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HIGH-SPEED RAIL IN CALIFORNIA:
A Cost-Benefit Analysis

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Abstract

Very high speed rail may be a competitive mode of transportation for California's future. This article presents an evaluation of the economic and comprehensive benefits and costs associated with such an endeavor. The results indicate competitive comprehensive rates of return and a potential for project self-financing, suggesting that such a project merits serious consideration by the State.

Introduction

High-speed rail (HSR) has been proposed as a competitive transportation mode for California's future. Proponents of HSR point to its possibilities in reducing emissions, land and petroleum consumption, injury and death from accident, road and sky congestion, and urban sprawl. Its critics and skeptics question the need for such a system, given the expense. While several studies (Hall *et al.* 1992a, Leavitt *et al.* 1993, Kanafani and Youssef 1993, Sands 1991, Vaca 1993, Wu 1991) have addressed HSR issues of construction costs, impacts, and competition with alternative modes in California, none has considered demand, costs, and benefits all together and in relation to one another. This article comprehensively examines and evaluates such a project using standard cost-benefit techniques.

A comprehensive cost-benefit analysis enables public- and private-sector decision-makers to estimate the net value of a policy or investment. This is done by considering and calculating the expected benefits and costs of a project over its lifetime, and discounting values to a common year (typically to present dollars). The valuation of certain benefits and costs may be impractical-especially when markets do not currently exist to price particular results, such as air pollution and noise. Additionally, the choice of a discount rate is a source of debate; low interest rates tend to yield higher present values for projects that provide benefits in the future. For these reasons I value VHSR benefits conservatively--and only where studies detailing such values exist-and base the discount rate on market lending rates for state securities. Finally, a positive net present value is not enough reason to undertake a project; regressivity, equity, and risk implications should be considered, as they are here.

Project Definition

Very high-speed ground transportation for use around the world is currently being considered in two forms: electrically powered[1] trains running on high-design rail (*i.e.*, Very HSR); and magnetically levitated vehicles propelled over a guideway (*i.e.*, maglev).[2] Hall *et al.* recommend that California now consider only VHSR technologies, and not maglev, because of the "clear advantages in cost-effectiveness combined with compatibility, performance, and proven reliability in revenue service" (Hall *et al.* 1992a: x). Thus, this report considers only VHSR technologies.

Figure 1

Very High Speed Rail: Projected Route

Map by Martha Conway and Rolf Pendall

In their studies of HSR as an alternative transportation mode for California, Kanafani and Youssef (1993) conclude that HSR cannot compete well with the air carriers currently providing service between San Francisco and Los Angeles because of the low fares, high frequency, and time savings provided by air travel on this relatively long route. Acknowledging these expectations, the route chosen for the present analysis primarily follows State Highway 99 from Sacramento through Bakersfield (see Figure 1). Where Highway 99 joins Interstate Highway 5, just south of Bakersfield, the line follows the I-5 median through Los Angeles to San Diego. In addition, a rail spur from Modesto north to Manteca and then west along Highway 580 to Hayward's BART station area was chosen to tap California's last potentially large market, the San Francisco Bay Area (SFBA). Station sites chosen are: San Diego, Los Angeles, Bakersfield, Fresno, Modesto, Hayward (SFBA), and Sacramento. Significant tunneling will be necessary through the Grapevine pass, just north of Los Angeles, to keep grades at or below 3.5% and thereby allow relatively speedy and more energy-efficient passage through this section.

Ridership Forecasts

Ridership predictions must first determine likely users' valuation of California's principal intercity modes: the automobile, airplane, and, for this study, VHSR. Valuation necessarily incorporates out-of-pocket costs, station accessibility, total trip time and passengers' value of that time, service flexibility, and level of service.[3] Estimates of travelers' perceived out-of-pocket costs for the three modes are detailed in Table 1. VHSR generally entails lower out-of-pocket costs than does air travel, even under my conservative assumptions, but higher costs than auto travel.

Automobiles are further favored when one considers that cars usually carry more than the single person assumed for VHSR and air travel; assigned average occupancy rates range from 1.5 for the shorter auto trips to 1.7 for the longest automobile trips. However, VHSR trips are generally faster than those by autos. Air-travel time, on the other hand, prevails over VHSR in most of the considered markets. For this analysis, ridership time was valued at 30 percent of the California per-capita average income ($12/hour) for current auto travelers and 55 percent for air travelers.

