# An Economic and Policy Analysis of the Introduction of High-Speed Rail in California:

## Phase One from the San Francisco Bay Area to Los Angeles and Anaheim

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## Abstract

Should Phase One of California's high-speed rail (HSR) system be built? With a rapidly growing population and congested airports and highways, California plans to build the nation's first, true HSR system, with 800 miles of track connecting all major cities with 220 mph trains. California High-Speed Rail Authority (CHSRA) now estimates capital construction costs for Phase One alone (the 520-mile San Francisco to Los Angeles / Anaheim segment) will be $98.1 - $117.6 billion, up from a previous CHSRA estimate of $40 billion. The Rail Authority also asserts that comparable, expanded, intra-state transportation (airport and highway) capacity would have $171 billion in capital costs. Despite highly attractive (but debatable) HSR system benefit claims for the economy, environment, and congestion relief, California faces broad criticism for the project and an acute lack of funding to complete it. The state must now decide what to do, and quickly, as construction must begin on the HSR system in 2012 to avoid losing federal funds.

To help answer the basic research question, this author focused on a research objective of analyzing comparative capital construction costs of Option 1 (building the HSR system) and Option 2 (a combination of expanded highways and airports), in Net Present Value terms, on the assumption that California will definitely need to build *something* to ease existing congestion in places like Los Angeles and San Francisco and to accommodate significant future population growth across the next several decades (from 7.6 to 17.2 million more Californians by 2040). Numerous international and domestic HSR studies were consulted, but none contained NPV analyses, save for one document from CHSRA that had extremely minimal back-up data and whose conclusions are open to question. The author constructed dozens of spreadsheet-based scenarios to analyze the effects of varying numerous factors for Option 1 (e.g. low-cost versus high-cost capital scenarios, and whether to build the Initial Operating Segment to the North or South) and Option 2 (e.g. the number of highway lanes to expand and the sequence and length of construction time for both highways and airports). Sensitivity analysis also varied discount rates and included an estimation of total cost for Option 1 that includes Operations and Maintenance (O&M) costs and Capital Asset Renewal (CAR) costs for the HSR system.

Key research findings indicated that, based on current capital cost data, the HSR system should be built, even before considering the aforementioned possible strong benefits of such a system. HSR would save the state of California $25 billion in NPV terms versus Option 2 (based on a 4% real discount rate and the two best models the author could devise), and would still save about half that much even when conservatively including O&M and CAR estimations for Option 1 only (i.e. no O&M or CAR costs for Option 2). Varying discount rates and other parameters did not materially change this conclusion, though the magnitude of savings is altered when varying the discount rate. Though some significant uncertainty is perhaps inevitable with such a highly complex, unprecedented topic as high-speed rail in America, the robustness of these conclusions could be bolstered by future researchers if more complete data for analysis could be obtained, especially as relates to HSR ridership estimates and funding plans, future transportation demand and capacities, and the costs and benefits of expansion of airports and highways.

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# 1. Introduction

### 1.1. Research Question / Problem Statement

On November 4, 2008, California voters passed into state law Proposition 1A, The Safe, Reliable High-Speed Passenger Train Bond Act (California Secretary of State's Office, 2008b). The Act mandated the creation inside the state of California of an 800-mile-long high-speed passenger rail (HSPR) network, or, simply, high-speed rail (HSR) network (as freight is not customarily transported by high-speed trains) that would include all of California's major cities. $9.95 billion dollars in bonds were approved towards an envisioned $40 billion project, with hopes for federal, local, and private matching funds to make up the difference. Planning has continued apace in the last four years by the California High-Speed Rail Authority (CHSRA), established previously in 1996, to make the HSR system a reality, and over $3 billion in federal funding has been obtained, though projected costs have skyrocketed (California High-Speed Rail Authority, 2011b). Without a doubt, California's population continues to grow rapidly, despite the economic slowdown of recent years, and, together with congested air and highway networks in many parts of the state, new intra-state transportation capacity of some kind will need to be built in the coming decades to accommodate millions of additional travelers. However, with the Rail Authority's project management, and the very scope and funding of the project itself, under serious criticism from many reputable sources (California Chamber of Commerce, 2012; California High-Speed Rail Peer Review Group, 2011a & 2011b; California State Auditor. Bureau of State Audits, 2012b; Legislative Analyst's Office. California State Legislature, 2011a, 2011b & 2011c; Samuelson, 2010; Thronson, 2011), and with the project cost of Phase One alone (the 520 mile segment from San Francisco in the north to Los Angeles and Anaheim in the south) having risen to between $98.1 and $117.6 billion (California High-Speed Rail Authority, 2011n, p. 8-2) in Year-of-Expenditure (YOE) dollars (as opposed to, say, 2010 $), a very basic question is now being asked, and it is the main research question of this Masters Project: Should the California High-Speed Rail system be built?

### 1.2. Research Objective

This research question on whether or not to build the California HSR system could be approached in a great many ways. Certainly, there are those who are opposed to it on mainly ideological grounds, such as those for whom the love of the automobile is paramount – not an unusual philosophy in the sunny state of California. But this Masters Project is focuses on more data-driven economic and policy analysis of the HSR system. Still, there are countless ways to approach the economics and policy of this highly complex problem. Indeed, California's HSR system is today the largest, most expensive, and most ambitious single public works project in America, and it is indeed controversial. With the onset of construction of the Initial Construction Segment (ICS) scheduled for 2012 or 2013, the question of whether or not to build the HSR system after all has become a burning one in Sacramento, Washington, D.C., and around the rest California and the country (California High-Speed Rail Authority, 2011a).

Thus, the HSR network is inciting passions of ever greater intensity both among proponents and opponents. For example, Christopher J. Taylor (2012), the New York-based deputy director for HSR at the company AECOM, states in Issue 29 of Rail Magazine that

> HSR has the greatest potential to add needed transportation capacity in the most cost-effective manner possible. Other modes have reached capacity and are difficult, if not impossible, to expand. HSR is not a foreign idea or an extravagant, unnecessary concept. It is our nation's single greatest hope for expanding and improving our national, regional and local transportation network. (p. 40)

However, the website High Speed Boondoggle (2012), pointing out concerns by the California High Speed Rail Peer Review Group (CHSR PRG), California State Auditor's Office, and the Legislative Analyst's Office (LAO) of the California State Legislature, among others, writes that

> At a time when the state and federal governments are deeply in debt and cutting education, social service and other funding, can taxpayers afford a massive "bait and switch" infrastructure project that is virtually certain to cost even more than current estimates?

What are we to make of these diametrically opposed points of view?

