zones, in accordance with the Metropolitan Transportation Commission Superdistricts and the Southern California Association of Governments (SCAG) Regional Statistical Areas, respectively Total annual passenger trip-ends for each of the zone pairs in the study area were estimated using the valid survey responses.[16] The resulting trip distribution shows that downtown San Francisco generated the highest number of trips with over a million air trip-ends estimated for 1992 (see Table 2.6) This total is considerably higher than the number of trip ends for any other zone, and especially remarkable considering the small size of the downtown San Francisco zone and its relatively difficult airport access (see Figure 2 3)

Future Market Growth

Estimates of annual air passenger growth rates vary between 2 percent and 5 7 percent. The volatility of the air market and its particular sensitivity to price competition makes projecting the future market difficult. For example, in 1985 6 69 million passengers flew between the Bay Area and the Los Angeles region. By 1991, this number increased to about 9 million passengers, but dropped back down to about 7.2 million passengers in 1992 (see Table 2 7) This noticeable difference in passenger traffic can produce distinctly different growth rates, making reliable future growth estimates based on historical data problematic.

In addition, the driving forces of air travel continue to change Business travel, historically the main source of airline profit, has fallen in recent years The International Air Transport Association recently carried out a survey of business passengers who travel frequently. Some 30 percent of those surveyed reported travel budget cuts in 1993, and about 25 percent expected cuts in 1994[17] If business travelers continue to reduce trips or travel in economy class, the fundamental economics of airlines will change, with unpredictable effects on air routes and a likely rise in economy fares

The FAA has produced forecasts of passenger traffic at all airports in 1995, 2000, and 2005. The FAA forecasts do not designate the markets in which growth will occur, however, and are therefore not useful for predicting air traffic within the California corridor

Nationally, intercity travel has grown at an annual rate of 5 5 percent;[18] although few expect this rate to continue The Transportation Research Board (TRB) forecasts a growth rate of between 2 percent and 4 percent through the year 2010 [19] An annual growth rate in the middle of the TRB range, or 3 percent, was selected to forecast California corridor air traffic in the year 2010. A 3 percent annual growth rate results in an increase of 70 percent in total air traffic between 1992 and 2010, or an increase from 9 23 million corridor passengers to 15 7 million

Table 2.6

Air Passengers Estimated Total Trip-Ends for 1992

NORTHERN CALIFORNIA

ZONE		TOTAL PASSENGERS
1	Downtown San Francisco	1,036,844
2	Richmond District (SF)	497,600
3	Mission District (SF)	246,212
4	Sunset District (SF)	179,382
5	Daly City/San Bruno	478,742
6	San Mateo/Foster City	207,926
7	Redwood City/Menlo Park	244,338
8	Palo Alto/Los Altos	306,914
9	Sunnyvale/Mountain View	336,014
10	Saratoga/Los Gatos	234,224
11	Central San Jose	231,632
12	Milpitas/Alum Rock (SJ)	147,326
13	South San Jose	96,058
14	Coyote (SJ)/Gilroy	37,844
15	Livermore/Pleasanton	149,462
16	Fremont/Union City	239,736
17	Hayward/San Leandro	210,984
18	Oakland/Alameda	495,968
19	Berkeley/Albany	217,556
20	Richmond/El Cerrito	126,184
21	Concord/Martinez	144,164
22	Walnut Creek/Orinda	196,098
23	Danville/San Ramon	148,022
24	Antioch/Pittsburg	100,566
25	Vallejo/Benicia	50,418
26	Fairfield/Vacaville	128,370
27	Napa	36,554
28	St Helena/Calistoga	36,770
29	Petaluma/Sonoma	66,774
30	Santa Rosa/Sebastopol	145,580
31	Healdsburg/Cloverdale	53,998
32	Novato	82,316
33	San Rafael/San Anselmo	109,928
34	Mill Valley/Sausalito	82,400
35	Sacramento County	784,368
36	Stanislaus County	112,760
37	Sutter County	56,512
38	El Dorado County	111,388
39	Placer County	149,466
40	Stockton	143,982
41	Tracy	16,074
42	Northeast San Joaquin Co	296
43	Lodi	49,826
44	Escalon/Manteca	47,840
45	Stanislaus County	65,394
46	Merced	9,602
47	Madera	56,742
48	Fresno	53,362
49	Fresno County (w/o Fresno)	24,518
50	Kings County	1,124
51	Tulare County	3,250
52	Bakersfield	15,506
53	Kern County (w/o Bakersfield)	10,342
54	Santa Cruz County	91,172
55	Monterey County	42,512
56	San Benito County	6,808
57	San Luis Obispo County	0
108	North California Counties	375,850

SOUTHERN CALIFORNIA

ZONE		TOTAL PASSENGERS
58	Santa Barbara County	18,966
59	Los Padres National Forest	0
60	San Buenaventura	44,370
61	Oxnard/Camarillo	90,516
62	Simi Valley/Moorpark	60,720
63	Thousand Oaks	46,948
64	Agoura Hills	18,170
65	Westlake Village	35,468
66	Santa Clarita	40,582
67	Lancaster	35,574
68	Palmdale	28,248
69	Angeles National Forest	0
70	Woodland Hills/Van Nuys/Northridge	319,430
71	Burbank/North Hollywood	443,376
72	San Fernando/Granada Hills	76,164
73	Malibu/Topanga	52,644
74	Santa Monica/Westchester	555,958
75	Culver City/Mid-Wilshire	896,448
76	Inglewood/Hawthorne	552,770
77	Torrance/Carson	466,992
78	Long Beach/Lakewood	364,570
79	East L A /Compton	87,750
80	Downey/Whittier	147,562
81	Downtown L A	423,806
82	Glendale/Eagle Rock	256,368
83	Pasadena/El Monte	460,722
84	La Puente/Covina/Glendora	190,606
85	Pomona/Claremont	123,266
86	Ontario/Chino	422,424
87	San Bernardino/Colton	162,114
88	Big Bear/Lake Arrowhead	402
89	Buena Park/Los Alamitos	80,424
90	Fullerton/Brea	131,634
91	Anaheim/Garden Grove	403,448
92	Huntington Beach/Westminster	210,366
93	Newport Beach/Costa Mesa	280,516
94	Laguna Beach/San Clemente	293,896
95	Placentia/Yorba Linda	58,468
96	Santa Ana/Orange/Tustin	276,906
97	Lake Forest/Trabuco Canyon	45,396
98	North Irvine	243,048
99	Norco	4,874
100	Riverside/Corona	141,962
101	Moreno Valley/Perris	43,784
102	San Jacinto/Hemet	19,638
103	Rancho California/Temecula	20,538
104	Banning	9,034
105	Victorville/Barstow/Needles	191,452
106	Palm Springs/Blythe	230,704
107	San Diego County	28,700

Figure 2.3
CALSPEED ZONES
Air Passenger Trip-Ends

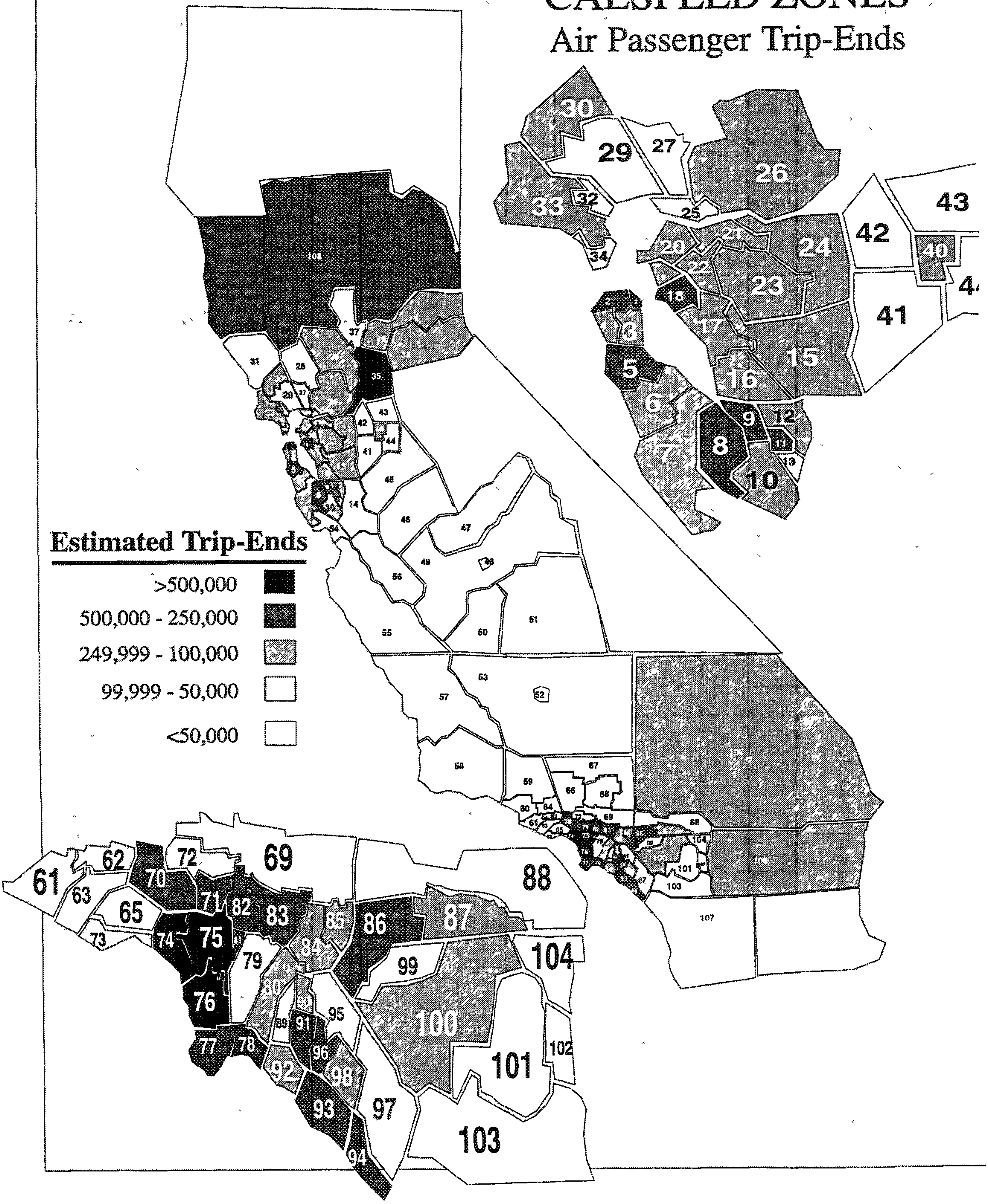
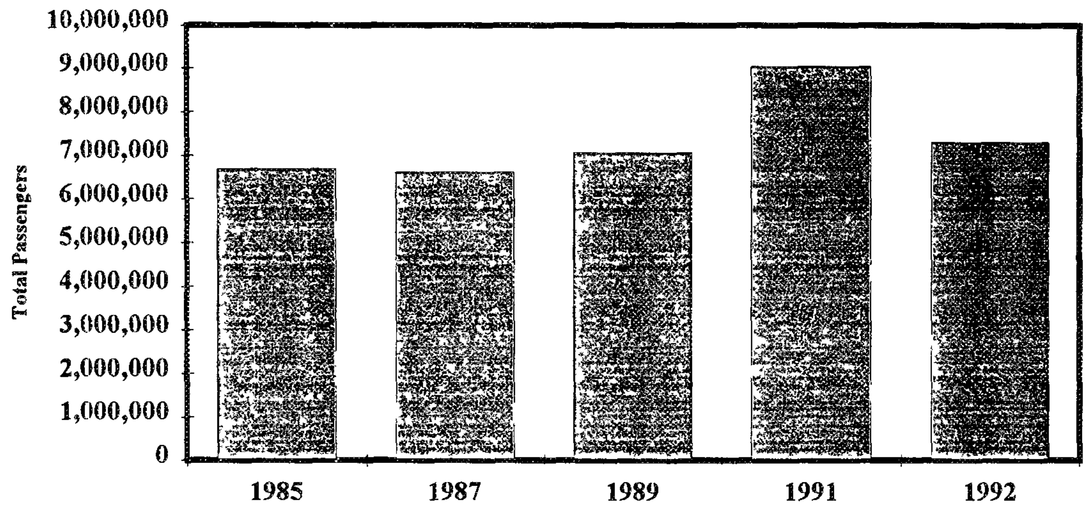


