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Potential for Improved Intercity Passenger Rail Service in California: Study of Corridors

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Working Paper
UCTC No. 222

The University of California
Transportation Center

University of California
Berkeley, CA 94720

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PREFACE

This report concludes IURD's study of the potential for high-speed passenger service in California (CalSpeed), conducted under the direction of Professor Peter Hall. Building upon previous work in the series, the primary purpose of this study is to investigate the potential for increasing inter-city passenger train speeds in various corridors throughout California.

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

Our thanks also goes to the individuals at public agencies and private firms who provided information, assistance, and advice over the course of the study. In particular, John A. Harrison of Parsons Brinckerhoff Quade & Douglas, Inc., Nick Brand of Rail Transportation Systems, Inc., and Steve Zimrick and Lynn Franks of Caltrans Division of Rail deserve mention for their help in accomplishing this research. Thanks also to CalSpeed research assistant Mashal Afredi for her tedious but valuable work on the population projections, to Kevin Keck for graphics, and as always to the staff at IURD. A special thanks to Barbara Hadenfeldt, Office Manager of IURD, who has supported this project since its beginning nearly three years ago and has been instrumental in any success CalSpeed has achieved.

EXECUTIVE SUMMARY

This report has met two objectives:

1. The state's existing intercity rail corridors have been evaluated for potential upgrading in terms of estimated costs, travel times, and population projections.
2. The most promising existing rail and "new-corridor" alternatives for high-speed service between downtown Los Angeles and downtown San Francisco have been compared and analyzed in terms of costs, travel times, and population projections.

1. Existing Rail Corridors

Ten existing intercity rail corridors were studied:

1. Los Angeles-San Diego
2. Los Angeles-Santa Barbara
3. Los Angeles-Santa Barbara-San Francisco
4. Los Angeles-Fresno-Oakland/Sacramento
5. San Jose-Sacramento
6. Sacramento-Redding
7. Sacramento-Truckee-Reno
8. Los Angeles-Las Vegas
9. Los Angeles-Yuma-Phoenix
10. San Rafael-Santa Rosa-Eureka

Table E.1 summarizes the alternatives for the ten corridors. Although many of these corridors overlap (the Los Angeles-Santa Barbara Corridor is entirely a subsection of the Los Angeles-San Francisco Coastal Corridor), each route is analyzed separately without any cost-sharing assumptions to simplify presentation and comparison of alternatives.

Most of the corridors within the state show great potential for 110-mph upgrade, exhibiting a combination of strong market potential (population), relatively flat terrain over most of the route, and existing infrastructure in good condition. 110-mph upgrades would be relatively easy to implement and cost-effective in these corridors. Only the Sacramento-Redding, the Sacramento-Truckee-Reno, and the San Rafael-Santa Rosa-Eureka corridors have little potential for upgrade beyond the 79-mph standard because of difficult terrain and/or low population served.

In particular, the Los Angeles-San Diego Corridor (LOSSAN) is the most promising candidate for 110-mph upgrading, largely as a result of the successful existing service and the substantial investment already made in the corridor. Furthermore, although this corridor has a number of constraints and obstacles, its large potential market makes the LOSSAN corridor the most likely to support 125-mph service.

Table E.1

Summary For Existing Rail Corridors

Corridor	DIST. (MILES)	POPULATION (MILLIONS)				EXIST. LOCAL SERVICE AVE MPH	79 MPH ALTERNATIVE					110 MPH ALTERNATIVE					125 MPH ALTERNATIVE				
		WITHIN 5 MILES		COUNTIES TOTAL			COST (BIL.)	COST/ MILE (MIL.)	AVERAGE SPEED (MPH)			COST (BIL.)	COST/ MILE (MIL.)	AVERAGE SPEED (MPH)			COST (BIL.)	COST/ MILE (MIL.)	AVERAGE SPEED (MPH)		
		1990	2010	1990	2010				EXPRESS	LOCAL	SKIP-STOP			EXPRESS	LOCAL	SKIP-STOP			EXPRESS	LOCAL	SKIP-STOP
1. SAN DIEGO - LOS ANGELES	128.5	6.48	8.00	13.84	18.02	46	----	----	----	----	----	0.17	1.33	74	59	68	2.66	21.21	91	69	81
Tilt-Train Alternative									----	----	----			79	62	71			100	70	85
2. LOS ANGELES - SANTA BARBARA	103.6	4.38	5.45	9.94	12.83	40	----	----	----	----	----	0.24	2.34	66	53	63	2.03	19.59	84	62	74
Tilt-Train Alternative									----	----	----			80	63	72			96	70	84
3. LA-BAY AREA (COASTAL ROUTE)	474.2	7.05	8.67	13.66	17.39	42	----	----	----	----	----	1.27	2.67	74	64	72	8.56	18.22	89	74	88
Tilt-Train Alternative									----	----	----			90	74	88			102	85	100
4. LA-BAY AREA (CENTRAL VALLEY)	484.6	6.58	9.55	13.79	19.04	53	----	----	----	----	----	0.89	1.84	69	59	67	8.75	19.13	101	83	96
Tilt-Train Alternative									----	----	----			77	64	74			108	88	102
5. SAN JOSE - SACRAMENTO	129.5	3.05	3.87	5.13	6.87	41	----	----	----	----	----	0.41	3.18	69	53	63	2.77	21.39	73	57	67
Tilt-Train Alternative									----	----	----			73	55	66			79	58	71
6. SACRAMENTO - REDDING	169.2	0.63	1.05	1.88	2.92	55	0.074	0.437	74	68	72	0.211	1.25	92	85	91	----	----	----	----	----
Tilt-Train Alternative									76	71	75			97	89	95			----	----	----
7. SACRAMENTO - TRUCKEE - RENO *	153.9	0.82	1.27	1.63	2.52	50	0.065	0.466	41	40	41	0.163	1.17	42	40	41	----	----	----	----	----
Tilt-Train Alternative									54	50	52			54	51	52			----	----	----
8. LOS ANGELES - LAS VEGAS *	337.1	6.01	7.99	14.84	20.99	49	0.096	0.331	65	62	64	0.37	1.27	72	69	70	----	----	----	----	----
Tilt-Train Alternative									72	69	70			84	80	82			----	----	----
9. LA - YUMA - PHOENIX **	251	7.16	9.79	16.19	23.1	57	0.076	0.3	70	67	69	0.348	1.39	80	76	78	----	----	----	----	----
Tilt-Train Alternative									75	72	74			91	86	89			----	----	----
10. SAN RAFAEL - EUREKA	267	0.46	0.6	0.82	1.05		0.244	0.914	41	39	40	0.49	1.84	41	39	41	----	----	----	----	----
Tilt-Train Alternative									51	47	49			52	48	50			----	----	----

* Cost projections to California border, distance, time and population projections to terminus.

** Distance, cost and time projections to California border, population projections to terminus.

The Los Angeles-Santa Barbara-San Francisco (Coastal), Sacramento-Truckee-Reno, and San Rafael-Santa Rosa-Eureka corridors are the most likely candidates for tilt-trains operations. With their highly curved routings, these three corridors would probably exhibit enough travel time savings to offset the higher operational and maintenance costs needed for tilt-trains.

Finally, limiting the number of stops will always improve travel times regardless of the corridor or improvement scenario. Therefore, a combination of skip-stop and express passenger rail service offers a low capital-cost alternative for improving travel times on any corridor. Capital improvement programs for each corridor should be planned to allow for skip-stop and express services as soon as the market can support the high frequencies that these types of services require.

2. Los Angeles-San Francisco

A corridor connecting the state's major travel markets – the Los Angeles Metropolitan Region and the San Francisco Bay Area--offers one of the strongest potential markets for high-speed rail in the United States. This study has researched the different alignments and technologies which present the greatest opportunity for high-speed rail service to connect these markets in the immediate or near future. Six alternatives, including four existing rail right-of-way alternatives (two at 110 mph and two at 125 mph) and two corridors which utilize new corridors over a significant portion of their routes allowing for maximum speeds exceeding 200 mph, were thoroughly researched. Table E.2 summarizes these six alternatives. Both Central Valley and coastal alternatives were studied.

Because of the tremendous capital needed to construct any 125-mph existing rail alternative or new-corridor (200-mph) alternative between these markets, only one such service could be constructed in the foreseeable future. This study concludes that for service of 125 mph or faster, a new "high-speed" corridor through the Central Valley is strongly preferable.

Only high ridership can justify the nearly $10 billion needed to construct a high-speed rail line between Los Angeles and San Francisco. Although similar in cost, the Central Valley new corridor alternative offers significantly faster travel times between the major markets and will be able to reach a larger population than a new coastal route or 125-mph upgrading of the existing Central Valley or coastal routes. Thus, this alternative will generate the most ridership (and revenue) and offers the greatest potential for economic benefit.

Existing rail right-of-way can be upgraded to speeds of 110 mph with relatively little capital expenditure. Thus, while travel times for these alternatives cannot compare to those possible with a new high-speed corridor through the Central Valley, construction of either or both of the 110-mph alternatives does not preclude the construction of a new corridor. On the contrary, improvements to either existing corridor would complement the market potential for a new corridor in the Central Valley. Indeed, the rationale for a very-high-speed rail service would be strengthened by the existence of strong local and feeder services.

Table E.2

Service Improvements Summary

Los Angeles to San Francisco

Alternative	Distance	Estimated Cost	Cost/Mile (millions)	Population (millions) Within 10 Miles		Travel Times (minutes)		
				1990	2020	Express	Local	Skip-Stop
New Corridors								
Central Valley	426.0	$9,597,000,000	$22.53	8.29	12.94	173	222	197
Coastal Route	415.4	$9,298,000,000	$22.38	7.88	10.73	219	260	231
Existing Rail Corridors – Tilt Train Travel Times								
Central Valley - 110 mph	484.6	$893,000,000	$1.84	7.23	12.51	379	451	392
Central Valley - 125 mph	457.5	$8,710,000,000	$19.04	7.23	12.51	253	313	269
Coastal – 110 mph	474.0	$1,266,000,000	$2.67	7.92	10.96	315	382	322
Coastal – 125 mph	469.7	$8,563,000,000	$18.23	7.92	10.96	275	330	282

INTRODUCTION

The primary purpose of this study is to investigate the potential for increasing intercity passenger train speeds in various corridors throughout California.

With the exception of the Los Angeles-San Diego (LOSSAN) corridor, where the top speed is 90 mph, the maximum speed for passenger trains in California is limited to 79 mph. However, the State Department of Transportation (Caltrans) is in the process of developing a capital program which will enable maximum passenger train speeds up to 110 mph on existing state-supported rail corridors, "where such speeds can be obtained."[1] The state is also planning to develop a high-speed ground transportation system that will operate in excess of 150 mph.

Both upgrading existing services and constructing new corridors are capital-intensive. At the same time, financing for intercity rail improvements in the many corridors throughout the state has been virtually non-existent in the past. Although interest in improving rail services has increased, funding remains scarce. Therefore, careful prioritization of future intercity rail improvements is critical.

This report provides a preliminary analysis of the potential for high-speed rail service on a number of corridors throughout the state. Ten existing rail corridors throughout California and two "new" corridors connecting the Los Angeles Metropolitan Region with the San Francisco Bay Area have been considered. This work is intended to assist the state in developing a 20-year high-speed intercity ground transportation plan by December 1995 as required by Senate Concurrent Resolution (SCR) 6. This report should also be useful in ranking infrastructure improvements and service expansions on existing conventional intercity passenger routes and should comply with provisions of the proposed federal High-Speed Rail Development Act of 1993.

The first chapter of this paper describes the different approaches used to estimate costs and travel times for both existing and new rail corridors. Chapter Two reviews the ten existing rail corridors studied, while Chapter Three focuses on two corridors connecting downtown Los Angeles and downtown San Francisco that utilize new "high-speed" alignments over a significant portion of their routing. Both Chapters Two and Three present potential costs, travel times, and population projections for each corridor. Chapter Four summarizes the findings from Chapters Two and Three for service between Los Angeles and the San Francisco Bay Area and compares the six alternatives presented to determine which have the most potential. This report concludes with a listing of key findings and some recommendations for future work.

1. ALTERNATIVE APPROACHES TOWARDS ACHIEVING HIGH SPEED

Four levels of capital improvement for high-speed passenger service were defined for this report (see Table 1.1). Three of the alternative levels apply to existing rail corridors, while one alternative applies to new high-speed corridors. Cost, travel time, and population projection methodologies may be found in the Technical Appendix of this paper.

Existing Rail Rights-of-Way

Existing Federal Railroad Administration (FRA) track classifications mandate a maximum operational rail speed of 110 mph without a special waiver. In the U.S., rail speeds exceed 110 mph only in the Northeast Corridor (maximum speed 125 mph), where the federal government has invested $2.5 billion to upgrade facilities. For most practical considerations, the maximum attainable speed for passenger operation on existing U.S. rail corridors is about 125 mph.[2]

This study defined three levels of improvement, representing the range of cost and performance that can be expected from upgrades of existing rail corridors. The levels are: diesel at 79 mph, diesel at 110 mph, and electric traction at 125 mph. Rolling stock for each of these alternatives may be either conventional or tilting. Tilting trains, such as the Swedish X-2000, could generally be used on existing corridors where operational speeds exceed 40 mph to increase curve speeds on curves by 25 percent to 30 percent.[3] However, both rolling stock and operation and maintenance costs would be significantly higher for tilt trains.

The 79-mph and 110-mph Diesel Alternatives

Diesel power is the least expensive means of incrementally improving speed on existing corridors. The two levels of improvement developed for diesel-powered locomotives present a range of costs and service that can be achieved with this technology. These alternatives vary significantly in the amount of investment required and the resulting estimated travel times.

The 79-mph alternative dictates a maximum speed of 79 mph in the corridor. This speed is the highest permitted by the FRA for trainsets without Automatic Train Stop (ATS) and/or Cab Signals and is virtually equivalent to the Class IV track limit.[4] This alternative is intended for corridors that currently have very limited or completely lack passenger service. It involves improvements to track (to Class IV), at-grade crossing protection, and rolling stock (to 3000 HP locomotives), as well as minor station improvements. In addition, some new track in rural areas for passing sidings is assumed. Since no curve realignments are included in this alternative, maximum speeds are attained only where existing track alignments permit.

As previously stated, Caltrans is developing a capital program to allow 110-mph diesel operation on all state-supported intercity routes. Currently, 110 mph is considered the "practical limit" for diesel locomotive technology in North America[5] and is also considered the limit for passenger operation in

Table 1.1

Alternatives for Improved Passenger Rail Service in California

Existing Rail Rights-of-Way			**New Corridors**
Diesel: 79 mph service	Diesel: 110 mph service	Electric: 125+ mph service	Electric: High-Speed Service
* Track Upgrade to Class IV, CWR * Increased Super-elevation on Curves * Improved At-Grade Crossing Protection	* Track Upgrade to Class VI, CWR * Signalling Improvements * Double-track through Major Urban Areas * Additional Sidings * Increased Superelevation on Curves * Improved At-Grade Crossing Protection * Curve Re-Alignment where Feasible	* New rail, fastenings, ballast, and concrete ties (CWR, Class VI minimum) * Double-track throughout * Increased Superelevation on Curves * Completely Grade Separated * Curve Realignments where Needed * Some Viaduct/Tunneling * New Signalling * Segregation from Standard Freight Operations	* Existing Rail R/W through Urban Regions (same as 125+ mph Alt.) * Design Speed 220+ mph (preferred) throughout New Corridors (otw. same as 125+ criteria)

mixed-used corridors with normal freight operations.[6] Thus, the 110-mph alternative represents the highest level of service obtainable without substantially increasing capital costs.

The 110-mph alternative includes improvements to track (to Class VI), at-grade crossing protection, and rolling stock (to 4000 HP locomotives). In addition, the 110-mph alternative includes new track, signaling improvements, new and improved stations, purchase of rights-of-way, and realignment of speed-restricting curves where feasible. 110-mph corridors are double-tracked through major urban areas and through 30 percent of rural areas (for passing sidings). Traffic Control System (TSC) signaling is added to the urban double-tracked segments, and Automatic Train Control (ATC) and cab signaling are provided throughout. The 110-mph alternative assumes the purchase of the rail rights-of-way unless they are already publicly owned.

Although a 110-mph electric-traction alternative is not presented in this work, its attributes would be very similar to the 110-mph diesel alternative. However, while improved acceleration would only slightly reduce travel times, electrification would be costly. Electrification would require catenary and substations along the route, additional signaling and control systems, and reconstruction at many overhead crossings. Thus, electrification of the 110-mph diesel alternative would add roughly $2 million per mile. This additional cost does not include locomotive or freight reconfiguration costs.

The 125-mph Electric-Traction Alternative

The 125-mph electric-traction alternative for existing rail corridors involves a high level of capital improvement. This alternative far exceeds the costs and performance of the 110-mph diesel alternative and represents the ultimate level-of-service improvement for existing rail corridors. Under this alternative, alignments will be electrified and completely double-tracked with new rail, fastenings, ballast, and concrete ties. An improved signal system capable of handling dense high-speed passenger services is assumed. Routes will be completely grade-separated, using viaduct or cut-and-cover tunnels where necessary. Restrictive curves will be realigned where feasible, especially in undeveloped regions. Considering the density of the service, the high speeds, and the light-weight rolling stock, the service would be completely segregated from existing rail operations. Therefore, an additional track is required where standard freight operations and/or existing passenger services will continue.

New High-Speed Corridors

While there are currently no new high-speed rail corridors in the United States, many examples may be found in Europe and Asia. A notable example is the French TGV. The TGV Atlantique and the TGV Nord currently maintain the world's highest operational speed at 186 mph throughout the new segments of their corridors. The next-generation TGV trainsets should travel at 200 mph. German ICE and Japanese Shinkansen technologies, while currently maintaining somewhat lower operational speeds than the French TGV, have similar programs of improvement. In the United States, the proposed Texas TGV would have a maximum cruising speed of 200 mph, with infrastructure designed to accommodate 250-mph operation.

One of the most important principals of high-speed railway operation is to maintain maximum speeds over long distances.[7] If trains must repeatedly slow for curves or to pass through developed areas, the travel time benefits of high-speed technology and energy efficiency are lost. Reaching and sustaining speeds significantly higher than 125 mph requires very straight alignments, free from environmental constraints. Therefore, achieving high speeds requires that a substantial portion of the route be on new right-of-way. Because of the high costs associated with new construction, only corridors with exceptionally high ridership potential and sufficient undeveloped land should be considered for new high-speed corridors.

Apart from very strict horizontal curve limitations, new high-speed corridors have the same standards as the 125-mph electric-traction alternative for existing rail corridors. Since direct service to downtown areas necessitate the use of existing rail rights-of-way at reduced speeds, such urban portions of the route are essentially identical to the 125-mph electric-traction alternative for existing rail corridors.

Station locations for high-speed rail corridors are largely determined by population concentration, route constraints, and the availability of land. Existing rail station sites become obvious locations for future high-speed rail stations through urban areas.[8] Where the alignment passes through rural or suburban areas, outlying stations should be as near as possible to the major population centers and have good access to the highway network.

Two high-speed alternatives between the Los Angeles Metropolitan Region and the San Francisco Bay Area are examined in this report. The new alignment segments of these alternatives were designed as straight as possible, with a minimum design speed of 220 mph. Although currently available technologies cannot economically maintain this speed, the new alignments should accommodate future technology improvements.

2. HIGH-SPEED RAIL IN EXISTING RAIL CORRIDORS

Ten existing intercity rail corridors were studied (see Figure 2.1):

1. Los Angeles-San Diego
2. Los Angeles-Santa Barbara
3. Los Angeles-Santa Barbara-San Francisco
4. Los Angeles-Fresno-Oakland/Sacramento
5. San Jose-Sacramento
6. Sacramento-Redding
7. Sacramento-Lake Tahoe-Reno
8. Los Angeles-Las Vegas
9. Los Angeles-Yuma-Phoenix
10. San Rafael-Santa Rosa-Eureka

The following sections summarize the existing conditions, population projections, and potential service improvements for each corridor. Table 2.1 summarizes the alternatives for the ten corridors. Although many of these corridors overlap, each route is analyzed separately, without any cost-sharing assumptions, to simplify presentation and comparison of alternatives. Note that the Los Angeles-Santa Barbara Corridor is entirely a subsection of the Los Angeles-Santa Barbara-San Francisco (Coastal) Corridor. These are presented separately in order to illustrate two very different services on the Southern Pacific (SP) Coastal right-of-way.

2.1. Los Angeles-San Diego Corridor (LOSSAN)

The Los Angeles-San Diego rail corridor (LOSSAN), extending 128.5 miles between L.A. Union Station and downtown San Diego, closely approximates the I-5 Corridor (Figure 2.1.1). Over 80 percent of the corridor is through urban regions, and well over six million residents live in cities within 5 miles of the rail line.

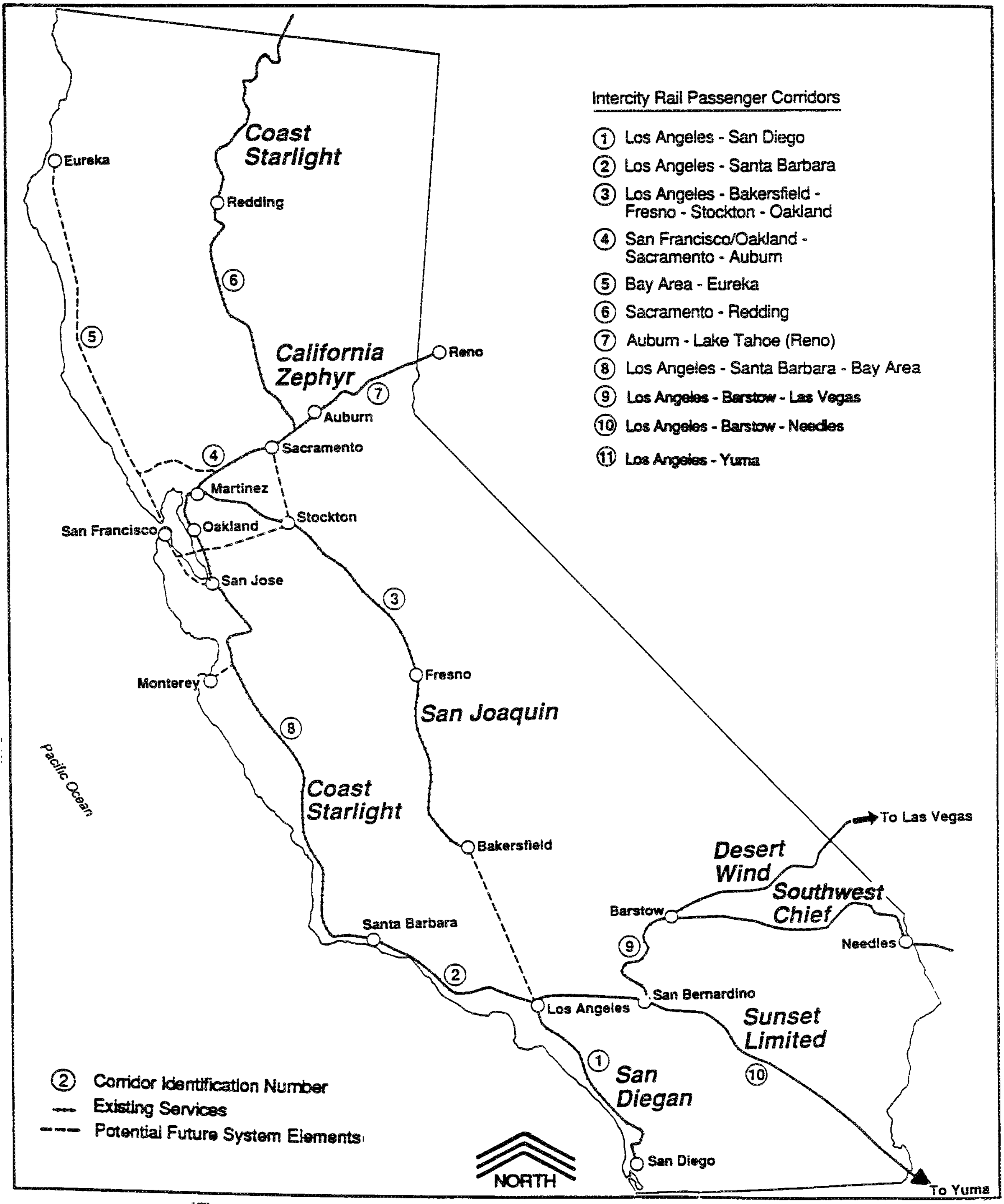
Existing Conditions

Freight Operations

The corridor was owned entirely by Atchison Topeka Santa Fe (ATSF) until recently, but regional and local agencies have purchased major segments of the corridor to facilitate commuter rail services. Today, ATSF owns only the 26-mile segment between Los Angeles and Fullerton, which is the only portion of the route heavily used by freight trains. Freight trains along this stretch are slow[9] and "make numerous stops on the main tracks and occasionally delay passenger trains."[10] From Fullerton to San Diego (102 miles), there is limited freight traffic, with only one daily through-freight operation.

Figure 2.1

Existing Intercity Rail Corridors



Source: Wilbur Smith, 1990.

Table 2.1

Summary For Existing Rail Corridors

Corridor	DIST. (MILES)	POPULATION (MILLIONS)				EXIST. LOCAL SERVICE AVE MPH	79 MPH ALTERNATIVE					110 MPH ALTERNATIVE					125 MPH ALTERNATIVE				
		WITHIN 5 MILES		COUNTIES TOTAL			COST (BIL.)	COST/ MILE (MIL.)	AVERAGE SPEED (MPH)			COST (BIL.)	COST/ MILE (MIL.)	AVERAGE SPEED (MPH)			COST (BIL.)	COST/ MILE (MIL.)	AVERAGE SPEED (MPH)		
		1990	2010	1990	2010				EXPRESS	LOCAL	SKIP-STOP			EXPRESS	LOCAL	SKIP-STOP			EXPRESS	LOCAL	SKIP-STOP
1. SAN DIEGO - LOS ANGELES	128.5	6.48	8.00	13.84	18.02	46	----	----	----	----	----	0.17	1.33	74	59	68	2.66	21.21	91	69	81
Tilt-Train Alternative									----	----	----			79	62	71			100	70	85
2. LOS ANGELES - SANTA BARBARA	103.6	4.38	5.45	9.94	12.83	40	----	----	----	----	----	0.24	2.34	66	53	63	2.03	19.59	84	62	74
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3. LA-BAY AREA (COASTAL ROUTE)	474.2	7.05	8.67	13.66	17.39	42	----	----	----	----	----	1.27	2.67	74	64	72	8.56	18.22	89	74	88
Tilt-Train Alternative									----	----	----			90	74	88			102	85	100
4. LA-BAY AREA (CENTRAL VALLEY)	484.6	6.58	9.55	13.79	19.04	53	----	----	----	----	----	0.89	1.84	69	59	67	8.75	19.13	101	83	96
Tilt-Train Alternative									----	----	----			77	64	74			108	88	102
5. SAN JOSE - SACRAMENTO	129.5	3.05	3.87	5.13	6.87	41	----	----	----	----	----	0.41	3.18	69	53	63	2.77	21.39	73	57	67
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Tilt-Train Alternative									76	71	75			97	89	95			----	----	----
7. SACRAMENTO - TRUCKEE - RENO *	153.9	0.82	1.27	1.63	2.52	50	0.065	0.466	41	40	41	0.163	1.17	42	40	41	----	----	----	----	----
Tilt-Train Alternative									54	50	52			54	51	52			----	----	----
8. LOS ANGELES - LAS VEGAS *	337.1	6.01	7.99	14.84	20.99	49	0.096	0.331	65	62	64	0.37	1.27	72	69	70	----	----	----	----	----
Tilt-Train Alternative									72	69	70			84	80	82			----	----	----
9. LA - YUMA - PHOENIX **	251	7.16	9.79	16.19	23.1	57	0.076	0.3	70	67	69	0.348	1.39	80	76	78	----	----	----	----	----
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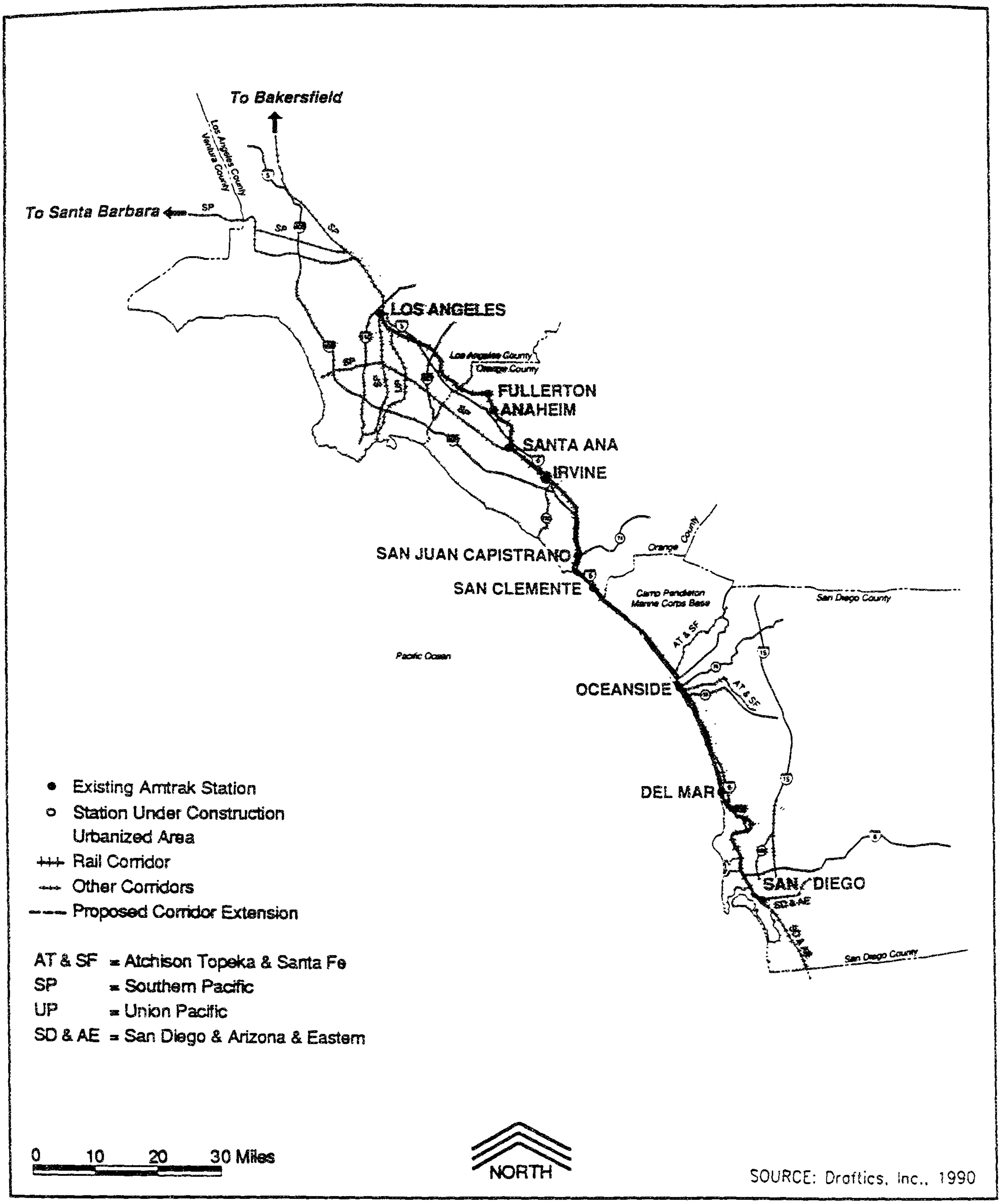
Tilt-Train Alternative									51	47	49			52	48	50			----	----	----

* Cost projections to California border, distance, time and population projections to terminus.

** Distance, cost and time projections to California border, population projections to terminus.

Figure 2.1.1

Los Angeles to San Deigo Corridor (LOSSAN)



Source: Wilbur Smith, 1990.

Passenger Service

Amtrak passenger trains (the San Diegans) have used this corridor since 1971. Currently, Amtrak provides nine round trips per day. Averaging around 1.7 million passengers a year with revenues almost equal to operational costs, the San Diegans have been a very successful service for Amtrak. In fact, within the Amtrak passenger system, only the Northeast Corridor exceeds the San Diegans in ridership.

Currently, the best service between Los Angeles and San Diego has a running time of 2 hours 47 minutes, representing an average speed of 46 mph. This includes eight stops between the termini. By eliminating time for stops, delays, and recovery allowances, trains could travel the route in about 2 hours 20 minutes, averaging 55 mph.[11]

As mentioned, local agencies own most of the Los Angeles-San Diego rail corridor for commuter rail operations. Two separate services are envisioned, one from Oceanside to Los Angeles Union Station (approximately 87.2 miles), the other from Oceanside to San Diego (41.3 miles). These services are intended to "supplement existing Amtrak service, with particular emphasis on peak period service."[12]

Right-of-Way

The right-of-way width of the corridor varies considerably. Through Los Angeles County, the right-of-way varies between 75 and 300 feet (the average being 175). In Orange County, the right-of-way varies between 40 and 400 feet (with an average of 125); and from San Clemente to San Diego, the minimum right-of-way width is 100 feet (with the exception of a short section of 80' width at Encinitas).[13] Other than a 2.5-mile stretch from Orange to Santa Ana (where the right-of-way width is about 40 feet), the LOSSAN Corridor right-of-way is wide enough for two or more tracks.

Track Condition

In recent years, the quality of the tracks in the LOSSAN Corridor has been much improved. Presently, about 90 percent of the LOSSAN tracks are continuously welded-rail with at least a FRA Class IV level. About 30 percent of the line is at Class V, suitable for 90 mph operation. Most of the corridor is single-tracked. Los Angeles-Fullerton (26 miles) and downtown San Diego (3.3 miles) are the most significant double-tracked segments on the route. Several sidings exist along the route, most commonly at existing station sites.

Station Locations

Including the terminus stations, there are ten existing station sites used by the San Diegan service. As shown on Figure 2.1.1, these are: L.A. Union Station, Fullerton, Anaheim, Santa Ana, Irvine, San Juan Capistrano, San Clemente, Oceanside, Del Mar and San Diego. Most of these stations are in good condition with adequate facilities for existing services. However, the stations at San Juan Capistrano, San Clemente and Del Mar "have inadequate platforms, platform space and access."[14]

Speed Restrictions

Caltrans Draft Rail Passenger Development Plan states that, "on the San Diegan Route speeds of 70 mph and above are allowed on approximately 95 percent of the track."[15] Nevertheless, at various points, speed restrictions limit operations to speeds as low as 15 mph. In fact, as previously noted, if a non-stop San Diegan express service were available today, it would only average 55 mph.

Curvature is a major speed restriction throughout the LOSSAN corridor. The existing alignment has an estimated 19 total miles of curvature greater than 1 degree (less than 5,700 ft horizontal radius), representing nearly 15 percent of the corridor.[16] The most severe curves are concentrated over a five-mile segment through the Soledad Canyon just north of the San Diego metropolitan area. Curves as tight as 10 degrees (576' horizontal curve radius) currently reduce speeds through the canyon to 25 mph. Most of the remaining restrictive curves are spread out over the 61 miles between L.A. Union Station and San Clemente. Within this segment there are 22 curves of 3 degrees or more, where current speeds are reduced as low as 15 mph.

The 76 at-grade crossings represent another speed restriction in the LOSSAN Corridor. Approximately 20 of these crossings currently restrict passenger service speeds due to the condition of the at-grade crossing protection. The most serious at-grade crossing restrictions are found in Anaheim, Oceanside and Los Angeles County.

A combination of freight operations and safety precautions for at-grade crossings currently impedes the speed of passenger services through Los Angeles County. However, the P.U.C.-imposed 65-mph maximum authorized speed through this segment should soon improve because of eight recently grade-separated crossings. Nonetheless, heavy freight activity over this portion of the corridor slows and delays passenger trains, and prevents increased speeds even when crossings are grade-separated. This 26-mile segment represents 20 percent of the route.

