3.4 Alignment Options

This section presents a more detailed description of alignment options within the selected SR-99 Corridor and extensions to San Diego and Sacramento (see Figure 3.2).

3.4.1 Central Valley Segments

Three alignment options were studied along the SR-99 Corridor: the Burlington Northern Santa Fe (BNSF),[3] the Southern Pacific (SP), and a new alignment. Each of these options passes through a portion of the San Joaquin Valley where terrain constraints are not as challenging as the mountain passes. Consequently, the key constraints throughout the Valley lie in the urban and suburban areas.

The differences among these alignment options are in their relative proximity to built-up areas and the associated space constraints and grade crossings. Segments that pass through built-up areas require a significant number of elevated segments and grade separations. These affect the structural make-up of the alignments and, consequently, capital costs.

Southern Pacific Corridor – The Southern Pacific right-of-way stretches through the Central Valley, passing through the heart of many urban areas along the SR-99 Corridor. Because of the density of these areas, this alternative requires numerous elevated segments and grade separations.

Burlington Northern Santa Fe (BNSF) Corridor – The existing BNSF railway right-of-way through the Central Valley is more rural than the Southern Pacific, and requires fewer elevated segments and grade separations. The BNSF alignment is 7 percent longer than the Southern Pacific and 17 percent longer than the new alignment.

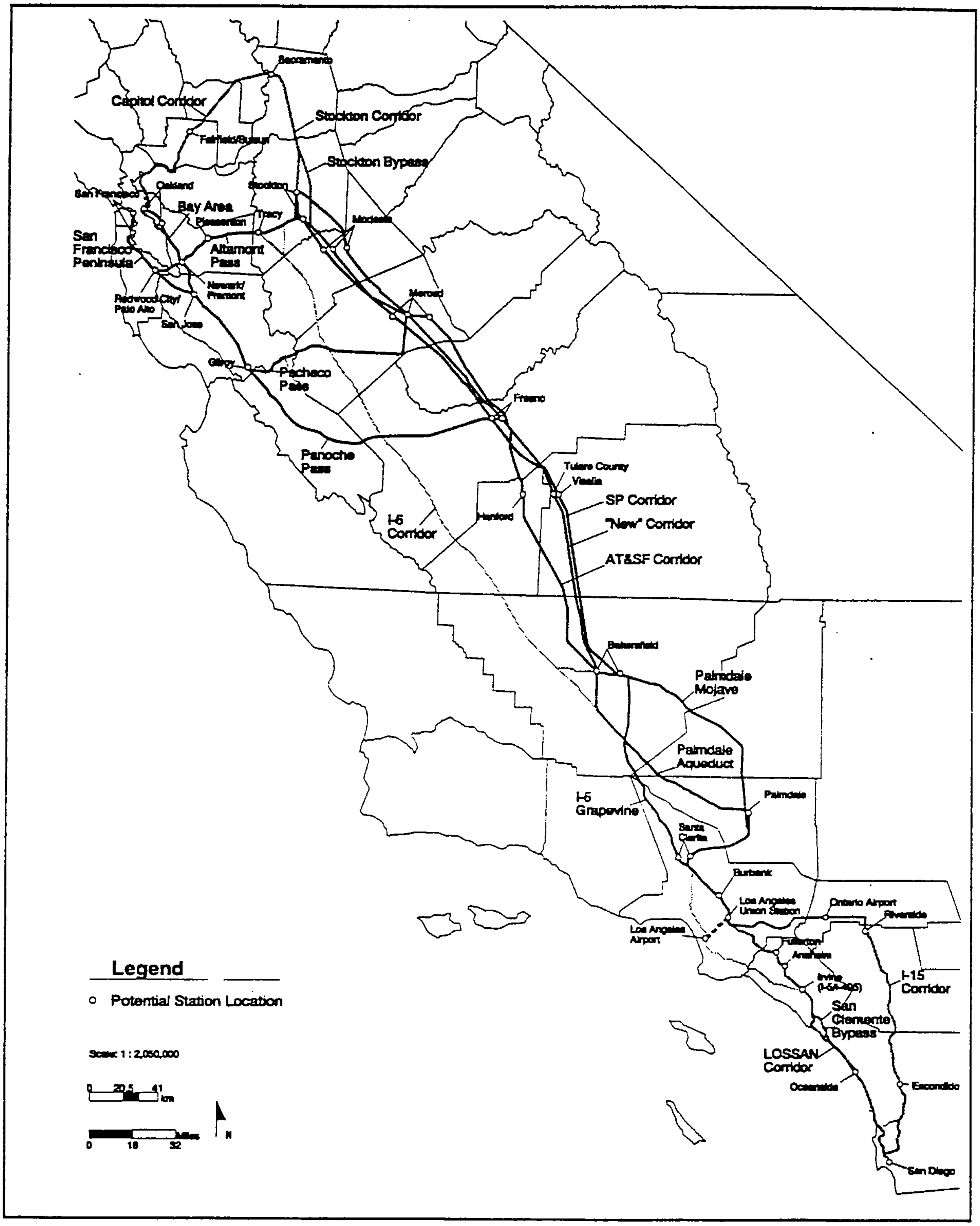
New Alignment Corridor – The alignment investigated generally lies a few miles west of State Route 99 within the SR-99 Corridor, but out of the existing rail rights-of-way, frequently traversing farmland. The alignment bypasses the more densely populated areas, minimizing the need for grade crossings and nearly eliminating the need for elevated sections.

3.4.2 Northern Mountain Passes

The three alternatives for crossing the Coastal Range between the San Joaquin Valley and the San Francisco Bay Area include the Altamont, Pacheco, and Panoche Passes.

[3]Until recently, this line was the Atchison Topeka & Santa Fe (AT&SF).

Figure 3.2 Potential Alignment Segments



Altamont Pass – This is the northernmost of the three passes, and its route includes the cities of Livermore, Pleasanton, Fremont, and Newark. Because of space constraints and roadway crossings in these urban areas, this pass requires a higher percentage of elevated guideway than the other passes. This pass also requires some tunnel segments, due to its topography. Tunneling can be minimized along this pass by using an alignment parallel to Interstate 205 with 3 percent to 4 percent grades (higher grades of 5 to 10 percent would result in only minor tunneling reductions). Very tight curves along the existing rail alignment are not compatible with high-speed operations, requiring a tunnel through Pleasanton ridge and into Niles Canyon.

Pacheco Pass – This pass stretches from Los Banos to Gilroy. While State Route 152 extends through the length of this pass, it is not possible to follow the existing roadway alignment along most of the pass. Numerous tunnel and elevated segments are required to maintain high-speed rail design speeds. The need for tunnel segments can be minimized along this pass by exploring the entire range of profile grade options. The key constraints of this pass include terrain and the San Luis Reservoir.

Panoche Pass – This pass extends from the I-5 Corridor to Gilroy, passing through mountainous and valley terrain. The mountainous areas provided an opportunity to test vertical alignments with 3.5 percent and 5.0 percent maximum grades. However, the use of the steeper grade did not allow for significant tunnel reductions. There is less tunneling and cut-and-fill compared to the other passes due to the milder slopes and terrain. However, the mountainous terrain extends for a longer distance on this pass.

In order to minimize earthwork and impacts, the Panoche Pass joins the existing rail corridor at grade south of Hollister. Elevated portions are proposed at Hollister and Gilroy, where space constraints and the number of at-grade crossings support the use of elevated guideway through these built-up areas.

3.4.3 Southern Mountain Passes

The Tehachapi Mountains are formidable terrain features between Los Angeles and the Central Valley, posing a significant engineering challenge. The mountains are steep, rugged, and traversed by active seismic faults. The options for traveling between the Los Angeles Basin and the San Joaquin Valley include three passes of the Tehachapi Mountains: I-5 (the Grapevine), Aqueduct, and Mojave. The latter two passes serve Palmdale and the Antelope Valley.

I-5 Pass (Grapevine) – This pass approximates the I-5 route over the Grapevine and into the San Joaquin Valley. Closely following the existing highway alignment is not possible without significantly reducing rail speeds. In some areas, the existing grade does not accommodate the geometric requirements of any of the high-speed rail technologies. Thus, significant lengths of tunnel are required on the steep north face of this pass. The most significant earthquake faults on this segment include the San Andreas and Garlock

Faults.[4] The San Andreas fault can be traversed by high-speed rail alignment at-grade; however, the Garlock Fault can be crossed at-grade only with a 5 percent profile.