Table 2.7 Annual Air Passenger Traffic, Bay Area - Los Angeles



Note Includes non-paying passengers
Source FAA ticket sample

Future Air Capacity

Over the next 20 years, the California airports are expected to grow considerably more congested, largely due to increased international traffic. In response to this problem, the airports are planning a number of facilities expansions and upgrades to deal with increased traffic.

In Northern California, three of the four major airports will add significantly to their facilities:

- Sacramento Airport will add a new $100 million terminal by June 1995, adding eight gates to its current fourteen and increasing its capacity by 40 percent.
- Pending environmental approval, Oakland is scheduled to add six to ten gates and to extend its runway by the year 2002, increasing its capacity by about 40 percent. Beyond the year 2002, a light rail connection to the BART rail system, as well as an additional terminal and runway, are likely.
- San Francisco International Airport has a two-phase, $2.6 billion project that will expand all aspects of the airport's operations. This project will include 20-30 percent more space for domestic flights, renovation of the existing domestic terminal, 100 percent more space for international flights, and a people-mover. Most of these additions will be completed by 1997. Also likely is an extension of BART to the airport.

Although most of the airports in the Central Valley currently operate significantly below capacity, some are planning expansion:

- Fresno will add jetway loading within 5-10 years, allowing the airport to handle wide-body jets. By the year 2010, Fresno might add ten gates to its current fourteen and six additional gates with jetways.

- Bakersfield plans to replace its current three gates with six more in a new module The estimated cost is $28 million, and construction would be completed after the year 2000
- Stockton, depending on the need, could have a new, $100 million terminal within 15-20 years Stockton also has 750 acres, currently without infrastructure, available for airport expansion, as well as hotel, commercial, and industrial development

In Southern California, three airports have significant plans for expansion

- Burbank has a two-phase program By 1998, Burbank will have a new, $300-million terminal adding 19 gates to its current 14 and serving 70 percent more passengers than in 1992 The second, more tentative phase would add eight gates by 2010 and allow for nearly 80 percent more passengers.
- Ontario will have a new, $185 million, 32-gate terminal by 1997 that will double its current domestic capacity and free up 12 to 15 gates for international flights. Ontario might also extend its one runway.
- Los Angeles International Airport is considering five options that would help meet its anticipated future growth The most likely plan includes a new 24-gate international terminal, 11 domestic gates converted from the existing international terminal, 11 new gates if necessary, and a people-mover This project would allow the airport to serve the anticipated 38 percent growth by the year 2000 Additionally, a long-range, tentative plan exists to build an international terminal at Palmdale Airport with a high-speed rail connection to LAX. This arrangement would allow the transfer of LAX's international capacity to Palmdale and free up LAX for additional domestic flights.

Despite these long-range plans for airport expansions, accommodating growth in California intercity air travel will not necessarily require additional facilities If airlines operate larger-capacity aircraft, airports can accommodate more air travelers without necessarily increasing the number of landing slots or terminal gates [20]

Intercity Auto Travel

The private automobile is the most common mode for intercity transportation in California. The Caltrans Statewide Traffic Model 1987 trip tables contain 24,393 average daily vehicle trips of 200 miles or longer and 60,452 trips of at least 100 miles in length within the CalSpeed study area These numbers translate into an estimated 16 million annual passenger trips of at least 200 miles in length and 65 7 million annual passenger trips of at least 100 miles.

A comprehensive network of freeways and highways facilitates intercity auto travel throughout the state. Since its completion in the early 1970s, Interstate 5 (I-5) has been the principal link in the California freeway network Bypassing the urban areas in the Central Valley, I-5 offers the fastest, most direct route between the state's largest metropolitan regions. Route 99 and US101 handle most of the remaining intrastate travel. US101 provides a more coastal route between the Bay Area and Greater Los Angeles, while Route 99 directly serves the Central Valley population centers (see Figure 2 4)

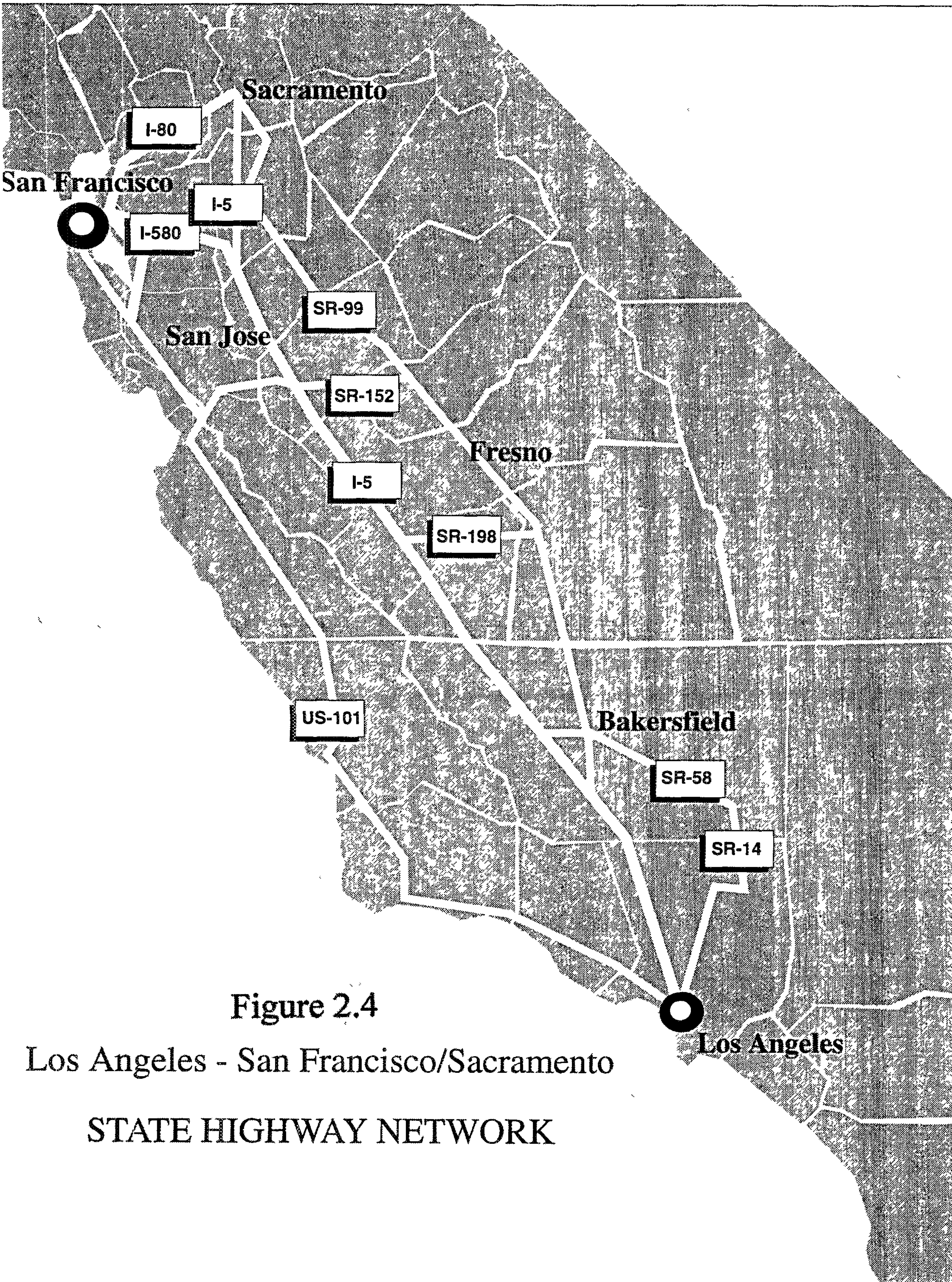


Figure 2.4

Los Angeles - San Francisco/Sacramento

STATE HIGHWAY NETWORK

Compared to air travel, the available information on intercity auto travel is considerably less precise The statewide origin and destination surveys upon which the Caltrans Statewide Model was based were completed decades ago Since then, the model has been updated and re-calibrated with new sociodemographic data and screenline counts Nevertheless, intercity auto travel estimates from the Caltrans Statewide Model will suffice for planning purposes Currently, the model applies socioeconomic and highway system data to the 1987 base year and 2010 forecast year to produce estimated vehicle trips between 1,495 delineated traffic zones.[22] Table 2 8 summarizes 1987 annual one-way vehicle trips and estimated passenger trips between selected regions.