Questions abound not only about the capital construction cost of the HSR system and an alternative intra-state transportation project of expanding airports and highways, but also about Operating and Maintenance (O&M) costs, ridership levels, current statewide transportation capacities and congestion, potential direct and indirect job creation from the HSR system, potential environmental benefits, time savings and efficiency improvements, social costs of all major travel modes (air, highway, HSR), social cost of capital, funding sources for HSR, management and oversight issues regarding CHSRA, political and intergovernmental challenges, and even the availability of adequate raw data (such as cash-flows, budget forecasts, plans for HSR Phase One and Phase Two, etc.) for rigorous analysis, and so on. Given this host of possible research objectives, this author has chosen to focus on the following one, key concern for his approach.

Given the likelihood that California will, in any event, have to build *something* quite large, extensive, and expensive in the coming decades to accommodate growing intra-state travel demand, this author will conduct an analysis of comparing incremental capital construction costs of Phase One of the HSR system (known hereafter as Option One) to the Rail Authority's characterization of the chief alternative to Option One, a large expansion of airports and highways along the Phase One corridor between northern and southern California (known hereafter as Option Two). Since something must be built/expanded, looking at which capital cost will be greatest/least is of obvious interest. Only Phase One is examined for HSR due to the fact that CHSRA has not put out any current data on Phase Two, the expansion of the system to include Sacramento to the north and San Diego to the south. And even with Phase One, capital cost data for analysis is fragmentary in some cases (such as no clear cash-flow data for the high-cost Phase One scenario; cash-flow data is only available for the low-cost scenario), making analysis more challenging. Indeed, so little in the way of cash-flow data is put forward by the Rail Authority for evaluating Option Two (airports and highways), numerous estimations and assumptions by this author have been necessary to have any potential basis for Option Two analysis. But some of this difficulty may be inherent in trying to analyze a currently ongoing, vast transportation project of a kind that our country has never before actually constructed.

Thus, this author will take a research objective of comparing incremental capital construction costs of Options One and Two, with a focus on computing and comparing Net Present Values (NPVs) of the two project options, a measure which accounts for the time value of money and the discount rate (which will be further explained below). Various attempts will be made at sensitivity analysis for varying discount rates, varying project lengths, phased construction approaches, and even an estimation of total project cost of the HSR project by including some analysis of O&M and Capital Asset Renewal (CAR) costs. And while a full benefit-cost analysis (BCA) would doubtless lead to the calculation of NPVs that include the revenues and benefits as well of Options One and Two, insufficient data and time have rendered this more comprehensive means of analysis beyond the scope of this Masters Project. Nevertheless, this author hopes that comparing the capital and O&M costs of Options One and Two, and looking more closely at a number of assumptions underlying those costs, will make a useful contribution to moving the debate forward on the key research question of whether or not to build the HSR system for California's transportation future.

## 1.3. Summary of Previous Studies / Key Data Sources

Countless previous studies of HSR in general and California's proposed HSR system in particular have been done. Innumerable newspaper articles and blog postings have covered these topics. However, finding quality studies pertinent to the key questions in hand for our research question and objective has been more challenging. Some of the more important studies and sources of data for this author's analysis are discussed here.

### *1.3.1. International High-Speed Rail Studies*

While our study focuses on California's HSR project, some benchmarking against international HSR experience has been in order. Five studies of interest in that regard are by the World Bank (Amos, Bullock and Sondhi, 2010), about the Chinese experiment with rapidly developing a massive, nationwide HSR system; by the Rail Authority on various international HSR projects (California High-Speed Rail Authority, 2011h); by the Lincoln Institute of Land Policy on international HSR lessons for the USA (Todorovich, Schned & Lane, 2011); and by Cal PIRG and U.S. PIRG on the same subject (California Public Interest Research Group Education Fund, 2010) (United States Public Interest Research Group Education Fund, 2010). However, none of these studies provided comparative capital construction cost NPV analysis.

### *1.3.2. General High-Speed Rail Studies*

Numerous general studies on HSR abound. Moyer (2009) and Brown (2010) describe well the potential benefits of HSR in *Scientific American.* Todorovich and Hagler (2009 & 2010) of America 2050 make interesting reading about where HSR works best and what its benefits could be for the USA in the context of the country's emerging “mega-regions” of development and transportation. And U.S. DOT's FRA describes the basics of the recent federal HSR funding program in several key documents (United States Department of Transportation. Federal

Railroad Administration, 2009a, 2009b & 2012). Studies more specific to the question of how to finance HSR in America, such as through PPPs (Public-Private Partnerships), can be found by United States Public Interest Research Group Education Fund (2011), Bogren (2012), and Sampson (2012a). Sampson also writes (both articles are to be found in *Rail Magazine*, as is Bogren's) about how to best communicate about and promote the benefits of HSR (2012b), as does Taylor (2012) in the same periodical. But once again, little was to be found in these studies about comparative capital construction cost NPV analysis.

### *1.3.3. California-Related High-Speed Rail Studies*

Two documents in particular do a good job of describing the basics of California's 2008 Proposition 1A to create the statewide HSR system (California Secretary of State's Office, 2008; University of California at Berkeley. Institute of Government Studies, 2008). CHSRA's recent (November 2011) *2012 Draft Business Plan* (California High-Speed Rail Authority, 2011n) is obviously a very key document for this author's analysis of any and all aspects of the California HSR system today. Several Rail Authority supporting documents are also of key importance: the *California High-Speed Rail Benefit-Cost Analysis* (California High-Speed Rail Authority, 2011a); the *Cost Changes from 2009 Report to 2012 Business Plan Capital Cost Estimates* (California High-Speed Rail Authority, 2011b); the *Cost of Providing the Equivalent Capacity to High-Speed Rail Through Other Modes* (California High-Speed Rail Authority, 2011c); the *Economic Impact Analysis Report* (California High-Speed Rail Authority, 2011d); *Estimating High-Speed Train Operating and Maintenance Cost for the CA HSRA 2012 Business Plan* (California High-Speed Rail Authority, 2011e); and the unusually succinctly titled *Funding Plan* (California High-Speed Rail Authority, 2011g). Taken together, the CHSRA reports propose many possible benefits of HSR for California, though they often do not show all (or any, in some cases) of their supporting cash-flow (or other) data for their claims, such as with the *BCA*'s proposed NPV's for the entire project (including cash-in and cash-out for capital and O&M). This lack of supporting data renders the summaries presented much less credible, especially in light of accusations against the Rail Authority of mismanagement, understaffing, overuse of contractors, poor supervision of contractors, poor public relations, poor accountability to the state legislative and executive branches, and conflicts of interest (such as with the preparation of most of the aforementioned documents by Parsons Brinckerhoff, a consulting firm that is asserted to have contributed generously to funding the initial California campaign to pass Proposition 1A (High-Speed Rail Boondoggle, 2012). Nevertheless, the Authority and its contractors have given much good food for thought on the benefits of HSR side. Data is more lacking on the costs of HSR and the costs of airport and highway expansions; and is completely lacking on the benefits of airport and highway expansions. These are significant deficiencies in the Rail Authority's reports, and this lack of transparency and thoroughness gives rise to this author's interest in performing what analysis he can in what is intended to be a more rigorous way on the comparative incremental capital costs of Options One and Two.