Aqueduct Pass – This option follows Soledad Canyon into the Antelope Valley and continues along the California Aqueduct through the Tehachapi Range to the Central Valley. As with the Grapevine, the San Andreas Fault can be crossed at-grade; however, the Garlock Fault can be crossed at-grade only with profile grades exceeding 5 percent. This pass is the shortest distance through the Tehachapis but involves a very abrupt crossing.

Mojave Pass – This segment also follows Soledad Canyon but follows the Southern Pacific rail alignment through the Antelope Valley and the Tehachapi Mountains. This portion of the mountain range is rugged but the pass is longer and generally more gradual in ascent and descent than the I-5 and Aqueduct crossings. Tunneling can be effectively minimized with a 3.5 percent grade option and both the San Andreas Fault and the Garlock Fault can be crossed at-grade. The Mojave Pass involves the least challenging terrain of the three.

3.4.4 Los Angeles Area

Los Angeles (Metrolink Corridor) – The proposed alignment north of Los Angeles Union Station uses the Los Angeles County Metropolitan Transportation Authority's Metrolink right-of-way. Operating rights on this alignment are held by Metrolink and Southern Pacific. This right-of-way must accommodate commuter rail, future light rail, and freight trains as well as pipeline and fiber optic elements. This Corridor is densely developed, with a parallel roadway and numerous roadway crossings at grade. While these conditions tend to require aerial structure along significant parts of the route, there are options for maximizing at-grade operations between Union Station and downtown Burbank.

3.4.5 San Francisco Area

Two routes were examined to provide high-speed rail service in the San Francisco Bay Area: the East Bay Corridor, serving Oakland, and the Peninsula Corridor, serving San Francisco.

East Bay Corridor (Oakland) – This route follows the Southern Pacific Mulford Line from San Jose to Oakland. This Corridor accommodates two other rail lines: the Union Pacific/Bay Area Rapid Transit (BART) and the Southern Pacific Niles Line. The Mulford Line accommodates freight service and AMTRAK passenger service for a portion of its length, but is less densely developed and has fewer at-grade crossings and grade separations than the other rights-of-way. Connections to San Francisco would be made via BART at a relocated West Oakland station.

[4]The *Los Angeles-Bakersfield High-Speed Ground Transportation Preliminary Engineering Feasibility study* found that the greatest seismic hazard to high-speed rail is a tunnel crossing of the Garlock Fault.

Peninsula Corridor (San Francisco) – The route along the Peninsula primarily uses the Peninsula Corridor Joint Powers Board (PCJPB) right-of-way, which accommodates commuter rail (*CalTrain*) and freight service. Large segments of this densely developed corridor are quite narrow and will require additional right-of-way to accommodate freight, commuter, and high-speed rail service. There are numerous grade crossings and grade separations throughout. The line would terminate in downtown San Francisco at either the Transbay Terminal or the 4th and Townsend site.

3.4.6 San Diego Extension

Two main alternatives were studied between Los Angeles and San Diego: the LOSSAN Corridor and the I-15 Corridor.

LOSSAN Corridor – This rail Corridor between Los Angeles and San Diego accommodates commuter rail service (*Metrolink* service in Los Angeles and Orange Counties and *Coaster* service in San Diego County), AMTRAK passenger service, freight service, and light rail transit in San Diego. This Corridor is densely developed in the Los Angeles and San Diego metropolitan areas with many at-grade crossings, grade separations, and speed-restricting curves. The Corridor's proximity to beach recreation areas and beachfront residential communities would cause significant impacts that would be difficult to mitigate. For this reason, an option to bypass the coast at San Clemente was considered. The LOSSAN Corridor becomes very congested as it approaches downtown San Diego, being occupied by a double-track passenger/freight line as well as a double-track light rail transit line. All these factors effectively restrict speeds to 150 mph or less. For express trips, average speeds on the LOSSAN Corridor would remain at about 107 mph for VHS technology and 132 mph for Maglev.

Interstate 15 (I-15) Corridor – This route follows the Metrolink Corridor from Los Angeles to Riverside and continues south along the Interstate 215 (I-215) and Interstate 15 freeways to San Diego. The approach to San Diego include Mission Valley (via Interstate 8) and a portion of the LOSSAN Corridor. The Metrolink Corridor to Riverside is heavily developed and the transition through Riverside to the I-215 Corridor is constrained by development and terrain. Difficult terrain is also found between Escondido and Temecula. The part of the corridor south of Escondido is heavily constrained by development adjacent to the freeway and its interchanges. The Mission Valley route is heavily constrained by existing development and would require extensive right-of-way purchases and local access reconfiguration. An option to use Penasquitos Canyon was studied and found not feasible.

3.4.7 Sacramento Extension

Two alternatives for this extension between the San Francisco Bay Area and Sacramento were considered: the Capitol Corridor from Oakland, and the Stockton Corridor through the San Joaquin Valley.

Capitol Corridor – This route follows the Southern Pacific rail line from Oakland to Sacramento, and accommodates freight service, AMTRAK passenger service, and commuter rail service (the *Capitols).* From Oakland to the Benicia-Martinez Bridge, the Corridor is highly constrained by existing development and terrain (the alignment follows the edge of San Pablo Bay). Because any widening or significant geometric improvements would have considerable cost implications, speed restrictions have been assumed along this portion of the Corridor.

Stockton Corridor – This route uses the Southern Pacific rail line through Stockton to Sacramento. The existing rail corridor accommodates freight and AMTRAK passenger service to Stockton (the *San Joaquins).* The Corridor is constrained by encroaching development, at-grade crossings and grade separations through the urban areas of Stockton and Sacramento. A low cost alternative, bypassing Stockton to the east through rural or undeveloped land, would avoid these constraints.

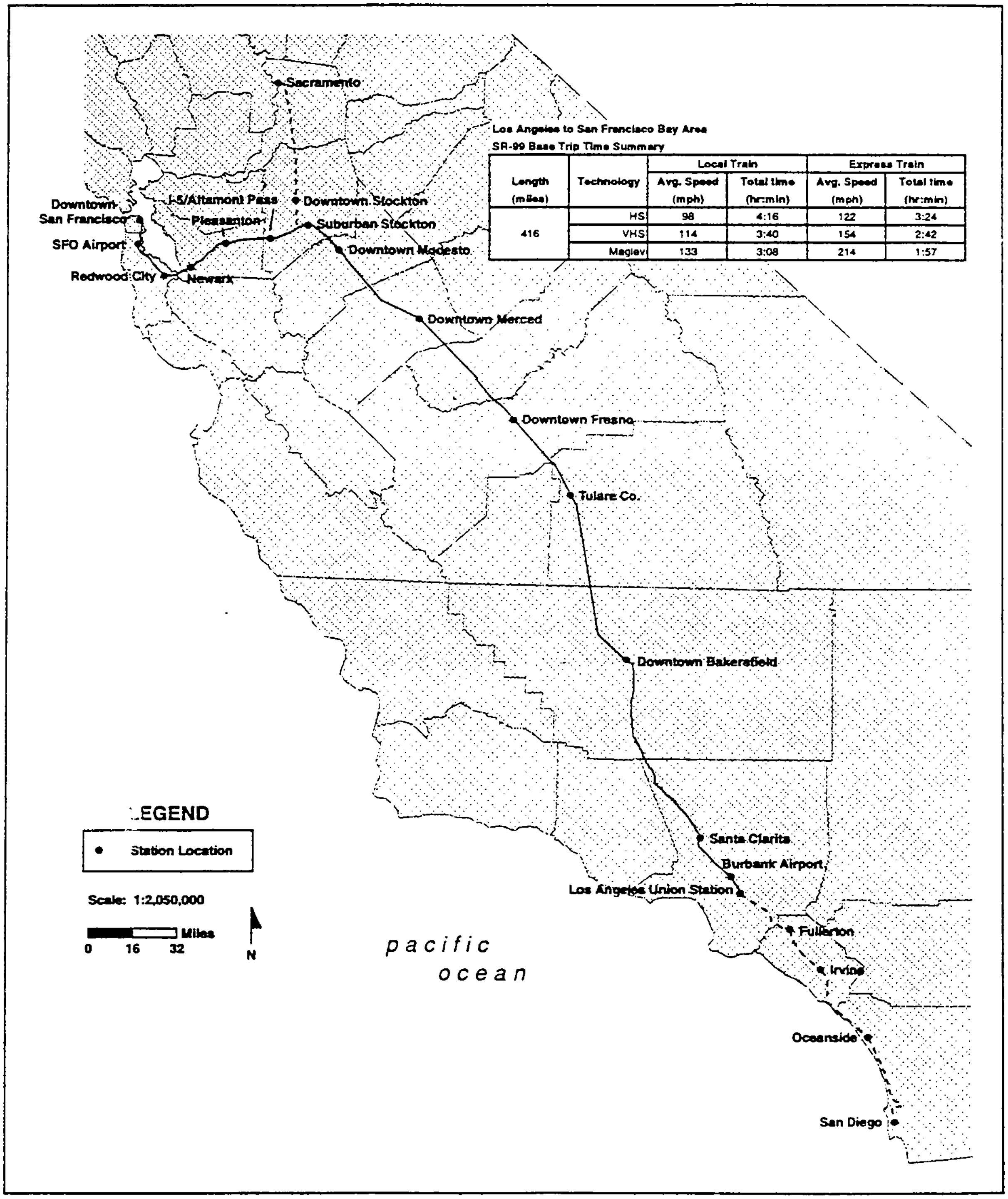
■ 3.5 SR-99 Alignment Scenarios

For ease of comprehension and presentation, the 58 potential high-speed rail alignment segments were aggregated into three statewide alignment scenarios between Los Angeles and the Bay Area.

