Title

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Authors

Leavitt, Dan
Ennis, Sean
McGovern, Pat

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Dan Leavitt
Sean Ennis
Pat McGovern

Institute of Urban and Regional Development
University of California at Berkeley
Berkeley, CA 94720

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CONTENTS

PREFACE

This is one of a series of reports now being published as the output of IURD's study of the potential for a high-speed passenger train service in California. The present series includes twelve studies. This is the eleventh of twelve studies, ten of which have already been published.

We gratefully acknowledge the support provided by the United States Department of Transportation and the California Department of Transportation [CALTRANS] through the University of California Transportation Center. Of course, any errors of fact or interpretation should be assigned to us and not to our sponsors.

PETER HALL
Principal Investigator

AUTHOR'S NOTE

My thanks go to Gary Griggs of Parsons Brinckerhoff, and Denis Douté of Rail Transportation Systems, Inc., who were most helpful in providing information and offering comments and criticism on the draft version of this report. Thanks also go to Joel Tranter and Erin Vaca of the CalSpeed study group for their contributions, and to the staff at I.U.R.D for their support in producing this report.

SUMMARY

This report is a follow-up study to last year's CalSpeed publication, "High-Speed Trains for California," Working Paper No. 565. The purpose of this paper is to test rigorously and critically the cost estimate methodology presented in that previous working paper. This has been accomplished primarily by focusing on the issue of cost escalation of rail projects, with reference to both U.S. and foreign experience.

By examining the cost escalation of previous rail projects and reviewing the arguments of researchers who have asserted that cost estimates of rail projects have been routinely underestimated, we have concluded that the problem of high overruns is mainly confined to cost estimates done in the conceptual stages of the projects. Design estimates are most likely to escalate when engineers lack experience with the specific type of project or technology.

Since the CalSpeed estimates are conceptual planning estimates, based upon our study of previous experience, we decided on a few steps which could improve our original efforts. First, we concluded that a large contingency factor should be used to compensate for the inadequate base of information. Second, a range of costs should be presented in order to emphasize the uncertainty involved. Finally, to as great a degree as possible, the unit costs used to derive the estimates should be compared against those of other recent similar projects to verify that they are reasonable.

While recognizing the great potential for estimates to escalate due to inflation, design changes, and unanticipated delay, we determined that no attempt should be made by the CalSpeed estimates to compensate for these factors. We believe that in the conceptual stages of a project, it is more appropriate to think in current dollar terms.

Using a comparison of the unit costs from other high-speed rail proposals and from previous rail transit experience, we were able to re-evaluate and refine our original estimates. These revised estimates revealed that between $8 and $11.5 billion (1991 $) is needed to construct the infrastructure for the proposed mainline between downtown Los Angeles and downtown San Francisco. In comparison, the original CalSpeed estimate for this same infrastructure was $9 billion.

The CalSpeed estimates are for planning purposes only. They were created to assist the state and engineering firms in determining the feasibility of high-speed rail in California. To attain better accuracy, more detailed estimates will be necessary. It is important to note, however, that the relatively large range of the cost estimates for the L.A.-S.F. mainline is due primarily to the difficulty in estimating construction costs for the mountain passes. Therefore, to produce more precise estimates, it is especially important to have carefully thought-out geological and engineering studies of these regions.

INTRODUCTION

In concluding the first year of its CalSpeed study last June, the Institute of Urban and Regional Development (IURD) published "High-Speed Trains for California." A portion of that report used available cost data to produce an estimate of total construction costs for a proposed high-speed rail (HSR) network throughout the state. The report focused on a mainline connecting the downtowns of San Francisco and Los Angeles. Infrastructure costs for this mainline were estimated at about $9.0 billion (1991 $). This translates to an average cost of $22.6 million per mile.

The CalSpeed research group recognizes the importance of providing realistic cost estimates for high-speed rail in California. The expected cost of the system will be a significant factor in the determination of its feasibility. Furthermore, assuming that public money will be necessary to build a high-speed system in California, we will need to use accurate cost and ridership estimates to predict how much financial support will have to come from public coffers. Moreover, some prominent research has concluded that the preliminary cost estimates of recent rail projects have been consistently low.

Considering these facts, we decided to expand upon the cost estimation work which was done for "High-Speed Trains for California." The purpose of this paper is to re-evaluate and refine our previous estimates. We have focused on the issue of cost escalation of rail projects, with emphasis on existing HSR systems.

This paper is divided into two parts. The first examines the cost escalation of previous rail projects and reviews some researchers' arguments that preliminary cost estimates of rail projects have been routinely underestimated. This section's examples cover a wide range of rail projects, including high-speed and conventional, and both international and American rail projects. The section concludes with some ideas about why the costs of rail projects have escalated and how past experience can lead to improved cost estimates. The second part of this paper uses the first section's conclusions as a basis for a systematic re-evaluation of the original CalSpeed planning estimates.

PART 1: COST ESCALATION OF RAIL PROJECTS

Cost escalation occurs when actual costs exceed previously estimated values. While this is a straightforward concept, the differences between "nominal" cost escalation and "real" cost escalation can lead to confusion. Nominal costs are dollar amounts without regard to time, whereas real costs are constant dollar amounts. Thus, nominal cost escalation includes inflation while real cost escalation does not. For Part 1 of this paper, unless stated otherwise, *nominal* cost dollar values are listed. This is consistent with the literature reviewed for this paper.

Another clarification is necessary before a study of cost escalation can be made. Different types of cost estimates are done at different stages in the development of a project. The period before a specific project alternative has been chosen and funds have been set aside for its design is often referred to as the "conceptual planning" stage of a project. Cost estimates which are done in the conceptual planning stage have a level of detail *much less* than the estimates done afterwards, in the design phases. Thus, conceptual planning estimates can be expected to be less precise than design estimates. As a result, caution must be taken when comparing the amount of cost escalation of different projects. To make a valid comparison, the cost estimates used must be taken from the same stage of their respective project's development.

THE U.S. HIGH-SPEED RAIL EXPERIENCE

Since high-speed rail can have many different definitions, it is unclear whether or not such a system already exists in the United States. The only real claim to U.S. HSR service is in the Northeast Corridor (NEC) (see Figure 1), where Amtrak's Metroliners reach a top speed of 125 mph between Washington, D.C., and New York. In 1989, Amtrak's best possible service averaged 85 mph between these two major markets, while making four stops.[1] By comparison, the French TGV Atlantique trains which began service in 1989, maintain a top operational speed of 186 mph, and average speeds between major markets are as high as 140 mph.[2] Moreover, TGV trainsets have been safely tested at speeds over 300 mph. Nevertheless, Amtrak's NEC service is the fastest, most heavily trafficked, and most highly invested in intercity rail corridor in the United States, and it has become an integral part of the transportation infrastructure of the northeast. Thus, regardless of one's definition of HSR, when considering potential HSR application in the United States, it is important to study the history of Amtrak's Northeast Corridor Service.

While the Northeast Corridor represents the only existing U.S. service which could be considered HSR, over the last couple of decades there have been numerous proposals for high-speed corridors throughout the country. Though construction has not yet begun on any of these, a few have

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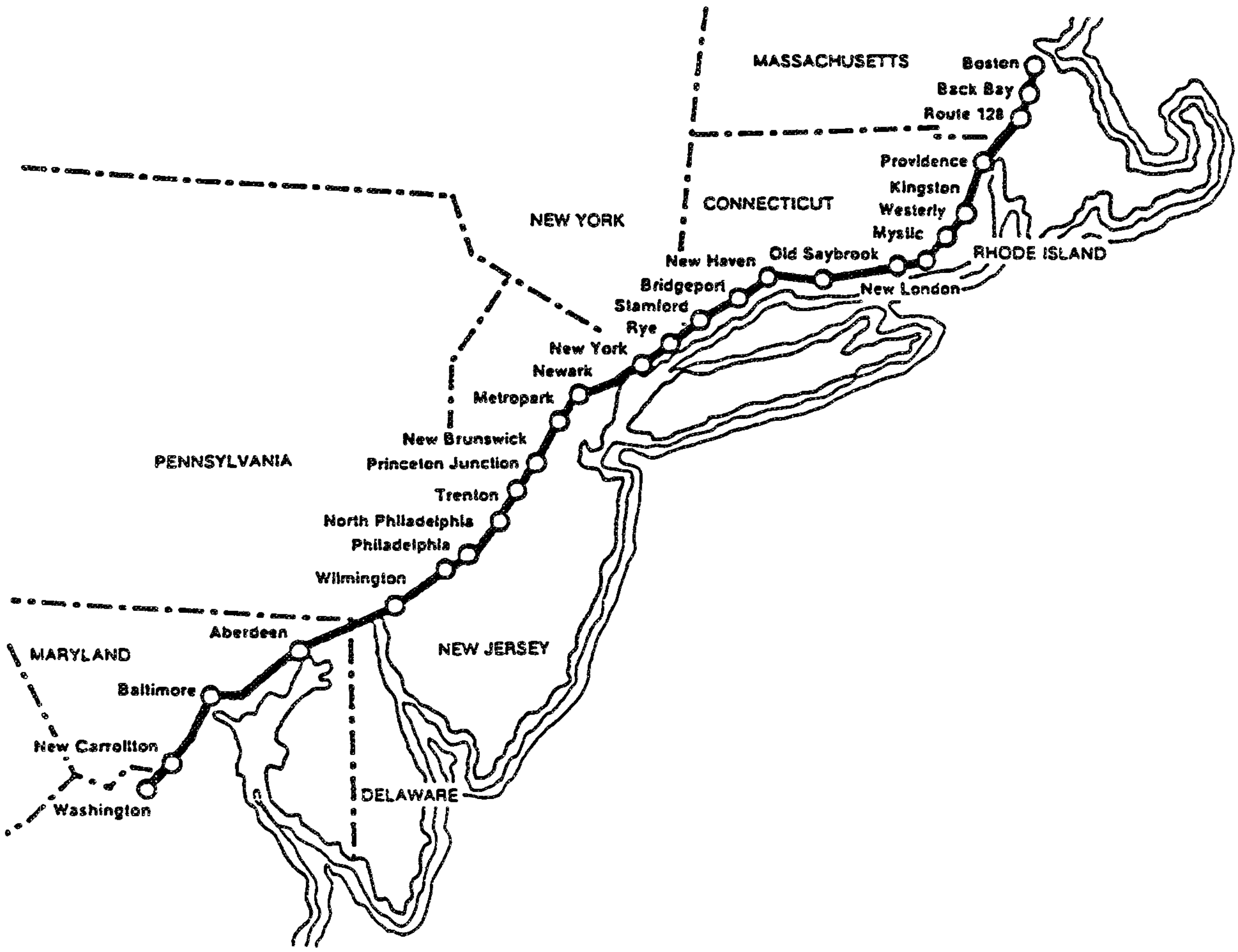
[1]Cupper, April 1989.
[2]Streeter, April 1992.

Figure 1

THE NORTHEAST RAIL CORRIDOR



Source: Coalition of Northeastern Governors, Policy Research Center. 1983.

received extensive study and consideration. For this paper then, in addition to reviewing the experience of the NEC, it seemed worthwhile to examine the failed attempt to build a "bullet train" in the Los-Angeles-to-San-Diego Corridor. This proposal was the most serious attempt thus far to bring HSR to California.

The Northeast Corridor Upgrade

The Northeast Corridor Improvement Project (NECIP) represents the largest U.S. federal investment in intercity rail passenger service in this century. Between 1976 and 1986, $2.19 billion was spent to upgrade the existing service on Amtrak's 455-mile-long mainline between Boston, New York, and Washington. "The upgrading has enhanced all aspects of Amtrak's NEC facility: way and structures, power and control, fencing and grade crossings, service facilities and stations."[3] Table 1 summarizes the improvements that made up the core of the NECIP project, and Table 2 illustrates the cost breakdown for the various project elements. The NECIP program resulted in a 12 percent improvement in Metroliner (express trains) trip time between New York and Washington, and a 7 percent improvement between New York and Boston.

Construction Cost Escalation History

From the conception of high-speed improvements in the NEC in the mid-1960s to the completion of the NECIP, the federal government commissioned a series of successive studies which estimated projected costs for the corridor. The findings from the most significant of these efforts are summarized in Table 3. Notably, the final cost for the NECIP represents a nominal amount *4.76* times greater than the amount the USDOT recommended be included in 1971 funding legislation. Furthermore, the travel times ultimately achieved within the corridor were significantly longer (33 percent longer for N.Y.-Washington, 61 percent longer for N.Y.-Boston) than the original goals.

The total cost and service levels of the completed NECIP prove to be far more accurate when compared to the amount agreed upon in 1976 legislation. The final cost was 25 percent higher than initially planned. Travel time between New York and Boston was only 9 percent higher than planned, while service expectations between New York and Washington were met. However, in order to keep actual cost low, significant portions of the NECIP program were cut. Electrification from New Haven to Boston and a new signalling system were both eliminated. Had these been included, the expected travel times between New York and Boston would have been met, but the cost overrun would have risen to over 40 percent of what was estimated. One other problem was the length of the construction period. In 1976, the construction period was estimated at five years,

[3]U.S.D.O.T., November 1986.

Table 1

FIXED PLANT IMPROVEMENTS CENTRAL TO THE NECIP
(Status as of project completion)

	WAY AND STRUCTURES
Section Improvements:	o Curves realigned at 22 locations
	o 36 interlockings (crossover points) built new or reconfigured, 7 interlockings removed
	o Roadbed drainage improved or restored throughout NEC
Tunnels:	o In Baltimore & Potomac Tunnel, Baltimore: complete track replacement and structural improvements including new drainage facilities. Track rehabilitation in New York City tunnels.
Bridges:	o 202 bridges rehabilitated (including 10 movable bridges); 10 bridges replaced (including 2 movable bridges).
Track Improvements:	o Concrete ties installed in 410 track-miles
	o 735,000 wooden ties installed in 650 track-miles
	o Continuous welded rail installed in 535 track-miles
	o 634 track-miles resurfaced for high-speed operation
	o Track structure rehabilitation of 65 interlockings
	o Advanced equipment provided to meet Amtrak's future track upkeep and upgrading needs
	POWER AND CONTROL
Electrification:	o Between Queens and New Rochelle, New York: Conversion of power supply to 12.5kV, 60Hz, with major rehabilitation of catenary system
	o Between Queens, New York, and Washington: Selective repair of critical elements of existing catenary system
Signaling:	o 64 mechanically-locked interlockings converted to all-electric operation
	o Proportion of track-miles signaled for bi-directional operation increased from 25 percent to 56 percent
	o Centralized traffic control introduced between Washington and Wilmington, and in Boston vicinity.
	OTHER ESSENTIAL PROJECT ELEMENTS
Grade Crossings:	o Two-thirds of NEC highway grade crossings extant prior to NECIP eliminated, including last remaining public crossings between Washington and New Haven
Service Facilities:	o New, renovated, or augmented facilities installed at Washington, Wilmington, New York, New Haven, and Boston for all levels of equipment repair, inspection, storage, washing, and servicing
	o Four new maintenance-of-way bases constructed to support Amtrak's track upkeep
Stations:	o Three new stations constructed (Providence, RI, Stamford, CT, New Carrollton, MD), ten existing stations improved or rehabilitated
	o At existing stations: improvement of passenger safety, comfort, processing, and platform access; rehabilitation of essential building systems and repair work to assure continued occupancy; and provision of access to handicapped
	o With shared state/local funding: improvement of commuter facilities in 12 stations, parking additions at 6 stations

Source: U.S.D.O.T. 1986. "Northeast Corridor: Acheivement and Potential"

Table 2

FUNCTIONAL GROUPING OF NEC PROJECT ELEMENTS

Group	Function	Project Elements	Funding ($ millions)
WAY AND STRUCTURES	Provide a reconfigured, high-quality roadbed for safe, efficient, comfortable operation at reduced trip times	Section improvements	169.2
		Tunnels	54.2
		Bridges	178.8
		Track improvements	691.3
		Group Total	1,093.5
POWER AND CONTROL	Provide improved electrical systems to propel and direct train operations	Electrification	85.1
		Signalling and Communications	344.1
		Group Total	429.2
SEPARATION	Isolate the NEC from its environment to protect train operations, neighbors, and motorists	Grade crossing elimination	14.0
		Fencing	6.5
		Group Total	20.5
SERVICE FACILITIES	Provide facilities for efficient maintenance of equipment, way, and structures	Group Total	174.2
STATIONS	Improve quality of passenger experience in entering and leaving NEC system; enhance efficiency of station operations	Group Total	191.1
PROGRAM ENGINEERING AND MANAGEMENT		Group Total	281.5
		TOTAL NECIP	2,190.0

Table 3

Northeast Corridor: Change of Estimation Costs/Project Scope

Estimate	(1)	(2)	(3)	(4)	(5)
Service Goals (hours)					
NY-WASH	2.50	2.00	2.67	2.67	2.67
NY-Boston	3.00	2.45	3.67	3.67	4.00
Cost (billions)					
Total *	$0.535	$0.460	$1.750	$2.404	$2.190
Projected Completion Date			1981	1983	1986

* Basic Improvements to track and structure and electrification

(1) Louis Klander & Associates, June 1964/November 1965
(2) USDOT "Recommendations for Northeast Corridor Transportation", Sept 1971
(3) NECIP "Railroad Revitalization and Regulatory Reform Act of 1976", Feb. 1976
(4) USDOT "Redirection Study", January 1979
(5) USDOT "Northeast Corridor: Achievement and Potential", Nov 1986

ending in 1981. Although the project reached its "construction height" in 1980-81, [4]and was about 70 percent complete by 1984, [5]its actual completion date slipped to late 1986.

Although there was escalation of both the conceptual cost estimates of the 1960s and the preliminary design estimates done in 1976, the factors behind the escalation were different. One explanation for the inaccuracy of the earlier estimates is given by Arrigo Mongini, Deputy Associate Administrator for the NECIP, in a 1984 article. According to Mongini, much of the conceptual studies' efforts involved research of extremely expensive forms of high-speed travel. This affected accuracy in two ways. First, not enough resources went to providing detailed estimates for improved rail service. Second, the focus on improbable projects delayed the upgrading project. Politicians were reluctant to spend large sums of money on improvements to the existing technology while it appeared that new, superior technologies would soon be available. "It took almost eight years for the Government to realize that a railroad reconstruction project was virtually the only alternative that could be feasible for such a regional project and it took another five years for funds to become available." [6]During this delay, not only was there high inflation, but the condition of the NEC railroad deteriorated further, increasing the costs of improving service in the corridor. A lack of previous experience exacerbated the inadequacy of the cost estimates since this project was the "first of its kind and the only one to date" in the United States. As previously noted, the conceptual estimates hardly resembled the final NECIP product. The result was a far less ambitious service provided at nearly five times the expected cost.

In early 1978, then-Secretary of Transportation Brock Adams concluded that the cost estimates from the Railroad Revitalization and Regulatory Reform Act of 1976 had been inadequate. As a result, a "Redirection Study" was undertaken to create a realistic plan. This study concluded that the $1.75 billion NECIP program suffered from "overoptimism, underestimation, inflation and immense problems associated with creating and managing a project of the NECIP's magnitude." [7]Satisfying the NECIP's goals would require both additional time and money. Mongini confirms the Redirection Study's findings: "a combination of the worst inflation in decades and some overly optimistic cost estimates reflecting a lack of experience with railroad construction of any significant scale in the U.S. led very quickly to the need for additional funds . . . ."[8] Other sources indicate that additional escalation can be explained by the fact that the original $1.75 billion budgeted for the project represented a political compromise rather than good engineering estimates.[9] Although certainly not the catastrophe that the conceptual estimates were, the preliminary engineering estimates of 1976 also turned

[4]U.S.D.O.T, November 1986
[5]Mongini, 1984.
[6]Mongini, 1984.
[7]USDOT, January 1979.
[8]Mongini, 1984.
[9]USDOT, 1976; Coalition of NE Governors, 1983

out to be understated. In order to control the increased cost of the project, the quality of the NEC service was sacrificed.

In the 1986 report, "Northeast Corridor: Achievement and Potential," the Federal Railroad Administration offers lessons to be learned from the NECIP experience. Among them are the following:

> Preparation of the scope of the project must be thorough and complete before final funds are committed. It is essential that scope, funding, and project schedule be realistic and coordinated.
>
> In the early stages of planning, estimates do not reflect the detailed scrutiny necessary to obtain firm and reliable figures.
>
> Once the final scope has been established and timetables set, any changes will usually bring increased costs and delay the project. A system of control of changes, governing physical and financial aspects, is vital and must be vigorously enforced.
>
> There must be a recognition that there will be a need for compromise and change.

Bullet Train from Los Angeles to San Diego

In 1982, the American High-Speed Rail Corporation (AHSRC) was established with the intent to "construct, operate, and maintain" a privately funded high-speed passenger service between Los Angeles and San Diego. [10] The technology and design of the proposed system was based on the Japanese bullet train (Shinkansen), and capital costs were expected to be $2.1 billion (1982 $). It was to be strictly a high-speed passenger service, with a maximum cruising speed of 160 mph. It would operate on new tracks, totally grade-separated, and segregated from freight or other, slower passenger services. The 130-mile route would have nine stations, including stops at Los Angeles International Airport, and Union Station in downtown Los Angeles (see Figure 2). The AHSRC planned to have the entire system operating by 1990, and to attract 100,000 passengers per year.

In November 1984, one year after Caltrans and FHWA had notified the public and cooperating agencies of the proposal, the AHSRC had Caltrans stop work as the state environmental lead agency. [11] The AHSRC cited a lack of short-term financing as the leading cause of the project's termination. However, while it is unclear just how much effect opposition to the project had on the consortium's ability to obtain financing, it is clear that by the time AHSRC withdrew its proposal, opposition to the project was significant.