As for published critical studies of the California HSR system plans and proposals, there are several key ones to consider. First, Eric Thronson (2011) at the Legislative Analyst's Office (LAO) of the California State Legislature published a general study in May of that year that is a must-read. And interviewing his successor at LAO on HSR and transportation issues, Brian Weatherford, was invaluable to this author. The LAO also (2011a & 2011b) published two short studies in November to begin the process of examining the Rail Authority's *2012 Draft Business Report* that speak to all the major issues of funding, comparison to air and highway needs and capacities, accountability, management, transparency, questionable choice of Initial Construction Segment location, and so on. A good review in certain respects of the Authority's new plan is also to be found from the California State Auditor's Office's Bureau of State Audits (2012b, as well as 2010). The California Chamber of Commerce (2012) has a short but interesting rebuttal to the Authority's new plan. And the California High-Speed Rail Peer Review Group provides some interesting criticism as well (2011a & 2011b) from before the new plan was released. However, in all of these studies, once again, there are no NPV analyses of comparative capital construction costs or total project costs to be found.

# 2. Background

## 2.1. What is High-Speed Rail?

### *2.1.1. Speeds and Travel Times.*

High-Speed Rail is a term that has been used variously by different people. For example, the current rail improvements in North Carolina between Charlotte and Raleigh (where the maximum speed of the Amtrak passenger trains is being upgraded from 79 mph to 90 mph) and between Raleigh and Washington, D.C. (where the maximum speed of the Amtrak passenger trains is being upgraded from 90 mph to 110 mph) is sometimes referred to as HSR (Federal Railroad Administration, 2012). Such a characterization is reflected in this 2009 FRA map.


Figure 1. U.S. DOT Map of Proposed HSR Corridors (Federal Railroad Administration, 2012)

However, we find this to be a misnomer. Upon closer examination, we note that the U.S. Department of Transportation's Federal Railroad Administration defines HSR (or, more precisely, "HSR-Express," which we refer to hereafter simply as "HSR," for simplicity's sake) as applying only to trains that run 150 mph or greater (Federal Railroad Administration, 2009b, p. 2). This definition is compatible with international standards such as those in Europe. And indeed, California's Proposition 1A called for the state's HSR system to be a proven technology of steel wheels on steel rails (as opposed to, say, maglev, ground effect, or vactrain technology) that would run a majority of the time at its rated maximum speed of 220 mph (California Secretary of State's Office, 2008a, p.4). No doubt this was motivated in part by the desire to have high-speed trains fast enough to compete with short-haul air travel in California, which is further exhibited by Proposition 1A's insistence that travel times in various HSR segments must meet the following criteria (California Secretary of State's Office, 2008a, p. 11):

2704.09. The high-speed train system to be constructed pursuant to this chapter shall be designed to achieve the following characteristics:

(a) Electric trains that are capable of sustained maximum revenue operating speeds of no less than 200 miles per hour.

(b) Maximum nonstop service travel times for each corridor that shall not exceed the following:

(1) San Francisco-Los Angeles Union Station: two hours, 40 minutes.

(2) Oakland-Los Angeles Union Station: two hours, 40 minutes.

(3) San Francisco-San Jose: 30 minutes.

(4) San Jose-Los Angeles: two hours, 10 minutes.

(5) San Diego-Los Angeles: one hour, 20 minutes.

(6) Inland Empire-Los Angeles: 30 minutes.

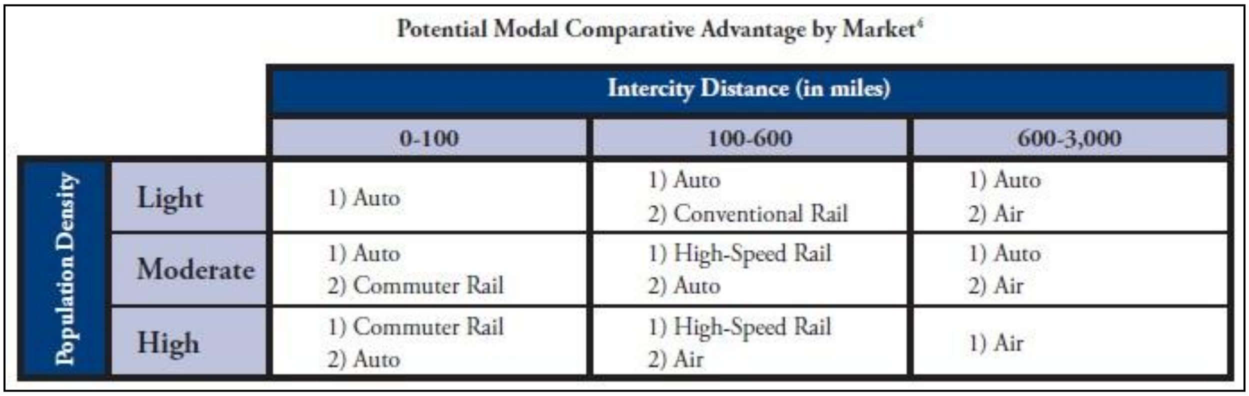
(7) Sacramento-Los Angeles: two hours, 20 minutes.

The law goes on to specify that California's HSR system must have achievable operating headway (i.e. time between successive trains) of five minutes or less. Also, to facilitate rapid express service, the total number of stations for the entire system (Phases One and Two) was limited by the law at a maximum of 24 (California Secretary of State's Office, 2008a, p. 11).

### *2.1.2. The Market Niche for High-Speed Trains*

Advocates of HSR do not, of course, see it as a panacea for all domestic travel needs in California or around the country. Rather, it is proposed to be an important part of a mix of travel modes that each fits best in a certain category or niche of travel needs. HSR, for example, would not be an effective means of traveling just a few blocks, obviously – a car or bus would be much better for that. At the other extreme, HSR might not be the best way to travel from Alaska to Florida, if a jet flight were available instead. But that still leaves a great deal of travel needs in the middle of these two extremes that can be effectively addressed by HSR. Thus the Rail Authority and the FRA propose that the market niche where HSR fits best is for trips of 100-600 miles (such as the 381 mile trip from San Francisco to Los Angeles on I-5). For trips over 600 miles, air is the best option. For trips under 100 miles, automobiles, local mass transit, bicycles, or pedestrian options may be best, though HSR can have some use there as well (such as the 26 mile Los Angeles to Anaheim trip, which is often very congested and time-consuming)

(California High-Speed Rail Authority, 2011n, p. 1-5) (United States Department of Transportation, Federal Railroad Administration, 2009b). These principles are illustrated here.