- The **SR-99 Base** alignment is an intermediate length option using the Grapevine Pass in the south and the Altamont Pass in the north. Under this scenario, an extension to Sacramento would likely use the Stockton route (Figure 3.3).
- The **SR-99 Short** alignment scenario uses the Grapevine Pass in the south and the Panoche Pass in the north (Figure 3.4).
- The **SR-99 Long** alignment scenario uses the Palmdale option to cross the Tehachapis in the south and the Altamont Pass in the north (Figure 3.5).

Travel times corresponding to these alignment scenarios were inputs to the ridership and revenue forecasts (see Chapter 4.0). Capital costs corresponding to the SR-99 Base alignment scenario were inputs to the financing plan (see Chapter 6.0) and the economic impacts analysis (see Chapter 7.0). Capital costs were also estimated for the four potential extension corridors to San Diego and Sacramento including the LOSSAN Corridor (Los Angeles to San Diego), the I-15 Corridor (Los Angeles to San Diego), the Capitol Corridor (Oakland to Sacramento), and the Stockton Corridor (Stockton to Sacramento).

Figure 3.3 SR-99 Base Alignment (with extensions shown)

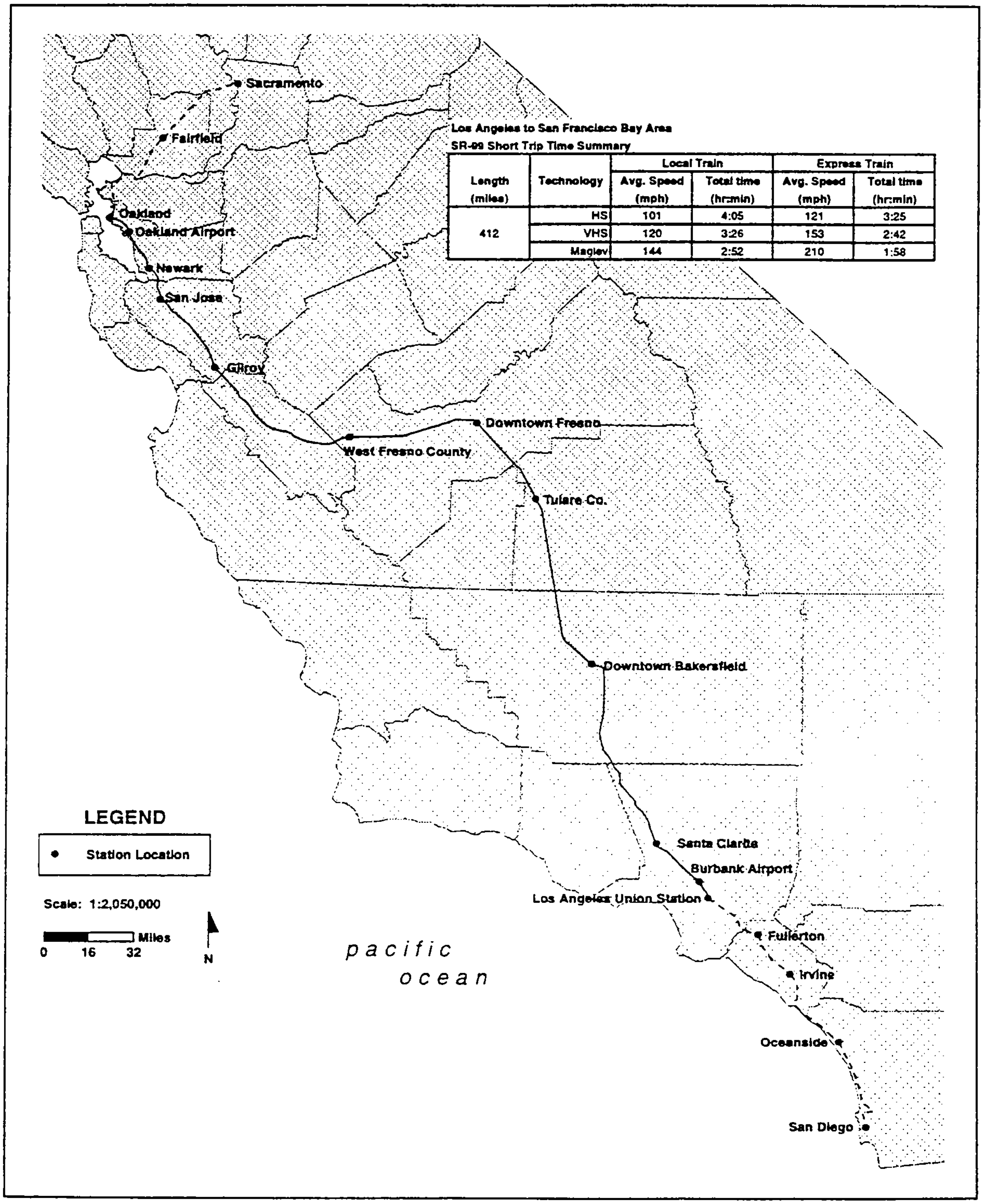


Los Angeles to San Francisco Bay Area
SR-99 Base Trip Time Summary

Length (miles)	Technology	Local Train		Express Train	
		Avg. Speed (mph)	Total time (hr:min)	Avg. Speed (mph)	Total time (hr:min)
416	HS	98	4:16	122	3:24
	VHS	114	3:40	154	2:42
	Maglev	133	3:08	214	1:57

Source: Parsons Brinckerhoff.

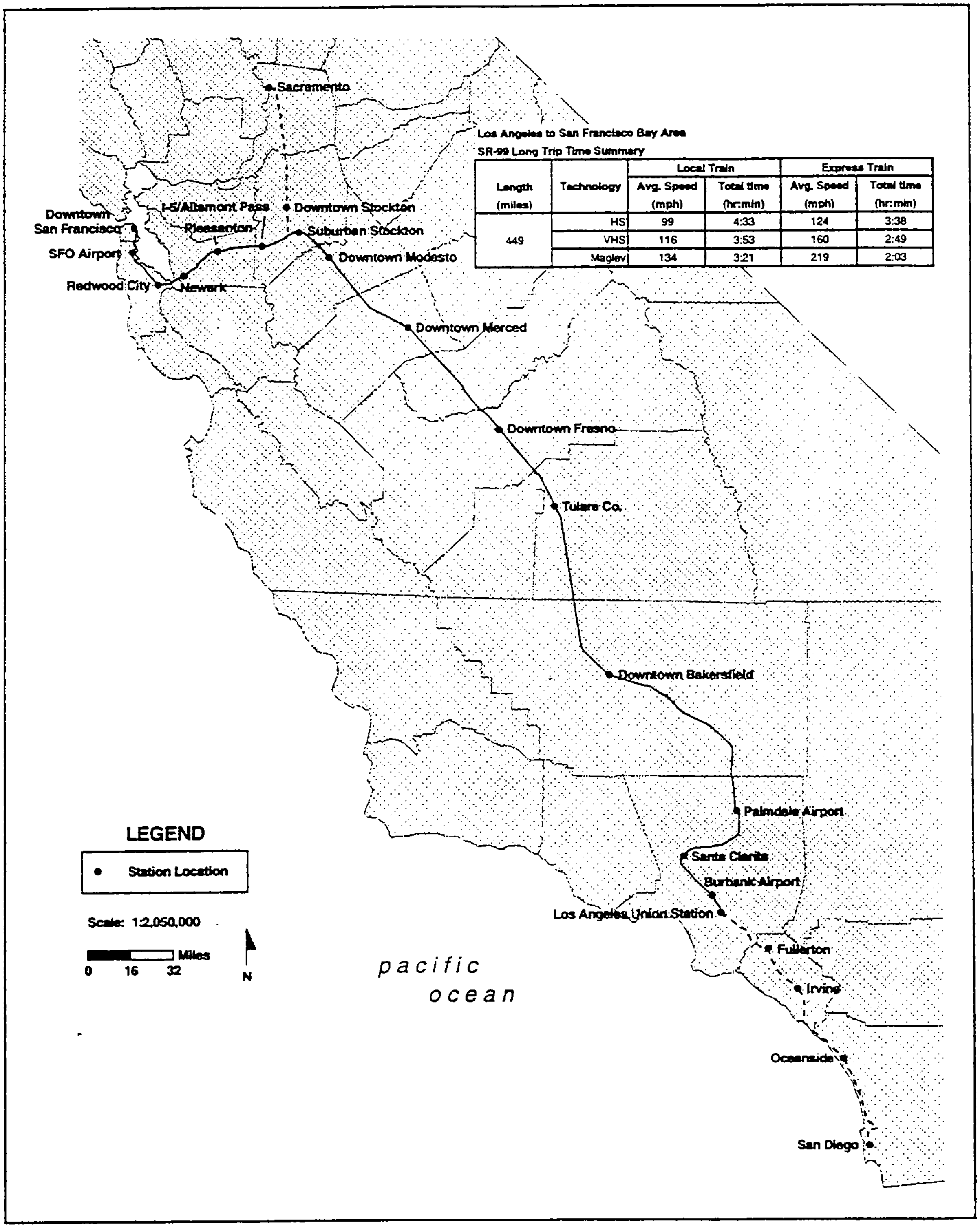
Figure 3.4 SR-99 Short Alignment (with extensions shown)