Arguments against the project were primarily based on environmental concerns and doubts about the reliability of ridership estimates, and were made by citizens groups, university professors, and several coastal cities. The most complete argument came in the form of a study written by

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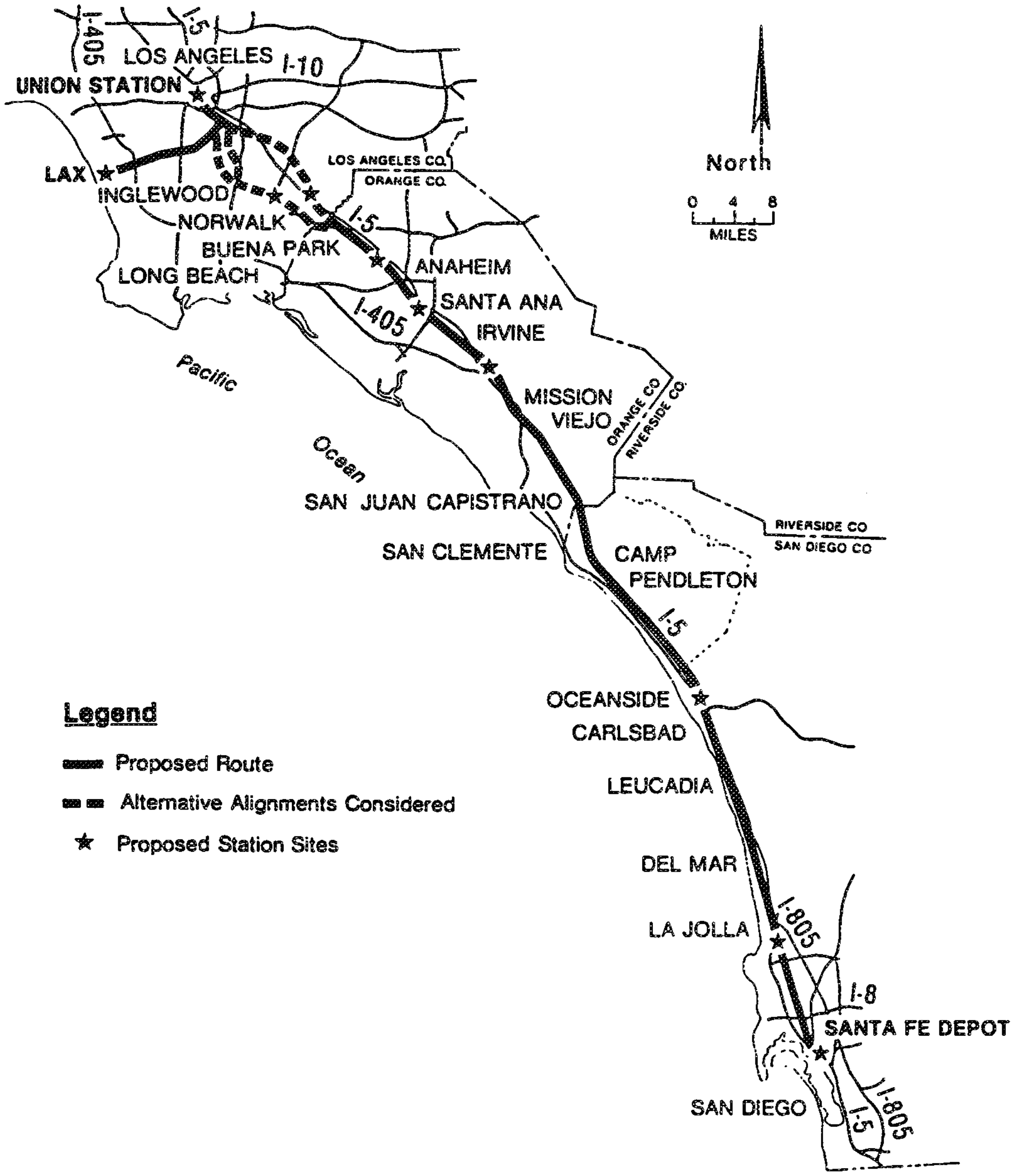
[10]Smith, 1987.
[11]Smith, 1987.

Figure 2

PROPOSED ROUTE: LA–SD "BULLET TRAIN"



Source: Smith, 1987.

Jonathan Richmond and released by The City of Tustin. This study focused on ridership forecasts and estimated costs of the proposal, and concluded that the proposed service would "carry only a small fraction of projected demand and quickly default on its debts."[12]

Potential Cost Escalation

Since the Bullet Train proposal was never constructed, there is no escalation history to review. However, Richmond's, "Slicing the Cake — The case for a Los Angeles-San Diego bullet train service," was very critical of the proposal's cost estimates, which were produced by the Japanese Railway Technology Corporation. While we do not wish to speculate what the true costs of the Bullet Train project might have been, it is interesting to review Richmond's methodology and findings.

Richmond contrasted the conceptual planning estimates for the Bullet Train proposal against the actual cost experience of heavy rail rapid transit systems. He systematically examined each element of the bullet train project by comparing its proposed unit costs to ranges of costs from recent studies of rail construction,[13] and to the actual cost experiences of the WMATA (Washington, D.C.) and MARTA (Atlanta) systems. He examined all elements of construction, including earthwork, structures, track, electrification, control, stations, and vehicles.

From the comparisons, Richmond concluded that most of the elements of construction were severely underestimated. However, he noted, "a particularly serious under-representation of costs is given for stations."[14] Richmond found that even the lower end of his range of costs was far greater than the $2.1 billion estimated for the bullet train proposal. This led him to assert that the proposed construction would result in cost overruns of *1.5* to *4 times* the proposed costs. He criticized the estimates for being based on general costs applied to the various sections of the route, and argued that a "working plan based on particular circumstances at each stage of the route"[15] should be prepared.

FOREIGN HIGH-SPEED RAIL EXPERIENCES

While the Northeast Corridor stands as the United States' lone successful effort to achieve significantly improved intercity rail service, high-speed rail networks are flourishing in both Japan and Europe. Unlike the NEC, many of the more prominent foreign projects involve the construction of totally new infrastructure as well as the upgrading of existing lines. Furthermore, the technology used to achieve increased performance from steel-wheel-on-rail trains far exceeds the sophistication of what currently exists in the United States.

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[12]Richmond, 1983.
[13]Dyer, 1976. "Rail Transit System Cost Study," and Caltrans, 1979. "Rail Transit Criteria for System Review and Preliminary Design."
[14]Richmond, 1983.
[15]Richmond, 1983.

Studying the cost escalation of foreign high-speed rail projects helps one better understand what could be expected if similar types of projects were undertaken in the United States. For this paper, research was done on the experience of the Japanese Shinkansen and French TGV services, as well as on the privately financed "Eurotunnel" link between England and France (still under construction). For the examples, no documentation was found regarding conceptual planning estimates. Thus, only estimates from the design stages of the projects could be compared against the actual costs. The estimates presented represent the greatest level of detail which we were able to obtain.

The Japanese Shinkansen

High-speed rail service in Japan began in October 1963, with the introduction of the Tokaido Shinkansen service between Tokyo and Osaka. The overwhelming success of this line led to the planned construction of subsequent Shinkansen lines in order to create a nation-wide high-speed rail network. Today, this network consists of the Tokaido line, Sanyo line (opened 1975), Tohoku line (1982), Joetsu line (1982), and the newly opened Yamagata line (1992). This network is summarized and illustrated in Figure 3.

The maximum speed of the original Tokaido Shinkansen was 131 mph, and a trip between Tokyo and Osaka took a minimum of four hours. Since then, with the introduction of new Shinkansen lines, the Japanese have been continually improving the performance of their high-speed trains. Both the Tohoku and Joetsu lines were built to run at 162 mph, and by 1984 the Tohoku line began operations at 149 mph. Today, the Tokaido, Joetsu, and Tohoku all operate at speeds of 162 mph or faster, with further speed improvements planned. Since March of 1992, the fastest Shinkansen service has connected Tokyo to Osaka in just two and a half hours. Tokaido trains run at intervals of 3.5 minutes, carrying an average of 335,000 passengers a day. The entire system averages 742 trains and 759,000 passengers per day.[16]

Construction Cost Escalation History

Construction records of the existing Shinkansen lines' initial services show that the final estimates[17] have typically been about 2 to 3.5 times higher than the original design cost estimates. Although this is an extraordinary escalation, inflation and changes as a result of technology improvements apparently account for most of the additional costs. In fact, if these two factors are taken into consideration, the estimates themselves can be considered very accurate. The cost escalation of the plans for the Tokaido, Tohoku, and Joetsu lines are summarized in Tables 4-6.

Inflation has been the greatest cause of cost escalation for Shinkansen projects. It accounted for 50 percent of the increase in cost for the Joetsu line, and for over 60 percent of the increase for

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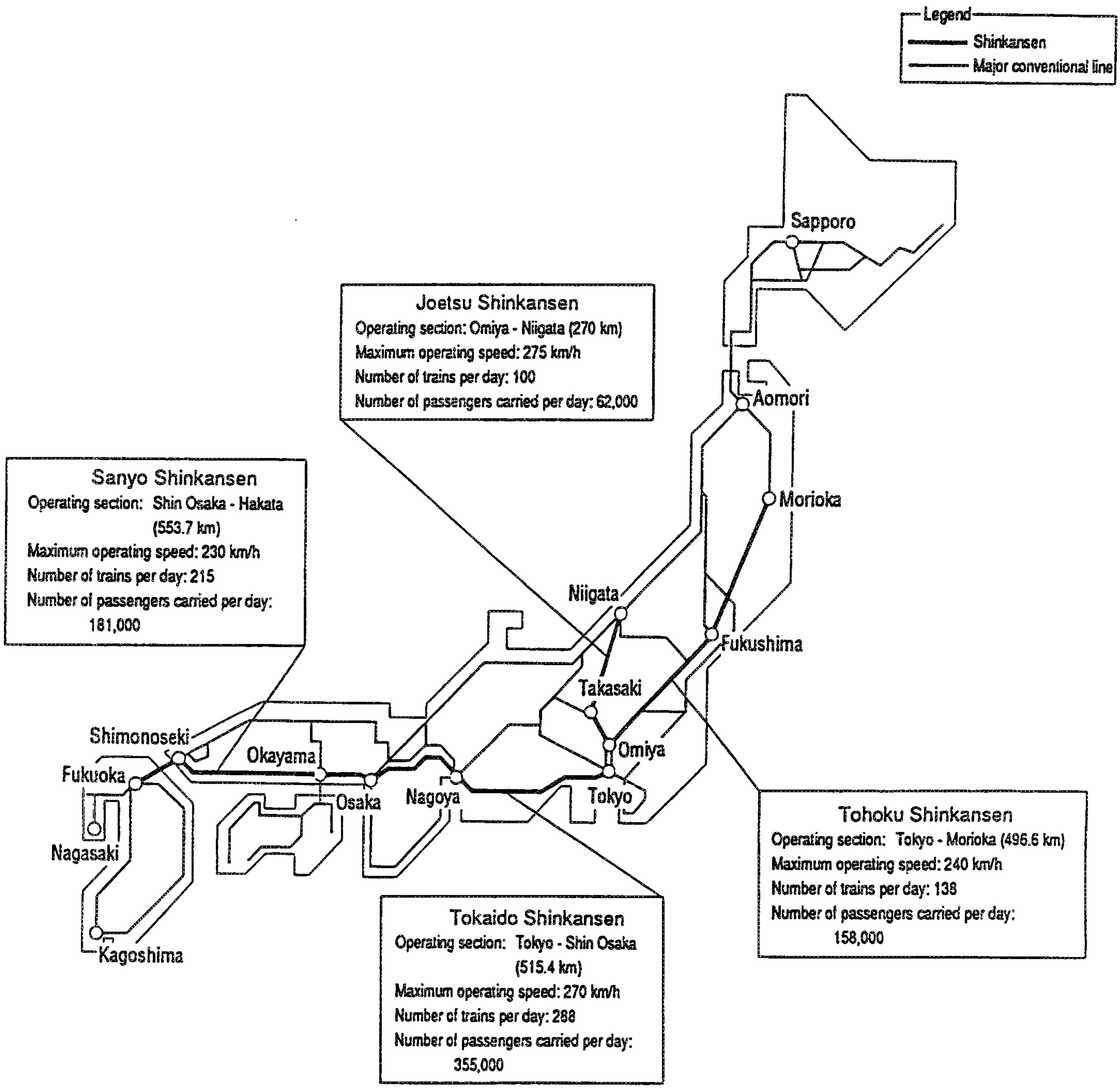
[16]Japan Railways Group. 1992.

[17]Actual costs were generally equivalent to the final estimated values.

Figure 3

TODAY'S HIGH SPEED RAIL NETWORK IN JAPAN



Source: Japan Railways Group, 1992.

Table 4

Tokaido Shinkansen: Change of Estimation Costs in Billions of Yen

Items	1st Plan (1959)	Additional Cost After 1st Plan						2nd Plan (1961)
		Land	Construction Agreement	Change of Plan	Inflation of Wage	Other*	Subtotal	
Land Cost	14.6	36.4					36.4	51.0
Infrastructure	122.5		15.9	1.9	16.6		34.4	156.9
Electric Equip.	18.4		0.5	7.3	1.6		9.4	27.8
Vehicle	10.0						0.0	10.0
Others	7.0					5.6	5.6	12.6
Subtotal	172.5	36.4	16.4	9.2	18.2	5.6	85.8	258.3
Interest	24.7					9.6	9.6	34.3
Total	197.2	36.4	16.4	9.2	18.2	15.2	95.4	292.6

Items	2nd Plan (1961)	Additional Cost After 2st Plan					Subtotal	3rd Plan (1963)
		Land	Construction Agreement	Change of Plan	Inflation of Wage	Other*		
Land Cost	51.0	8.8					8.8	59.8
Infrastructure	156.9		27.1	19.1	11.7	4.2	62.1	219.0
Electric Equip.	27.8		0.5	3.4	1.9	4.1	9.9	37.7
Vehicle	10.0					3.0	3.0	13.0
Others	12.6					0.5	0.5	13.1
Subtotal	258.3	8.8	27.6	22.5	13.6	11.8	84.3	342.6
Interest	34.3					3.1	3.1	37.4
Total	292.6	8.8	27.6	22.5	13.6	14.9	87.4	380.0

* Including compensation costs & technology improvement costs

Source: Japanese Civil Engineering Journal, Oct 1984.

Table 5

Tohoku Shinkansen: Change of Estimation Costs in Billions of Yen

	Original Plan	Change #1 (Feb 1975)		Change #2 (March 1977)		Changes #3–5 (Dec 1977–Jan 1980)		Change #6 (March 1980)		Change #7: Final Est (April 1982)	
	October 1971	Extra Cost	New Estimate	Extra Cost	New Estimate	Extra Cost	New Estimate	Extra Cost	New Estimate	Extra Cost	New Estimate
Construction Costs											
Land	120.0	70.6	190.6	39.3	229.9	64.9	294.8	4.8	299.6	106.0	405.6
Infrastructure	525.6	486.5	1012.1	246.4	1258.5	20.6	1279.1	319.8	1598.9	72.9	1671.8
Trackwork	70.7	43.2	113.9	49.4	163.3	0.7	164.0	18.5	182.5	–32.1	150.4
Electric Facility	105.2	67.2	172.4	31.6	204.0	7.9	211.9	38.0	249.9	2.5	252.4
Related Const. Work	18.5	13.5	32.0	8.9	40.9	1.4	42.3	9.0	51.3	12.7	64.0
Subtotal	840.0	681.0	1521.0	375.6	1896.6	95.5	1992.1	390.1	2382.2	162.0	2544.2
Management Cost	40.0	32.0	72.0	100.4	172.4	8.5	180.9	33.9	214.8	42.0	256.8
Total	880.0	713.0	1593.0	476.0	2069.0	104.0	2173.0	424.0	2597.0	204.0	2801.0
Causes of Escalation:											
Inflation		543.1		161.4		95.5		273.4		119.9	
Land Price		49.7						13.5		36.7	
Infrastructure		493.4		161.4				259.9		83.2	
Change Equipment				84.2				9.7		16.9	
Change of Const. Method				23.1				28.0		–47.3	
Environmental Concern				52.8				2.6		14.2	
Countermeasure for Snow				12.3				11.9		1.0	
Change of Construction Cost		32.0		100.4		8.5		42.0		42.0	
Upgrade from Previous Plan		111.9									
Housing for Const. Workers		26.0									
Test Line				2.4							
Consent with Other Agency				23.7				21.8		40.3	
Maintenance Cost				15.7				15.0		7.5	
Countermeasure for Earthquake								22.3			
Related Construction Work								5.4		10.4	

Source: Reference of Record of Tohoku Shinkansen Construction, JNR

Table 6

Joetsu Shinkansen: Change of Estimation Costs in Billions of Yen

	Original Plan Oct 1971	Change #1 (Mar 1977)		Change #2 (Mar 1980)		Change #3 (Mar 1981)		Change #4 (Mar 1983)		Increased Cost	
		Extra Cost	New Estimate	Extra Cost	New Estimate	Extra Cost	New Estimate	Extra Cost	New Estimate	Total	Rate (%)
Construction Costs											
Land	67.9	61.2	129.1	10.9	140.0	2.4	142.4	-3.3	139.1	71.2	105
Infrastructure	283.1	521.8	804.9	281.5	1086.4	50.3	1136.7	26.2	1162.9	879.8	311
Trackwork	40.5	51.5	92.0	11.6	103.6	7.1	110.7	-35.4	75.3	34.8	86
Electric Facility	49.9	56.6	106.5	25.3	131.8	10.2	142.0	-15.0	127.0	77.1	155
Related Const. Work	18.6	24.9	43.5	23.7	67.2	2.0	69.2	12.7	81.9	63.3	340
Subtotal	460.0	716.0	1176.0	353.0	1529.0	72.0	1601.0	-14.8	1586.2	1126.2	245
Management Cost	20.0	54.0	74.0	7.0	81.0	4.0	85.0	14.8	99.8	79.8	399
Total	480.0	770.0	1250.0	360.0	1610.0	76.0	1686.0	0.0	1686.0	1206.0	251
Causes of Escalation:											
Inflation		375.8		151.5		72.0		7.5		606.8	50%
Land Price		14.5		5.4				-5.5		14.4	1%
Infrastructure											
Change Equipment				56.9				-104.2		-47.3	-4%
Change of Const. Method		58.6		60.7				32.9		152.2	13%
Environmental Concern		74.2		7.3				42.9		124.4	10%
Countermeasure for Snow		21.2		20.2						41.4	3%
Change of Construction Cost		54.0		7.0		4.0		14.8		79.8	7%
Upgrade from Previous Plan		156.1		21.9						178.0	15%
Housing for Const. Workers											
Test Line											
Consent with Other Agency											
Maintenance Cost											
Countermeasure for Earthquake											
Related Construction Work											

Source: Reference of Record of Joetsu Shinkansen Construction, JNR the Tohoku line. Much of this inflation occurred during the construction periods of the Shinkansen lines, and came about because of the tremendous economic growth in Japan from the mid-1950s through the 1980s. Table 7 shows that during the period between the original and final estimates for the Joetsu line, Japan's overall inflation rate for construction increased nearly threefold. For the Shinkansen projects, estimation of costs were habitually created without the use of inflation factors. Rather than attempt to estimate future inflation, the Japanese simply understood that the nominal costs of the projects would be significantly higher than the initial estimates.

After original cost estimates had been made, and in fact even after construction of the lines had begun, the engineers of the Shinkansen projects worked to improve the technology in order to increase performance. This was particularly the case for the Tokaido line, since it was really the first true high-speed rail project ever constructed. For the Tohoku and Joetsu lines, improvements in snow removal, earthquake resistance, and environmental effects after the initial estimates had been completed contributed significantly to the increase in overall construction cost of the projects. At the same time, however, the rapid economic growth that had brought high inflation had also created great increases in the demand for intercity travel. So, according to Japan National Railways (JNR), while operational improvements raised the cost of the Shinkansen projects, this increase was compensated for by improved performance, which attracted greater ridership. JNR believed that as long as the demand for Shinkansen service was increasing, the ridership gains would be sufficient to justify any later increase in costs.

The French TGV

The French Train à Grande Vitesse (TGV) has been operating in France for more than ten years. In 1981, the Paris-Southeast service (TGV-PSE) began with 186 miles of newly constructed "high-speed" infrastructure. Utilizing a combination of upgraded track and new high-speed track, TGV-PSE trains served a total network of 550 miles. By 1983, the French National Railways (SNCF) expanded the high-speed segment to 259 miles, and the overall network to 990 miles (see Figure 4). Since service began, TGV-PSE trains have maintained speeds of up to 168 mph on the high-speed segments and reach a maximum of just over 100 mph on upgraded tracks. SNCF claims that this service has been extremely profitable.

Building on the success of the TGV-PSE, SNCF continued with an ambitious program of expansion for high-speed service in France. In 1989, SNCF introduced the TGV-Atlantique to serve the western portion of France. By 1990, this new service had added 177 miles of high-speed tracks and increased the total TGV network to 2,730 miles of service (see Figure 5). For the TGV-Atlantique service, new and improved TGV trainsets were developed. These trains are the world's fastest, main

Table 7

Joetsu Shinkansen: Change in Cost, due to Inflation

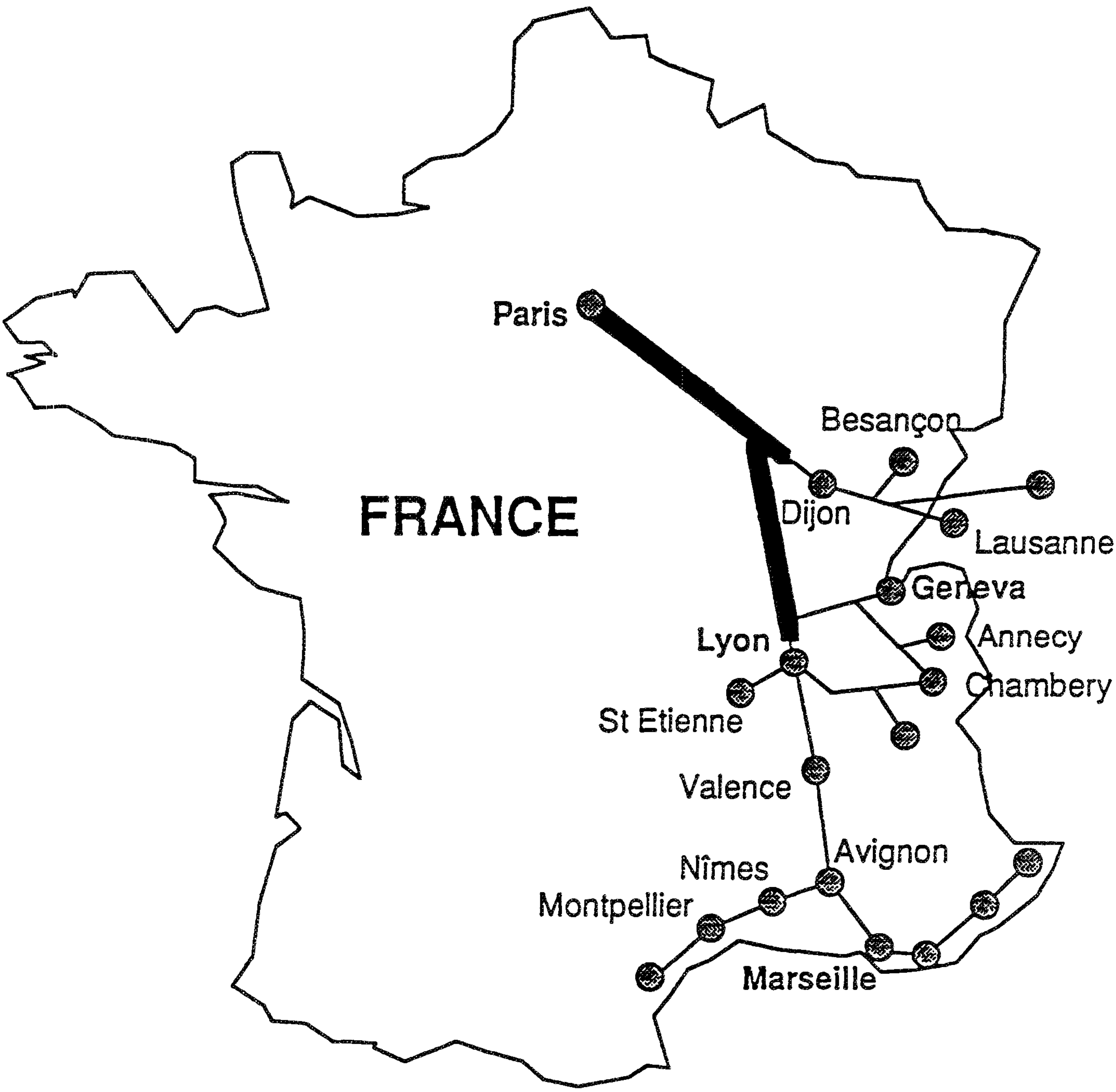
	1971	1982
Total Construction Cost	100	289
Land Price	100	272
Infrastructure	100	283
At-grade	100	306
Bridge/Viaduct	100	283
Tunnel	100	303
Trackwork	100	266
Building for Const Work	100	300
Electric Power	100	213
Rail	100	251
Power Plant	100	234
Communication Facility	100	278
Construction Machines	100	223
Related Constr. Work	100	386