Future Market Growth

Based on the Caltrans Statewide Model, intercity travel in general will increase by about 44 percent in California by 2010 Within the study area, an estimated 23 million automobile passenger trips per year of at least 200 miles and 95 6 million of at least 100 miles will occur Table 2 8 also summarizes annual one-way passenger trips between the selected regions for the forecast year 2010 and Table 2.9 presents the expected percent increase in passenger trips between these regions from 1987 to 2010

Future Network Capacity

To help alleviate existing congestion and maintain current levels of service amidst expected increases in intercity traffic, Caltrans has both immediate and long-range plans for increasing statewide highway network capacity These plans mainly involve the addition of lanes to existing facilities, since the intrastate network is largely complete and any new major highway corridors would likely elicit strong citizen opposition. Aside from some urban segments, the medians of the intrastate highways generally provide ample width for additional lanes

While Caltrans plans improvements for all of the major intrastate routes, increasing the capacity of State Highway 99 is the top non-urban highways priority Through the Central Valley counties of Kern, Tulare, Fresno, and Madera (Caltrans District 6), most of this freeway is four lanes wide (two lanes in each direction), with the remainder being six lanes wide. Within the next 20 years, Caltrans will expand the entirety of Highway 99 through this region to a six-lane freeway Through Stanislaus, Merced, and San Joaquin Counties (Caltrans District 10), Highway 99 is currently a four-lane expressway. This segment will be a completely grade-separated freeway of at least four and possibly six lanes by 2010

Most of the significant capacity improvements for I-5 and US101 over the next 20 years are likely to be concentrated in urban areas High-Occupancy Vehicle (HOV) lanes are planned for most of I-5 and US101 in the Los Angeles region In the Bay Area, US101 between San Jose and Gilroy will be entirely a six-lane facility by 1998 By 2010, Caltrans expects to add two additional lanes in the median to enlarge this segment of US101 to eight lanes

Table 2.8

Intercity Automobile Travel Between Selected Regions

a) **Annual Passenger Trips, 1987**

	Bay Area	Sacramento	Fresno	Bakersfield
Los Angeles	6,449,769	909,945	1,422,405	2,486,777
Bay Area	—	18,133,123	1,328,454	276,597
Sacramento	18,133,123	—	228,636	36,135

b) **Annual Passenger Trips, 2010**

	Bay Area	Sacramento	Fresno	Bakersfield
Los Angeles	8,758,467	1,470,366	2,006,478	3,432,644
Bay Area	***	29,745,524	1,915,812	382,374
Sacramento	29,745,524	***	367,263	63,729

Notes
Annual Passengers = (Avg daily vehicle trips)(365)(vehicle occupancy factor)
Vehicle Occupancy Factors = 1 8 and 1 23 depending upon trip length
Los Angeles = SCAG region
Bay Area = MTC region
Sacramento = Sacramento County
Fresno = CalSpeed Zone for Fresno Metropolitan Area
Bakersfield = CalSpeed Zone for Bakersfield Metropolitan Area

Source for Average Daily Vehicle Trips Caltrans Statewide Model

Table 2.9

Intercity Automobile Travel Between Selected Regions

Percent Increase: From 1987 to 2010

	Bay Area	Sacramento	Fresno	Bakersfield
Los Angeles	35 8%	61 6%	41 1%	38 4%
Bay Area	***	63 9%	44 2%	38 2%
Sacramento	63 9%	***	60 6%	76 4%

Another high priority for additional lanes is I-205, located in San Joaquin County. Currently experiencing some of the worst traffic problems in the Central Valley, this freeway will expand from four to six lanes in the near future Caltrans envisions that eventually I-205 will be an eight-lane facility with an HOV lane in each direction

Although additional projects to increase the capacity of the existing intrastate highway network are planned, their funding is less certain A tightening state budget places many of these projects in jeopardy For example, plans to widen I-5 between Stockton and Sacramento from four to six lanes may largely depend on the availability of private-sector financing

Other Intercity Travel Modes

Although the vast majority of intercity trips in California are either by air or automobile, findings on bus and conventional rail transportation still merit reporting.

Conventional Rail

Amtrak operates all intercity passenger rail service in California The main rail service between the Bay Area and Los Angeles region is provided by the San Joaquins, which make four trips a day in each direction. The trip takes about eight to nine hours with a one-way fare of $75 and round-trip fare of $82 as of June 1993 This service requires a transfer to or from feeder buses at Bakersfield The San Joaquins are slightly faster and more expensive for a round trip than the bus, but cost about the same as an air trip Between Oakland to Fresno, there are four trains per day in each direction The trip takes about five hours, and costs $39 for a one-way ticket and $46 for a round-trip This service is slower and more expensive than bus service and auto, but costs considerably less than flying In 1992, the San Joaquin line carried 483,600 one-way passengers The average trip length was 147 miles, while the average revenue per passenger was $25.58[23]

The "Coast Starlight," utilizing Southern Pacific's coastal rights-of-way from Los Angeles to Seattle, is another conventional rail option from Los Angeles to Northern California However, only one train a day runs in each direction, and the Coast Starlight provides a considerably slower service than the San Joaquins for intrastate travel Although the Coast Starlight requires no transfer, this train takes a more circuitous route with many speed restrictions Many of the Coast Starlight passengers ride the Coast Starlight for the scenic route rather than for its speed and cost attributes,[24] and many do not travel exclusively in California. For these reasons, only the San Joaquin service truly represents intercity rail ridership (and potential HSR ridership) between Northern California and Greater Los Angeles

The San Diego-Los Angeles (LOSSAN) corridor is one of Amtrak's most successful routes Only Amtrak's Northeast Corridor had greater patronage than the 1.67 million annual passengers who rode the San Diegans in 1991/92.[25] The LOSSAN service is relevant to this study because it would initially serve as a feeder service to the HSR mainline and ultimately would carry through-service from the HSR mainline on upgraded LOSSAN tracks

Intercity Bus Service

Since Greyhound Bus Lines acquired Trailways in the late 1980s, the company has held a virtual monopoly on intercity bus travel in California Its intercity bus service consists of two primary north-south routes One route roughly follows Highway 101 from San Francisco to Los Angeles The other route goes from Sacramento to Los Angeles with stops in the larger urban areas in the Central Valley Together, these routes carried approximately 1.3 million passengers in 1992, with only about one-fourth of them traveling the full length[26] Because buses are well suited to short-haul routes (such as Fresno to Bakersfield) and because air travel either does not exist or costs considerably more, Greyhound bus service plays an important role for intercity travel in the Central Valley area

Greyhound's bus service costs less than air travel, especially for short- to medium-distance trips (under 200 miles) These lower fares are offset by longer trip times and less flexible scheduling, however

Greyhound schedules 11 daily departures from Oakland to Los Angeles and charges $39 for a one-way ticket for a nine- to eleven-hour trip In contrast, the average air fare for the same route is about $50 for a flight that takes less than two hours For shorter trips, Greyhound offers more substantial price advantages as well as a smaller time penalty For example, bus service from Oakland to Fresno costs $22 50 and takes between four and five hours Air travel in this market costs between $60 to $80 more

Summary

The existing intercity transportation network in the California corridor is heavily utilized and serves a large and continuously growing population base Although market forces have driven carriers out of the corridor, some newer carriers have thrived and the potential for new carriers, including HSR, remains strong

Table 2 10 summarizes the current and future volume of passenger trips in the California corridor for different modes With the exception of a portion of the automobile trips,[27] the air and auto trips in Table 2 10 represent a considerable potential market for high-speed rail. Although projections for intercity bus and conventional rail ridership are not available, the current demand for these modes demonstrates a potentially divertable market for high-speed rail as well In addition, the relatively high fares for air travel, the longer travel times for conventional rail and bus, and the relative lack of service frequency suggest a possible latent demand for common carrier travel in the Central Valley.

Given the projected increasing demand for air and auto travel, the long-term expansion plans for most of the airports and highway facilities in the study area are not surprising To the extent that HSR can alleviate congestion on other modes, the need for some of these expansions may be reevaluated

Table 2.10

Bay Area/Sacramento-Los Angeles Region Corridor: Estimated Annual Passenger-Trips by Mode

Mode (Base Year)	Base Year	Forecast Year (2010)
1 Private Automobile (1987)	16,000,000	23,100,000
2 Air (1992)	9,200,000	15,700,000
3 Intercity Bus (1992)	1,300,000	n/a
4 Conventional Rail (1992)	483,600	n/a

Sources
1 Based on Caltrans Statewide Model vehicle trips at least 200 miles in long within the CalSpeed study area
2 Onboard Database (FAA 10 percent ticket sample), 1992
3 Greyhound, Inc , 1992
4 San Joacuin ridership from California Rail Passenger Program Report (1993)

3. RIDERSHIP

The forecasts presented in this chapter estimate the high-speed rail ridership that would be diverted from the future intercity highway and air markets. The approach taken to the market study reflects the resources available to the researchers as well as theoretical and practical considerations The methodology used to produce these ridership forecasts is only briefly discussed here, a more thorough description may be found in the Technical Appendix, published separately.

Overview of Methodology

The process of forecasting ridership diverted to high-speed rail from the air and auto modes involved six tasks as follows:

1 Select the form of the mode choice model, taking into account both theoretical considerations and the available data.

2 Quantify the total current intercity travel market, defined as the current volume of air and auto travel in the corridor

3 Calculate the modal attributes — the variables such as total travel time, access time to airports and rail stations, fares, and frequency of service — upon which people make their travel decisions

4 Combine all the information on travel patterns, choices, and modal attributes to estimate the coefficients of the mode choice model (i.e , how people weigh the modal attributes in their decision-making process)

5 Determine the size of the future intercity travel market, defined as the forecast air and auto traffic in the corridor

6 Apply the mode choice model to the forecasted 2010 intercity travel market to produce the predicted market shares of auto, air, and high-speed rail.

Figure 3 1 illustrates the sequence of steps in the demand forecasting process, along with the sources of data required for each step These steps are discussed in complete detail in the Technical Appendix

Existing data was used in almost every step of the process. The sources of existing data included the California Statewide Traffic Model highway network and vehicle trip tables, the Federal Aviation Administration (FAA) ten percent ticket sample, and regional highway network models

One significant gap in the existing data was the lack of true origins and destinations for air passengers in the California Corridor While accurate counts of the volume of air passengers between *airports* was easily available, little information existed on the actual points of origin and final destination for these passengers. Since the potential for high-speed rail to better serve true origins and destinations is an important factor in its competitiveness, the CalSpeed study undertook an air passenger survey at the major airports in the Bay Area and Greater Los Angeles to supplement the FAA data.