Length (miles)	Technology	Local Train Avg. Speed (mph)	Local Train Total time (hr:min)	Express Train Avg. Speed (mph)	Express Train Total time (hr:min)
412	HS	101	4:05	121	3:25
	VHS	120	3:26	153	2:42
	Maglev	144	2:52	210	1:58

Source: Parsons Brinckerhoff.

Figure 3.5 SR-99 Long Alignment (with extensions shown)



Los Angeles to San Francisco Bay Area
SR-99 Long Trip Time Summary

Length (miles)	Technology	Local Train		Express Train	
		Avg. Speed (mph)	Total time (hr:min)	Avg. Speed (mph)	Total time (hr:min)
449	HS	99	4:33	124	3:38
	VHS	116	3:53	160	2:49
	Maglev	134	3:21	219	2:03

Source: Parsons Brinkerhoff.

3.6 Capital Costs

Capital cost estimates were prepared for each of the 58 alignment segments and aggregated according to the alignment scenarios described above. The capital costs for the scenarios demonstrate the range of costs to be expected given the different alignment alternatives. To fully demonstrate the range of possible costs, a low and high option was estimated for each alignment scenario. These low and high cost options account for the cost differences associated with profile options as well as more subtle horizontal alignment alternatives.

3.6.1 Capital Cost Methodology

Capital cost estimates were prepared using a parametric approach. After determining the appropriate capital cost elements and unit costs, cost element quantities were tabulated from high-speed rail alignment plans. Quantities were then multiplied by the unit costs to provide a complete cost estimate for each alignment segment. The total capital cost for each alternative includes allowances for design, construction management, and contingencies. The cost estimates are in 1996 dollars.

The capital cost elements include:

- Alignment Costs
  - Track and guideway items
  - Earthwork and related items
  - Structures
  - Grade separations
  - Rail and utility relocation
- System Costs
  - Signals and communications
  - Electrification items
- Passenger Station Costs
  - Passenger stations
  - Site development and parking
- Right-of-Way Costs
- Environmental Impact Mitigation Costs
- Vehicle Costs
- Support Facility Costs
- Program Implementation Costs
  - Program and design management
  - Final design

- Construction and design management
- Force account costs
- Risk management
- Testing and pre-revenue operations

- Contingencies

Unit costs developed for the *Los Angeles Bakersfield HSGT Preliminary Engineering Feasibility Study* provided the basis for capital cost estimates in this study. These unit costs are the result of extensive research and data collection, developed specifically for California's unique geographic and geologic features, conditions, and construction practices. The costs were arrived at through detailed preliminary engineering analysis of tunnels, aerial structures, and other fixed facilities, as well as system elements such as electrification, communications, and signals and controls. Consideration of geotechnical information and safety issues was paramount throughout the analysis.

In addition to "base" unit costs that are the same throughout the system (for example, the cost per mile of track), certain specialized unit costs were developed to reflect various site specific conditions (for example, earthwork will be more expensive in mountainous terrain than in flat areas). Table 3.2 lists the alignment unit costs developed for this study.

3.6.2 Cost Estimates

Capital cost estimates for the basic Los Angeles-San Francisco system range from $11.1 billion for the low-cost SR-99 Base alignment scenario with VHS technology to $21.4 billion for the SR-99 Long scenario with Maglev. The extension to San Diego will add another $4.5 to 7.9 billion and the extension to Sacramento will add $1.6 to 3.5 billion, depending upon routes and technology. Tables 3.3 and 3.4 provide a comparative breakdown by system element of the capital costs for the three SR-99 alignment scenarios and the extensions.

The estimated capital costs for high-speed rail in California are somewhat higher than costs estimated for other high-speed rail corridors in the nation. Due to seismic design issues, costs in California tend to be higher where structures are proposed. Construction costs in California also tend to be higher than those found in operating high-speed rail systems in Europe, primarily due to added costs of seismic design and construction industry costs. In addition, since there has been relatively little rail investment in California over the past decades, greater capital investment is now required to upgrade existing corridors to high-speed standards or essentially construct high-speed alignments from scratch.

Other studies suggest a range of construction costs from $10 to $45 million per mile. The average cost per mile in this study ranges from $13.9 million for construction in flat, sparsely populated areas to $58.6 million for very difficult construction on the congested San Francisco Bay Peninsula (See Table 3.5). The average cost per mile for the basic system between Los Angeles and San Francisco ranges from $28 to $39 million per mile for VHS technology and $40 to $50 million per mile for Maglev, depending upon the alignment scenario.

Table 3.2 Alignment Unit Costs

Track and Guideway Items		Unit	Unit Price
1	HS/VHS Track - Ballasted	mile	$1,062,000
2	HS/VHS Track - Direct Fixation	mile	2,221,000
3	Maglev - At Grade Slab and Track Beam	mile	4,957,000
4	Maglev - Track Beam (Aerial and Tunnel)	mile	3,259,000
5	Special Trackwork (VHS) - Suburban	mile	282,000
6	Special Trackwork (VHS) - Dense Suburban	mile	443,000
7	Special Trackwork (VHS) - Urban	mile	644,000
8	Special Trackwork (VHS) - Dense Urban	mile	644,000
9	Special Trackwork (UHS) - Suburban	mile	541,000
10	Special Trackwork (UHS) - Dense Suburban	mile	850,000
11	Special Trackwork (UHS) - Urban	mile	1,236,000
12	Special Trackwork (UHS) - Dense Urban	mile	1,236,000
Earthwork and Related Items			
1	Clearing and Grubbing	acre	$31,000
2	Erosion Control	acre	15,000
3	Excavation	cu-yd	5
4	Imported Borrow	cu-yd	8
5	Subballast	cu-yd	5
6	Fencing (Both Sides of R/W)	mile	72,000
7	Drainage Facilities % (5% of Earthwork Cost)		
Structures, Tunnels and Walls			
1	Standard Aerial Structures	mile	$17,284,000
2	Special Aerial Structures	mile	47,283,000
3	Cut and Cover Tunnels	mile	30,578,000
4	Double Track Tunnels - Drill and Blast	mile	34,923,000
	Double Track Tunnels - Mined (soft soil)	mile	96,561,000
5	2 Single Track Tunnels - Drill and Blast	mile	73,386,000
6	2 Single Track Tunnels - Tunnel Boring Machine	mile	45,866,000
7	Sound Walls	mile	595,000
8	Crash Walls	mile	1,770,000
9	Seismic Chamber	each	55,000,000
10	Retaining Walls	mile	5,198,000
Grade Separations			
1	Under Crossing - (Dense Urban, Urban)	each	$13,200,000
2	Over Crossing - (Dense Urban, Urban)	each	12,600,000
3	Under Crossing- (Dense Suburban)	each	5,000,000
4	Over Crossing- (Dense Suburban)	each	4,800,000
5	Under Crossing - (Suburban, Undeveloped)	each	850,000
6	Over Crossing - (Suburban, Undeveloped)	each	800,000
7	Close Existing At Grade Crossing	each	130,000
8	Waterway Crossing - Primary	each	5,000,000
9	Waterway Crossing - Secondary	each	2,500,000
10	Irrigation/Canal Crossing	each	300,000