Finally, I add a "penalty" to VHSR and air-travel costs because users of these modes will not have an automobile at their destination. Since it is difficult to impose an exact dollar value on inconvenience, I consider two scenarios: a "liberal," $10 estimate (which is more favorable to VHSR) and a more conservative, $20 estimate. In the final cost comparisons, shown in Table 2, the automobile clearly dominates the VHSR/car split, even under the "VHSR-favorable" scenario, and VHSR dominates the VHSR/air split.[4]

Table 1

"Perceived" Out-of-pocket Costs, HSR vs. Car and Air Travel

	By Car (per vehicle)						
By HSR	Sacto.	Modesto	Hayward	Fresno	Bakersf.	L.A.	S. Diego
Sacto.	$0.00	$14.00	$29.40	$33.00	$54.60	$75.60	$100.60
Modesto	**22.50**	0.00	15.40	19.00	40.60	61.60	86.60
Hayward	**41.75**	**24.25**	0.00	34.40	56.00	74.00	99.00
Fresno	**46.25**	**28.75**	**48.00**	0.00	21.60	42.60	67.60
Bakersf.	**73.25**	**55.75**	**75.00**	**32.00**	0.00	21.00	46.00
L.A.	**99.50**	**82.00**	**101.25**	**58.25**	**31.25**	0.00	25.00
S. Diego	**130.75**	**113.25**	**132.50**	**89.50**	**62.50**	**36.25**	0.00

	By Air						
By HSR	Sacto.	Modesto	Hayward	Fresno	Bakersf.	L.A.	S. Diego
Sacto.	$0.00	$135.00	$115.00	$145.00	$170.00	$150.00	$165.00
Modesto	**22.50**	0.00	115.00	135.00	150.00	130.00	115.00
Hayward	**41.75**	**24.25**	0.00	130.00	140.00	65.00	75.00
Fresno	**46.25**	**28.75**	**48.00**	0.00	115.00	90.00	100.00
Bakersf.	**73.25**	**55.75**	**75.00**	**32.00**	0.00	70.00	80.00
L.A.	**99.50**	**82.00**	**101.25**	**58.25**	**31.25**	0.00	40.00
S. Diego	**130.75**	**113.25**	**132.50**	**89.50**	**62.50**	**36.25**	0.00

HSR values have gray background; auto and air values have white background.

Notes: Cars were assumed to travel at 60 mph, with a one-hour stop per trip over 150 miles long; VHSR travel is estimated at 175 mph, with 15-minute stopping times per station. Access times were also added: for cars, to and from principal highways—about 12 minutes total per trip; and for VHSR, to and from stations—about 42 minutes on average. VHSR access times were highest for San Francisco Bay Area-oriented trips (a minimum of one hour) because the Hayward BART station is far from central. Times also were elevated for Los Angeles because of the region's very dispersed population. Airplane total-time calculations incorporated in-airport time as well as flight and access times. For longer hauls some time was added to account for possible baggage claims.

Work-travel time is estimated to be worth between 40% and 45% of wage (Becker 1965, Lisco 1967, Kraft and Kraft 1974, Lave 1969); leisure-time value is likely to be lower. Auto users were assigned a lower percentage valuation because auto travelers are expected to travel relatively more for leisure and because more children are likely to travel by car, whereas business and wealthier travelers are more likely to fly.

I assume that VHSR users will be charged 25¢/passenger-mile to account for marginal costs *plus* $5 per passenger-trip to recover capital costs. These charges are based on nine North American heavy rail properties, whose operating expenses were 26¢/passenger-mile in 1990 (Gray 1992). In calculating perceived out-of-pocket costs, auto users were assessed per vehicle at 20¢/mile, a rate less than half the actual per-mile cost of 42¢ (AAA 1993) but consistent with drivers' failure to factor depreciation into their own cost calculations. Car costs listed in this table are *per vehicle*—not per traveler. Airline users were charged according to well-established, 14-day pre-purchase fares. These fares have dropped on some corridors since mid-1994, however, and may make air travel more competitive with VHSR.

Table 2

Total One-way Trip "Costs" per Person by Mode (including $10 "Inconvenience Factor" for HSR & Air Travelers)

By HSR \ ***By Car***	Sacto.	Modesto	Hayward	Fresno	Bakersf.	L.A.	S. Diego
Sacto.	$0.00	$14.25	$29.14	$34.84	$52.82	$71.65	$93.68
Modesto	**36.64**	0.00	15.61	19.09	40.38	59.22	81.24
Hayward	**60.17**	**40.33**	0.00	37.57	54.06	70.23	92.26
Fresno	**63.24**	**43.40**	**66.94**	0.00	21.60	42.34	64.36
Bakersf.	**93.37**	**73.52**	**97.06**	**46.92**	0.00	21.02	45.18
L.A.	**123.40**	**103.56**	**127.09**	**76.95**	**46.83**	0.00	25.07
S. Diego	**157.40**	**137.56**	**161.09**	**110.95**	**80.83**	**52.24**	0.00