The P.U.C. has upheld a 40-mph speed restriction over a 3.6-mile strip through San Clemente, where the alignment virtually runs along the beach. Although the alignment is straight and completely grade-separated, low speeds are necessary for pedestrian crossing safety.

Finally, the eight stops that each train makes between Los Angeles and San Diego further restrict average train speeds. The Los Angeles-San Diego travel time could be reduced by about 27 minutes without any additional capital improvements to the corridor if a non-stop express service were offered.

Population Projections

Recent and projected populations for the LOSSAN Corridor are presented in Table 2.1.1 (Corridor Population Projections). The population of 6.48 million people living in cities within a 5-

Table 2.1.1 Corridor Population Projections
Los Angeles to San Diego

City	1990	2000	2010	2020	% Change
On Line					
Anaheim	266,406	329,946	370,456	437,375	64.2%
Carlsbad	63,126	84,954	100,826	127,677	102.3%
Commerce	12,135	14,063	16,147	18,626	53.5%
Dana Point	31,896	37,831	39,653	44,297	38.9%
Del Mar	4,860	5,300	5,561	5,950	22.4%
Encinitas	55,386	58,135	64,309	69,320	25.2%
Fullerton	114,144	124,997	129,062	137,296	20.3%
Irvine	110,330	135,201	145,682	167,749	52.0%
La Mirada	40,452	44,361	47,922	52,161	28.9%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.6%
Oceanside	128,398	143,708	172,017	199,215	55.2%
San Clemente	41,100	51,450	58,002	68,998	67.9%
San Diego	1,110,549	1,218,798	1,344,880	1,479,987	33 3%
San Juan Capistrano	26,183	32,253	34,876	40,336	54.1%
Santa Ana	293,742	321,883	334,482	356,996	21.5%
Solana Beach	12,962	15,363	16,385	18.448	42.3%
Tustin	50,689	67,293	69,848	82,624	63.0%
Total (On Line)	5,847,766	6,560,441	7,282,221	8,136,804	39.1%
Within 5 mile Radius					
Bell Gardens	42,355	45,185	47,900	50,939	20.3%
Buena Park	68,784	79,546	83,967	94,606	37 5%
Coronado	26,540	26,313	27,480	27,972	5.4%
Downey	91,444	95,401	102,087	107,873	18.0%
Huntington Park	56,065	64,485	68,562	75,878	35.3%
Mission Viejo	72,820	82,420	81,177	85,916	18.0%
Montebello	59,564	65,004	70,813	77,210	29.6%
Monterey Park	60,738	64,533	68,636	72,962	20.1%
Norwalk	94,279	99,938	105,757	112,010	18.8%
Pico Riviera	59,177	61,900	62,887	64,835	9.6%
Vernon	152	89	89	71	-53.5%
Total (w/in 5 miles)	6,479,684	7,245,255	8,001,576	8,907,076	37.5%
Within 10 mile Radius					
Alhambra	82,106	87,865	91,301	96,288	17.3%
Artesia	15,464	16,270	16,669	17,308	11.9%
Bellflower	61,815	64,430	67,488	70,517	14.1%
Brea	32,873	37,454	40,871	45,583	38.7%
Costa Mesa	96,358	110,970	111,430	120,110	24 6%
Cypress	42,655	48,492	50,295	54,671	28.2%
Fountain Valley	53,691	54,539	55,416	56,299	4 9%
Garden Grove	143,050	156,753	162,048	172,546	20.6%
Hawaiien Gardens	13,639	14,763	16,242	17,725	30.0%
La Habra Heights	6,226	7,393	9,243	11,266	80.9%
Laguna Beach	23,170	25,544	25,462	26,726	15.3%
Laguna Niguel	44,399	61,516	64,286	78,125	76.0%
Lynwood	61,945	69,147	73,492	80,073	29.3%
National City	54,249	55,203	55,434	56,037	3 3%
Placentia	41,259	48,477	55,003	63,516	53.9%
San Marcos	38,974	46,977	63,993	82,153	110.8%
South Gate	86,284	89,661	91,643	94,449	9 5%
Stanton	30,491	33,844	37,010	40,776	33.7%
Vista	71,872	71,298	77,256	80,175	11.6%
Westminster	78,293	85,944	89,501	95,726	22 3%
Whittier	77,671	82,280	86,123	90,690	16.8%
Yorba Linda	52,422	66,874	74,725	89,412	70.6%
Total (w/in 10 miles)	7,688,590	8,580,949	9,416,507	10,447,248	35.9%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Los Angeles	8,897,500	10,180,868	11,441,900	12,916,552	45.2%
San Diego	2,520,500	3,018,363	3,476,093	3,980,473	57 9%
Orange	2,424,100	2,866,832	3,104,100	3.306,383	36 4%
TOTALS	13,842,100	16,066,063	18,022,093	20,203,408	46 0%

mile radius of the rail right-of-way is expected to grow to more than 8.00 million by the year 2010, an increase of 23 percent over the 20-year period. Projections for 2010 and 2020 show about 72 percent of the population located in the terminus cities of Los Angeles and San Diego.

Service Improvements

Since the LOSSAN corridor already has a mature intercity service which exceeds 79 mph, only 110-mph and 125-mph service improvement alternatives are presented here. Table 2.1.2 summarizes the costs and travel times for these alternatives.

Table 2.1.2 Service Improvements Summary:
Los Angeles-San Diego Corridor (LOSSAN)

Alternative	Distance (miles)	Estimated Cost	Travel Times (minutes)			Travel Times - Tilt Trains (min)		
			Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing (90 mph)	128.5		140.0*	167				
110-mph Alt.	128.5	$171,000,000	104	130	114	97	125	108
125-mph Alt.	125.4	$2,660,000,000	83	109	93	75	107	89

* No actual service exists, estimated by Wilbur Smith, 1987.
Notes: Estimated Costs do not include new rolling stock.
Skip-stop service assumes three stops.

110-mph Maximum Speed Alternative

Caltrans' *California Rail Passenger Program Report, 1993/4-2002/3*, recommends increasing intercity service to 14 round-trips per day, with maximum speeds "up to 110 mph where track configuration allows" in the LOSSAN Corridor over the next ten years. Because considerable track and signal improvements have been made throughout much of the alignment, the cost of a 110-mph alternative is relatively low. The estimated $171 million required to create such a service results in an average of only $1.33 million per mile, including realignment of four speed-restricting curves.

A non-stop express time of about 1 hour 44 minutes between San Diego and Los Angeles is possible with 4000 HP diesel locomotives, representing an average speed of 74 mph. Local service stopping at each existing station would take about 2 hours 10 minutes between the termini, averaging 59 mph. The skip-stop alternative, making three stops (Fullerton, Oceanside, and Del Mar were modeled), would take 1 hour 54 minutes, averaging nearly 68 mph. Expected travel times for the different alternatives could be reduced by 3.8 percent-6.7 percent with tilting trainsets.

125-mph Maximum Speed Alternative

Averaging $21 million per mile, the 125-mph alternative in the LOSSAN Corridor would cost $2.7 billion. This cost includes a two-mile bore tunnel through Rose Canyon to eliminate the speed restrictions of the Soledad Canyon. The Rose Canyon tunnel reduces the overall length of the route by 3.1 miles. Costs for this alternative also include 4.5 miles of cut-and-cover tunnel to mitigate speed restrictions through San Clemente.

Non-stop express travel between San Diego and Los Angeles would take 1 hour 23 minutes, averaging 93 mph. Local and skip-stop services would take 1 hour 49 minutes and 1 hour 33 minutes, respectively. The new alignment/tunnel through Rose Canyon alone would decrease potential travel times by about 4 minutes. While tilt-trains would reduce the express service time by almost 10 percent, local and skip-stop services would show only about a 2 percent improvement.

Summary

The Los Angeles-San Diego corridor already supports a highly successful intercity passenger rail service. Yet, while the San Diegans can achieve a 90-mph speed on about 25 percent of the route, the current service averages only 46 mph between Los Angeles and San Diego. The 110-mph service alternative suggests that local service travel time between Los Angeles and San Diego can be reduced substantially, by about 37 minutes. The 125-mph alternative provides for greater time savings, but at a considerable additional cost.

Significant investment has already been made in the LOSSAN corridor, currently the only 90-mph corridor in the state. Considering this investment, upgrading LOSSAN to 110-mph service is the most simple and cost-effective alternative. Given the large population in the corridor and the many popular destinations along the route, future service improvements will certainly result in substantial increases in ridership.

2.2. The Los Angeles-Santa Barbara Corridor

The 103.6-mile-long Los Angeles-Santa Barbara corridor (Figure 2.2.1) lies between Los Angeles Union Station and the Santa Barbara station to the Northwest. Heading north from Los Angeles, the rail alignment roughly follows the Los Angeles River to the Burbank Junction, where it cuts westward across the San Fernando Valley and Ventura County. From Oxnard to Santa Barbara, the corridor turns northwest and follows the U.S. Highway 101 alignment.

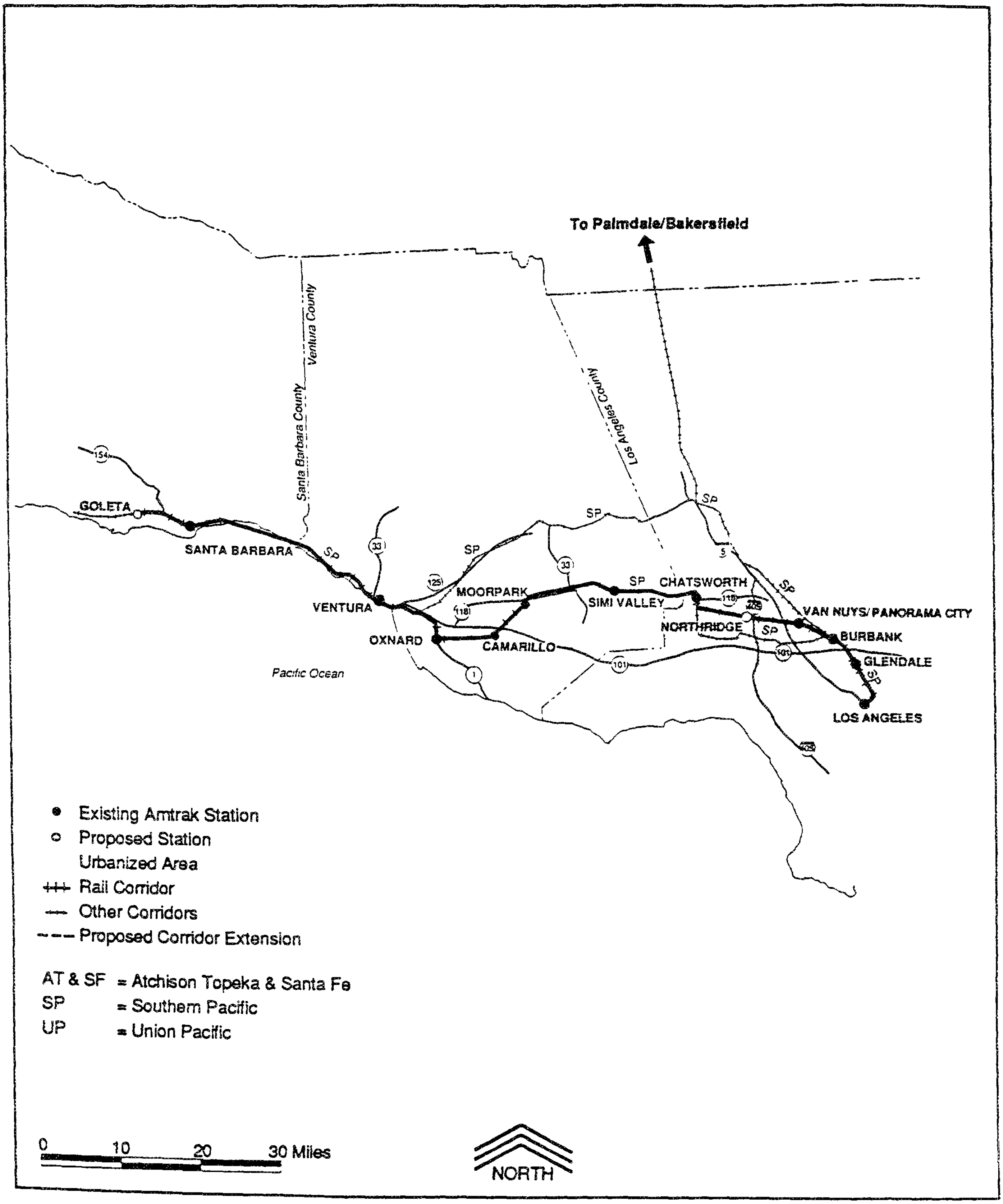
Existing Conditions

Existing Service

Amtrak operates two passenger rail services between Los Angeles and Santa Barbara. The San Diegan extends two of its nine daily round trips originating in San Diego to Santa Barbara from Los

Figure 2.2.1

Los Angeles to Santa Barbara Corridor



Source: Wilbur Smith, 1990.

Angeles Union Station. In addition, the Coast Starlight, which originates in Seattle and terminates at Los Angeles, makes one daily trip through the Los Angeles-Santa Barbara corridor in each direction and offers a direct connection to the Amtrak San Diegan at Union Station. Minimum running time for the Los Angeles-Santa Barbara service is currently 2 hours 35 minutes. Approximately 215,792 passengers rode the Los Angeles-Santa Barbara extension of the San Diegan service in 1991/92.

Freight Operations

Southern Pacific (SP) Railroad operates a daily freight train between Los Angeles and Oakland which passes through the Los Angeles-Santa Barbara corridor. Ten additional SP local freight trains operate on segments of the corridor as well. Expanded passenger rail service would potentially result in interference between freight and passenger trains throughout the corridor. Between Oxnard and Goleta, expanded passenger service would necessitate "improvement of the signaling system and expansion of siding capacity." In addition, expanded passenger service could "[create] conflicting demands for the main track throughout the day," and "adversely affect the ability of the railroad to serve its customers or be flexible enough to adjust to the changing traffic needs if no improvements were made."[17]

Right-of-Way

The right-of-way and trackage (except for a one-mile segment near Union Station, which belongs to Union Pacific Railroad) in the Los Angeles-Santa Barbara Corridor was, until recently, entirely owned by SP. The route consists of two separate SP rail lines. The segment between Burbank Junction and Santa Barbara is the SP Coast line, which continues northward to its terminus in San Jose. At the Burbank Junction, the Coast line merges with the SP Valley Line and continues southward until the approach to Union Station. The Los Angeles-Moorpark segment of the route is now publicly owned by the Los Angeles County Transportation Commission (LACTC) and is a part of its commuter rail network.

The minimum right-of-way width on the Coast line is 100 feet throughout the Los Angeles-Santa Barbara corridor, except for a 4.5-mile segment west of Moorpark and 1-mile segments in Montecito, Ventura, and Chatsworth, which are 60 feet wide.

Track Condition

Over 70 percent of the 104 track-miles along the corridor meets the FRA Class IV standard. All the trackage between Oxnard and Burbank Junction has been upgraded within the last 20 years and is 132# or 136# continuously welded rail (CWR). Conditions north of Oxnard are less consistent. About half of the rail up to Santa Barbara is welded, while the rest is bolted. There are also sections of 113# and 119# rail along this segment.

Most of the corridor consists of single-track with passing sidings. The route is double-tracked with each track signaled for one-way operation from Burbank Junction to Los Angeles. There is also a three-mile double-tracked segment just south of Santa Barbara.

Stations

Amtrak San Diegans serving the Los Angeles-Santa Barbara corridor stop at nine stations located in Los Angeles, Glendale, Burbank (scheduled to reopen Fall 1993), Panorama City/Van Nuys, Chatsworth, Simi Valley, Moorpark, Oxnard, Ventura, and Santa Barbara. Currently, only the Los Angeles Union Station, Glendale, and Santa Barbara stations are staffed. Facility and parking improvements are planned for the Glendale, Moorpark, Oxnard, and Van Nuys stations, and additional stations are under consideration for Camarillo and Northridge.[18] The Coast Starlight operates on the same right-of-way but only serves Los Angeles, Glendale, Simi Valley, Oxnard, and Santa Barbara.

Speed Restrictions

Curvature is a major speed constraint throughout the Los Angeles-Santa Barbara Corridor. An estimated 14.5 miles of the existing alignment has a curvature greater than 1 degree (less than 5,700-ft horizontal radius), representing about 14 percent of the corridor. Nearly all the curves along the corridor are either in heavily urbanized areas or along the coast, making realignment of most curves virtually impossible. The curves are found throughout the corridor, the most severe being 6 degrees.

A total of 85 at-grade crossings exist in this corridor, and the condition of the at-grade crossing protection at many of these crossings restricts passenger service speeds. The most significant speed restrictions caused by at-grade crossings are found in Santa Barbara and through Los Angeles County. Six at-grade crossings over a 1.2-mile segment just outside the downtown Santa Barbara station restrict speed through Santa Barbara to 20 mph.

Population Projections

Table 2.2.1 shows the current and projected population for the Los Angeles-Santa Barbara Corridor. In 1990, 4.38 million people lived in cities within a 5-mile radius of the rail right-of-way. However, 81 percent of this population (3.49 million)is located in the city of Los Angeles. The corridor is expected to grow to about 5.45 million by the year 2010, resulting in a 24 percent increase over the 20-year period.

Service Improvements

Only 110-mph and 125-mph service improvement alternatives were considered for the Los Angeles-Santa Barbara Corridor. Table 2.2.2 presents the costs and travel times associated with these alternatives.

Table 2.2.1 Corridor Population Projections
Los Angeles to Angeles to Santa Barbara

City	1990	2000	2010	2020	% Change
On Line					
Burbank	93,643	107,462	120,518	136,732	46.0%
Camarillo	52,303	61,500	69,500	80,131	53.2%
Carpinteria	13,747	16,945	20,293	24,659	79.4%
Glendale	180,038	197,492	211,474	229,211	27.3%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.6%
Moorpark	25,494	38,500	52,000	74,381	191.8%
San Fernando	22,580	23,592	24,414	25,386	12.4%
Santa Barbara*	85,571	93,276	100,415	108,778	27.1%
Simi Valley	100,219	119,200	137,000	160,203	59.9%
Unincorporated Santa Barbara	87,676	93,936	101,252	108,810	24.1%
Ventura	92,575	104,558	115,758	129,450	39.8%
Total (on line)	4,239,254	4,731,366	5,284,737	5,907,489	39.4%
Within 5-mile Radius					
Oxnard	142,217	154,621	167,027	181,012	27.3%
Total (w/in 5 miles)	4,381,471	4,885,987	5,451,764	6,088,500	39.0%
Within 10-mile Radius					
Alhambra	82,106	87,865	91,301	96,288	17.3%
Monterey Park	60,738	64,533	68,636	72,962	20.1%
Pasadena	131,591	141,996	153,116	165,165	25.5%
Port Hueneme	20,319	24,419	28,381	33,547	65.1%
South Pasadena	23,936	25,196	27,306	29,168	21.9%
Thousand Oaks	104,351	115,800	128,000	141,764	35.9%
Vernon	151	89	89	71	-53.2%
West Hollywood	36,118	37,073	39,313	41,020	13.6%
Total (w/in 10 miles)	4,840,781	5,382,958	5,987,906	6,668,486	37.8%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Los Angeles	8,897,500	10,180,868	11,441,900	12,916,552	45.2%
Santa Barbara	371,400	435,798	484,765	536,509	44.5%
Ventura	671,600	782,688	905,622	1,040,456	54.9%
TOTALS	9,940,500	11,399,354	12,832,287	14,493,517	45.8%

Table 2.2.2 Service Improvements Summary: Los Angeles-Santa Barbara

Alternative	Distance (miles)	Estimated Cost ($)	Travel Times (minutes)			Travel Times - Tilt Trains (min.)		
			Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing (79 mph)	103.6			155				
110-mph Alt.	103.6	242,000,000	93	116	99	74	100	84
125-mph Alt.	103.6	2,032,000,000	78	99	86	65	89	74

Notes: Estimated Costs do not include new rolling stock.
Skip-stop service assumes three stops.

110-mph Maximum Speed Alternative

Upgrading the Los Angeles-Santa Barbara corridor to 110-mph diesel locomotive standards would cost $242 million or $2.34 million per mile. Acquisition of the right-of-way currently owned by SP constitutes the single largest expenditure at an estimated $82 million. Other costs include three curve realignments and three station upgrades.

With a 4000 HP locomotive, express service linehaul time would be 1 hour 35 minutes, resulting in a 66-mph average speed. The time increases to 1 hour 58 minutes with a local service for an average speed of 53 mph. Skip-stop service would result in a time of 1 hour 38 minutes and average speed of 63 mph. Tilt-train service would reduce the express service time by about 20 percent, the local service by 14 percent, and the skip-stop services by 15 percent.

125-mph Maximum Speed Alternative

The 125-mph alternative in the Los Angeles-Santa Barbara Corridor would cost $2.0 billion at an average cost per mile of $19.6 million. Major costs include 1.5 miles of cut-and-cover tunnel in downtown Santa Barbara, a new standard bore tunnel through the Santa Susana Pass, and eight curve realignments.

Non-stop express travel between Los Angeles and Santa Barbara would take 1 hour 18 minutes, averaging 80 mph. Local and skip-stop services would take 1 hour 39 minutes and 1 hour 26 minutes, respectively. Tilt-train service would reduce the express service time by almost 17 percent, the local service by 10 percent, and the skip-stop services by 14 percent.

Summary

The potential exists to improve substantially service in the Los Angeles-Santa Barbara Corridor. An estimated $242 million for the 110-mph alternative could reduce local service times by 39 minutes with conventional rolling stock and 55 minutes with tilting trainsets. Express travel times under the 125-mph alternative are about 16 percent less than the comparable 110-mph service. However, note that the travel times for the 110-mph tilting train service are virtually identical to the 125-mph alternative with conventional rolling stock at a fraction of the capital costs.

2.3. The Coastal Corridor (L.A.-Santa Barbara-San Francisco)

The Coastal Corridor traverses 474 miles between Los Angeles Union Station and San Francisco (see Figure 2.3.1), roughly following the alignment for U.S. Highway 101 and State Highway 1. Much of the route between Ventura and San Luis Obispo runs directly along the shoreline. Although the route intersects most of the major coastal cities between Los Angeles and the Bay Area (Santa Barbara, San Luis Obispo, and Salinas), most of the corridor (291.9 miles) passes through rural areas. The rail line is the same as described in the previous section (2.2) from Los Angeles to Santa Barbara.

Existing Conditions

Passenger Service

The Coast Starlight is the only Amtrak passenger rail service on the Coast corridor. This service begins in Los Angeles, travels up the coast to San Jose and Oakland in the Bay Area, and continues north to its terminus in Seattle. One daily train departs in each direction.

Ridership for the entire route totaled 596,400 during the fiscal year 1989/90 with an average of 817 passengers per train. The route offers direct connections to the Amtrak San Diegan at Union Station and to the San Joaquin route at Martinez.

Freight Operations

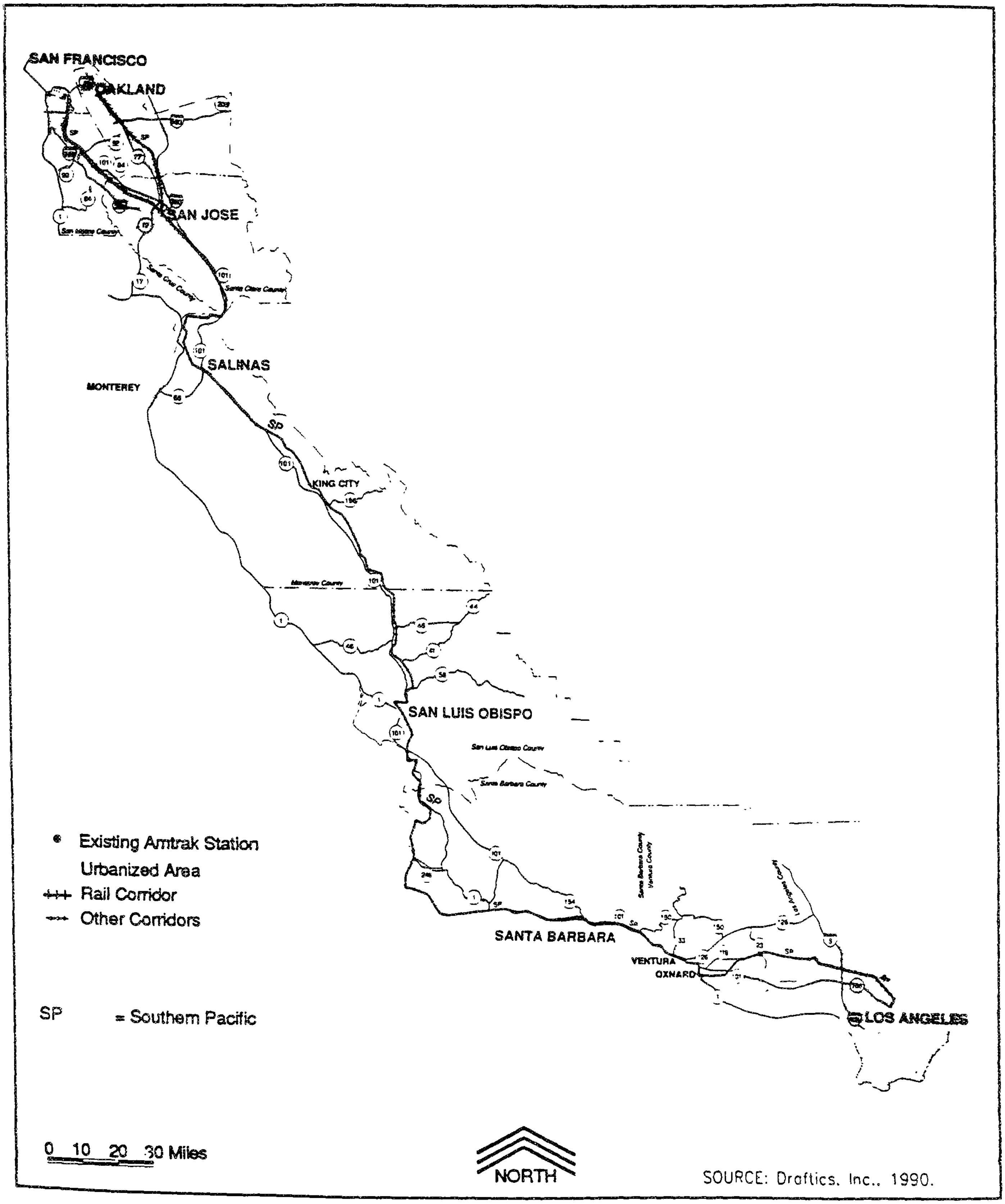
SP operates one daily freight train between Los Angeles and Oakland, with ten local operations connecting to the Santa Barbara corridor segment. However, most of the freight moved up and down the Pacific coast is routed further inland through the Tehachapi Pass, which on average carries about 50 daily freight trains.

Right-of-Way

Four different SP rail segments make up the Coast corridor. The segment from Los Angeles to the Burbank Junction is part of the SP Valley line. At the Burbank Junction, the Valley line veers northward while the Coast corridor continues in a northwest direction as the SP Coast route. The corridor splits at San Jose, with the Coast route right-of-way continuing up to its terminus in San Francisco. The segment leading to Oakland begins at San Jose and follows the SP "DA" Mainline route to the Niles Tower south of Hayward. From the Niles Tower, the corridor continues to its terminus in Oakland along the SP "D" Mainline right-of-way. With some exceptions, the Coast line has a 100-foot minimum right-of-way. Except for segments from San Francisco to Gilroy and Los Angeles to Moorpark which are publicly owned, SP owns the entire right-of-way and trackage along the coast.

Figure 2.3.1

Los Angeles – Santa Barbara – San Francisco Corridor (Coastal Route)



Source: Wilbur Smith, 1990.

Track Condition

With the exception of the San Francisco-San Jose segment and short segments in Santa Barbara (3 miles) and Los Angeles (11 miles), most of the Coast corridor is single-tracked. Although tie renewal programs have improved track conditions along much of the corridor, about half of the route remains bolted/jointed rail. Most of the route meets the FRA Class IV standard.

Stations

Between Los Angeles and Oakland, the Coast Starlight route currently services nine stations. These locations include Los Angeles Union Station, Glendale, Simi Valley, Oxnard, Santa Barbara, San Luis Obispo, Salinas, San Jose, and Oakland. These stations are in adequate condition, except for the San Jose station, which needs a seismic upgrade, and Oakland, which suffered earthquake damage in 1989. The Oakland station will be replaced by a new facility at Jack London Square. With the exception of Simi Valley and Oxnard, these stations are staffed facilities.

Speed Restrictions

Because the Coast corridor alignment roughly follows the winding Pacific coast line from Ventura County north to San Luis Obispo, curvature is a major speed impediment. The most severe speed restrictions are found at the Cuesta Grade through the Santa Lucia range just north of San Luis Obispo. Here, 10-degree curves combined with a 2.2 percent grade slow trains down to 25 mph for a 17-mile stretch. Altogether, there are about 78 curve miles in the corridor (if the corridor terminates in San Francisco rather than Oakland), representing over 16 percent of its total length.

The corridor is intersected by 221 at-grade crossings. Although most of the crossings are spaced more than one-half mile apart, denser concentrations of at-grade crossings exist in some cities (most notably Santa Barbara and some of the urban areas along the San Jose-San Francisco segment).

Population Projections

Table 2.3.1 gives the current and projected population for the Los Angeles-San Francisco Coastal Route Corridor. A population of 7.93 million lived in cities within a 10-mile radius of the rail right-of-way in 1990. The corridor is expected to grow to about 9.71 million by the year 2010, increasing by about 22 percent in 20 years. Total population for the ten counties connected by this route was 13.6 million in 1990 and is expected to rise 28 percent to 17.4 million by 2010.

A vast majority of the growth in this corridor will occur in the Los Angeles metropolitan region. Los Angeles County alone should increase by more than 2.5 million residents from 1990 to 2010. At the same time, Ventura County should pass the 900,000 mark by the year 2010, an increase of 35 percent.

Table 2.3.1 Corridor Population Projections
Existing Coastal Route Corridor

City	1990	2000	2010	2020	% Change
On Line					
Belmont	24,641	25,700	25,500	25,949	5.3%
Burbank	93,643	107,462	120,518	136,732	46.0%
Burlingame	26,701	28,000	28,300	29,140	9.1%
Carpinteria	13,747	16,945	20,293	24,659	79.4%
Gilroy	36,831	49,400	67,400	91,180	147.6%
Glendale	180,038	197,492	211,474	232,152	28.9%
Gonzales	4,660	5,950	6,510	7,717	65.6%
Grover beach	11,656	14,572	17,951	22,278	91.1%
Guadalupe	5,479	6,646	7,793	9,296	69.7%
King City	7,634	10,190	11,140	13,524	77.2%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.6%
Menlo Park	33,447	35,200	35,300	36,275	8.5%
Milbrea	20,476	21,300	21,300	21,729	6.1%
Moorpark	25,494	38,500	52,000	74,381	191.8%
Morgan Hill	31,234	36,200	47,300	58,312	86.7%
Mountain View	70,089	76,700	79,600	84,859	21.1%
Oxnard	142,217	154,621	167,027	181,012	27.3%
Palo Alto	73,309	75,900	79,100	82,165	12.1%
Pismo Beach	7,669	9,539	11,677	14,409	87.9%
Redwood City	88,035	103,900	107,200	118,562	34.7%
Salinas*	110,387	144,500	175,000	220,509	99.8%
San Bruno	38,665	40,300	40,400	41,304	6.8%
San Carlos	27,619	29,300	29,700	30,807	11.5%
San Francisco	723,959	766,100	778,900	808,076	11.6%
San Jose	825,411	952,500	1,024,300	1,141,762	38.3%
San Luis Obispo	41,958	50,566	59,658	71,142	69.6%
San Mateo	89,971	98,200	99,900	105,333	17.1%
Santa Barbara*	85,571	93,276	100,415	108,778	27.1%
Santa Clara	93,333	107,300	116,500	130,211	39.5%
Simi Valley	100,219	119,200	137,000	160,203	59.9%
Soledad	7,146	20,380	22,200	43,748	512.2%
South San Francisco	54,337	58,000	58,900	61,342	12.9%
Sunnyvale	117,254	128,800	134,700	144,417	23.2%
Unincorporated Santa Barbara	87,676	93,936	101,252	108,810	24.1%
Ventura	92,575	104,558	115,758	129,450	39.8%
TOTAL (On Line)	6,878,489	7,696,038	8,444,080	9,399,971	36.7%
Within 5 Mile Radius					
Atascadero	23,138	29,494	37,282	47,326	104.5%
Campbell	38,169	40,100	41,400	43,118	13.0%
East Palo Alto	23,286	29,300	30,500	35,063	50.6%
Greenfield	7,456	10,540	11,300	14,044	88.4%
Los Altos	28,927	28,600	29,100	29,190	0.9%
San Fernando	22,580	23,592	24,414	25,386	12.4%
Watsonville	31,099	46,530	53,000	69,834	124.6%
TOTAL(w/in 5-miles)	7,053,144	7,904,194	8,671,077	9,663,933	37.0%
Within 10-Mile Radius					
Alhambra	82,106	87,865	91,301	96,288	17.3%
Cupertino	46,911	51,200	53,000	56,354	20.1%
Daly City	96,653	103,800	105,000	109,489	13.3%
Lompoc	37,649	44,767	51,239	59,786	58.8%
Los Gatos	30,941	32,000	33,100	34,235	10.6%
Marina	26,436	28,700	31,330	34,107	29.0%
Milpitas	50,769	61,900	63,100	70,629	39.1%
Monterey Park	60,738	64,533	68,636	72,962	20.1%
Pacifica	37,670	39,700	40,700	42,309	12.3%
Pasadena	131,591	141,996	153,116	165,165	25.5%
Port Hueneme	20,319	24,419	28,381	33,547	65.1%
San Juan Batista	1,570	2,069	2,646	3,435	118.8%
Santa Maria	61,284	75,046	89,089	107,427	75.3%
Saratoga	28,530	29,300	30,300	31,226	9.4%
South Pasadena	23,936	25,196	27,306	29,168	21.9%
Thousand Oaks	104,351	115,800	128,000	141,764	35.9%
Vernon	151	89	89	71	-53.2%
West Hollywood	36,118	37,073	39,313	41,020	13.6%
TOTAL(w/in 10-miles)	7,930,867	8,869,647	9,706,722	10,792,917	36.1%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Los Angeles	8,897,500	10,180,868	11,441,900	12,916,552	45.2%
Monterey	358,800	414,014	485,297	574,082	60.0%
San Benito	37,000	50,658	66,454	83,212	124.9%
San Francisco	723,900	774,011	781,735	777,391	7.4%
San Luis Obispo	219,500	263,209	306,781	351,400	60.1%
San Mateo	652,100	740,370	787,291	825,627	26.6%
Santa Barbara	371,400	435,798	484,765	536,509	44.5%
Santa Clara	1,502,200	1,703,936	1,839,696	1,958,603	30.4%
Santa Cruz	230,800	263,974	291,762	322,329	39.7%
Ventura	671,600	782,688	905,622	1,040,456	54.9%
TOTAL	13,664,800	15,609,526	17,391,303	19,386,161	41.9%

Service Improvements

Only the 110-mph and 125-mph service improvement alternatives were researched for the Coastal Corridor. Analysis for each alternative included only alignments from Los Angeles to San Francisco. Results from the cost and travel time calculations are presented in Table 2.3.2.

Table 2.3.2 Service Improvements Summary:
Los Angeles-San Francisco, Coastal Route

	Distance	Estimated	Travel Times (minutes)			Travel Times - Tilt Train (min.)		
Alternative		Cost	Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing				675*				
110 mph	474.2	$1,266,000,000	387	443	395	315	382	322
125 mph	469.7	$8,563,000,000	327	380	334	275	330	282

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes four stops.
* Oakland-Los Angeles; Amtrak 1993 Timetable.

110-mph Maximum Speed Alternative

The cost of improving the 474-mile corridor for 110-mph operations totaled $1.27 billion, or $2.67 million per mile. Major capital costs included 64 minor realignments and three major curve realignments near Chittenden, Casmalia, and just north of Pismo Beach. The three major curve projects included the realignment of 26 curves of up to 10 degrees. These projects would require 11.33 miles of new track, 1.1 miles of standard bore tunneling, and over half a mile of viaduct. The curves at Casmalia and Pismo Beach would be realigned to 2 degrees, while the Chittenden curves would be realigned to 3 degrees.