Potential Modal Comparative Advantage by Market[6]

| Population Density | Intercity Distance (in miles): 0-100 | 100-600 | 600-3,000 |
|---|---|---|---|
| Light | 1) Auto | 1) Auto<br>2) Conventional Rail | 1) Auto<br>2) Air |
| Moderate | 1) Auto<br>2) Commuter Rail | 1) High-Speed Rail<br>2) Auto | 1) Auto<br>2) Air |
| High | 1) Commuter Rail<br>2) Auto | 1) High-Speed Rail<br>2) Air | 1) Air |

Table 1. Most Efficient Methods of Travel by Mode (Federal Railroad Administration, 2009b, p. 1)

The Rail Authority goes on to add that, between 100 and 600 miles, automotive and air travel become less efficient than HSR, measured in terms of cost, time, energy usage, and greenhouse gas emissions. Installing HSR in such segments between key cities also has the potential to free up airport capacity for long-haul flights, contributing to efficiency in both travel modes.

### 2.2. High-Speed Rail in California and the Rest of the United States of America

The United States of America has made some previous, isolated attempts to create regional HSR systems, namely in Texas and Florida. However, both of these projects were abandoned in the early stages, before construction had begun, in 1995 and 2004, respectively (United States Government Accountability Office, 2009). More recently, California passed Proposition 1A on November 4, 2008, appropriating $9.95 billion towards a HSR system within the state (Figure 2) (California Secretary of State, 2008). The California High-Speed Rail Authority (CHSRA, or the Rail Authority, or, simply, the Authority), previously established in 1996, has worked across the last few years to take the plans embodied in Proposition 1A and turn them into reality by commissioning studies, creating plans, soliciting federal and private matching funding, and making preparations to begin construction on the Initial Construction Section (ICS) as early as 2012 (California High-Speed Rail Authority, 2012b). While the Rail Authority's management of this vast undertaking has faced significant criticism, it can at least be granted that they have applied great effort over long years to attempt to bring to fruition something that Americans have never done before (as Amtrak's Acela Express train along the

Northeast Corridor only averages 75 mph, in reality, out of its theoretical maximum speed of 150 mph) (Amtrak, 2010, p. 8-9).

Additionally, the American Reinvestment and Recovery Act (ARRA) of 2009 appropriated billions of dollars for higher-speed rail in various segments across the USA (Figure 1), including true HSR funding of $3.3 billion for California and $2.4 billion for Florida for a 168-186 mph HSR corridor from Tampa to Orlando to Miami, among others (Freemark, 2011). Since the mid-term elections of November 2010, new Republican governors in the states of Florida, Ohio, and Wisconsin have returned billions of dollars in HSR funds to the federal government, saying these funds and improvements are unwanted and wasteful. Thus, it can be argued that, while more intermediate-speed rail improvements are still underway in various places around the USA (e.g. North Carolina, Virginia), funded by ARRA via the FRA, California remains the only state in the country currently embarked upon a true HSR program. California once again is playing the role of vanguard for ambitious (and controversial) new ideas for American society, and the success or failure of HSR in that state will very possibly serve as a test case for whether or not it is again attempted in any other U.S. state for the foreseeable future.

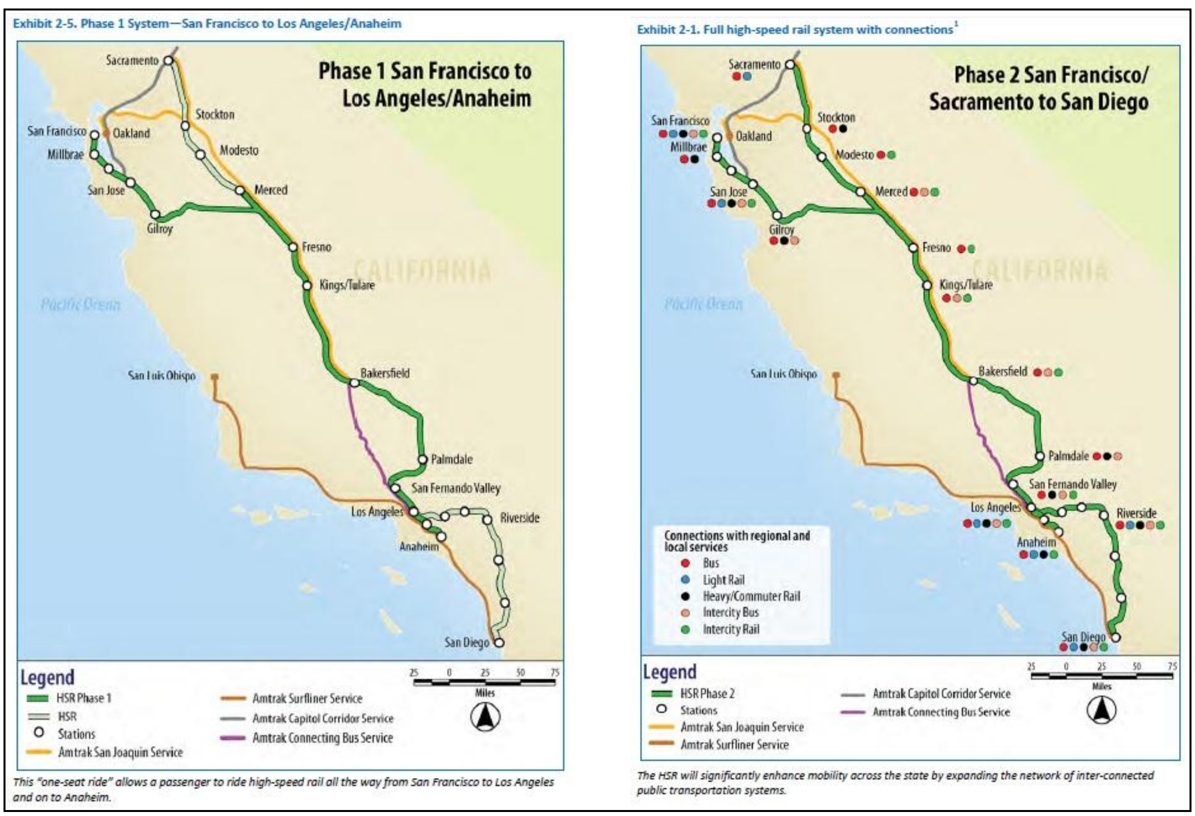



Figure 2. Maps of HSR Phases 1 & 2 (California High-Speed Rail Authority, 2011n, p. 2-20 & 2-2)