By HSR \ ***By Air***	Sacto.	Modesto	Hayward	Fresno	Bakersf.	L.A.	S. Diego
Sacto.	$0.00	$154.90	$136.22	$166.88	$193.20	$173.20	$190.18
Modesto	**40.09**	0.00	136.22	154.90	171.88	153.20	140.18
Hayward	**67.19**	**45.40**	0.00	151.22	162.54	91.50	101.50
Fresno	**69.07**	**47.28**	**74.39**	0.00	134.90	113.86	123.20
Bakersf.	**101.80**	**80.01**	**107.11**	**51.02**	0.00	91.22	103.86
L.A.	**134.98**	**113.19**	**140.29**	**84.20**	**51.48**	0.00	61.22
S. Diego	**171.27**	**149.48**	**173.28**	**120.50**	**87.77**	**54.26**	0.00

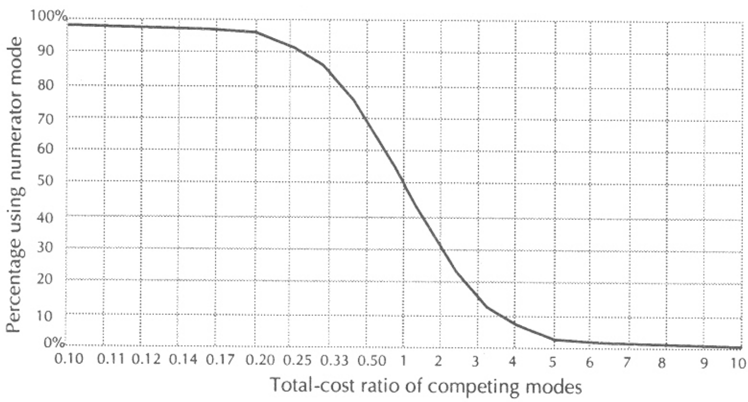
HSR values have gray background; auto and air values have white background.

"Inconvenience factors" include buying tickets, having to pay to store one's car or be taken to the station, and not having a car at one's destination. It is assumed that this imposes an average net cost of $10/person upon those not driving in the first, "high ridership" scenario. The more conservative "low ridership" scenario assigns an inconvenience cost of $20 to HSR and air travel; these values are not shown here, but can be calculated by adding $10 to the HSR and air-travel costs shown above. HSR costs in the air market are higher that those in the auto market because of the higher time value associated with those who normally travel by air.

In order to forecast ridership from these values, one must consider *modal split.* Travel is a multi-attribute good, in terms of time, out-of-pocket cost, and inconvenience. Consumers place different values on each of these attributes, and as a result, a mode that on average appears to be less expensive will not capture the entire market. One generally estimates modal split(s) using some form of a logit curve, which plots a mode's market capture against a trip attribute. The modal split assumed here, reproduced as Figure 2, plots percentage capture versus the ratio of competing-mode costs and exhibits a sharp fall-off between either pair of modes as the total-cost ratio varies from one. However, the splits assumed here are approximations and the curve may be more or less steep.

Figure 2.

Modal Split, Percent Using vs. Total-Cost Ratio



By applying these modal-split percentages to existing trips, one can estimate first-order VHSR ridership. Based on my modal-split assumptions, the available estimates of current travel (Caltrans 1992, FAA 1992), and assumptions about the share of inter-regional travelers who might constitute a market for VHSR, I estimate a total of 67,889 VHSR trips per day assuming the $10 penalty on non-auto trips and 51,459, assuming the $20 penalty (see Table 3). The markets where high numbers of auto users switched from automobile to VHSR were Los Angeles-San Diego, Los Angeles-Bakersfield, and SFBA-Sacramento, corresponding to the heavy current flows in those areas. The principal market for air traffic diversion to VHSR was the SFBA-Los Angeles market (due to current high travel), but Los Angeles-Sacramento was also strong.

Since California is growing, the number of travelers will expand in the next several decades. In all, California's population is expected to exceed 48 million by the year 2020 (California Dept. of Finance 1993), a number that corresponds to an average annual growth rate of 1.56 percent. I use this 1.56% annual growth rate to project ridership levels (and, in the next sections, costs, revenues, emissions, deaths, and consumer surplus). Actual increases may be significantly greater, especially in the Central Valley station areas.

Table 3

Considered-Population's Estimated Daily Travel by Car + Air vs. HSR

$10 convenience penalty

	Car + Air						
HSR	Sacto.	Modesto	Hayward	Fresno	Bakersf.	L.A.	S. Diego
Sacto.	0	2,792	18,579	306	693	547	23
Modesto	**834**	0	5,081	2,311	25	1,378	24
Hayward	**8,777**	**1,439**	0	754	176	9,094	543
Fresno	**191**	**944**	**515**	0	2,011	239	24
Bakersf.	**410**	**15**	**121**	**862**	0	25,894	937
L.A.	**688**	**848**	**5,910**	**181**	**10,582**	0	70,332
S. Diego	**17**	**16**	**333**	**16**	**551**	**34,641**	0
Tot. HSR	**10,916**	**3,262**	**6,878**	**1,059**	**11,133**	**34,641**	**0**

