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Air, High Speed Rail, or Highway: A Cost Comparison in the California Corridor

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Abstract:

This study evaluates the full cost of three modes of intercity transportation: air, highway, and high speed rail for the California Corridor, connecting the Los Angeles Basin and the San Francisco Bay Area in order to compare the economic implications of investment in, or expansion of, any of these three modes. In this study we include estimates of four types of external, social costs: accidents, congestion, noise, and air pollution. Based on the results, we find that the full cost of air transportation for the California Corridor ($0.1315 per passenger-kilometer traveled (pkt)) is significantly less costly than the other two modes. High speed rail and highway transportation have approximately the same full cost; rail costs $0.2350/pkt and highway costs $0.2302/pkt. However, the modes have a different distribution of internal and external costs, automobiles have the highest external costs while high speed rail has the highest internal costs.

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INTRODUCTION

Continuing fiscal pressures, interest in new rail technologies, and privatization are causing the transportation profession to reconsider the share of resources devoted to the air, high speed rail, and highway transportation modes. However, major investments should not be made without a clear and accurate portrayal of the full costs of each mode. Full costs include the social costs of accidents, air pollution, noise, and congestion as well as the internal costs of providing and operating infrastructure and vehicles, and users' travel time. While there is strong evidence that the social costs of high speed rail are lower than those of highway transportation for example, it has remained unclear whether these reduced social costs offset rail's high capital and operating costs. The development of cost estimates of the type presented in this research are essential to gauging the true costs of transportation in the different modes, and is a prerequisite to sound investment decisions. Our research compares the full cost of developing a high speed rail system in the California Corridor compares with its alternatives -- expanding airports or highways -- to meet future passenger demand.

The 677 kilometer California Corridor represents one of the alignments of a proposed high speed rail system between Los Angeles and San Francisco. Our methodology constructs cost functions that relate costs to levels of output, as measured by passenger-kilometers. Because the construction of a new high speed rail system is neither a marginal change to the transportation network nor a short run proposition, we focus in this paper on the total and average long run costs. We develop the highway and air cost models from basic principles using actual data and system design characteristics observed in the California corridor. We estimate rail costs with models adapted from studies of the French high speed rail system, the TGV. Other works by the authors detail the full analysis (Levinson et al. 1996, 1997, 1998a,b).

ANALYTICAL FRAMEWORK FOR COST MODELING

The full long run cost calculation includes the internal cost of building, operating, and maintaining infrastructure, as well as carrier, user, and external or social costs such as noise, pollution, and accidents. We begin by developing a taxonomy for representing the full costs of transportation, independent of mode:

Infrastructure Costs -- including capital costs of construction and debt service (ICC), and costs of maintenance and operating costs as well as service costs to government or private sector (IOC);

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Carrier Costs -- aggregate of all payments by carriers in capital costs to purchase a vehicle fleet (CCC), and maintain and operate a vehicle fleet (COC), minus those costs (such as usage charges) which are transfers to infrastructure, which we label **Carrier Transfers (CT).**

User Money Costs -- aggregate of all fees, fares and tariffs paid by users in capital costs (UCC) to purchase a vehicle, and money spent to maintain and operate the vehicle or to ride on a carrier (UOC); less those costs (such as fares) which are transfers to carriers or infrastructure, and accident insurance, which is considered under social costs, which we label **User Transfers** (UT).

User Travel Time Costs (UTC) -- the amount of time spent traveling under both congested and uncongested conditions multiplied by the monetary value of time.

Social Costs -- additional net external costs to society due to emissions (SEC), accidents (SAC), and noise (SNC) and are true resource costs used in making and using transportation services;

Adding and subtracting the above factors, thereby avoiding double-counting, we have the following equation:

$$FC = ICC + IOC + CCC + COC - CT + UCC + UOC - UT + UTC + SEC + SNC + SAC$$

Each of these cost elements is a function of a number of parameters. Except for the fixed cost components, these elements depend on the amount of travel. In our study, we estimated flow dependent cost functions whenever possible. In the case of high speed rail, we use designs and alignments proposed by previous studies for the California Corridor. Table 1 lists the cost elements for each mode. Despite the different natures of these technologies, it is nonetheless possible to compare three categories broadly defined as: infrastructure costs, user operating costs, carrier operating costs, and social costs.