Using 4000 HP diesels, the one-stop express time between Los Angeles and San Francisco would be 6 hours 27 minutes, with an average speed of 74 mph. Local service would take 7 hours 23 minutes, with an average speed of 64 mph. Skip-stop trains would take 6 hours 35 minutes, with an average speed of 72 mph. Use of tilting trainsets could substantially reduce travel times for this alternative. Tilt-trains would reduce express service by 72 minutes (19 percent), local service by 61 minutes (14 percent), and skip-stop service by 73 minutes (18 percent).

125-mph Maximum Speed Alternative

The 125-mph alternative would require an estimated $8.6 billion for construction on the Coast Route from Los Angeles to San Francisco, averaging $18.2 million per mile. In addition to the 64 minor curve realignments and three major curve realignments assumed under the 110-mph alternative, this alternative included 1.5 miles of cut-and-cover tunnel in downtown Santa Barbara, 4 miles of standard bore tunneling through the Santa Lucia Range just north of San Luis Obispo, 9.7 miles of cut-and-cover tunneling in the San Jose area, and a new terminal in downtown San Francisco.

One-stop express travel between Los Angeles and San Francisco would take 5 hours 27 minutes, averaging 86 mph. Local and skip-stop services would take 6 hours 20 minutes and 5 hours 34 minutes, respectively. As with the 110-mph alternative, the use of tilting trainsets could greatly reduce travel times. Tilt-train service would reduce the express service time by almost 16 percent, the local service by 13 percent, and skip-stop services by 16 percent.

Summary

Significant service improvements between Los Angeles and San Francisco on the Coastal Corridor will require a substantial amount of curve realignment, resulting in a relatively high ($2.6 million) cost per mile for the 110-mph alternative. In addition, the numerous curves on this corridor suggest an outstanding potential for tilt-train service on the Coastal Route. In particular, note that tilt train travel times under the 110-mph alternative are superior to conventional rolling stock travel times under the 125-mph alternative at a fraction of the capital cost.

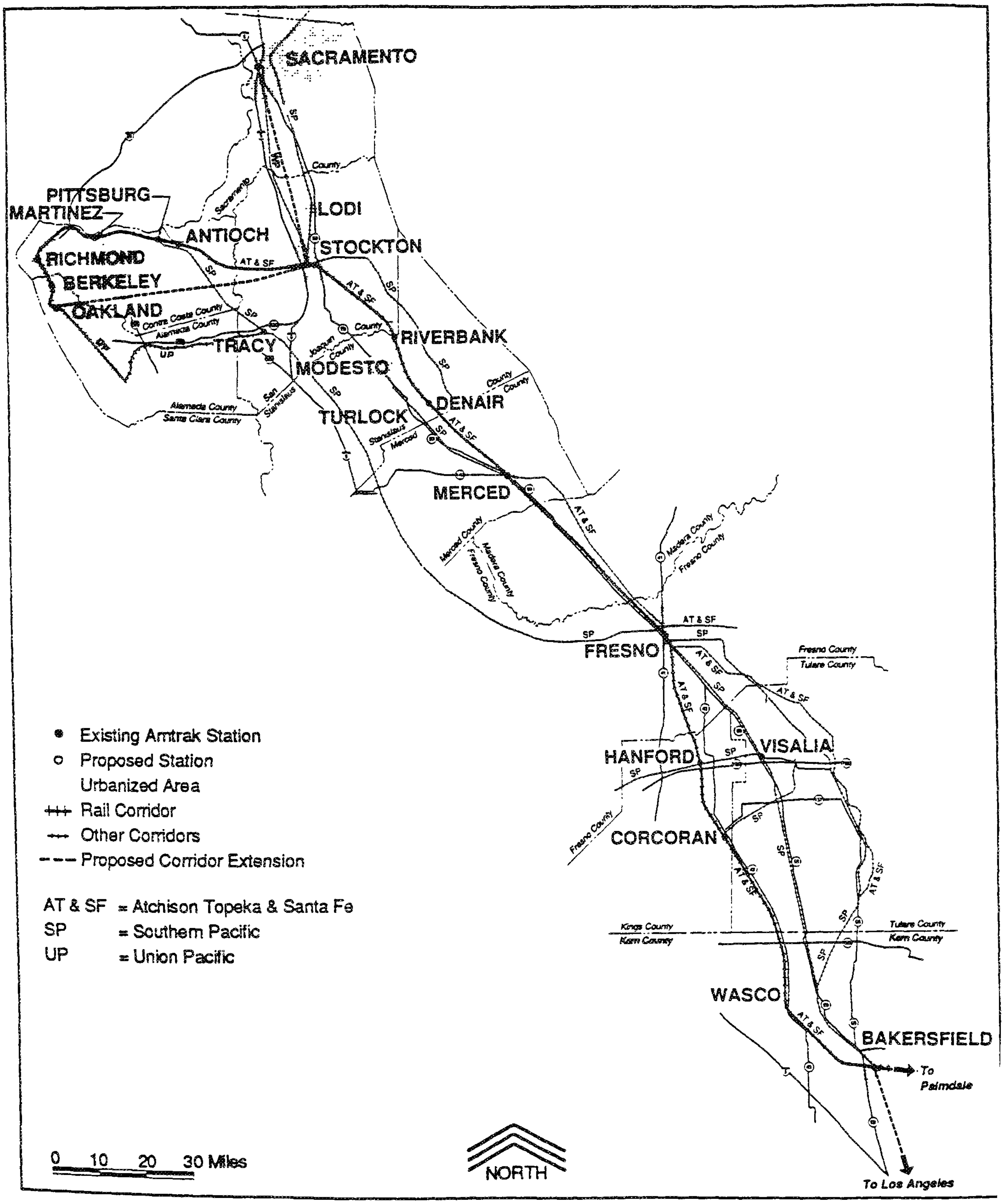
2.4. Los Angeles-Central Valley-Oakland/Sacramento Corridor

The Los Angeles-Central Valley-Oakland/Sacramento rail corridor links the two most populous regions in the state and traverses the rapidly growing communities of the Central Valley. Using existing rail right-of-way through the Central Valley, the distance between Oakland and Los Angeles is about 485 miles, with an additional 54 miles extending to Sacramento from Stockton.

Passenger rail service would operate on SP right-of-way from Los Angeles to Bakersfield. The alignment heads north through the Los Angeles Basin, then east to Palmdale/Lancaster via Soledad Canyon, continues north through Antelope Valley, and then northwest through the Tehachapi mountains to Bakersfield. Figure 2.4.1 illustrates the Bakersfield-Bay Area/Sacramento section of the corridor. Passenger service could use either the ATSF or the SP alignments from Bakersfield to Port Chicago (near Martinez). Both alternatives have their advantages and each directly serve the major Central Valley population centers of Fresno and Stockton. Due to resource constraints, only one alignment was evaluated for this study. The ATSF alternative was chosen primarily because of Caltrans' June 1993 decision to keep the San Joaquin service on the ATSF. Use of SP right-of-way was assumed for the Port Chicago-Martinez and Stockton-Sacramento segments. However, completion of the proposed Fresno Freight Consolidation Project (FFCP) would move passenger operations through Fresno to the SP line, making complete use of the SP alignment from Fresno to Oakland worthy of consideration.

Figure 2.4.1

Los Angeles – Central Valley – Oakland/Sacramento Corridor



Source: Wilbur Smith, 1990.

Existing Conditions

Freight Operations

A considerable volume of freight traffic travels through the corridor, particularly in the southern segment between Los Angeles and Bakersfield. The Tehachapi Pass segment "is one of the busiest single-track freight lines in the West, if not the entire country."[19] This segment handles nearly all of the freight for SP and ATSF between the Mid-West and Northern/Central California, in addition to serving as SP's mainline from the Pacific Northwest (and Northern California) to Southern California. In total, freight traffic through this segment averages about 50 trains per day. Between Sacramento and Bakersfield, SP runs seven to eight daily freight operations in each direction, with numerous local operations throughout the route. In addition, ATSF operates ten freight trains between Fresno and Bakersfield, as well as one or two daily operations north of Fresno.

Significantly, ATSF freight trains are shorter, lighter, and operate at higher speeds than SP trains. Therefore, although ATSF operates more through trains in the Central Valley, these trains "consume less time in meeting and passing each other than is the case on the SP."[20]

Passenger Service

Although the existing rail right-of-way could provide a direct link between the Sacramento/Bay Area regions and Los Angeles, the existing San Joaquin service begins in Oakland and terminates at Bakersfield, requiring a bus connection for trips further south. Amtrak runs four of these round trips per day. Passenger volume on the route has grown steadily since the resumption of passenger rail service in 1974. San Joaquin ridership was over 480,000 for fiscal year 1991/92 with a farebox ratio of 66.3 percent.

Currently, nearly all trains between Oakland and Bakersfield take about 6 hours, at an average speed of 52 mph. This time includes 13 stops between the termini.

Right-of-Way

The Amtrak San Joaquin trains operate on segments currently owned by both SP and ATSF. ATSF owns the right-of-way used between Bakersfield and Port Chicago, whereas the SP tracks are used between Port Chicago and Oakland. However, SP owns right-of-way from Los Angeles through the Central Valley to the Bay Area and Sacramento. Thus, passenger service could use SP tracks throughout the entire corridor.

Most of the rail right-of-way through this corridor is thought to be about 100 feet wide and even wider through cities and towns with stations.[21] However, widths may be narrower where parcels have been sold for development.

Track Condition

Most of the corridor is single-tracked CWR with a Class IV rating. While only about 12 percent of the total route is double-tracked, the entire segment between Oakland and Martinez and much of the Los Angeles urban area is double-tracked.

Station Locations

Seventeen stations are currently served by the San Joaquins, nine of them staffed. These are located in Bakersfield, Hanford, Fresno, Merced, Stockton, Martinez, Richmond, Emeryville, and Oakland. Unstaffed stations generally consist of a platform, shelter, lighting, and limited parking. The eight unstaffed staffed stations are located in Wasco, Allensworth, Corcoran, Madera, Denair (Turlock), Riverbank (Modesto), Antioch, and Berkeley. Most of the existing facilities are adequate for the current level of service. However, studies are underway to identify sites and construct new intermodal stations at Bakersfield, Fresno, and Stockton. In addition, the Port of Oakland has a agreement with the state to construct a new station at Jack London Square to replace the Oakland SP, station which was damaged in the 1989 Loma Prieta earthquake.

If passenger service in this corridor is extended to Los Angeles, several additional stops would be added. With Union Station as the southern terminus, new facilities would likely be added at Palmdale, Lancaster, and Newhall. For the extension to Sacramento, stops would be added at the existing Sacramento Amtrak station and a restored Lodi SP station.

Speed Restrictions

Curvature is a major speed constraint only through the Los Angeles-Bakersfield and Richmond-Martinez segments. There are over 71 miles of track with curves restricting speed to 25-30 mph south of Bakersfield, through the Tehachapi Mountains and Soledad Canyon. These 71 miles account for nearly 15 percent of the total corridor and 42 percent of the Los Angeles-Bakersfield portion of the route. In the 20-mile stretch between Martinez and Richmond, Amtrak trains only average 40 mph as a result of 9 miles of curvature.

Most of the Los Angeles-Central Valley-Oakland/Sacramento Corridor is very straight, mainly because of the Central Valley portion of the corridor. From Sacramento to Bakersfield, over 98 percent of the route is free of speed-restricting curves.[22]

Of the 384 at-grade crossings found along the Los Angeles-Central Valley-Oakland/Sacramento Corridor, 176 lie in urban areas. Speeds are most seriously affected in the major urban regions and the condition of the at-grade crossing protection restricts speeds at various locations throughout the corridor. Largely because of the many at-grade crossings in Central Valley urban areas, Amtrak trains travel through Bakersfield, Fresno, and Stockton at 20 mph. Additionally, tracks actually lie within street rights-of-way for about 1.2 miles through Oakland's Jack London Square area, restricting passenger rail speeds to 15 mph or less.

The number of stops made by the present Amtrak service also constitutes a speed restriction. Amtrak currently makes 13 stops between Oakland and Bakersfield. Travel times could be significantly improved by reducing the number of stops each train makes even without major capital improvements in the corridor.

Population Projections

Table 2.4.1 presents recent and projected populations for the Los Angeles-Central Valley-Oakland portion of this corridor. About 7.24 million residents lived in cities within a 10-mile radius of the rail right-of-way in 1990, and this number is expected to grow to more than 10.52 million by the year 2010, a 45 percent increase in 20 years. The 1990 population of 13.8 million in counties within 10 miles of the rail line should increase to 19.0 million by 2010, a 38 percent increase.

Although growth should occur throughout the corridor, the Central Valley is expected to experience a phenomenal population increase. In 1990, the Central Valley counties served by the existing rail alignment contained a population of about 2.46 million. Twenty years later, (2010) this figure should rise to 4.38 million, an increase of 78 percent from 1990 levels. The Fresno metropolitan region alone is expected to grow by 403,000, totaling 885,000 residents by the year 2010. Nonetheless, the greatest actual increase in population in the corridor will occur in Southern California. Los Angeles county alone is expected to increase by more than 2.54 million residents from 1990 to 2010, a 29 percent increase.

If service were extended to Sacramento, the Central Valley cities of Sacramento and Lodi would contribute to the corridor population totals. The combined 1990 population of these cities was 421,200. By 2010, the total should reach 615,200, an increase of 46 percent (see Table 2.4.2).

Service Improvements

Since Amtrak already provides a 79-mph service on most of the Los Angeles-Central Valley-Oakland/Sacramento Corridor, only the 110-mph and 125-mph service improvement alternatives were studied. Table 2.4.3 presents costs and travel times for these alternatives.

110-mph Maximum Speed Alternative

Caltrans' *California Rail Passenger Program Report, 1993/4 - 2002/3* recommends increasing intercity service to six round-trips per day with maximum speeds "up to 110 mph where track configuration allows" for the San Joaquin Service over the next ten years. The report also specifies service extensions to both Sacramento and Los Angeles.

Table 2.4.1 Corridor Population Projections

Los Angeles - Central Valley - Oakland/Sacramento Corridor

City	1990	2000	2010	2020	% Change
On Line					
Albany	16,327	16,900	17,300	17,808	9.1%
Antioch	63,057	98,400	120,900	168,604	167.4%
Bakersfield	329,106	465,022	567,314	654,972	99.0%
Burbank	93,643	107,462	120,518	136,732	46.0%
Corcoran	13,364	18,736	25,616	35,467	165.4%
Emeryville	5,740	8,700	10,300	13,903	142.2%
Escalon	4,437	5,787	7,437	9,629	117.0%
Fresno	482,000	676,500	885,000	1,137,000	135.9%
Glendale	180,038	197,492	211,474	229,211	27.3%
Hanford	30,897	41,597	53,930	71,263	130.6%
Hughson	3,259	4,374	5,607	7,357	125.7%
Lancaster	97,291	152,280	212,138	313,782	222.5%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.6%
Madera	29,281	42,653	55,374	76,276	160.5%
Merced	56,216	77,929	108,083	149,867	166.6%
Newhall/Santa Clarita	151,051	313,883	483,229	633,229	319.2%
Oakland	372,219	391,700	406,400	424,661	14.1%
Palmdale	240,562	440,891	654,743	854,793	255.3%
Pittsburg	65,260	81,000	93,500	111,990	71.6%
Richmond	100,150	115,100	117,600	127,655	27.5%
Riverbank	8,547	11,966	16,046	21,991	157.3%
San Fernando	22,580	23,592	24,414	25,386	12.4%
San Pablo	28,552	32,300	32,400	34,577	21.1%
Shafter	8,409	11,844	15,229	20,515	144.0%
Stockton	269,644	335,000	385,000	460,389	70.7%
Tehachapi	5,791	8,061	10,253	13,657	135.8%
Wasco	12,412	17,386	22,240	29,801	140 1%
Total (On Line)	6,175,241	7,571,459	8,994,158	10,610,262	71.8%
Within 5 mile Radius					
Alameda	76,459	82,400	83,800	87,768	14 8%
Atwater	22,282	29,849	39,760	53,113	138 4%
Benicia	24,446	36,200	42,900	57,184	133.9%
Berkeley	102,724	104,600	105,600	107,069	4.2%
Brentwood	9,464	26,500	43,300	95,997	914 3%
El Cerrito	29,332	29,000	30,300	30,808	5.0%
Hercules	16,829	20,900	22,700	26,423	57.0%
Martinez	39,743	43,700	45,300	48,384	21.7%
McFarland	7,005	9,934	12,860	17,442	149.0%
Piedmont	10,602	10,600	10,700	10,749	1.4%
Pinole	27,982	28,500	30,200	31,380	12.1%
Turlock	42,198	61,934	88,394	127,947	203 2%
Total (w/in 5 miles)	6,584,307	8,055,577	9,549,971	11,304,526	71.7%
Within 10 mile Radius					
Vernon	151	89	89	71	-53 2%
Alhambra	82,106	87,865	91,301	96,288	17.3%
Ceres	26,314	40,924	63,951	99,697	278.9%
Chowchilla	5,930	8,367	10,530	14,055	137.0%
Delano	22,762	32,052	41,204	55,495	143 8%
Fowler	3,208	4,340	5,573	7,348	129.0%
Huntington Park	56,065	64,485	68,562	75,878	35.3%
Livingston	7,317	10,401	14,915	21,296	191.0%
Modesto	164,730	239,000	320,000	446,363	171.0%
Montebello	59,565	65,004	70,813	77,210	29.6%
Monterey Park	60,738	64,533	68,636	72,962	20.1%
Oakdale	11,961	16,378	21,417	28,666	139.7%
Vallejo	112,054	143,600	143,800	164,142	46.5%
Waterford	4,771	6,699	9,013	12,390	159.7%
West Hollywood	36,118	37,073	39,313	41,020	13 6%
Total (w/in 10 miles)	7,238,097	8,876,386	10,519,089	12,517,407	72.9%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Alameda	1,282,400	1,457,409	1,561,851	1,664,155	29 8%
Contra Costa	810,301	971,282	1,096,253	1,212,788	49.7%
Fresno	673,900	945,908	1,237,432	1,589,665	135 9%
Kern	549,800	801,991	1,037,673	1,310,050	138.3%
Kings	102,500	135,222	168,926	207,506	102.4%
Los Angeles	8,897,500	10,180,868	11,441,900	12,916,552	45.2%
Madera	89,800	133,976	171,802	214,097	138.4%
Merced	180,600	238,985	313,616	401,947	122.6%
San Juaquin	483,800	620,322	778,404	956,456	97.7%
Solano	345,700	477,727	557,403	625,347	80.9%
Stanislaus	376,100	517,618	670,009	840,191	123.4%
TOTAL	13,792,401	16,481,308	19,035,269	21,938,754	59 1%

Table 2.4.2 Corridor Population Projections
Extension to Sacramento

City	1990	2000	2010	2020	% Change
Sacramento	369,365	448,000	529,000	633,133	71.4%
Lodi	51,874	67,394	86,239	111,197	114.4%
Total (On Line)	421,239	515,394	615,239	744,330	76.7%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Sacramento	1,051,400	1,329,062	1,579,339	1,839,529	75.0%

Table 2.4.3 Service Improvements Summary
Los Angeles - Central Valley-Oakland/Sacramento (California Corridor)

			Travel Times (minutes)			Tilt Train Times (min.)		
	Distance (miles)	Estimated Cost	Express	Local	Skip-Stop	Express	Local	Skip-Stop
Los Angeles-Central Valley-Oakland								
110 mph	484.6	$893,000,000	424	492	435	379	451	392
125 mph	457.5	$8,750,000,000	271	329	285	253	313	269
Bakersfield-Oakland								
Existing	315.5			360				
110 mph	315.5	$653,000,000	218	270	223	206	263	215
125 mph	315.5	$4,660,000,000	194	241	201	178	226	185
Stockton-Sacramento								
110 mph	53.9	$149,000,000	35	40	36	34	38	35
125 mph	53.9	$820,000,000	32	36	33	30	33	30

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes four stops between Los Angeles and San Francisco; two stops between Oakland and Bakersfield.

Since most of the corridor is straight, with the existing track in good condition, improvement to 110-mph standards is relatively inexpensive for much of the corridor. The estimated $893 million to improve the corridor to 110 mph from Oakland to Los Angeles results in a comparatively low average cost $1.84 million per mile. Note, however, that this cost includes the realignment of just five speed-restricting curves and that only superelevation improvements were assumed for the mountain passes. The cost for improving the Oakland-Bakersfield portion of the route would be about $653 million, or $2.07 million per mile. The extension to Sacramento would cost an additional $150 million, or about $2.76 million per mile.

A one-stop express train between Oakland and Los Angeles would take about 7 hours 4 minutes with 4000 HP diesel locomotives at an average speed of 68.5 mph. Local service stopping at 17 stations would take about 8 hours 12 minutes between the termini, averaging 59 mph. Skip-stop service, making four stops (Bakersfield, Fresno, Stockton, and Martinez were modeled), would take about 7 hours 15 minutes, averaging nearly 67 mph. If tilting trainsets were used, expected local service travel times would be reduced 8 percent and express service times by 10.6 percent. Over 70 percent of the time savings from tilting would accumulate though the mountainous regions of the Los Angeles-Bakersfield portion of the corridor.

A one-stop express service between Oakland and Bakersfield would require only 3 hours 38 minutes, averaging nearly 87 mph. Trains would average 100 mph or greater over nearly 60 percent of this segment. Local service stopping at 13 stations would take about 4 hours 30 minutes between Oakland and Bakersfield, averaging 70 mph. This service, while making the same number of stops, would take 90 minutes less than the current San Joaquin service. The skip-stop service alternative, making two stops (Fresno and Martinez were modeled), would take about 3 hours 43 minutes, averaging 85 mph. Since the alignment is so straight, tilting trainsets would reduce local service travel times by only 2.5 percent, and express times by 5.5 percent.

A one-stop express service from Sacramento to Los Angeles would take 6 hours 31 minutes at an average speed of 70 mph. Local and skip-stop services would take 7 hours 22 minutes and 6 hours 38 minutes, respectively.

125-mph Maximum Speed Alternative

Because of the extremely circuitous existing alignment through the Tehachapi Mountains and Soledad Canyon, the 125-mph alternative would require a new alignment from the San Fernando Pass to Bakersfield. After tunneling through the Tehachapi mountains several miles east of the I-5 alignment, the route would then follow the general alignment of the California Aqueduct through Antelope Valley to Palmdale. A new alignment through the Soledad Canyon would connect with the existing SP right-of-way at the outskirts of San Fernando. This route would require over 13 total miles of bore tunneling. The cost of the 142-mile new alignment from Los Angeles to Bakersfield is estimated at about $4 billion, averaging about $28 million per mile.

The total costs from Oakland to Los Angeles are estimated at $8.75 billion, an average cost of $19.1 million per mile. In addition to the new alignment segment, costs for this alternative also include a total of 9.5 miles of cut-and-cover tunnel through the downtowns of Bakersfield, Fresno, Stockton, and Jack London Square in Oakland, and a new station at West Oakland. In addition, the same five curve realignments as the 110-mph alternative would be required. The Oakland-Bakersfield segment of the route would cost about $4.66 billion, averaging $14.8 million per mile, while the extension to Sacramento would cost $820 million, averaging $15.2 million per mile.

One-stop express travel between Oakland and Los Angeles would take 4 hours 31 minutes, averaging 101 mph. Local and skip-stop services would take 5 hours 29 minutes and 4 hours 45 minutes, respectively. Tilt-train service would reduce the express service time by 6.6 percent, local service by about 4.9 percent and skip-stop service by 5.6 percent. The Oakland-Bakersfield section of the route would take 3 hours 14 minutes for the express service and 4 hours 1 minute for the local service, averaging 98 mph and 79 mph, respectively. Express service from Sacramento to Los Angeles would take 4 hours 4 minutes, while local service would take 4 hours 48 minutes. Average speeds for these services would be 106 mph and 90 mph, respectively.

Summary

The Tehachapi mountains separating the Central Valley from the Los Angeles Basin present the primary obstacle to improving rail service in this corridor. Even under the most optimistic assumptions, the trip between Bakersfield and Los Angeles would take about 3 hours on the existing SP right-of-way under the 110-mph alternative and using tilt-train technology. Although extension of San Joaquin service to Los Angeles is the most frequently requested improvement for this corridor,[23] heavy freight use through the Tehachapies and the shorter travel times offered by connecting buses (including transfer-time) make through service from Bakersfield to Los Angeles impractical without a new alignment.

In contrast, significant potential exists for improving the existing rail service from Oakland to Bakersfield. The relatively straight alignment through the Central Valley presents an excellent opportuity for sustained speeds above 100 mph with relatively little capital expenditure. A similar opportunity exists for the continuation of intercity rail service to Sacramento. Note that without a through service from Los Angeles to Bakersfield, the predominately straight alignment from Oakland to Bakersfield minimizes any advantage that might be gained with use of tilt train technology in this corridor.

The second major impediment to improved service in the Los Angeles-Central Valley-Oakland/ Sacramento Corridor is its alignment in the Bay Area. The alignment, reaches Oakland via a circuitous route along the East Bay shoreline that does not well serve either San Francisco or the San Jose metropolitan region.[24] However, if a new rail station were built at West Oakland, access to San Francisco could be greatly improved by providing a direct connection with BART.

2.5. San Jose-Oakland-Sacramento Corridor (Capitol)

The San Jose-Oakland-Sacramento rail corridor (hereafter referred to as the Capitol corridor) links the Bay Area with the rapidly growing Sacramento region. The 129.5-mile route roughly approximates the highway alignment of Interstate 80 (see Figure 2.5.1). Because of the increasing automobile congestion on Interstate 80 (I-80) between Sacramento and the Bay Area, the Capitol corridor has been specifically targeted for improved passenger rail services.

Existing Conditions

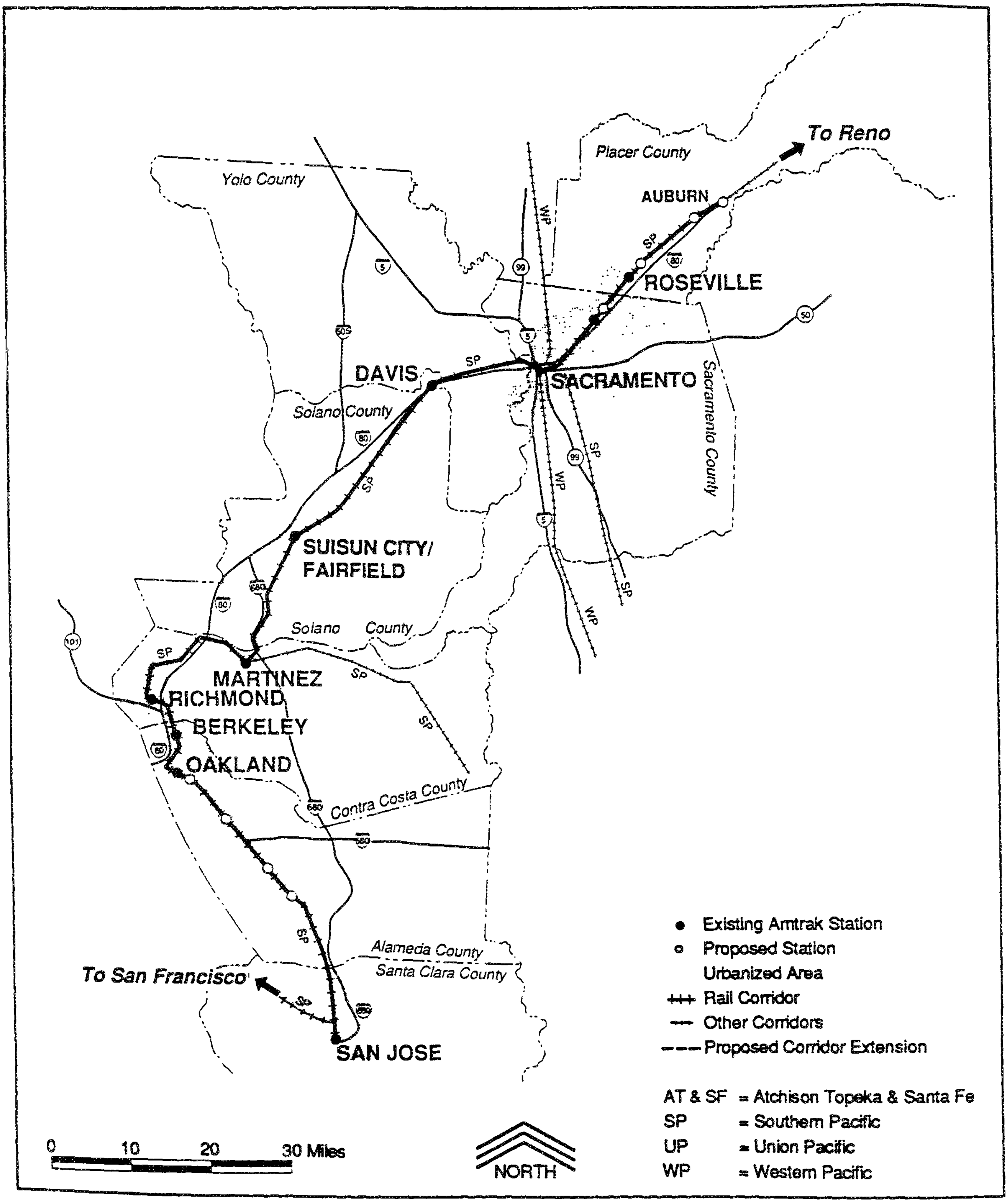
Freight Operations

Freight traffic varies throughout the Capitol corridor. Two to three daily through trains and two additional local daily freight operations take place in the San Jose-Oakland segment. However, about half this traffic operates at night, and these freight operations can also operate on the parallel SP line through Elmhurst, Niles, and Warm Springs.

Between Oakland and Sacramento, freight operations increase, with at least three or four daily freight trains operating in each direction. In addition, several additional trains from the San Joaquin

Figure 2.5.1

San Jose to Sacramento Corridor (Capitol Corridor)



Source: Wilbur Smith, 1990.

Valley and/or Southern California use the Oakland-Martinez segment of the line. Southern Pacific also uses this segment for local switching operations.

Passenger Service

Amtrak's "Capitol" service currently has three daily trips in each direction. The trip from San Jose to Sacramento requires 3 hours 10 minutes to 3 hours 20 minutes, averaging between 40 and 43 mph.

Passenger service on the Capitol Route began in December 1991. From February 8 to April 9, 1992, Amtrak offered a popular "buy-one, get-one-free" promotion. Because of the low fares and the novelty of the service, ridership over this period averaged nearly 37,000 passengers per month, far exceeding expectations. However, once the promotion was ended, ridership dropped off significantly. The following year (May 92-April 93), nearly 225,400 passengers rode the Capitol trains, an average of about 19,000 passengers per month.

Right-of-Way

As previously noted, SP owns the rail right-of-way, which is generally assumed to measure about 100 feet in width.[25] Two SP alignments run from just south of Oakland to San Jose. Currently, Amtrak services have been relegated to the eastern line from Oakland to Fremont, then to another SP line westward through Newark to the SP western alignment. Nevertheless, only the western alignment was studied for this report since the current Amtrak routing is longer, has severe speed restrictions, and would be more costly to upgrade.

Track Condition

Track condition varies throughout the corridor. The route is entirely double-tracked between Sacramento and Oakland. However, while the entire segment is rated at Class IV, about 80 percent of this segment is jointed rail. Between Oakland and San Jose, about 85 percent of the route is single-tracked. While most of the Oakland-San Jose segment is CWR, about half is rated at Class III and the other half at Class IV.

Station Locations

The Capitol service makes ten stops between the terminus stations at San Jose and Sacramento. These stations locations include Santa Clara, Fremont, Oakland, Emeryville, Berkeley, Richmond, Martinez, Fairfield (Suisun City), and Davis. The Berkeley, Fremont, and Santa Clara stations are unstaffed. With the exception of the Emeryville station, a completely new facility, most of these stations need facility improvements. In particular, nearly all of the stations have inadequate parking. Additional stations are planned for Hayward and the Oakland Coliseum.

Speed Restrictions

Over 15 miles or 12 percent of the Capitol corridor has a curvature greater than 1 degree (less than 5,700 ft horizontal radius). Most of the curves (about 62 percent of the curve mileage) are concentrated in a 20-mile segment between Richmond and Martinez. Curves as tight as 6 degrees (957-ft horizontal curve radius) reduce speeds through this segment to 40 mph. Most of the remaining alignment is relatively straight, particularly the 40-mile stretch between Fairfield and Sacramento.

While several structures along the route restrict passenger train speeds, the worst of these are the Yolo Causeways and the Benicia-Martinez Bridge. The Yolo Causeways are four elevated timber structures between Davis and Sacramento totaling 1.73 miles in length. Speeds are currently restricted to 40 mph over a 3.4-mile stretch.[26] Over the Benicia-Martinez crossing of the Carquinez Straits, speeds are reduced to 30 mph due to curves, grades, and the condition of the bridge. While the bridge itself is approximately 1 mile long, speed restrictions are currently in effect over a 2.7-mile segment.

The Capitol Corridor has approximately 100 at-grade crossings, of which only 15 are through non-urban areas. Speeds are restricted by the condition of the at-grade crossing protection at various locations in the corridor. At-grade crossings most seriously restrict speeds at Oakland's Jack London Square area, where tracks are actually within street rights-of-way for about 1.2 miles, with speed limitations of 15 mph or less.

The number of stops also severely increases travel times throughout the corridor. Two additional stations will be added to the ten existing Capitol service stops in the near future. Travel times between the major markets could significantly improve if express or skip-stop services were offered.

Population Projections

In 1990, 3.05 million residents lived in cities within a 5-mile radius of the rail right-of-way. By 2010, this population should increase to more than 3.87 million, an increase of 27 percent over 20 years (see Table 2.5.1).

Currently, most of the population is concentrated at the terminus cities of San Jose and Sacramento, and in the East Bay at Oakland. However, by 2010, rapid growth in the North Bay suburbs of Fairfield (85 percent), Vacaville (71 percent), and Vallejo (28 percent) will lead to a relatively evenly distributed population along this corridor.

Service Improvements

Since Amtrak's Capitol trains maintain operational speeds of 79 mph over part of the corridor and Caltrans has recommended a 110-mph maximum speed (where track configuration allows), only the 110-mph and 125-mph service improvement alternatives were studied. Table 2.5.2 presents the costs and travel times associated with these alternatives.