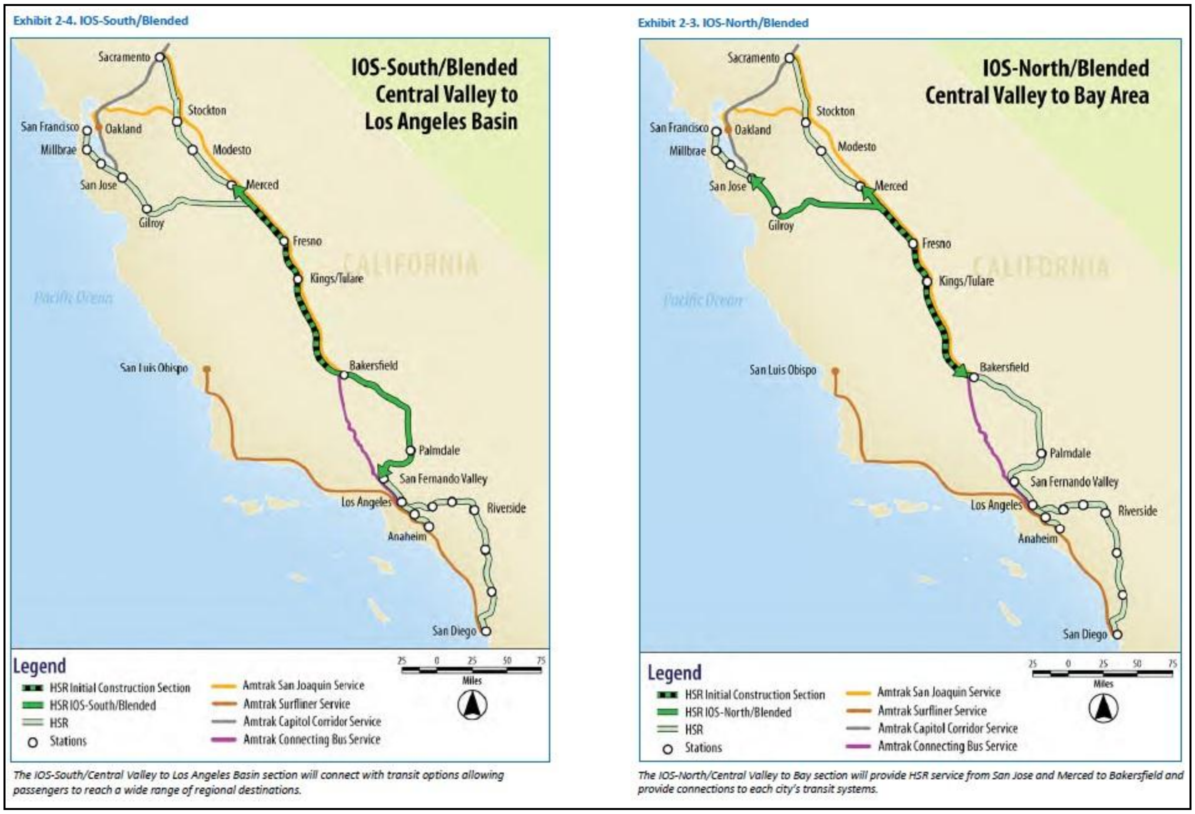



Figure 3. Maps of IOS-S & IOS-N First (California High-Speed Rail Authority, 2011n, p. 2-15 & 2-12)


Figure 4. Map of Which Airports To Be Expanded Under BAU / Option 2 (CHSRA, 2011n, p. 2-20)

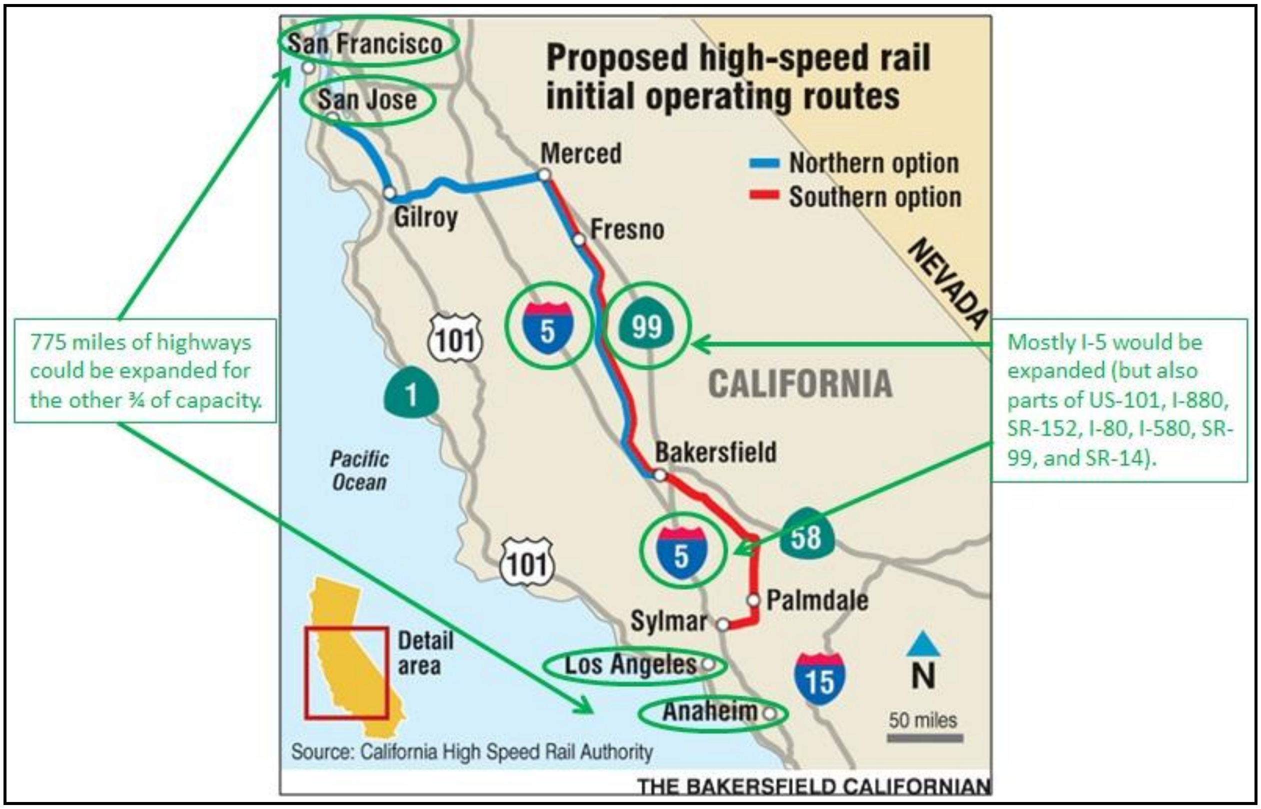



Figure 5. Map of Which Highways To Be Expanded Under BAU / Option 2 (CHSRA, 2012b)