HSR Total: 67,889 trips/day

$20 inconvenience penalty

	Car + Air						
HSR	Sacto.	Modesto	Hayward	Fresno	Bakersf.	L.A.	S. Diego
Sacto.	0	3,154	20,490	331	715	560	23
Modesto	**471**	0	5,668	2,669	28	1,422	25
Hayward	**6,866**	**852**	0	807	181	9,125	560
Fresno	**166**	**586**	**463**	0	2,241	247	25
Bakersf.	**388**	**12**	**116**	**632**	0	29,176	967
L.A.	**676**	**804**	**5,879**	**173**	**7,300**	0	79,779
S. Diego	**17**	**15**	**315**	**15**	**521**	**25,193**	0
Tot. HSR	**8,584**	**2,269**	**6,772**	**820**	**7,821**	**25,193**	**0**

HSR Total: 51,459 trips/day

HSR values have gray background; auto and air values have white background. Individual cell totals are rounded; totals for HSR are based on unrounded numbers.

To ensure consistently conservative assumptions of demand for VHSR, I start with Caltrans' estimates of interregional travel (Caltrans 1992) and adjust these downward by between 0.5 (for large urbanized areas) and 0.85 (for small counties), at each end of a trip, because of the assumption that not everyone in a region will consider VHSR as an alternative for his/her trip. As a result, the final potential number of interregional trips that might be captured by VHSR drops to 208,789 per day, about 35 percent of the 570,657 that Caltrans logged via its survey. FAA data on 1992 air trips are much more reliable, but trips involving San Diego were not available and had to be estimated. Total air trips were subtracted from the reduced Caltrans all-mode survey results. All resulting air- and ground-travel data were split using the logit curve's rough percentages.[5]

Costs

The construction and operations costs considered in this section are all direct and transacted. I consider such indirect costs as airline losses that will arise from undertaking the project alongside related benefits in the next section.

Several estimates are available for pricing the *capital investment costs* of such a system. Figuring in substantial contingency and add-on costs, Hall *et al.* (1992b) estimated their system's fixed-capital cost at $11 billion (in 1992 dollars). The Hall *et al.* (1992a, 1992b) routing is more involved than the one under consideration here, and thus more expensive,[6] but $11.8 billion (1994$) can be assumed to represent a conservative (*i.e.*, high-cost) estimate, for an average of $20.3 million/mile.[7] Necessary land purchases are covered by this $11.8 billion estimate.[8] In addition, the purchase price of each trainset of six passenger cars and two power cars is estimated at $35.3 million (1994$), again based on the conservative assumptions used by Hall *et al.* (1992b). A trainset can carry up to 680 passengers, with room for dining and a self-service bistro. Therefore, totals of twenty and fifteen trainsets (for the $10 and $20 scenarios, respectively) are expected to be necessary the first year of project implementation, assuming that 25 percent of the trains are not in service at any given time, and assuming an average loading factor of less than 0.6. I estimate that rolling stock have useful lives of 15 to 20 years, requiring that trainsets be purchased during project lifetime and that their price be figured into the economic analysis. Furthermore, additional trainsets must be purchased as demand increases throughout the project life; these, too, are included in the calculation of costs.

These capital costs do not include costs of *operation*. Each trainset is expected to require a crew of seven, plus food servers (Sands 1992), and operate an average of 13.5 hours/day. Based on current operations costs in existing transit systems, the first-year operations cost is computed to be $320 million for the first scenario and $239 million for the second scenario.[9] These costs are expected to increase, along with population and ridership, at a real rate of 1.56% annually.

Benefits

Benefits obtained through implementation of the proposed project include direct revenues, a reduction of negative externalities, and indirect benefits.

Direct Revenue Benefits

Multiplying appropriate fares by the number of trips, after accounting for trip routings, yields an expected total *yearly* fare revenue of $1,080 million (for the $10 penalty scenario) and $869 million (for the $20 penalty scenario).[10] In addition, after the project's evaluated "life-span," some salvage value may exist; rates of return are calculated here both without and with a $10 billion salvage value. Since salvage value is not assured, the most important return rates to consider are those assuming zero salvage value.

Non-Transacted Benefits and Externalities

Other, non-traded but direct benefits exist, as do reductions in negative externalities. In theory these benefits can be traded; they include increases in consumer surplus and safety and diminished noxious emissions. Externalities, such as air pollution, occur when one person's actions "spill over" and impose either costs or benefits upon others. A VHSR project also promises abated noise, lessened land takings, congestion reductions, and added option value, but for these four positive externalities I have found it impractical to assign accurate values.