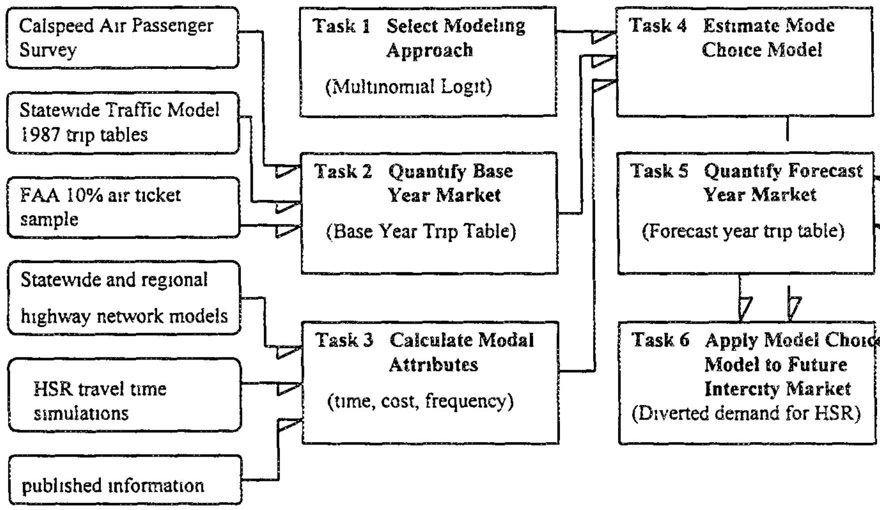


Figure 3.1 CalSpeed Ridership Study Technical Approach

The study of intercity travel required the development of a spatial framework or zone system (see Figure 3 2) The number and size of zones were guided by the requirement for a fine enough grain to make the analysis meaningful, combined with the need to keep the database size manageable In the major metropolitan areas, the regional model zone systems formed the basis for the CalSpeed study zones the Metropolitan Transportation Commission "superdistricts" form the Bay Area zones; Southern California Association of Governments "regional statistical areas" form the Los Angeles zones. Outside the two major metropolitan areas, the zones consist of counties or parts of counties as delineated in the California Statewide Traffic Model zone system.

Ridership Forecasts

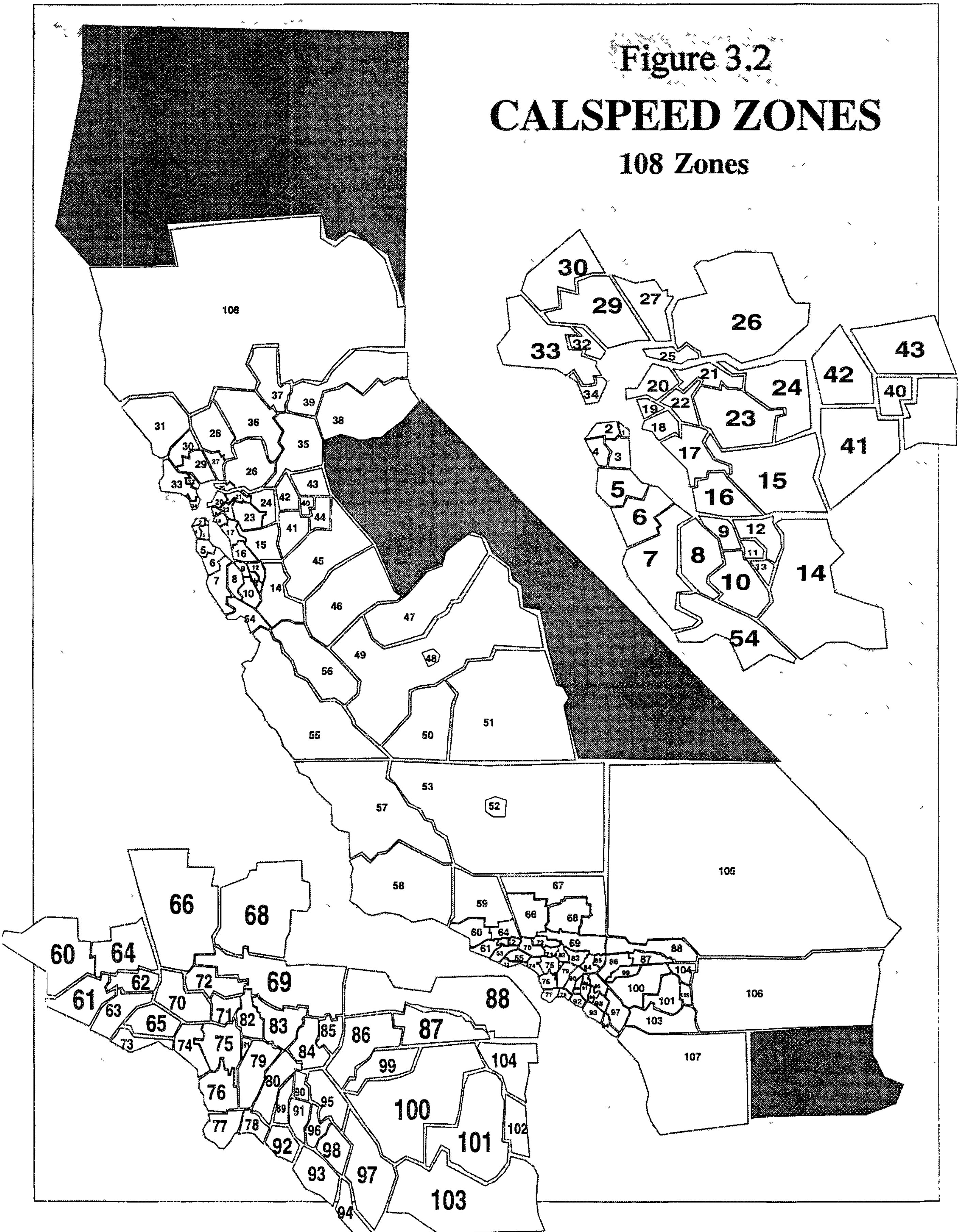
These high-speed rail (HSR) ridership forecasts are considered a "first look" at the overall potential in the CalSpeed corridor The total annual HSR ridership presented for each scenario represents travel that might be diverted from the intercity air and auto markets in the year 2010

Markets and Scenarios

The forecasted HSR ridership is broken down into seven market segments as defined below:

1 Travel between the San Francisco Bay Area and all of Southern California (between CalSpeed zones 1-34 and 59-107).

Figure 3.2
CALSPEED ZONES
108 Zones



2 Travel between the other Northern California zones (including the Sacramento region and San Joaquin County) and Southern California (between CalSpeed zones 35-44 and 108, and CalSpeed zones 59-107)

3 Travel between Fresno and all of Northern California (between CalSpeed zone 48 and CalSpeed zones 1-44 and 108)

4 Travel between Fresno and all of Southern California (between CalSpeed zone 48 and CalSpeed zones 59-107)

5 Travel between Bakersfield and all of Northern California (between CalSpeed zone 52 and CalSpeed zones 1-44 and 108)

6 Travel between Bakersfield and all of Southern California (between CalSpeed zone 52 and CalSpeed zones 59-104, 106, and 107)

7 All other travel markets

Four HSR service scenarios were developed in order to test the sensitivity of the forecasts to assumptions regarding the HSR service attributes of fare, frequency, and linehaul time. The scenarios were developed from a basic service assumption, characterized by a high frequency of service, 200-mph maximum operating speed, and fares set at 75 percent of average air fare (see Table 2 4) Additional service scenarios were defined by varying one attribute (fare, frequency, and linehaul time) in each scenario.

The "reduced frequency" scenario reduced the number of express trains per day between Los Angeles and San Francisco from fifteen to ten and the number of express trains per day between Los Angeles and Sacramento from five to three. Two skip-stop trains in each direction were also eliminated between San Francisco and Los Angeles for this scenario. The "higher fare" scenario assumed that HSR fares would be equal to air fares in the comparable market Last, the "125 mph" scenario assumed maximum operating speeds of 125 mph rather than 200 mph, and travel times were recalculated accordingly.

Interpretation of Ridership Figures

When interpreting the figures in the ridership tables, the reader should keep in mind the following important points·

- *Forecasting for new modes always embodies an extra element of uncertainty, particularly with respect to travelers' propensity to switch from existing modes.*
- *The forecasts do not consider intercity travel demand induced from increases in accessibility, changes in land use patterns, changes in propensity to travel, or economic development that the availability of high-speed rail might bring about* Estimates of induced demand used in other high-speed rail studies vary widely, and while the notion of induced demand seems reasonable, induced demand cannot be rigorously estimated without an in-depth understanding of the underlying economy Induced demand is therefore yet another issue which deserves further study

- *The size of the travel market, especially the automobile market, depends upon the accuracy of the Statewide Traffic Model forecasts and other existing data sources.* After assessing the existing data sources and carrying out this study, the researchers concluded that the existing state of knowledge on intercity travel patterns in California is simply inadequate While the ridership estimates presented in this report are satisfactory for preliminary planning purposes, investment-grade studies will require a significant data collection effort.
- *The forecasts reflect specific assumptions about a competitive level of high-speed rail service which imply a significant investment in HSR infrastructure, operations, and planning.* As mentioned in the first chapter, this report is concerned with a mature HSR system operating a fairly ambitious schedule.
- *The forecasts assume the supply characteristics of the competing modes— automobile and air— remain constant* The main issue here is the possibility of a price war started by the airlines in order to keep their market share. Also possible is a significant increase in the operating cost of private automobiles
- *The forecasts exclude shorter-distance commuter markets, such as one between San Francisco and San Jose* [27] These markets were not included because commuter travel differs in nature from intercity travel and is not appropriately analyzed with an intercity mode choice model. In addition, commuter services would have a different operating cost structure and may well fall under the authority of a different operator than intercity services Thus, excluding potential commuter ridership at this point also simplified the revenue and cost analysis.
- *These ridership figures do not reflect the availability of the San Diegan and Capitol Corridor trains as feeder services.* The ridership effect of the San Diegans and Capitol Corridor trains was omitted primarily due to practical difficulties in modeling the services but also due to uncertainties regarding the future levels of service in these corridors Highway networks represented access to airports and high-speed rail stations in the forecasting methodology adopted. Conventional rail feeder services would have either constituted a new access mode to high-speed rail or have defined a new intercity travel mode (a combination of conventional and high-speed rail), greatly complicating the task.

  Whether the feeder services would have a significant impact on mainline ridership depends to a great extent on the level of service provided by the feeder services For example, at its present frequency of service, the Capitol Corridor service would not be a very useful access mode to the high-frequency HSR service out of San Jose. As another example, the feeder routes would be much more attractive if electrified and upgraded to allow through-running of trains from the HSR mainline Issues such as these, surrounding the role of feeder services and investment in the entire California rail network, should receive further attention and should be part of the planning process for HSR. These issues are only briefly mentioned here to point out their importance and to emphasize their potential impact on HSR ridership.
- *The current San Joaquin and Greyhound bus ridership were not considered as potential HSR markets.* While conventional rail and bus do not currently represent a large portion of the intercity travel

market, recall that these two modes carried approximately 1 7 million passengers in the base year. Many of these passengers are potentially divertable to HSR, especially if Central Valley communities are well served

Thus, the ridership estimates presented in the following tables reflect the analysis of the HSR mainline as a stand-alone corridor, without the network effect of feeder services and without any induced ridership In addition, there are some methodological issues, mainly related to the need for better data, affecting the ridership estimates that are presented in the Technical Appendix In light of these factors, Table 3 1 presents potential mainline HSR ridership in ranges The calculated ridership for each service scenario is presented as the point estimate, with a 20 percent variation on either side to account for uncertainties in the analysis. Table 3 2 summarizes ridership by station pair These tables present only the point-estimate ridership and are intended to illustrate the relative ridership contribution of selected station pairs along the corridor.