Table 1: Cost Elements Analyzed for Each Mode

Auto:	Infrastructure - land, capital, operating, signaling, maintenance
	User costs: vehicle ownership and operation, time
	Social costs - air pollution, noise pollution, safety, congestion
Air:	Aviation System: ATC, ANS, capital and operating
	Airport - land, capital, maintenance, operating
	Carrier costs
	User costs: time

	Social costs - air pollution, noise pollution, safety, congestion
HSR:	Infrastructure - land, rail capital, operating and maintenance
	Rolling stock - capital, operating, maintenance
	User costs: time
	Social costs - air pollution, noise pollution, safety, congestion

INTERMODAL COMPARISON OF AVERAGE COSTS

Table 2 shows the long run average costs per passenger-kilometer. We find that for the California Corridor air transportation, at $0.13/pkt costs, is significantly less expensive than the other two modes overall. High speed rail and highway transportation appear close in their average full cost, with rail costing $0.24/pkt and highway costing $0.23/pkt. Figure 1 decomposes the full cost into three categories: internal, travel time, and external. We find that rail has lower social costs but higher internal costs than highway, primarily due to its high capital costs.

The internal, or private, monetary costs comprising infrastructure, carrier, and vehicle operating costs are clearly highest for rail ($0.19/pkt), followed by air ($0.11/pkt) and then highway ($0.10/pkt). It is important to recognize the high fixed costs inherent in these transportation systems, especially rail. In particular, the average cost of infrastructure depends very much on how many passengers share the total cost. While the highway and air system can spread their infrastructure costs over many origin-destination pairs serving both passenger and freight, the high speed rail system is highly constrained, serving mostly passenger trips between the relatively few points along the line. If the demand for high speed rail were higher than we assume, the average infrastructure cost per passenger would be lower.

As is to be expected, user time costs are highest for the slowest mode, the highway system, followed by rail and then air. The analysis undertaken here attempts to maintain consistency between modes by using the same value of time for each ($10/hour). However, we recognize that travelers self-select their mode by value of time. A second factor to consider when judging the importance of time costs is the way we treat access costs. In this study, we assume the cost to access the various intercity travel departure points (airport, train station, interchange) was approximately equal, and so exclude this cost element. However we should distinguish between private and public transportation systems. The highway system allows point to point travel without any schedule delay, while air and train travelers can only depart on specific schedules. This schedule delay increases access costs, and may or may not be significant, depending on the frequency of service between markets. In the California corridor, multiple planes per hour serve San Francisco and Los Angeles. We assume that high speed train service will also have departures more than once an hour. Similarly, there is a money cost to get from home or work to the point of departure. Whether travel is by taxi, shuttle, passenger car, or mass transit, getting to the train station or airport requires some outlay. These access costs collectively favor automobile transportation over the other modes.

Combining private money and time costs we arrive at the internal system costs, which adds up to costs of $0.12/pkt for air; $0.23/pkt for rail; and $0.20/pkt for highway. In other words, if we disregard external costs then we find that high speed rail is nearly twice as costly as air and somewhat more expensive than highway.

However, when we include social costs (congestion, air pollution, noise, and accidents) the picture changes. For external, or social, costs we find that high speed rail is clearly less costly than the other modes. As was shown in Table 2 the only measurable social cost of high speed rail is that of noise, which at $0.002/pkt is significantly lower than that of air at $0.0043/pkt and highway at $0.0045/pkt. We should note that these noise cost estimates are quite tentative. Though based on fairly accurate measures, noise cost estimates still depend on many assumptions regarding the type and distribution of land uses near the transportation systems. The noise costs of rail assume current high speed rail technology, similar to the type anticipated for California. In the case of air on the other hand, we have not taken into consideration the upcoming switch to stage III aircraft, mandated for the year 2000. With the advent of stage III aircraft one can expect at least a halving of the cost of airport noise. We derive the aircraft noise cost estimates from a broad cross-section of estimates from other countries. California's major airports are surrounded by lower density than international airports. More importantly, California's airports have approach and departure flight paths located over water, which further reduces the noise externality.