### 2.3. High-Speed Rail in Other Countries

An entire Masters Project (or several of them) could be written based on the experience of foreign countries in building, operating, and upgrading HSR systems. But at least some mention of them is warranted in this paper, as these other countries have been blazing the trail for decades that California now hopes to follow. The first operational HSR system in the world was Japan's Shinkansen (literally, "new trunk line") system, colloquially known as the "bullet train," which was began to operate in 1964 from Tokyo to Shin to Osaka, with a maximum operating speed of 130 mph. Japan was followed by France, which began HSR operations in 1981 with the Train à Grande Vitesse (TGV), running between Paris and Lyon. Spain followed with its AVE system between Madrid and Seville in 1992, South Korea opened its KTX system between Seoul and Daegu in 2004, and Taiwan started operations for its THSTC between Taipei and Kaohsiung in 2007. Germany (ICE), Italy (TAV), the Netherlands (Thalys), Britain (Eurostar), and China have all built HSR networks as well (California High-Speed Rail

Authority, 2011n, p. 2-27). The following table and figures illustrate some of this history of successful deployment of international HSR systems.

**Exhibit 2-8. International high-speed rail phased implementation**

| Country | Initial Segment | Network Extensions | Under Construction |
|---|---|---|---|
| France–TGV (high-speed lines) | Paris–Lyon (1981) | Lyon–Valence/Marseille (1992/2001)<br>Paris–Tours and Le Mans (1990)<br>Paris–Lille and Calais (1993)<br>Paris–Rheims/Strasbourg(2007)<br>Paris Interconnection (1994)<br>Perpignan–Figueres (2010) | Dijon–Mulhouse (2011)<br>Tours–Bordeaux (2017)<br>Le Mans–Rennes (2019) |
| Spain–AVE | Madrid–Seville (1992) | Madrid–Zaragoza/Barcelona (2003/2008)<br>Madrid–Malaga (2007)<br>Madrid–Valencia (2010) | Alicante (2012)<br>Barcelona–Figueres (2012) |
| South Korea–KTX | Seoul–Daegu (2004) | Daegu–Busan (2010) | Daegu–Mokpo (2014) |
| Japan–Shinkansen | Tokyo–Shin-Osaka (1964) | Shin-Osaka–Hakata (1972-1975)<br>Tokyo–Shin-Aomori (1982 -2010)<br>Omiya–Niigata (1982)<br>Takasaki–Nagano (1997)<br>Hakata–Kagoshima–Chuo (2004–2011) | Shin-Aomori–Shin–Hakodate (2015)<br>Nagano–Kanazawa (2014) |
| Taiwan–THSTC | Taipei–Kaohsiung (2007) | None planned | |

Table 2. Some International HSR Systems (California High-Speed Rail Authority, 2011n, p. 2-27)

**Exhibit 2-10. Japan's high-speed rail system and six decades of expansion**


Figure 6. Map of Japan's Shinkansen System (California High-Speed Rail Authority, 2011n, p. 2-29)

**Exhibit 2-9. France's high-speed rail system and four decades of expansion**


*After three decades, France continues to expand its dedicated high-speed rail network building on the system's success. To date, seven segments have been constructed.*

Figure 7. Map of France's TGV System (California High-Speed Rail Authority, 2011n, p. 2-28)

The experience of these countries with building HSR systems is well-known to the California High-Speed Rail Authority. In an attempt to harvest as much experience and wisdom as possible from foreign HSR agencies, the Authority has signed Memoranda of Understanding (MOUs) for cooperation and information exchange with no less than nine foreign governments (Figure 8).

**California High-Speed Rail Authority International MOUs and Cooperation Agreements**

- UK Trade and Investment, United Kingdom, MOU on Cooperation, dated May 17, 2011
- Belgian Federal Public Service Foreign Affairs, Foreign Trade and Development Cooperation, Kingdom of Belgium, Cooperation Agreement, dated July 7, 2010
- French Ministry for Ecology, Energy, Sustainable Development, French Republic, Cooperation Agreement, dated August 28, 2009
- The Federal Ministry of Transport, Building, and Urban Affairs, Federal Republic of Germany, Memorandum of Understanding, dated March 9, 2010
- Ministry of Land, Transport and Maritime Affairs, Republic of Korea, Memorandum of Understanding, dated February 11, 2010
- Ministry of Railways of the People's Republic of China, Memorandum of Understanding, dated December 3, 2009
- Ministry of Land, Infrastructure and Transport of Japan, Memorandum Concerning Cooperation, dated September 28, 2009
- Italian Ministry of Infrastructures and Transportation, Italy, Cooperation Agreement, dated September 3, 2009
- Spanish Ministry of Development, Spain, Cooperation Agreement, dated July 31, 2003

Figure 8. International MOUs with the CHSRA (California High-Speed Rail Authority, 2011n, p. 5-8)

## 2.4. Phased Implementation Plan for California High-Speed Rail, Phase One

The California High-Speed Rail Authority proposes to build Phase One of the HSR system from San Francisco in the north to Los Angeles and Anaheim, Orange County, to the south. Phase One, once completed, would stretch for a length of 520 miles. At a later date, Phase Two would be built to link to Sacramento, to the north, as well as to San Diego, to the south. Phase Two, once completed, would add 280 miles to the HSR system (Figure 2), for a total of 800 miles (California High-Speed Rail Authority, 2011n, p. ES-7).

Within the plan for construction of Phase One, the Rail Authority proposes to construct it in several phased sections. First, an Initial Construction Section (ICS) of 130 miles will be built at a cost of $5.2 billion in 2010 $, or $6.0 billion in YOE $, using a combination of federal funds from the American Recovery and Reinvestment Act (ARRA), via the U.S. Department of Transportation's Federal Railroad Administration (FRA), as well as California state funds from the 2008 Proposition 1A HSR bond proceeds. The ICS will not be capable of train operations by itself, and it has been sited by the Rail Authority in the vicinity of Fresno to Bakersfield. When the next section, the Initial Operations Section (IOS), is added to the IOS, then high-speed train operations will commence. This IOS will take place either in an alignment just to the north of the ICS, which will be known as the IOS-N (Bakersfield to Merced and San Jose), or else in an alignment just to the south of the ICS, which will be known as IOS-S (Merced to the San Fernando Valley). Capital construction cost estimates for the IOS vary, depending on which alignment is chosen. In any event, following the completion of one IOS or the other, high-speed train operations will commence along the IOS. Concurrently, completion of the Bay to Basin section will commence, which will build out the remaining section that was not chosen for the initial IOS. The final step, to save on capital construction costs, will be the Phase One Blended section, where the HSR tracks will use some existing commuter/intercity rail infrastructure after certain improvements have been made. This is in contrast to the rest of the HSR system, which will take place on dedicated (i.e. HSR-only) tracks. However, the Phase One Blended section has been identified as capable of supporting both regular and HSR simultaneously, without serious impediment to the high-speed trains running at high speeds. There is also an alternative to build the last section of Phase One without the blended option, but this is not the alternative currently favored by the Rail Authority, as capital construction costs would be higher. Figure 9 and Table

3 illustrate phased implementation of California's HSR Phase One (California High-Speed Rail Authority, 2011n, p. ES-7).