As shown in Table 3.1, the markets serving trips between Northern California and Southern California account for the bulk of the ridership Ridership in market segments one and two (Bay Area-Los Angeles and other Northern California-Southern California) constitutes 58-68 percent of total ridership, depending upon the service scenario Station-pair ridership also reflects the contribution of the north-south markets, with ridership between the downtown San Francisco and Los Angeles Union stations accounting for about a quarter of total ridership

While the shorter distance markets make up a much smaller portion of the total ridership, note that these markets were defined fairly narrowly Market segment three, Fresno-Northern California, for example, includes only trips which begin or end in the city of Fresno zone and does not include trips to or from the remainder of Fresno County.

Market Shares by Mode

Figure 3.3 presents the overall market shares by mode for intercity travel in the California corridor under the baseline HSR service scenario. The trips represented in this figure include only those that could be reasonably served by high-speed rail and those strictly defined as intercity trips. This practice eliminated a large number of automobile trips from the illustration which were not truly candidates for high-speed rail diversion. Since the baseline scenario represents the highest level of service envisioned for HSR, the 17 percent market share shown in the figure is the highest market share HSR could attain under the four scenarios Note that air would lose a relatively greater proportion of its market share, dropping from 21 percent to 14 percent of the overall market, while the automobile would remain the dominant intercity travel mode

With regard to the mode shares by market (Figure 3.4), HSR achieves the highest market shares in the longer distance markets, such as between the Bay Area and the Los Angeles Region, where HSR would capture on the order of 30-40 percent of the market These higher market shares reflect the high

Table 3.1

Forecasted High-Speed Rail Ridership in 2010

Scenario 1. Baseline Assumptions

Market Segment	Ridership Range High	Point Estimate	Low
1 Bay Area-Southern California	8,374,800	6,979,000	5,583,200
2 Other N California-S California	1,863,600	1,553,000	1,242,400
3 Fresno-Northern California	418,800	349,000	279,200
4 Fresno-Southern California	788,400	657,000	525,600
5 Bakersfield-Northern California	156,000	130,000	104,000
6 Bakersfield-Southern California	379,200	316,000	252,800
7 Other	3,003,600	2,503,000	2,002,400
Total	14,984,400	12,487,000	9,989,600

Scenario 2. Higher HSR Fares

Market Segment	Ridership Range High	Point Estimate	Low
1 Bay Area-Southern California	6,698,400	5,582,000	4,465,600
2 Other N California-So California	1,506,000	1,255,000	1,004,000
3 Fresno-Northern California	369,600	308,000	246,400
4 Fresno-Southern California	698,400	582,000	465,600
5 Bakersfield-Northern California	132,000	110,000	88,000
6 Bakersfield-Southern California	336,000	280,000	224,000
7 Other	2,648,400	2,207,000	1,765,600
Total	12,388,800	10,324,000	8,259,200

Scenario 3. Lower HSR Frequency

Market Segment	Ridership Range High	Point Estimate	Low
1 Bay Area-Southern California	8,139,600	6,783,000	5,426,400
2 Other N California-So California	1,792,800	1,494,000	1,195,200
3 Fresno-Northern California	446,400	372,000	297,600
4 Fresno-Southern California	754,800	629,000	503,200
5 Bakersfield-Northern California	182,400	152,000	121,600
6 Bakersfield-Southern California	360,000	300,000	240,000
7 Other	2,860,800	2,384,000	1,907,200
Total	14,536,800	12,114,000	9,691,200

Scenario 4. 125 mph

Market Segment	Ridership Range High	Point Estimate	Low
1 Bay Area-Southern California	4,104,000	3,420,000	2,736,000
2 Other N California-So California	889,200	741,000	592,800
3 Fresno-Northern California	332,400	277,000	221,600
4 Fresno-Southern California	502,800	419,000	335,200
5 Bakersfield-Northern California	103,200	86,000	68,800
6 Bakersfield-Southern California	279,600	233,000	186,400
7 Other	2,361,600	1,968,000	1,574,400
Total	8,572,800	7,144,000	5,715,200

Table 3.2 Annual Ridership Between Selected Station Pairs

Scenario 1.

Between/and	Fresno	Bakersfield	Burbank	L A Union	Other
San Francisco	148,000	91,000	776,000	3,228,000	349,000
San Jose	125,000	38,000	226,000	1,235,000	65,000
Sacramento	106,000	41,000	184,000	1,142,000	1,130,000
Fresno	—	60,000	169,000	551,000	88,000
Bakersfield	—	—	312,000	451,000	121,000
Other	75,000	20,000	235,000	1,456,000	65,000
				Total	12,487,000

Scenario 2.

Between/and	Fresno	Bakersfield	Burbank	L A Union	Other
San Francisco	130,000	77,000	614,000	2,583,000	302,000
San Jose	112,000	32,000	178,000	994,000	54,000
Sacramento	93,000	34,000	153,000	911,000	1,028,000
Fresno		54,000	151,000	488,000	79,000
Bakersfield			274,000	398,000	109,000
Other	66,000	16,000	183,000	1,156,000	54,000
				Total	10,324,000

Scenario 3

Between/and	Fresno	Bakersfield	Burbank	L A Union	Other
San Francisco	140,000	87,000	834,000	3,131,000	333,000
San Jose	125,000	38,000	226,000	1,163,000	65,000
Sacramento	106,000	41,000	184,000	1,077,000	1,130,000
Fresno		60,000	155,000	532,000	88,000
Bakersfield			279,000	432,000	121,000
Other	75,000	20,000	235,000	1,372,000	65,000
				Total	12,114,000

Scenario 4

Between/and	Fresno	Bakersfield	Burbank	L A Union	Other
San Francisco	117,000	59,000	371,000	1,514,000	242,000
San Jose	102,000	26,000	118,000	625,000	38,000
Sacramento	85,000	27,000	81,000	532,000	1,039,000
Fresno		49,000	106,000	356,000	61,000
Bakersfield			224,000	323,000	101,000
Other	58,000	11,000	105,000	737,000	37,000
				Total	7,144,000

frequency of service between the terminal stations as well as the effect of distance and speed on mode choice Note that under the 125-mph scenarios, HSR would capture only about 10-15 percent of the market, reflecting the mode's speed and time disadvantage relative to air.

In the shorter distance markets, the automobile remains dominant. HSR captures only 12-14 percent of the Bakersfield-Southern California market, for example, under the 200-mph scenarios and about 10 percent under the 125-mph scenario