Consumer surplus arises when people get more than they pay for, that is, when they value a good more than its total cost to them. Price reductions add consumer surplus to existing markets, as will be the case in the introduction of VHSR to California—especially for many current air travelers. To approximate consumer surplus, I compare average total-trip costs across trips; where VHSR costs less, I multiply the difference by the total number of persons who previously used the costlier mode. Therefore, I assume that current car travelers will experience no added consumer surplus, but that many air travelers will gain since VHSR costs less (on average) over most routes. This yields a first-order predicted consumer surplus annually of $25.7 million, for both scenarios. However, given the ridership predictions of over 18 million passenger trips per year, this estimated value is probably low.

Riding a train is *safer*, on average, than traveling by automobile, but not quite as safe as traveling by commercial airplane. Automobiles are currently responsible for about 1.61 deaths, 61 injury accidents, and 374 "other" (*i.e.*, solely property) accidents per 100 million passenger-miles traveled. In contrast, railroads claim only 0.06 deaths and air travel only about 0.03 deaths (on domestic flights) per 100 million passenger-miles (NHTSA 1988, NSC 1993).

Life, injury, pain and suffering are not costs upon which one can easily place a value, but attempts have been made. The economic costs of death in 1992 were estimated to be $880,000, resulting primarily from lost productivity (NSC 1993). Comprehensive costs to account for quality-of-life aspects and, in some cases, willingness to pay to prevent accidents range from just over $3 million (NSC 1993) to over $13 million (Viscusi 1983). For this study, I assume a value of $4 million per life. I multiply the passenger-miles switched from flying to VHSR by negative 0.03 and $4 million, balancing this against 1.55 times the passenger-miles switched from driving to VHSR times $4 million. This yields total savings of $198 million per year in the cost of death alone for the VHSR-favorable $10 scenario and $152 million per year for the more conservative $20 scenario.

Air pollution through emissions is currently an externality and not priced directly. Air pollution generated could be priced, however, if vehicles (such as planes, trains, and automobiles) were charged according to emissions performance, miles driven (or flown), and number of cold starts.[11] Based on current estimates (NRDC 1993, Cameron 1991), I assume an average of 5 cents per passenger mile for automobile air-pollution costs. While airplanes use an average of 1.8 kWh per passenger-mile, automobiles use an average of 0.9 and electric high-speed trains only 0.24 (Envitrak 1992). Assuming that emissions, and thus their costs, are proportional to energy use, air travel can be assessed at 10 cents per passenger-mile and VHSR at 1.33 cents per passenger-mile.[12] To be conservative in valuing the air- quality benefits of VHSR, this report assumes a cost of two cents per passenger-mile for VHSR. Using these as estimates, VHSR would generate yearly emissions savings worth over $120 million for both scenarios modeled. Since I assume that ridership will grow with population, these savings grow over time.

Finally, there are several other benefits that defy pricing. These externalities are not included in the dollar estimates of costs and benefits, but do figure into the overall matrix.[13]

- A *reduction in total travel noise* is expected for the VHSR corridors. Built in the center of freeways, the system does not audibly affect new areas significantly and is expected to generate ten percent less noise than automobiles on highways carrying the same number of passengers (Bondada and Wayson 1993).
- In comparison to highways, and even airports, a rail system significantly *reduces land-takings* to provide the same capacities (Bondada and Wayson 1993), especially when constructed largely in existing highway-median space. Freeway widening to accommodate the same travel demands, for example, may cost the public more in the long run. Additionally, expansion of airports may be more costly than land purchases for railways in less urban areas.

- Currently, portions of Interstate 5, Route 99, and Highway 101 are all subject to *congestion and delay* during certain times. If congestion on these corridors makes people switch to rail, higher fares can be charged and/or other farebox benefits will be evident. Unfortunately, no good estimates exit of congestion delays along I-5, Routes 99 and 101, or at the various airports. While current congestion costs probably are not major, they could be in 15 or more years as the state's population rises and the capacity of facilities changes relatively little.
- The introduction of a third major intercity mode for California *increases the current set of mobility options* for travelers. Enhanced choice increases competition and, generally, reduces costs for travelers. It also means reduced risk for future travel possibilities.

Indirect Benefits and Costs

Indirect benefits and costs are likely to accrue through several mechanisms. First, growth and investment may be redirected within the state. Second, out-of-state investment may be attracted to California. Third, rail may promote a more concentrated urban form at station locations, avoiding some sprawl. While one may attempt to quantify a few of these indirect benefits, the uncertainty of any such estimate is great and depends to a high degree on system specifics and the state and local economies. For these reasons I do not evaluate these indirect impacts monetarily.

Growth redirection can have a positive net impact on California's private enterprises, although it may harm some current businesses and their employees. Since much of the project's investment in materials, labor, technology, and expertise will be "local," several firms and groups will benefit from such a large (albeit mostly temporary) investment in the state economy. And technologies developed by California (and U.S.) firms may increase domestic competitiveness, possibly spurring a new major industry for future economic benefits. On a smaller scale, station siting may boost BART use in the Bay Area and help revitalize declining neighborhoods in urban areas across the State through their judicious siting. Moreover, growth redirection benefits many of those who are presently located near future station sites. However, it may also impose moving costs on nearby residents and businesses who do not wish to be near a station.