Table 3.2 Alignment Unit Costs (continued)

Building Items		Unit	Unit Price
1	Terminal Station	LS	$88,000,000
2	Site Development/Parking (Terminal Station)	LS	22,000,000
3	Urban Station	LS	44,000,000
4	Site Development/Parking (Urban Station)	LS	11,000,000
5	Suburban Station	LS	22,000,000
6	Site Development/Parking (Suburban Station)	LS	5,500,000
7	Rural Station	LS	11,000,000
8	Site Development/Parking (Rural Station)	LS	2,200,000
Rail and Utility Relocation			
1	Existing R/R Relocation	mile	$1,609,000
2	Utility Relocation - Dense Urban	mile	1,046,000
3	Utility Relocation - Urban	mile	805,000
4	Utility Relocation - Dense Suburban	mile	563,000
5	Utility Relocation - Suburban	mile	322,000
6	Utility Relocation - Undeveloped	mile	16,000
Right-of-Way			
1	Right-of-way - Dense Urban	mile	$7,725,000
2	Right-of-way - Urban	mile	4,989,000
3	Right-of-way - Dense Suburban	mile	1,448,000
4	Right-of-way - Suburban	mile	644,000
5	Right-of-way - Undeveloped	mile	322,000
Environmental Impact Mitigation			
1	Landscaping	acre	$0
2	Environmental Mitigation	%	(3% of Construction)
Signaling and Communications			
1	Signaling - HS/VHS	mile	$563,000
2	Communications - HS/VHS	mile	145,000
3	Signaling - Maglev	mile	1,239,000
4	Communications - Maglev	mile	145,000
Electrification			
1	Traction Power Substations - HS/VHS	mile	$547,000
2	Traction Power Distribution Systems - HS/VHS	mile	1,207,000
3	Traction Power Substations - Maglev	mile	1,030,000
4	Traction Power Distribution Systems - Maglev	mile	3,927,000

Source: Parsons Brinckerhoff

Table 3.3 Capital Cost Summary for SR-99 Alignment Scenarios Los Angeles to San Francisco Bay Area ($ millions, 1996)

	HS/VHS Technology					
	SR-99 Short		SR-99 Long		SR-99 Base	
Item	Low	High	Low	High	Low	High
Station Costs	$481	$564	$536	$646	$495	$619
Track and Guideway Systems	573	664	631	724	570	691
Earthwork and Related Items	1,180	1,302	639	684	503	633
Structures	2,220	3,232	2,180	3,280	1,926	3,336
Grade Separations	722	1,126	758	1,440	789	1,379
Right of Way	551	881	796	1,191	735	1,154
Environmental Impact Mitigation	191	257	188	268	170	261
Rail & Utility Relocations	143	344	179	475	149	455
Signals and Communications	280	288	314	319	281	294
Electrification Items	694	744	778	821	697	758
Subtotal	**$7,036**	**$9,401**	**$7,001**	**$9,849**	**$6,315**	**$9,581**
Program Implementation (30%)	2,111	2,820	2,100	2,955	1,894	2,874
Contingency (25%)	1,759	2,350	1,750	2,462	1,579	2,395
Vehicles	979	979	979	979	979	979
Support Facilities	285	285	285	285	285	285
Total Cost	**$12,170**	**$15,836**	**$12,115**	**$16,530**	**$11,052**	**$16,114**
Total Length (miles	**397.8**	**406.4**	**439.1**	**448.4**	**399.3**	**414.5**
Cost Per Mile	$31	$39	$28	$37	$28	$39

Table 3.3 Capital Cost Summary for SR-99 Alignment Scenarios Los Angeles to San Francisco Bay Area ($ millions, 1996) (continued)

	Maglev Technology					
	SR-99 Short		SR-99 Long		SR-99 Base	
Item	Low	High	Low	High	Low	High
Station Costs	$481	$564	$536	$646	$495	$619
Track and Guideway Systems	2,041	2,043	2,331	2,331	2,104	2,122
Earthwork and Related Items	1,104	1,206	639	684	427	538
Structures	2,371	3,445	2,199	3,250	2,076	3,548
Grade Separations	722	1,126	819	1,379	850	1,379
Right of Way	551	857	796	1,191	735	1,130
Environmental Impact Mitigation	191	257	188	268	170	261
Rail & Utility Relocations	143	344	179	475	149	455
Signals and Communications	547	562	615	625	550	575
Electrification Items	1,958	2,014	2,202	2,239	1,970	2,059
Subtotal	**$10,109**	**$12,418**	**$10,505**	**$13,089**	**$ 9,525**	**$12,686**
Program Implementation (30%)	3,033	3,725	3,152	3,927	2,858	3,806
Contingency (25%)	2,527	3,105	2,626	3,272	2,381	3,171
Vehicles	796	796	796	796	796	796
Support Facilities	285	285	285	285	285	285
Total Cost	**$16,749**	**$20,329**	**$17,364**	**$21,368**	**$15,845**	**$20,744**
Total Length (miles)	**397.8**	**406.4**	**439.1**	**448.4**	**399.3**	**414.5**
Cost Per Mile	$42	$50	$40	$48	$40	$50

Source: Parsons Brinckerhoff, 1996.

Table 3.4 Capital Cost Summary for San Diego and Sacramento Extensions ($ millions, 1996)

	HS/VHS Technology						
	San Diego Extension				Sacramento Extension		
	LOSSAN Corridor		I-15 Corridor		Capitol	Stockton Corridor	
Item	San Clemente	Bypass	Penasquitos Cyn.	Mission Cyn.	Corridor	Low	High
Station Costs	$248	$248	$248	$248	$138	$124	$165
Track and Guideway Systems	202	202	256	255	143	94	99
Earthwork and Related Items	139	210	379	308	25	20	20
Structures	601	676	868	882	353	171	281
Grade Separations	740	689	1,052	1,231	191	244	300
Right of Way	384	388	320	304	290	191	190
Environmental Impact Mitigation	78	80	104	106	42	28	34
Rail & Utility Relocations	222	201	175	160	171	81	101
Signals and Communications	89	89	117	116	62	41	42
Electrification Items	221	219	289	287	153	101	105
Subtotal	**$2,925**	**$3,002**	**$3,807**	**$3,898**	**$1,568**	**$1,096**	**$1,337**
Program Implementation (30%)	878	900	1,142	1,169	470	329	401
Contingency (25%)	731	750	952	974	392	274	334
Total Cost	**$4,534**	**$4,653**	**$5,901**	**$6,042**	**$2,431**	**$1,698**	**$2,072**
Total Length (miles)	**120.2**	**119.1**	**159.0**	**157.8**	**87.5**	**57.7**	**59.7**
Cost Per Mile	$38	$39	$37	$38	$28	$29	$35

Table 3.4 Capital Cost Summary for San Diego and Sacramento Extensions ($ millions, 1996) (continued)

	Maglev Technology						
	San Diego Extension				Sacramento Extension		
	LOSSAN Corridor		I-15 Corridor		Capitol	Stockton Corridor	
Item	San Clemente	Bypass	Penasquitos Cyn.	Mission Cyn.	Corridor	Low	High
Station Costs	$248	$248	$248	$248	$138	$124	$165
Track and Guideway Systems	651	637	820	805	493	324	320
Earthwork and Related Items	139	210	379	308	25	20	20
Structures	601	676	868	882	353	171	281
Grade Separations	740	689	1,052	1,231	191	244	300
Right of Way	384	388	320	304	290	191	190
Environmental Impact Mitigation	78	80	104	106	42	28	34
Rail & Utility Relocations	222	201	175	160	171	81	101
Signals and Communications	175	173	228	227	121	80	83
Electrification Items	625	620	817	812	434	286	296
Subtotal	**$3,863**	**$3,922**	**$5,011**	**$5,083**	**$2,257**	**$1,549**	**$1,789**
Program Implementation (30%)	1,159	1,176	1,503	1,525	677	465	537
Contingency (25%)	966	980	1,253	1,271	564	387	447
Total Cost	**$5,988**	**$6,079**	**$7,767**	**$7,878**	**$3,498**	**$2,401**	**$2,774**
Total Length (miles)	**120.2**	**119.1**	**159.0**	**157.8**	**87.5**	**57.7**	**59.7**
Cost Per Mile	$50	$51	$49	$50	$40	$42	$46

Source: Parsons Brinckerhoff, 1996.