Source: Reference of Record of Joetsu Shinkansen Construction, JNR

Figure 4

TGV NETWORK IN 1983

259 miles of new High Speed Line
(Total TGV network: 990 miles)

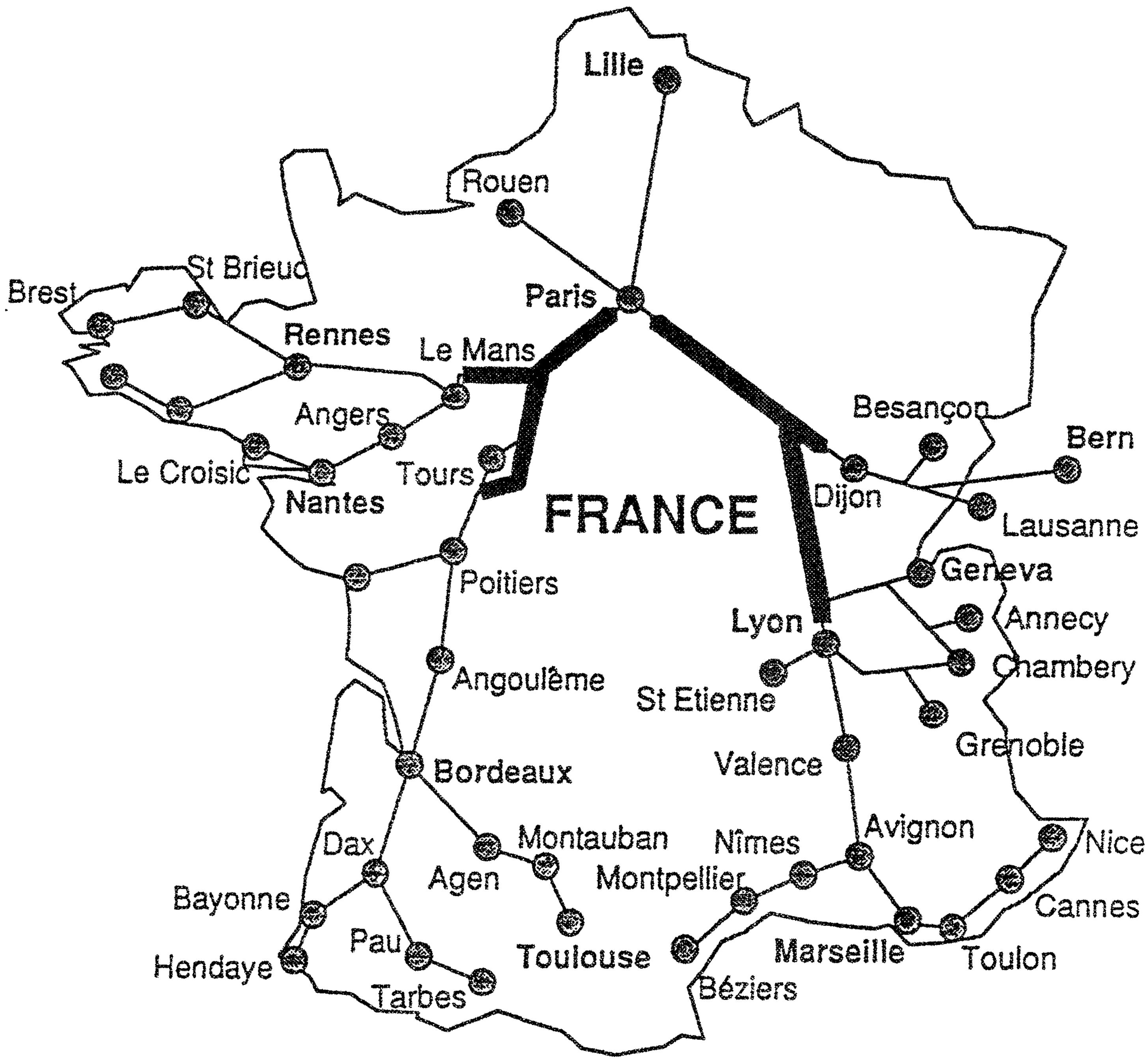


Source: SNCF, 1992.

Figure 5

TGV NETWORK IN 1990

436 miles of new High Speed Line
(Total TGV network: 2,730 miles)



Source: SNCF, 1992.

taining a speed of 186 mph over the high-speed segments and reaching a maximum of 137 mph on upgraded tracks.[18]

Construction Cost Escalation History

According to SNCF, inflation alone has accounted for virtually all of the difference between design estimates and actual expenditures for the high-speed infrastructure (including right-of-way acquisition) constructed in France. In January 1975, SNCF reports to the Transportation Ministry estimated that the capital costs of the high-speed segments of the TGV-PSE would be 2,901 million francs (MF). Table 8 shows the project's reported actual expenditures for each year of its construction period. When completed in 1985, the new line actually cost 5,376 MF, 1.85 times more than had been originally estimated. However, like the JNR cost estimates for the Shinkansen, SNCF did not account for inflation in their cost estimates. Thus, ignoring inflation, the actual expenditures of the project in 1975 francs were only 2,926 MF;[19] therefore, the real cost escalation was a nearly negligible 1 percent.

Table 9 presents SNCF's breakdown of the estimated and actual costs of various infrastructure and superstructure components of the TGV-PSE high-speed segment in 1975 MF. Although the earthwork (due to extremely wet weather which delayed the work) and enclosure costs were underestimated by 12 and 14 percent respectively, the overall escalation of infrastructure costs was minimal because right-of-way acquisition and structures were overestimated by 18 percent and 8 percent. In addition, superstructure costs were actually slightly underestimated since unexpected economies of scale led to cost savings in trackwork and catenary/substations.

Eurotunnel

The Eurotunnel project is an example of a massive public works project that is designed to accommodate rail service, but far exceeds the usual rail infrastructure in its scope.

The Eurotunnel is currently being constructed between the Folkestone area of south Britain and the Calais area of northern France. It is to be fifty kilometers in length, consisting of two 7.6-meter operating tunnels and a utility tunnel, built under the sea bed in the English Channel.[20]

The tunnel will include TGV high-speed rail passenger service, freight service, and a fleet of "tourist wagons" which will shuttle automobiles and trucks between the French and British terminals.[21] The tunnel is due to open in November 1993 with the large "tourist wagon" shuttle service for cars and trucks. Direct TGV high-speed rail service between Paris and London and between

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[18]Streeter, 1992.
[19]Leboeuf, M. 1985.
[20]Holliday, 1991. p. 18.
[21]*Sunday Times*. "Eurotunnel's Brave Face," July 30, 1989.

Table 8

Actual Expenditures for TGV–PSE Construction Period

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Total
Expenditures	8	85	130	646	860	1,215	1,256	817	301	58	5,376
In 1985 MF	20	194	273	1,234	1,488	1,886	1,752	1,017	342	62	8,268
In 1975 MF											2,926

Ministry Reports, estimates of cost = 2,901 MF (Jan 1975)

Table 9

TGV–PSE: Estimated vs. Actual Costs in 1975 MF

	COSTS		
	ESTIMATE (1975 MF)	ACTUAL (1975 MF)	% DIFF.
Infrastructure			
Right–of–way Aquistion	172	141	–18%
Earthwork	883	993	12%
Structures (bridges, tunnels, etc.)	410	377	–8%
Route Enclosure (grade separation, fencing, etc.)	69	79	14%
TOTAL INFRASTRUCTURE	1,534	1,590	4%
Superstructure			
Trackwork	659	625	–5%
Signal/Control	229	248	8%
Catenary/Substations	272	249	–8%
Buildings (Stations, Inspect./Service Fac. etc.)	207	214	3%
TOTAL SUPERSTRUCTURE	1,367	1,336	–2%
TOTAL	2,901	2,926	1%

Source: Leboeuf, M. 1985

Brussels and London are planned to follow, together with conventional freight service on the same track.[22]

The administrative organization of the project was set up in several layers by the enabling agreement between France and the United Kingdom. The agreement created the Eurotunnel Group, a holding company that will eventually operate the tunnel and its train service, and which has been responsible for raising capital. Eurotunnel has then contracted with Transmanche Link, a consortium of British and French construction firms. In addition, the syndicate of international banks financing the project has a staff of on-site consultants to monitor the progress of the project.[23]

Construction Cost Estimate History

The initial design estimate of the project in 1985 was 4.3 billion pounds (British). That cost quickly escalated to 7.7 billion by 1990, as shown in Table 10. Recent cost estimates are approximately 8 billion pounds.[24] An important point shown by this table is that the total financing cost of the project has increased at least as quickly as the construction costs.

The major elements of the enormous cost escalation of the Eurotunnel project include the increased financing costs, increased construction costs, technical design changes, and unexpected logistical problems.

Because the project relies on private finance markets, delays and plan changes often have required renegotiation of loan terms and amounts, which often have resulted in higher interest and charges.[25] Consequently, financing costs have increased more rapidly than actual costs. This presents an important new dimension not seen in American government-funded projects, reflecting the private financing of Eurotunnel. In addition, construction costs were adversely affected by the robust health of the British construction industry during the Docklands project construction in London. For instance, in 1987 Eurotunnel estimated a 4.5 percent increase in construction costs for 1988. However, the Docklands project along with other smaller simultaneous projects increased demand for construction services in southeast Britain, resulting in a 20 percent increase in those costs in 1988. Thus, the cost of the project was again enormously increased because of the reliance on the market, and lack of control over construction costs.[26]

Technical design changes have included major revisions of the project; for example, changing the rail service to include the additional large "tourist wagon" vehicle and passenger carriers in addition to the original TGV and freight service. Design changes have also included increases in the size of the tunnels and infrastructure, and changes in the size of the terminals. Moreover, after each public

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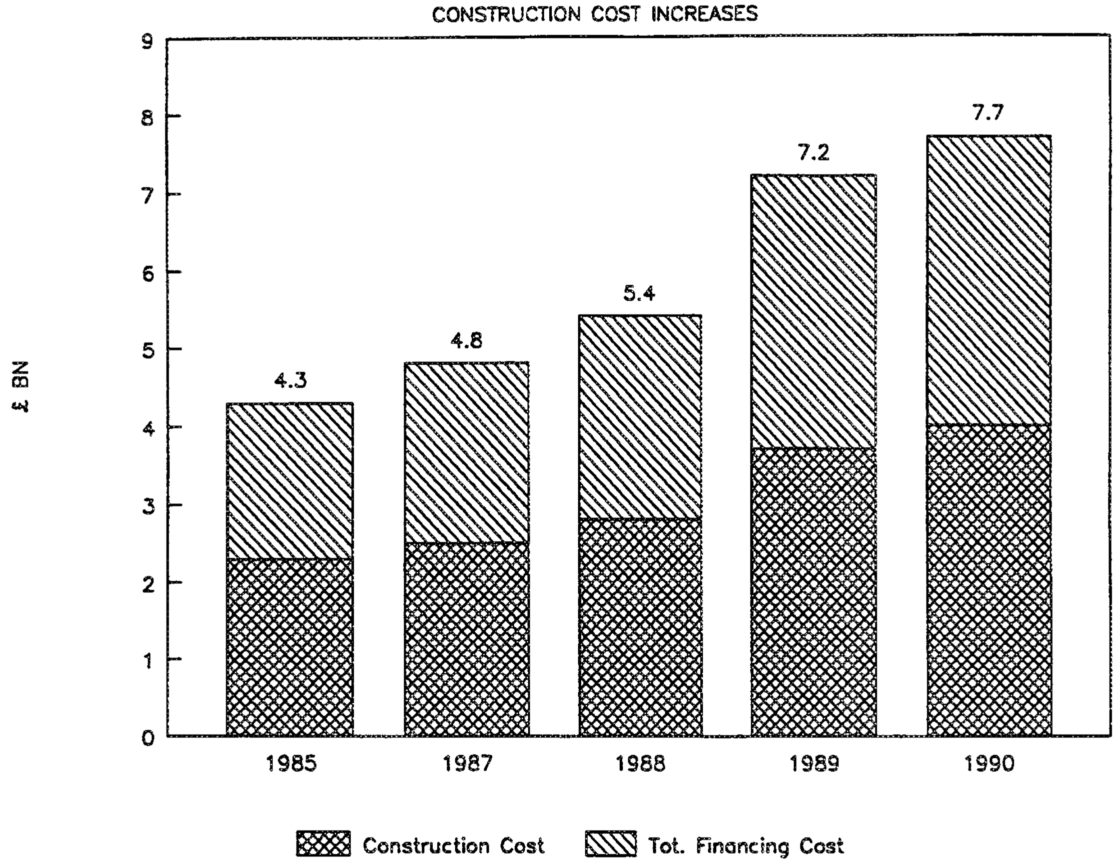
[22]SCNF, 1992.
[23]Holliday, 1991, pp. 20-21.
[24]*London Times*. January 23, 1992.
[25]*London Times*. February 11, 1992.
[26]*Sunday Times*. July 30, 1989.

Table 10


CONSTRUCTION COST INCREASES
£ BN
9
8
7
6
5
4
3
2
1
0
4.3
4.8
5.4
7.2
7.7
1985
1987
1988
1989
1990
Construction Cost
Tot. Financing Cost

transit accident in Europe, new safety features have been added to soothe a new set of public fears. All of these changes resulted from both testing and public response to the project. And again, because of the reliance on market finance and market construction resources, the delay caused by each change then triggered increased costs through inflated construction costs and new financing costs.[27]

Additionally, the unprecedented size of the project caused its own unusual logistical problems of scale. As the two initial strands of the tunnel met under the Channel in 1991, the increased time to move workers, equipment, and high-tech devices in and out of the tunnel far exceeded the original time estimates. In addition, the size and duration of the project, along with the multi-layer administrative structure, has produced an army of 800 officials from Eurotunnel, Transmanche, and the bank consortium monitoring the project.[28]

Thus, the Eurotunnel project presents two new sets of cost overrun elements not found in the traditional American government-funded infrastructure or rail projects— market costs and costs of scale. The market costs include both the finance and construction cost increases resulting from reliance on market financing. Because of the dependence on a consortium of private banks, each increase in credit or extension of repayment terms required Eurotunnel to meet bank demands for higher interest rates and renegotiation of existing loans as the completion and eventual success of the project became less certain. Moreover, competition within private markets for short-term construction services has proven to be a highly volatile and unpredictable element of capital costs for the tunnel. In addition, there are the overall costs of scale resulting from the complications of managing and building a project of such enormous scale, with a geometric effect in added costs and time delays.

THE U.S. RAIL TRANSIT EXPERIENCE

Considering the present lack of HSR experience in this country, researching the experience of U.S. rapid rail transit projects is essential to better understanding the potential cost escalation of future U.S. HSR projects. The new urban rail transit systems, where there are many examples to study, represent a type of construction somewhat similar to that of HSR. Since researchers have previously examined the cost escalation of recent rail projects, this section primarily draws from their work.

In an effort to test the theoretical analyses of the cost overruns of rail projects in a more specific setting, the Bay Area Rapid Transit (BART) system was examined. BART is the only heavy rail rapid transit system operating in California, and is particularly relevant to this study because it involved both the complete construction of a new system and the extensive use of new technology.

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[27]*London Times.* February 11, 1992.
[28]*London Times.* October 8, 1989.

Previous Research on Rail Transit Cost Escalation

Planning and transportation academics have produced a significant amount of literature on the cost estimation experience of recent urban rail projects. These studies provide valuable perspectives and methods for refining the cost estimates for rail transportation proposals. This paper focuses on the work of Leonard Merewitz and Don Pickrell.

Merewitz

Leonard Merewitz of the University of California at Berkeley conducted some early useful research on the subject of cost escalation in the early 1970s.[29] Merewitz assembled and analyzed the cost overrun experiences of the Bay Area Rapid Transit system and other transit systems, as well as highways, public buildings, and military procurement programs.

Merewitz used a quantitative methodology that provided both a measure of cost overrun and an analysis of causes. To make comparisons between estimated and actual costs, he opted to use only the cost estimate on which the investment decision to build the project was based. He categorized projects both by type and by specific factors causing unexpected cost escalations. Based on 180 projects, he found an average ratio of actual to estimated costs of 1.50, with eight rapid transit projects averaging 1.51. He found that the original BART construction resulted in a 1.45 ratio. By comparison, highway projects were the lowest, with an average ratio of 1.26. Thus, Merewitz' study suggested that nominal cost overruns in the range of 50 percent were common in public works projects through the 1960s. Merewitz's findings are summarized on Table 11.[30]

In assembling the various causes of the overruns, Merewitz found that the primary sources of increased costs were size of a project (larger projects tended to have greater escalation), incompleteness of preliminary surveys, engineering uncertainty, inflation, design changes, enlargement of projects, external delays, and administrative complexity or inexperience.

Finally, Merewitz concluded that cost overruns tended to be higher and more persistent in *ad hoc* building, [31] and rapid transit projects using state-of-the art technology, compared to ongoing programs of construction and renovation. He found this distinction particularly held true in highway projects.

Merewitz made general proposals for improvement in cost estimation methods. Those recommendations included striving to include complete preliminary surveys, acknowledging the possibility of price and cost increases by addressing them in the original estimate, and presenting costs in ranges or with contingency factors. He also advocated shorter time lags between approval and implementation.[32]

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[29]Merewitz, 1973. Reprint #114
[30]Merewitz, Leonard. 1973.
[31]Projects built for immediate problems or needs.
[32]Merewitz, 1973, p. 287.

Table 11

SUMMARY OF COST ESTIMATION EXPERIENCE

Type of Project	No. of Projects	Mean Ratio = Actual/Estimate
Water Resources	49	1.39
Highway	49	1.26
Building	59	1.63
Rapid Transit	8	1.51
Ad Hoc	15	2.11
Grand Mean	180	1.50

Source: Merewitz, 1973.

Merewitz' data documents the difficulty in accurate cost estimation of technologically sophisticated projects, particularly in a market economy within a frequently heated local political setting. Although dated, the broad range of experiences in the study provides general guidelines for refining preliminary cost estimates of major public works projects.

Pickrell

Recently, Don Pickrell of the Volpe National Transportation Systems Center has conducted focused, ongoing research studying the cost estimation and ridership projections of eight recent rapid transit projects.[33] Pickrell examined the Washington, D.C., Atlanta, Baltimore, and Miami heavy rail rapid transit projects, as well as the Buffalo, Pittsburgh, Portland, and Sacramento light rail projects. These studies focused on the accuracy of the cost estimates that were "available to local decision-makers at the time the choice among alternative transit improvement projects was actually made."[34] Thus, like the Merewitz study, Pickrell's findings are based upon conceptual planning estimates. Pickrell found a consistent pattern of cost overruns in each project, as seen in Table 12.[35]

Pickrell categorized the elements of capital costs for each project into right-of-ways, design and engineering, construction of facilities, and vehicle/equipment cost. His study found nominal overruns ranging from 17 to 156 percent for these rail systems, whereas real cost overruns ranged from -11 to 83 percent. Pickrell argued that while much of the increased construction costs could be explained by inflation and design changes, a considerable portion of the overruns were not explained by those traditional factors. Table 13 presents a breakdown of the percent of cost overrun by spending category as presented in Pickrell's latest report. This table shows that "most of these projects were also beset by very large real cost overruns, particularly for design and engineering services, facility construction, and vehicle purchases."[36,37]

The historical practice of federal government picking up the lion's share of cost overruns in new systems, Pickrell concluded, has encouraged local governments to underestimate costs to obtain federal support for rail projects, at the expense of alternative systems.

Pickrell suggested several changes in construction cost estimation methods to mediate the problem of underestimation. First, "probably the most critical step toward improving the cost estimates would be for local agencies to conduct additional engineering studies prior to selecting a preferred option."[38] Second, cost estimates should be compared with other recent systems.

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[33]Pickrell, 1990.
[34]Pickrell, 1990. p. 3.
[35]Pickrell, 1990, p. 33.
[36]Pickrell, 1992.
[37]Pickrell, 1992.
[38]Pickrell, 1992.

Table 12

SUMMARY OF FORECAST VS. ACTUAL CAPITAL COSTS

	Heavy Rail Transit Projects				Light Rail Transit Projects			
	Wash- ington	Atlanta	Balt- imore	Miami	Buffalo	Pitts- burgh	Port- land	Sacra- mento
	Period During Which Capital Outlays Were Made							
Forecast	1969-76	72-77	73-78	78-83	78-82	79-83	81-85	82-85
Actual	1971-85	75-86	74-83	79-85	79-86	80-87	82-87	83-87
	Total Capital Outlays in Nominal Dollars (millions)							
Forecast	1,713	793	405	795	336	NF	188	147
Actual	4,375	1,838	790	1,042	536	537	240	172
% Difference	156%	132%	95%	31%	59%	---	28%	17%
	Equivalent Total Capital Outlays in 1988 Dollars (millions)							
Forecast	4,352	1,723	804	1,008	478	699	172	165
Actual	7,968	2,720	1,289	1,341	722	622	266	188
% Difference	83%	58%	60%	33%	51%	-11%	55%	13%

NF = No Forecast Obtainable

Table 13

PERCENT OF COST OVERRUN BY SPENDING CATEGORY

	Heavy-rail Transit Projects				Light-rail Transit Projects			
	Wash.	Atlanta	Balt.	Miami	Buffalo	Pittsburg	Portland	Sac.
Right-of-way	3	4	0	12	0	0	0	7
Design and engineering	7	17	12	16	8	0	55	16
Construction of facilities	19	10	37	63	19	0	16	53
Vehicles and equipment	9	1	9	0	0	0	29	0
Subtotal, real cost escalation	38	32	58	91	27	0	100	76
Unanticipated inflation	62	68	42	9	73	100	0	24
Total, all sources	100	100	100	100	100	100	100	100

Third, technical, economic, and political uncertainty should be acknowledged early in a project, and such devices as contingency allowances and ranges of costs should be used to hedge against those uncertainties. Finally, the "financial consequences" for local transit planning and operating agencies should be increased.