Table 2.5.1 Corridor Population Projections
Sacramento to San Jose Corridor

City	1990	2000	2010	2020	% Change
Albany	16,327	16,900	17,300	17,808	9.1%
Davis	46,209	58,400	65,000	77,247	67.2%
Dixon	10,638	14,900	17,900	23,288	118.9%
Emeryville	5,740	8,700	10,300	13,903	142.2%
Fairfield	80,114	118,100	148,600	203,018	153.4%
Martinez	39,743	43,700	45,300	48,384	21.7%
Newark	37,861	41,300	44,100	47,598	25.7%
Oakland	372,219	391,700	406,400	424,661	14.1%
Pinole	27,982	28,500	30,200	31,380	12.1%
Richmond	100,150	115,100	117,600	127,655	27.5%
Sacramento	369,365	448,000	529,000	633,133	71.4%
San Jose	825,411	952,500	1,024,300	1,141,762	38.3%
San Leandro	68,223	73,600	75,300	79,137	16.0%
San Pablo	28,552	32,300	32,400	34,577	21.1%
Union City	53,762	61,600	67,000	74,821	39.2%
Vallejo	112,054	143,600	143,800	164,142	46.5%
W.Sacramento	28,898	42,700	71,900	113,654	293.3%
TOTAL (on line)	2,386,670	2,775,600	3,042,500	3,471,237	45.4%
Within 5 mile Radius					
Benicia	24,446	36,200	42,900	57,184	133.9%
Berkeley	102,724	104,600	105,600	107,069	4.2%
El Cerrito	29,332	29,000	30,300	30,808	5.0%
Freemont	173,339	202,400	212,000	234,799	35.5%
Hayward	118,279	128,600	142,700	156,749	32.5%
Hercules	16,829	20,900	22,700	26,423	57.0%
Mountain View	70,089	76,700	79,600	84,859	21.1%
Piedmont	10,602	10,600	10,700	10,749	1.4%
Santa Clara	93,333	107,300	116,500	130,211	39.5%
Sunnyvale	117,254	128,800	134,700	144,417	23.2%
Vacaville	72,437	108,700	124,100	163,954	126.3%
Total (w/in 5 miles)	3,051,912	3,545,400	3,868,200	4,403,389	44.3%
Within 10 mile Radius					
Alameda	76,459	82,400	83,800	87,768	14.8%
Campbell	38,169	40,100	41,400	43,118	13.0%
Cupertino	46,911	51,200	53,000	56,354	20.1%
Milpitas	50,769	61,900	63,100	70,629	39.1%
Pleasant Hill	38,427	43,600	43,600	46,485	21.0%
Vallejo	112,054	143,600	143,800	164,142	46.5%
Total (w/in 10 miles)	3,414,701	3,968,200	4,296,900	4,871,885	42.7%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Alameda	1,282,400	1,457,409	1,561,851	1,664,155	29.8%
Contra Costa	810,301	971,282	1,096,253	1,212,788	49.7%
Sacramento	1,051,400	1,329,062	1,579,339	1,839,529	75.0%
Santa Clara	1,502,200	1,703,936	1,839,696	1,958,603	30.4%
Solano	345,700	477,727	557,403	625,347	80.9%
Yolo	142,500	192,608	237,828	285,883	100.6%
TOTAL	5,134,501	6,132,024	6,872,370	7,586,305	47.8%

Table 2.5.2 Service Improvements Summary
San Jose-Oakland-Sacramento (Capitol Corridor)

	Distance (miles)	Estimated Cost ($)	Travel Times (minutes)			Travel Times - Tilt Train (min.)		
			Express	**Local**	**Skip-Stop**	**Express**	**Local**	**Skip-Stop**
Existing				190				
110 mph	129.5	412,000,000	113	147	124	106	141	118
125 mph	129.5	2,780,000,000	105	136	115	98	133	109

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes four stops.

110-mph Maximum Speed Alternative

In addition to increasing maximum speeds to 110 mph, *Caltrans' California Rail Passenger Program Report, 1993/4-2002/3* recommends increasing intercity service to ten round-trips per day over the next ten years. Even though no curve realignment was assumed, costs per mile for this alternative are relatively high compared to other corridors in the state. The estimated $412 million required to create such a service results in an average of $3.18 million per mile. Since most of the right-of-way runs through urban areas and is not publicly owned, purchase of the right-of-way for this corridor would be expensive. Furthermore, although much of the route is double-tracked, the condition of the track is inferior compared to other state-supported routes.

Using 4000 HP diesel locomotives, a one-stop express time of about 1 hour 53 minutes could be achieved between San Jose and Oakland for an average speed of 69 mph. Local service stopping at each station location would take about 2 hours 27 minutes between the termini, averaging 53 mph. The skip-stop alternative, making three stops (Martinez, Oakland, and Hayward were modeled), would take about 2 hours 4 minutes, averaging nearly 63 mph. Tilting trainsets would reduce expected travel times by 6 percent for the express alternative, 4 percent for the local alternative, and 5 percent for the skip-stop alternative. Most of the time savings from using tilt-trains accrue between Richmond and Martinez.

125-mph Maximum Speed Alternative

The 125-mph alternative in the Capitol Corridor would cost $2.78 billion, or about $21.5 million per mile. This cost includes a two-mile cut-and-cover tunnel through the Jack London Square speed-restricted segment in Oakland, new structures for the Yolo Causeways, and a new station at West Oakland.

Under this alternative, one-stop express travel between San Jose and Sacramento would require 1 hour 45 minutes, averaging 74 mph. Local and skip-stop services would take 2 hours 16 minutes and 1 hour 55 minutes, respectively. Using tilt-trains could reduce the express service time by almost 7 percent and skip-stop service by 5 percent, but only 2 percent for local service.

Summary

The estimated $3.2 million per mile needed to create a 110-mph maximum speed service could reduce local service times by well over 40 minutes. However, upgrading costs are significantly higher compared to the other state-supported corridors because of relatively poor track condition and the urban character of much of the route.

While the 125-mph alternative requires a much higher level of improvement than the 110-mph upgrade, travel times are only reduced about 7 percent since the corridor is relatively short. Speeds would be virtually identical under both alternatives through the urban areas. Only on the 40-mile Fairfield-Sacramento segment could maximum speeds be achieved. Additionally, tilt train times under the 110-mph alternative would be virtually equal to conventional trains times under the 125-mph alternative as a result of tilt-train time savings through the severely curved 20-mile stretch between Richmond and Martinez.

As with the Los Angeles-Central Valley-Oakland Corridor, San Francisco is currently not well served by Capitol Corridor. Ridership potential for both intercity services would be greatly improved by an intermodal station at West Oakland that provided a direct connection with BART.

Finally, use of the western SP alignment between Oakland and San Jose would reduce travel times and minimize upgrading costs.

2.6. Sacramento-Redding Corridor

The Sacramento-Redding Corridor, shown in Figure 2.6.1, is about 169 miles long and roughly approximates State Highway 99 and Interstate 5. This corridor overlaps the Sacramento-Reno rail corridor from Sacramento to Auburn.

Existing Conditions

Freight Operations

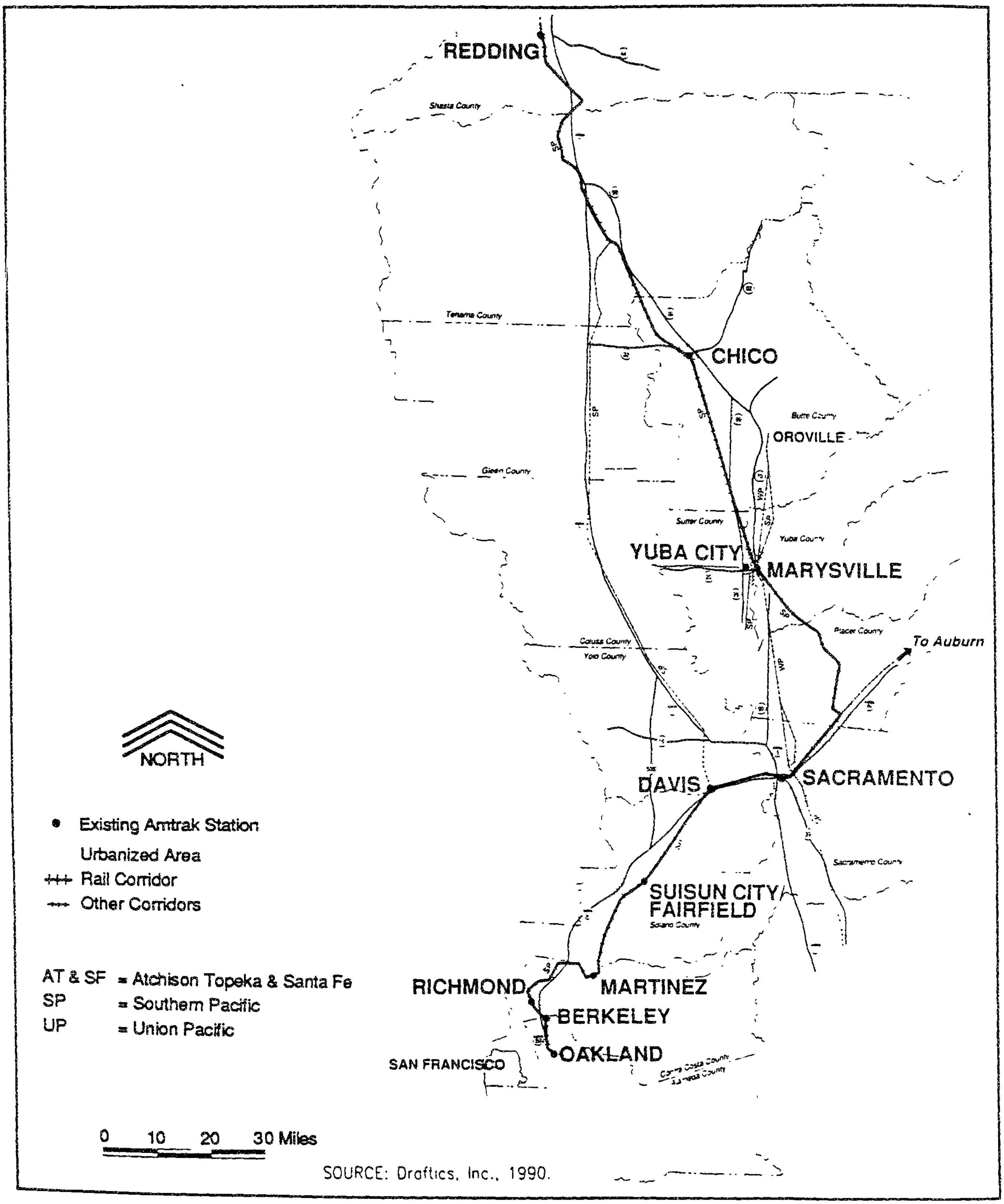
Freight activity is very heavy between Sacramento and Roseville, with 20-25 daily freight trains using the right-of-way.

Passenger Service and Stations

Currently, only one passenger rail service, the Amtrak Coast Starlight, operates on the Roseville-Redding segment. Existing station locations along the route include Roseville, Marysville, Chico, and Redding.

Figure 2.6.1

Sacramento to Redding Corridor



SOURCE: Draftics, Inc., 1990.

Source: Wilbur Smith, 1990.

Rights-of-Way and Track Condition

From the downtown Sacramento station, the route heads northeast along the SP 'A' mainline to the Roseville Junction. At Roseville, the route continues northward on the SP 'C' mainline right-of-way.

Most of the ties between Roseville and Redding were replaced between 1983 and 1986. The rail weight along the entire route is either #132 or #136. Except for a two-mile stretch at Tehama and a five-mile segment between Sacramento and Roseville, the route meets the FRA Class IV standards.

Speed Restrictions

Since the route travels across mostly flat terrain, relatively few curves restrict speed along the way. Potential speed restrictions exist along the Feather River Bridge and areas prone to flooding. In addition, the route sits on fill and includes some low timber trestles that require special maintenance. To what degree these factors restrict speed remains unresolved.

Population Projections

Table 2.6.1 presents recent and projected populations for the Sacramento-Redding Corridor. The population of 648,800 in cities within a 10-mile radius of the rail right-of-way is expected to grow to just over 1.10 million by the year 2010, an increase of nearly 70 percent.

With over 369,000 residents in 1990, nearly 57 percent of the population resided in Sacramento along this corridor. With an expected population of 529,000 by the year 2010, Sacramento's share of the corridor's population should decrease to about 48 percent. The northern terminus at Redding will grow from 66,400 in 1990 to about 147,500 by 2010, representing a population increase of 122 percent.

Service Improvements

Since minimal intercity passenger service exists in this corridor, only the 79-mph and 110-mph service improvement alternatives were studied. Table 2.6.2 presents costs and travel times associated with alternatives.

79-mph Diesel Locomotive Service

Improvements for 79-mph service cost approximately $74 million in the Sacramento-Redding Corridor, averaging about $439,000 per mile. The major costs for the improvement would be new track construction, and grade crossing improvements.

Traveling from Sacramento to Redding with a maximum speed of 79 mph using 3000 horsepower locomotives requires a minimum time of 2 hours 18 minutes for express service. Minimum local service time would be 2 hours 28 minutes, and the skip-stop service would require 2 hours 21 minutes.

Table 2.6.1 Corridor Population Projections
Sacramento to Redding

City	1990	2000	2010	2020	% Change
On Line					
Anderson	8,299	10,791	12,850	16,004	92.84%
Biggs	1,581	1,946	2,301	2,776	75.59%
Chico	40,079	51,738	64,628	82,080	104.80%
Gridley	4,631	5,645	6,609	7,897	70.52%
Lincoln	7,248	11,500	23,800	43,509	500.29%
Live oak	4,320	6,200	8,350	11,615	168.86%
Marysville	12,324	12,728	18,970	23,933	94.19%
Red Bluff	12,363	15,728	18,472	22,597	82.78%
Redding	66,462	100,001	147,542	219,841	230.78%
Roseville	44,685	77,000	101,000	153,261	242.98%
Sacramento	369365	448000	529000	633,133	71.41%
Tehama	401	496	564	670	67.08%
Wheatland	1,631	2,600	4,140	6,596	304.41%
Total (On Line)	573,389	744,373	938,226	1,223,910	113.45%
Within 5 mile Radius					
Yuba City	27,437	38,000	43,200	54,472	98.53%
W.Sacramento	28,898	42,700	71,900	113,654	293.29%
Total (w/in 5 miles)	629,724	825,073	1,053,326	1,392,036	121.05%
Within 10 mile Radius					
Rocklin	19,033	35,000	52,000	86,440	354.16%
Total (w/in 10 miles)	648,757	860,073	1,105,326	1,478,476	127.89%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Butte	183900	228708	267,579	310,921	69.07%
Placer	175600	247,119	312,267	369050	110.17%
Sacramento	1051400	1329062	1579339	1839529	74.96%
Shasta	148800	196754	231,640	267,226	79.59%
Sutter	65100	89885	124095	168600	158.99%
Tehama	50100	63782	72,893	82,950	65.57%
Yolo	142500	192608	237,828	285,883	100.62%
Yuba	58700	76,827	96,481	121,759	107.43%
TOTALS	1,876,100	2,424,745	2,922,122	3,445,918	83.67%

Table 2.6.2 Sacramento-Redding Corridor

	Distance (miles)	Estimated Cost	Travel Times (minutes)			Travel Times - Tilt Train (min.)		
			Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing				183*				
79 mph	169.2	$74,400,000	138	148	140	134	144	136
110 mph	169.2	$211,000,000	110	119	112	104	114	107

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes one stop.
* Sacramento-Redding; Amtrak 1993 Timetable.

Using a 79-mph tilt-train, the route from Sacramento to Redding would require 2 hours 14 minutes for direct service, 2 hours 23 minutes for local service, and 2 hours 16 minutes for skip-stop service. Compared with the standard-body 79-mph trains, tilt-body trains would provide a time advantage of only four minutes.

110-mph Diesel Locomotive Service

Upgrading to 110-mph service would require improvements costing $211 million, an average of $1.24 million per mile. The high standard of the existing rail and absence of curve realignments contribute to the relatively low improvement cost. Major expenditures for this route include right-of-way acquisition, siding construction, 39 interlockings, and 108 grade-crossing improvements.

Except for station stops and speeds restrictions in urban areas, the corridor is mostly free of curve restrictions and can accommodate high speeds throughout the route. The minimum time required to travel from Sacramento to Redding was 1 hour 50 minutes. Local service required 1 hour 59 minutes and skip-stop service required 1 hour 52 minutes.

Because of the linear nature of the alignment, using tilt-trains would not produce a significant travel time savings. With a tilt-train, the minimum travel time from Sacramento to Redding was 1 hour 45 minutes, or a 5-minute improvement over conventional rolling stock. Local service along the route required 1 hour 54 minutes, while skip-stop service required 1 hour 47 minutes.

Summary

The Sacramento-Redding route has no major track curvature or grade problems. However, several factors that limit the corridor's potential should be addressed. First, the considerable volume of freight traffic between Sacramento and Roseville may interfere with future expansions of passenger rail service. Second, while the terrain is relatively flat with few significant curve restrictions, maintenance problems with the low timber trestles and any speed restriction that they may impose need further study. Additionally, flooding, along with the fact that much of the route "sits on fill," may pose potential problems on the route as well.

Taking advantage of the considerable stretches of straight track along the route, the 110-mph alternative produces travel times 26 percent less than the 79-mph alternative. The lack of track curvature makes the value of using tilt-trains questionable for both alternatives. With time savings of generally less than 4 minutes, tilt-trains did not constitute a significant improvement over the standard trainsets.

2.7. Sacramento-Lake Tahoe-Reno Corridor

The Sacramento-Reno corridor roughly approximates the Interstate 80 alignment. The route, generally running northeast from Sacramento, is 139.6 miles in length to the California border and 153.9 miles to Reno, Nevada (see Figure 2.7.1). Only 20 percent of the corridor passes through urban areas, and most of the terrain is mountainous with steep grades and sharp curves. For the different service improvement alternatives, costs projections terminate at the California border, while population and time projections continue to Reno, Nevada.

Existing Conditions

Freight Operations

This route functions as an important trunk line for SP's midwest-bound freight trains. Between four and six daily freight trains move through in each direction.

Passenger Service

Amtrak operates the California Zephyr through the Reno corridor, with one daily train in each direction. In addition, seasonal weekend excursion trains operate between Oakland and Reno. Stations along the route currently in use include Sacramento, Roseville, Colfax, Truckee, and Reno.

Track Conditions and Rights-of-Way

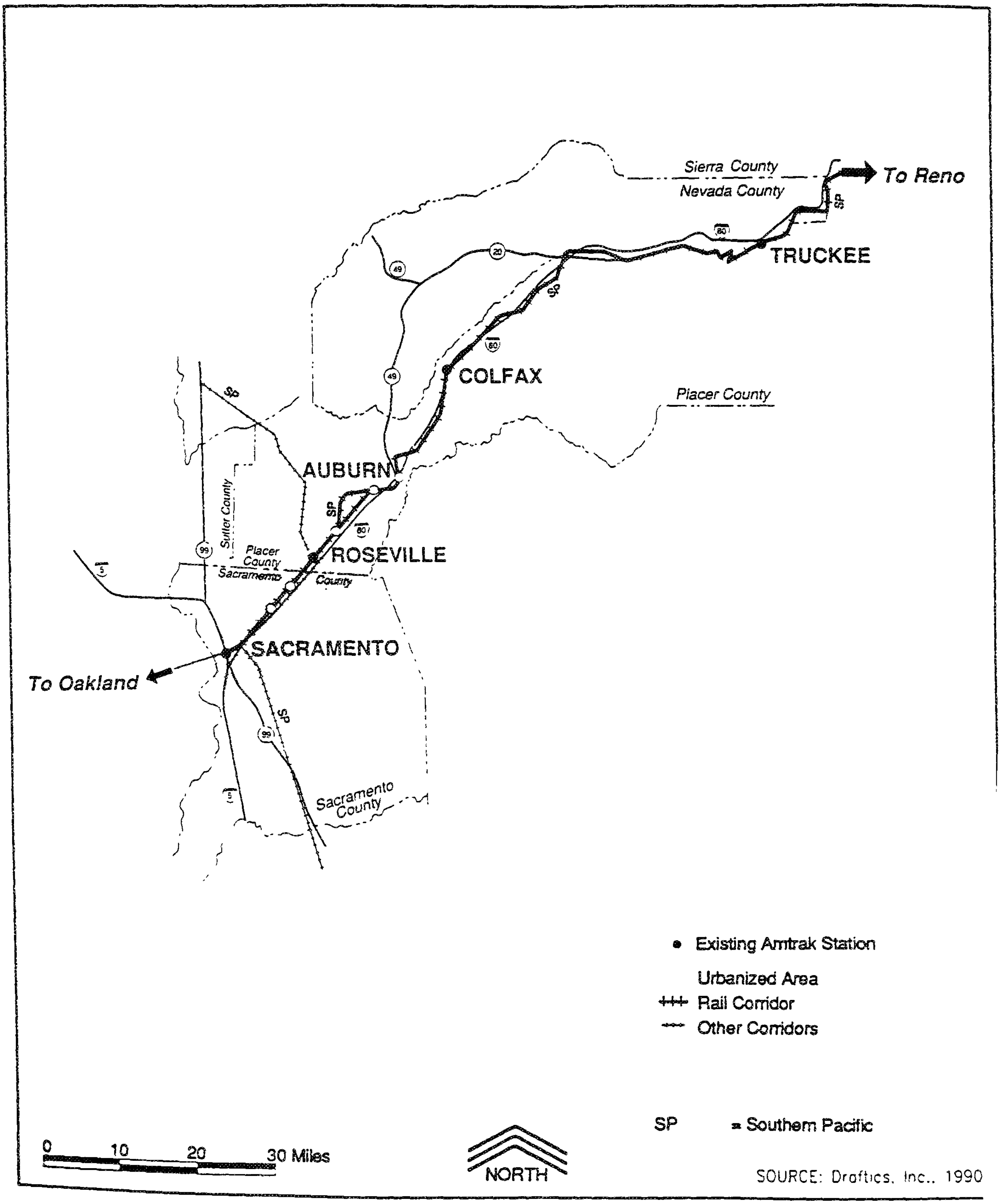
The Reno corridor is a part of SP's 'A' mainline right-of-way. Currently, a single track exists throughout the entire right-of-way. However, nearly all of the right-of-way was until recently double-tracked, utilizing two separate alignments. With the exception of some bolted rail at Roseville Junction, the entire right-of-way consists of 132# or 136# CWR. Nearly all of the track is rated at FRA Class III.

Speed Restrictions

Virtually the entire route is constrained by significant curvature. Curves are generally between 3 and 6 degrees from Sacramento to Auburn. North of Auburn, curvature ranges from 6 to 11 degrees in the more mountainous terrain. In addition to the curve restrictions, the route traverses some relatively steep grades. North of Auburn, the uphill grades are generally in the 1.88-2.43 percent range. Forty-two at-grade crossings intersect the route, 14 of which are located in urban areas. Seven of these at-grade crossings lack automatic gates.

Figure 2.7.1

Sacramento – Lake Tahoe – Reno Corridor



Source: Wilbur Smith, 1990.

Population Projections

Recent and projected populations for the Sacramento-Reno Corridor show a population of 816,000 living in cities within a five-mile radius of the rail rights-of-way, which is expected to grow to more than 1.27 million by the year 2010, an increase of about 56 percent. About 73 percent of the population is expected to be concentrated in the terminus cities of Sacramento and Reno by 2010 (see Table 2.7.1).

Service Improvements

The service improvement scenarios assume completion of the Auburn rail station. Due to the mountainous terrain of the route and the lack of current passenger service for this corridor, only the 79-mph and 110-mph alternatives were considered. Table 2.7.2 presents the results from the cost and travel time analysis of these alternatives.

79-mph Maximum Speed Alternative

The 79-mph upgrade would cost an estimated $65 million, or $466,000 per mile. About a quarter of this cost can be attributed to track upgrades to FRA Class IV. Other major items include 4.1 miles of new track construction, welding jointed rail, and station construction and rehabilitation.

The minimum non-stop travel time between Sacramento and Reno would be 3 hours 42 minutes, for an average speed of 41.5 mph. Local service would require 3 hours 53 minutes, with an average speed of 39.6 mph. Skip-stop service with two intermediate stops would take 3 hours 48 minutes, with an average speed off 40.5 mph.

The travel time along the route can be reduced by 23 percent using tilt-trains. Non-stop service required a minimum travel time of 2 hours 51 minutes at an average speed of 53.9 mph, local service 3 hours 4 minutes, and skip-stop service 2 hours 57 minutes.

110-mph Maximum Speed Alternative

Upgrading the corridor to 110-mph service would require an estimated $163 million. About a third of this cost can be attributed to right-of-way acquisition costs. Other major expenses include track upgrades, station construction, and signal retrofitting. Because of the significant curvature throughout the route, no curve realignments were considered for the 110-mph service alternatives.

Using 4000 HP locomotives, the travel time between Sacramento and Reno would be 3 hours 41 minutes, at an average speed of 41.7 mph. This time represents only a 1-minute reduction over the 79-mph service and can be attributed only to the faster acceleration times for the more powerful locomotives. Local service would take 3 hours 51 minutes at an average speed of 39.9 mph, and skip-stop service would require 3 hours 46 minutes at an average speed of 40.8 mph.

Table 2.7.1 Corridor Population Projections
Sacramento to Reno Corridor

City	1990	2000	2010	2020	% Change
On Line					
Auburn	10,592	13,300	15,500	18,763	77.1%
Rocklin	19,033	35,000	52,000	86,440	354.2%
Roseville	44,685	77,000	101,000	153,261	243.0%
Tahoe/ unincorp plac	86,500	96,450	108,149	121,267	40.2%
Sacramento	369,365	448,000	529,000	633,133	71.4%
Reno*	257,120	317,850	392,924	485,730	88.9%
Total (On Line)	787,295	987,600	1,198,573	1,498,594	90.3%
Within 5 mile Radius					
W.Sacramento	28,898	42,700	71,900	113,654	293.3%
Total (w/in 5 miles)	816,193	1,030,300	1,270,473	1,612,248	97.5%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Placer	175,600	247,119	312,267	369,050	110.2%
Sacramento	1,051,400	1,329,062	1,579,339	1,839,529	75.0%
Washoe	257,120	317,850	392,924	485,730	88.9%
Yolo	142,500	192,608	237,828	285,883	100.6%
TOTAL	1,626,620	2,086,639	2,522,358	2,980,192	83.2%

Table 2.7.2 Service Improvements Summary
Sacramento-Lake Tahoe-Reno Corridor

	Distance to Reno (miles)	Distance to border (miles)	Cost to Border ($million)	Estimated Travel Times to Reno (minutes)			Travel Times to Reno Tilt Train (minutes)		
				Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing					258				
79 mph	153.9	139.6	$65	223	233	228	171	184	177
110 mph	153.9	139.6	$163	221	231	226	171	182	176

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes two stops.

As with the 79-mph trains, use of tilt-trains in the 110-mph scenario yielded about a 23 percent reduction in travel times. The express tilt-train provided a minimum travel time of 2 hours 51 minutes with an average speed of 54.1 mph, virtually identical to the time and speed for the 79-mph trains. Local service required 3 hours 2 minutes at an average speed of 50.8 mph, and skip-stop service required 2 hours 56 minutes with an average speed of 52.5 mph.

Summary

The potential of the Sacramento-Reno route is somewhat limited by its mountainous terrain. Trains operating on this route must travel through winding stretches and ascend steep grades. Although the tracks are already in good condition and double-tracked along nearly the entire route, the curve restrictions represent major obstacles to improving passenger rail service.

Because of the severe track curvature, speeds along most of the route are limited to less than 46 mph. Therefore, the effectiveness of using 4000 HP locomotives is compromised without substantial route realignment at very high costs. For both standard and tilt-body trains, the time advantage of the 110-mph alternative was only 1-2 minutes.

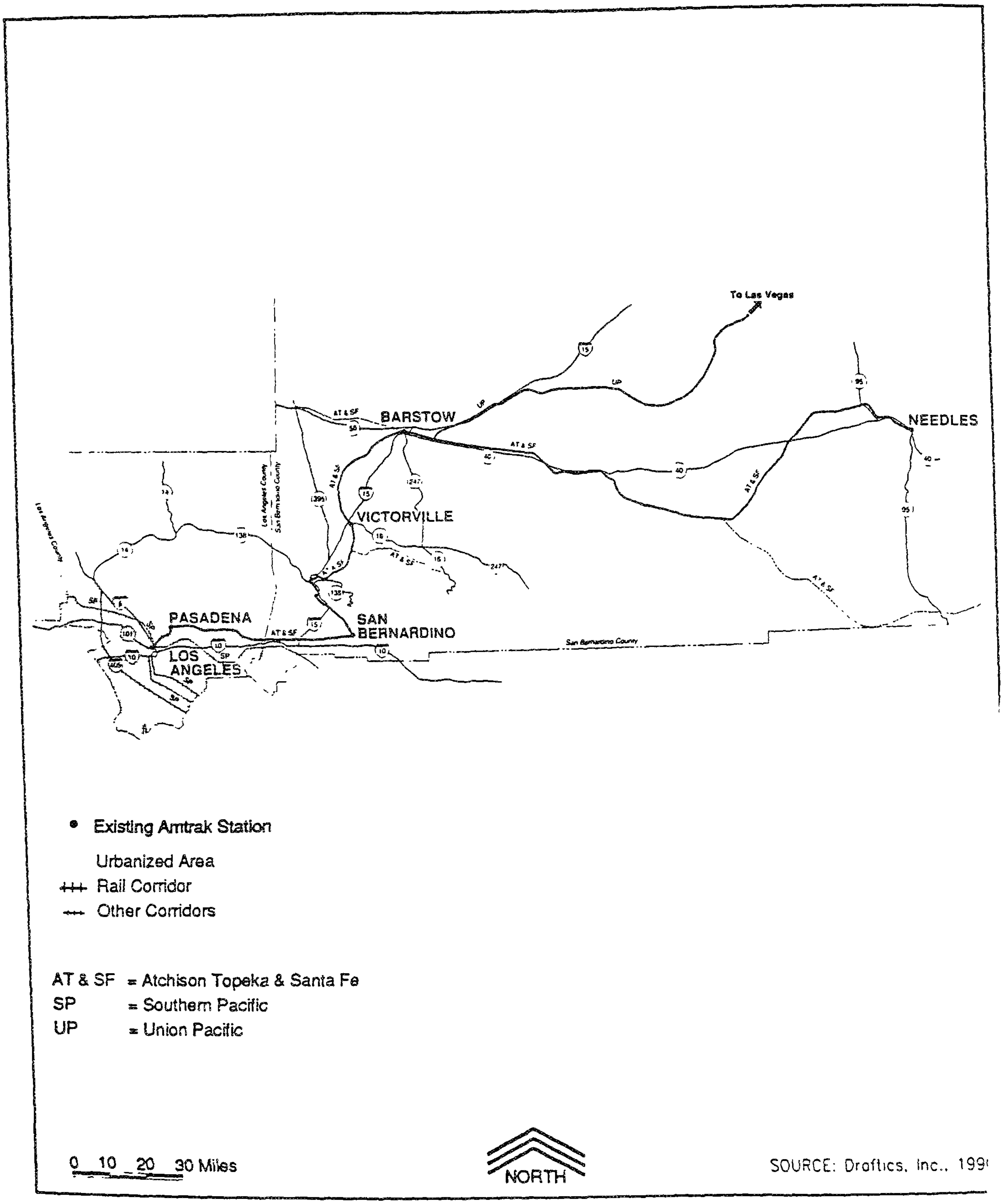
Finally, the severe curvature along most of the route gives a decided advantage to tilting train-sets. With a time advantage of 23 percent over conventional rolling stock, tilt-trains would be a cost-effective alternative to curve straightening or new alignments.

2.8. Los Angeles-Las Vegas Corridor

The California portion of the Los Angeles-Las Vegas route traverses a variety of terrain beginning in the urban areas of Los Angeles and San Bernardino counties and continuing through the California high desert before crossing the state border into Nevada (see Figure 2.8.1). The segment from Los Angeles to the California border measures 291 miles, with 88 miles passing through urban areas. From Los Angeles to San Bernardino, the route roughly parallels the Interstate 10 alignment before turning

Figure 2.8.1

Los Angeles to Las Vegas Corridor



Source: Wilbur Smith, 1990.

northward through the Cajon Pass, then westward again, roughly following the Interstate 15 alignment. Downtown Las Vegas lies about 46.1 miles from the California border, bringing the total length of the Los Angeles-Las Vegas Corridor to 337.1 miles.

For the different service isubstantially provement alternatives, cost projections only include the section from Los Angeles to the California border, while population and time projections include Las Vegas, Nevada.

Existing Conditions

Freight Operations

The corridor carries a high volume of freight volume, particularly between Riverside and Daggett.

Passenger Service and Stations

Existing passenger rail service along the corridor is provided by Amtrak's Desert Wind, which runs from Los Angeles to Salt Lake City, Utah. Current station stops along the corridor include Los Angeles, Fullerton, San Bernardino, Barstow, and Las Vegas. One daily train operates in each direction.

Rights-of-Way and Track Condition

Right-of-way along the corridor follows four separate rail segments owned by two different railroad companies. The Atchison, Topeka and Santa Fe Railway (ATSF) owns the portion of the route from Los Angeles to Barstow (Daggett Junction), while Union Pacific Railroad owns the segment from Daggett to Las Vegas. The first segment of the Desert Corridor follows the LOSSAN corridor from Los Angeles to Fullerton. From Fullerton, the route continues in a northeasterly direction along the ATSF 2B mainline until it reaches the San Bernardino Yard. At this point, the route rejoins the ATSF 2 mainline and turns northward through the Cajon Pass. This segment continues eastward through Barstow to Daggett, where it turns into the Union Pacific 3 mainline and heads northeast towards Las Vegas.

The rail itself is in good condition, with nearly all of the rail along the Los Angeles-Calada segment either 133# or 136#. Signaling for the entire route is by Centralized Traffic Control.

Speed Restrictions

Although the route passes through a wide range of terrain, most of it is free from major curve restrictions. The areas outside of Los Angeles with tight curve limits include the 15-mile segment just south of San Bernardino, the mountainous segment south of Hesperia, the urban right-of-way through Victorville, and the segment just south of Barstow. All of these stretches have curves of at least 5 degrees.

The corridor also contains 87 at-grade crossings, 60 of which are in urban areas. Thirteen of these crossings lack automatic gates, 8 of which are along the Union Pacific right-of-way and only one of which is in an urban area.

Population Projections

Recent and projected populations for the Los Angeles-Las Vegas Corridor are presented on Table 2.8.1. Approximately 6.01 million residents lived in cities within a 5-mile radius of the rail right-of-way in 1990. By the year 2010, this number should increase to 7.99 million, an increase of about 33 percent. Much of the growth in the corridor is projected for the two terminal cities. In fact, of the 1.98 million new residents anticipated by 2010, nearly 70 percent are expected to settle in the city of Los Angeles (846,700) and the Las Vegas metropolitan area (536,000).

Service Improvements

Since minimal intercity passenger service exists in this corridor, only 79-mph and 110-mph service improvement alternatives were studied. Table 2.8.2 presents the results from the cost and travel time analysis of these alternatives.

79-mph Maximum Speed Alternative

Improvements for the 79-mph alternative will cost about $96 million, or $331,000 per mile. The major expenditures in this total include new track construction and other track upgrades, grade crossing improvements, and station construction/rehabilitation.

The minimum travel time for nonstop service between Los Angeles and Las Vegas would be 5 hours 12 minutes. Local service required 5 hours 25 minutes, while skip-stop service would require 5 hours 18 minutes.

Use of tilt-trains could reduce travel times by about 10 percent. The nonstop time using tilt-trains is 4 hours 41 minutes. Times for local and skip-stop service would be 4 hours 54 minutes and 4 hours 48 minutes, respectively.

110-mph Maximum Speed Alternative

Improvements required for 110-mph service would cost an estimated $384 million, or $1.32 million per mile. The major expenditures include right of way acquisition, new track construction, signal improvements, bridge improvements, crossing improvements, and station construction/ rehabilitation.