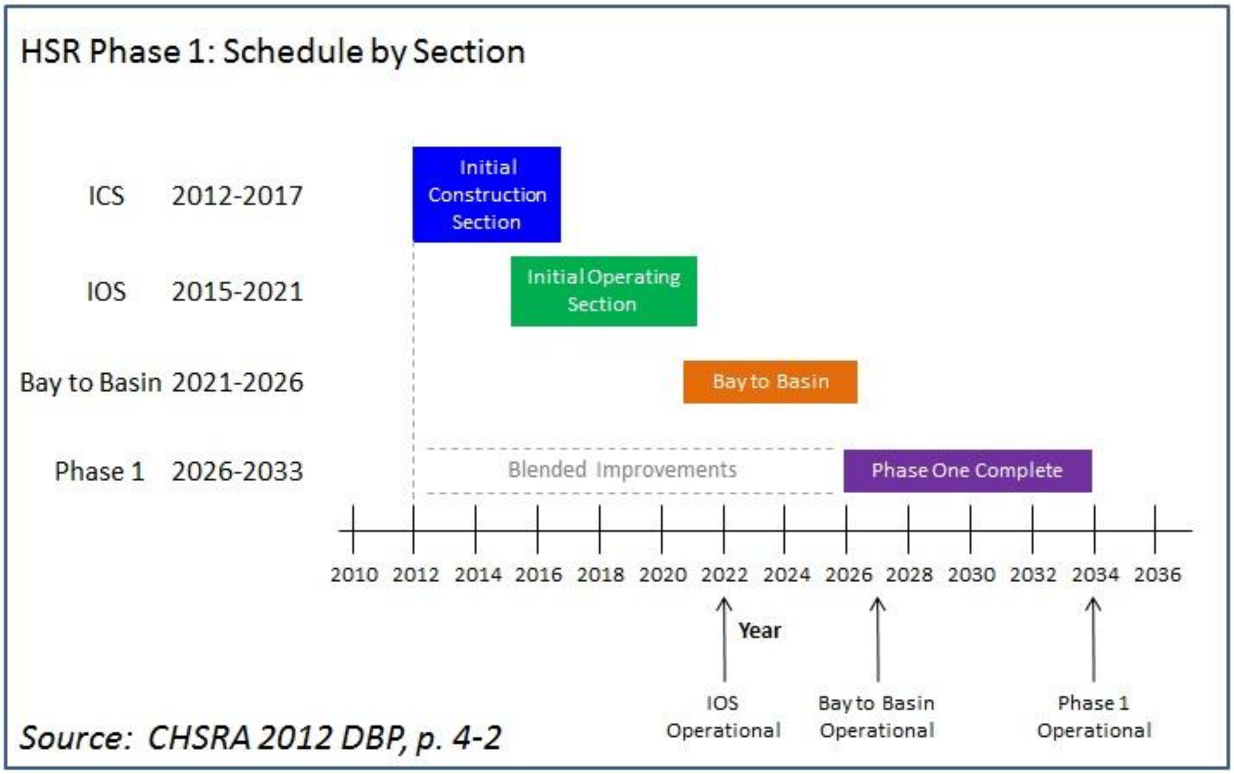



Figure 9. Schedule of Phased Construction Sections (California High-Speed Rail Authority, 2011, p. 4-2)

Exhibit ES-1. Capital costs for phased sections (billions 2010$)

| Section[1] | Length (approx) | Endpoints | Service Description | Incremental Cost (billions 2010$)[2] | Cumulative Cost (billions 2010$)[2] |
|---|---|---|---|---|---|
| Initial Construction Section | 130 miles | Fresno–Bakersfield | Provides track and structures to support system spine | 5.2 | 5.2 |
| IOS-North | 290 miles | Bakersfield to Merced and San Jose | Supports 220 mph HSR service; includes trains and systems. Ridership and revenues sufficient to attract private participation. Connects with regional/local rail for blended operations | 19.4 to 26.4 | 24.6 to 31.7 |
| IOS-South | 300 miles | Merced to the San Fernando Valley | Supports 220 mph HSR service; includes trains and systems. Ridership and revenues sufficient to attract private participation. Connects with regional/local rail for blended operations. | 21.4 to 25.8 | 26.6 to 31.0 |
| Bay to Basin | 410 miles | San Jose and Merced to the San Fernando Valley | First HSR service to connect the San Francisco Bay area with the Los Angeles Basin. | 14.2 to 17.3 | 40.8 to 48.3 |
| Phase 1 Blended | 520 miles | San Francisco to Los Angeles/ Anaheim | Builds on Bay to Basin with blended operations with existing commuter/intercity rail, and additional improvements for a one-seat ride, connecting downtown San Francisco and Los Angeles/ Anaheim. Caltrain corridor electrified for HSR, and new dedicated lines into Los Angeles and Anaheim | 14.1 to 18.0 | 54.9 to 66.3 |
| Full Phase 1 | 520 miles | San Francisco to Los Angeles/ Anaheim | Continues dedicated high-speed alignment in full from San Jose to San Francisco and into Los Angeles/Anaheim. | 8.2 to 10.5 | 65.4 to 74.5 |

[1] Decision on which IOS to advance will be made at a future date, as described in Chapter 2, A Phased Implementation Strategy.
[2] Ranges reflect the difference between the combination of lowest cost feasible options and the combination of highest cost feasible options.

Table 3. Capital Costs for HSR Phased Sections (California High-Speed Rail Authority, 2011n, p. ES-7)

## 2.5. Proposed Benefits of the California High-Speed Rail System

The subject of the proposed benefits of the California high-speed rail system is a very large and complex one, and could easily give rise to a Masters Project unto itself. But succinctly put, the Rail Authority claims the major benefits will include the following categories.