Pickrell's work has been subject to vigorous rebuttals by the management of many of the systems he discussed, and by the American Public Transit Association (APTA).[39] Those rebuttals criticize Pickrell's methodology in using the cost estimates of the Alternative Analyses element of the draft Environmental Impact Statements (EIS) for each of the systems. Reliance on that data is criticized for using the earliest, most speculative estimates, rather than the later preliminary engineering estimates from the final EIS or the final design estimates provided to FTA at the signing of the Full Funding Agreement for each system. That is, Pickrell erred according to the transit management and the industry, by using conceptual planning estimates rather than design estimates. Their argument is that if the Full Funding Agreement is taken as the baseline estimate, most systems were completed at or near estimated cost. An example often used by APTA is the Portland light rail system, which was constructed below FFA cost estimates, but well above the draft EIS estimate. These costs are summarized in Table 14.[40]

Summary

The research of Merewitz and Pickrell has suggested a wide range of cost overruns, and an assortment of causal elements to explain those overruns. Both the variety of conclusions and the sources of data examined vary widely. However, despite this wide variety of conclusions, it is a useful exercise to categorize the findings by the specific elements of overrun. Table 15 attempts to do so.

In reading this table, "Inflation" refers to inflation rates greater than the rates assumed in the original estimates. "Estimation methodology" refers to errors in the methods used for the original estimates. "Construction costs" refer to unexpected increases in construction costs, for reasons other than economy-wide inflation. "Control of bids" refers to the related problem of being unable to actually obtain the lowest market bids for work at the implementation stage. "Land costs" refer to serious increases in land values. "Community opposition" is the argument that increased costs were the unexpected result of community, environmental, NIMBY (not in my back yard), or other political opposition to the project location. "Design changes" refer to both technological upgrades which became available after the original estimates, and remedial changes required by testing of the system.

This table shows a wide range of factors. An interesting difference between the findings is that Pickrell focused on cost estimation methodological errors as a major element in cost overruns or

[39] APTA, 1990.
[40] APTA. 1990.

Table 14

CAPITAL COSTS VS. ACTUAL EXPERIENCE, TRI–MET. LIGHT RAIL, PORTLAND

Projection in 1978	Full Funding Agreement in 1982	Experience in 1986
$161 million for highway improvements and 14.4 mile line completed in 1984 ($259.2 million, 1986 dollars)*	$328.5 milllion (includes annual inflation factor of 12%) for highway–transit project	$321 million highway–transit: $214 – 15.1 mile light rail line $107 – 5 miles of highway improvements

* inflation calculated according to the Means Historical Cost Indexes, 1988.

Table 15

ELEMENTS OF COST OVERRUNS

Element	Merewitz	Pickrell
Inflation	X	X
Estimation Methodology		X
Construction Costs	X	X
Control of Bids	X	
Land Costs	X	
Community Opposition	X	
Design Changes	X	

in explaining cost overruns. Merewitz simply does not discuss that element in his more descriptive study.

The BART Experience

Estimates from the San Francisco Bay Area Rapid Transit (BART) system's conceptual planning stage in the 1960s are well documented. Consisting of 70 miles of line in three Bay Area counties, the system's capital costs were estimated in 1962 to be $923 million. This was the amount upon which the investment decision to build BART was based.[41] BART was envisioned as having a new, modern rolling stock of lightweight cars able to achieve speeds of 80 mph, running at headways of 90 seconds, with spacious interiors to provide every passenger a comfortable seat (thus eliminating traditional subway standing). In addition, the system was to have a computerized control system at the cutting edge of technology, and a transbay tube under the San Francisco Bay between San Francisco and Oakland. In short, BART was an ambitious effort to create a totally new public transit model. As a result, almost every aspect of the original BART project involved new technology.[42]

Much of the new technology proved problematic, with major delays and design changes resulting from speed and safety failures of the new cars, and failure of the computerized train control system to detect trains on the track. Because of the interdependency of this bundle of new technology, both the failure of the control system, in particular, and also the unreliability of the new lightweight cars resulted in delays in opening such vital parts of the system as the transbay tube. Thus, the use of all-new technology, interlinked in a new system, compounded the delays and changes required.

Compounding the problems posed by the technology demands of the system was the fact that financing the original BART project relied on public funds, primarily from voter-approved bond issues and sales tax increases. This funding required support from both elected political officials and voters at the statewide level, and at a local level within the three counties in the Bay Area to which BART provided service and in which it collected taxes. A sales tax increase in 1969 to pay increased costs required time-consuming statewide political negotiations. In addition, because the system was built between 1962 and 1974, its largest construction costs came at a time of high inflation brought about by the Vietnam War.[43]

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[41]Merewitz, 1973.
[42]Hall, 1980.
[43]Hall, 1980.

As a result of these factors, the cost of the BART system escalated from the original 1962 estimate of $923 million to an actual cost of approximately $1.6 billion in 1974, when the system was completed. This represented a cost escalation for the entire project of 50 percent.[44]

According to Peter Hall, the most important elements of that cost escalation were an unrealistic construction schedule which did not anticipate delays from community opposition to location of the lines, low inflation estimates of 3 percent (actual inflation was about 6.5 percent), and low estimates of engineering design contingencies (10 percent), which proved unrealistic in a system of almost totally new technology.[45]

Leonard Merewitz provides a different perspective on BART's cost overruns. Table 16 itemizes the areas of cost overrun he found in the original system. Merewitz believed that the cost overrun experience of the BART construction was not significantly different from other urban rapid transit systems in Europe and North America.[46] He concluded that BART was an example of a totally new, *ad hoc* system built by a public agency with no expertise or experience with this kind of rapid rail transit, where a 50 percent cost overrun was not unusual. Furthermore, according to Merewitz, if the original BART estimates are adjusted for "price changes," then BART experienced virtually no cost overrun.[47]

When debating the severity of BART's cost overruns, it must be noted that the service provided never measured up to what had been promised. Once the original BART system was completed in 1974, it failed to provide the expected levels of service. Most of those problems resulted from new technology. The cutting-edge automatic train control system failed to detect stalled trains on tracks, causing the California Public Utilities Commission to refuse to allow use of the system without a manual check for trains on the tracks. That drastically slowed speeds and increased headways for several years, and delayed the opening of the important transbay tube link between San Francisco and Oakland. Recurring failures of various elements of the new technologically advanced cars, including dangerous brake and door failures, reduced the availability of vehicles and further decreased the system's speed while increasing headways.[48] In addition, shortly after the opening of the transbay tube, hand rails had to be retro-fitted to the ceilings of all BART cars to provide for standing passengers, even though ridership was far below projected levels. BART's first ten years of operation were marred by frequent breakdowns and a general inability to maintain a schedule. Today, BART operates nearly flawlessly, yet BART's minimum scheduled headway at major stations during peak hour is 3 minutes (two times greater than originally planned). Furthermore, top speeds are only achieved through the transbay tube.

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[44]Hall, 1980; Webber, 1976.
[45]Hall, 1980, p. 127.
[46]Merewitz, 1973, p. 485.
[47]Merewitz, Reprint No. 114.

Table 16

EXTENT OF COST OVERRUN ON MAJOR COMPONENTS OF BART: R = ACTUAL COSTS (1972) DIVIDED BY ESTIMATED COSTS (1962)

BASIC SYSTEM		TRANS-BAY LINE	
	$R > 2.0$		
Stations	2.4	Train Control	3.6
Engineering and Charges	2.4	Utility Relocation	2.9
Train Control	2.3		
	$1.0 < R < 2.0$		
Yards and Shops	1.9	Track and Structures	1.9
Track and Structure	1.8	Engineering and Charges	1.2
Right-of-way	1.3		
Utility Relocation	1.1		
	$R < 1.0$		
Electrification	0.8	Right-of-way	1.0
		Electrification	0.4
Pre-Operating Expenses	5.3		
Rolling Stock	1.8		

Source: Merewitz, 1973. Reprint No. 104

[48] Hall, 1980, pp. 117-119.

SUMMARY AND CONCLUSIONS

This research suggests that recent large rail projects have produced significant cost overruns. Yet, while various critics of rail projects have stated this for years, it appears that problems in estimation methodology are mostly confined to conceptual planning estimates. For example, while costs did escalate significantly for both the French and Japanese rail systems, our research suggests that most of the escalation for these services can be attributed to either inflation alone (TGV), or a combination of inflation and design changes (Shinkansen). Thus, for these services, the design estimates themselves *appear* to be very accurate. Furthermore, although the authors that we researched agreed that rail projects' conceptual planning costs escalate, none challenged the accuracy of more detailed design estimates of rail projects. In fact, both Merewitz and Pickrell argue that cost estimates can best be improved by increasing their detail. This tends to support APTA's claim that design estimates for rail transit projects are quite accurate.

Design estimates appear most likely to be inaccurate in projects where engineers lack previous experience with the type of project or technology. Our examples of the NEC, Eurotunnel, and BART reveal that while inflation and design changes accounted for much of these projects' escalation, delay, overoptimistic estimates, new technology, and project size were also significant factors.

While estimation techniques for the design phases of rail projects appear to be sound, the same cannot be said for conceptual planning estimates. All the research we have reviewed indicates that there have been noticeable difficulties in developing accurate conceptual estimates. Pickrell suggests the problem is largely political, that competition for federal funding "leads officials to encourage their planning staffs and consultants to underestimate rail transit projects' cost . . . ."[49] Merewitz, on the other hand, emphasizes the problem of incompleteness, stressing that estimates should be as complete as possible. Both authors however, offer insight about the lessons that can be learned from previous experience towards improving the accuracy of cost estimates done in the conceptual planning stage of a project.

First, in the case of projects for which it is difficult to find good examples of similar experience, a large contingency factor should be used to compensate for the inadequate base of information. Second, a range of costs should be presented to emphasize the uncertainty involved. Third, as far as possible, the reasonability of capital costs should be checked against other recent comparable projects. Fourth, the estimates should be as detailed as possible. Finally, for cost estimates in general, the potential impacts of inflation, design changes, and environmental concerns need to be evaluated in terms of how they might delay and escalate the cost of a project.

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[49]Pickrell, 1992.

PART II: RE-EVALUATING AND REFINING THE CALSPEED ESTIMATES

THE ORIGINAL CALSPEED ESTIMATES

Figure 6 shows the high-speed rail network we envision for California. This network is conceptual, and the estimates which were created for "High-Speed Trains For California" (HSTFC) are for planning purposes only. These estimates are summarized in Table 17. As shown, infrastructure costs for the mainline connecting Los Angeles and San Francisco were estimated at $9.0 billion. A branch to provide service between Los Angeles and Sacramento was estimated at an additional $1.3 billion.

Table 18 is a copy of the "Capital Cost Estimate" sheets created for HSTFC. The unit costs used to create these sheets were primarily a synthesis of many recent sources which estimate rail construction costs in the state of California, and the costs provided in the Texas TGV franchise application. A key explaining the derivation of each cost item, and the research from which the values for each item was determined, was provided in Appendix B of HSTFC. Volume II of HSTFC contains all the actual calculations by which the original CalSpeed estimates were determined.

The objective of this paper is to improve these original estimates based on what has been learned from previous rail projects. To accomplish this, the following sections will create a framework by which more realistic conceptual planning estimates for HSR in California can be derived.

RE-EVALUATING THE CALSPEED ESTIMATES

The first part of this paper concluded by suggesting several methods to avoid underestimating costs in conceptual planning estimates. To re-evaluate our original CalSpeed estimates, we used those which were most significant to our work. We found it was important to deal appropriately with inflation, to compare costs with those of similar projects, and to include a large contingency factor.

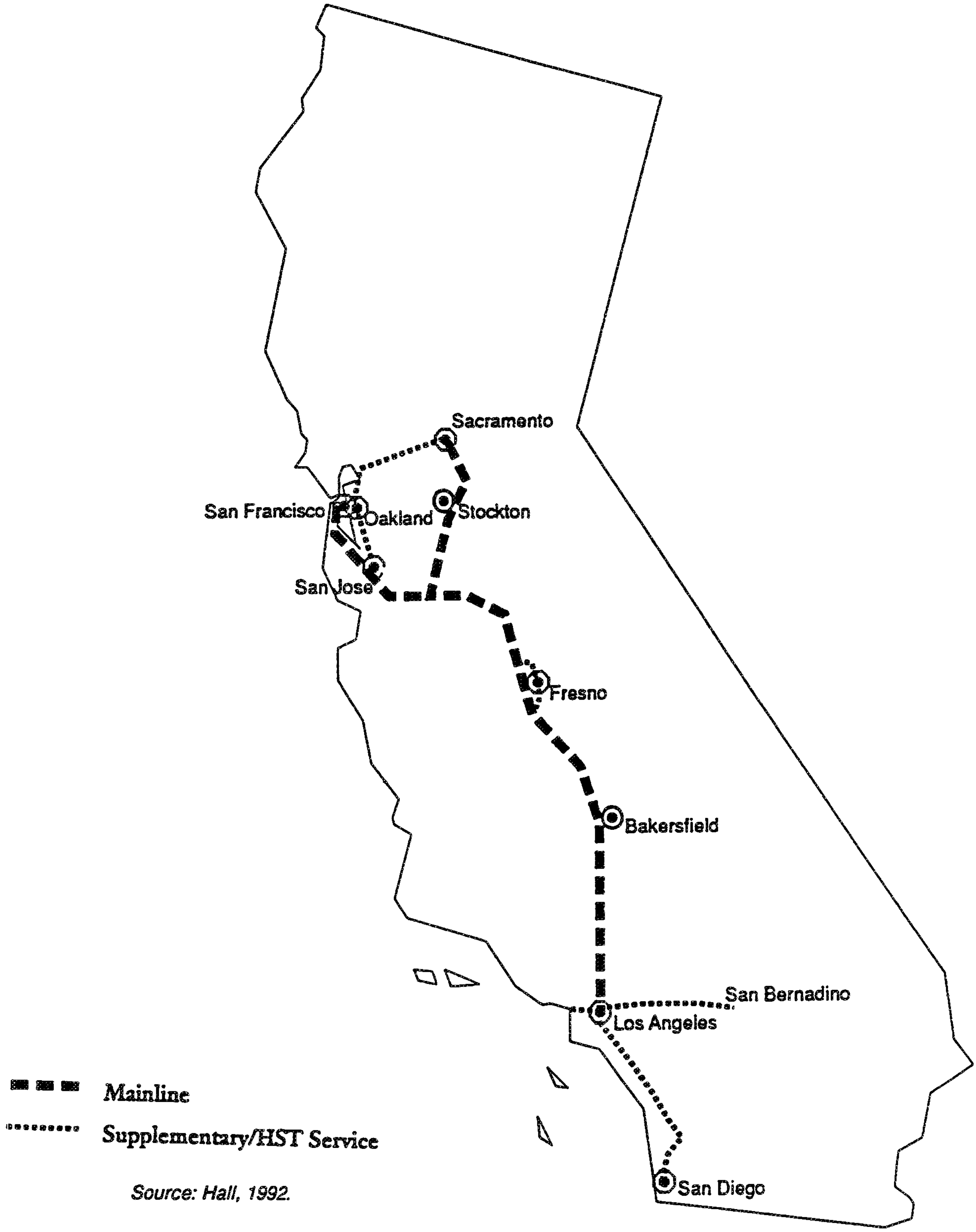
Dealing with Inflation and Delay

In the first part of this paper, our survey of previous cost estimates for rail projects found two main approaches towards costs, which can be called the real cost approach and the nominal cost approach. The difference between these approaches revolves around the question of whether or not inflation should be included as a cost. This is an important issue because we found that many cost overruns were due in large part to inflation.

Most U.S. conceptual planning cost estimates for rail that we considered included inflation as a cost. These estimates are *nominal* cost estimates. In contrast, high-speed rail estimates from Japan and France tend to ignore future inflation, and are *real* cost estimates.

Figure 6

THE CALSPEED NETWORK



Source: Hall, 1992.

Table 17

High Speed Trains For California Summary

DISTANCES, EXPRESS TRAVEL TIMES AND COSTS

SEGMENT	DISTANCE TOTAL (MILES)	MAXIMUM SPEED (MPH)	AVERAGE SPEED (MPH)	TRAVEL TIME TOTAL (HOURS)	TRAVEL TIME TOTAL (MINUTES)	TOTAL COST (1991 $)
1. LOS ANGELES TO SAN FRANCISCO:						
L.A. BASIN	32	125	89.8	0.36	21.6	1,043,100,000
GRAPEVINE 5.0%	49	200	167.5	0.29	17.5	2,017,000,000
CENTRAL CORRIDOR	205	200	200.0	1.03	61.5	2,236,600,000
PACHECO PASS 5.0%	34	200	183.4	0.18	11.0	1,237,300,000
SCV: US-101	29	150	126.6	0.23	13.7	514,200,000
BAY AREA: SJ-SF	49	100	77.4	0.63	38.0	1,922,800,000
TOTAL:	398	200	146.1	2.72	163.3	$8,971,000,000
2. MAINLINE EXTENTION TO SACRAMENTO:						
PP-SAC NEW R/W	111	200	170.2	0.65	39.0	$1,258,000,000
3. SAN JOSE TO SACRAMENTO:						
	130	155	89.7	1.45	87.0	$2,858,000,000
4. LOS ANGELES TO SAN DIEGO						
	123	125	105.7	1.16	69.6	$3,239,000,000

ADDTIONAL COST:	
TRAINSETS	$33 MILLION EACH

Source: Hall, 1992.

Table 18

HIGH SPEED TRAINS FOR CALIFORNIA: Capital Cost Estimate Sheets

LENGTH OF SEGMENT = __________ miles

AVE. R/W WIDTH = __________ feet

	QTY	UoM	UNIT COST	AMOUNT
EARTHWORKS				
GRADING		ACRE	$400	
EXCAVATION		CY	$3.5	
BORROW		CY	$4.5	
LANDSCAPE/MULCH		ACRE	$2,000	
FENCING		MI	$81,000	
SUBBALLAST		SY	$8.0	
SOUND WALLS		MI	$835,000	
CRASH WALLS		MI	$1,700,000	
SUBTOTAL				
CONTINGENCY (25%)				
TOTAL:				
STRUCTURES				
STD VIADUCT 20'-25'		MI	$14,000,000	
VIADUCT 25'-100'Pier		MI	$25,000,000	
VIADCT 100'-200' Pier		MI	$35,000,000	
VIADUCT > 200' Pier		MI	$50,000,000	
SHORT SPAN BRIDGE		EA	$1,000,000	
GRADE SEPARATION RUR		EA	$1,000,000	
GRADE SEPARATION URB		EA	$8,500,000	
ROAD CLOSURE		EA	$50,000	
DEPRESSED SECTION		MI	$16,000,000	
CUT AND COVER TUNNEL		MI	$35,000,000	
STD BORE		MI	$70,000,000	
BOX CULVERT		EA	$83,000	
CULVERT		EA	$3,500	
SUBTOTAL				
CONTINGENCY (25%)				
TOTAL:				
BUILDINGS				
REGIONAL STATION		EA	$50,000,000	
URBAN STATION		EA	$30,000,000	
SUBURBAN STATION		EA	$5,000,000	
INSP./SERVICE FAC.		EA	$6,000,000	
MOW BUILDINGS		EA	$300,000	
WAYSIDE PLATFORMS		EA	$200,000	
DEMOLITION		EA	$100,000	
SUBTOTAL				
CONTINGENCY (25%)				
TOTAL:				

Table 18

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

Source: Hall, 1992.

Our analysis suggests we should follow the real cost approach. Perhaps the most fundamental reason for adopting this cost approach is that when thinking about how much a project will cost, we cannot help but associate a dollar of estimated cost with a dollar in our wallets today. This is a simple psychological phenomenon, but its importance cannot be underestimated. If cost estimates are made by combining a 1999 dollar with a 1992 dollar, these estimates will be intrinsically difficult to evaluate. Because people think in terms of current dollars, it is sensible for cost estimates to be in current dollars.

A second reason for following the real cost approach is to help compare alternative uses for the same money. To take a very simple example, suppose that two alternative transportation projects are being considered, Project A and Project B, and we want to choose the cheaper one. The distribution of real and nominal costs over time for the two projects is displayed in Table 19, which assumes an annual inflation rate of 10 percent. Note that Project A has a high cost at the outset, while Project B has an unusually high cost at the end of the building period.

In nominal terms, Project A costs less than Project B. However, in real terms, Project B costs less than Project A. Since we want to choose the lower-cost project, we must decide which type of costs is appropriate for comparing the two projects. It turns out that real costs are correct. To understand why, suppose further that we are going to make one bond issue right now to pay for our chosen project. Once money is raised through bonds, it will earn interest that will counteract the effect of inflation. Expected inflation can therefore essentially be ignored when considering the amount of the bonds, and bonds can be issued for the current dollar cost of the project. Thus, for Project A we would need to issue bonds for $1 billion, while for Project B we could issue bonds for $900 million. This is another way of saying that Project B is the cheaper one. Although this example is simple, it does illustrate that real costs, not nominal costs, are of interest in comparing alternative uses of money. This idea becomes even more important when projects have different completion times and different benefits.

A final reason for thinking in current dollar terms as opposed to nominal dollar terms is that nominal estimates require a prediction of future inflation in construction, whereas real estimates do not. Predictions of inflation are fraught with difficulty. Unanticipated inflation has often played a large role in increasing the nominal costs of a project. However, unanticipated inflation does *not* indicate that the cost estimates are poor. Making real-cost estimates avoids the inherent dangers in predicting future inflation.

In addition to inflation, another cost commonly mentioned results from unanticipated delay. Delay adds to the nominal costs of a project by postponing the date at which certain phases of construction are carried out, so that nominal construction costs are higher for reasons of inflation. But delay in itself does not add to the real cost of a project, and we have established that real costs are of primary importance. When we consider that a simple delay would not require the issuing

Table 19

NOMINAL VS. REAL COSTS (in millions of dollars)

Real Cost Table (in 1994 dollars)								
	1994	1995	1996	1997	1998	1999	2000	TOTAL
Project A	$400	$100	$100	$100	$100	$100	$100	$1,000
Project B	$100	$100	$100	$100	$100	$100	$300	$900

Nominal Cost Table								
	1994	1995	1996	1997	1998	1999	2000	TOTAL
Project A	$400	$110	$121	$133	$146	$161	$177	$1,249
Project B	$100	$110	$121	$133	$146	$161	$531	$1,303

Assuming 10% inflation rate for nominal costs of new bonds, since the money raised from the initial bond issue would be earning interest to compensate for the inflated costs from delay, it becomes clear that delay alone does not affect real costs. The significant problem that arises from delay is simply that the benefits of having completed a project do not occur as early as anticipated, so that some benefits are lost forever. To avoid this loss of benefits, it is worth taking steps to avoid predictable sources of delay, such as not addressing environmental concerns until late in the planning process or during construction. However, since this paper concentrates on construction cost estimates, and delay does not add to the real cost of construction, we need not consider possible delays in our conceptual planning cost estimates.

At more advanced stages in the planning process, when engineering estimates of costs are made, it may be worth estimating nominal costs in order to form an estimate of future nominal cash flows. Furthermore, if a high-speed rail project receives federal funding, it is important to consider the government guidelines for nominal and real cost increases in a project, which may further emphasize the role of nominal cost estimates. At this early stage in the discussion of high-speed rail, however, our focus is on real-cost estimates, since these are of primary importance in evaluating high-speed rail projects in comparison to other possible projects.