With 4000 HP locomotives, the 110-mph alternative would have a minimum travel time of 4 hours 41 minutes. The travel times for local and skip-stop service required 4 hours 53 minutes and 4

Table 2.8.1 Corridor Population Projections
Los Angeles to Los Vegas Corridor

City	1990	2000	2010	2020	% Change
On Line					
Barstow	21,472	27,199	33,737	42,291	97.0%
Colton	40,213	49,086	62,408	77,762	93.4%
Corona	76,095	113,278	155,929	223,379	193.6%
Fullerton	114,144	124,997	129,062	137,296	20.3%
Grand Terrace	10,945	12,184	13,424	14,867	35.8%
Hesperia	50,418	72,057	99,576	139,959	177.6%
Las Vegas	880,716	1,117,190	1,417,157	1,797,666	104.1%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.6%
Pico Riviera	59,177	61,900	62,887	64,835	9.6%
Placentia	41,259	48,477	55,003	63,516	53.9%
Riverside	226,505	273,253	330,038	398,389	75.9%
San Bernadino	164,164	194,907	228,264	269,170	64.0%
Victorville	40,674	64,720	88,120	130,098	219.9%
Total (On Line)	5,211,190	6,034,153	7,007,718	8,188,978	57.1%
Within 5 mile Radius					
Bell Gardens	42,355	45,185	47,900	50,939	20.3%
Buena Park	68,784	79,546	83,967	94,606	37.5%
Commerce	12,135	14,063	16,147	18,626	53.5%
Cudahy	22,817	24,090	24,341	25,147	10.2%
Downey	91,444	95,401	102,087	107,873	18.0%
Hunington Park	56,065	64,485	68,562	75,878	35.3%
Maywood	27,851	28,880	30,182	31,420	12.8%
Montebello	59,565	65,004	70,813	77,210	29.6%
Monterey Park	60,738	64,533	68,636	72,962	20.1%
Norco. ,	23,302	27,304	32,243	37,928	62.8%
Norwalk	94,279	99,938	105,757	112,010	18.8%
Rialto	72,388	94,589	126,516	167,269	131.1%
Stanton	30,491	33,844	37,010	40,776	33.7%
Vernon	151	89	89	71	-53.2%
Villa Park	6,304	6,455	6,528	6,643	5.4%
Whittier	77,671	82,280	86,123	90,690	16.8%
Yorba Linda	52,422	66,874	74,725	89,412	70.6%
Total (w/in 5 miles)	6,009,952	6,926,713	7,989,344	9,288,437	54.6%
Within 10 mile Radius					
Adelanto	8,517	27,000	61,000	165,596	1844.3%
Alhambra	82,106	87,865	91,301	96,288	17.3%
Anaheim	266,407	329,946	370,456	437,375	64.2%
Apple Valley	46,079	61,500	90,900	127,838	177.4%
Bellflower	61,815	64,430	67,488	70,517	14.1%
Brea	32,873	37,454	40,871	45,583	38.7%
Cerritos	53,240	55,339	56,213	57,765	8.5%
Cypress	42,655	48,492	50,295	54,671	28.2%
Fontana	87,534	121,343	163,654	223,791	155.7%
Garden Grove	143,050	156,753	162,048	172,546	20.6%
Glendale	180,038	197,492	211,474	229,211	27.3%
Highland	34,439	44,628	62,610	84,486	145.3%
La Habra	51,266	55,692	57,766	61,335	19.6%
La Palma	15,392	16,777	16,535	17,160	11.5%
Loma Linda	17,400	21,772	26,422	32,563	87.1%
Lynwood	61,945	69,147	73,492	80,073	29.3%
Orange	110,684	123,129	129,279	139,775	26.3%
Paramount	47,669	50,826	52,402	54,950	15.3%
South Gate	86,284	89,661	91,643	94,449	9.5%
Total (w/in 10 miles)	7,439,345	8,585,959	9,865,193	11,534,411	55.0%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Clark	880716	1117190	1,417,157	1797665	104.11%
Los Angeles	8897500	10180868	11441900	12916552	45.17%
Orange	2,424,100	2,866,832	3,104,100	3,306,383	36.40%
Riverside	1195400	1775042	2,406,655	3,146,936	163.25%
San Bernadino	1440700	1993762	2,621,482	3,356,444	132.97%
TOTAL	14,838,416	17,933,694	20,991,294	24,523,980	65.27%

Table 2.8.2 Service Improvements Summary
Los Angeles-Las Vegas Corridor

	Distance to Vegas (miles)	Distance to Border (miles)	Cost to Border ($million)	Travel Times (minutes) to Las Vegas			Travel Times - to Las Vegas Tilt Trains (min.)		
				Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing					415				
79 mph	337.1	291	$96	312	325	318	280	294	288
110 mph	337.1	291	$384	281	293	287	241	253	247

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes two stops.

hours 47 minutes respectively. This time represents a 10 percent improvement over the 79-mph service, and is comparable with the 79-mph tilt-trains.

Combined with tilt-body cars, the 110-mph trains could reduce travel times by 14 percent over the non-tilt trains. The travel times for express, local, and skip-stop services would be 4 hours 1 minute, 4 hours 13 minutes, and 4 hours 7 minutes, respectively.

Summary

While only the 79-mph and 110-mph alternatives were studied, the Los Angeles-Las Vegas route may be a good candidate for higher-speed service eventually. The relative lack of speed restrictions between the major cities and the expected concentrations of population in Los Angeles and Las Vegas could support an express service running at high speeds between the termini. However, the high volume of freight operations might present a problem for expanding passenger services in this corridor.

2.9. Los Angeles-Yuma-(Phoenix) Corridor

The Los Angeles-Yuma portion of this corridor crosses just over 250 miles of mostly flat desert terrain in a southeasterly direction. As shown in Figure 2.9.1, the route roughly parallels the westbound Interstate 10 alignment to Indio, where it turns southeast and roughly follows the State Highway 111 alignment to the Salton Sea.

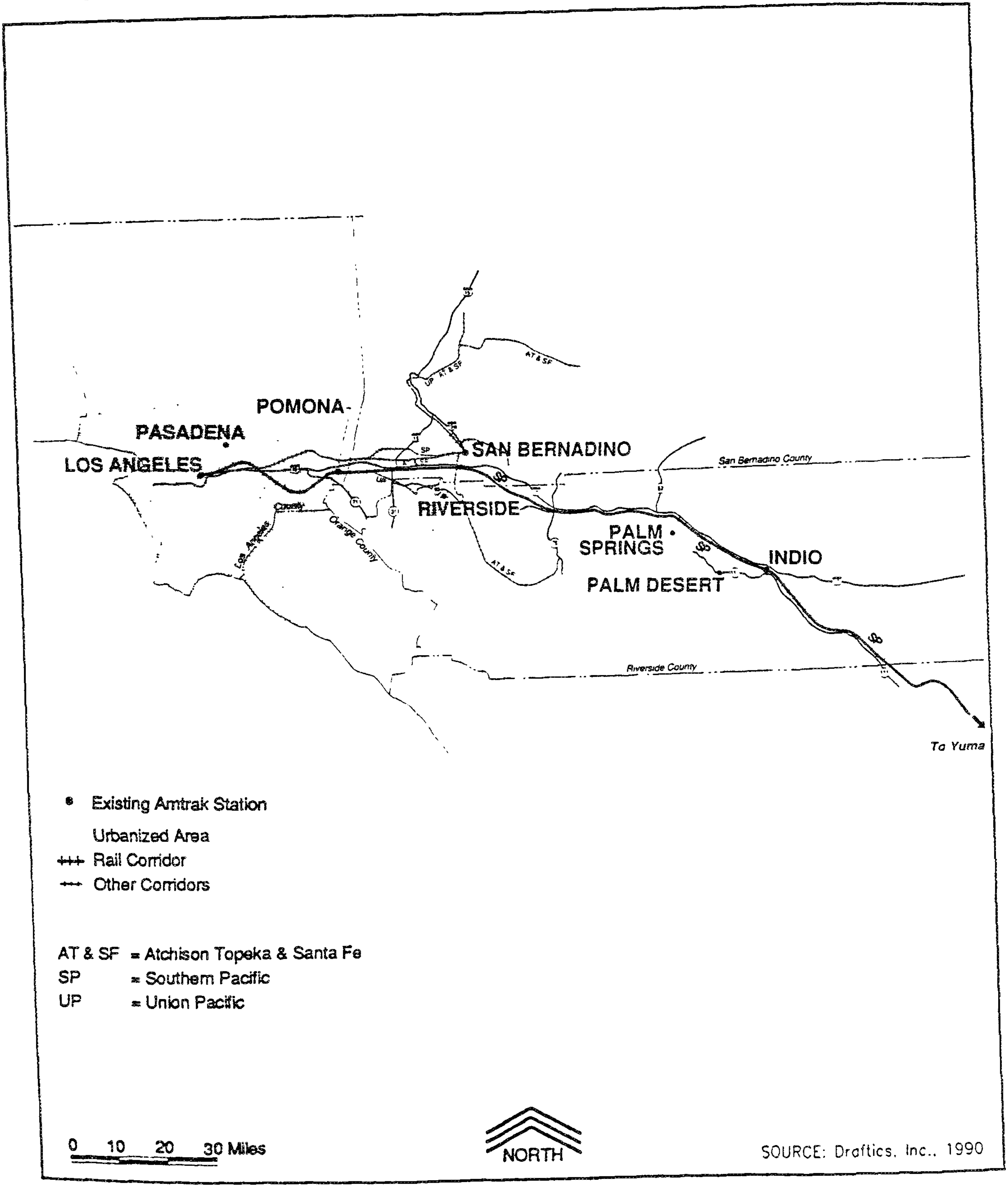
Existing Conditions

Rights-of-Way and Freight Operations

SP owns the entire right-of-way to Yuma, and the route follows the SP "B" mainline alignment. However, with the advent of existing and proposed commuter rail services from San Bernardino and Riverside to Los Angeles, other routes paralleling the SP line could conceivably fall under the ownership

Figure 2.9.1

Los Angeles – Yuma – Phoenix Corridor



Source: Wilbur Smith, 1990.

of local agencies. In addition, SP operates a trunk line for freight operations from this route, which connects the West Coast with Arizona, New Mexico, the Gulf Coast, Kansas City, St. Louis, and Chicago.

Passenger Rail Service and Station Locations

Passenger rail service along the corridor is provided by the Amtrak Sunset Limited, which runs a tri-weekly service in each direction. This train currently makes station stops in Pomona, Indio, and Yuma, with the final terminus in New Orleans.

Track Condition

The trackage consists entirely of CWR, and with the exception of 43 miles of double track, the route is mostly single-tracked. Ongoing tie renewal programs, other maintenance, and a relatively dry climate all contribute to generally good track conditions.

Speed Restrictions

From outside Los Angeles to Ontario, the route is mostly free from major curve restrictions; only near the City of Industry and Walnut do the curve limits approach 2 degrees. Around Colton through Redlands, the curvature increases to about 6 degrees at the limit. With the exception of some 2- and 1.5-degree curves around the Salton Sea, the line has no major curves from West Palm Springs to the California border.

In addition, 94 at-grade crossings intersect the route, with 72 located in urban areas. Only five of the crossings lack automatic gates, two of which are in Coachella with the others located in the rural desert areas.

Population Projections

Recent and projected populations for the Los Angeles-Phoenix Corridor are presented in Table 2.9.1. The population of 7.16 million living in cities within a 5-mile radius of the rail right-of-way is expected to grow to more than 9.79 million by the year 2010, a 37 percent increase. Most of the growth in this corridor is expected to occur in the two terminal cities. Of the 2.63 million new residents anticipated by the year 2010, over 79 percent are expected to settle in the city of Los Angeles (846,700) and the Phoenix metropolitan area (1.23 million).

For the Los Angeles-Yuma portion of the corridor, the 1990 population of 5.03 million is expected to increase to 6.43 million by 2010, an increase of 28 percent. The city of Los Angeles alone is likely to account for 67 percent of the anticipated 2010 corridor population, whereas cities in Los Angeles County should account for 79 percent of the total.

Table 2.9.1 Corridor Population Projections Los Angeles-Phoenix

City	1990	2000	2010	2020	% Change
Alhambra	82,106	87,865	91,301	96,288	17.27%
Banning	20,568	27,884	36,386	48,404	135.34%
Beaumont	9,685	14,555	16,779	22,279	130.04%
Coachella	16,896	23,331	36,263	53,219	214.98%
Colton	40,213	49,086	62,408	77,762	93.38%
El Monte	106,209	116,418	117,657	123,938	16.69%
Indio	36,793	49,456	66,226	88,851	141.49%
La Puente	36,955	39,258	40,701	42,717	15.59%
Loma Linda	17,400	21,772	26,422	32,563	87.14%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.57%
Ontario	133,180	142,751	158,742	173,337	30.15%
Palm Springs	40,181	48,977	64,189	81,183	102.04%
Phoenix Metro*	2,130,400	2,715,100	3,362,685	4,116,200	93.21%
Pomona	131,723	150,104	174,530	200,908	52.52%
Redlands	60,394	72,555	84,976	100,805	66.91%
San Gabriel	37,120	39,654	40,746	42,857	15.46%
Temple City	31,100	34,440	37,831	41,725	34.16%
Walnut	29,105	30,559	31,535	32,826	12.79%
Yuma	54,923	67,189	80,154	94,439	71.95%
Total (On Line)	6,500,359	7,605,859	8,861,644	10,300,051	58.45%
Within 5-mile Radius					
Baldwin Park	69,330	76,542	82,646	90,240	30.16%
Calimesa	4,647	6,900	9,578	13,759	196.07%
Grand Terrace	10,945	12,184	13,424	14,867	35.83%
Montclair	28,434	32,282	38,704	45,173	58.87%
Monterey Park	60,738	64,533	68,636	72,962	20.13%
Rancho Cucamunga	101,414	136,644	182,593	245,008	141.59%
Rialto	72,388	94,589	126,516	167,269	131.07%
Rosemead	51,638	58,416	65,168	73,211	41.78%
San Bernadino	164,164	194,907	228,264	269,170	63.96%
San Marino	12,959	13,131	13,343	13,539	4.48%
South El Monte	20,850	21,820	22,549	23,450	12.47%
Upland	63,375	69,591	79,253	88,641	39.87%
Total (w/in 5 miles)	7,161,241	8,387,398	9,792,318	11,417,341	59.43%

Table 2.9.1 Corridors

Within 10-mile Radius

City	1990	2000	2010	2020	% Change
Arcadia	48,290	51,146	55,797	59,984	24.22%
Cathedral City	30,085	39,173	51,009	66,419	120.77%
Chino	59,662	70,849	78,212	89,609	50.19%
Claremont	32,503	35,063	37,463	40,220	23.74%
Commerce	12,135	14,063	16,147	18,626	53.49%
Covina	43,207	46,499	48,534	51,445	19.07%
Desert Hot Springs	11,668	18,945	22,411	31,450	169.54%
Duarte	20,688	23,755	24287	26,359	27.41%
Highland	34,439	44,628	62,610	84,486	145.32%
Huntington Park	56,065	64,485	68,562	75,878	35.34%
La Habra	51,266	55,692	57,766	61,335	19.64%
La Verne	30,897	35,246	37,468	41,286	33.62%
Maywood	27,851	28,880	30,182	31,420	12.81%
Monrovia	35,761	39,800	44,717	50,004	39.83%
Montebello	59,565	65,004	70,813	77,210	29.62%
Palm Deserts	23,252	29,843	34,932	42,861	84.33%
Pasadena	131,591	141,996	153,116	165,165	25.51%
Riverside	226,505	273,253	330,038	398,389	75.89%
San Dimas	32,398	35,839	37,970	41,115	26.91%
Sierra Madre	10,762	11,225	11,854	12,441	15.60%
West Covina	96,086	100,095	101,682	104,609	8.87%
Whittier	77,671	82,280	86123	90,690	16.76%
Total (w/in 10 miles)	8,313,588	9,695,157	11,254,011	13,078,342	57.31%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Los Angeles	8,897,500	10,180,868	11,441,900	12,916,552	45.17%
Maricopa	2,122,101	2,715,100	3,362,675	4,116,600	93.99%
Orange	2,424,100	2,866,832	3,104,100	3,306,383	36.40%
Riverside	1,195,400	1,775,042	2,406,655	3,146,936	163.25%
San Bernadino	1,440,700	1,993,762	2,621,482	3,356,444	132.97%
Yuma	106,895	133,750	159,550	188,000	75.87%
TOTAL	16,186,696	19,665,354	23,096,362	27,030,915	66.99%

Service Improvements

Since only minimal intercity passenger service exists in this corridor, only the 79-mph and 110-mph service improvement alternatives were considered. For costs and travel times associated with these alternatives, see Table 2.9.2. Both service improvement alternatives assumed a station at West Palm Springs in addition to the existing station locations in Pomona and Indio.

Table 2.9.2 Service Improvements Summary
Los Angeles-Yuma-(Phoenix) Corridor

	Distance to Phoenix (miles)	Distance to Yuma (miles)	Cost to Yuma ($million)	Travel Times (minutes) to Yuma			Travel Times to Yuma Tilt Trains (min.)		
				Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing					262				
79 mph		251	$76	215	225	219	200	210	204
110 mph		251	$348	188	198	192	165	176	169

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes one stop.

79-mph Maximum Speed Diesel Alternative

Though much of the route east of West Palm Springs already supports a 79-mph maximum speed, additional improvements of the route would cost about $76 million, or $303,000 per mile. Due to the high standard of the existing tracks, none of this cost can be attributed to track upgrades. About one-third of the total cost goes towards constructing new passing sidings along the rural stretches. Other major costs include a new station at Palm Springs, a major station upgrade at Union Station, and at-grade crossing improvements.

Using 3000 HP locomotives and standard-body trains, the Los Angeles-Yuma route required a minimum travel time of 3 hours 35 minutes, with an average speed of 70.1 mph. The local and skip-stop services produced travel times of 3 hours 45 minutes and 3 hours 39 minutes, with average speeds of 66.8 mph and 68.9 mph, respectively. Use of a tilting train would decrease the minimum non-stop time from Los Angeles to Yuma by 15 minutes to 3 hours 20 minutes with an average speed of 75.2 mph. Local service times improved by 15 minutes as well using tilt-trains, and the average speed increased to 71.6 mph. The skip-stop service time would decrease to 3 hours 24 minutes, with an average speed of 74 mph.

110-mph Maximum Speed Alternative

Upgrading the Los Angeles-Yuma portion of the corridor to accommodate 110-mph service would cost an estimated $ 348 million, or $ 1.39 million per mile. About a third of this cost can be attributed to right-of-way acquisitions, a third of which runs through more costly urbanized areas. Other major expenses in the total cost include new track construction, signaling upgrades, overhead bridge modifications for newly double-tracked segments, crossing protection improvements, and station upgrades.

A 110-mph non-stop service would require a minimum travel time of 3 hours 8 minutes at an average speed of 80.3 mph. The travel time for local service would be 3 hours 18 minutes, with a 76-mph average speed. Skip-stop trains would take 3 hours 12 minutes and average 78.6 mph.

Using tilt-trains, the non-stop service time would decrease by 23 minutes, and the average speed would increase by 9.9 mph. Local tilt-train service would require 2 hours 56 minutes and average 85.6 mph, while the skip-stop tilt-trains would require 2 hours 49 minutes with an 89.1 mph average speed. About 12 minutes of the time savings for a tilt-train can be attributed to the 50-mile segment between Colton and Beaumont, where curvatures range between 3 and 6 degrees.

Summary

Since more than half of the existing tracks can already support 79-mph speeds, the Los Angeles-Yuma portion of the corridor is a good candidate for upgrade. However, the Los Angeles-Yuma train currently runs only three times per week, and any upgrade plan would need a commitment to a much more frequent service to justify the capital cost. Demand for such a service largely depends upon the continued growth of Los Angeles and Phoenix.

If upgraded, the route is a good candidate for 110-mph service, since most of the route is flat and relatively free of curves. Most of the advantage in using tilt-trains would come during the stretch between Colton and Beaumont, where most of the severe curves are located. If this stretch were straightened, the advantage of using tilt-trains would be considerably reduced.

2.10. San Rafael-Eureka Corridor

The San Rafael-Eureka corridor, roughly approximating the north-south alignment of U.S. Highway 101 and the Eel River, measures about 267 miles (see Figure 2.10.1). Approximately 50 miles of the route passes through urban areas, and the communities along the route in Marin, Sonoma, Mendocino, and Humboldt counties have a combined population of about 1 million. Presently, there is no passenger rail service along the corridor, except for a spur route running east-west between Willits and Fort Bragg. The route requires some right-of-way reacquisition because some parcels south of Ignacio have been converted to other uses.

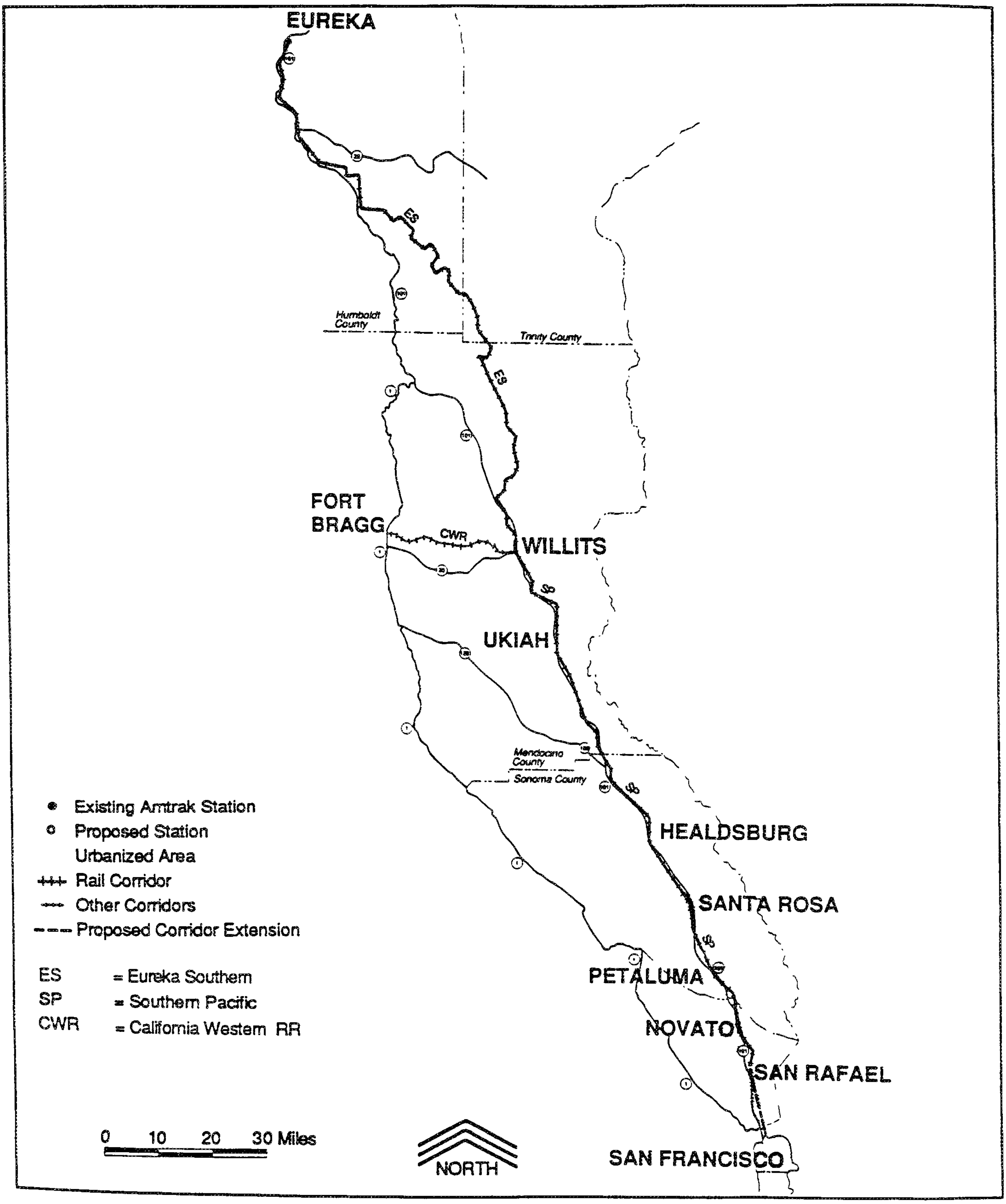
Existing Conditions

Passenger Service

Passenger service between Marin County and Eureka existed between the late 1920s and the early 1970s. Today, passenger service in this corridor is limited to the Eureka Southern Railroad excur-

Figure 2.10.1

San Rafael – Santa Rosa – Eureka Corridor



Source: Wilbur Smith, 1990.

sion trains, which operate on some weekends between Willits and Eureka, and the daily California Western Railroad (Skunk) trains, which intersect the route at Willits and travel west to Fort Bragg.

Freight Operations

One daily freight train travels over most of the route in each direction. Most of this freight traffic comes from the north, and about 30-40 cars move off the line daily.

Rights-of-Way

Two separate right-of-way segments form the San Rafael-Eureka corridor. Southern Pacific Railroad owns most of the right-of-way between San Rafael and Willits, a segment originally operated as the Northwestern Pacific Railroad. However, the Golden Gate Bridge and Highway Department owns a portion of this right-of-way, and public agencies are in the process of buying this entire segment.[27] Between Willits and Eureka, the North Coast Railroad Authority owns the right-of-way.

Originally, the right-of-way extended down into Sausalito, where passengers could connect with San Francisco-bound ferries. The right-of-way between Sausalito and San Rafael currently functions as a bike trail, with most of the rail removed. In addition, the right-of-way between Ignacio and San Rafael is also abandoned, but the track still exists.

Track Conditions

All the rail along the corridor is single-tracked with passing sidings. Rail weights vary throughout the corridor, but only about 34 percent of the rail is 132#-136#. Most of the CWR sections are 132#, and everything north of Willits is either 110# or 113#. Over the entire route, less than 20 percent of the rail sections are CWR, and nearly all of the rail north of Willits is bolted. Most of the line underwent tie renewals between 1968 and 1977, although most of the rail along the line is about 35 years old. North of San Rafael, most of the rail is either FRA Class II or III.

Stations

No rail stations along the corridor are currently used for passenger services. Station buildings used for other railroad-related purposes exist at Petaluma, Ukiah, Willits, and Eureka, with additional station buildings at Fort Seward, Healdsburg, and San Rafael. For time-calculation purposes, proposed passenger rail station locations were located in San Rafael, Ignacio, Petaluma, Santa Rosa, Healdsburg, Cloverdale, Ukiah, Willits, and Eureka.

Speed Restrictions

With the exception of an approximately 10-mile-long stretch north of Santa Rosa, every segment along the route contains significant curve-related speed restrictions. Some segments have relatively minor 2-degree curves. However, most of the route exhibits a curvature of at least 6 degrees, with some segments as high as 15 degrees. Only the 10-mile segment north of Santa Rosa allows for speeds above 80 mph. In addition, the track curvature north of Willits only allows for maximum speeds of 36-46 mph. Except for a 20-mile segment north of Ukiah, grades along the route do not exceed 2 percent.

At-grade crossings intersect the route at 121 locations, the majority of which occur in urban areas. Of these crossings, 21 are fixed signs without automatic gates. Most of these crossings are spaced at least a half-mile apart, except for some crossings located in urban centers that may be as little as a block apart.

Population Projections

Recent and projected populations for the San Rafael-Eureka Corridor are presented in Table 2.10.1. The population of 487,000 living in cities within a 10-mile radius of the rail rights-of-way is expected to grow by 32 percent to just under 642,000 by 2010.

Service Improvements

Because of the mountainous terrain of the route and the current lack of passenger service in this corridor, only the 79-mph and 110-mph alternatives were considered. Table 2.10.2 presents costs and travel times for these alternatives.

79-mph Maximum Speed Diesel Alternative

The improvements required for 79-mph passenger rail service would cost about $ 242 million, or $906,000 per mile. Track and signal improvements and new station construction constitute the bulk of this cost.

With 3000 HP locomotives, the minimum travel time between San Rafael and Eureka would be 6 hours 30 minutes, for an average speed of 41 mph. The local service required 6 hours 51 minutes, with an average speed of 39.0 mph. Minimum travel time for the skip-stop service was 6 hours 40 minutes, for an average speed of 40.1 mph.

For the 79-mph alternative, use of tilting trainsets significantly improved the calculated minimum travel times along the corridor. At 5 hours 17 minutes with an average speed of 50.4 mph, a tilt-train would decrease the expected 79 mph express service time by 1 hour 13 minutes. The local service time of 5 hours 40 minutes (47.1 mph average speed) could be improved by 1 hour 11 minutes. A tilt-train skip-stop service would take 5 hours 27 minutes at an average speed of 48.9 mph.

110-Maximum Speed Diesel Alternative

Costs for improving the 267-mile corridor to allow for 110-mph operations would total $510 million, or $1.91 million per mile. Most of this cost can be attributed to track and signal upgrades and to new station construction. The station construction costs assume that at least two of the existing stations

Table 2.10.1 Corridor Population Projections
San Rafael to Eureka Corridor

City	1990	2000	2010	2020	% Change
On Line					
Cloverdale	6,372	9,500	13,700	20,091	215.30%
Corte Madera	8,490	9,300	9,300	9,744	14.77%
Eureka	27,025	30,775	33,271	36,929	36.65%
Fortuna	8,788	10,944	13,195	16,171	84.01%
Healdsburg	9,924	12,300	15,200	18,811	89.56%
Novato	53,827	61,700	70,400	80,512	49.58%
Petaluma	44,099	55,500	63,900	76,996	74.60%
Rio Dell	3,012	3,416	3,679	4,068	35.06%
Rohnert Park	37,302	42,700	49,800	57,544	54.26%
San Rafael	61,183	70,100	76,400	85,400	39.58%
Santa Rosa	128,683	154,400	179,700	212,379	65.04%
Ukiah	14,599	17,667	21,056	25,288	73.22%
Willits	5,027	6,175	7,477	9,120	81.41%
Total (On Line)	408,331	484,477	557,079	653,052	59.93%
Within 5 mile Radius					
Mill Valley	23,204	23,600	23,900	24,256	4.53%
San Anselmo	13,929	14,000	13,900	13,886	-0.31%
Sausalito	9,741	10,100	10,100	10,286	5.60%
Total (w/in 5 miles)	455,205	532,177	604,979	701,480	54.10%
Within 10 mile Radius					
Belvedere	2,147	2,250	2,250	2,304	7.31%
Fairfax	8,035	8,900	8,800	9,224	14.80%
Ferndale	1,331	1,495	1,595	1,747	31.28%
Sebastapol	8,050	9,000	9,700	10,650	32.29%
Tiburon	12,680	14,500	14,600	15,698	23.80%
Total (w/in 10 miles)	487,448	568,322	641,924	741,103	52.04%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Humboldt	119800	139,744	152,147	164940	37.68%
Marin	231200	248,571	245,454	240010	3.81%
Mendocino	81000	98,224	116,719	136041	67.95%
Sonoma	392000	468,601	534,335	580903	48.19%
TOTAL	824,000	955,140	1,048,655	1,121,894	36.15%

Table 2.10.2 Service Improvements Summary
San Rafael-Eureka Corridor

	Distance (miles)	Est. Cost to Yuma (Smil.)	Travel Times (minutes)			Travel Times Tilt Train (min.)		
			Express	Local	Skip-Stop	Express	Local	Skip-Stop
Existing								
79 mph	267	$242	390	411	400	317	340	328
110 mph	267	$510	388	407	395	310	332	321

Notes: Estimated Costs do not include new rolling stock.
Skip-Stop Service assumes two stops.

currently used for other railroad-related activities require only minor upgrades for passenger rail use. Due to the extensive curvature throughout the route, the cost estimates assumed no curve realignments.

Using 4000 HP diesel locomotives would result in a minimum non-stop travel time between San Rafael and Eureka of 6 hours 28 minutes and an average speed of 41.3 mph. The minimum time for the local service making eight station stops along the line would be 6 hours 47 minutes at an average speed of 39.3 mph, and 6 hours 35 minutes with an average speed of 40.6 mph for a skip-stop service. Although the locomotives and track configuration allow for 110-mph operation, speeds would exceed 80 mph only along one 10-mile segment because of curve restrictions along the rest of the route.

Because of the corridor's curvilinear topography, use of tilt-trains would result in significantly faster travel times. The minimum calculated travel time directly between San Rafael and Eureka was 5 hours 11 minutes at an average speed of 51.5 mph. Use of a tilt-train would pare 1 hour 17 minutes off the express travel time and produced similar, albeit slightly smaller, time savings for the other services. The local service would require 5 hours 32 minutes at an average speed of 48.1 mph. Analysis of skip-stop service yielded a minimum travel time of 5 hours 21 minutes and an average speed of 49.9 mph.

Summary

Implementing passenger rail service along the San Rafael-Eureka route presents a number of challenges. To begin with, no regularly scheduled passenger rail has run on the corridor since the 1970s. In addition to the marketing problem, a portion of the right-of-way in Marin County has already been converted to other uses. Depending on the extent of right-of-way reconstruction required, land reacquisition could add to the already high capital costs. Extension of the right-of-way further south into Sausalito would allow for a connection with San Francisco-bound ferries but would face similar obstacles in the areas of right-of-way acquisition and reconstruction of facilities (including a collapsed tunnel at Corte Madera).

Another major obstacle in this corridor is the topography. In Marin County to Santa Rosa, the curvature is generally limited to 2-6 degrees. However, along the 198-mile segment north of Cloverdale, the curvature varies from 6 to 15 degrees all the way to Eureka. Since curve-straightening of this magnitude is not a practical option and creating an all-new right-of-way would be prohibitively expensive, particularly when considering the relatively small market size, tilt-body rolling stock may offer the best option to address the corridor's physical constraints.

Considering that 79-mph operation can only be achieved along a small portion of the route without substantial re-alignment, upgrading to 110-mph service is not necessary. The 110-mph alternative offers only a 2-minute improvement in the express travel times over the 79-mph alternative. The quicker acceleration of the 110-mph locomotives improves the time margin to four minutes when comparing local service times. However, any potential time advantage offered by the 4000 HP locomotives is limited by the curvature along the route. Using tilt-trains, the express service time for the 79-mph locomotives would be only 6 minutes slower than the 110-mph tilt-train express time.

3. NEW HIGH-SPEED RAIL CORRIDORS

This chapter presents and compares two new high-speed rail alignments connecting downtown Los Angeles and downtown San Francisco. The Los Angeles Metropolitan Region, with a 1990 Census population of 14.5 million, and the San Francisco Bay Area, with 6.3 million, make up the state's major travel markets. These two metropolitan areas, some 380 miles apart by the most direct line, offer one of the strongest potential markets for high-speed rail in the United States.

In planning a new high-speed corridor between Los Angeles and Bay Area, the fundamental choice is between an alignment through the Central Valley and a coastal route via the Salinas Valley. These routes are the only two viable alternatives for sustained high-speed operation between the state's major metropolitan regions.

Preferred alignments have been determined for both of these alternatives. Each assumes the same two terminal stations at the Transbay Terminal in downtown San Francisco (via a Peninsula route serving San Jose), and Union Station in downtown Los Angeles. The following sections describe both routes and their respective attributes, followed by a comparison of the two routes.

3.1. Los Angeles-San Francisco: The Central Valley Route

Much of the previous CalSpeed work focused on a new high-speed corridor from San Francisco/Sacramento to Los Angeles via the Central Valley. A substantial portion of "High-Speed Trains For California" (Hall, 1992) was devoted to determining a preferred alignment for this alternative. Subsequently, "Ridership and Revenue Potential for a High-Speed Rail Service in the San Francisco/Sacramento-Los Angeles Corridor" (Leavitt, Vaca, and Hall, 1994) prepared an initial set of demand forecasts and revenue projections for high-speed rail service through this corridor. This section relies heavily on findings from these previous works.

With an average width of about 50 miles, mostly flat and sparsely populated, the Central Valley offers many possibilities for new high-speed corridors. Realistically, however, only two alternatives through the valley deserve serious consideration: an alignment paralleling the I-5 corridor, which would minimize travel time between the two major markets, and an alignment approximating the Route 99 corridor, which would best serve the major Central Valley population centers.

More than 1.5 million people currently reside in this portion of the Central Valley, and this figure is expected to rapidly increase over the next 20 years. Nearly all of this population is concentrated along the Route 99 corridor and would not be served with an I-5 alignment. This portion of the state is not well served by air transportation and often has winter weather conditions (severe fog) which make air or automobile travel dangerous. Assuming no speed restrictions, travel time from Los Angeles to San Francisco with a route paralleling Route 99 would require only about six minutes more than the I-5 alternative. Thus, the preferred alternative is a new alignment a few miles west of Route 99 which avoids all urban areas yet allows for frequent service to the major Central Valley population centers.

The crossing of the Tehachapi Mountains between Bakersfield and the Los Angeles Metropolitan Region presents the most difficult engineering problem in creating a high-speed rail link between northern and southern California via the Central Valley. In *High-Speed Trains For California*, two alternatives were determined to warrant further study: a Grapevine alternative just east of the I-5 alignment and a Palmdale alternative which runs through Antelope Valley and Soledad Canyon.

Although the Grapevine alternative is nearly 30 miles shorter than the Palmdale route, travel times are expected to be only about 5 minutes less, due to speed restrictions through the Newhall/Santa Clarita urban area. Moreover, since this route traverses more difficult terrain, the Palmdale alternative would cost about the same or less than the Grapevine route.