Given their small magnitude, social costs play a relatively minor role in the comparison of total costs across modes. The relatively high social cost of highway transportation is primarily due to the cost of accidents, an externality nearly absent in the other two modes. Travelers already internalize the accident and congestion externalities, as the accident externality generates higher insurance costs while congestion increases travel time. The most relevant externalities are therefore pollution and noise, which have approximately equal costs in the case of highway transportation. However for air and rail, noise appears to be the major source of social costs.

From Table 2 we see that externalities represent 1% of the full cost of high speed rail, 6% of the full cost of air, and a relatively large 14% of the full cost of highway transportation. Therefore, when comparing highway and high speed rail, careful judgment of the valuation of social costs is necessary to make a final comparison. The differences in total costs between rail and highway are not significant given the accuracy of data and models used to estimate the numbers. Increased sensitivity to social costs may favor investing in high speed rail as opposed to highways. In the case of the comparison between rail and air, it will be hard to displace air as the low cost mode. For one thing, the full cost of air is nearly half that of rail, which means that any diversion of traffic from air to rail will result in significant increases in the cost of transportation. For another, the main source of difference in social costs is the cost of noise discussed earlier. Here our estimates are quite conservative and tend to favor high speed rail transportation. Consequently, the difference in full cost between rail and air is far more significant and unlikely to change because of adjustments to data or to model parameters. One can confidently conclude that air transportation is a less expensive means of providing intercity transportation in the context of the California corridor, even when taking social costs into consideration.

COMPARISONS OF TOTAL COST

We apply the cost models developed in our study to estimate the full costs of the three modes as they arise in California. The corridor represents one of the alignments of a proposed high speed rail system between Los Angeles and San Francisco. We apply the cost functions and unit cost estimates developed in Levinson et al. (1996) to levels of demand as estimated by Leavitt et. al. (1994) for the year 2015. We evaluate the models for individual links, each of which represents a major city-pair market in the corridor. We summarize long run average costs for the corridor as a whole and make an intermodal comparison of the full cost per passenger-kilometer and its elements.

Table 3 compares the total cost of a trip by mode in each market. For example, for a trip between San Francisco and Los Angeles the total full cost would be $156 by highway, $82 by air, and $159 by high speed rail. The social costs (accidents, congestion, noise, and air pollution) imposed by a trip in each of these modes would be $21.08 by highway; $4.58 by air; and $1.35 by high speed rail. It is noteworthy that the recovery of these social costs might imply the addition of fare premiums in the air and rail systems equal to these amounts. For highway transportation, recovery of social costs implies a premium about $1.50 per gallon of gasoline!

Taking these cost estimates into account, the study also looked at the effect of high speed rail development on other modes and the resulting economic impacts. If high speed rail diverts traffic away from air transportation, it increases total cost $0.1035/pkt diverted. If, on other hand, rail diverts traffic away from highway transportation, the change in total cost is negligible given the results of this study. But, there will probably be a measurable reduction in social costs of about $0.0302/pkt diverted, primarily environmental impacts. There would also be a measurable saving in the value of time spent in transportation of about $0.056/pkt diverted from highway to high speed rail.

IMPLICATIONS

High speed rail appears to be the costliest of the three modes for the corridor analyzed. But rail's full costs are close to highway transportation, and social costs are lower. However, highway's lower per user infrastructure costs compensate for the greater external costs than high speed rail. Users bear many highway costs: accidents and congestion are imposed by one driver on another, and so are internal to the highway transportation system as a whole.