Comparable Estimates

Since there are no existing HSR projects in the U.S. that are comparable to the proposed CalSpeed system, we had hoped to make a comparison using recent foreign experiences. Unfortunately, although several high-speed systems have recently been constructed in Europe, it has not been possible to obtain truly useful cost data from these projects. Our experience suggests that detailed breakdowns of the actual unit costs for these projects are either confidential or unavailable. Since it was not possible to compare the CalSpeed unit costs to actual costs from previous projects, we have instead compared the CalSpeed numbers with the unit costs from the Texas TGV franchise proposal, the West Taiwan HSR Feasibility Study, and those recommended for HSR in the Transportation Research Board's "In Pursuit of Speed" (see Table 20). Each of these examples is highly relevant to the CalSpeed proposal and provides unit costs which can be compared against the CalSpeed unit costs. In addition, we compare CalSpeed's projected average urban cost per mile against estimates of cost for U.S. rail transit (see Table 21).

The Texas TGV Franchise Proposal

On May 28, 1991, the Texas HSR Authority awarded the Texas TGV consortium the franchise to construct and operate a HSR network in the state of Texas. The consortium is led by Morrison Knudsen Engineering and includes G.E.C. Alsthom, the maker of the TGV trainsets, and Sofrérail, the consulting arm of the French National Railways (SNCF). The ultimate goal of the

Table 20

Capital Cost Estimates Comparison: HSR Cost Estimates
1991 $ per mile of two-track equivalent guideway

	CALSPEED	TEXAS	TRB	TAIWAN
EARTHWORKS/MILE				
AVERAGE (FLAT)	$768,000	$548,000	$200,000	
AVERAGE (ROLLING)			$1,100,000	
AVERAGE (MOUNTAINS)	$6,200,000			
RETAINED CUT, 49.2 FT				$32,900,000
RETAINED FILL, 49.2 FT				$37,743,564
FENCING	$81,000	$64,000	$110,000	
STRUCTURES/MILE				
STD VIADUCT 20'-25'	$14,000,000			
VIADUCT 25'-100'Pier	$25,000,000			
VIADCT 100'-200' Pier	$35,000,000			
VIADUCT > 200' Pier	$50,000,000			
AERIAL STRUCTURE		$8,400,000		$18,040,000
VIADUCT		$10,200,000		$26,090,000
SHORT SPAN BRIDGE	$1,000,000			
GRADE SEPARATION			$1,700,000	$36,800,000
GRADE SEP. RUR (EACH)	$1,000,000	$475,000	$400,000	
GRADE SEP. URBN (EACH)	$8,500,000			
MODIFY OH BRIDGES			$3,000,000	
DEPRESSED SECTION	$16,000,000	$8,400,000		
CUT AND COVER TUNNEL	$35,000,000	$27,000,000		$62,290,000
STD BORE	$70,000,000			
TUNNEL, CONVENTIONAL			$1,140,000	$43,140,000
TUNNEL, SPECIAL				$115,520,000
SOUND BARRIER	$835,000	$670,000		$715,000
BOX CULVERT	$83,000	$65,000		
CULVERT	$3,500	$2,500		
BUILDINGS, EACH				
REGIONAL STATION	$50,000,000	$49,000,000		
URBAN STATION	$30,000,000	$28,000,000	$30,000,000	$9,000,000
SUBURBAN STATION	$5,000,000		$15,000,000	
VEHICLE MAINT. FACILITY		$28,000,000		
INSP./SERVICE FAC.	$6,000,000	$4,800,000		
MOW BUILDINGS	$300,000	$220,000		
WAYSIDE PLATFORMS	$200,000	$140,000		
DEMOLITION	$100,000			
MAINT. FACILITIES (TOT)				$119,000,000

Table 20

Page 2

	CALSPEED	TEXAS	TRB	TAIWAN
RAIL				
TRACKWORK	$1,520,000	$1,200,000	$1,700,000	$1,900,000
RAIL RELOCATION	$760,000	$600,000		
POWER/SIGNALS				
CATENARY/SUBSTATIONS	$1,800,000	$1,040,000	$960,000	$1,400,000
SIGNAL/CONTROL	$760,000	$600,000	$450,000	$780,000
RIGHT-OF-WAY/ACRE				
AVERAGE		$14,000		
RANGE LAND	$1,500			
PASTURE/CULTIVATED	$5,000		$3,700	
SCATTERED DEVELOP.	$25,000			
URBAN RAILROAD LAND	$120,000			
SUBURBAN			$75,000	
LEGAL COSTS	$3,500			
CONTINGENCY	25%	3%-10%	25%	25%
ADD-ONS	20%	15%	25%	16%

Sources:

CALSPEED: Hall, "High Speed Trains For California" 1992.
TEXAS: Texas TGV, "Texas TGV Franchise Application" 1991.
TRB: TRB, "In Pursuit of Speed" 1991.
TAIWAN: Parsons Brinckerhoff Int., "West Taiwan HSR Feas. Study", 1990.

Table 21

ESTIMATES OF UNIT CONSTRUCTION COST FOR CALSPEED & RAIL TRANSIT

Millions of constant 1991 $ per mile of two-track equivalent guideway

	CALSPEED	RAIL TRANSIT	
Component	(1) (Urban) Unit Cost (millions)	(2) Pickrell Unit Cost (millions)	(3) Dyer * Unit Cost (millions)
At-grade	27.2	26.72	14.22
Cut or fill			24.98
Elevated	31.2	47.37	47.26
Underground	52.5	125.11	85.50

Sources:

(1) Hall, 1992; average from urban areas used for "at-grade"

*(2) Pickrell, 1985; converted from 1983 $ by cost index 1.2145 ***

*(3) Pushkarev & Zupan, 1980; converted from 1977 $ by cost index 1.9213 ***

** costs are averages of high and low observations; they exclude shops, yards, and land aquisition. Thomas K. Dyer, Inc. 1974*

*** Source: Engineering News Record; 20 Cities Construction Cost Index.*

franchise is the construction of HSR links between Houston, Dallas, Fort Worth, Austin, and San Antonio. The Texas TGV rolling stock will have a maximum cruising speed of 200 mph, with the infrastructure designed for 250 mph top speeds. The 256-mile line between Dallas and Houston, with an estimated cost of $2.5 billion, is the first phase of the project, and is scheduled to be operational by the end of 1998. The total cost for the 6020-mile network, including costs for rolling stock, is estimated at $5.6 billion.

The estimates done by the Texas TGV consortium represent the most comprehensive estimates done for a North American HSR project. Millions of dollars were spent preparing comprehensive engineering and financial proposals for the franchise agreement. Moreover, the estimates done by the consortium are supported by earlier conceptual planning estimates from the 1989 feasibility study done for the Texas HSR Authority. The more detailed franchise estimates are 10 to 15 percent higher in real costs than the previous planning effort.[50]

We believe the Texas TGV estimates are an excellent resource for determining costs of HSR in the United States. With the exception of the mountain crossings, the design parameters recommended by CalSpeed are virtually the same as those planned for the Texas TGV. Consequently, when creating the CalSpeed cost methodology, we relied heavily on the consortium's work.

The West Taiwan HSR Feasibility Study

The West Taiwan HSR Feasibility Study was completed in March 1990 by a consulting team that included Parsons Brinckerhoff International and Deutsche Eisenbahn-Consulting. The study was commissioned by Taiwan's Institute of Transportation, Ministry of Communications, in January of 1989. The consulting team concluded that "a high-speed rail system was feasible in the West Taiwan Corridor and will be required to meet the transportation needs of the future."[51] Consequently, Taiwan is moving forward with the project, which is planned to be completed by July 1999. The feasibility study proposed a 227-mile HSR link between Taipei and Kaohsiung, which was estimated to cost approximately $11 billion. The relatively high average cost per mile ($48.5 million/mile) is largely a result of the tremendous amount of structures required. More than 60 percent of the total length of the route is on viaduct and bridges, while an additional 10 percent is in tunnel.

The cost estimates created for the feasibility study offer an interesting comparison for the CalSpeed estimates. This project represents Taiwan's first experience in constructing a HSR system. Like California, Taiwan is susceptible to earthquakes, so the line was designed for seismic conditions similar to what would be required for California. Furthermore, according to an engineer who worked on the feasibility study, costs of construction for HSR in the U.S. would generally be comparable to those for Taiwan.

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[50]Lichliter/Jameson & Asso., 1989; Texas TGV, 1991.
[51]Parsons Brinckerhoff International, 1990.

In Pursuit of Speed

The Transportation Research Board published *In Pursuit of Speed* in 1991. According to the book's preface, the TRB was requested by the U.S. Department of Transportation to "assess the applicability of high-speed ground transportation (HSGT) technologies to meet the demand for passenger transportation service in high-density travel markets and corridors in the United States."[52] For this book, the TRB contracted with Parsons Brinckerhoff Quade and Douglas, Inc., to create the cost methodology used to estimate costs for a hypothetical corridor. The cost estimation methodology presented in *In Pursuit of Speed* is relevant to the CalSpeed study because it was completed recently and the unit costs were created specifically to apply to U.S. corridors and construction practices. Moreover, the costs presented in Table 20 are from the book's "Alternative 5: HSR Service," which basically represents the same type of service recommended by CalSpeed for California.

Rail Transit

The results from two studies done in the 1980s were used to make a comparison between the projected costs of CalSpeed and those based on previous U.S. rapid transit construction. The first, *Urban Rail in America*, by Boris Pushkarev and Jeffrey Zupan, was published by the U.S. Department of Transportation in 1980. This study, which explored the travel volumes necessary to warrant fixed-guideway investments, included a summary of capital costs for the construction of rapid transit. This summary is reproduced in Table 21. The second source is Don Pickrell's 1985 Transportation Research Record article, *Estimates of Rail Transit Construction Costs*. As with the Pushkarev and Zupan study, a summary of capital costs was provided in this work. The numbers from both examples were synthesized from actual construction costs of recent rapid transit projects. For Table 21, inflation factors have been used to raise the dollar values presented in these studies to 1991 equivalent values.

One must be careful when drawing comparisons between the construction of rapid transit systems and HSR. These are very different types of rail systems with very different cost considerations. Nonetheless, because of the lack of HSR experience in the U.S., such a comparison is desirable as a general indicator of estimation accuracy.

To improve the comparison, we compensated for two of the major intrinsic differences between HSR and rapid transit. First, we omitted from the estimates calculations for stations since the costs for rapid transit and HSR stations would be extremely different. Rapid transit systems have many stations over relatively few route miles, with most systems averaging about one station per mile.[53] In comparison, HRS networks, which generally connect cities 100-500 miles apart, would

[52]TRB, 1991.
[53]Pushkarev, 1980.

have fewer stations separated by much greater distances. Furthermore, HSR stations would be larger and provide more services than rapid transit stations.

Second, we used only the estimated urban costs of CalSpeed in the comparison since rapid transit systems are urban systems. Only 25 percent of the CalSpeed mainline between San Francisco and Los Angeles traverses urban land. Since construction costs through the flat, rural Central Valley or rugged mountain passes simply cannot be compared to urban conditions, these terrains have been omitted from the comparison with rapid transit.

Analyzing the Cost Estimate Comparisons

The comparisons summarized in Tables 20 and 21, while largely supporting the methodology of our original CalSpeed estimates, have helped highlight several areas where adjustments should be made to future unit costs.

Compared to both the Texas TGV and TRB numbers, CalSpeed costs are for the most part somewhat higher. This is to be expected since construction costs in California are high and the geography of the state presents many unusual challenges. Considering these two sources, only the TRB's cost for suburban stations is significantly higher than CalSpeed's comparable unit cost ($15 million vs. $5 million each). However, the Texas TGV estimates included a vehicle maintenance facility ($28 million), whereas costs for a similar facility were overlooked in the CalSpeed estimates.

Costs from the West Taiwan Feasibility Study and the rapid transit comparison show more discrepancy with the CalSpeed numbers than the other examples. For the Taiwan study— while costs for rail, power/signals, and contingency costs are very similar to the CalSpeed figures— earthwork costs and several of the structure costs are substantially higher. In a cut or fill section, the Taiwan study estimated average earthwork costs to be $35 million per mile. In comparison, CalSpeed estimated the earthwork costs (in a cut or fill section) through the mountain passes to average only $6.2 million.[54] For bore tunneling, the Taiwan study provided two unit cost alternatives ($115.5 million and $43 million), whereas CalSpeed simply estimated $70 million per mile. In addition, standard viaduct costs and cut-and-cover tunnel costs were substantially higher for the Taiwan estimates. Both were nearly twice the unit costs used for the CalSpeed estimates. Finally, the Taiwan study assumed a far greater cost for maintenance facilities than the CalSpeed study.

The comparison between CalSpeed's urban cost per mile and those calculated for urban rail transit systems tends to reinforce the findings from the CalSpeed and Taiwan study estimate comparison. CalSpeed's similar at-grade unit cost per mile, shown in Table 21, supports the notion that CalSpeed's unit costs for rail, power/signals, r/w acquisition, urban earthworks (flat), and contingencies are reasonable. On the contrary, the CalSpeed costs per mile, which are only

[54]Hall, 1992. Vol. 2. —based on average costs from the Grapevine 5 percent and Pacheco Pass 5 percent alternatives.

about half of rail transit's cost experience for the elevated portions of networks, and less than half when underground, suggest that the unit costs for CalSpeed's structures are far too low.

Contingency Factors

For large projects, contingency costs should be included as a part of the total estimated cost of the project. Contingency costs account for unknown costs. Their magnitude should coincide with the degree of uncertainty involved with the estimate. As previously mentioned, there has been no U.S. experience in constructing a HSR system like that proposed by CalSpeed. Moreover, capital costs for rail systems are very corridor-specific and are difficult to estimate without detailed design and engineering studies.[55] As a result, the contingency costs for the CalSpeed system can be expected to be high. Yet, following the example of the French and Japanese, one should *not* include in the estimates contingencies to cover additional costs related to delays and inflation. Therefore, the contingency costs for our revised estimates will account for only the underestimation of "real" project costs and minor changes in project scope.

Table 20 includes a comparison of the percentages of capital costs used for contingencies by the different sources. However, since we lack both existing similar HSR services in the U.S. and detailed information from foreign HSR projects, we should also look at the contingency cost experience of recent rail projects in this country. In his study of urban rail transit systems, Pickrell claimed the contingency factors used in conceptual estimates were far too low. Pickrell found that while the projects he reviewed generally had contingency allowances of 5 percent to 10 percent of their estimated project costs, they had an average 77 percent nominal-dollar cost overrun.[56] This led Pickrell to suggest that the contingency cost applied to the conceptual planning estimates of an urban rail project should equal 80 percent of its total construction costs.[57] While this figure is extremely high in comparison to those suggested by Table 20, it must be noted that Pickrell's recommended contingency includes overruns resulting from both inflation and delay, which he has documented as the primary cause of cost escalation.

To conclude, while the comparison with other HSR estimates is supportive of our original contingency factor, Pickrell's rail transit study suggests higher factors may be appropriate through urban areas and mountain passes, where predicting construction costs is difficult. Since it is unrealistic to pinpoint an exact amount for contingencies, a high and low range will be utilized for contingency factors to further emphasize the uncertainty involved. Two different ranges for contingency factors will be used: a low range for construction through rural areas, where construction is relatively simple, and a higher one for mountain passes and urban areas.

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[55]TRB, 1991.
[56]Pickrell, 1990.
[57]Pickrell, 1992. Conversation.

REFINING THE CALSPEED ESTIMATES

Based on the findings from this paper, changes have been made to the CalSpeed cost-estimating methodology used for HSTFC. Appendix A summarizes this "revised" methodology. As with the previous CalSpeed methodology, capital cost estimate sheets, a key explaining the derivation of each cost item, and the additional research from which the values for each item was determined are provided. Since conceptual planning estimates should be shown as a "range of costs," high and low unit cost values have been applied to those items with a high level of uncertainty. This format has similarly been applied to contingency and add-on costs. Standard costs have been used for such categories as rail and signal/control, where our research has suggested that the previous unit costs were both accurate and relatively certain. Of the various cost items, tunneling, excavation, and borrow unit costs were altered the most. Both cut-and-cover and bore tunneling units costs have been significantly changed. For cut-and-cover tunnels, separate costs for rural and urban areas should be used. For rural areas, the original CalSpeed estimate of $35 million per mile is assumed, while for urban areas a range of $35 million to $70 million per mile is used. For bore tunneling, a range of costs from $50 to $100 million per mile is likewise recommended. Original CalSpeed estimates had assumed a $70 million per mile standard cost.

Earthwork costs for excavation and borrow have been divided into two separate categories, one for flat areas and one for mountainous areas. The original CalSpeed estimates of $3.5 and $4.5 per cubic yard for excavation and borrow are assumed to be adequate only for relatively flat regions. For the mountain passes, we now estimate that unit costs would be significantly higher, and a range of costs is necessary to account for uncertainty ($7 to $10 per cubic yard for excavation, and $9 to $14 per cubic yard for borrow).

SUMMARY

The revised CalSpeed estimates are summarized in Table 22. Calculations on which this summary is based are provided in Appendix B. Infrastructure costs for the Los Angeles to San Francisco (L.A.-S.F.) mainline are estimated to be between $8 and $11.5 billion in 1991 dollars. While the original CalSpeed estimate of $9 billion is within this range, it is clearly towards the low end. The higher estimate is primarily a result of increases to the revised estimates' contingency and add-on percentages for mountain passes and urban regions, and of greater earthwork costs assumed for the mountain passes. Since the Sacramento extension is mostly through flat and rural land, the revised cost for this mainline extension (a suggested range of $1.1 to $1.3 billion) conforms with the original CalSpeed estimate of $1.2 billion.

We estimate the average cost per mile of the total L.A.-S.F. mainline to be between $20 and $29 million per mile. However, since cost per mile is highly contingent on terrain and population, it is important to differentiate between the costs of different types of landscapes. For urban

Table 22

CalSpeed Train Routing Summary

Distances and Range of Costs

SEGMENT	DISTANCE TOTAL (MILES)	REVISED CALSPEED ESTIMATE RANGE LOW COST (1,000,000)	HIGH COST (1,000,000)	MID-RANGE AMOUNT (1,000,000)	ORIGINAL CALSPEED ESTIMATE (1,000,000)
1. LOS ANGELES TO SAN FRANCISCO					
L.A. BASIN	32	$955.4	$1,247.9	$1,101.7	$1,043.1
GRAPEVINE 5.0%	49	$1,741.5	$3,177.0	$2,459.3	$2,017.0
CENTRAL CORRIDOR	205	$1,876.7	$2,228.1	$2,052.4	$2,236.6
PACHECO PASS 5.0%	34	$1,157.6	$2,023.2	$1,590.4	$1,237.3
SCV: US-101	29	$480.9	$597.3	$539.1	$514.2
BAY AREA: SJ-SF	49	$1,920.4	$2,267.4	$2,093.9	$1,922.8
TOTAL:	398	$8,132.5	$11,540.9	$9,836.7	$8,971.0
2. MAINLINE EXTENSION TO SACRAMENTO					
PP-SAC NEW R/W	111	$1,107.2	$1,341.8	$1,224.5	$1,258.0

ADDITIONAL COST:	
TRAINSETS	$33 MILLION EACH

areas, we estimate the range of costs to be from $31 to $37 million per mile; for mountain passes, $35 to $63 million per mile; and for flat, rural areas, only $9 to $10 million per mile.

Much of the relatively large difference between the high and low estimates for the L.A.-S.F. mainline can be attributed to the difficulty in estimating construction costs through the mountain passes. Although they comprise only 20 percent of the route length, the Grapevine and Pacheco Pass segments account for 65 percent of the L.A.-S.F. mainline estimate uncertainty. Most of the uncertainty comes from the difficulty in determining bore tunneling and earthwork costs through California's mountain ranges. Only through detailed geological and engineering studies will it be possible to accurately estimate costs for HSR crossings of Californian mountain passes.

CONCLUSIONS

Creating conceptual cost estimates for HSR in California has been difficult. The mountain ranges and sprawling urban areas that must be traversed present major engineering challenges which in turn lead to much uncertainty in cost. This uncertainty is exacerbated by the lack of previous experience in the U.S. with constructing HSR systems like the one proposed by CalSpeed. Although there are several recent foreign HSR examples, obtaining data on their experiences with cost escalation has been problematic. While we have found some general information, more detailed data seems to be largely unavailable or confidential. Thus, to test critically our original estimates, we have drawn largely from the experience of previous urban rail projects in this country.

While our research suggests that recent large rail projects have produced significant cost escalation, it appears that much of the escalation has often been related to the nominal cost of the project rather than its real cost. Our evaluation of the impacts from inflation and unanticipated delay reveals that these additional nominal costs should *not* be accounted for in the CalSpeed estimates.

Most of the escalation problems attributed to actual estimate error have been confined to those estimates done in the conceptual planning stages of rail projects. To improve planning estimates such as our CalSpeed estimates, a large contingency factor should be used, the reasonability of capital costs should be checked against other recent comparable projects, and a range of costs presented. Following these guidelines, we re-evaluated and refined our original cost estimate methodology. The revised estimates for the capital costs of HSR infrastructure[58] from downtown Los Angeles to downtown San Francisco produced a range between $8 and $11.5 billion.

It must be re-emphasized that CalSpeed cost estimates are conceptual planning estimates. Our estimates are for planning purposes. They were created to help the state and engineering firms determine the feasibility of HSR in California. Before such a system can be built, more accurate, detailed design estimates will be required. Since there is a high degree of uncertainty in

[58]Does not include trainsets.

estimating costs for the mountain passes, it is particularly important to have a carefully thought-out, preliminary engineering study of these regions.