Table 3.5 Average Construction Costs Per Mile

Corridor	Features	Cost per Mile ($ millions, 1996)
Central Valley (Bakersfield-Fresno)	Flat, sparsely populated	$13.9
Tehachapi Crossing (I-5)	Mountainous, lengthy tunnels	$35.0
Los Angeles Basin	Urban, congested	$44.0
San Francisco Bay Peninsula	Urban, narrow, congested, with subway in dense urban area	$58.6

Source: Parsons Brinckerhoff, 1996.

Key findings regarding the relative cost of various technology alternatives and alignments are listed below:

Technology – Infrastructure costs for HS and VHS technology are about the same since California's existing rail corridors have not been substantially improved and shared use of existing facilities is usually not an option. Infrastructure costs for Maglev are about 40 percent higher than HS or VHS, primarily because of Maglev's more expensive guideway, signaling, communications, and electrification elements.

Central Valley – A new alignment is the least costly option through the Central Valley, due to extensive at-grade running and minimal land use constraints. The Burlington Northern Santa Fe (BNSF) and Southern Pacific (SP) Corridors cost approximately $1 billion and $3 billion more than the new corridor. This additional cost is associated with the more urbanized setting of the BNSF and SP alignments and the need to share the alignments with freight.

Sacramento Extension – The Stockton Corridor is shorter and has fewer physical constraints than the Capitol Corridor, and is thus $350 million to $1.1 billion less expensive, depending on which alignment and technology is used (existing rail vs. new alignment skirting the urban areas).

San Diego Extension – The LOSSAN Corridor is $1.2 to $1.9 billion less expensive than the I-15 Corridor depending on the alignment options in the Mission Valley and San Clemente areas and technology. This is primarily due to the shorter length of the LOSSAN Corridor.

San Francisco Bay Alignments – Assuming the Altamont Pass entrance to the Bay Area, the Peninsula Corridor is estimated to cost about 60-70 percent more than the East Bay route ($868 million more with VHS and $962 million more with Maglev), measured from Newark to the system terminus. Much of the additional cost involved is due to the congested PCJB right-of-way and the need for a tunnel to downtown San Francisco to reach the Transbay Terminal. Some cost savings could be realized were the Peninsula Corridor to end at 4th and Townsend.

Northern Mountain Passes – The Altamont pass is the least costly of the three passes in total. The Pacheco Pass is $719-737 million more costly than Altamont Pass in total, and is 37-45 percent higher on a per mile basis. The Panoche Pass is $1.2-1.5 billion more costly than Altamont Pass in total, but slightly less costly than the Altamont Pass on a per mile basis.

Southern Mountain Passes – If constructed at a 3.5 percent maximum grade, costs for the three southern mountain pass options are roughly comparable for the rail technologies. Using a more aggressive profile on the Aqueduct and Mojave Passes does not result in significant cost savings. However, the Grapevine (I-5 Pass) is less expensive than the other t options if a 5 percent vertical profile is used. The Grapevine alternative is always less costly for Maglev technology.

3.7 Station Locations

The location, number of, and spacing between stations sited along the high-speed rail system will impact the system's ridership and revenue as well as local land uses. The location of the stations with respect to travel markets and transportation infrastructure, the relative ease of intermodal access to stations, and travel time to and from stations will be critical determinants of system performance, with ridership balanced against system costs. There is an important tradeoff between system accessibility and line-haul travel time.

Twenty-nine potential station service areas were analyzed, with an average spacing between service areas of roughly 40 miles. The criteria used to identify station service areas included proximity to key population and employment centers, proximity to high growth areas and/or major tourism and recreational areas, potential to serve key travel markets or city pairs, accessibility by auto, connectivity to other modes (transit, air) and station spacing. Station site options within each station service area were also evaluated according to similar criteria.[5]

Five station service types describe the roles and/or types of services afforded by the various station service areas and station site options, in conjunction with the conceptual operating plan described in the following section.

- **Urban Hub Station** – Urban Hub Stations are typically located at major city centers to address the significant demand for downtown service as well as to take advantage of intermodal access and businesses located in or around Central Business Districts. The Urban Hub Stations that serve as the system's terminals (for example, Los Angeles Union Station) will need to be adjacent or near service and maintenance facilities, connect with regional transit systems, and offer attractive opportunities for (re)development.

- **Urban Intermediate Station** – Urban Intermediate Stations are also located near city centers, but at sites relatively less likely to serve as a major intermodal hub for the surrounding area. Urban Intermediate Stations must be designed to allow through running at maximum speed, in order to accommodate the skip-stop and express services.

- **Suburban Hub Station** – Suburban Hub Stations are sited at suburban locations with the potential to evolve into intermodal hubs and gateways to entire metropolitan areas. These stations are typically located 5-15 miles from downtowns and are usually close to major activity centers. In most cases, such stations are integrated or closely linked with an existing urban transit system.

- **Suburban Intermediate Station** – These locations are often currently rural, are on the urban fringe (20-50 miles from the city center), and are considered because of the potential for developing the surrounding land. Suburban Intermediate Stations are

[5]The evaluations and findings are documented in *Candidate High Speed Rail Stations and Intermodal Connectivity: California High-Speed Rail Study.*

alternatives to suburban hub stations and would generally be served by local or skip-stop rail service. Suburban Intermediate Stations must be designed to allow through running at maximum speed, to accommodate the skip-stop and express service.

- **Airport Connection Station** – High-speed rail stations are located at or close to major airports wherever possible to take advantage of the intermodal connectivity offered at these sites. When located close to the airport, the sites should be linked with a people mover of some type to facilitate transfers between air and rail.

Not all high-speed rail trains would stop at every station. Urban Hub Stations, Airport Connection Stations, and Suburban Hub Stations would likely be served with express or semi-express high-speed rail service, as well as local service. Urban Intermediate Stations and Suburban Intermediate Stations would more likely be served only by local or skip-stop service. Each station service type would have different implications with regard to intermodal connectivity, as well as station dimensions and access and parking requirements.

While twenty-nine station service areas and forty-seven potential station sites were evaluated, the actual number of stations included in the high-speed rail system will be far fewer, depending on the alignment selected and final service pattern. The conceptual operating plan developed for the SR-99 Base alignment scenario assumed fourteen stations between Los Angeles Union Station and downtown San Francisco.

3.8 Operating Scenario and Travel Times

Operating scenarios were developed in conjunction with high-speed rail ridership forecasts, reflecting expected service requirements in the Los Angeles to San Francisco Bay Area Corridor and the associated extensions to San Diego and Sacramento. As preliminary ridership forecasts were refined, the operating plan was also adjusted to achieve the most appropriate operating plan – this was an iterative process between the ridership and corridor evaluation studies. Trains with a capacity of 600 to 650 passengers would generally operate with at least 60 percent occupancy rate using the final operational plan.

For any passenger rail operation, there is a trade-off between travel time and the number of station stops. More stops mean more of the population can be served, but at the cost of increased travel time. These conflicting objectives can be addressed by operating trains according to two or more stopping patterns, usually designated local and express. Express trains serve the market for travel between two major cities, making few, if any, intermediate stops, and offer the fastest travel time. Local trains serve the market for travel between smaller cities or between a small city and a large city. Local train travel times are much longer than express trains. Intermediate level services make more stops than express trains, but fewer than local trains.

Forty-eight weekday trains in each direction were assumed in the base operating scenario for 2015 in four service categories:

- **Express (18 trains/day)** – Trains running from either Sacramento or San Francisco to Los Angeles and San Diego without intermediate stops in the Valley.
- **Semi-Express (12 trains/day)** – Trains running between similar end points as the express, with intermediate stops at major Valley cities such as Modesto, Fresno and Bakersfield.
- **Suburb-Express (six trains/day)** – Trains running "local" during either the beginning or the end of the trip while running express through the intermediate points.
- **Local (12 trains/day)** – Trains stopping at all intermediate stops. At Stockton, the trains branch off to serve both Sacramento and Bay Area branches.