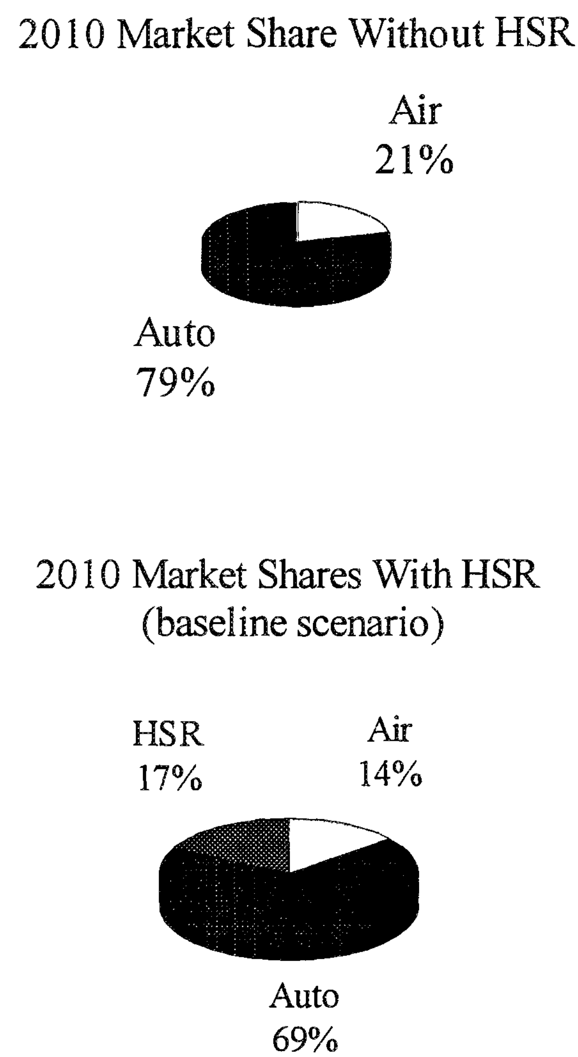


Figure 3.3 2010 Mode Shares

Note Includes only zone pairs with HSR competition

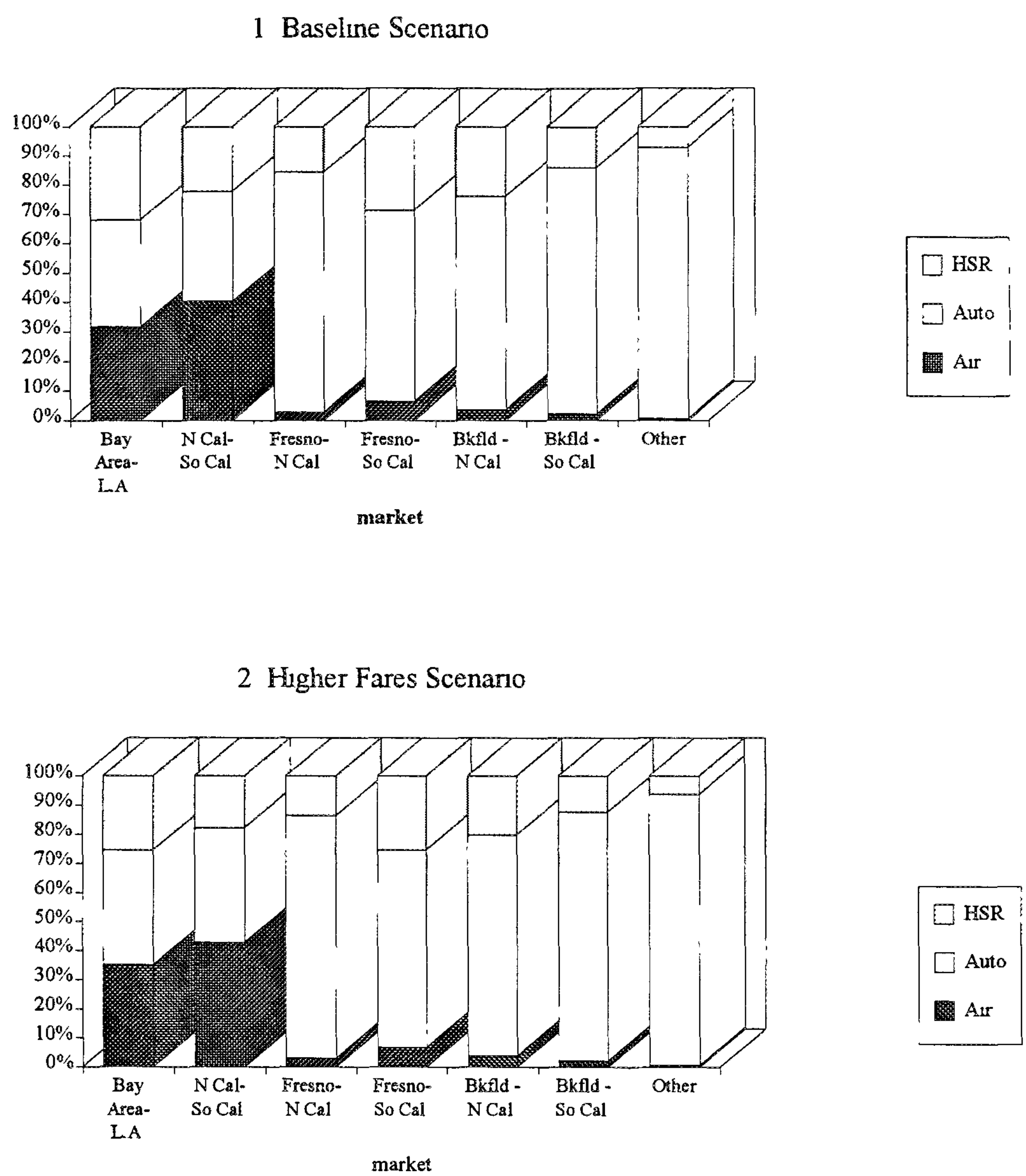
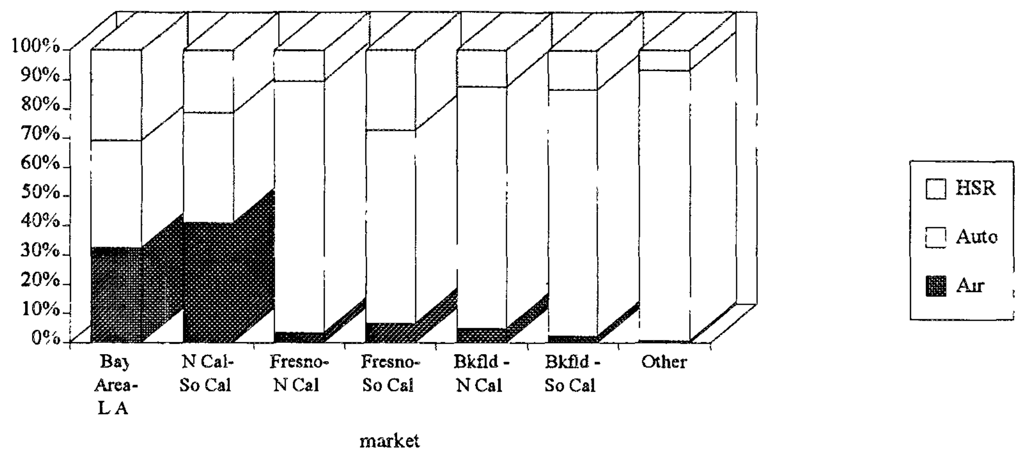


Figure 3.4 Mode Share by Market Segment

3 Lower Frequency Scenario



4 125 mph Scenario

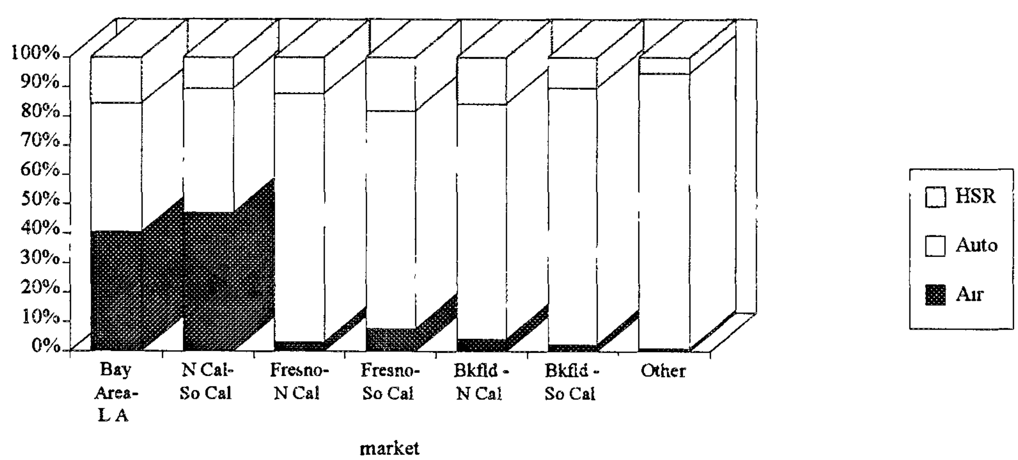


Figure 3.4 continued: Mode Share by Market Segment

Conclusion

The ridership forecasts show that, if the intercity travel markets grow at the projected rates, 200-mph high-speed rail will be able to capture a significant portion of the increase in travel, while 125-mph rail would capture somewhat less While these ridership estimates are preliminary, the results are promising enough to warrant further investigation of the potential role that high-speed rail might play in California's transportation system Meanwhile, these estimates will serve as the base for the initial revenue and cost analysis, presented in the next chapter.

4. HSR REVENUE AND COST

The potential cost and revenue of the proposed high-speed rail (HSR) service will weigh heavily in the system's feasibility as well as impact its financial and institutional structures This chapter presents the capital costs (construction and equipment costs), annual maintenance and operation costs, and expected ticket sales revenue of the proposed HSR mainline

Capital Costs

Preliminary cost estimates for the HSR mainline appeared in *High Speed Trains For California* These estimates were re-evaluated and refined in the subsequent working paper, The *Cost Escalation of Rail Projects* [29] Table 4 1 summarizes the revised mainline cost estimates developed for that subsequent report As shown, the estimated capital costs for the HSR infrastructure from downtown Los Angeles to downtown San Francisco range between $8 1 and $11.5 billion ($1991) The infrastructure for the extension to Sacramento would cost between $1 1 and $1 3 billion

Table 4.1

CalSpeed Train Routing Summary Distances and Range of Costs

Segment	Total Distance (miles)	Revised CalSpeed Estimate Range: Low Cost ($millions)	Revised CalSpeed Estimate Range: Mid-Range Amount ($millions)	Revised CalSpeed Estimate Range: High Cost ($millions)	Original CalSpeed Estimates ($millions)
1. Los Angeles to San Francisco					
Los Angeles Basin	24 5	$778 6	$853 6	$928 5	$795 5
Palmdale Alternative	86	$2,073 4	$2,924 6	$3,775 7	$2,390 1
Central Corridor	205	$1,876 7	$2,052 4	$2,228 1	$2,236 6
Pacheco Pass	34	$1,157 6	$1,590 4	$2,023 2	$1,237 3
Santa Clara Valley (US101)	29	$480 9	$539 1	$597 3	$514 2
Bay Area San Jose-S F	49	$1,920 4	$ 2,093 9	$ 2,267 4	$1,922 8
TOTAL	427 5	$8,132 5	$10,053 9	$11,540 9	$9,096 5
2. Mainline Extension to Sacramento					
Pacheco Pass-Sac (New R/W)	111	$1,107 2	$1,224 5	$1,341 8	$1,258 0
Additional Cost Trainsets	$33 million each				

Rolling stock represents a substantial additional capital cost. The number of trainsets required is largely determined by the level of service provided on the HSR mainline The baseline service scenario envisioned for 2010 assumes 90 one-way trips per day along the Los Angeles-San Francisco corridor, with the additional 30 one-way trips per day in the LA-Sacramento corridor Assuming each trainset could operate approximately 350,000 miles per year, the projected 2010 service would require around 50 trainsets for the baseline frequency scenario and 43 for the reduced frequency scenario At $33 million per trainset, rolling stock represents an additional capital cost of $1 65-1 42 billion The total capital cost of the HSR mainline proposal, including the Sacramento branch and 50 trainsets, would therefore fall between $10 9 and $14 5. billion in 1991 dollars.

Operational and Maintenance Costs

Operation and maintenance costs for the proposed 2010 mainline service were estimated using the methodology developed in the Transportation Research Board (TRB) Special Report 233, *In Pursuit of Speed. New Options for Intercity Passenger Transport*[29] Based upon previous U S high-speed ground transportation studies and professional judgment, the TRB study developed operating cost factors relating the system size (measured by capital cost, route miles, track miles, and number of stations) and level of operations (measured by annual seat miles, seat hours, and passengers) to annual operating and maintenance costs. Tables 4.2 and 4 3 describe results of the TRB model application for TGV-type technology using the CalSpeed system specifications. Since frequency of service is a prime determinant of operation and maintenance costs using this methodology, the TRB model was applied to the two frequency scenarios defined for this study As shown, the total estimated yearly operational and maintenance cost for the HSR mainline proposal ranges from $340 to $376 million depending on the frequency of service offered

Revenue

Ticket sales would by far be the most significant form of revenue generated by the proposed HSR mainline. Revenue could also be generated by such supplementary sources as express freight (express package/mail type services), concessions (both in stations and on board trains), rental car operations, and parking fees. The *Texas Triangle High Speed Rail Study*,[30] for example, concluded that supplementary sources could total to as much as six to eight percent of the total ticket sales revenue. For this preliminary study, however, only ticket sales revenue was estimated.

Ticket sales revenue for each scenario was calculated by multiplying the forecast ridership for each station pair by the corresponding expected fare. Table 4 4 summarizes the expected ticket sales revenue from the HSR mainline service for the forecast year, in 1992 dollars As shown, the total yearly revenue from ticket sales ranges from $296 to $561 million

Not surprisingly, the largest portion of total revenue comes from trips between the system's termini Ridership between the Los Angeles and San Francisco stations accounts for about 32 percent of total system revenue under the 200-mph scenarios (scenarios 1-3) Under the 125-mph scenario, high-speed rail becomes less competitive in this longer-distance market and contributes only about 28 percent of total revenue. Ridership between Sacramento and Los Angeles and between San Jose and Los Angeles also accounts for a large portion of the revenue at about 10 percent and 12 percent, respectively In total, about 85 percent of the system revenue would come from trips with an end in either Los Angeles or San Francisco.