APPENDIX A

Revised CalSpeed Cost-Estimating Methodology

REVISED CALSPEED CAPITAL COST ESTIMATES

Range of Unit Costs

	UoM	UNIT COSTS		
		HIGH	STANDARD	LOW
EARTHWORKS				
GRADING	ACRE		$400	
EXCAVATION (Flat)	CY		$3.5	
BORROW (Flat)	CY		$4.5	
EXCAVATION (Mount)	CY	$10.0		$7.0
BORROW (Mount)	CY	$14.0		$9.0
LANDSCAPE/MULCH	ACRE		$2,000	
FENCING	MI		$81,000	
SUBBALLAST	SY		$8.0	
SOUND WALLS	MI		$835,000	
CRASH WALLS	MI		$1,700,000	
STRUCTURES	UoM	HIGH	STANDARD	LOW
STD VIADUCT 20'-25'	MI	$25,000,000		$14,000,000
VIADUCT 25'-100'Pier	MI	$30,000,000		$25,000,000
VIADCT 100'-200' Pier	MI	$40,000,000		$35,000,000
VIADUCT > 200' Pier	MI	$55,000,000		$50,000,000
SHORT SPAN BRIDGE	EA		$1,000,000	
GRADE SEPARATION RUR	EA		$1,000,000	
GRADE SEPARATION URB	EA		$8,500,000	
ROAD CLOSURE	EA		$50,000	
DEPRESSED SECTION	MI		$16,000,000	
CUT & COVER TNL RUR	MI		$35,000,000	
CUT & COVER TNL URB	MI	$70,000,000		$35,000,000
STD BORE	MI	$100,000,000		$50,000,000
BOX CULVERT	EA		$83,000	
CULVERT	EA		$3,500	
BUILDINGS	UoM	HIGH	STANDARD	LOW
REGIONAL STATION	EA		$50,000,000	
URBAN STATION	EA		$30,000,000	
SUBURBAN STATION	EA	$15,000,000		$5,000,000
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	

REVISED CALSPEED CAPITAL COST ESTIMATES

	UoM	UNIT COSTS		
		HIGH	STANDARD	LOW
RAIL				
TRACKWORK	TRK-MI		$760,000	
RAIL RELOCATION	TRK-MI		$760,000	
POWER/SIGNALS	UoM	HIGH	STANDARD	LOW
CATENARY/SUBSTATIONS	TRK-MI		$900,000	
SIGNAL/CONTROL	MI		$760,000	
RIGHT-OF-WAY	UoM	HIGH	STANDARD	LOW
RANGE LAND	ACRE		$1,500	
PASTURE/CULTIVATED	ACRE		$5,000	
SCATTERED DEVELOP.	ACRE		$25,000	
URBAN RAILROAD LAND	ACRE		$120,000	
LEGAL COSTS	ACRE		$3,500	

PERCENT OF TOTAL CONSTRUCTION COSTS

	HIGH	STANDARD	LOW
CONTINGENCY (RURAL)	25%		10%
CONTINGNCY (URB/MNT)	35%		20%
ADD-ONS	25%		20%

CAPITAL COST ESTIMATES KEY

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.[1] For the mountain crossing segments, where large quantities of cut and fill were required, higher costs were used for "excavation" and "borrow."

Grading:

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 right-of-way width. For this report, an average right-of-way 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 right-of-way flat segments. It was assumed that no excavation could be utilized where existing rail right-of-way was used since 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 of the California CST network.

For the mountain passes, quantities were estimated based on profiles derived from USGS topographical maps. These calculations assumed a level cross-section. The track section used was 50 feet with side slopes of 3 feet horizontal distance to every 2 feet of vertical height. It is very difficult to estimate unit costs for excavation and borrow in the mountain passes, creating the need for a range of costs. To obtain the low value, we doubled the unit costs assumed for relatively flat sections. The $9.0 per CY, for borrow, is equivalent to the cost used for "excavation, backfill, and spoil" for the California-Nevada Super Speed Ground Transportation Project proposal.[2] The high values are about three times the unit costs expected for relatively flat sections. 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:

Calculated using the same quantities as grading.

Fencing:

An 8-foot chain link fence, to be required throughout the entire length of at-grade segments (on each side of right-of-way).

Subballast:

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

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[1]Source: Means Heavy Construction Cost Data 1991. Calculated using the average cost indexes of selected cities in California and Texas.

[2]Bechtel Corporation, 1990.

Sound Walls:
Used through areas sensitive to noise, particularly on aerial structures. This report limited their use to areas where CST right-of-way was directly adjacent to hospitals, schools, or residential subdivisions.

Crash Walls:
Needed in shared right-of-way to separate freight from CST and to protect piers of viaducts from freight. For the Texas project, engineers are still working on an acceptable design for this problem. The most likely solution appears to be a concrete barrier similar to the Jersey Barrier now used on freeways.

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 needed to cross California's mountain ranges. Moreover, the Texas project does not run in urban areas to the extent that California CST lines would, 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 at the end of this Cost Estimation Appendix (see Cost Estimate Research sheets).

Standard Viaduct 20-25 feet:
A prestressed reinforced concrete aerial structure that predominately maintains a standard clearance height in order to provide grade separation from highways, streets, marsh lands, and so on. This type of structure would also be necessary in shared right-of-way 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 low unit cost of $14.0 million/mile was chosen and a high of $25.0 million.

Viaduct Greater Than 25-Foot 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:
A 200- to 300-foot span bridge, able to cross most streams, canals, or streets. The cost calculation is based on a structural engineering firm's estimate for a 25-foot prestressed reinforced bridge designed for railroad loads.

Grade Separation:
The higher 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.

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:
This is used primarily in rural areas. Some roads would be closed rather than construct a costly grade separation. The cost includes a standard Caltrans barricade and signing on each side of the rail right-of-way. Costs were anticipated to be minor, and an average of $50,000 each was assumed.

Depressed Section:
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:
Shallow tunnel that is created by first excavating from the surface, then building a structure within, and 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. As it is very difficult to calculate an average cost for urban cut and cover tunnels, a range of $35 million/mile to $70 million/mile was derived after consulting several sources (see Cost Estimate Information). The low cost ($35 million) was assumed for rural cut-and-cover tunnels.

Standard Bore:
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 geography are all factors that 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 6 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. The range provided by our conversations with professionals was thought to represent a reasonable range of costs for the planning purposes of this report.

Box Culverts:
Necessary for drainage and as undercrossings (cattle, tractors). The Texas TGV system will be primarily built on new right-of-way 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 right-of-way. The $83,000 cost per box culvert was derived from the Texas report.

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

BUILDINGS

Regional/Urban Station:

The primary stations in the CST network. Each of the major metropolitan areas served by the CST would have a CBD station. This report assumes two regional stations, one in Los Angeles and one in the Bay Area. These stations would require a greater 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 Station:

Small stations, predominately in urban areas where only some of the CST trains would stop. The CST network would have the flexibility of having many of these stations, depending on demand. These stations were assumed to be somewhat similar to existing new major rail stations. 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.[3] A $5 million cost, about 1.67 times as much as those reviewed by Wilbur Smith Asso., was used for the low estimate for suburban stations, whereas $15 million per station suggested by the TRB source was used for the high estimate.

Maintenance Facilities:

It is assumed that one facility will be necessary for the CalSpeed network. The unit costs were 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 and perhaps at Sacramento. 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:

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:

Throughout the CST network, alignments have been chosen that 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:

Includes everything above the sub-ballast: rail and fastenings, ballast, and concrete ties. Trackwork is a lump sum figure based on the Texas estimates that includes the costs of turnouts, crossovers,

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[3]Wilbur Smith Associates, October 1989.

and rail yards. In Texas, trackwork averages about $600,000 per mile of single track; for double track (according to an engineer who worked on the estimate) this cost is doubled. Escalating the cost for California, the cost per mile of single track would increase to $760,000 per mile.

Rail Relocation:
Freight tracks occupy the center portion of most existing rail right-of-way, and would need to be moved for the CST tracks to share the right-of-way. In most cases the track/tracks would have to be replaced with new track/tracks. 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 needed for the proposed network. In urban areas, the CST will make use of existing transportation corridors. Therefore, no attempt was made to generalize urban land values beyond the pricing of existing rail corridors (according to recent federal legislation, the CST could use interstate highway medians without purchasing the right-of-way 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 right-of-way by SCRRA Metrolink[4] and the Peninsula Joint Powers Board;[5] this was used for the estimated cost of rail right-of-way. Since much of the rail right-of-way identified for use by the CalSpeed proposal is, or soon will be, publicly owned, it is reasonable to assume that use of the right-of-way might be permitted without purchase. Since lease costs will be considered as operational costs, $0.00 per acre is used for publicly owned rail right-of-way. Other land values were synthesized from estimates given by county officials.

CONTINGENCY COSTS AND 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 (see Cost Estimate Information) and the other sources used for this paper. To reflect the conceptual nature of the CalSpeed estimates, the contingency cost must be high and ranges are necessary. 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. A high of 40 percent and a low of 20 percent of the construction cost total has been chosen to create the urban/mountain pass contingency range. For the rural segments, 25 percent and 10 percent are appropriate. For the Add-Ons, the 20 to 25 percent range suggested by the TRB source was adopted.

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[4]Metrolink paid $245 million for 174.5 miles of SP right-of-way. This amounted to 2115 acres purchased or $120,000 per acre. LACTC, 1992.

[5]For $211.6 million, the Joint Powers Board purchased 51.4 miles of SP mainline. This amounted to 607 total acres or $120,000 per acre. Peninsula Corridor Study Joint Powers Board, November 1991.

CalSpeed

COST ESTIMATION RESEARCH

1 Caltrans Estimates	*(from conversation, estimating division)*							
BRIDGES: STD width double tk =			43	feet				
Prestressed Reinforced Concrete – Highway								
25' height =	$65	/sq ft			$14.8	million/mile		
25–100' hieght =	$80	/sq ft			$18.2	million/mile		
> 100' height =	$100	/sq ft			$22.7	million/mile		
Steel (go up faster, longer spans):								
average =	$150	/sq ft			$34.1	million/mile		
worst case =	$170	/sq ft			$38.6	million/mile		
(Advanced Planning Studies Manual, 1991)								
CIP Box Girder R.R. =	$100.0	to			$250.0	/sq ft		
	$22.7				$56.8	million/mile		
TUNNELS:								
45' bore, mostly rock =			$15,000	/ln–ft			$79.2	million/mile
(Caldecott Tunnel PV)								
CUT AND COVER TUNNELS:								
45'–5–' opening, 6' fill =			$7,000	to			$8,000	/ln–ft
(Broadway)			$37.0	to			$42.2	million/mile
65' opening (6 lanes) =			$160	/sq ft			$54.9	million/mile
45' opening =							$38.0	million/mile

2 Texas TGV Franchise Application						
Segmental Bridge =			$1,938	/ln–ft	$10.2	million/mile
(Viaduct, 20')						
23' Wide Tunnel =			100	/sq ft	$12.1	million/mile
43' Wide Tunnel =			72	/sq ft	$16.3	million/mile
(conversation with engineer)						
TRACK						
Main Line =	$86.0	/track ft			$454.1	thousand/mile
Yard =	$77.0	/track ft			$406.6	thousand/mile
Rail Reloc =	$86.0	/track ft			$454.1	thousand/mile
TURNOUTS						
STD	$515.0	thousand each				
#46	$148.0	thousand each				
#21	$450.0	thousand each				
Yard =	$50.0	thousand each				
Contingencies			3–10	%	Subheading Subtotal	
Engineering/Design			7	%	Project Subtotal	
Contruction Management			3	%	Project Subtotal	
Utility Relocation			1	%	Project Subtotal	
Customer Communications			1	%	Project Subtotal	
Sales Tax			3	%	Project Subtotal	
Trainsets			$26	million each		

3	**SCAG: High Speed Rail Feasibility Study, 1991.**			
	Bridges	$19.7	million/mile	(double track)
	Tunnels	$31.7	million/mile	(single track)
		$30.9	million/mile	(TGV A)
	Contingency	25%		

4	**Civil Engineering for Underground Transport (J.T. Edwards, 1990)**				
	Civil Engineering Costs (do not include land aquisition)				
	TUNNELS: Range of Costs =	$16.4	to	$123.1	million/mile
	Twin tunnels with a single track in each				
	Lower figure: small-diameter tunnels, good cohesive ground, expanded concrete linings				
	Higher Cost: larger-diameter, poor ground, special techniques				
	CUT AND COVER TUNNELS:	$13.7	to	$32.8	million/mile
	Single structure containing two tracks				
	Lower Figure: good ground, above water table				
	Higher Figure: water-bearing ground, substantial temporary works, services diversions				
	SURFACE RAILWAY:	$5.5	to	$10.9	million/mile
	ELEVATED RAILWAY:	$13.7	to	$27.4	million/mile
	Viaduct Cost =	$8.2	to	$16.4	million/mile
	COST OF EQUIPPING TUNNELS:	$5.5	to	$10.9	million/mile
	(track, signalling and electrical supplies)				
	STATIONS: Range of Costs =	$2.7	to	$41.0	million/mile
	Lower Figure: simple surface station				
	Higher Figure: deep level station with escalators				
	ROLLING STOCK DEPOT:	$54.7	to	$109.4	million/mile
	(for 30 6 -car trains, surface construction)				

5	**Train Riders Associate of California (per conversation)**		
*	Base Tunnels (through Teh.) 30 miles =	$100.0	million/mile
	* contractor's estimate		

6	**Structural engineering firm, specializing in bridge design**				
	(conversation with engineer)				
	Assume STD width double trk =		43	feet	
	25' Pier, Highway	$80.0	sqft	$18.2	million/mile
	add 8% for railway	$6.4	sqft	$1.5	million/mile
	add 20% for mountains	$16.0	sqft	$3.6	million/mile
	Total =	$102.4	sqft	$23.2	million/mile
	Up to 600' span =	$170.0	to	$190.0	sqft
		$38.6	to	$43.1	million/mile
	Up to 900' span =	$220.0	to	$270.0	sqft
		$49.9	to	$61.3	million/mile

7	KORVE Engineering Inc.: San Francisco Bay Crossing Study, 1991.				
	BART (double track)				
	At-Grade	$30.0	to	$40.0	million/mile
	Aerial	$40.0	to	$60.0	million/mile
	Suburban Subway	$70.0	to	$100.0	million/mile
	Urban Subway	$170.0	to	$210.0	million/mile
	Transbay Tube	$160.0	to	$170.0	million/mile
	Main Bridge Span	$35.0	to	$40.0	million/mile
	Trestle Bridge	$20.0	to	$32.0	million/mile

8	PUC: 1990-91 Nomination for Proposed Separations *		
	Average Cost Overhead Separation =	$8.6	million
	Average Cost Underpass =	$8.1	million
	High Cost: Overhead =	$21.1	million
	Underpass =	$18.9	million
	Low Cost: Overhead =	$2.7	million
	Underpass =	$1.0	million
	* high-volume traffic areas with high accident potential, predominately urban areas represented		

9	Bureau of Reclamation		
	Pacheco Pass Tunnel, 1979 =	$62.0	million
	(9.5' diameter, 7.1 mile length)		
	1991 ($) =	$102.5	million

10	Bechtel Civil, Inc.: Dublin/Pleasanton Extension Project *(BART: Capital Cost Methodology, May 1989)*				
	Double Track				
	Subballast =	$22.0	/CY	$22.0	/LF
	Grading =	$1.0	/SY	$6.0	/LF
	Ballast =	$27.0	/CY	$54.0	/LF
	Ties =	$125.0	EA	$100.0	/LF
	(Concrete @ 30" OC)				
	Rail & Fstngs	$1,900.0	/TON	$152.0	/LF
	TRACK =			$306.0	/LF
	(minus grading & subballast)			$1.6	million/mile
*	Aerial Structure (25' h)			$11.7	million/mile
*	Aerial Structure (35' h)			$13.3	million/mile
*	Aerial Structure (45' h)			$15.3	million/mile
*	Aerial Structure (55' h)			$17.5	million/mile
	(height from ground to top of rail)				
*	Retained Fill Section (8' h)			$5.3	million/mile
*	Retained Fill Section (12' h)			$7.2	million/mile
*	Depressed Section (8' h)			$16.1	million/mile
*	Depressed Section (12' h)			$22.4	million/mile

10 Bechtel Civil, Inc. (continued)				
(BART: Capital Cost Methodology, May 1989)				
* Cut and Cover Tunnel (20' h)			$25.1	million/mile
* Cut and Cover Tunnel (30' h)			$34.2	million/mile
* Cut and Cover Tunnel (40' h)			$43.9	million/mile
(height from track to surface)				
* Fixed Double Track Costs subtracted				
At-Grade Minimum Median 58' (freeway median strip)				
Excavation =	$22.0	/LF	$0.1	million/mile
Backfill =	$50.0	/LF	$0.3	million/mile
Concrete Wall Footings =	$48.0	/LF	$0.3	million/mile
Concrete Wall Stems =	$180.0	/LF	$1.0	million/mile
Reinforcing =	$39.0	/LF	$0.2	million/mile
8" Underdrain =	$25.0	/LF	$0.1	million/mile
Chain Link Fence =	$20.0	/LF	$0.1	million/mile
Ballasted Double Track =	$335.0	/LF	$1.8	million/mile
Total =	$719.0	/LF	$3.8	million/mile
Contingencies	25%			
Eng./Const. Management	25%			
per BART (extension project manager)				

11 Construction Company, Heavy Construction Division		
Twin Bores through Tehachapis =	$50.0	million/mile
BART 3 mile Tunnel (1966-9) =	$12.0	million/mile
1991 Dollars =	$42.6	million/mile

12 CIGGT Report TGV System for California		
(1984 constr. $ X 1.16; land aqui. $ X 1.44)		
Tunnels =	31.3	million/mile
Land Aquisition		
Range Land =	$922	acre
Pasture/Cultivated =	$4,025	acre
Orchards =	$18,000	acre
Vineyards =	$10,217	acre
Built Up, Scattered =	$18,720	acre
Built Up, Dense =	$142,307	acre
Railroad/Hghwy land =	$144,000	acre
Industrial land =	$252,000	acre
Legal Costs =	$4,392	acre
Superstructure		
Track =	$602,161	trk-mi
Turnouts =	$440,800	each
Crossovers =	$1,392,000	each
Signalling =	$368,254	trk-mi
Catenary =	$319,514	trk-mi

12	CIGGT Report TGV System for California (continued)		
	Power Supply =	$101,270	trk-mi
	Telecommunications =	$16,240	rte-mi
	Buildings =	$64,960	rte-mi
	Terminals =	$83,238,120	lump sum
	Maintenance fac. =	$80,550,400	lump sum
	Trainset prep. cnter =	$1,765,520	lump sum

13	TRB, 1991. "In Pursuit of Speed"			
	Right of Way and Land Aquisition (per 80 ft r/w)			
	Urban Core Area	$2,120,000	per acre	
	Urban	$212,000		
	Suburban	$159,000		
	Rural	$26,500		
	Design, Engineering, and Contingency Costs			
	Prelimin. Engineering	3-5	%	
	Final Design	5-10	%	
	Contingencies	10-20	%	
	Construct. Management	8	%	
	Totals:	26-43	%	
	TGV trainsets (400-mile corr.)			$24 million each

14	MK Engineers, Inc: RCTC/AT&SF Commuter Rail Study, 1991.	
	Contingency	30%
	Engineering	15%

15	Parsons De Leuw Inc.: So. Cal. Accelerated Rail Elect. Program	
	Contingency (approx.)	62%
	Project Reserve	20%

16	Lichliter/Jameson & Asso.: Eval. of Ground Trans. Options, 1991. For Imperial County Regional Airport		
	Railroad Bridges	$20.6	million/mile
	Railroad Tunnel	$52.8	million/mile
	Downtown Station	$40	million
	Airport Station	$25	million
	Eng & Constr. Man.	10%	
	Contingencies	15%	
	Add ons	3%	

APPENDIX B

Revised Cost-Estimate Methodology

CalSpeed: Revised Capital Cost Estimates, Low Estimate

L.A. BASIN – SP R/W

LENGTH OF SEGMENT = 32.00 miles
AVE. R/W WIDTH = 100 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	387.88	ACRE	$400	155,152
EXCAVATION (Flat)	0	CY	$3.5	0
BORROW (Flat)	860,800	CY	$4.5	3,873,600
EXCAVATION (Mount)	0	CY	$7.0	0
BORROW (Mount)	0	CY	$9.0	0
LANDSCAPE/MULCH	387.88	ACRE	$2,000	775,758
FENCING	64.00	MI	$81,000	5,184,000
SUBBALLAST	576,000	SY	$8.0	4,608,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	32.00	MI	$1,700,000	54,400,000
SUBTOTAL				68,996,509
CONTINGENCY (20%)				13,799,302
TOTAL:				$82,796,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$14,000,000	0
VIADUCT 25'-100'Pier	0.00	MI	$25,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$35,000,000	0
VIADUCT > 200' Pier	0.00	MI	$50,000,000	0
SHORT SPAN BRIDGE	4	EA	$1,000,000	4,000,000
GRADE SEPARATION RUR	4	EA	$1,000,000	4,000,000
GRADE SEPARATION URB	28	EA	$8,500,000	238,000,000
ROAD CLOSURE	0	EA	$50,000	0
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	1.32	MI	$50,000,000	66,000,000
BOX CULVERT	0	EA	$83,000	0
CULVERT	70	EA	$3,500	246,400
SUBTOTAL				312,246,400
CONTINGENCY (20%)				62,449,280
TOTAL:				$374,696,000

L.A. BASIN – SP R/W

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	1	EA	$50,000,000	50,000,000
URBAN STATION	1	EA	$30,000,000	30,000,000
SUBURBAN STATION	1	EA	$5,000,000	5,000,000
MAINTENANCE FACILITY	1	EA	$35,000,000	35,000,000
INSP./SERVICE FAC.	1	EA	$6,000,000	6,000,000
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				126,000,000
CONTINGENCY (20%)				25,200,000
TOTAL:				$151,200,000
RAIL				
TRACKWORK	64.00	TRK-MI	$760,000	48,640,000
RAIL RELOCATION	32.00	TRK-MI	$760,000	24,320,000
SUBTOTAL				72,960,000
CONTINGENCY (20%)				14,592,000
TOTAL:				$87,552,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	64.00	TRK-MI	$900,000	57,600,000
SIGNAL/CONTROL	32.00	MI	$760,000	24,320,000
SUBTOTAL				81,920,000
CONTINGENCY (20%)				16,384,000
TOTAL:				$98,304,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URB RAILROAD LAND *	387.88	ACRE	$0	0
LEGAL COSTS	387.88	ACRE	$3,500	1,357,576
SUBTOTAL				1,357,576
CONTINGENCY (20%)				271,515
TOTAL:				$1,629,000
SUBTOTAL				$796,177,000
ADD-ONS (20%)				$159,235,400
TOTAL:				$955,400,000

* The right-of-way is publically owned

CalSpeed: Revised Capital Cost Estimates, High Estimate

L.A. BASIN – SP R/W

LENGTH OF SEGMENT = 32.00 miles
AVE. R/W WIDTH = 100 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	387.88	ACRE	$400	155,152
EXCAVATION (Flat)	0	CY	$3.5	0
BORROW (Flat)	860,800	CY	$4.5	3,873,600
EXCAVATION (Mount)	0	CY	$10.0	0
BORROW (Mount)	0	CY	$14.0	0
LANDSCAPE/MULCH	387.88	ACRE	$2,000	775,758
FENCING	64.00	MI	$81,000	5,184,000
SUBBALLAST	576,000	SY	$8.0	4,608,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	32.00	MI	$1,700,000	54,400,000
SUBTOTAL				68,996,509
CONTINGENCY (35%)				24,148,778
TOTAL:				$93,145,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$25,000,000	0
VIADUCT 25'-100'Pier	0.00	MI	$30,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$40,000,000	0
VIADUCT > 200' Pier	0.00	MI	$55,000,000	0
SHORT SPAN BRIDGE	4	EA	$1,000,000	4,000,000
GRADE SEPARATION RUR	4	EA	$1,000,000	4,000,000
GRADE SEPARATION URB	28	EA	$8,500,000	238,000,000
ROAD CLOSURE	0	EA	$50,000	0
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	1.32	MI	$100,000,000	132,000,000
BOX CULVERT	0	EA	$83,000	0
CULVERT	70	EA	$3,500	246,400
SUBTOTAL				378,246,400
CONTINGENCY (35%)				132,386,240
TOTAL:				$510,633,000