In addition, enhanced intrastate mobility has potential to generate new, outside investments in the State by increasing tourism within the State, reducing business costs, and improving the quality of life for employees and their families. The magnitude of these investments is difficult to anticipate.

Finally, fixed-rail investment with localized nodes helps concentrate development by making urban expansion along the state's thousands of miles of highways less attractive. Under this scenario, growth and construction would be refocused toward urban areas, as long as stations are built relatively close to city/regional centers. Many people find sprawl unsightly, and some studies show it to be subsidized.[14] Many people argue that this unsightly "waste" of land and infrastructure should not be promoted any further; VHSR can aid in this policy objective. But the net effects on urban form and private enterprise remain highly uncertain.

Choice of Discount Rates and Period of Analysis

A cost-benefit analysis requires not only a setting of locational boundaries for impact analyses, but also a time boundary, discounting level, and criteria by which to gauge return on the investment. Since no major innovations in transportation are projected significantly to reduce any of the costs previously discussed during the next 20 or 30 years, but may occur later than that, I use a time horizon of 30 years for a comparison of benefits and costs.

Future benefits and costs require discounting because people have a time value of money, and money must be borrowed to finance the project. Moreover, the billions of dollars that are needed to finance the project could be invested in alternatives (such as education or life-saving medical research) which also may exhibit significant rates of return. A first approximation for a minimum return rate is the market rate of 30-year government debt instruments; the project's economic rate of return should exceed this if it is to be self-financing. Currently, 30-year federal treasury bills yield a nominal rate of about 7.8 percent. The real (inflation-adjusted) interest rate is expected to be about 4 percent less than the nominal, or 3.8 percent. If the State finances the project, the purchase is not as riskless as that of federal bonds. However, the State may be able to sell its bonds at a real interest rate of about 4.0 percent if the bonds are exempt from federal taxes.

Because of the uncertainty in the discount rate's estimation and because of the need to channel government resources where most beneficial, I evaluate the project based on two interest rates: a "liberal"—but reasonable—discount rate of four percent (which favors long-term projects with significant future benefits, such as VHSR) and a conservative rate of seven percent. Use of either of these discount rates yields a project's net present value, which can then be compared against those of competing projects.

Additionally, I estimate internal rates of return, both economic and comprehensive, for the two ridership scenarios. Internal rates of return can be one criterion by which to compare different projects. Payback periods are another comparison criterion and are calculated for added information regarding the project's stream of benefits versus its costs.

Analysis and Evaluation

All costs and benefits of the project are tabulated in matrix form in Table 4 to exhibit clearly the results of different scenarios. Those that are assessed monetarily are shown at net present value assuming a project life of 30 years and the two discount rates. The values are in *millions* of 1994 dollars, and all rates are real (*i.e.*, inflation-adjusted).

Table 4

Decision Matrix: Costs and Benefits of VHSR

	Low Ridership		High Ridership	
	4% disc.	7% disc.	4% disc.	7% disc.
Costs ($M)				
Capital cost	($12,518)	($12,196)	($12,812)	($12,429)
Operating expense	(4,571)	(3,151)	(6,124)	(4,222)
Benefits ($M)				
Revenues	$16,629	$11,466	$20,667	$14,250
Consumer Surplus	491	339	491	339
Lives Saved	2,909	2,005	3,789	2,612
Air Quality	2,335	1,610	2,756	1,890
Net Present Value ($M)*				
Economic**	($459)	($3,882)	$1,729	($2,401)
Comprehensive	5,276	72	8,765	2,450

	Low Ridership		High Ridership	
Rates of Return	No salvage†	Salvage†	No salvage†	Salvage†
Economic	3.70%	5.27%	5.06%	6.28%
Comprehensive	7.06%	7.90%	8.79%	9.40%

Payback Period††	Low ridership	High ridership
Economic	20 years	19 years
Comprehensive	15 years	13 years

*Net present values exclude salvage value.
**Economic net present values exclude lives saved and air-quality benefits.
†With and without a $10 billion salvage value at the end of the project life.
††Payback period uses non-discounted values.

(continues next page)

Table 4 (cont.)

Non-valued Benefits of VHSR

Other Benefits	Marginal	Moderate	Uncertain
Advertising		✓	
Value capture	✓		
Noise reduction			✓
Land takings	✓		
Congestion reduction		✓	
Option value		✓	
Aesthetics		✓	
National security	✓		
Petroleum-related environmental effects	✓		
Growth redirection			✓
Investment attraction	✓		
Urban form	✓		

Summing Up: Who Benefits? Who Pays?