Table 4.2

Estimated Yearly Operational and Maintenance Costs

Baseline Frequency Scenario

System Characteristic	Cost Quantity	Cost Factor	Element (millions)
Capital Costs ($ millions)	11,910	0 0053	$63 12
Route-miles	539	0 0341	$18 38
Track-miles	1078	0 0191	$20 59
Number of Stations	14	1 0846	$15 18
Annual Seat-miles (mill)	9,333	0 0053	$49 46
Annual Seat-hours (mill)	65 7	3 0142	$198 03
Annual Passengers (mill)	10 95	1 0269	$11 24
TOTAL			$376 02

Assuming
Annual Miles = (FREQ)(Distance)(365)

	Daily Frequency	Distance	Annual Miles
San Francisco-Los Angeles	90	427 8	14,053,230
Sacramento-Los Angeles	30	421 2	4,612,140
TOTAL	120	849 0	18,665,370

# of Trains (375,000 miles per trainset, per year) = 50

Capital Costs:

L A - S F Mainline	= $9 00 billion
Sacramento-Extension	= $1 26 billion
Trainsets (50)	= $1 65 billion
TOTAL	= $11 91 billion

- Route-miles = 539
- Stations = 14
- # of Seats per Trainset = 500
- Annual Seat-miles = (FREQ)(# of seats)(DISTANCE)(365)
- Annual Seat-hours = (FREQ)(end-to-end trip duration)(# of seats)(365)
- Annual Passengers = (FREQ)(# of seats)(365)(5 load factor)

Source *In Pursuit of Speed*, TRB 1991

Revenue/Cost Relationship

As shown in Table 4.5, ticket revenues from the proposed HSR mainline would cover operating costs and a portion of the annual debt service on capital cost under the 200-mph scenarios The 125-mph service, however, would not attract enough ridership to cover its operating costs and would require an annual operating subsidy of about $80 million in addition to debt service. The calculated average annual load factors suggest that 500-seat capacity trainsets may be slightly larger than appropriate for California.

Table 4.3

Estimated Yearly Operational and Maintenance Costs

Reduced Frequency Scenario

System Characteristic	Cost Quantity	Cost Factor	Element (millions)
Capital Costs ($ millions)	11,680	0 0053	$61 90
Route-miles	539	0 0341	$18 38
Track-miles	1078	0 0191	$20 59
Number of Stations	14	1 0846	$15 18
Annual Seat-miles (mill)	8,088	0 0053	$42 87
Annual Seat-hours (mill)	56 9	3 0142	$171 63
Annual Passengers (mill)	9 49	1 0269	$ 9 75
TOTAL			$340 30

Assuming
Annual Miles = (FREQ)(Distance)(365)

	Daily Frequency	Distance	Annual Miles
San Francisco-Los Angeles	78	427 8	12,179,466
Sacramento-Los Angeles	26	421 2	3,997,188
TOTAL	104	849 0	16,176,654

# of Trains (375,000 miles per trainset, per year) = 43

Capital Costs:

L A - S F Mainline	= $9 00 billion
Sacramento-Extension	= $1 26 billion
Trainsets (43)	= $1 42 billion
TOTAL	= $11 68 billion

- Route-miles = 539
- Stations = 14
- # of Seats per Trainset = 500
- Annual Seat-miles = (FREQ)(# of seats)(DISTANCE)(365)
- Annual Seat-hours = (FREQ)(end-to-end trip duration)(# of seats)(365)
- Annual Passengers = (FREQ)(# of seats)(365)(5 load factor)

Source *In Pursuit of Speed*, TRB 1991

This analysis implies an average fare of around $44 for the 200-mph scenarios and $41 for the 125-mph scenario. At these fares, the break-even ridership to just cover operating and maintenance costs would be about 7.5 to 8 million passengers per year The ridership required to cover capital debt service as well as operating and maintenance would be considerably higher and would approach or exceed the system's capacity (about 21 9 million)

While this analysis provides a comparison of the magnitudes of the costs and revenues involved, the analysis does not take into account the phasing of the HSR project This analysis assumes that the entire capital cost of the project would be borrowed at the outset and would be paid down by a constant

Table 4.4

High-Speed Rail Revenue by Station Pair

Scenario 1 Revenue (@ 75 percent fares)

	Gilroy	Stockton	Modesto	Fresno	Bakersfield	Palmdale	S Clarita	Burbank	L A Union
San Francisco	1,371,000	0	0	4,453,000	3,641,000	8,868,000	4,853,000	43,461,000	180,751,000
SFO	190,000	0	0	382,000	205,000	612,000	114,000	3,787,000	17,611,000
Palo Alto	1,000	0	0	493,000	209,000	459,000	452,000	4,382,000	23,709,000
San Jose	0	0	0	3,131,000	1,315,000	1,915,000	865,000	12,668,000	69,181,000
Gilroy	0	0	0	0	0	265,000	77,000	2,319,000	13,430,000
Sacramento	0	12,848,000	3,000,000	2,644,000	1,642,000	2,073,000	821,000	6,447,000	57,121,000
Stockton	0	0	0	575,000	84,000	12,000	157,000	961,000	11,782,000
Modesto	0	0	0	185,000	248,000	219,000	3,000	525,000	9,872,000
Fresno	0	0	0	0	1,085,000	1 550,000	518,000	4,728,000	16,529,000
Bakersfield	0	0	0	0	0	1,570,000	678,000	7,180,000	11,278,000
Average Annual Load Factor = 0 57									$561,505,000

Scenario 2 Revenue (@ 100 percent fares)

	Gilroy	Stockton	Modesto	Fresno	Bakersfield	Palmdale	S Clarita	Burbank	L A Union
San Francisco	1,203,000	0	0	3,901,000	3,095,000	7,844,000	3,991,000	34,380,000	144,674,000
SFO	168,000	0	0	323,000	169,000	520,000	86,000	2,870,000	13,510,000
Palo Alto	1,000	0	0	425,000	171,000	371,000	355,000	3,366,000	18,468,000
San Jose	0	0	0	2,789,000	1,128,000	1,628,000	669,000	9,943,000	55,692,000
Gilroy	0	0	0	0	0	218,000	63,000	1,873,000	11,055,000
Sacramento	0	11,770,000	2,752,000	2,321,000	1,361,000	1,734,000	668,000	5,347,000	45,554,000
Stockton	0	0	0	519,000	69,000	9,000	133,000	796,000	9,755,000
Modesto	0	0	0	169,000	202,000	175,000	2,000	419,000	7,741,000
Fresno	0	0	0	0	978,000	1,394,000	456,000	4,218,000	14,642,000
Bakersfield	0	0	0	0	0	1,414,000	602,000	6,293,000	9,956,000
Average Annual Load Factor = 0 47									$456,398,000

Scenario 3 Revenue (@ 75 percent fares)

	Gilroy	Stockton	Modesto	Fresno	Bakersfield	Palmdale	S Clarita	Burbank	L A Union
San Francisco	1,227,000	0	0	4,213,000	3,491,000	8,579,000	4,629,000	46,751,000	175,336,000
SFO	190,000	0	0	382,000	205,000	612,000	114,000	3,787,000	16,055,000
Palo Alto	1,000	0	0	493,000	209,000	459,000	452,000	4,382,000	21,736,000
San Jose	0	0	0	3,131,000	1,315,000	1,915,000	865,000	12,668,000	65,143,000
Gilroy	0	0	0	0	0	265,000	77,000	2,319,000	12,385,000
Sacramento	0	12,848,000	3,000,000	2,644,000	1,642,000	2,073,000	821,000	6,447,000	53,865,000
Stockton	0	0	0	575,000	84,000	12,000	157,000	961,000	11,782,000
Modesto	0	0	0	185,000	248,000	219,000	3,000	525,000	9,872,000
Fresno	0	0	0	0	1,085,000	1,550,000	518,000	4,339,000	15,970,000
Bakersfield	0	0	0	0	0	1,570,000	678,000	6,419,000	10,807,000
Average Annual Load Factor = 0 64									$544,285,000

Scenario 4 Revenue (@ 75 percent fares)

	Gilroy	Stockton	Modesto	Fresno	Bakersfield	Palmdale	S Clarita	Burbank	L A Union
San Francisco	1,340,000	0	0	3,505,000	2,376,000	6,038,000	2,723,000	20,798,000	84,806,000
SFO	190,000	0	0	301,000	130,000	363,000	50,000	1,643,000	8,526,000
Palo Alto	1,000	0	0	384,000	129,000	228,000	218,000	1,944,000	11,769,000
San Jose	0	0	0	2,541,000	900,000	1,170,000	452,000	6,608,000	35,001,000
Gilroy	0	0	0	0	0	133,000	38,000	1,060,000	7,076,000
Sacramento	0	12,375,000	2,620,000	2,118,000	1,092,000	1,163,000	392,000	2,828,000	26,596,000
Stockton	0	0	0	434,000	53,000	5,000	84,000	427,000	6,368,000
Modesto	0	0	0	149,000	157,000	113,000	1,000	220,000	4,870,000
Fresno	0	0	0	0	890,000	1,110,000	323,000	2,954,000	10,679,000
Bakersfield	0	0	0	0	0	1,328,000	531,000	5,146,000	8,065,000
Average Annual Load Factor = 0 33									$295,531,000

Note load factors based upon 500-seat trains

Table 4.5

Revenue & Costs
(amounts in $millions,

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Projected Revenue	561,505,000	456,398,000	544,285,000	295,532,000
Operation & Maintenance	376,020,000	376,020,000	340,300,000	376,020,000
Revenues less O&M	185,485,000	80,378,000	203,985,000	(80,488,000)
Capital Costs	11,910,000,000	11,910,000,000	11,680,000,000	11,910,000,000
Debt Service*	$688,756,000	$688,756,000	$675,456,000	$688,756,000
% debt service covered	27%	12%	30%	-12%
annual shortfall	$503,271,000	$608,378,000	$479,071,000	$769,244,000
Implied average fares	$44 97	$44 21	$44 93	$41 37
Break-even riderships				
1) O&M costs only	8,362,000	8,505,000	7,575,000	9,090,000
2) Capital and O&M	23,679,000	24,084,000	22,610,000	25,740,000

*at 4 percent over 30 years

annual revenue stream In reality, while the project would require a large capital outlay for the commencement of construction, some phasing of the borrowing and construction could reduce interest costs More seriously, the revenue streams projected below would not be seen until system maturity several years after project commencement

Conclusions

The revenue and cost relationships presented in this chapter have implications for the institutional structure and financing scheme of the HSR mainline. These relationships illustrate why total private-sector financing of high-speed rail is highly unlikely. Clearly, the private sector would be very hesitant to invest in the enormously risky process of constructing a new rail alignment in California.