Under this plan, 25 trains per day stop at the San Jose station. Although passengers traveling to or from San Jose would not have to transfer, a time penalty would be incurred at Newark/Fremont to connect or disconnect the trains. The conceptual operating plan, which applies to all three types of technology, is shown in Table 3.6. Service would be decreased from the schedule shown in this table by approximately 30 percent on weekends. While this plan represents the final/best scenario for these feasibility studies, this plan will need further refinement during preliminary engineering, final design and initial high-speed rail system operations.

All operating scenarios reflect the general constraints on full-speed operations along the Corridor. The basic strategy for achieving fast end-to-end travel times involves full-speed operations through most of the flat, rural areas between the Bay Area and Los Angeles and slower speeds through urban areas. For example the average speed for VHS service between San Francisco and San Jose is 80 mph; between Los Angeles and San Diego it is 107 mph. Of course, local and skip stop service to the intermediate stations will involve reduced maximum and average speeds through the Central Valley. High-speed trains will also cross the mountain passes at slower than maximum speeds due to equipment limitations and safety considerations. Table 3.7 gives a general overview of the average speeds and travel times expected between Los Angeles and the San Francisco Bay Area for express and local service. Table 3.8 lists the travel times between representative city pairs.

■ 3.9 Operating Costs

Train-related operating and maintenance (O&M) costs are based on data from similar systems around the world. For HS and VHS technologies, specific comparisons were made where significant data were available. For the Maglev technology group, passenger revenue service experience does not exist and costs were based on projections by the consultant team. O&M costs were developed on a per train-mile basis to permit factoring over a wide range of service plans. Maintenance-of-way costs are based on track type and length, and the facilities to be constructed.

Table 3.6 Conceptual Operating Plan (Weekday Operation)

NORTHBOUND

	Service Assumptions				Station Stops																						
Train No.	Origin	Destination	Departs LA	Service Type	SD	ESC OCD	RIV IRV	OCA ONT FUL	LAX LA	BURD BURA	SC5 SC14	PLM	15/58 SBAK BAK	TUL	WFC SFRO FRO	MER LB GIL	MOD1 MOD2 MOD3	T/M	SJ	AP	PLE	FRE NW PA RC	OAP SFO	OAK SF	FF STO	SAC	Total Stops
1	SD	SF/OAK	600	Express	•				•															•			1
2	SD	SF/OAK/SAC	610	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
3	SD	SAC	620	Suburb-Ex	•	•	•	•	•	•	•	•														•	7
4	SD	SF/OAK	630	Suburb-Ex	•	•	•	•	•	•	•	•												•			7
5	LA	SF/OAK	645	Semi-Ex					•				•		•		•		•					•			4
6	LA	SF/OAK	700	Express					•															•			0
7	LA	SF/OAK	710	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			18
8	LA	SAC	715	Semi-Ex					•				•		•		•								•	•	4
9	SD	SAC	730	Express	•				•																•	•	2
10	SD	SF/OAK	745	Suburb-Ex	•	•	•	•	•	•	•	•							•					•			8
11	SD	SF/OAK	800	Express	•				•															•			1
12	SD	SF/OAK/SAC	810	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
13	LA	SAC	830	Express					•																	•	0
14	SD	SF/OAK	845	Semi-Ex	•				•				•		•		•		•					•			5
15	LA	SF/OAK	900	Express					•										•					•			1
16	SD	SF/OAK	910	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			18
17	SD	SAC	915	Semi-Ex	•				•				•		•		•								•	•	6
18	LA	SF/OAK	1000	Express					•															•			0
19	SD	SF/OAK/SAC	1010	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
20	LA	SF/OAK	1100	Semi-Ex					•				•		•		•		•					•			4
21	SD	SF/OAK	1200	Express	•				•															•			1
22	SD	SF/OAK/SAC	1210	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
23	LA	SAC	1230	Express					•																	•	0
24	SD	SF/OAK	1245	Semi-Ex	•				•				•		•		•		•					•			5
25	LA	SF/OAK	100	Express					•										•					•			1
26	LA	SF/OAK	115	Semi-Ex					•				•		•		•		•					•			4
27	SD	SF/OAK	200	Express	•				•															•			1
28	SD	SF/OAK/SAC	210	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
29	SD	SF/OAK	300	Semi-Ex	•				•				•		•		•		•					•			5
30	LA	SF/OAK	400	Express					•															•			0
31	SD	SF/OAK/SAC	410	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
32	SD	SAC	420	Suburb-Ex	•				•									•							•	•	3
33	SD	SF/OAK	430	Suburb-Ex	•				•										•	•	•	•	•	•			6
34	SD	SAC	445	Semi-Ex	•				•				•		•		•								•	•	5
35	LA	SF/OAK	500	Express					•															•			0
36	SD	SF/OAK	510	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			18
37	SD	SF/OAK	515	Semi-Ex	•				•				•		•		•		•					•			5
38	LA	SAC	530	Express					•																•	•	1
39	SD	SF/OAK	545	Suburb-Ex	•				•										•	•	•	•	•	•			6
40	SD	SF/OAK	600	Express	•				•															•			1
41	SD	SF/OAK/SAC	610	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
42	LA	SAC	630	Express					•																	•	0
43	SD	SAC	645	Semi-Ex	•				•				•		•		•								•	•	5
44	LA	SF/OAK	700	Express					•															•			0
45	LA	SF/OAK	710	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			18
46	LA	SF/OAK	715	Semi-Ex					•				•		•		•		•					•			4
47	SD	SF/OAK	800	Express	•				•															•			1
48	SD	SF/OAK/SAC	810	Local	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
		TOTAL TRAINS			32	15	15	15	48	15	15	15	24	12	24	12	24	13	25	14	14	14	14	37	15	19	

Station Legend

SD = San Diego
ESC = Escondido
OCD = Oceanside
RIV = Riverside
IRV = Irvine
OCA = Orange Co. Airport
ONT = Ontario
FUL = Fullerton
LAX = Los Angeles Airport
LA = Los Angeles Union Sta
BURD = Burbank (Downtown)
BURA = Burbank (Airport)
SC 5= Santa Clarita (I-5)
SC 14= Santa Clarita (ISR-14)
PLM = Palmdale
I5/58 = I-5/SR-58
SBAK = Suburban Bakersfld
BAK = Bakersfield
TUL = Tulare County
FRO = Fresno
SFRO=Suburban Fresno
WFC = West Fresno Co.
MER = Merced
SMER=Suburban Merced
LB = Los Banos
GIL = Gilroy
SJ = San Jose
MOD1= Modesto(Downtown)
MOD2=Modesto (Briggmore)
MOD3=Modesto (Riverbank)
T/M = Tracy/Manteca
AP = Altmont Pass
PLE = Pleasanton
FRE = Fremont
NW = Newark
PA = Palo Alto
RC = Redwood City
OAP = Oakland Airport
SFO = San Francisco Airport
OAK = Oakland

Table 3.7 Trip Time Summary
Los Angeles to San Francisco Bay Area

			Local Train		Express Train	
Alternative	**Length (miles)**	**Technology**	**Average Speed (mph)**	**Total Time**	**Average Speed (mph)**	**Total Time**
SR-99 Short	412	HS	101	4 hr. 5 min.	121	3 hr. 25 min.
		VHS	120	3 hr. 26 min.	153	2 hr. 42 min.
		MAGLEV	144	2 hr. 52 min.	210	1 hr. 58 min.
SR-99 Long	449	HS	99	4 hr. 33 min.	124	3 hr. 38 min.
		VHS	116	3 hr. 53 min.	160	2 hr. 49 min.
		MAGLEV	134	3 hr. 21 min.	219	2 hr. 3 min.
SR-99 Base	418	HS	98	4 hr. 15 min.	122	3 hr. 25 min.
		VHS	115	3 hr. 39 min.	155	2 hr. 42 min.
		MAGLEV	133	3 hr. 8 min.	214	1 hr. 57 min.
San Diego Extensions						
I-15 Corridor	158	HS	107	1 hr. 29 min.	119	1 hr. 20 min.
		VHS	117	1 hr. 21 min.	132	1 hr. 12 min.
		MAGLEV	137	1 hr. 9 min.	163	58 min.
LOSSAN Corridor	121	HS	94	1 hr. 17 min.	105	1 hr. 9 min.
		VHS	94	1 hr. 17 min.	107	1 hr. 8 min.
		MAGLEV	113	1 hr. 4 min.	132	55 min.

Source: Parsons Brinckerhoff, 1996.