Using the data available, the project appears worthy of serious consideration because of its competitive comprehensive rates of return and potential to be self-financing. The comprehensive net present values for both discount rates are positive, and thus the project would increase net benefits to society (as long as "optimal" time preferences for money do not exceed the internal rates of return).

According to a Kaldor-Hicks decision criterion, if this project yields a positive net present value, it is recommendable (Kaldor 1939, Hicks 1940, Scitovsky 1941). Furthermore, because the net impacts on low-income populations are likely to be positive (through improved air quality and enhanced ability to travel between cities quickly without owning a car or paying airfare), the project also realizes one of Rawls' criteria: avoiding regressivity (Rawls 1971). But a comparison of this project with others is necessary to maximize present values and/or promote progressivity. Moreover, uncertainties in information and assumptions are high because of the rather simple nature of this analysis. Therefore, more sophisticated behavioral modeling and project evaluations and comparisons are desirable and are recommended before investing the billions of dollars required to finance this project.

Beyond these estimates of the project's net benefits and return rates, one must consider the project's equity implications. Such consideration entails identification of those who "lose" and those who benefit from the system's implementation.

If general-obligation (GO) bonds were sold by the State to finance the VHSR project, then all taxpayers would repay the loan in proportion to their state taxes. However, residents of Eureka and South Lake Tahoe, for example, would realize few benefits from the project and would pay as much as those who gain substantial consumer surplus from the existence of such a project. The majority of Californians would receive at least minor benefit from the project (as a result of cleaner air, less highway congestion, greater tourism, and so on), but not in proportion to their costs—especially if GO bonds were sold. Thus, to avoid substantial bias in project impacts and much of the inequitable distribution of costs and benefits that would result from GO financing, revenue bonds should be used to finance the project.

Revenue bonds could probably be sold at real interest rates of about 5 percent, which is more than GO bonds would have to pay because of an added risk of repayment. Under the "favorable" ridership scenario, revenues should be sufficient to cover the costs of thirty-year, five percent (real interest rate) bond repayment, as detailed in Table 4. But ridership may be lower than hoped, and costly overruns and accidents may occur, adding costs not originally anticipated or included in the analysis. Therefore, problems in repayment could arise, but revenue bonds would not indebt the general taxpayers; the "losers" under such a scenario would be the bond holders, who probably would represent much of middle- and upper-class society throughout the U.S. and perhaps outside of the U.S.

In all likelihood, however, bondholders would benefit from the tax-exempt status of their investment in VHSR. Beyond these investors, the primary beneficiaries of the project likely would be those who travel along the project corridors and thus would benefit from a new travel alternative, perceived total cost savings, possible fare reductions by the competing airlines, improved air quality, and reduced road and sky traffic. While those who use VHSR would pay an amount probably sufficient to cover the economic costs of the undertaking, they would be reaping some rewards of consumer surplus while not experiencing many of the project's possible negative effects.

Those who would suffer most from the project's potential negative externalities are those who lose jobs in the airline industry and some workers in small towns whose economies rely on auto travel on Interstate 5 and/or Highway 99. The effect on airlines, especially those emphasizing short hauls, would be particularly significant. If the state's regional economies are large enough to absorb new workers and businesses, those losing jobs and/or profits could move themselves and their resources to more profitable sectors.

For many reasonable rates of return, the project's comprehensive benefits exceed its costs; in theory, therefore, it should offer enough "surplus" for everyone. The problem lies in shifting resources to their "most productive" uses.[15] Movements toward a Pareto optimum (where no one suffers disbenefits) through compensation of "losers" are not feasible because of uncertainties in impact, but perhaps first-hire preference can be given to airline attendants and administrators and highway-service persons who are expected to be laid off. The State also could adopt other schemes to avoid inequitable losses, including assistance in property purchases near station sites by businesses that would have to close elsewhere; and could work with airlines to facilitate transfers between VHSR and air-travel systems for travelers who wish to fly long hauls from major hubs.

In general, by financing with revenue bonds instead of GO bonds and by paying attention to where transition losses would be greatest for those least able to absorb them, a well-planned VHSR project for California should be able to mitigate severe inequities. Those who pay for the privilege of use will be primary beneficiaries, but those who enjoy cleaner air, the aesthetics of fewer highways and less sprawl, and increased tourism and investment in California's economy (among other benefits) will be many and diverse.

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NOTES

[1] Electric propulsion is preferred because of the weight reductions permitted by not requiring on-board diesel engines and fuel.

[2] The name "very high-speed rail" (VHSR) is used for systems with a maximum operating speed over 155 mph (Hall *et al.* 1992a). This technology is already in use in Japan, France, and Germany with potential top speeds of 220 mph, while maglev (with speeds expected to reach 275-300 mph) has not yet been implemented. Tilting trains have

maximum speeds of about 185 mph, 35 mph less than that for current VHSR technologies, so they were not considered in the California studies.