L.A. BASIN – SP R/W

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	1	EA	$50,000,000	50,000,000
URBAN STATION	1	EA	$30,000,000	30,000,000
SUBURBAN STATION	1	EA	$15,000,000	15,000,000
MAINTENANCE FACILITY	1	EA	$35,000,000	35,000,000
INSP./SERVICE FAC.	1	EA	$6,000,000	6,000,000
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				136,000,000
CONTINGENCY (35%)				47,600,000
TOTAL:				$183,600,000
RAIL				
TRACKWORK	64.00	TRK-MI	$760,000	48,640,000
RAIL RELOCATION	32.00	TRK-MI	$760,000	24,320,000
SUBTOTAL				72,960,000
CONTINGENCY (35%)				25,536,000
TOTAL:				$98,496,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	64.00	TRK-MI	$900,000	57,600,000
SIGNAL/CONTROL	32.00	MI	$760,000	24,320,000
SUBTOTAL				81,920,000
CONTINGENCY (35%)				28,672,000
TOTAL:				$110,592,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URB RAILROAD LAND *	387.88	ACRE	$0	0
LEGAL COSTS	387.88	ACRE	$3,500	1,357,576
SUBTOTAL				1,357,576
CONTINGENCY (35%)				475,152
TOTAL:				$1,833,000
SUBTOTAL				$998,299,000
ADD-ONS (25%)				$249,574,750
TOTAL:				$1,247,900,000

CalSpeed: Revised Capital Cost Estimates, Low Estimate

GRAPEVINE: 5.0% ALTERNATIVE

LENGTH OF SEGMENT = 49.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	772.12	ACRE	$400	308,848
EXCAVATION (Flat)	3,027,500	CY	$3.5	10,596,250
BORROW (Flat)	941,500	CY	$4.5	4,236,750
EXCAVATION (Mount)	1,002,315	CY	$7.0	7,016,205
BORROW (Mount)	14,660,555	CY	$9.0	131,944,995
LANDSCAPE/MULCH	772.12	ACRE	$2,000	1,544,242
FENCING	59.00	MI	$81,000	4,779,000
SUBBALLAST	882,000	SY	$8.0	7,056,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	0.00	MI	$1,700,000	0
SUBTOTAL				167,482,291
CONTINGENCY (20%)				33,496,458
TOTAL:				$200,979,000
STRUCTURES				
STD VIADUCT 20'-25'	1.44	MI	$14,000,000	20,160,000
VIADUCT 25'-100'Pier	2.99	MI	$25,000,000	74,750,000
VIADCT 100'-200' Pier	2.48	MI	$35,000,000	86,800,000
VIADUCT > 200' Pier	0.95	MI	$50,000,000	47,500,000
SHORT SPAN BRIDGE	5	EA	$1,000,000	5,000,000
GRADE SEPARATION RUR	10	EA	$1,000,000	10,000,000
GRADE SEPARATION URB	0	EA	$8,500,000	0
ROAD CLOSURE	6	EA	$50,000	300,000
DEPRESSED SECTION	0.95	MI	$16,000,000	15,200,000
CUT & COVER TNL RUR	0.63	MI	$35,000,000	22,050,000
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	10.98	MI	$50,000,000	549,000,000
BOX CULVERT	5	EA	$83,000	415,000
CULVERT	108	EA	$3,500	377,300
SUBTOTAL				831,552,300
CONTINGENCY (20%)				166,310,460
TOTAL:				$997,863,000

GRAPEVINE: 5.0% ALTERNATIVE

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	0	EA	$5,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	35	EA	$100,000	3,500,000
SUBTOTAL				3,500,000
CONTINGENCY (20%)				700,000
TOTAL:				$4,200,000
RAIL				
TRACKWORK	98.00	TRK-MI	$760,000	74,480,000
RAIL RELOCATION	0.00	TRK-MI	$760,000	0
SUBTOTAL				74,480,000
CONTINGENCY (20%)				14,896,000
TOTAL:				$89,376,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	98.00	TRK-MI	$900,000	88,200,000
SIGNAL/CONTROL	49.00	MI	$760,000	37,240,000
SUBTOTAL				125,440,000
CONTINGENCY (20%)				25,088,000
TOTAL:				$150,528,000
RIGHT-OF-WAY				
RANGE LAND	641.18	ACRE	$1,500	961,770
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	130.95	ACRE	$25,000	3,273,750
URBAN RAILROAD LAND	0.00	ACRE	$0	0
LEGAL COSTS	772.12	ACRE	$3,500	2,702,424
SUBTOTAL				6,937,944
CONTINGENCY (20%)				1,387,589
TOTAL:				$8,326,000
SUBTOTAL				$1,451,272,000
ADD-ONS (20%)				$290,254,400
TOTAL:				$1,741,500,000

CalSpeed: Revised Capital Cost Estimates, High Estimate

GRAPEVINE: 5.0% ALTERNATIVE

LENGTH OF SEGMENT = 49.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	772.12	ACRE	$400	308,848
EXCAVATION (Flat)	3,027,500	CY	$3.5	10,596,250
BORROW (Flat)	941,500	CY	$4.5	4,236,750
EXCAVATION (Mount)	1,002,315	CY	$10.0	10,023,150
BORROW (Mount)	14,660,555	CY	$14.0	205,247,770
LANDSCAPE/MULCH	772.12	ACRE	$2,000	1,544,242
FENCING	59.00	MI	$81,000	4,779,000
SUBBALLAST	882,000	SY	$8.0	7,056,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	0.00	MI	$1,700,000	0
SUBTOTAL				243,792,011
CONTINGENCY (35%)				85,327,204
TOTAL:				$329,119,000
STRUCTURES				
STD VIADUCT 20'-25'	1.44	MI	$25,000,000	36,000,000
VIADUCT 25'-100'Pier	2.99	MI	$30,000,000	89,700,000
VIADCT 100'-200' Pier	2.48	MI	$40,000,000	99,200,000
VIADUCT > 200' Pier	0.95	MI	$55,000,000	52,250,000
SHORT SPAN BRIDGE	5	EA	$1,000,000	5,000,000
GRADE SEPARATION RUR	10	EA	$1,000,000	10,000,000
GRADE SEPARATION URB	0	EA	$8,500,000	0
ROAD CLOSURE	6	EA	$50,000	300,000
DEPRESSED SECTION	0.95	MI	$16,000,000	15,200,000
CUT & COVER TNL RUR	0.63	MI	$35,000,000	22,050,000
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	10.98	MI	$100,000,000	1,098,000,000
BOX CULVERT	5	EA	$83,000	415,000
CULVERT	108	EA	$3,500	377,300
SUBTOTAL				1,428,492,300
CONTINGENCY (35%)				499,972,305
TOTAL:				$1,928,465,000

GRAPEVINE: 5.0% ALTERNATIVE

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	0	EA	$15,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	35	EA	$100,000	3,500,000
SUBTOTAL				3,500,000
CONTINGENCY (35%)				1,225,000
TOTAL:				$4,725,000
RAIL				
TRACKWORK	98.00	TRK-MI	$760,000	74,480,000
RAIL RELOCATION	0.00	TRK-MI	$760,000	0
SUBTOTAL				74,480,000
CONTINGENCY (35%)				26,068,000
TOTAL:				$100,548,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	98.00	TRK-MI	$900,000	88,200,000
SIGNAL/CONTROL	49.00	MI	$760,000	37,240,000
SUBTOTAL				125,440,000
CONTINGENCY (35%)				43,904,000
TOTAL:				$169,344,000
RIGHT-OF-WAY				
RANGE LAND	641.18	ACRE	$1,500	961,770
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	130.95	ACRE	$25,000	3,273,750
URBAN RAILROAD LAND	0.00	ACRE	$0	0
LEGAL COSTS	772.12	ACRE	$3,500	2,702,424
SUBTOTAL				6,937,944
CONTINGENCY (35%)				2,428,280
TOTAL:				$9,366,000
SUBTOTAL				$2,541,567,000
ADD-ONS (25%)				$635,391,750
TOTAL:				$3,177,000,000

CalSpeed: Revised Capital Cost Estimates, Low Estimate

CENTRAL CORRIDOR: NEW R/W (Mainline)

LENGTH OF SEGMENT = 205.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	3230.30	ACRE	$400	1,292,121
EXCAVATION (Flat)	17,744,800	CY	$3.5	62,106,800
BORROW (Flat)	5,514,500	CY	$4.5	24,815,250
EXCAVATION (Mount)	0	CY	$7.0	0
BORROW (Mount)	0	CY	$9.0	0
LANDSCAPE/MULCH	3230.30	ACRE	$2,000	6,460,606
FENCING	410.00	MI	$81,000	33,210,000
SUBBALLAST	3,690,000	SY	$8.0	29,520,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	0.00	MI	$1,700,000	0
SUBTOTAL				157,404,777
CONTINGENCY (10%)				15,740,478
TOTAL:				$173,145,000
STRUCTURES				
STD VIADUCT 20'-25'	0.38	MI	$14,000,000	5,320,000
VIADUCT 25'-100'Pier	0.00	MI	$25,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$35,000,000	0
VIADUCT > 200' Pier	0.00	MI	$50,000,000	0
SHORT SPAN BRIDGE	33	EA	$1,000,000	33,000,000
GRADE SEPARATION RUR	100	EA	$1,000,000	100,000,000
GRADE SEPARATION URB	0	EA	$8,500,000	0
ROAD CLOSURE	73	EA	$50,000	3,650,000
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	0.00	MI	$50,000,000	0
BOX CULVERT	103	EA	$83,000	8,549,000
CULVERT	451	EA	$3,500	1,578,500
SUBTOTAL				152,097,500
CONTINGENCY (10%)				15,209,750
TOTAL:				$167,307,000

CENTRAL CORRIDOR: NEW R/W (Mainline)

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	2	EA	$30,000,000	60,000,000
SUBURBAN STATION	0	EA	$5,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	4	EA	$300,000	1,200,000
WAYSIDE PLATFORMS	3	EA	$200,000	600,000
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				61,800,000
CONTINGENCY (10%)				6,180,000
TOTAL:				$67,980,000
RAIL				
TRACKWORK	410.00	TRK-MI	$760,000	311,600,000
RAIL RELOCATION	0.00	TRK-MI	$760,000	0
SUBTOTAL				311,600,000
CONTINGENCY (10%)				31,160,000
TOTAL:				$342,760,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	410.00	TRK-MI	$900,000	369,000,000
SIGNAL/CONTROL	205.00	MI	$760,000	155,800,000
SUBTOTAL				524,800,000
CONTINGENCY (10%)				52,480,000
TOTAL:				$577,280,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	3230.30	ACRE	$5,000	16,151,515
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URBAN RAILROAD LAND	0.00	ACRE	$120,000	0
LEGAL COSTS	3230.30	ACRE	$3,500	11,306,061
SUBTOTAL				27,457,576
CONTINGENCY (10%)				2,745,758
TOTAL:				$30,203,000
SUBTOTAL				$1,358,675,000
ADD-ONS (20%)				$271,735,000
TOTAL:				$1,630,400,000

CalSpeed: Revised Capital Cost Estimates, Low Estimate

CENTRAL CORRIDOR – FRESNO LOOP

LENGTH OF SEGMENT = 26.00 miles
AVE. R/W WIDTH = 100 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	315.15	ACRE	$400	126,061
EXCAVATION (Flat)	822,320	CY	$3.5	2,878,120
BORROW (Flat)	699,400	CY	$4.5	3,147,300
EXCAVATION (Mount)	0	CY	$7.0	0
BORROW (Mount)	0	CY	$9.0	0
LANDSCAPE/MULCH	315.15	ACRE	$2,000	630,303
FENCING	52.00	MI	$81,000	4,212,000
SUBBALLAST	468,000	SY	$8.0	3,744,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	16.50	MI	$1,700,000	28,050,000
SUBTOTAL				42,787,784
CONTINGENCY (10%)				4,278,778
TOTAL:				$47,067,000
STRUCTURES				
STD VIADUCT 20'–25'	0.00	MI	$14,000,000	0
VIADUCT 25'–100'Pier	0.00	MI	$25,000,000	0
VIADCT 100'–200' Pier	0.00	MI	$35,000,000	0
VIADUCT > 200' Pier	0.00	MI	$50,000,000	0
SHORT SPAN BRIDGE	0	EA	$1,000,000	0
GRADE SEPARATION RUR	0	EA	$1,000,000	0
GRADE SEPARATION URB	5	EA	$8,500,000	42,500,000
ROAD CLOSURE	0	EA	$50,000	0
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	0.00	MI	$50,000,000	0
BOX CULVERT	0	EA	$83,000	0
CULVERT	57	EA	$3,500	200,200
SUBTOTAL				42,700,200
CONTINGENCY (10%)				4,270,020
TOTAL:				$46,970,000

CENTRAL CORRIDOR – FRESNO LOOP

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	0	EA	$5,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				0
CONTINGENCY (10%)				0
TOTAL:				$0
RAIL				
TRACKWORK	26.00	TRK-MI	$760,000	19,760,000
RAIL RELOCATION	16.50	TRK-MI	$760,000	12,540,000
SUBTOTAL				32,300,000
CONTINGENCY (10%)				3,230,000
TOTAL:				$35,530,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	26.00	TRK-MI	$900,000	23,400,000
SIGNAL/CONTROL	26.00	MI	$760,000	19,760,000
SUBTOTAL				43,160,000
CONTINGENCY (10%)				4,316,000
TOTAL:				$47,476,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	115.15	ACRE	$5,000	575,750
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URBAN RAILROAD LAND	200.00	ACRE	$120,000	24,000,000
LEGAL COSTS	315.15	ACRE	$3,500	1,103,030
SUBTOTAL				25,678,780
CONTINGENCY (10%)				2,567,878
TOTAL:				$28,247,000
SUBTOTAL				$205,290,000
ADD-ONS (20%)				$41,058,000
TOTAL:				$246,300,000

CalSpeed: Revised Capital Cost Estimates, High Estimate

CENTRAL CORRIDOR: NEW R/W (Mainline)

LENGTH OF SEGMENT = 205.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	3230.30	ACRE	$400	1,292,121
EXCAVATION (Flat)	17,744,800	CY	$3.5	62,106,800
BORROW (Flat)	5,514,500	CY	$4.5	24,815,250
EXCAVATION (Mount)	0	CY	$10.0	0
BORROW (Mount)	0	CY	$14.0	0
LANDSCAPE/MULCH	3230.30	ACRE	$2,000	6,460,606
FENCING	410.00	MI	$81,000	33,210,000
SUBBALLAST	3,690,000	SY	$8.0	29,520,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	0.00	MI	$1,700,000	0
SUBTOTAL				157,404,777
CONTINGENCY (25%)				39,351,194
TOTAL:				$196,756,000
STRUCTURES				
STD VIADUCT 20'-25'	0.38	MI	$25,000,000	9,500,000
VIADUCT 25'-100'Pier	0.00	MI	$30,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$40,000,000	0
VIADUCT > 200' Pier	0.00	MI	$55,000,000	0
SHORT SPAN BRIDGE	33	EA	$1,000,000	33,000,000
GRADE SEPARATION RUR	100	EA	$1,000,000	100,000,000
GRADE SEPARATION URB	0	EA	$8,500,000	0
ROAD CLOSURE	73	EA	$50,000	3,650,000
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	0.00	MI	$100,000,000	0
BOX CULVERT	103	EA	$83,000	8,549,000
CULVERT	451	EA	$3,500	1,578,500
SUBTOTAL				156,277,500
CONTINGENCY (25%)				39,069,375
TOTAL:				$195,347,000

CENTRAL CORRIDOR: NEW R/W (Mainline)

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	2	EA	$30,000,000	60,000,000
SUBURBAN STATION	0	EA	$15,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	4	EA	$300,000	1,200,000
WAYSIDE PLATFORMS	3	EA	$200,000	600,000
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				61,800,000
CONTINGENCY (25%)				15,450,000
TOTAL:				$77,250,000
RAIL				
TRACKWORK	410.00	TRK-MI	$760,000	311,600,000
RAIL RELOCATION	0.00	TRK-MI	$760,000	0
SUBTOTAL				311,600,000
CONTINGENCY (25%)				77,900,000
TOTAL:				$389,500,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	410.00	TRK-MI	$900,000	369,000,000
SIGNAL/CONTROL	205.00	MI	$760,000	155,800,000
SUBTOTAL				524,800,000
CONTINGENCY (25%)				131,200,000
TOTAL:				$656,000,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	3230.30	ACRE	$5,000	16,151,515
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URBAN RAILROAD LAND	0.00	ACRE	$120,000	0
LEGAL COSTS	3230.30	ACRE	$3,500	11,306,061
SUBTOTAL				27,457,576
CONTINGENCY (25%)				6,864,394
TOTAL:				$34,322,000
SUBTOTAL				$1,549,175,000
ADD-ONS (25%)				$387,293,750
TOTAL:				$1,936,500,000

CalSpeed: Revised Capital Cost Estimates, High Estimate

CENTRAL CORRIDOR – FRESNO LOOP

LENGTH OF SEGMENT = 26.00 miles
AVE. R/W WIDTH = 100 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	315.15	ACRE	$400	126,061
EXCAVATION (Flat)	822,320	CY	$3.5	2,878,120
BORROW (Flat)	699,400	CY	$4.5	3,147,300
EXCAVATION (Mount)	0	CY	$10.0	0
BORROW (Mount)	0	CY	$14.0	0
LANDSCAPE/MULCH	315.15	ACRE	$2,000	630,303
FENCING	52.00	MI	$81,000	4,212,000
SUBBALLAST	468,000	SY	$8.0	3,744,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	16.50	MI	$1,700,000	28,050,000
SUBTOTAL				42,787,784
CONTINGENCY (25%)				10,696,946
TOTAL:				$53,485,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$25,000,000	0
VIADUCT 25'-100'Pier	0.00	MI	$30,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$40,000,000	0
VIADUCT > 200' Pier	0.00	MI	$55,000,000	0
SHORT SPAN BRIDGE	0	EA	$1,000,000	0
GRADE SEPARATION RUR	0	EA	$1,000,000	0
GRADE SEPARATION URB	5	EA	$8,500,000	42,500,000
ROAD CLOSURE	0	EA	$50,000	0
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	0.00	MI	$100,000,000	0
BOX CULVERT	0	EA	$83,000	0
CULVERT	57	EA	$3,500	200,200
SUBTOTAL				42,700,200
CONTINGENCY (25%)				10,675,050
TOTAL:				$53,375,000

CENTRAL CORRIDOR – FRESNO LOOP

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	0	EA	$15,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				0
CONTINGENCY (25%)				0
TOTAL:				$0
RAIL				
TRACKWORK	26.00	TRK-MI	$760,000	19,760,000
RAIL RELOCATION	16.50	TRK-MI	$760,000	12,540,000
SUBTOTAL				32,300,000
CONTINGENCY (25%)				8,075,000
TOTAL:				$40,375,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	26.00	TRK-MI	$900,000	23,400,000
SIGNAL/CONTROL	26.00	MI	$760,000	19,760,000
SUBTOTAL				43,160,000
CONTINGENCY (25%)				10,790,000
TOTAL:				$53,950,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	115.15	ACRE	$5,000	575,750
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URBAN RAILROAD LAND	200.00	ACRE	$120,000	24,000,000
LEGAL COSTS	315.15	ACRE	$3,500	1,103,030
SUBTOTAL				25,678,780
CONTINGENCY (25%)				6,419,695
TOTAL:				$32,098,000
SUBTOTAL				$233,283,000
ADD-ONS (25%)				$58,320,750
TOTAL:				$291,600,000

CalSpeed: Revised Capital Cost Estimates, Low Estimate

PACHECO PASS: 5.0% ALTERNATIVE

LENGTH OF SEGMENT = 34.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	535.76	ACRE	$400	214,303
EXCAVATION (Flat)	1,989,500	CY	$3.5	6,963,250
BORROW (Flat)	618,700	CY	$4.5	2,784,150
EXCAVATION (Mount)	971,667	CY	$7.0	6,801,669
BORROW (Mount)	17,172,407	CY	$9.0	154,551,663
LANDSCAPE/MULCH	535.76	ACRE	$2,000	1,071,515
FENCING	47.20	MI	$81,000	3,823,200
SUBBALLAST	612,000	SY	$8.0	4,896,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	0.00	MI	$1,700,000	0
SUBTOTAL				181,105,750
CONTINGENCY (20%)				36,221,150
TOTAL:				$217,327,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$14,000,000	0
VIADUCT 25'-100'Pier	0.47	MI	$25,000,000	11,750,000
VIADCT 100'-200' Pier	1.72	MI	$35,000,000	60,200,000
VIADUCT > 200' Pier	1.36	MI	$50,000,000	68,000,000
SHORT SPAN BRIDGE	6	EA	$1,000,000	6,000,000
GRADE SEPARATION RUR	4	EA	$1,000,000	4,000,000
GRADE SEPARATION URB	0	EA	$8,500,000	0
ROAD CLOSURE	3	EA	$50,000	150,000
DEPRESSED SECTION	0.76	MI	$16,000,000	12,160,000
CUT & COVER TNL RUR	0.89	MI	$35,000,000	31,150,000
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	5.57	MI	$50,000,000	278,500,000
BOX CULVERT	2	EA	$83,000	166,000
CULVERT	50	EA	$3,500	175,000
SUBTOTAL				472,251,000
CONTINGENCY (20%)				94,450,200
TOTAL:				$566,701,000

PACHECO PASS: 5.0% ALTERNATIVE

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	1	EA	$5,000,000	5,000,000
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	10	EA	$100,000	1,000,000
SUBTOTAL				6,000,000
CONTINGENCY (20%)				1,200,000
TOTAL:				$7,200,000
RAIL				
TRACKWORK	68.00	TRK-MI	$760,000	51,680,000
RAIL RELOCATION	0.00	TRK-MI	$760,000	0
SUBTOTAL				51,680,000
CONTINGENCY (20%)				10,336,000
TOTAL:				$62,016,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	68.00	TRK-MI	$900,000	61,200,000
SIGNAL/CONTROL	34.00	MI	$760,000	25,840,000
SUBTOTAL				87,040,000
CONTINGENCY (20%)				17,408,000
TOTAL:				$104,448,000
RIGHT-OF-WAY				
RANGE LAND	394.83	ACRE	$1,500	592,245
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	134.89	ACRE	$25,000	3,372,250
URBAN RAILROAD LAND	0.00	ACRE	$0	0
LEGAL COSTS	535.76	ACRE	$3,500	1,875,152
SUBTOTAL				5,839,647
CONTINGENCY (20%)				1,167,929
TOTAL:				$7,008,000
SUBTOTAL				$964,700,000
ADD-ONS (20%)				$192,940,000
TOTAL:				$1,157,600,000