Given the relatively low airfares in California and the low cost of operating private automobiles, ticket sales revenue from the proposed high-speed rail system would not cover total costs True high-speed service (200 mph) *would* cover operational and maintenance costs, however This suggests that the appropriate role for the private sector might be to operate various high-speed services on the HSR mainline The public sector, on the other hand, would be better suited to undertake the risk of constructing the mainline and to determine the configuration that would best contribute to the state's transportation network and policy goals Thus, the public sector could act as an infrastructure authority, leasing time slots on the track to private rail operators

5. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Summary of Findings

1 Choice of Technology and Route

- Steel-wheel-on-steel-rail technology is the only practicable option for high-speed ground transportation in California for the immediate and foreseeable future
- A mainline connecting the San Francisco Bay Area to Greater Los Angeles through the Central Valley with an extension to Sacramento would form the core of a statewide high-speed rail (HSR) network
- In order to compete with existing modes of transportation and justify the considerable investment involved, the HSR mainline should allow for sustained operation of at least 200 mph

2. The Intercity Market

- Currently, air travel and the private automobile account for over 90 percent of intercity trips in the Bay Area/Sacramento-Los Angeles Region corridor Demand for these modes is expected to rise over the next two decades
- An estimated 9 23 million air passengers travelled in the corridor in 1992. Assuming a 3 percent annual growth rate, air passenger traffic should increase to 15 7 million passengers by 2010, a 70 percent increase from 1992 levels
- An estimated 1 million air passenger trips began or ended in the Downtown San Francisco zone in 1992.
- There were an estimated 16 million auto passenger trips of at least 200 miles within the study area in 1987 By 2010, this number is expected to increase by 44 percent to 23 million passenger-trips

3 Ridership

- High-speed rail could divert approximately 12 5 million passengers from the air and automobile travel markets in the year 2010 under a baseline service scenario Higher fares and slightly lower frequencies than the baseline scenario would result in 10.3 million and 12 1 million diverted passengers, respectively
- The longer travel times involved in 125-mph operation would result in the diversion of only about 7 1 million passengers in the year 2010
- Well over half the projected ridership comes from travel between the Los Angeles region and the Bay Area/Sacramento/San Joaquin County region under all scenarios Ridership between the downtown Los Angeles and San Francisco stations accounts for about one quarter of the total

- These ridership figures reflect the analysis of the HSR mainline as a stand-alone corridor, without the network effects of feeder services and without induced ridership
- These figures also omit potential short-distance or commuter ridership Such commuter services would probably require a different type of rolling stock and a separate fare structure than intercity services These shorter-distance services could, however, provide a greater degree of congestion relief than intercity services and thus potentially justify subsidization of operating costs
- The ridership estimates are, by necessity, preliminary because of the current lack of knowledge regarding intercity travel patterns in California Investment grade studies will require a significant data collection effort

4 Cost/Revenue

- The estimated capital cost for the proposed HSR system, including trainsets and an extension to Sacramento, totals over $13 billion Annual operating and maintenance costs are estimated at $340 million and $376 million, depending upon the frequency of service offered
- Revenue from ticket sales for a 200-mph system could cover all of the operating and maintenance costs and a portion of the capital costs If the system were operated at 125-mph, the lower resulting ridership would not generate enough revenue to cover operating and maintenance costs, however
- The proposed HSR system operating at 200 mph would need to attract between 7 5 to 8 5 million annual passengers, depending upon the service scenario, to break even or just cover annual operating costs Total (capital and operating expense) cost recovery would require a ridership approaching or exceeding the system's capacity
- Due to the lack of total cost recovery and the high level of risk involved, a totally privately financed system is not feasible Since the 200-mph services could more than recover operating and maintenance expenses, however, operation of high-speed train services and stations may provide a more practicable opportunity for private participation

Recommendations

Interest in developing a high-speed rail system in California has increased in recent years Significant sums of public money will likely be spent in studying if not actually building high-speed rail over the coming decades Based upon the considerable research conducted in support of this working paper, the following recommendations are made to the state

1. Develop specific policy goals for high-speed ground transportation (HSGT) in California.

Before undertaking a program of HSGT study or design, the state should establish clear policies concerning its goals for the proposed HSGT and priorities for investment Given the magnitude of the investment involved and the level of consensus required among policymakers, private citizens, and special interest groups throughout the state, this will not be an easy task Nonetheless, formulating clear policy goals should be the first-priority task of any public body established to study HSGT

HSGT may be used as a policy tool toward economic development, land use, or environmental goals Because HSGT implementation will require a significant public investment, the policy goals articulated by the public sector will drive the physical and institutional structure of HSGT in California These factors, in turn, will greatly affect the ridership of any proposed HSGT system. Clearly defined policy goals will help narrow the range of alternatives that need to be studied, conserving scarce funding and ultimately contributing to the likelihood of actual HSGT implementation

2 Conduct a large-scale origin/destination study for all existing intercity modes

After assessing the existing data sources and carrying out this study, the researchers conclude that the existing state of knowledge on intercity travel patterns in California is simply inadequate. While the ridership estimates presented in this report are satisfactory for preliminary planning purposes, the state should not commit substantial resources towards HSGT planning or construction without first conducting a statewide survey of intercity travellers

The need for such a data collection effort is critical because almost all other aspects of HSGT planning, in particular a comparison of costs and benefits, will depend upon ridership forecasts. At a minimum, the survey should collect passenger origin and destination, the purpose of travel, the cost of travel or fare paid, the size of the travel party, and the means of access to the primary or linehaul travel mode. The state may also wish to conduct in-depth interviews, perhaps using stated-preference techniques, to better understand the tradeoffs between fare, frequency of service, and perceived comfort and convenience that people might make in choosing a new mode

3. Investigate the potential for induced demand

Induced demand is a potentially substantial source of ridership not addressed in this report Depending upon its magnitude, induced demand could influence future investment decisions Induced demand should be studied from several perspectives a new mode with very different service attributes than existing modes, improved service to areas not well served by air transportation, changes in demographics, and changes in land-use patterns induced by HSGT. As mentioned previously, understanding the potential for induced demand will require better information about origin and destination patterns and the state's economy.

4. Using the findings from this study, evaluate the economic costs and benefits of the proposed HSR mainline.

Given that high-speed rail will almost certainly involve some level of public investment, the question of costs versus benefits arises This study does not specifically address this question except to note its importance as an issue for further study Any assessment of costs and benefits should attempt to quantify the creation of new jobs, and environmental and developmental benefits, as well as total costs Ideally, the investment decision will be made in the context of the state's entire transportation system

5. Study potential sources for public financing.

This study has shown that a market exists for high-speed rail in California but that the capital costs would almost certainly require some public participation Funding a program of HSGT construction will present as big a challenge to HSGT implementation as the sometimes difficult terrain such a system would cross

This study has concentrated on the Los Angeles-San Francisco/Sacramento mainline because, in the absence of any overall plan for development of HSGT in the state, this segment appeared to be the most viable Any such overall development plan would need to contain an ordered prioritization of different segments, arrayed in terms of financial viability and overall cost-benefit ratios Absent the funding for immediate construction of the mainline, some shorter integral segment might be completed in advance, so long as it were technically and operationally compatible with the long-term project Developing such a long-term comprehensive plan for high-speed ground transportation, incorporating both financial planning and policy goals, should be a high priority for the state

NOTES

[1]A final working paper in the series, *Potential for Improved Intercity Passenger Rail Service in California Study of Corridors*, analyzes both existing and potential new corridors in California and should be published concurrently or shortly after the present report

[2]Hall, 1992

[3]Hall, 1992

[4]SCAG, 1993 Conversation with Javier Minjares Projections include unincorporated areas

[5]Slow approaches to steep grades should be avoided in order to preserve energy efficiency, prevent undue wear on the trainsets, and enable high-speed operation throughout the pass Grapevine alternatives require a long steep grade beginning only a few miles north of Newhall Since the train would take nearly 15 miles to reach top-speed, a Santa Clarita/Newhall stop would be undesirable with a Grapevine alternative

[6]Although testing different alignment alternatives for their effect on ridership would have been desirable, the study's time and resources allowed modeling of only one alignment alternative

[7]Preliminary schematic drawings for the reconstruction of Union Station and a New Transbay Terminal for San Francisco are shown in two papers prepared by GEST (May 1993) These papers help illustrate the type of facilities needed for the terminus stations

[8]"Outlying" stations are those which are built outside of urban areas These stations are designed to allow non-stopping trains to travel through without reducing speed

[9]HSR fares were set at 75 percent or 100 percent of average air fare for the major air markets between northern and southern California In the Central Valley markets, where air fares tend to be relatively high, HSR fares were set slightly higher than the current rail and bus fares

[10]The term "high-speed freight" should not be confused with standard U S rail freight operations Freight operating at current U S standards is not compatible with any high-speed rail system

[11]According to John Prideaux of Union Railways (England), 3 5 percent grades are compatible with freight operation but might lead to unacceptable energy consumption

[12]Code-sharing carriers are small airlines that share flight codes and names with larger airlines

[13]The air data is the FAA 10 percent ticket sample accessed through the Onboard database product

[14]The percentages sum to more than 100 because some people travel from the Central Valley to Sacramento

[15]These passengers were not thought to be good candidates for diversion to high-speed rail While most connecting passengers' trips would not be well-served by replacing a portion of the journey with high-speed rail, a few of these passengers might be potentially diverted, most notably, those connecting through SFO Thus, exclusion of connecting passengers from the potential market results is a slightly conservative assumption

[16]Origins and destinations of connecting passengers were not recorded

[17]See Technical Appendix for an explanation of methodology

[18]*The Economist*, 1993

[19]TRB, 1991

[20]TRB, 1988

[21]Vetrovsky, 1993

[22]For information regarding the Statewide Model, see "California Statewide Model, 1987 Base Year Update," Caltrans 1991

[23]Caltrans, 1993

[24]The Coast Starlight service is both slower and more expensive than air travel between the Bay Area and Los Angeles

[25]Caltrans, 1993

[26]Estimates derived from Greyhound's July 1993 passenger counts and the 1992 annual totals for passengers traveling directly between Los Angeles and San Francisco/Sacramento The July numbers included a separation between passengers traveling the full route and those who utilized stops in between

[27]These are mainly east-west trips that cannot be served by the proposed HSR

[28]Note that some shorter distance markets, such as Bakersfield to Burbank, *are* included where significant diverted demand is forecast to occur because of regional geography and station location

[29]Leavitt, 1993

[30]TRB 1991

[31]Lichliter/Jameson & Associates, 1989