3 Note that safety considerations were assumed not to enter into a person's valuation of the different modes, although VHSR should be less safe than air travel but much safer than automobile travel. This was assumed because people are generally not entirely rational in their travel decisions with respect to safety (*e.g.*, more people fear flying than driving), and because most have paid health insurance and car insurance whether or not they travel by rail, air, or car—so the internalization of this cost/benefit becomes less clear. Reduction of accidents is considered as a non-transacted benefit in the benefits category later in the discussion.

4 In estimating true demands for VHSR, one should expect a total travel-market expansion because of reduced travel costs. But because price declines are not expected to be dramatic and because relatively few trips currently take place on the routes expected to exhibit reduced costs, new trips are estimated to represent less than 1% of total trips.

5 These results suggest modal splits of 32% and 24% for the population of trips considered, which represents only about one-third of the total currently occurring between the stations' respective regions. Assuming that Caltrans' total-trip data are correct, expected splits, yielding the same number of VHSR trips daily, are closer to 12% and 9% between the various regions. Such splits appear to be reasonable in light of the fact that AMTRAK captures about 45% of the air/rail market between Washington, D.C., and New York City (Mead 1994) and Leavitt *et al.* predict a 17% capture of all intercity travel between Sacramento, the SFBA, and Los Angeles (given VHSR fares of about $50) (Leavitt *et al.* 1994).

6 Hall *et al.*'s (1992a, 1992b) VHSR system's Bay Area spur passes through San Jose to both Oakland and San Francisco, rather than stopping only in Hayward, and uses track spurs out to most of the Highway 99 cities. However, their Grapevine crossing assumes a steeper grade (thereby requiring less tunneling) than does this analysis. The $11.8 billion as an upper bound on construction costs should account for these factors.

7 Texas' VHSR system was calculated to cost $7.51 million/system-mile (1994$) for all infrastructure, facilities, right-of-way, rolling stock, and contingencies necessary to operate the 618-mile system (TTA 1989). This rate would imply a cost of only $4.35 billion for the VHSR system proposed here—far lower than the $11.8 billion (not including rolling stock) being used. The Chicago-to-Milwaukee Tri-State Study (DOTs 1991) projected costs of $13.9 million/mile, so the assumption used here of $20.3 M/mi. is probably conservative. France's TGV, built greatly on existing right of way and using existing structures, cost about $17 M/mile (1994$) (Mathieu 1991). However, Germany's ICE cost $27.1 million/mile for capital investment (which includes rolling stock); if applied to the 580 miles of this report's proposed California system, the cost would be $15.7 billion—much higher than Hall *et al.*'s estimates even if one includes rolling stock. This is probably because the ICE system undertook significant tunneling to keep grades minimal in order to share the rails with freight trains.

8 The median of Highway 99—where the VHSR will run—is generally over 40 feet wide, but it narrows to 20 feet or less through principal cities, such as Fresno (Caltrans-Fresno, 1994). The widening of highways and overpasses for double track would be necessary in many locations and is included in the cost estimate.

9 Assumptions for estimation of operations costs are: 1) every full-time operator is matched by an administrator or service worker; 2) a work-week consists of eight-hour days, five days a week per employee; 3) operating costs per employee are $700,000

annually (1994$), as they are for large bus companies such as AC Transit (FTA 1991); and 4) each trainset is used an average of 13.5 hours/day, seven days a week. The first three of these estimates are higher than those used in other studies (see TTA 1989, Sands 1992), and are thus in line with my consistent use of conservative estimates to avoid favoring a VHSR project.

[10] Other possible, but lesser, revenues may be obtained through advertising located at stations and aboard trains, and perhaps through purchase (via eminent domain) and re-sale (at higher value) of lands near station areas for relatively intense development. While viable methods of revenue generation, these strategies are not necessarily major revenue generators and their payoff is uncertain; therefore, they were not estimated for purposes of this analysis.

[11] Time of day, weather, and location also influence air-quality effects, but the administrative costs of pricing such differences are probably prohibitive.

[12] This method of emissions pricing ignores differences of impact by pollution type; a more sophisticated analysis would estimate these impact differences.

[13] In addition, improved aesthetics and incommensurables such as habitat preservation and lesser dependence on foreign oil are potential benefits from VHSR; these are included (but not valued) in Table 4.

[14] A complex web of government activities subsidizes sprawl. The federal government insures mortgages, allows mortgage-interest tax deductions for homeowners, and has spent billions of dollars on the Interstate Highway System; furthermore, new infrastructure is often funded using inefficient average-cost (not marginal-cost) pricing.

[15] Selection of the most productive use of public (or private) investment requires comparison with other investment possibilities. Given the proposed project's comprehensive real rates of return of 8.8% and 7.1% ($10 and $20 scenarios, respectively), the project should be able to compete with many projects where externalities are decidedly negative although economic returns are high, or where revenues are minimal but benefits substantial.

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