CalSpeed: Revised Capital Cost Estimates, High Estimate

PACHECO PASS: 5.0% ALTERNATIVE

LENGTH OF SEGMENT = 34.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	535.76	ACRE	$400	214,303
EXCAVATION (Flat)	1,989,500	CY	$3.5	6,963,250
BORROW (Flat)	618,700	CY	$4.5	2,784,150
EXCAVATION (Mount)	971,667	CY	$10.0	9,716,670
BORROW (Mount)	17,172,407	CY	$14.0	240,413,698
LANDSCAPE/MULCH	535.76	ACRE	$2,000	1,071,515
FENCING	47.20	MI	$81,000	3,823,200
SUBBALLAST	612,000	SY	$8.0	4,896,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	0.00	MI	$1,700,000	0
SUBTOTAL				269,882,786
CONTINGENCY (35%)				94,458,975
TOTAL:				$364,342,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$25,000,000	0
VIADUCT 25'-100'Pier	0.47	MI	$30,000,000	14,100,000
VIADCT 100'-200' Pier	1.72	MI	$40,000,000	68,800,000
VIADUCT > 200' Pier	1.36	MI	$55,000,000	74,800,000
SHORT SPAN BRIDGE	6	EA	$1,000,000	6,000,000
GRADE SEPARATION RUR	4	EA	$1,000,000	4,000,000
GRADE SEPARATION URB	0	EA	$8,500,000	0
ROAD CLOSURE	3	EA	$50,000	150,000
DEPRESSED SECTION	0.76	MI	$16,000,000	12,160,000
CUT & COVER TNL RUR	0.89	MI	$35,000,000	31,150,000
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	5.57	MI	$100,000,000	557,000,000
BOX CULVERT	2	EA	$83,000	166,000
CULVERT	50	EA	$3,500	175,000
SUBTOTAL				768,501,000
CONTINGENCY (35%)				268,975,350
TOTAL:				$1,037,476,000

PACHECO PASS: 5.0% ALTERNATIVE

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	1	EA	$15,000,000	15,000,000
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	10	EA	$100,000	1,000,000
SUBTOTAL				16,000,000
CONTINGENCY (35%)				5,600,000
TOTAL:				$21,600,000
RAIL				
TRACKWORK	68.00	TRK-MI	$760,000	51,680,000
RAIL RELOCATION	0.00	TRK-MI	$760,000	0
SUBTOTAL				51,680,000
CONTINGENCY (35%)				18,088,000
TOTAL:				$69,768,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	68.00	TRK-MI	$900,000	61,200,000
SIGNAL/CONTROL	34.00	MI	$760,000	25,840,000
SUBTOTAL				87,040,000
CONTINGENCY (35%)				30,464,000
TOTAL:				$117,504,000
RIGHT-OF-WAY				
RANGE LAND	394.83	ACRE	$1,500	592,245
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	134.89	ACRE	$25,000	3,372,250
URBAN RAILROAD LAND	0.00	ACRE	$0	0
LEGAL COSTS	535.76	ACRE	$3,500	1,875,152
SUBTOTAL				5,839,647
CONTINGENCY (35%)				2,043,876
TOTAL:				$7,884,000
SUBTOTAL				$1,618,574,000
ADD-ONS (25%)				$404,643,500
TOTAL:				$2,023,200,000

CalSpeed: Revised Capital Cost Estimates, Low Estimate

SANTA CLARA VALLEY: US–101 MEDIAN (70')

LENGTH OF SEGMENT = 29.00 miles
AVE. R/W WIDTH = 70 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	175.76	ACRE	$400	70,304
EXCAVATION (Flat)	2,508,500	CY	$3.5	8,779,750
BORROW (Flat)	672,500	CY	$4.5	3,026,250
EXCAVATION (Mount)	0	CY	$7.0	0
BORROW (Mount)	0	CY	$9.0	0
LANDSCAPE/MULCH	175.76	ACRE	$2,000	351,520
FENCING	50.00	MI	$81,000	4,050,000
SUBBALLAST	522,000	SY	$8.0	4,176,000
SOUND WALLS	0.00	MI	$835,000	0
RETAINED SECTION 16'*	4.00	MI	$5,300,000	21,200,000
CONCRETE WALL/FTG *	41.00	MI	$1,300,000	53,300,000
CRASH WALLS	4.50	MI	$1,700,000	7,650,000
SUBTOTAL				102,603,824
CONTINGENCY (20%)				20,520,765
TOTAL:				$123,125,000
STRUCTURES				
STD VIADUCT 20'–25'	0.00	MI	$14,000,000	0
VIADUCT 25'–100'Pier	4.00	MI	$25,000,000	100,000,000
VIADCT 100'–200' Pier	0.00	MI	$35,000,000	0
VIADUCT > 200' Pier	0.00	MI	$50,000,000	0
SHORT SPAN BRIDGE	5	EA	$1,000,000	5,000,000
GRADE SEPARATION RUR	0	EA	$1,000,000	0
GRADE SEPARATION URB	0	EA	$8,500,000	0
STRUCTURE EXCAVATION	11	EA	$100,000	1,100,000
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	0.00	MI	$50,000,000	0
BOX CULVERT	0	EA	$83,000	0
CULVERT	64	EA	$3,500	223,300
SUBTOTAL				106,323,300
CONTINGENCY (20%)				21,264,660
TOTAL:				$127,588,000

SANTA CLARA VALLEY: US-101 MEDIAN (70')

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	0	EA	$5,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				0
CONTINGENCY (20%)				0
TOTAL:				$0
RAIL				
TRACKWORK	58.00	TRK-MI	$760,000	44,080,000
RAIL RELOCATION	8.50	TRK-MI	$760,000	6,460,000
SUBTOTAL				50,540,000
CONTINGENCY (20%)				10,108,000
TOTAL:				$60,648,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	58.00	TRK-MI	$900,000	52,200,000
SIGNAL/CONTROL	29.00	MI	$760,000	22,040,000
SUBTOTAL				74,240,000
CONTINGENCY (20%)				14,848,000
TOTAL:				$89,088,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URB RAILROAD LAND **	72.12	ACRE	$0	0
LEGAL COSTS	72.12	ACRE	$3,500	252,420
SUBTOTAL				252,420
CONTINGENCY (20%)				50,484
TOTAL:				$303,000
SUBTOTAL				$400,752,000
ADD-ONS (20%)				$80,150,400
TOTAL:				$480,900,000

* Concrete Barrier/Ftg: Jersey Barrier protection from freeway
Structure Excavation: Around US-101 OC central piers
Retained Fill: 8' retaining walls both sides of tracks

** The right-of-way is owned by the Joint Powers Board

CalSpeed: Revised Capital Cost Estimates, High Estimate

SANTA CLARA VALLEY: US-101 MEDIAN (70')

LENGTH OF SEGMENT = 29.00 miles
AVE. R/W WIDTH = 70 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	175.76	ACRE	$400	70,304
EXCAVATION (Flat)	2,508,500	CY	$3.5	8,779,750
BORROW (Flat)	672,500	CY	$4.5	3,026,250
EXCAVATION (Mount)	0	CY	$10.0	0
BORROW (Mount)	0	CY	$14.0	0
LANDSCAPE/MULCH	175.76	ACRE	$2,000	351,520
FENCING	50.00	MI	$81,000	4,050,000
SUBBALLAST	522,000	SY	$8.0	4,176,000
SOUND WALLS	0.00	MI	$835,000	0
RETAINED SECTION 16'*	4.00	MI	$5,300,000	21,200,000
CONCRETE WALL/FTG *	41.00	MI	$1,300,000	53,300,000
CRASH WALLS	4.50	MI	$1,700,000	7,650,000
SUBTOTAL				102,603,824
CONTINGENCY (35%)				35,911,338
TOTAL:				$138,515,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$25,000,000	0
VIADUCT 25'-100'Pier	4.00	MI	$30,000,000	120,000,000
VIADCT 100'-200' Pier	0.00	MI	$40,000,000	0
VIADUCT > 200' Pier	0.00	MI	$55,000,000	0
SHORT SPAN BRIDGE	5	EA	$1,000,000	5,000,000
GRADE SEPARATION RUR	0	EA	$1,000,000	0
GRADE SEPARATION URB	0	EA	$8,500,000	0
STRUCTURE EXCAVATION	11	EA	$100,000	1,100,000
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	0.00	MI	$100,000,000	0
BOX CULVERT	0	EA	$83,000	0
CULVERT	64	EA	$3,500	223,300
SUBTOTAL				126,323,300
CONTINGENCY (35%)				44,213,155
TOTAL:				$170,536,000

SANTA CLARA VALLEY: US-101 MEDIAN (70')

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	0	EA	$30,000,000	0
SUBURBAN STATION	0	EA	$15,000,000	0
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				0
CONTINGENCY (35%)				0
TOTAL:				$0
RAIL				
TRACKWORK	58.00	TRK-MI	$760,000	44,080,000
RAIL RELOCATION	8.50	TRK-MI	$760,000	6,460,000
SUBTOTAL				50,540,000
CONTINGENCY (35%)				17,689,000
TOTAL:				$68,229,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	58.00	TRK-MI	$900,000	52,200,000
SIGNAL/CONTROL	29.00	MI	$760,000	22,040,000
SUBTOTAL				74,240,000
CONTINGENCY (35%)				25,984,000
TOTAL:				$100,224,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URB RAILROAD LAND **	72.12	ACRE	$0	0
LEGAL COSTS	72.12	ACRE	$3,500	252,420
SUBTOTAL				252,420
CONTINGENCY (35%)				88,347
TOTAL:				$341,000
SUBTOTAL				$477,845,000
ADD-ONS (25%)				$119,461,250
TOTAL:				$597,300,000

* Concrete Barrier/Ftg: Jersey Barrier protection from freeway
Structure Excavation: Around US-101 OC central piers
Retained Fill: 8' retaining walls both sides of tracks

** The right-of-way is owned by the Joint Powers Board

CalSpeed: Revised Capital Cost Estimates, Low Estimate

SAN JOSE – SAN FRANCISCO

LENGTH OF SEGMENT = 49.00 miles
AVE. R/W WIDTH = 100 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	593.94	ACRE	$400	237,576
EXCAVATION (Flat)	0	CY	$3.5	0
BORROW (Flat)	1,318,100	CY	$4.5	5,931,450
EXCAVATION (Mount)	0	CY	$7.0	0
BORROW (Mount)	0	CY	$9.0	0
LANDSCAPE/MULCH	593.94	ACRE	$2,000	1,187,879
FENCING	93.64	MI	$81,000	7,584,840
SUBBALLAST	882,000	SY	$8.0	7,056,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	46.82	MI	$1,700,000	79,594,000
SUBTOTAL				101,591,745
CONTINGENCY (20%)				20,318,349
TOTAL:				$121,910,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$14,000,000	0
VIADUCT 25'-100'Pier	0.00	MI	$25,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$35,000,000	0
VIADUCT > 200' Pier	0.00	MI	$50,000,000	0
SHORT SPAN BRIDGE	0	EA	$1,000,000	0
GRADE SEPARATION RUR	0	EA	$1,000,000	0
GRADE SEPARATION URB	55	EA	$8,500,000	467,500,000
ROAD CLOSURE	0	EA	$50,000	0
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	0.00	MI	$50,000,000	0
BOX CULVERT	0	EA	$83,000	0
CULVERT	103	EA	$3,500	360,500
SUBTOTAL				467,860,500
CONTINGENCY (20%)				93,572,100
TOTAL:				$561,433,000

SAN JOSE - SAN FRANCISCO

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
NEW TERMINAL PROJECT	1	EA	$400,000,000	400,000,000
REGIONAL STATION	1	EA	$50,000,000	50,000,000
URBAN STATION	1	EA	$30,000,000	30,000,000
SUBURBAN STATION	1	EA	$5,000,000	5,000,000
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	1	EA	$6,000,000	6,000,000
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				491,000,000
CONTINGENCY (20%)				98,200,000
TOTAL:				$589,200,000
RAIL				
TRACKWORK	98.00	TRK-MI	$760,000	74,480,000
RAIL RELOCATION	93.64	TRK-MI	$760,000	71,166,400
SUBTOTAL				145,646,400
CONTINGENCY (20%)				29,129,280
TOTAL:				$174,776,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	98.00	TRK-MI	$900,000	88,200,000
SIGNAL/CONTROL	49.00	MI	$760,000	37,240,000
SUBTOTAL				125,440,000
CONTINGENCY (20%)				25,088,000
TOTAL:				$150,528,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URB RAILROAD LAND *	593.94	ACRE	$0	0
LEGAL COSTS	593.94	ACRE	$3,500	2,078,788
SUBTOTAL				2,078,788
CONTINGENCY (20%)				415,758
TOTAL:				$2,495,000
SUBTOTAL				$1,600,342,000
ADD-ONS (20%)				$320,068,400
TOTAL:				$1,920,400,000

* The right-of-way is owned by the Joint Powers Board

CalSpeed: Revised Capital Cost Estimates, High Estimate

SAN JOSE – SAN FRANCISCO

LENGTH OF SEGMENT = 49.00 miles
AVE. R/W WIDTH = 100 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	593.94	ACRE	$400	237,576
EXCAVATION (Flat)	0	CY	$3.5	0
BORROW (Flat)	1,318,100	CY	$4.5	5,931,450
EXCAVATION (Mount)	0	CY	$10.0	0
BORROW (Mount)	0	CY	$14.0	0
LANDSCAPE/MULCH	593.94	ACRE	$2,000	1,187,879
FENCING	93.64	MI	$81,000	7,584,840
SUBBALLAST	882,000	SY	$8.0	7,056,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	46.82	MI	$1,700,000	79,594,000
SUBTOTAL				101,591,745
CONTINGENCY (35%)				35,557,111
TOTAL:				$137,149,000
STRUCTURES				
STD VIADUCT 20'–25'	0.00	MI	$25,000,000	0
VIADUCT 25'–100'Pier	0.00	MI	$30,000,000	0
VIADCT 100'–200' Pier	0.00	MI	$40,000,000	0
VIADUCT > 200' Pier	0.00	MI	$55,000,000	0
SHORT SPAN BRIDGE	0	EA	$1,000,000	0
GRADE SEPARATION RUR	0	EA	$1,000,000	0
GRADE SEPARATION URB	55	EA	$8,500,000	467,500,000
ROAD CLOSURE	0	EA	$50,000	0
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	0.00	MI	$100,000,000	0
BOX CULVERT	0	EA	$83,000	0
CULVERT	103	EA	$3,500	360,500
SUBTOTAL				467,860,500
CONTINGENCY (35%)				163,751,175
TOTAL:				$631,612,000

SAN JOSE – SAN FRANCISCO

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
NEW TERMINAL PROJECT	1	EA	$400,000,000	400,000,000
REGIONAL STATION	1	EA	$50,000,000	50,000,000
URBAN STATION	1	EA	$30,000,000	30,000,000
SUBURBAN STATION	1	EA	$15,000,000	15,000,000
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	1	EA	$6,000,000	6,000,000
MOW BUILDINGS	0	EA	$300,000	0
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				501,000,000
CONTINGENCY (35%)				175,350,000
TOTAL:				$676,350,000
RAIL				
TRACKWORK	98.00	TRK-MI	$760,000	74,480,000
RAIL RELOCATION	93.64	TRK-MI	$760,000	71,166,400
SUBTOTAL				145,646,400
CONTINGENCY (35%)				50,976,240
TOTAL:				$196,623,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	98.00	TRK-MI	$900,000	88,200,000
SIGNAL/CONTROL	49.00	MI	$760,000	37,240,000
SUBTOTAL				125,440,000
CONTINGENCY (35%)				43,904,000
TOTAL:				$169,344,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	0.00	ACRE	$5,000	0
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URB RAILROAD LAND *	593.94	ACRE	$0	0
LEGAL COSTS	593.94	ACRE	$3,500	2,078,788
SUBTOTAL				2,078,788
CONTINGENCY (35%)				727,576
TOTAL:				$2,806,000
SUBTOTAL				$1,813,884,000
ADD-ONS (25%)				$453,471,000
TOTAL:				$2,267,400,000

* The right-of-way is owned by the Joint Powers Board

CalSpeed: Revised Capital Cost Estimates, High Estimate

PACHECO PASS TO SACRAMENTO, NEW R/W

LENGTH OF SEGMENT = 117.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	HIGH UNIT COST	AMOUNT
EARTHWORKS				
GRADING	1843.64	ACRE	$400	737,455
EXCAVATION (Flat)	8,993,584	CY	$3.5	31,477,544
BORROW (Flat)	3,147,300	CY	$4.5	14,162,850
EXCAVATION (Mount)	0	CY	$10.0	0
BORROW (Mount)	0	CY	$14.0	0
LANDSCAPE/MULCH	1843.64	ACRE	$2,000	3,687,273
FENCING	234.00	MI	$81,000	18,954,000
SUBBALLAST	2,106,000	SY	$8.0	16,848,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	12.60	MI	$1,700,000	21,420,000
SUBTOTAL				107,287,121
CONTINGENCY (25%)				26,821,780
TOTAL:				$134,109,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$25,000,000	0
VIADUCT 25'-100'Pier	0.00	MI	$30,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$40,000,000	0
VIADUCT > 200' Pier	0.00	MI	$55,000,000	0
SHORT SPAN BRIDGE	17	EA	$1,000,000	17,000,000
GRADE SEPARATION RUR	72	EA	$1,000,000	72,000,000
GRADE SEPARATION URB	9	EA	$8,500,000	76,500,000
ROAD CLOSURE	6	EA	$50,000	300,000
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$70,000,000	0
STD BORE	0.00	MI	$100,000,000	0
BOX CULVERT	52	EA	$83,000	4,316,000
CULVERT	257	EA	$3,500	900,900
SUBTOTAL				171,016,900
CONTINGENCY (25%)				42,754,225
TOTAL:				$213,771,000

PACHECO PASS TO SACRAMENTO, NEW R/W

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	1	EA	$30,000,000	30,000,000
SUBURBAN STATION	2	EA	$15,000,000	30,000,000
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	1	EA	$300,000	300,000
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				60,300,000
CONTINGENCY (25%)				15,075,000
TOTAL:				$75,375,000
RAIL				
TRACKWORK	234.00	TRK-MI	$760,000	177,840,000
RAIL RELOCATION	12.60	TRK-MI	$760,000	9,576,000
SUBTOTAL				187,416,000
CONTINGENCY (25%)				46,854,000
TOTAL:				$234,270,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	234.00	TRK-MI	$900,000	210,600,000
SIGNAL/CONTROL	117.00	MI	$760,000	88,920,000
SUBTOTAL				299,520,000
CONTINGENCY (25%)				74,880,000
TOTAL:				$374,400,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	1690.01	ACRE	$5,000	8,450,050
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URBAN RAILROAD LAND	152.73	ACRE	$120,000	18,327,600
LEGAL COSTS	1843.64	ACRE	$3,500	6,452,727
SUBTOTAL				33,230,377
CONTINGENCY (25%)				8,307,594
TOTAL:				$41,538,000
SUBTOTAL				$1,073,463,000
ADD-ONS (25%)				$268,365,750
TOTAL:				$1,341,800,000

CalSpeed: Revised Capital Cost Estimates, Low Estimate

PACHECO PASS TO SACRAMENTO, NEW R/W

LENGTH OF SEGMENT = 117.00 miles
AVE. R/W WIDTH = 130 feet

	QTY	UoM	LOW UNIT COST	AMOUNT
EARTHWORKS				
GRADING	1843.64	ACRE	$400	737,455
EXCAVATION (Flat)	8,993,584	CY	$3.5	31,477,544
BORROW (Flat)	3,147,300	CY	$4.5	14,162,850
EXCAVATION (Mount)	0	CY	$7.0	0
BORROW (Mount)	0	CY	$9.0	0
LANDSCAPE/MULCH	1843.64	ACRE	$2,000	3,687,273
FENCING	234.00	MI	$81,000	18,954,000
SUBBALLAST	2,106,000	SY	$8.0	16,848,000
SOUND WALLS	0.00	MI	$835,000	0
CRASH WALLS	12.60	MI	$1,700,000	21,420,000
SUBTOTAL				107,287,121
CONTINGENCY (10%)				10,728,712
TOTAL:				$118,016,000
STRUCTURES				
STD VIADUCT 20'-25'	0.00	MI	$14,000,000	0
VIADUCT 25'-100'Pier	0.00	MI	$25,000,000	0
VIADCT 100'-200' Pier	0.00	MI	$35,000,000	0
VIADUCT > 200' Pier	0.00	MI	$50,000,000	0
SHORT SPAN BRIDGE	17	EA	$1,000,000	17,000,000
GRADE SEPARATION RUR	72	EA	$1,000,000	72,000,000
GRADE SEPARATION URB	9	EA	$8,500,000	76,500,000
ROAD CLOSURE	6	EA	$50,000	300,000
DEPRESSED SECTION	0.00	MI	$16,000,000	0
CUT & COVER TNL RUR	0.00	MI	$35,000,000	0
CUT & COVER TNL URB	0.00	MI	$35,000,000	0
STD BORE	0.00	MI	$50,000,000	0
BOX CULVERT	52	EA	$83,000	4,316,000
CULVERT	257	EA	$3,500	899,500
SUBTOTAL				171,015,500
CONTINGENCY (10%)				17,101,550
TOTAL:				$188,117,000

PACHECO PASS TO SACRAMENTO, NEW R/W

	QTY	UoM	LOW UNIT COST	AMOUNT
BUILDINGS				
REGIONAL STATION	0	EA	$50,000,000	0
URBAN STATION	1	EA	$30,000,000	30,000,000
SUBURBAN STATION	2	EA	$5,000,000	10,000,000
MAINTENANCE FACILITY	0	EA	$35,000,000	0
INSP./SERVICE FAC.	0	EA	$6,000,000	0
MOW BUILDINGS	1	EA	$300,000	300,000
WAYSIDE PLATFORMS	0	EA	$200,000	0
DEMOLITION	0	EA	$100,000	0
SUBTOTAL				40,300,000
CONTINGENCY (10%)				4,030,000
TOTAL:				$44,330,000
RAIL				
TRACKWORK	234.00	TRK-MI	$760,000	177,840,000
RAIL RELOCATION	12.60	TRK-MI	$760,000	9,576,000
SUBTOTAL				187,416,000
CONTINGENCY (10%)				18,741,600
TOTAL:				$206,158,000
POWER/SIGNALS				
CATENARY/SUBSTATIONS	234.00	TRK-MI	$900,000	210,600,000
SIGNAL/CONTROL	117.00	MI	$760,000	88,920,000
SUBTOTAL				299,520,000
CONTINGENCY (10%)				29,952,000
TOTAL:				$329,472,000
RIGHT-OF-WAY				
RANGE LAND	0.00	ACRE	$1,500	0
PASTURE/CULTIVATED	1690.01	ACRE	$5,000	8,450,050
SCATTERED DEVELOP.	0.00	ACRE	$25,000	0
URBAN RAILROAD LAND	152.73	ACRE	$120,000	18,327,600
LEGAL COSTS	1843.64	ACRE	$3,500	6,452,727
SUBTOTAL				33,230,377
CONTINGENCY (10%)				3,323,038
TOTAL:				$36,553,000
SUBTOTAL				$922,646,000
ADD-ONS (20%)				$184,529,200
TOTAL:				$1,107,200,000