The Palmdale route was chosen for this study, primarily because it better serves the dispersed population of the Los Angeles Metropolitan Region. The Southern California Association of Governments (SCAG) projects that the Palmdale/Lancaster area population (currently at about 241,000) will increase to nearly 655,000 by the year 2010. Furthermore, this alternative also serves the Santa Clarita/Newhall population (currently at 151,000) which SCAG projects will increase to 540,000 by 2010.[28]

Alignment

The proposed 426-mile Central Valley Route Alternative begins at Union Station in downtown Los Angeles (see Figure 3.1.1). After running on reconstructed SP right-of-way north to the San Fernando Pass, the line veers east, beginning the new corridor segment of this route. The new corridor follows the Soledad Canyon to Palmdale, where it heads north through Antelope Valley and the Tehachapi mountains to the Central Valley. Reaching the Central Valley, the new corridor continues north, west of Route 99, serving Bakersfield and Fresno on new right-of-way just to the west of these cities. Northwest of Fresno, near Los Banos, the new corridor splits, with one branch going to the San Francisco Bay Area and the other to Sacramento.

To the Bay Area, the new corridor traverses the Pacheco Pass west to Gilroy at the southern end of the Santa Clara Valley, where the new corridor segment of this alternative terminates. From Gilroy, the US101 median strip brings the alignment north to San Jose. The corridor then uses SP (CalTrain) right-of-way up the peninsula to San Francisco, terminating in downtown San Francisco at a new Transbay Terminal.

The branch to Sacramento continues from Los Banos with a new corridor north through the Central Valley to Sacramento. The branch follows the SP right-of-way through Sacramento to the downtown terminal at the Sacramento Amtrak Station.

Los Angeles - San Francisco/Sacramento
HSR Mainline and Station Locations

CENTRAL VALLEY ROUTE

Stations

Fourteen station locations were identified along the Central Valley Route Alternative. Figure 3.1.1 schematically illustrates these stations. A list of the stations and descriptions of their likely locations follows:

1. Los Angeles Downtown Station: The southern terminus would be located at Union Station in downtown Los Angeles. This implies major reconfiguration of Union Station's general layout in order to accommodate the tremendous increase in both train and passenger activity at this location. In addition to serving as the southern high-speed rail terminus, Union Station would also be 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[29] suburban station in the Santa Clarita/Newhall area, adjacent to Highway 14.
4. Palmdale Station: An outlying 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 loop line connecting to the new corridor would serve downtown Fresno via SP 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 US101 and Route 152 located in the median of US101.
8. San Jose Downtown Station: An urban station would be constructed on the Caltrain San Jose station site (Cahill) to serve as the hub of rail services in the San Jose region. The San Jose station would connect high-speed rail, Caltrain, and future light rail services.
9. Palo Alto Station: The Caltrain Station at Palo Alto would be reconstructed to accommodate high-speed rail service at this location.
10. San Francisco International Airport Station: A new suburban station to be built near the airport terminal. This station should be incorporated into plans bring future BART service to the airport terminal. Ideally, a people mover would connect these three modes.
11. San Francisco Downtown Station: A new Transbay Terminal would replace the existing facility. This terminal would serve both the high-speed rail and Caltrain services and would connect to the existing Montgomery Street BART/Muni station. The downtown San Francisco station would be the Bay Area high-speed rail terminus.
12. Modesto Station: An outlying station just north of Modesto near Route 99.
13. Stockton Station: An outlying station just west of Stockton near Highway 26.
14. Sacramento Downtown Station: The existing Amtrak station in Downtown Sacramento would be reconfigured to serve as the terminal station of the Sacramento extension of the Central Valley Route Alternative. A future light rail extension would ultimately provide a direct connection at this facility to the existing Sacramento LRT system.

Population Projections

Population projections for the Central Valley Route Alternative between Los Angeles and San Francisco show that about 8.29 million residents lived in cities within a 10-mile radius of the rail right-of-way in 1990, and this figure should grow to over 11.27 million by 2010 (see Table 3.1.1). This represents an increase in population of about 36 percent over this 20-year period. Considering all the counties directly served by the Central Valley Route, the total 1990 population of 13.9 million will increase to 18.6 million (a 34 percent increase) by 2010.[30]

A substantial portion of the expected growth will occur in the Central and Antelope valleys. Of the 2.98 million new residents expected to live in cities within 10 miles of the rail line by 2010, about 1.25 million (42 percent) will be located in these valleys. Thus, the population in these regions should increase from 1.28 million (1990) to 2.54 million by 2010, which represents a 98 percent increase. In the Central Valley alone, this high-speed rail alternative would serve over 836,000 new residents.

Nevertheless, like the Los Angeles-Oakland existing rail alternative through the Central Valley, a great portion of the increase in population for this new corridor will occur in the Los Angeles metropolitan region. Cities in the Los Angeles Basin within 10 miles of the rail line are expected to add more than 950,000 residents between 1990 and 2010.

The extension to Sacramento substantially expands the projected population served under this alternative. In 1990, 927,000 residents lived in cities within 10 miles of the proposed route from just north of Los Banos to Sacramento. Tremendous growth is expected in this section of the valley, and by 2010, the population should increase to nearly 1.46 million. The total population of Stanislaus, San Joaquin, and Sacramento Counties, about 2.09 million in 1990, should increase to nearly 3.34 million by the year 2010 (see Table 3.1.2).

Cost

The estimated cost for the Central Valley Route Alternative from Los Angeles to San Francisco is $9.6 billion. This cost includes $230 million for a 26-mile loop to directly serve downtown Fresno from the high-speed mainline. A 111-mile extension to Sacramento would cost an additional $1.2 billion. Table 3.1.3 summarizes the various segments of this alignment.

As expected, capital costs are high through the urban segments and mountain passes, averaging $30 to $46 million per mile. Crossing the Tehachapi and San Gabriel mountains between Bakersfield and Los Angeles requires 13 miles of standard bore tunneling and 4.5 miles of viaduct, assuming a 3.5 percent maximum gradient. Crossing the Pacheco Pass in Northern California requires 6.4 miles of tunneling and 3.4 miles of viaduct. While the cost per mile through the flat, rural Central Valley is less than $10 million, the average cost for the Los Angeles-San Francisco portion of this alternative is $22.4 per mile.

Table 3.1.1 Corridor Population Projections
New Los Angeles to San Francisco Corridor

City	1990	2000	2010	2020	% Change
On Line					
Belmont	24,641	25,700	25,500	25,949	5.31%
Burbank	93,643	107,462	120,518	136,732	46.01%
Burlingame	26,701	28,000	28,300	29,140	9.13%
Delano	22,762	32,052	41,204	55,495	143.81%
Gilroy	36,831	49,400	67,400	91,180	147.56%
Glendale	180,038	197,492	211,474	229,211	27.31%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.57%
Menlo Park	33,447	35,200	35,300	36,275	8.46%
Milbrea	20,476	21,300	21,300	21,729	6.12%
Morgan Hill	31,234	36,200	47,300	58,312	86.69%
Mountain View	70,089	76,700	79,600	84,859	21.07%
Palo Alto	73,309	75,900	79,100	82,165	12.08%
Redwood City	88,035	103,900	107,200	118,562	34.68%
S. San francisco	54,337	58,000	58,900	61,342	12.89%
San Bruno	38,665	40,300	40,400	41,304	6.83%
San Carlos	27,619	29,300	29,700	30,807	11.54%
San Fernando	22,580	23,592	24,414	25,386	12.43%
San Francisco	723,959	766,100	778,900	808,076	11.62%
San Jose	825,411	952,500	1,024,300	1,141,762	38.33%
San Mateo	89,971	98,200	99,900	105,333	17.07%
Santa Clara	93,333	107,300	116,500	130,211	39.51%
Total (On Line)	6,062,489	6,739,503	7,369,323	8,143,580	34 33%
Within 5 mile Radius					
Don Palasos	4,196	5,525	7,231	9,492	126.21%
East Palo Alto	23,286	29,300	30,500	35,063	50.58%
Fowler	3,208	4,340	5,573	7,348	129.04%
Fresno	482,000	676,500	885,000	1,137,000	135.89%
Hillsborough	10715	10800	10,800	10,843	1 19%
Kingsburg	7,205	10,052	13,302	18,081	150 95%
Los Altos	28,927	28,600	29,100	29,190	0.91%
McFarland	7,005	9,934	12,860	17,442	148.99%
Newhall/Santa Clarita	151,051	313,883	483,229	633,229	319.22%
Palmdale	240,562	440,891	654,743	854,793	255.33%
Selma	14,757	20,729	27,635	37,829	156.35%
Sunnyvale	117,254	128,800	134,700	144,417	23.17%
Tulare	33,249	44,980	58,355	77,325	132 56%
Total (w/in 5 miles)	7,185,904	8,463,837	9,722,350	11,155,632	55 24%
Within 10 mile Radius					
Alhambra	82,106	87,865	91,301	96,288	17.27%
Bakersfield	329,106	465,022	567,314	654,972	99.02%
Campbell	38,169	40,100	41,400	43,118	12.97%
Cupertino	46,911	51,200	53,000	56,354	20 13%
Daly City	96,653	103,800	105,000	109,489	13.28%
Greenfield	7,464	9,621	12,927	17,017	127.99%
Hunington Park	56,065	64,485	68,562	75,878	35.34%
Los Banos	14519	19,000	24,716	32,247	122.10%
Los Gatos	30,941	32,000	33,100	34,235	10.65%
Madera	29,281	42,653	55,374	76,276	160.50%
Milpitas	50,769	61,900	63,100	70,629	39 12%
Montebello	59,565	65,004	70,813	77,210	29.62%
Monteray Park	60,738	64,533	68,636	72,962	20.13%
Pacifica	37,670	39,700	40,700	42,309	12.32%
Saratoga	28,530	29,300	30,300	31,226	9 45%
Shafter	8,409	11,844	15,229	20,515	143 97%
Vernon	151	89	89	71	-53 16%
Visalia	75,636	106,870	146,869	204,678	170.61%
Wasco	12,412	17,386	22,240	29,801	140.10%
West Hollywood	36,118	37,073	39,313	41,020	13 57%
Total (w/in 10 miles)	8,287,117	9,813,282	11,272,333	12,941,929	56 17%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Fresno	673900	945908	1,237,432	1589665	135.89%
Kern	549800	801991	1,037,673	1310050	138.28%
Los Angeles	8897500	10180868	11441900	12916552	45.17%
Madera	89800	133976	171,802	214,097	138.42%
Merced	180600	238985	313,616	401,947	122.56%
Monterey	358800	414014	485,297	574082	60 00%
San Francisco	723900	774011	781735	777391	7.39%
San Mateo	652100	740370	787291	825627	26.61%
Santa Clara	1502200	1703936	1839696	1958603	30 38%
Tulare	314600	417314	521,231	644357	104 82%
TOTAL	13,943,200	16,351,373	18,617,673	21,212,371	52.13%

Table 3.1.2 Corridor Population Projections
New Sacramento Extension

City	1990	2000	2010	2020	% Change
On Line					
Sacramento	369,365	448,000	529,000	633,133	71.41%
Total (On Line)	369,365	448,000	529,000	633,133	71.41%
Within 5 mile Radius					
Gustine	3,931	5,069	6,507	8,371	112.96%
Lodi	51,874	67,394	86,239	111,197	114.36%
Manteca	40,773	56,722	79,289	110,568	171.18%
Modesto	164,730	239,000	320,000	446,363	170.97%
Newman	4,151	5,635	7,303	9,689	133.42%
Ripon	7,455	10,369	14,492	20,205	171.02%
Total (w/in 5 miles)	642,279	832,189	1,042,829	1,339,526	108.56%
Within 10 mile Radius					
Lathrop	6,841	8,771	11,067	14,076	105.76%
Pattersons	8,626	12,623	17,939	25,872	199.93%
Stockton	269,644	335,000	385,000	460,389	70.74%
Total (w/in 10 miles)	927,390	1,188,583	1,456,834	1,839,864	98.39%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Merced	180,600	238,985	313,616	401,947	122.56%
Sacramento	1,051,400	1,329,062	1,579,339	1,839,529	74.96%
San Juaquin	483,800	620,322	778,404	956,456	97.70%
Stanislaus	376,100	517,618	670,009	840,191	123.40%
TOTAL	2,091,900	2,705,987	3,341,368	4,038,123	93.04%

Table 3.1.3 CENTRAL VALLEY ROUTE ALTERNATIVE:
San Francisco-Los Angeles: Summary High-Speed Corridor

	Distance (miles)	Cost	Cost Per Mile	Travel Time (minutes)
Los Angeles Basin	24.5	$742,000,000	$30,300,000	17.2
Tehachapi Mnt. via Palmdale	86	$2,760,000,000	$32,100,000	27.6
Central Valley *	205	$2,010,000,000	$9,800,000	61.5
Pacheco Pass - Gilroy	34	$1,590,000,000	$46,800,000	10.3
Gilroy - San Jose	29	$531,000,000	$18,300,000	18
San Jose - San Francisco	49	$1,964,000,000	$40,100,000	38.5
TOTALS: LA-SF	427.5	$9,597,000,000	$22,400,000	173.1
Sacramento Extension	110.5	$1,194,000,000	$10,800,000	37.2
TOTALS: LA-SAC	426.0			143.5

*Includes cost for 26-mile Fresno Loop.

Travel Times

Travel times for selected city-pairs are shown on Table 3.1.4. The one-stop express service between Los Angeles and San Francisco would take 2 hours 53 minutes, averaging 149 mph. Skip-stop service, stopping at Burbank, Bakersfield, Fresno, and San Jose, would take 3 hours 19 minutes for the Los Angeles-San Francisco trip, averaging 130 mph. Stopping at all nine stations, the local service would take 3 hours 42 minutes, averaging 116 mph.

High average speeds for the express service, and skip-stop services are possible because of the 318-mile new corridor segment from the edge of the Los Angeles to the edge of the Santa Clara Valley at Gilroy. This high-speed segment, without speed restriction, represents nearly 75 percent of the total route.

3.2. Los Angeles-San Francisco: The Coastal Route

A more coastal rail corridor using a new alignment that generally approximates the US101 corridor through the Salinas, Nipomo, and Santa Maria valleys presents an alternative to the Central Valley route. Unlike the Central Valley, these valleys are relatively narrow (generally less than 10 miles wide) and offer limited alignment choices.

Alignment

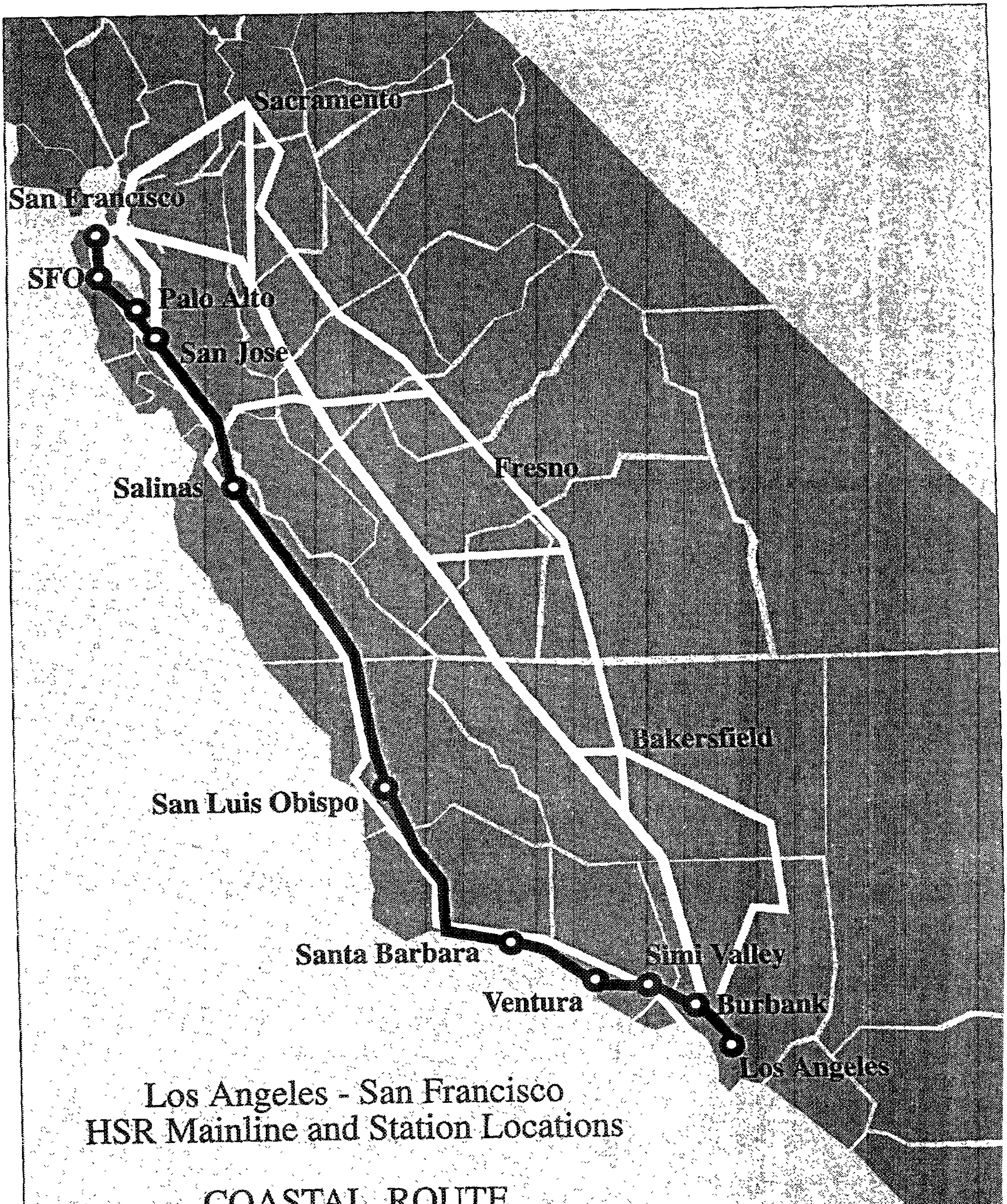
The proposed 415-mile Coastal Route Alternative begins at Union Station in downtown Los Angeles (see Figure 3.2.1). SP right-of-way (used for Amtrak's "Coast Starlight" service) is utilized for over 100 miles, from Los Angeles past Santa Barbara to Goleta. The new high-speed corridor begins at the point where US101 heads north through the Santa Ynez Mountains, passing through these mountains and the Purisima Hills to the Santa Maria Valley. Continuing north, the new corridor bypasses

Table 3.1.4

Los Angeles - San Francisco, High-Speed Corridor

Central Valley Route Alternative

SELECTED TRAVEL TIMES	No. of Stops	Distance (miles)	Time (min.)	Average Speed
Express				
Los Angeles - San Francisco	1	427.9	173.1	148
Los Angeles - San Jose	0	380.7	133.0	172
Skip-Stop				
Los Angeles - Bakersfield	1	136.2	57.9	141
Los Angeles - Fresno	2	244.2	100.0	147
Los Angeles - San Jose	3	380.7	156.8	146
Los Angeles - San Francisco	4	427.9	196.8	130
Burbank - Bakersfield	0	123.2	45.7	162
Burbank - Fresno	1	231.2	87.7	158
Burbank - San Jose	2	367.7	144.5	153
Burbank - San Francisco	3	414.9	184.5	135
Bakersfield - San Jose	1	244.5	97.3	151
Bakersfield - San Francisco	2	291.7	137.4	127
Fresno - San Jose	0	136.5	55.3	148
Fresno - San Francisco	1	183.7	95.3	116
San Jose - San Francisco	0	47.2	38.5	74
Local				
Los Angeles - Bakersfield	3	136.2	70.8	115
Los Angeles - Palmdale	2	56.5	39.0	87
Los Angeles - Fresno	4	244.2	112.8	130
Los Angeles - Palo Alto	7	397.4	191.2	125
Los Angeles - SFO	8	416	206.3	121
Los Angeles - San Francisco	9	427.9	221.8	116
Burbank - Bakersfield	2	123.2	58.5	126
Burbank - Fresno	3	231.2	100.6	138
Santa Clarita - Fresno	2	216.8	88.3	147
Santa Clarita - San Jose	4	353.3	150.5	141
Santa Clarita - San Francisco	7	400.5	197.3	122
Palmdale - Bakersfield	0	79.7	30.2	158
Palmdale - Fresno	1	187.7	72.3	156
Palmdale - San Jose	3	324.2	134.5	145
Palmdale - San Francisco	6	371.4	181.3	123
Bakersfield - Fresno	0	108	40.6	160
Bakersfield - San Jose	2	244.5	102.8	143
Bakersfield - SFO	4	279.8	134.0	125
Bakersfield - San Francisco	5	291.7	149.6	117
Fresno - San Jose	1	136.5	60.7	135
Fresno - SFO	3	171.8	92.0	112
Fresno - San Francisco	4	183.7	107.5	103



Los Angeles - San Francisco
HSR Mainline and Station Locations

COASTAL ROUTE

Santa Maria to the east. Past Santa Maria to the Nipomo Valley, the alignment lies a few miles east of US101. Continuing north, following the general alignment of existing powerlines, the route bypasses Nipomo, Arroyo Grande/Grover City, and San Luis Obispo, reaching the Santa Lucia Range, closely approximating US101. Thereafter, for over 100 miles to Salinas, the HSR alignment is a few miles west of US101, avoiding all towns. From Salinas, existing powerline right-of-way is followed through the Gabilan Range to the Santa Clara Valley. From Gilroy, the US101 median strip brings the alignment north to San Jose. SP (CalTrain) right-of-way is followed up the peninsula to San Francisco, where the Coastal Route Alternative terminates in downtown San Francisco at a new Transbay Terminal.

Stations

Eleven station locations were identified along the Coastal Route Alternative. Figure 3.2.1 schematically illustrates these stations. Following is a list of the stations and description of their likely locations:

1. Los Angeles Downtown Station: Same as the Central Valley Route Alternative.
2. Burbank Station: An urban station to be constructed along Southern Pacific right-of-way near the Burbank International Airport.
3. Simi Valley Station: A suburban station to be constructed along the SP right-of-way at the existing Amtrak Simi Valley station site.
4. Ventura Station: A suburban station to be constructed along the SP right-of-way at the existing Amtrak Ventura station site.
5. Santa Barbara Station: An urban station to be constructed along the SP right-of-way near the existing Amtrak Santa Barbara station site.
6. San Luis Obispo Station: An outlying station southeast of San Luis Obispo serving the cities of San Luis Obispo County
7. Salinas Station: An outlying station just east of Salinas, located at Williams Road.
8. San Jose Downtown Station: Same as the Central Valley Route Alternative.
9. Palo Alto Station: Same as the Central Valley Route Alternative.
10. San Francisco International Airport Station: Same as the Central Valley Route Alternative.
11. San Francisco Downtown Station: Same as the Central Valley Route Alternative.

Population Projections

Population projections for the Coastal Route Alternative between Los Angeles and San Francisco are presented with Table 3.2.1. In 1990, there were about 7.88 million residents living in cities within a ten-mile radius of the new rail right-of-way. By 2010, this figure is expected to grow to about 9.65 million, an increase of 22 percent. Regarding counties directly served by the Coastal Route, the total 1990 population of 13.4 million should escalate to 17.1 million (28 percent increase) by the year 2010.

Table 3.2.1 Corridor Population Projections
New Coastal Route Corridor

City	1990	2000	2010	2020	% Change
On Line					
Belmont	24,641	25,700	25,500	25,949	5.31%
Burbank	93,643	107,462	120,518	136,732	46.01%
Burlingame	26,701	28,000	28,300	29,140	9.13%
Camarillo	52,303	61,500	69,500	80,131	53.20%
Carpinteria	13,747	16,945	20,293	24,659	79.38%
Gilroy	36,831	49,400	67,400	91,180	147.56%
Glendale	180,038	197,492	211,474	229,211	27.31%
Los Angeles	3,485,408	3,874,905	4,332,113	4,829,749	38.57%
Menlo Park	33,447	35,200	35,300	36,275	8.46%
Milbrae	20,476	21,300	21,300	21,729	6.12%
Moorpark	25,494	38,500	52,000	74,381	191.76%
Morgan Hill	31,234	36,200	47,300	58,312	86.69%
Mountain View	70,089	76,700	79,600	84,859	21.07%
Oxnard	142,217	154,621	167,027	181,012	27.28%
Palo Alto	73,309	75,900	79,100	82,165	12.08%
Redwood City	88,035	103,900	107,200	118,562	34.68%
S San francisco	54,337	58,000	58,900	61,342	12.89%
San Bruno	38,665	40,300	40,400	41,304	6.83%
San Carlos	27,619	29,300	29,700	30,807	11.54%
San Francisco	723,959	766,100	778,900	808,076	11.62%
San Jose	825,411	952,500	1,024,300	1,141,762	38.33%
San Juan Buatista	1570	2,069	2,646	3,435	118.82%
San Mateo	89,971	98,200	99,900	105,333	17.07%
Santa Barbara	85,571	93,276	100,415	108,778	27 12%
Santa Clara	93,333	107,300	116,500	130,211	39.51%
Simi Valley	100,219	119,200	137,000	160,203	59 85%
Sunnyvale	117,254	128,800	134,700	144,417	23.17%
Uninc. Santa Barbara	87,676	93,936	101,252	108,810	24.10%
Ventura	92,575	104,558	115,758	129,450	39 83%
Total (On Line)	6,735,773	7,497,264	8,204,296	9,077,973	34 77%
Within 5 mile Radius					
Atascadero	23138	29,494	37,294	47,348	104.63%
East Palo Alto	23,286	29,300	30,500	35,063	50 58%
Gonzales	4660	5950	6510	7,717	65.61%
Hillsborough	10715	10800	10,800	10,843	1.19%
Los Altos	28,927	28,600	29,100	29,190	0.91%
Paso Robles	18583	24,393	32,176	42,339	127.84%
San Luis Obispo	41958	50,567	59,680	71,180	69.65%
Santa Maria	61284	75,046	89,089	107,427	75.29%
Soledad	7146	20380	22200	43,748	512.20%
Solvang	4741	5,563	6,273	7,218	52.24%
Vernon	151	89	89	71	-53 16%
Total (w/in 5 miles)	6,960,362	7,777,446	8,528,008	9,480,117	36.20%
Within 10 mile Radius					
Alhambra	82,106	87,865	91,301	96,288	17.27%
Arroyo Grande	14378	17,942	22,057	27,320	90.01%
Campbell	38,169	40,100	41,400	43,118	12.97%
Cupertino	46,911	51,200	53,000	56,354	20 13%
Daly City	96,653	103,800	105,000	109,489	13.28%
Greenfield	7464	10540	11300	14,036	88.05%
Grover Beach	11656	14,572	17,957	22,289	91.23%
Huntington Park	56,065	64,485	68,562	75,878	35.34%
King City	7634	10190	11140	13,524	77.16%
Los Gatos	30,941	32,000	33,100	34,235	10.65%
Milpitas	50,769	61,900	63,100	70,629	39.12%
Montebello	59,565	65,004	70,813	77,210	29 62%
Monterey Park	60,738	64,533	68,636	72,962	20.13%
Pacifica	37,670	39,700	40,700	42,309	12.32%
Port Hueneme	20,319	24,419	28,381	33,547	65.10%
Salinas	108777	144500	175000	222,204	104.28%
San Fernando	22,580	23,592	24,414	25,386	12.43%
Saratoga	28,530	29,300	30,300	31,226	9 45%
Thousand Oaks	104,351	115,800	128,000	141,764	35.85%
West Hollywood	36,118	37,073	39,313	41,020	13 57%
Total (w/in 10 miles)	7,881,756	8,815,961	9,651,482	10,730,909	36.15%

Total County Projections Along Corridor

County	1990	2000	2010	2020	% Change
Los Angeles	8,897,500	10,180,868	11,441,900	12,916,552	45 17%
Monterey	358,800	414,014	485,297	574,082	60 00%
San Benito	37,000	50,658	66,454	83,212	124.90%
San Francisco	723,900	774,011	781,735	777,391	7.39%
San Luis Obispo	219,500	263,209	306,781	351,400	60.09%
San Mateo	652,100	740,370	787,291	825,627	26 61%
Santa Barbara	371,400	435,798	484,765	536,509	44.46%
Santa Clara	1,502,200	1,703,936	1,839,696	1,958,603	30.38%
Ventura	671,600	782,688	905,622	1,040,456	54.92%
TOTAL	13,434,000	15,345,552	17,099,541	19,063,832	41 91%

A relatively modest increase in population is expected in the coastal valleys over the next 20 years, with the bulk of the growth occurring the major metropolitan areas. For example, of the 1.77 million new residents expected to settle in cities within ten miles of the rail line by 2010, only about 175,000 (9.9 percent) are expected to locate in the predominately rural new corridor segment of this alternative which represents nearly half of the entire corridor length.

Cost

The estimated cost for the Coastal Route Alternative from Los Angeles to San Francisco is $9.3 billion, or an average of $22.4 million per mile. Table 3.2.2 summarizes the various segments of this alignment.

Table 3.2.2 COASTAL ROUTE ALTERNATIVE:
San Francisco-Los Angeles: Summary High-Speed Corridor

	Distance (miles)	Cost	Cost Per Mile	Travel Time (minutes)
Los Angeles-Santa Barbara	103.6	$2,058,000,000	$19,900,000	78.4
Santa Barbara-Gaviota	30.5	$409,000,000	$13,400,000	21.1
Gaviota-Gilroy	203.25	$4,336,000,000	$21,300,000	63.4
Gilroy-San Jose	29	$531,000,000	$18,300,000	18
San Jose-San Francisco	49	$1,964,000,000	$40,100,000	38.5
TOTALS: LA-SF	415.35	$9,298,000,000	$22,400,000	219.4

Through the 203-mile new corridor segment of this route (from Gaviota to Gilroy), three mountain ranges must be traversed at considerable cost. In total, an estimated 13 miles of bore tunneling and 8.3 miles of viaduct are required for the passes. Thus, while most of the new corridor runs through flat, rural land, the average cost per mile is relatively high at $21.3 million per mile.

Travel Times

The one-stop express service between Los Angeles and San Francisco would take 3 hours 39 minutes, averaging 114 mph. Skip-stop service, stopping at Simi Valley, Santa Barbara, San Luis Obispo, and San Jose, would take 3 hours 51 minutes for the Los Angeles-San Francisco trip, averaging 108 mph. Stopping at all nine stations, the local service would take 4 hours 20 minutes, averaging 96 mph. Travel times for selected Coastal Route city pairs are shown in Table 3.2.3.

High average speeds for the express service and skip-stop services are possible because of the new corridor segment. This high-speed segment, without speed restriction, represents nearly 49 percent of the total route.

3.3. Comparison of High-Speed Route Alternatives

The development of a high-speed corridor between the Los Angeles Metropolitan Region and the San Francisco Bay Area necessitates a choice between use of the Central Valley or the coastal valleys for

Table 3.2.3

Los Angeles - San Francisco, High-Speed Corridor

Coastal Route Alternative

SELECTED TRAVEL TIMES	No. of Stops	Distance (miles)	Time (min.)	Average Speed
Express				
Los Angeles - San Francisco	1	415.4	219.4	114
Los Angeles - San Jose	0	368.2	179.4	123
Skip-Stop				
Los Angeles - Simi Valley	0	36.5	28.6	77
Los Angeles - Santa Barbara	1	103.6	82.5	75
Los Angeles - San Luis Obispo	2	194.6	127.7	91
Los Angeles - San Jose	3	368.2	190.7	116
Los Angeles - San Francisco	4	415.4	230.7	108
Simi Valley - Santa Barbara	0	67.1	52.4	77
Simi Valley - San Luis Obispo	1	158.1	97.6	97
Simi Valley - San Jose	2	331.7	160.6	124
Simi Valley - San Francisco	3	378.9	200.6	113
Santa Barbara - San Jose	1	264.6	106.7	149
Santa Barbara - San Francisco	2	311.8	146.7	128
San Luis Obispo - San Jose	0	173.6	61.5	169
San Luis Obispo - San Fran.	1	220.8	101.6	130
San Jose - San Francisco	0	47.2	38.5	74
Local				
Los Angeles - Ventura	2	76.0	72.7	63
Los Angeles - Santa Barbara	3	103.6	99.4	63
Los Angeles - San Luis Obispo	4	194.6	144.5	81
Los Angeles - Palo Alto	7	384.9	229.2	101
Los Angeles - SFO	8	403.5	244.3	99
Los Angeles - San Francisco	9	415.4	259.8	96
Burbank - Santa Barbara	2	90.2	84.5	64
Burbank - Salinas	4	307.5	173.1	107
Burbank - San Jose	5	354.8	198.1	107
Burbank - SFO	7	390.1	229.4	102
Burbank - San Francisco	8	402.0	244.9	98
Ventura - Salinas	2	244.9	113.9	129
Ventura - San Jose	3	292.2	138.9	126
Ventura - Palo Alto	4	308.9	155.1	119
Ventura - San Francisco	6	339.4	185.7	110
Salinas - San Francisco	3	94.5	70.2	81
Salinas - San Luis Obispo	0	126.3	42.0	180
Salinas - Santa Barbara	1	228.7	100.2	137
Salinas - Simi Valley	3	284.4	149.0	115
Salinas - Los Angeles	5	320.9	188.1	102
SFO - Santa Barbara	4	311.3	156.5	119

the new corridor portion of the route. Since construction costs are tremendously high and both alternatives serve the state's two major transportation markets, it is extremely unlikely that constructing both alternatives would be attractive. Each alternative boasts distinct benefits, which are worthy of review.

The Central Valley Route

1. Travel times between the terminus stations are significantly better for the Central Valley Route.

Express travel times are over 21 percent shorter, and both local and skip-stop services are about 15 percent shorter than the comparable Coastal Route services. Travel times are an important advantage for the Central Valley Route since the service will compete against existing intercity travel modes (particularly air) for the Los Angeles-Bay Area market. Note that the estimated travel times for the local service (nine stops) for the Central Valley Route are nearly equivalent to the one-stop express Coastal Route service.

End-to-end travel times for the Central Valley Route alternative are very low because nearly 75 percent of the route was assumed to be traversed without speed restriction. Superior service for the Central Valley Route between Los Angeles and the Bay Area is contingent upon a through route which avoids both curves and developed areas.

2. A larger portion of the state's existing and projected population is served by the Central Valley Route.

Tables 3.3.1 and 3.3.2 summarize the estimated population exclusive to the Central Valley and Coastal Route Alternatives, respectively. For cities within a ten-mile radius of the rail line, the Central Valley Route population was about 404,000 more than the Coastal Alternative in 1990. By 2010, this population differential should reach nearly 1.62 million. For counties exclusive to each route, the figures are very similar. County population for the Central Valley Route is expected to exceed the Coastal Route county population by 509,000 in 1990, increasing and by 1.52 million by 2010.

3. The Central Valley Route alignment easily accommodates a low cost extension of high-speed service to Sacramento.

At a cost of only $10.8 million per mile, continuing up the Central Valley to Sacramento would be relatively inexpensive once the Los Angeles-San Francisco route was completed. Stations near Modesto and Stockton and a downtown station at Sacramento would serve this rapidly growing portion of the state well. For example, express travel time (non-stop) between Sacramento and Los Angeles would take only 2 hours 24 minutes.

In comparison, the fastest service to Sacramento using the Coastal Route would use the Capitol Corridor from San Jose, which travels through the urbanized and speed restricted Bay Area. Assuming the 125-mph service on the Capitol Route (at a cost of $3.5 billion), travel time for a two-stop express service between Los Angeles and Sacramento would be 4 hours 44 minutes.