Table 3.8 Express Travel Times Between Major City Pairs VHS Technology (minutes)

	San Diego	Los Angeles	Riverside	Palmdale	Bakersfield	Fresno	Merced	Modesto	Stockton	Newark	San Jose	San Francisco	Sacramento
San Diego	-	70	33	102	120	151	166	177	187	204	213	231	213
Los Angeles	70	-	39	32	51	82	97	108	118	135	145	162	144
Riverside	33	39	-	70	89	120	135	146	157	173	183	200	182
Palmdale	102	32	70	-	30	60	75	87	97	113	123	140	122
Bakersfield	120	51	89	30	-	32	47	58	68	85	94	112	94
Fresno	151	82	120	60	32	-	16	27	38	54	64	81	63
Merced	166	97	135	75	47	16	-	13	23	39	49	66	48
Modesto	177	108	146	87	58	27	13	-	11	28	37	54	36
Stockton	187	118	157	97	68	38	23	11	-	29	39	56	26
Newark	204	135	173	113	85	54	39	28	29	-	11	28	55
San Jose	213	145	183	123	94	64	49	37	39	11	-	37	64
San Francisco	231	162	200	140	112	81	66	54	56	28	37	-	81
Sacramento	213	144	182	122	94	63	48	36	26	55	64	81	-

Table 3.8 Express Travel Times Between Major City Pairs Maglev Technology (minutes) (continued)

	San Diego	Los Angeles	Riverside	Palmdale	Bakersfield	Fresno	Merced	Modesto	Stockton	Newark	San Jose	San Francisco	Sacramento
San Diego	-	55	28	79	93	115	125	133	141	151	158	171	162
Los Angeles	55	-	30	24	39	61	71	79	87	97	104	117	107
Riverside	28	30	-	53	68	89	100	108	115	126	133	146	136
Palmdale	79	24	53	-	22	44	54	62	70	80	87	100	91
Bakersfield	93	39	68	22	-	23	33	41	49	59	66	79	69
Fresno	115	61	89	44	23	-	11	19	27	37	44	58	48
Merced	125	71	100	54	33	11	-	9	17	27	34	54	37
Modesto	133	79	108	62	41	19	9	-	9	19	26	39	29
Stockton	141	87	115	70	49	27	17	9	-	22	29	42	22
Newark	151	97	126	80	59	37	27	19	22	-	8	21	43
San Jose	158	104	133	87	66	44	34	26	29	8	-	28	50
San Francisco	171	117	146	100	79	58	54	39	42	21	28	-	63
Sacramento	162	107	136	91	69	48	37	29	22	43	50	63	-

Source: Parsons Brinckerhoff, 1996.

Train operating cost estimates are broken down into eight categories:

- **Train Operations** includes direct labor costs associated with train operations, transportation supervision and on-board services, as well as train supplies.
- **Maintenance of Equipment** includes all running maintenance and progressive overhaul costs for rolling stock (cars and locomotives).
- **Maintenance of Way** includes maintenance and progressive replacement costs for track and all permanent structures, including bridges, tunnels and power distribution systems.
- **Station Services** includes labor and other operating costs for stations, including ticketing and upkeep.
- **Marketing and Reservations** includes sales and advertising costs, and operation of reservation systems.
- **Insurance** includes casualty, liability and property insurance costs.
- **General Support** includes corporate, administrative, and overhead costs, such as accounting, finance, and executive management.

Unit costs for operations and maintenance are shown in Table 3.9. Annual operating and maintenance cost estimates for the Corridor range from $224-262 million for the basic system to about $317-375 million for the system with extensions. Table 3.10 shows the operating and maintenance costs for the SR-99 Base alignment.

3.10 Environmental Impacts

The Environmental Constraints and Impacts Analysis was conducted to identify those environmental issues that could affect the system's feasibility, routing, and technology selection. The analysis is not an Environmental Impact Report (EIR). The EIR necessarily will come much closer to the actual implementation of the high-speed rail system. Following selection of a specific route alignment, full environmental documentation pursuant to the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) would be required.

Each segment of the alignments was analyzed separately to identify potential environmental constraints and impacts. By combining the constraints and impacts for a number of segments, the overall level of environmental impact for entire corridors could be characterized. A number of conceptual stations sites along the alignments were also analyzed to identify impacts associated with stations, such as air quality impacts and growth inducement.

The environmental constraints and impacts analysis was organized into five overall categories, each of which is comprised of multiple types of impacts or constraints.

Table 3.9 Operating Costs per Train Mile

Item	Long-Term Avoidable Cost (per train mile)
Commercial Cost Components	
Train Operations	$5.53
Equipment Maintenance	$6.48
Station Services	$0.45
Marketing and Reservations	$1.16
Insurance	$1.11
General Support	$0.85
Subtotal	$15.58
Maintenance-of-Way	$2.17
Total	$17.75

Source: Parsons Brinckerhoff, 1996.

Table 3.10 Operations & Maintenance Cost Estimate Summary – SR-99 Base Alignment

Basic System (without Extensions)

		Operating Unit Costs (per train-mile)			Annual
Technology	Annual Train-Miles (millions)	Non-Power	Energy	Total	O & M Cost*
HS/VHS	11.6	$17.75	$2.72	$20.47	$238.2
Maglev	11.6	$17.75	$3.12	$20.87	$243.0

*Note: Cost in millions of 1996 dollars.

With Extensions to San Diego and Sacramento

		Operating Unit Costs (per train-mile)			Annual
Technology	Annual Train-Miles (millions)	Non-Power	Energy	Total	O & M Cost *
HS/VHS	15.4	$17.75	$2.72	$20.47	$314.9
Maglev	15.4	$17.75	$3.12	$20.87	$321.1

*Note: Cost in millions of 1996 dollars.

Source: Parsons Brinckerhoff.

- Natural Environment Impacts
  - Water Resources/Flood Plane Impacts
  - Wetlands Impacts
  - Threatened and Endangered Species Impacts
  - Air Quality Impacts

- Social/Cultural Resources Impacts
  - Parks and Recreation/Wildlife
  - Refuge Impacts
  - Cultural Resources Impacts
  - Displacements
  - Socioeconomic Impacts
  - Environmental Justice

- Farmland Impacts

- Land Use Impacts
  - Land Use Compatibility
  - Consistency with Regional Plans
  - Growth Inducement
  - Visual Quality Impacts
  - Noise and Vibration Impacts
  - Electromagnetic Field (EMF) Impacts

- Engineering / Environmental Constraints
  - Soils/Slope Constraints
  - Seismic Constraints
  - Hazardous Materials/Waste Constraints
  - Regulatory Compliance
  - Mitigation Costs

Overall, no "fatal flaws" were found which would preclude high-speed rail implementation. Based on the quantitative environmental analysis, the following overall impacts were identified as key areas for the high-speed rail system:

Central Valley – Overall, environmental constraints and impacts of most high-speed rail segments through the Central Valley are low to low-medium in severity, particularly between Bakersfield and Stockton.

Bay Area Access – Environmental constraints and impacts of the East Bay Corridor (Oakland) segments are somewhat lower than the segments between San Jose and San Francisco. Both options are low to low-medium in impact severity.

Los Angeles Access – Segments which would provide access to Los Angeles are along existing rail lines; as such, these would result in low to medium environmental impacts.

Sacramento-Bay Area-Stockton – Segments connecting Sacramento, the Bay Area, and Stockton would result in low to medium environmental constraints and impacts.

San Diego-Los Angeles – The two routes between San Diego and Los Angeles, generally along I-5 and I-15, would result in potentially significant impacts. The I-15 segment is ranked high in most impact categories. It would traverse undeveloped land that is rich in habitat for threatened and endangered species, wetlands, and water resources. The portion of the segment closer to San Diego and that between Los Angeles and Riverside would result in substantial residential displacements, socioeconomic impacts, and potentially high and adverse disproportional impacts to minorities and low-income populations. In addition, this segment would traverse the largest number of potential hazardous materials/waste sites.

For the I-5 segments, the portion between Los Angeles and Fullerton is ranked low to medium in impacts. Between Fullerton and San Diego, the visual impacts in coastal areas, impacts to parks and recreation areas, and noise and vibration impacts to surrounding residential areas would be substantial. These impacts may render the segments along the coast infeasible for very high speed operations.

Mountain Passes-Northern California – The Panoche and Pacheco passes would have higher impacts than the Altamont Pass, particularly to wetlands and habitat for threatened and endangered species.

Mountain Passes-Southern California – The Grapevine Pass would result in higher impacts than the Aqueduct or the Mojave options due to wetlands impacts, parks and recreation impacts, land use incompatibility, and a number of engineering and environmental constraints.