It is crucial to understand the linkages between demand, supply, and cost. If large fixed costs dominate the cost function, as happens with high speed rail, providing more riders will lower the average cost to users. Our cost estimates depend on demand forecasts by Leavitt et al. (1994), and though the precise numbers may change with forecasts, the general result will remain. High speed rail forecasts assumed subsidized fares. If market fares (to recover the infrastructure and carrier costs) were in place without subsidy, it is likely that the rail system would be unsustainable.

In this regard, an important implication of the cost comparisons is the effect of diversion from the air mode to high speed rail. If, as is commonly predicted in demand studies, high speed rail diverts traffic from air, then there will be an increase in the total cost of transportation. Such an increase can be scarcely justified on the basis of the cost of noise. If on the other hand the high speed rail system is configured to divert traffic from highway transportation, then the switch is closer to a break-even proposition overall. Gains due to reduced social costs and higher speeds almost offset private monetary costs such as infrastructure, operation, and maintenance of the respective systems. Table 4 shows the increases in the total cost of transportation that would result from the re-allocation of corridor demands among high speed rail, air, and highway transportation. This analysis assumes the rail alignment in the whole corridor, and the diversion of traffic predicted by the current models of mode choice.

The implications of this are clear and far reaching. They suggest that the most cost effective high speed rail configuration in California would be as an alternative to highway, rather than to air transportation. Any new high speed rail line should complement rather than compete with air transportation. Perhaps design alternatives that favor shorter distance markets (such as Los Angeles-San Diego or San Francisco-Sacramento) would be more advantageous than those in this study. These alternatives should avoid significant new capital expenditures for right-of-way or grading, and connect airports and local transit systems to a broader region.

Finally, we remind the reader that the results of this study depend on a number of models that include assumptions and approximations. Some of these are fairly accurate, and other are less so. The quality of the results and the confidence with which one should interpret them for policy analyses are only as good as the state of the art in cost modeling. While this study may contribute to the transportation field, we recognize that its contribution is modest and that much more research is needed on the full cost of transportation systems.

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Table 2: Intermodal Comparison of Long Run Average Costs

Cost Category	Air System	High Speed Rail	Highways
Infrastructure: Construction and Maintenance	$0.0182	$0.1290	$0.0120
Carrier: Capital Cost	$0.0606	$0.0100	$0.0000
Carrier: Operating Cost	$0.0340	$0.0500	$0.0000
External: Accidents	$0.0004	$0.0000	$0.0200
External: Congestion	$0.0017	$0.0000	$0.0046
External: Noise	$0.0043	$0.0020	$0.0045
External: Pollution	$0.0009	$0.0000	$0.0031
User: Fixed + Variable	$0.0000	$0.0000	$0.0860
User: Time	$0.0114	$0.0440	$0.1000
TOTAL	$0.1315	$0.2350	$0.2302

note: $/pkt, highways assume 1.5 passengers per car; all transfers are subtracted out

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Table 3: Comparison of the Full Cost of S.F.- L.A. Trip

	Internal	External	Total
Highway	135.00	21.00	156.00
Air	77.50	4.50	82.00
H.S. Rail	157.65	1.35	159.00

In dollars per passenger

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Table 4: Comparison of Total Annual Costs Between Modes

Mode	**San Francisco Los Angeles**	**Fresno San Francisco**	**Fresno Los Angeles**	**Bakersfield San Francisco**	**Bakersfield Los Angeles**	**TOTAL**
High Speed Rail (‘000)	$1216759	$22294	$57601	$13137	$18745	$1328535
Highway (‘000)	$595953	$18781	$40626	$9265	$15791	$680416
Air (‘000)	$339191	$2096	$9610	$2192	$1762	$354851
Highway + Air	$935144	$20877	$50235	$11457	$17554	$1035266
HSR deficit:						
Highway + Air - High Speed Rail (‘000)	$-281615	$-1417	$-7366	$-1680	$-1191	$-293268

note: comparison of total annual cost of diverted trips, full costs in thousands; see text for discussion

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Figure 1 Full Cost Comparisons