Table 3.3.1

Los Angeles – San Francisco: Population Exclusive to Central Valley Route

CITIES WITHIN A 10 MILE RADIUS OF RAIL LINE

City	County	1990	2000	2010	2020
Fowler	Fresno	3,208	4,340	5,573	7,348
Fresno	Fresno	482,000	676,500	885,000	1,137,000
Kingsburg	Fresno	7,205	10,052	13,302	18,081
Selma	Fresno	14,757	20,729	27,635	37,829
Bakersfield	Kern	329,106	465,022	567,314	654,972
Delano	Kern	22,762	32,052	41,204	55,495
McFarland	Kern	7,005	9,934	12,860	17,442
Shafter	Kern	8,409	11,844	15,229	20,515
Wasco	Kern	12,412	17,386	22,240	29,801
Newhall/S. Clrta	L.A.	151,051	313,883	483,229	633,229
Palmdale/Lancstr	L.A.	240,562	440,891	654,743	854,743
Vernon	L.A.	151	89	89	71
Madera	Madera	29,281	42,653	55,374	76,276
Don Palasos	Merced	4,196	5,525	7,231	9,492
Los Banos	Merced	14,519	19,000	24,716	32,247
Tulare	Tulare	33,249	44,980	58,355	77,325
Visalia	Tulare	75,636	106,870	146,869	204,678
		1,435,509	2,221,750	3,020,961	3,866,544

COUNTY PROJECTIONS

County	1990	2000	2010	2020
Kern	549,800	801,991	1,037,673	1,310,050
Fresno	673,900	945,908	1,237,432	1,589,665
Merced	180,600	238,985	313,616	401,947
Madera	89,800	133,976	171,802	214,097
Tulare	314,600	417,314	521,231	644,357
	1,808,700	2,538,174	3,281,754	4,160,116

Table 3.3.2

Los Angeles – San Francisco: Population Exclusive to Coastal Route

CITIES WITHIN A 10 MILE RADIUS OF RAIL LINE

City	County	1990	2000	2010	2020
Vernon	L.A.	151	89	89	71
Gonzales	Monterey	4,660	5,950	6,510	7,717
King City	Monterey	7,634	10,190	11,140	13,524
Salinas	Monterey	110,387	144,500	175,000	222,204
Soledad	Monterey	7,146	20,380	22,200	43,748
San Juan Buatista	S. Benito	1,570	2,069	2,646	3,435
Carpinteria	S. Barbara	13,747	16,945	20,293	24,659
Santa Barbara	S. Barbara	85,571	93,276	100,415	108,778
Santa Maria	S. Barbara	61,284	75,046	89,089	107,427
Solvang	S. Barbara	4,741	5,563	6,273	7,218
Unincorp. SB	S. Barbara	87,676	93,936	101,252	108,810
Arroyo Grande	S.L.O.	14,378	17,942	22,057	27,320
Atascadero	S.L.O.	23,138	29,494	37,294	47,348
Grover Beach	S.L.O.	11,656	14,572	17,957	22,289
Paso Robles	S.L.O.	18,583	24,393	32,176	42,339
San Luis Obispo	S.L.O.	41,958	50,567	59,680	71,180
Camarillo	Ventura	52,303	61,500	69,500	80,131
Moorpark	Ventura	25,494	38,500	52,000	74,381
Oxnard	Ventura	142,217	154,621	167,027	181,012
Port Hueneme	Ventura	20,319	24,419	28,381	33,547
Simi Valley	Ventura	100,219	119,200	137,000	160,203
Thousand Oaks	Ventura	104,351	115,800	128,000	141,764
Ventura	Ventura	92,575	104,558	115,758	129,450
		1,031,758	1,223,510	1,401,738	1,658,556

COUNTY PROJECTIONS

County	1990	2000	2010	2020
San Benito	37,000	50,658	66,454	83,212
San Luis Obispo	219,500	263,209	306,781	351,400
Santa Barbara	371,400	435,798	484,765	536,509
Ventura	671,600	782,688	905,622	1,040,456
	1,299,500	1,532,353	1,763,622	2,011,577

The Coastal Route

1. The Coastal Route should be somewhat less costly than the Central Valley Route.

Although a greater percentage of the Coastal Route passes through urban areas, the three mountain ranges which it crosses are less problematic than the three ranges which the Central Valley route traverses. Moreover, the large population in Fresno dictated downtown service by a loop from the mainline at an additional cost of $230 million for the Central Valley Alternative. Thus, this study concludes that the cost of the Coastal Route would be about $300 million less than the Central Valley alternative.

2. California's tourist destinations are better served by the Coastal Route alternative.

Some of California's most attractive coastal regions would be served by the proposed Coastal Route. The popularity of Ventura, Santa Barbara, San Luis Obispo (Pismo Beach/Morro Bay), and Salinas (Monterey/Carmel) as tourist destinations would certainly have a positive impact on ridership. Furthermore, these internationally known coastal locations would be useful in marketing the service.

4. LOS ANGELES-SAN FRANCISCO: Summary and Analysis of Alternatives

As previously noted, a corridor connecting the state's major travel markets, the Los Angeles Metropolitan Region and the San Francisco Bay Area, offers one of the strongest potential markets for high-speed rail in the United States. This study has reviewed the steel-wheel-on-steel-rail technology alternatives and the route alignments that present the greatest opportunity for high-speed service to connect these markets. Both Central Valley and Coastal alternatives have been considered. The following sections analyze the different alternatives in order to evaluate which have the most potential.

Summary of Alternatives

Six different alternatives for improved intercity rail service between Los Angeles and San Francisco have been presented in this paper. These include four existing rail right-of-way alternatives and two alternatives operating on new "high-speed" alignments over a significant portion of their routes (see Table 4.1). The following analysis compares these alternatives in terms of cost, travel times, and population. The travel times shown assume tilt-train service for the existing rail alternatives. Therefore, these times depict the *best* possible times likely to be achieved on existing rail right-of-way.

Table 4.1 Service Improvements Summary
Los Angeles-San Francisco

				Population. w/in Ten Miles (millions)		Travel Times (minutes)		
Alternative	**Distance (miles)**	**Cost (millions)**	**Cost/Mile (millions)**	**1990**	**2010**	**Express**	**Local**	**Skip-Stop**
New Corridors								
Central Valley	426	$9,597	$22.53	8.29	11.27	173	222	197
Coastal Route	415.4	$9,298	$22.38	7.88	9.65	219	260	231
Existing Rail Corridors - Tilt Train Travel Times								
Central Valley - 110 mph	484.6	$893	$1.84	7.24	10.52	379	451	392
Central Valley - 125 mph	457.5	$8,750	$19.13	7.24	10.52	253	313	269
Coastal - 110 mph	474	$1,266	$2.67	7.93	9.71	315	382	322
Coastal - 125 mph	469.7	$8,563	$18.23	7.93	9.71	275	330	282

Cost

Except for the two 110-mph alternatives, costs for the remaining alternatives are relatively similar. There is only an 11 percent difference between the highest-cost new corridor (the Central Valley Route) and the lowest-cost 125-mph alternative (Coastal Route). In contrast, both of the 110-mph alternatives are substantially lower than the 125-mph alternatives. The 110-mph alternatives should cost 85 percent to 91 percent less than the 125-mph or new corridor options.

Travel Times

Travel times for the new corridor alternatives are significantly better than those for the existing rail alternatives, as should be expected, since these alternatives assume sustained speeds of 200 mph over a significant portion of their routes. Travel times for the one-stop express service from Los Angeles to San Francisco under the new corridor alternative are 1 hour 20 minutes less than the Central Valley 125-mph alternative, and 3 hours 26 minutes less than the Central Valley 110-mph alternative. Express travel times for the new corridor along the coast are 56 minutes less than the 125-mph Coastal alternative and 1 hour 36 minutes less than the 110-mph Coastal alternative.

Comparing the existing rail rights-of-way alternatives, travel times for the Central Valley 125-mph alternative are about 30 percent less than the 110-mph Central Valley travel times, while times for the Coastal 125-mph alternative are only about 13 percent less than the corresponding 110-mph option. The Central Valley travel times reflect the significant effect of a new alignment through the Southern California mountain ranges for the 125-mph alternative.

High-speed rail ridership heavily depends upon minimizing travel times between major markets. This is particularly true for the market between the Los Angeles Metropolitan Region and the San Francisco Bay Area, where any intercity service must compete against a strong existing air service. In *Revenue and Ridership Potential for a High-Speed Rail Service in the San Francisco/Sacramento-Los Angeles Corridor*, the projected high-speed rail ridership for the Central Valley New Corridor Alternative decreased 43 percent when the maximum speed was reduced from 200 mph to 125 mph. For the Bay Area-Southern California market, projected high-speed rail ridership reduced 51 percent.[31] Since ticket prices would be highest for the Bay Area-Southern California travelers, reducing maximum speed to 125 mph would result in a revenue loss of 47 percent. Moreover, the study concluded that while revenue from the 200-mph service alternatives would exceed operational and maintenance costs, the 125-mph alternative would operate at a loss.

Population

With a 1990 Census population of 14.5 million in the Los Angeles Metropolitan Region and 6.3 million in the San Francisco Bay Area, any corridor connecting these two metropolitan regions will draw from a tremendous existing population base. Despite a recent statewide economic slump, population throughout the state is expected to continue to rise. While each intercity rail alternative would serve a large portion of the state's current and future population, the alignments would serve significantly different markets.

Comparing the populations of cities and communities[32] within ten miles of the proposed alignments accentuates population differences between the alternative routes. Of the Central Valley Route alternatives, the New Corridor alternative directly serves the most population (8.29 million in 1990), while the existing rail options serve the least (7.23 million). Each Coastal alternative serves a population of about 7.92 million. The populations for the New Central Valley Corridor and the Coastal alternatives are higher than the existing Central Valley rail right-of-way, since they directly serve the greatest population concentrations of the Bay Area; the San Jose vicinity and the San Francisco Peninsula. Comparisons of the New Central Valley Corridor to the Coastal alternatives show that between Los Angeles and San Jose, a greater percentage of the state's population is concentrated inland than along the coast.

By 2010, the population of the new corridor alternative for the Central Valley should increase by 2.99 million to 11.27 million for cities within ten miles of the rail route. In comparison, coastal alternatives should show a notably smaller population increase of 1.77 million for a total of 9.65 million. The existing rail corridor for the Central Valley will experience the greatest growth. With 3.28 million new residents, population along this corridor should reach 10.52 million by 2010. Clearly, over the next 20 years much of the population growth in the area between Los Angeles and San Francisco will concentrate in the inland valleys. Furthermore, between (but not including) Los Angeles and San Jose, significantly more residents will live inland than along the coast.

Conclusions

Technology and alignment decisions must be made for high-speed rail to connect the Los Angeles Metropolitan region and San Francisco Bay Area markets. Because of the tremendous capital needed to construct both 125-mph and new-corridor (200-mph) alternatives, only one might be built in the forseeable future. This study strongly concludes that of the alternatives studied, the Central Valley New-Corridor Alternative is to be preferred.

Both of the new-corridor alternatives are superior to either of the 125 mph alternatives. Only high ridership can justify the nearly $10 billion needed to construct a high-speed rail line between Los Angeles and San Francisco. Travel times for the new-corridor alternatives are significantly superior to the 125-mph alternatives while costing little more. Thus, ridership and revenue would be substantially higher for either of the new corridor alternatives. Furthermore, since tilt-train operation was assumed for the 125-mph services, the differences in total costs are overstated. Indeed, higher operational and maintenance costs for tilt-train operation may offset the capital cost savings of the 125-mph alternatives. In addition, while travel times for the Central Valley 125-mph alternative are significantly better than the 125-mph Coastal alternative, the Central Valley existing rail corridor alternative bypasses the San Jose Area and does not directly serve San Francisco in the Bay Area.

Comparing the new-corridor (200-mph) alternatives, the advantages of the Central Valley route far outweigh those of for the Coastal Alternative. While costing only 3 percent more than a coastal route, the Central Valley offers significantly superior travel times between the major markets and will serve a far greater percentage of the state's future growth, much of which will take place in California's inland valleys. Therefore, the Central Valley alternative will generate substantially more revenue. Furthermore, economic benefits would be maximized by greatly increasing accessibility to the Central Valley, where tremendous growth is expected, rather than along the more environmentally sensitive coast. Finally, the Central Valley alternative easily permits the extension of high-speed rail service to rapidly growing Central Valley counties of Sacramento, San Joaquin, Stanislaus, and Merced.

Existing rail right-of-way can be upgraded to speeds of 110 mph with relatively little capital expenditure. Thus, while travel times for these alternatives cannot compare to those possible with a new high-speed corridor through the Central Valley, construction of either or both of 110-mph alternatives does not preclude the construction of a new corridor. On the contrary, improvements to either existing corridor would complement and strengthen the market potential for a new corridor in the Central Valley.

Of the two 110-mph alternatives, the Coastal Route is much better suited for service from Los Angeles to San Francisco. Travel times between the major markets are far superior and the Coastal route directly serves both San Francisco and San Jose. Furthermore, the Coastal Route does not conflict with the heavy freight traffic through the Tehachapi Mountains. However, while the Coastal Route is preferable for Los Angeles-San Francisco 110-mph service, it is evident that benefits can also be gained by upgrading the existing San Joaquin service from Northern California to Bakersfield.

When considering high-speed rail for California, a network between Los Angeles and San Francisco should be envisioned. The core of this network would consist of an electrified high-speed mainline connecting the downtown of Los Angeles and San Francisco via a new corridor through the Central Valley. This mainline service would be supplemented by existing rail 110-mph diesel services throughout the Coastal Route and Central Valley Route (between Oakland and Bakersfield). While the 110-mph Central Valley service would initially be a diesel feeder service to the high-speed mainline, ultimately this route might be electrified and integrated with the mainline service.

5. FINDINGS AND RECOMMENDATIONS

Key Findings

- *High-speed (125 mph or faster) service between the Los Angeles Metropolitan region and the San Francisco Bay Area would be best provided by a new alignment through the Central Valley.* Although similar in cost, this preferred alternative offers significantly faster travel times and will be able to reach a larger population than a new coastal route or upgrading the existing Central Valley or coastal routes. Thus, this alternative will generate the most revenue and offers the greatest potential for economic benefit. However, high-speed service on a new alignment should in no way preclude improvement of the existing coastal or Central Valley routes to 110-mph standards. Indeed, the rationale for a very high-speed service would be strengthened by the existence of strong local and feeder services.
- *Several corridors within the state show great potential for 110-mph upgrades.* These corridors exhibit a combination of strong market potential (population), relatively flat terrain over most of the route, and existing infrastructure in good condition where 110-mph upgrades would be relatively easy to implement and cost-effective. Los Angeles-San Diego (LOSSAN) is by far the most promising candidate in this category because of the successful existing service and the substantial investment already made in the corridor. Other good candidates are Los Angeles-Las Vegas and Los Angeles-Yuma (Phoenix). 110-mph service also appears justifiable along the existing Coastal Route and, to a lesser extent, the Capitol Corridor and the Oakland/Sacramento-Bakersfield corridor.
- *Because of difficult terrain and/or low population served, three corridors may have less potential for upgrades beyond the 79-mph standard.* These corridors are the Sacramento-Redding, the Sacramento-Truckee-Reno, and the San Rafael-Eureka corridor. Upgrading to 110-mph standards in the Sacramento-Reno and the San Rafael-Eureka corridors would produce a negligible benefit without huge capital investments.
- *The LOSSAN corridor is the most promising candidate for 125-mph service.* While this corridor has a number of physical constraints and obstacles, the route's large potential market will likely produce the greatest benefit for the investment. The Los Angeles-Las Vegas and Los Angeles-Phoenix corridors might also become good candidates for 125-mph service once these markets were developed due to their relatively easy terrain and large populations.
- *Tilt train technology will be most useful in the Los Angeles-Bay Area coastal route, which includes the Los Angeles-Santa Barbara corridor.* In this corridor, tilt train travel times under the 110-mph upgrade alternative would be very close to conventional 125-mph trainset travel times. The higher operation and maintenance costs for the tilting technology would likely be offset by a large savings in capital costs. To a lesser extent, tilt-trains might prove cost-effective in the San Rafael-Eureka and Sacramento-Reno corridors for 79-mph services. Other corridors, exhibiting predominantly straight alignments, would not gain significant travel time savings.
- *A combination of skip-stop and express passenger rail service offers a low capital cost alternative for improving travel times on any corridor.* Non-stop or one-stop express services would provide travel times 17-23 percent faster than all-stop services on the state-supported intercity rail corridors under the 110-mph upgrade alternative. Skip-stop services, making three or four stops, would provide an 11-17 percent faster service. Limiting the number of stops will always improve the travel times, whatever the improvement scenario. Therefore, capital improvement programs for intercity rail corridors should be planned to allow for skip-stop and express services as soon as the market can support the high frequencies that these types of service require.

Recommendations

The extensive research embodied in this report should provide the state with the means to begin assessing and prioritizing proposed rail projects throughout the state. Given the scarcity of funding for rail projects, future rail studies should confirm the need for rail service in specific corridors and should build upon this effort rather than duplicating the preliminary research and conceptual planning process. The authors would make two recommendations towards these ends:

First, the state should carefully estimate the potential ridership and resulting benefits of 110-mph upgrade projects. Corridor population serves only as an indication of ridership *potential.* Although separate research has more definitely shown the existence of a market for *very high-speed service (200 mph)* between Los Angeles and San Francisco/Sacramento, these indicators do not equate to comparable ridership potential for 110-mph services in any corridor.

Market analysis for 110-mph services will not only confirm the demand for intercity service in various corridors but will also help prioritize improvement projects for the corridors which have a high potential. Upgrading existing corridors to 110 mph is a substantial undertaking and careful consideration should be given to each project. While upgrading to a 79-mph standard is less costly and risky, these projects deserve careful thought as well.

The second recommendation involves the possibility of a new, high-speed rail corridor constructed along the San Francisco-Central Valley-Los Angeles corridor. Extensive analysis of all the feasible alternatives has convinced the authors that a Central Valley alignment closely approximating the alignment described in Working Papers 564[33] and 609[34] will provide the most benefit. Resources committed to planning a new, high-speed corridor should be devoted to more detailed analysis of a new corridor through the Central Valley rather than expended to once again compare the basic alternatives.

NOTES

[1] Caltrans, September 1993.
[2] TRB, 1990; Hall, 1992; Wilbur Smith, 1993.
[3] Wilbur Smith, 1993.
[4] FRA, Safety Standards, 1992.
[5] Caltrans, September 1993.
[6] Wilbur Smith, 1993.
[7] Hall, 1992; VFT, 1990.
[8] Leavitt, Vaca, and Hall, 1994.
[9] While maximum authorized speed is 55 mph, typical freight operating speeds are much lower.
[10] Wilbur Smith, 1990, p. 27.
[11] Wilbur Smith, 1987.
[12] SCCRCC, 1991.
[13] Wilbur Smith, 1990.
[14] Wilbur Smith, 1990.
[15] Caltrans, 1993: 51.
[16] Wilbur Smith, 1990.
[17] Wilbur Smith, 1990.
[18] Caltrans, 1993.
[19] Wilbur Smith, 1990.
[20] Wilbur Smith, 1990.
[21] Caltrans, Draft, 1993; Wilbur Smith, 1990.
[22] Curves greater than 1 degree.
[23] Caltrans, Sept. 1993.
[24] To reach San Francisco, automobiles or buses must cross the heavily congested Bay Bridge, whereas a BART connection must be made at the Richmond Station.
[25] Wilbur Smith, 1990.
[26] Wilbur Smith, 1990.
[27] Caltrans, comments from Division of Rail staff, 1994.
[28] Although the Grapevine alternative passes through Santa Clarita, alignment restrictions make service to this area virtually impossible.
[29] "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.
[30] Includes all counties within ten miles of HSR line.
[31] Leavitt, Vaca, and Hall, 1994.
[32] Major unincorporated areas have also been included in the population projections.
[33] Hall, 1992.
[34] Leavitt, Vaca, and Hall, 1994.

References

Association of Bay Area Governments. 1990. *Projections to 2010.*

Association of Monterey Bay Area Governments. 1993. Population projections to 2015 supplied by staff.

Bakersfield Department of City Planning. 1993. Telephone conversation with staff.

California Department of Finance. 1992. *California Statistical Abstract 1992.*

Caltrans. 1993. *Draft California Rail Passenger Program Report 1993/94 - 2002/3.*

____ 1993. *Tahoe Intercity Rail Study: I-80 Corridor Extension Improvements and Equipment.* Working Paper No. 2.

Caltrans, Division of Rail. 1993. *Draft, Proposition 116 California Rail Right-of-Way Survey Technical Supplement.*

Fresno Department of City Planning. 1993. Telephone conversation with staff.

Gannett Fleming. 1992. *High Speed Ground Transportation Study, Final Report.* Prepared by HSGT Steering Committee for the Washington State Transportation Commission.

Hall, P., D. Leavitt, and E. Vaca. 1992. *High-Speed Trains For California, Strategic Choice: Comparisons of Technologies and Choice of Route.* Institute of Urban and Regional Development, University of California at Berkeley, Working Paper No. 564.

California Department of Statistics. 1992. *California County Projections to 2040: 1992.* Department of Labor & Finance.

Hornor, E., ed. 1993. *California; Cities, Towns & Counties: Basic data Profiles for all Municipalities & Counties.* Palo Alto, CA: Information Press.

Las Vegas Department of City Planning. 1993. Telephone conversation with staff.

Leavitt, D. 1993. *The Cost Escalation of Rail Projects: Using Previous Experience to Re-Evaluate the CalSpeed Estimates.* Institute of Urban and Regional Development, University of California at Berkeley, Working Paper No. 567.

Leavitt, D., and E. Vaca, with P. Hall. 1994. *Revenue and Ridership Potential in the San Francisco/Sacramento-Los Angeles Corridor.* Institute of Urban and Regional Development, University of California at Berkeley, Working Paper No. 609.

Lichliter/Jameson & Associates, Inc. 1989. *Texas Triangle High Speed Rail Study.* Texas.

Modesto Department of City Planning. 1993. Telephone conversation with staff.

Parsons Brinckerhoff Quade & Douglas, Inc. 1990. *Final Consultants' Report to the Los Angeles-Fresno-Bay Area/Sacramento High-Speed Rail Corridor Study Group.*

Phoenix Department of City Planning. 1993. Telephone conversation with staff.

Reno Department of City Planning, 1993. Telephone conversation with staff.

Sacramento Association of Governments. 1993. Projections to 2010 supplied by staff.

Salinas Department of City Planning. 1993. Telephone conversation with staff.

San Diego Association of Governments. 1993. Projections to 2010 supplied by staff.

San Luis Obispo Department of City Planning. 1993. Telephone conversation with staff.

Santa Barbara Department of City Planning. 1993. Telephone conversation with staff.

Southern California Association of Governments. 1993. Population projections to 2010 provided by staff.

Stockton Department of City Planning. 1993. Telephone conversation with staff.

Texas TGV. 1991. *Texas TGV Franchise Application to Construct, Operate, Maintain, and Finance a High-Speed Rail Facility*. Texas High-Speed Rail Authority, Austin.

TMS/Benesch. 1990. *Tri-State High Speed Rail Study, Chicago-Milwaukee-Twin Cities Corridor (Final Report & Technical Reports 1-5).* Michigan Department of Transportation.

Transportation Research Board. 1991. *In Pursuit of Speed: New Options for Intercity Passenger Transport.* National Research Council, Washington, D.C.

URS Consultants. 1991. *Detroit-Chicago Rail Passenger Corridor Developmental Blueprint, Technical Documents No. 1-5.* Michagan Department of Transportation.

U.S. Department of Census. 1992. *U.S. City and County Data Book, 1973, 1982 & 1992.*

Wilbur Smith Associates. 1987. *Los Angeles - San Diego (LOSSAN) State Rail Corridor Study: Summary Report.*

____ 1987. *Los Angeles - Santa Barbar Rail Corridor Study: Executive Summary.*

____ 1989. *Intercity Rail Corridor Upgrade Study: Summary Report, Auburn-Sacramento-Oakland-Sacramento Corridor.* Metropolitan Transportation Commission.

____ 1990. *Intercity Rail Right-of-Way Inventory.* Caltrans Division of Mass Transit.

____ 1992. *Alternatives For High Speed Passenger Service: SP Coast Line Analysis.* Southern Pacific Transportation Company.

____ 1992. *Southern Pacific Coast Line Analysis.* Southern Pacific Transportation Company.

COST-ESTIMATION METHODOLOGY

This study has attempted to make use of the best available information on rail construction costs to formulate estimates for four different levels of rail improvement. It must be stressed, however, that these are planning estimates, meant for planning purposes only. Ultimately, if improvements are to be seriously considered, more detailed preliminary engineering estimates will be required to produce more accurate estimates.

Costs for new high-speed corridors and the 125-mph alternative for existing rail corridors were primarily based upon the methodology developed in previous CalSpeed work, most notably, "High-Speed Trains For California."

The methodology formulated in "In Pursuit of Speed" (TRB, 1991) was used as the basis for estimating costs for the 79-mph and 110-mph upgrades of existing rail corridors. This methodology was supplemented by several sources, including the Detroit-Chicago Rail Passenger Corridor Developmental Blueprint (URS Consultants/PBQD Michigan, 1991), the Southern Pacific Coast Line Analysis (Wilbur Smith, 1993), and costs suggested by respected professionals in the field of rail transportation.

The cost estimation methodologies used for this report were reviewed by the Capital Projects Office of Caltrans Division of Rail. This office is in charge of hiring consultants and monitoring contracts for all state-supported intercity rail improvements. The methodologies used for this study and the estimates for each existing rail corridor have been revised on the basis of feedback from Caltrans Division of Rail.

CAPITAL COST ESTIMATES KEY:

79-MPH AND 110-MPH UPGRADES

Rail Rights-of-Way Acquisition

For the 79-mph alternative, it was assumed that there would be no purchase of rights-of-way (r/w), whereas for the 110-mph alternative, all r/w should be publicly owned.

A $120,000 per acre cost for urban rail corridors was derived from the recent purchases of SP r/w by SCRRA Metrolink and the Peninsula Joint Powers Board; this was used as a general cost of rail r/w in metropolitan areas. For rural/suburban areas, a cost of $20,000 per acre was assumed.

A significant amount of rail r/w considered for service improvements is, or soon will be publicly owned. It is reasonable to assume that publicly owned r/w would encourage service improvements without purchase fees. Since lease costs will be considered as operational costs, $0.00 per acre is used for publicly owned rail r/w.

New Track Construction

The new Class VI track was based on the TRB "In Pursuit of Speed" construction cost.

Weld-Jointed Rail

This was based upon the cost used in Wilbur Smith's Southern Pacific Coastline Analysis.

Track Upgrades

Based upon the methodology used in TRB's "In Pursuit of Speed," a ballast, tie, line, and surface program is applied to all track. For the 79-mph alternative, track is improved to Class IV, whereas the 110-mph alternative is improved to Class VI.

Interlockings

This was based upon the methodology used in TRB's "In Pursuit of Speed" for both the 79- and 110-mph alternatives. Eight new interlockings were assumed for each terminus urban area, and two for each passing siding.

Curve Reduction

No curve reduction was considered for the 79-mph alternative. For the 110-mph alternative, relatively minor, single curve reductions were assumed to have an average cost of $3.3 million each. This cost was derived by averaging the minor curve realignments calculated for the Wilbur Smith "Southern Pacific Coastline Analysis."

For segments with several curves being realigned, through somewhat difficult terrain, USGS topo maps were used to plot profile sections of new alignments. The cost estimation methodology for new high-speed corridors was then applied for structures and earthwork.

Raise Curve Superelevation

This was based upon the cost used in Parsons Brinkerhoff's June 1990 "Final Consultants' Report to the Los Angeles-Fresno-Bay Area/Sacramento High-Speed Rail Corridor Study Group."

Signalling

This was based upon the methodology used in TRB's "In Pursuit of Speed." For the 110-mph alternative, Traffic Control System (TSC) signaling is used in double-tracked urban segments to provide reverse-running capabilities. Automatic Train Control (ATC) and cab signaling are provided throughout (no costs are included for freight locomotives to operate under ATC).

Fencing

This was based upon the cost used in TRB's "In Pursuit of Speed."

Modify Existing Overhead Bridges

Based upon the methodology derived in "In Pursuit of Speed" (TRB, 1991), overhead bridge modifications were estimated to cost an average of $750,000 each. Double-tracking programs were assumed to effect about 50 percent of the existing overhead structures.

Modify Existing Under-Grade Bridges

Based upon the methodology derived in "In Pursuit of Speed" (TRB, 1991), rehabilitation of under-grade bridge structures were estimated to average $67,500 each.

Short-Span Bridges

This is a 200'- to 300'-span bridge, able to cross most streams, canals, or streets. The cost calculation is based on an structural engineering firm's estimate for a 25' prestressed reinforced bridge designed for railroad loads.

Grade Crossing Protection Improvements

These costs were suggested by an engineer who has worked on recent rail improvement projects in California. Costs include new gates, flashers, and the electronics needed to permit 110-mph operations.

Road Closure

Primarily in rural areas or where crossings are a very short distance apart, some roads would be closed to reduce upgrading costs. For a rural closure, the cost only includes a standard Caltrans barricade and signing on each side of the rail r/w, whereas urban closures include costs for rerouting the closed road to a grade-separated alternative.

Stations

This was based upon the costs used in TRB's "In Pursuit of Speed."

125-MPH ULTIMATE SERVICE AND NEW HIGH-SPEED CORRIDORS

Earthworks

For the majority of the route segments, Earthwork unit costs were derived from the Texas TGV cost estimates provided in the franchise application reports and inflated by a factor of approximately 1.27 to account for higher construction costs in California . For the mountain-crossing segments, where large quantities of cut and fill were required, higher costs were used for "excavation" and "borrow."

Grading:

This includes clearing, grubbing, and leveling. The top soil is taken off and kept for landscaping and mulch. The total amount for "grading" is determined by multiplying the length of segment by the r/w width. For this report, an average r/w width was assumed for each segment.

Excavation and Borrow:

Excavation represents the lesser quantity of cut or fill for a segment. Since costs can be reduced by using cut segments for fill requirements, excavation is an equivalent amount of cut/fill for a segment. For Texas, which is very flat, the total amount of excavation averaged 86,560 CY/mile. Similarly, for California, this number was used for new r/w flat segments. It was assumed that no excavation could be utilized where existing rail r/w was used, as no cut was assumed.

Borrow is the difference between the cut and fill quantities. An average 26,900 CY/mile of borrow was used for the Texas TGV estimates. This average was used for all flat segments.

For the mountain passes, quantities were estimated based on profiles derived from USGS topo maps. These calculations assumed a level cross-section. The track section used was 50-foot with side slopes of 3 feet horizontal distance to every 2 feet of vertical height. Unit costs for the mountain passes were derived to be about 2.5 times the unit costs expected for relatively flat sections. The $11.0 per CY, for borrow is $2 greater than the cost used for "excavation, backfill, and spoil" for the California-Nevada Super Speed Ground Transportation Project proposal. Through the mountain passes, there would be much greater amounts of cut than fill; therefore, a large quantity of borrow is shown for these segments.

Landscape and Mulching:

This was calculated using the same quantities as grading.

Fencing:

An 8' chain link fence is required throughout the entire length of at-grade segments (on each side of r/w).

Subballast:

This is an 8" filter zone layer between fill and rock ballast. It is calculated for the entire segment length, based on an average estimated width.

Noise Attenuation Measures:

These are used through areas extremely sensitive to noise, particularly on aerial structures. Since speeds are assumed to be reduced through urban areas, only in exceptional situations would such measures be employed.

Structures

The Texas TGV report provided only a few applicable unit costs for the different structure subheadings. Since Texas is very flat, there are no costs for structures and tunneling comparable to those which would be required to cross California's mountain ranges. Moreover, the Texas project does not run in urban areas to the extent that California's corridors do, which also greatly affects several unit costs. Therefore, cost information from various sources was synthesized to provide a suitable range of unit costs for tunneling, bridges, and grade separations. Details of the cost-estimating research conducted, including costs and sources, are provided in "High Speed Trains For California" (Hall, 1992).

Standard Viaduct 20'-25':

This is a pre-stressed reinforced concrete aerial structure that predominately maintains a standard clearance height in order to provide grade separation from highways, streets, marshlands, and so forth. This type of structure would also be necessary in shared r/w corridors where the width was inadequate for all services at-grade. An aerial structure with a standard pier height/vertical clearance of at least 20 feet was assumed. For this type of structure, the Texas TGV report used a cost of $10.2 million per mile. This would translate to $13.0 million per mile when escalated to California's costs. In light of higher costs obtained from several sources and strict seismic requirements for California, a unit cost of $18.0 million/mile was determined as an average cost.

Viaduct > 25' Pier:

The three different costs represent viaduct/bridge structures of various ranges of pier heights. These structures are primarily necessary in the mountain passes, and are assumed to be prestressed reinforced concrete structures. Costs were derived from unit costs provided by Caltrans and a respected structural design firm.

Short Span Bridge:

This is a 200'- to 300'-span bridge, able to cross most streams, canals, or streets. The cost calculation is based on an structural engineering firm's estimate for a 25-foot pre-stressed reinforced bridge designed for railroad loads.

Modify Existing OH Bridge:

Based upon the methodology derived in "In Pursuit of Speed" (TRB, 1991), overhead bridge modifications were estimated to cost an average of $750,000 each. Electrification and double-tracking programs were assumed to effect about 50 percent of the existing overhead structures.

Modify Existing UG Bridge:

Based upon the methodology derived in "In Pursuit of Speed" (TRB, 1991), rehabilitation of overhead bridge structures were estimated to average $67,500 each.

Grade Separation:

The cost for urban grade separations was based on California Public Utility Commission's "1990-1991 Nominations for Proposed Separations." The nominated separations in this report represented high-volume traffic areas with high accident potential, predominately in urban areas. The average cost for overhead separations and underpasses from this study was $8.5 million. This cost has been applied for metropolitan region grade separations. For suburban areas and relatively small cities, a cost of $4 million per crossing has been assumed.

Assuming that rural grade separations would be simpler and less expensive than urban separations, the minimum cost of $1 million was taken from the PUC report as the average cost per rural grade separation.

Road Closure:

Primarily in rural areas or where crossings are a very short distance apart, some roads would be closed rather than construct a costly grade separation. For a rural closure, the cost only includes a standard Caltrans barricade and signing on each side of the rail r/w, whereas urban closures include costs for rerouting the closed road to a grade separated alternative.

Depressed Section:

This is for the transition to tunnels, or for narrow sections not deep enough to need tunneling. A unit cost of $16 million/mile was taken from the 8-foot-high depressed section used for the Dublin/Pleasanton BART extension cost estimates.

Cut and Cover:

This is a shallow tunnel which is created by first excavating from the surface, then building a structure within, finally followed by reinstatement of the ground to surface level. This type of tunneling would be used primarily in urban areas under transportation corridors where grade separation is otherwise not possible. Cut-and-cover tunnels would also be needed for some rural/suburban freeway undercrossings. Although this tunneling method can be effectively used for noise abatement, the tremendous costs involved and the decrease in passenger comfort make cut-and-cover tunneling undesirable. Though it is very difficult to calculate an average cost for urban cut-and-cover tunnels, a cost of $50 million/mile was derived after consulting several sources (see "The Cost Escalation of Rail Projects," Leavitt 1993). A lower cost ($35 million) was assumed for rural cut and cover tunnels.

Standard Bore:

These are structures constructed beneath ground level that only require surface occupation at the openings of the tunnel. In California, as a result of the high costs involved, bored tunnels were assumed to be used only in the mountain passes. Determining costs for boring tunnels in California is extremely difficult. The mountain ranges that need to be traversed are very difficult to bore tunnels in. Earthquake faults, methane gas, water, and a problematic geology are all factors which contribute to uncertainty in cost. What can be concluded is that bore tunneling through the Tehachapi Mountains and the Coastal Range will be very expensive. Estimates from professionals specializing in tunnel construction in California ranged from $50 million/mile to $100 million/mile. The most recent example of a coastal range tunnel was completed by the Bureau of Reclamation in 1979. A 9.5-foot-diameter, 7.1-mile-long tunnel was built in the Pacheco Pass for the San Luis Dam project. This project cost $14.4 million/mile in 1991 dollars even though its cross-sectional area is nearly six times less than what would be needed for a single-track bore. Although it is difficult to calculate what economies of scale could be expected for larger bores, the Pacheco Pass tunnel helps give some perspective of the high cost of tunneling in the California mountains. A bore tunneling cost of $70 million/mile was thought to represent a reasonable estimate for the planning purposes of this report.

Box Culverts:

These are necessary for drainage and as undercrossings (cattle, tractors). The Texas TGV system will be primarily built on new r/w through rural areas, and therefore requires many box culverts. The Texas TGV report assumed an average box culvert (average 150'length) for every two miles of track. For this report, box culverts were only included in rural segments on new r/w. The $83,000 cost per box culvert was derived from the Texas report.

Culvert:

36" culverts are needed for drainage purposes. The Texas TGV project requires about 2.2 culverts per mile (assuming an average culvert length of 50'). A similar average would be needed for the California at a cost of $3,500 per culvert (derived from the Texas report).

Buildings

Regional/Urban Stations:

These are the primary stations for new high-speed services. Each of the major metropolitan areas served by a new corridor would have a CBD station. These stations would require a higher cost as a result of the greater frequency of trains and the high demand expected at these intermodal sites. Costs have been derived from the Texas TGV report. Regional station costs were inflated from an average of the Dallas Union Station and San Antonio Station costs, whereas the other "Urban Station" estimate was based on an average of the Dallas/Fort Worth Airport and Houston CBD stations.

Suburban Stations:

These are small stations predominately in urban areas. These stations were assumed to be somewhat similar to existing new rail stations. While the upgrade study for the San Jose to Auburn corridor estimates a station "similar to the Santa Ana or Oxnard multi-modal terminal" at $3 million, the TRB source suggested $15 million per station. A cost of $10 million per new suburban station was used for this report.

Maintenance Facilities:

It is assumed that one facility would be necessary for each new high-speed corridor. The unit cost was derived from the Texas TGV cost estimates.

Inspection/Service Facilities:

It is assumed that these facilities will only be necessary at the express station locations for new high-speed alignments. Unit costs were derived from the Texas TGV cost estimates.

MOW Buildings:

Maintenance-of-way buildings are needed to store equipment and materials use for regular track maintenance nightly. Based on the Texas estimates, these facilities would be required every 50 miles and cost approximately $300,000 each.

Wayside Platforms:

These are simple concrete slab platforms used at some maintenance facilities, or in long stretches without a station (transfer platform for trains with problems). Costs were taken from the Texas TGV report. Although the Texas project averages one wayside platform per 65 miles, these would only be necessary through rural areas in California.

Demolition:

For new high-speed alignments, routes have been chosen which avoid existing structures. This is particularly true in the urban areas where demolition would be very expensive. However, some locations require the need to remove buildings and other existing structures. For these locations, an average cost of only $100,000 was assumed since they occur predominately in sparsely populated regions.

Rail

Trackwork:

This includes everything above the sub-ballast: rail and fastenings, ballast, and concrete ties. Trackwork is a lump sum figure based on the Texas estimates, which include the costs of turnouts, crossovers, and rail yards. In Texas, trackwork averages about $600,000 per mile of single track. Escalating the cost for California, the cost per track-mile would increase to $760,000.

Rail Relocation:

Freight tracks occupy the center portion of most existing rail r/w, and would need to be moved for the new double-tracked service to share the r/w. In most cases, the track would have to be replaced with new track. The cost of removing and replacing the freight track would virtually be the same as the cost per mile for trackwork, according to a conversation with a Texas TGV engineer.

Power/Signals

Catenary, Substations, Signal/Control:

These costs were suggested by an engineer who has worked on recent electrification projects in California. The subheadings represent all costs necessary for the power and signalling requirements of the HSR network.

Right-of-Way

The different types of right-of-way used for the cost estimate were limited to those which would be needed for the proposed network. In urban areas, the passenger services will make use of existing transportation corridors. Therefore, no attempt was made to generalize urban land values beyond the costing of existing rail corridors (according to recent federal legislation, the high-speed rail alignments could use interstate highway medians without purchasing the r/w or paying fees). In rural areas, the value of rail corridors was assumed to be the same as the value of the surrounding land.

The $120,000 per acre cost of urban rail corridors was derived from the recent purchases of SP r/w by SCRRA Metrolink and the Peninsula Joint Powers Board; this was used for the estimated cost of rail r/w in metropolitan areas. Rural/suburban rail r/w is assumed to cost $20,000 per acre.

A considerable amount of rail r/w considered for service improvements is, or soon will be, publicly owned. It is reasonable to assume that publicly owned r/w would encourage service improvements without purchase fees. Since lease costs will be considered as operational costs, $0.00 per acre is used for publicly owned rail r/w. Other land values were synthesized from estimates given by county officials.

Contingency Costs & Add-Ons

The percentages for "Contingencies" and "Add-Ons" (engineering, construction management, utility relocation, insurance, etc.) were determined after examining the recent estimates used for several different California rail projects and the other sources used for this paper. To reflect the conceptual nature of the CalSpeed estimates, the contingency costs must be high. Since construction in urban areas and through the mountain passes is far more difficult to estimate, contingencies for these segment will be higher than the flat rural segments. For the Add-Ons, the 20 percent of the total costs was adopted.

Capital Cost Improvements – 79 mph upgrade

ITEMS	Unit	Unit Costs	Amount	TOTAL COST
New Track Construction	TM	$595,000		
Relay non-#132-#136 track	TM	$227,000		
Weld Jointed Rail	TM	$111,000		
Track Upgrade: Cl II/III to Cl IV	TM	$75,000		
Reduce Curve: Minor Realignment	TM	$3,300,000		
Raise Curve Superelevation	TM	$50,000		
New Automated Block Signalling	TM	$210,000		
Fencing	RM	$127,000		
Grade Crossing Protection Improv.	EA	$150,000		
Grade Crossing Protect. Improv., Rur.	EA	$100,000		
Road Closure, Urban I	EA	$800,000		
Road Closure, Urban II	EA	$250,000		
Road Closure, Rural	EA	$50,000		
Stations – New	EA	$5,000,000		
Station Upgrade – Major	EA	$8,000,000		
Station Upgrade – Minor	EA	$500,000		
Subtotals				
Contingency		20%		
Add-Ons		20%		
TOTALS				

Notes:

New Track Construction – 20% double-track in rural areas (passing sidings)

Upgrade Track to Class IV, CWR – throughout

Upgrade Track to #132-136 weight – throughout, except where rail is Class IV (or better) and CWR

Raise Curve Superelevation – throughout: to 5" for mixed-use corridor, 6" for passenger service only

New Automated Block Signalling – segments without existing service

Fencing – 5% of corridor

Grade Crossing Protection Improvements – throughout

Stations, New – as needed

Station Upgrade, Major – as needed

Station Upgrade, Minor – as needed

Service Improvements Include:

- New Rolling Stock
- Service = a minimum 4 round trips per day (additional improvements would depend on market responce to service)

Capital Cost Improvements – 110 mph upgrade

ITEMS	Unit	Unit Costs	Amount	TOTAL COST
Rail R/W Aquisition, Urban	AC	$120,000		
Rail R/W Aquisition, Rural	AC	$20,000		
New Track Construction	TM	$600,000		
Relay non-#132-#136 track	TM	$230,000		
Weld Jointed Rail	TM	$110,000		
Track Upgrade: Cl II/III to Cl VI	TM	$115,000		
Track Upgrade: Cl IV/V to Cl VI	TM	$40,000		
Interlockings	EA	$286,000		
Reduce Curve: Minor Realignment	EA	$3,300,000		
Reduce Curves: Major Realignment	LS			
Raise Curve Superelevation	TM	$50,000		
Signalling, New w/ATC	TM	$210,000		
ATC Retrofit	TM	$55,000		
TCS Retrofit	TM	$150,000		
Fencing	RM	$127,000		
Modify Existing OH Bridges	EA	$750,000		
Modify Existing UG Bridges	EA	$68,000		
Short Span Bridge	EA	$1,000,000		
Grade Separation, Urban I	EA	$8,500,000		
Grade Separation, Urban II	EA	$4,000,000		
Grade Separation, Rural	EA	$1,000,000		
Grade Crossing Protection Improv.	EA	$150,000		
Grade Crossing Protect. Improv., Rur.	EA	$100,000		
Road Closure, Urban I	EA	$800,000		
Road Closure, Urban II	EA	$250,000		
Road Closure, Rural	EA	$50,000		
Stations – New	EA	$5,000,000		
Station Upgrade – Major	EA	$8,000,000		
Station Upgrade – Minor	EA	$500,000		
Subtotals				
Contingency		25%		
Subtotals				
Add-Ons		20%		
TOTALS				

Capital Cost Improvements - 110 mph upgrade
Notes:

Rail R/W Aquisition - where r/w is not publically owned

New Track Construction - 30% double-track in rural areas (passing sidings), 100% double-track in major urban areas

Upgrade Track to Class VI, CWR - throughout

Upgrade Track to #132-136 weight - throughout, except where rail is Class IV (or better) and CWR

Reduce Curve, Minor Realignment - where feasible

Reduce Curves, Major Realignment - where feasible

Raise Curve Superelevation - throughout: to 5" for mixed-use corridor, 6" for passenger service only

Signalling, New w/ATC - segments that are newly double-tracked

ATC Retrofit - throughout

TCS Retrofit - urban double-tracked segments only

Fencing - 15% through rural areas, 100% in major urban areas

Modify Existing OH Bridges - 50% of bridges effected through newly double-tracked segments

Modify Existing UG Bridges - throughout

Grade Crossing Protection Improvements - throughout

Grade Separation - none

Road Closure - where possible

Stations, New - as needed

Station Upgrade, Major - as needed

Station Upgrade, Minor - as needed

Service Improvements Include:

* New Rolling Stock

* Service = a minimum 10 round trips per day (additional improvements would depend on market responce to service)

Capital Costs – Electric Traction

125 mph Existing Rail Rights–of–Way & New High–Speed Corridors

EARTHWORKS	UoM	UNIT COSTS	UNITS	AMOUNT
GRADING	ACRE	$400		
EXCAVATION (Flat)	CY	$3.5		
BORROW (Flat)	CY	$4.5		
EXCAVATION (Mount)	CY	$8.0		
BORROW (Mount)	CY	$11.0		
LANDSCAPE/MULCH	ACRE	$2,000		
FENCING	MI	$81,000		
SUBBALLAST	SY	$8.0		
NOISE ATTENUATION	MI	$835,000		

STRUCTURES	UoM	UNIT COSTS	UNITS	AMOUNT
STD VIADUCT 20’-25’	MI	$18,000,000		
VIADUCT 25’-100’Pier	MI	$27,000,000		
VIADCT 100’-200’ Pier	MI	$37,000,000		
VIADUCT > 200’ Pier	MI	$52,000,000		
SHORT SPAN BRIDGE	EA	$1,000,000		
MODIFY EX. OH BRIDGE	EA	$750,000		
MODIFY EX. UG BRIDGE	EA	$67,500		
GRADE SEPARATION RUR	EA	$1,000,000		
GRADE SEPARATION URB	EA	$8,500,000		
GRADE SEP. URBAN II	EA	$4,000,000		
ROAD CLOSURE-RUR	EA	$50,000		
ROAD CLOSURE-URB	EA	$800,000		
ROAD CLOSURE-URB II	EA	$250,000		
CURVE REALIGNMENT	EA	$3,300,000		
DEPRESSED SECTION	MI	$16,000,000		
CUT & COVER TNL RUR	MI	$35,000,000		
CUT & COVER TNL URB	MI	$50,000,000		
STD BORE	MI	$70,000,000		
BOX CULVERT	EA	$83,000		
CULVERT	EA	$3,500		

BUILDINGS	UoM	UNIT COSTS	UNITS	AMOUNT
REGIONAL STATION	EA	$50,000,000		
URBAN STATION	EA	$30,000,000		
SUBURBAN STATION	EA	$10,000,000		
MAINTENANCE FAC.	EA	$35,000,000		
INSP./SERVICE FAC.	EA	$6,000,000		
MOW BUILDINGS	EA	$300,000		
WAYSIDE PLATFORMS	EA	$200,000		
DEMOLITION	EA	$100,000		

Page 2: Electric Traction

RAIL	UoM	UNIT COSTS	UNITS	AMOUNT
TRACKWORK	TRK-MI	$760,000		
RAIL RELOCATION	TRK-MI	$760,000		
POWER/SIGNALS	UoM	UNIT COSTS	UNITS	AMOUNT
CATENARY/SUBSTATIONS	TRK-MI	$900,000		
SIGNAL/CONTROL	MI	$760,000		
RIGHT-OF-WAY	UoM	UNIT COSTS	UNITS	AMOUNT
RANGE LAND	ACRE	$1,500		
PASTURE/CULTIVATED	ACRE	$5,000		
SCATTERED DEVELOP.	ACRE	$25,000		
URBAN RAILROAD LAND	ACRE	$120,000		
RURAL RAILROAD LAND	ACRE	$20,000		
LEGAL COSTS	ACRE	$3,500		
SUBTOTAL				
		PERCENT		AMOUNT
CONTINGENCY (RURAL)		20%		
CONTINGNCY (URB/MNT)		30%		
SUBTOTAL				
ADD-ONS		20%		
TOTAL				

Notes:

Rail R/W Aquisition – where r/w is not publically owned

Trackwork (new rail, fastenings, ballast, concrete ties; includes cost for turnouts and rail yards) – throughout
includes cost for turnouts and rail yards) – double-tracked throughout

Rail Relocation – existing rail r/w with freight operations

Reduce Curve, Minor Realignment – where feasible

Reduce Curves, Major Realignment – where feasible

Raise Curve Superelevation – throughout

Power/Signals – throughout

Fencing – throughout

Modify Existing OH Bridges – 50% of bridges effected throughout

Modify Existing UG Bridges – throughout

Grade Separate – throughout

Road Closure – throughout

Stations – as needed

TRAVEL TIME METHODOLOGY

For planning purposes, approximate travel times for different rail service alternatives can be estimated once the speed limitations through curves and the acceleration/deceleration characteristics of the trainsets considered are known. The following sections describe the assumptions made regarding curve speeds and trainset performance for the travel time calculations of the various corridors.

Speeds Through Curves

The extent to which curves restrict passenger train speed is determined by a combination of curve horizontal radius, the amount that the curve is superelevated, and the amount of "unbalance" or non-existent superelevation. Smooth curves have large radii permitting high-speeds, whereas tight curves with small radii are restrictive. Superelevating curves (raising the outer rail) increases the safe speeds through curves; the greater the superelevation, the higher the allowable speed. The maximum curve superelevation FRA generally permits is 6 inches.

FRA speed standards are based upon passenger comfort rather than safety, since the limits imposed by comfort exceed those of "safe" operation. The FRA has set a limit of 3 inches as the amount of unbalance to which conventional passenger trainsets should exceed equilibrium speed. However, since Caltrans has determined that 4 inches of unbalance is acceptable for both passenger comfort and safety,[1] this report assumed the higher value of unbalance for travel time calculations.

A problem with superelevation arises where both freight and passenger trains operate on the same tracks. A high superelevation results in "too much inward tilt to slow-speed freight trains and excessive wear on the low rail."[2] Superelevation also leads to excessive wear on the wheels of the freight trainsets. Therefore, for mixed-use operations, while 6 inches of superelevation is in fact permissible, for safety, and low cost in maintenance, superelevation should be kept to a maximum of 5 inches.[3]

It is generally accepted that "tilting" trains traverse curves at higher speeds than conventional trains. Most sources agree that speeds around curves can be increased as much as 25-30 percent if tilting trainsets are utilized because of the improved passenger comfort. However, it must be noted that according to a recent Wilbur Smith report, "In practice, the Swedish active tilt mechanism becomes ineffective at speeds below about 40 mph, so that tilt-train technology loses its value in territory where speeds are very restricted."[4]

Tables T.1 and T.2 summarize the speeds which are achievable for conventional and tilting trainsets, based upon the standard FRA formula (also shown). In hopes of increasing the clarity of the chart, the amount of curvature is delineated by both horizontal radius length (R) and degree of curvature (d).

Acceleration/Deceleration

To determine appropriate rates of acceleration and deceleration for the various levels of service, the performance characteristics of three types of locomotives have been researched. Tables T.3 through T.5 have been used for existing rail corridor travel time calculations. Table T.3 shows the deceleration and acceleration for a General Motors 3000 HP diesel locomotive to 110 mph, assuming a two-locomotive and eight-car trainset.[5] Performance is defined by the distance necessary to achieve a certain speed. Tables T.4 and T.5 show the acceleration for a General Motors 4000 HP diesel locomotive and the proposed Texas TGV locomotive respectively.

The acceleration characteristics of the locomotives studied for use in existing rail corridors are very different, particularly at the higher speeds. Starting from a stop, it takes only 3.2 miles for the electric-traction trainset to achieve a speed of 110 mph. For the 4000 HP diesel trainset, it takes 5.1 miles to reach the same speed. However, for the 3000 HP diesel trainset to achieve 110-mph operation from a stop takes over 20 miles. Therefore, for the 110-mph diesel alternative, it has been assumed that a 4000 HP powered locomotive will be necessary to reach and maintain top speed. Since performance for the two diesel locomotives is comparable at reduced speeds, the 3000 HP powered trainset has been assumed for the 79-mph alternative.

In contrast, the deceleration characteristics for the three alternatives would not vary significantly for existing corridor alternatives. Therefore, the performance characteristics of the 3000 HP diesel locomotive has been assumed for each alternative.

Table T.6 shows the performance characteristics used for the new corridor "high-speed" alternatives. This chart was based upon the characteristics of the proposed Texas TGV trainsets.

Travel Time Calculations

Curvature information and distances detailed in Wilbur Smith's "Intercity Rail Right-of-Way Inventory" (1990) were utilized for the existing rail corridors. This information was supplemented by detailed study of U.S.G.S. topo maps.

Attainable average speeds were estimated and travel times were calculated for each alternative for both existing and new corridors, and for express, skip-stop, and local services.

Station dwell times were assumed to be 2.0 minutes per stop for the 79-mph and 110-mph alternatives, and 1.5 minutes for the electric traction alternatives.[6]

POPULATION PROJECTION METHODOLOGY

All county projections (1990, 2000, 2010, & 2020) were provided by the California Department of Finance, Bureau of Statistics.

For cities in the major metropolitan regions, population projections from the various councils of governments (Association of Bay Area Governments, Sacramento Council of Governments, Southern California Association of Governments, Association of Monterey Bay Area Governments, and the San Diego Association of Governments) were used for 1990, 2000, and 2010. Projections for 2020 were calculated using a simple trend based on the average projected growth rate from 1990-2010.[7] Since most of California's population is located within these councils of governments, their projections are the principal source for this report's "on line," "within 5 miles" and "within 10 miles" population projections.[8]

Projections for Bakersfield, Fresno, Las Vegas, Modesto, Phoenix, Reno, Stockton, Salinas, San Luis Obispo, Santa Barbara, Visalia, Phoenix, Las Vegas, and Yuma were provided by their respective planning agencies through 2010. With the exception of Visalia, all projections for these cities include unincorporated areas within their sphere of influence. For Phoenix and Yuma, projections were also given for 2020.

For cities outside of the council of governments and where planning departments were not consulted, projections for 2000, 2010, and 2020 were derived by using a weighted average growth rate calculated by averaging past city growth (weighted at 25 percent) with projected county growth (weighted at 75 percent). County projections, which were done through a cohort model, were weighted higher since they were thought to be more accurate and are more conservative than past city growth patterns. U.S. Department of Census data was used to obtain 1970, 1980, and 1990 city populations. The population growth rate between 1970 and 1990 was used to counterbalance the unusually high growth cecthat was experienced throughout California in the 1980s. Moreover, considering the current recession and the loss of many industries, a growth rate starting from 1970 should be more accurate.

NOTES

[1] Caltrans Division of Rail, Capital Projects Office (meeting 1993).

[2] Hay, W. 1953.

[3] Caltrans Division of Rail, Capital Projects Office (meeting 1993).

[4] Wilbur Smith, 1993.

[5] Equivalent to a one-locomotive, four-car trainset.

[6] As suggested by Caltrans Division of Rail, Operations Office. Conversation, 1993.

[7] With the exception of the Palmdale/Lancaster and Newhall/Santa Clarita 2020 projections. These were based on the average increase in population, since the tremendous growth expected between 1990 and 2000 would lead to unrealistic 2020 projections using growth rate trends.

[8] "On line" projections includes all cities throughout a corridor whose boundaries are crossed by the rail (or proposed rail) right-of-way, whereas "within 5 miles" and "within 10 miles" projections include all cities whose boundaries respectively fall within a 5- or 10-mile radius of the rail right-of-way.ec

CalSpeed

Curves – Speed Limitations

FRA/Caltrans standards

		Elevation of outer rail (inches)										
		0	0.5	1	2	3	4	5	6	7	8	9
R	**d**	**Maximum allowable operating speed**										
11459	0.50	106.90	113.39	119.52	130.93	141.42	151.19	160.36	169.03	177.28	185.16	192.72
5730	1.00	75.59	80.18	84.52	92.58	100.00	106.90	113.39	119.52	125.36	130.93	136.28
3820	1.50	61.72	65.47	69.01	75.59	81.65	87.29	92.58	97.59	102.35	106.90	111.27
2865	2.00	53.45	56.69	59.76	65.47	70.71	75.59	80.18	84.52	88.64	92.58	96.36
2293	2.50	47.81	50.71	53.45	58.55	63.25	67.61	71.71	75.59	79.28	82.81	86.19
1911	3.00	43.64	46.29	48.80	53.45	57.74	61.72	65.47	69.01	72.37	75.59	78.68
1638	3.50	40.41	42.86	45.18	49.49	53.45	57.14	60.61	63.89	67.01	69.99	72.84
1434	4.00	37.80	40.09	42.26	46.29	50.00	53.45	56.69	59.76	62.68	65.47	68.14
1275	4.50	35.63	37.80	39.84	43.64	47.14	50.40	53.45	56.34	59.09	61.72	64.24
1147	5.00	33.81	35.86	37.80	41.40	44.72	47.81	50.71	53.45	56.06	58.55	60.94
1043	5.50	32.23	34.19	36.04	39.48	42.64	45.58	48.35	50.96	53.45	55.83	58.11
957	6.00	30.86	32.73	34.50	37.80	40.82	43.64	46.29	48.80	51.18	53.45	55.63
883	6.50	29.65	31.45	33.15	36.31	39.22	41.93	44.47	46.88	49.17	51.36	53.45
821	7.00	28.57	30.30	31.94	34.99	37.80	40.41	42.86	45.18	47.38	49.49	51.51
766	7.50	27.60	29.28	30.86	33.81	36.51	39.04	41.40	43.64	45.77	47.81	49.76
719	8.00	26.73	28.35	29.88	32.73	35.36	37.80	40.09	42.26	44.32	46.29	48.18
677	8.50	25.93	27.50	28.99	31.76	34.30	36.67	38.89	41.00	43.00	44.91	46.74
639	9.00	25.20	26.73	28.17	30.86	33.33	35.63	37.80	39.84	41.79	43.64	45.43
606	9.50	24.53	26.01	27.42	30.04	32.44	34.68	36.79	38.78	40.67	42.48	44.21
576	10.00	23.90	25.35	26.73	29.28	31.62	33.81	35.86	37.80	39.64	41.40	43.09
549	10.50	23.33	24.74	26.08	28.57	30.86	32.99	34.99	36.89	38.69	40.41	42.06
524	11.00	22.79	24.17	25.48	27.91	30.15	32.23	34.19	36.04	37.80	39.48	41.09
502	11.50	22.29	23.64	24.92	27.30	29.49	31.52	33.44	35.25	36.97	38.61	40.19
481	12.00	21.82	23.15	24.40	26.73	28.87	30.86	32.73	34.50	36.19	37.80	39.34

TRACK GEOMETRY:

a) The outside rail of a curve may not be lower than the inside rail or have more than 6 inches of elevation.

b) The maximum allowable operating speed for each curve is determined by the following formula:

$$V(max) = \sqrt{(Ea+4)/0.0007d}$$

Where:

V(max) = Maximum allowable operating speed (miles per hour)
Ea = Actual elevation of the outside rail (inches).
d = Degree of curvature (degrees).
= is the angle subtended by a 100 ft chord at the center of a circular alignment.
R = horizontal radius

Table T.2

Travel Time Methodolody

Curves – Speed Limitations For Tilt–Trains

FRA/Caltrans standards

		Elevation of outer rail (inches)										
		0	0.5	1	2	3	4	5	6	7	8	9
R	d	Maximum allowable operating speed										
11459	0.50	138.98	147.41	155.38	170.21	183.85	196.54	208.46	219.74	230.47	240.71	250.54
5730	1.00	98.27	104.23	109.87	120.36	130.00	138.98	147.41	155.38	162.96	170.21	177.16
3820	1.50	80.24	85.10	89.71	98.27	106.14	113.47	120.36	126.87	133.06	138.98	144.65
2865	2.00	69.49	73.70	77.69	85.10	91.92	98.27	104.23	109.87	115.23	120.36	125.27
2293	2.50	62.15	65.92	69.49	76.12	82.22	87.90	93.23	98.27	103.07	107.65	112.05
1911	3.00	56.74	60.18	63.43	69.49	75.06	80.24	85.10	89.71	94.09	98.27	102.28
1638	3.50	52.53	55.71	58.73	64.33	69.49	74.29	78.79	83.05	87.11	90.98	94.70
1434	4.00	49.14	52.12	54.94	60.18	65.00	69.49	73.70	77.69	81.48	85.10	88.58
1275	4.50	46.33	49.14	51.79	56.74	61.28	65.51	69.49	73.25	76.82	80.24	83.51
1147	5.00	43.95	46.61	49.14	53.83	58.14	62.15	65.92	69.49	72.88	76.12	79.23
1043	5.50	41.90	44.44	46.85	51.32	55.43	59.26	62.85	66.25	69.49	72.58	75.54
957	6.00	40.12	42.55	44.85	49.14	53.07	56.74	60.18	63.43	66.53	69.49	72.33
883	6.50	38.54	40.88	43.09	47.21	50.99	54.51	57.82	60.94	63.92	66.76	69.49
821	7.00	37.14	39.40	41.53	45.49	49.14	52.53	55.71	58.73	61.59	64.33	66.96
766	7.50	35.88	38.06	40.12	43.95	47.47	50.75	53.83	56.74	59.51	62.15	64.69
719	8.00	34.74	36.85	38.84	42.55	45.96	49.14	52.12	54.94	57.62	60.18	62.64
677	8.50	33.71	35.75	37.69	41.28	44.59	47.67	50.56	53.29	55.90	58.38	60.77
639	9.00	32.76	34.74	36.62	40.12	43.33	46.33	49.14	51.79	54.32	56.74	59.05
606	9.50	31.88	33.82	35.65	39.05	42.18	45.09	47.82	50.41	52.87	55.22	57.48
576	10.00	31.08	32.96	34.74	38.06	41.11	43.95	46.61	49.14	51.53	53.83	56.02
549	10.50	30.33	32.17	33.91	37.14	40.12	42.89	45.49	47.95	50.29	52.53	54.67
524	11.00	29.63	31.43	33.13	36.29	39.20	41.90	44.44	46.85	49.14	51.32	53.42
502	11.50	28.98	30.74	32.40	35.49	38.33	40.98	43.47	45.82	48.06	50.19	52.24
481	12.00	28.37	30.09	31.72	34.74	37.53	40.12	42.55	44.85	47.04	49.14	51.14

Note: Speed are assumed to be 30% greater than Conventional Trainset Values (see Table T.1)

Table T.3

Diesel Performance Characteristics
3000 HP F59PHM Locomotive

Deceleration

(1.78 mph/sec, 110 mph to 70 mph; 1.8 mph/sec, 70 mph to 0 mph)

(mph)	Distance (miles)											
From/To	110	100	90	80	70	60	50	40	30	20	10	0
110	0.00	0.16	0.31	0.44	0.56	0.66	0.75	0.82	0.87	0.91	0.93	0.94
100		0.00	0.15	0.28	0.40	0.50	0.58	0.65	0.71	0.75	0.77	0.78
90			0.00	0.13	0.25	0.35	0.43	0.50	0.56	0.60	0.62	0.63
80				0.00	0.12	0.22	0.30	0.37	0.43	0.46	0.49	0.50
70					0.00	0.10	0.19	0.25	0.31	0.35	0.37	0.38
60						0.00	0.08	0.15	0.21	0.25	0.27	0.28
50							0.00	0.07	0.12	0.16	0.19	0.19
40								0.00	0.05	0.09	0.12	0.12
30									0.00	0.04	0.06	0.07
20										0.00	0.02	0.03
10											0.00	0.01
0												0.00

Acceleration

(1 locomotive, 4 cars)

(mph)	Distance (miles)											
From/To	0	10	20	30	40	50	60	70	80	90	100	110
0	0.00	0.02	0.08	0.19	0.33	0.71	1.17	1.84	2.63	4.75	10.69	20.31
10		0.00	0.04	0.13	0.25	0.63	1.08	1.76	2.54	4.67	10.60	20.23
20			0.00	0.06	0.17	0.54	1.00	1.68	2.46	4.58	10.52	20.15
30				0.00	0.08	0.46	0.92	1.59	2.38	4.50	10.44	20.06
40					0.00	0.38	0.83	1.51	2.29	4.42	10.35	19.98
50						0.00	0.46	1.14	1.92	4.04	9.98	19.60
60							0.00	0.68	1.46	3.58	9.52	19.15
70								0.00	0.78	2.91	8.84	18.47
80									0.00	2.13	8.06	17.69
90										0.00	5.94	15.56
100											0.00	9.63
110												0.00

Source: General Motors Locomotive Group, September 1992.

Table T.4

Diesel Performance Characteristics
4000 HP Locomotive

Acceleration

(2 locomotives, 8 cars)

(mph)	Distance (miles)											
From/To	0	10	20	30	40	50	60	70	80	90	100	110
0	0.0	0.0	0.1	0.2	0.3	0.5	0.7	1.1	1.5	2.2	3.3	5.1
10		0.0	0.0	0.1	0.2	0.4	0.6	1.0	1.5	2.1	3.3	5.0
20			0.0	0.1	0.2	0.4	0.6	1.0	1.4	2.1	3.2	5.0
30				0.0	0.1	0.3	0.5	0.9	1.4	2.0	3.2	4.9
40					0.0	0.2	0.4	0.8	1.2	1.9	3.1	4.8
50						0.0	0.2	0.6	1.1	1.7	2.9	4.6
60							0.0	0.4	0.9	1.5	2.7	4.4
70								0.0	0.5	1.1	2.3	4.0
80									0.0	0.7	1.8	3.5
90										0.0	1.1	2.9
100											0.0	1.7
110												0.0

Source: GM Locomotive Group, 1993 (conversation)

Table T.5

Electric Traction Performance
Texas TGV parameters

Acceleration

(2 locomotives, 8 cars)

(mph)	Distance (miles)													
From/To	0	10	20	30	40	50	60	70	80	90	100	110	120	130
0	0.0	0.1	0.1	0.2	0.3	0.4	0.7	1.0	1.3	1.6	1.9	3.2	4.5	5.8
10		0.0	0.1	0.2	0.2	0.3	0.6	0.9	1.2	1.5	1.8	3.1	4.4	5.7
20			0.0	0.1	0.1	0.2	0.5	0.8	1.1	1.4	1.7	3.1	4.4	5.6
30				0.0	0.1	0.1	0.4	0.7	1.0	1.3	1.6	3.0	4.3	5.6
40					0.0	0.1	0.4	0.7	1.0	1.3	1.6	2.9	4.2	5.5
50						0.0	0.3	0.6	0.9	1.2	1.5	2.9	4.1	5.4
60							0.0	0.3	0.6	0.9	1.2	2.5	3.8	5.1
70								0.0	0.3	0.6	0.9	2.2	3.5	4.8
80									0.0	0.3	0.6	1.9	3.2	4.5
90										0.0	0.3	1.7	2.9	4.2
100											0.0	1.4	2.6	3.9
110												0.0	1.3	2.6
120													0.0	1.3
130														0.0

Source: FRA, 1991

Table T.6

Electric Traction Performance Characteristics

Texas TGV Parameters

Deceleration (.75mph/sec)

(mph)	Distance (miles)																				
From/To	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
200	0.0	0.7	1.4	2.1	2.7	3.2	3.8	4.3	4.7	5.2	5.6	5.9	6.2	6.5	6.7	6.9	7.1	7.2	7.3	7.4	7.4
190		0.0	0.7	1.3	1.9	2.5	3.1	3.6	4.0	4.4	4.8	5.2	5.5	5.8	6.0	6.2	6.4	6.5	6.6	6.7	6.7
180			0.0	0.6	1.3	1.8	2.4	2.9	3.3	3.8	4.1	4.5	4.8	5.1	5.3	5.5	5.7	5.8	5.9	6.0	6.0
170				0.0	0.6	1.2	1.7	2.2	2.7	3.1	3.5	3.9	4.2	4.4	4.7	4.9	5.1	5.2	5.3	5.3	5.4
160					0.0	0.6	1.1	1.6	2.1	2.5	2.9	3.2	3.6	3.8	4.1	4.3	4.4	4.6	4.7	4.7	4.7
150						0.0	0.5	1.0	1.5	1.9	2.3	2.7	3.0	3.3	3.5	3.7	3.9	4.0	4.1	4.1	4.2
140							0.0	0.5	1.0	1.4	1.8	2.1	2.4	2.7	3.0	3.2	3.3	3.5	3.6	3.6	3.6
130								0.0	0.5	0.9	1.3	1.6	1.9	2.2	2.5	2.7	2.8	3.0	3.1	3.1	3.1
120									0.0	0.4	0.8	1.2	1.5	1.8	2.0	2.2	2.4	2.5	2.6	2.6	2.7
110									From	0.0	0.4	0.7	1.1	1.3	1.6	1.8	1.9	2.1	2.2	2.2	2.2
100											0.0	0.4	0.7	0.9	1.2	1.4	1.6	1.7	1.8	1.8	1.9
90												0.0	0.3	0.6	0.8	1.0	1.2	1.3	1.4	1.5	1.5
80													0.0	0.3	0.5	0.7	0.9	1.0	1.1	1.2	1.2
70														0.0	0.2	0.4	0.6	0.7	0.8	0.9	0.9
60															0.0	0.2	0.4	0.5	0.6	0.6	0.7
50																0.0	0.2	0.3	0.4	0.4	0.5
40																	0.0	0.1	0.2	0.3	0.3
30																		0.0	0.1	0.1	0.2
20																			0.0	0.1	0.1
10																				0.0	0.02

Acceleration

(2 locomotives, 8 cars)

(mph)	Distance (miles)																				
From\To	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
0	0.0	0.1	0.1	0.2	0.3	0.4	0.7	1.0	1.3	1.6	1.9	3.2	4.5	5.8	7.1	8.4	9.7	11.0	12.2	13.5	14.8
10			0.1	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	3.1	4.4	5.7	7.0	8.3	9.6	10.9	12.2	13.5	14.7
20				0.1	0.1	0.2	0.5	0.8	1.1	1.4	1.7	3.1	4.4	5.6	6.9	8.2	9.5	10.8	12.1	13.4	14.7
30					0.1	0.1	0.4	0.7	1.0	1.3	1.6	3.0	4.3	5.6	6.9	8.2	9.4	10.7	12.0	13.3	14.6
40						0.1	0.4	0.7	1.0	1.3	1.6	2.9	4.2	5.5	6.8	8.1	9.4	10.7	12.0	13.2	14.5
50							0.3	0.6	0.9	1.2	1.5	2.9	4.1	5.4	6.7	8.0	9.3	10.6	11.9	13.2	14.5
60								0.3	0.6	0.9	1.2	2.5	3.8	5.1	6.4	7.7	9.0	10.3	11.6	12.9	14.2
70									0.3	0.6	0.9	2.2	3.5	4.8	6.1	7.4	8.7	10.0	11.3	12.6	13.9
80										0.3	0.6	1.9	3.2	4.5	5.8	7.1	8.4	9.7	11.0	12.3	13.8
90											0.3	1.7	2.9	4.2	5.5	6.8	8.1	9.4	10.7	12.0	13.3
100												1.4	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0
110										From			1.3	2.6	3.9	5.2	6.5	7.7	9.0	10.3	11.6
120														1.3	2.6	3.9	5.2	6.5	7.7	9.0	10.3
130															1.3	2.6	3.9	5.2	6.5	7.7	9.0
140																1.3	2.6	3.9	5.2	6.5	7.7
150																	1.3	2.6	3.9	5.2	6.5
160																		1.3	2.6	3.9	5.2
170																			1.3	2.6	3.9
180																				1.3	2.6
190																					1.3

Derived from "Table 2 – Trainset Parameters" in
"Safety Relevant Observations on the TGV High Speed Train", FRA 1991