*2.5.1. Potential Economic and Environmental Benefits*

The Authority asserts that HSR will bring significant short-term and long-term benefits to California statewide, even for those who never actually ride the high-speed trains. This is due, for example, to the potential to grow the state's economy and to address environmental concerns, such as the reduction of three million tons of carbon dioxide emissions annually attributable to intra-state transportation by air or highway. For example, the lower energy usage per passenger mile (which points towards corresponding lower air pollution emissions) for HSR versus other principal modes of travel is illustrated below by Figure 10. The Central Valley, site of the ICS, has the highest unemployment rate in the state, and approximately 100,000 job-years (one job worked for one year by one person equals a job-year) will be created there, largely in the construction industry. Completion of Phase One between San Francisco and Los Angeles / Anaheim will generate a total of approximately 800,000 to 900,000 job-years, perhaps even over one million job-years (California High-Speed Rail Authority, 2011n, p. ES-4).

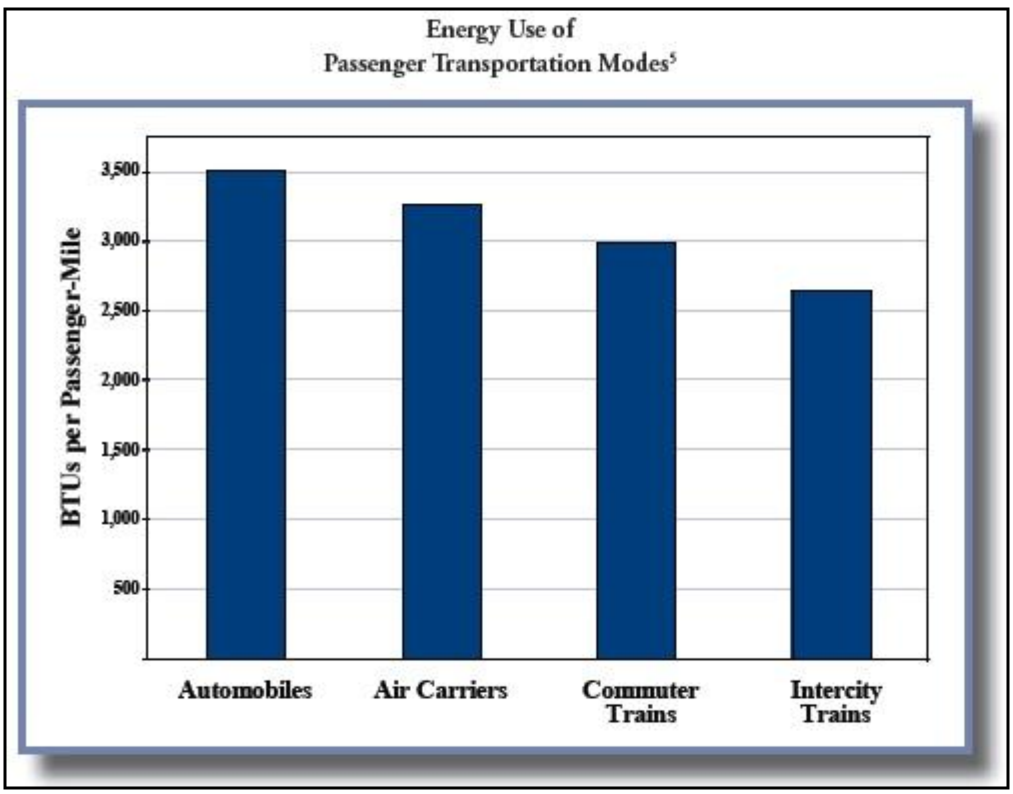



Figure 10. Energy Use of Transportation Modes in BTU's per Passenger Mile (FRA, 2009b, p. 3)

### *2.5.2. Potential airport and highway congestion relief*

California's drivers may see significant traffic congestion relief from HSR. The Authority asserts that there will be a reduction of 320 billion vehicle miles traveled (VMTs) over the next 40 years. That, in turn, should equate to 146 million hours saved for Californians annually. And there would be considerable value to that time saved in order to do "better things than sitting in traffic." By the same token, airport congestion should be reduced, based on international precedent. When Spain adopted HSR service Madrid and Seville, "the share of trips taken by plane was reduced from 40 percent to 13 percent, and rail trips grew from 16 percent to 51 percent" (Appendix II). Such a reduction in air travel should lead to limited airport capacity being used more efficiently for long-haul routes, where aviation can be more cost-effective and energy-efficient, rather than in short-haul routes such as between northern and southern California (California High-Speed Rail Authority, 2011n, p. ES-4). The Rail Authority further asserts that, given similar experiences in Taiwan, Germany, France, Japan, etc., HSR has also generated overall travel growth, not just a reallocation between modes. (This may be a good place to note that fare prices for California HSR trips between northern and southern California are to be set at no more than 83% of current, comparable airfares.) Increased mobility due to HSR ostensibly prompts greater travel, generating greater economic activity. For example, the Authority asserts that "on the high-speed route between Paris and Lyon, France, for example, half of the trips taken were new trips." Thus the Authority concludes that efficiency, reliability, and connectivity between California's economic centers provided by HSR would contribute to numerous, long-term economic benefits, such as up to 400,000 long-term jobs potentially being created as California's economy becomes more efficient (California High-Speed Rail Authority, 2011n, p. ES-5). While this author does not have the time or scope in this Masters Project to do a proper evaluation of the benefits of HSR, or the comparative benefits of an equivalent amount of expanded air and highway capacity, he does conclude from what he has studied that it is likely that the benefits to Californians would be great, and superior to those of the air-and-highways-only Option Two, if the HSR system is built, if it is affordable and convenient to travelers and thus much-used, if it is properly and carefully integrated with other modes of transportation, and if it is managed well. Thus the author returns to the subject of the comparative incremental capital construction cost analysis for Options One and Two.

# 3. Methodology

### 3.1. California Population Growth Leads to Greater Intra-State Transportation Demand

According to CHSRA's *2012 Draft Business Plan*, the state of California's current population is (as of 2010) 37 million people. That represents a cumulative growth of 3 million people or 8.8% over 2000 levels (34 million people) and 7 million people or 23.3% over 1990 levels (30 million people) (Figure 11). The most populous state in the United States of America, California is projected to continue to have a comparably high, if not higher, rate of population growth in the coming decades. According to the California Department of Finance's (DOF) pre-recession forecasts, California will reach 54.2 million people over the next 30 years (i.e. by 2040), an increase of 17.2 million people or 46.5% over 2010 levels. However, due to the economic recession in the country, the Rail Authority has adopted some more conservative California population growth projections in the new business plan. The low forecast is for California to reach 44.6 million people (+7.6 million or +20.5% over 2010 levels) by 2040, and the high forecast is for the state to attain 49.5 million people (+12.5 million or +33.8% over 2010 levels) (California High-Speed Rail Authority, 2011n, p. 6-4 to 6-5). Whichever one of these scenarios turns out to be the closest match to reality, it seems clear that California will add many millions of new residents in the next three decades and beyond, and that those people will create substantially increased demand for transportation capacity along the Phase One corridor between northern and southern California.

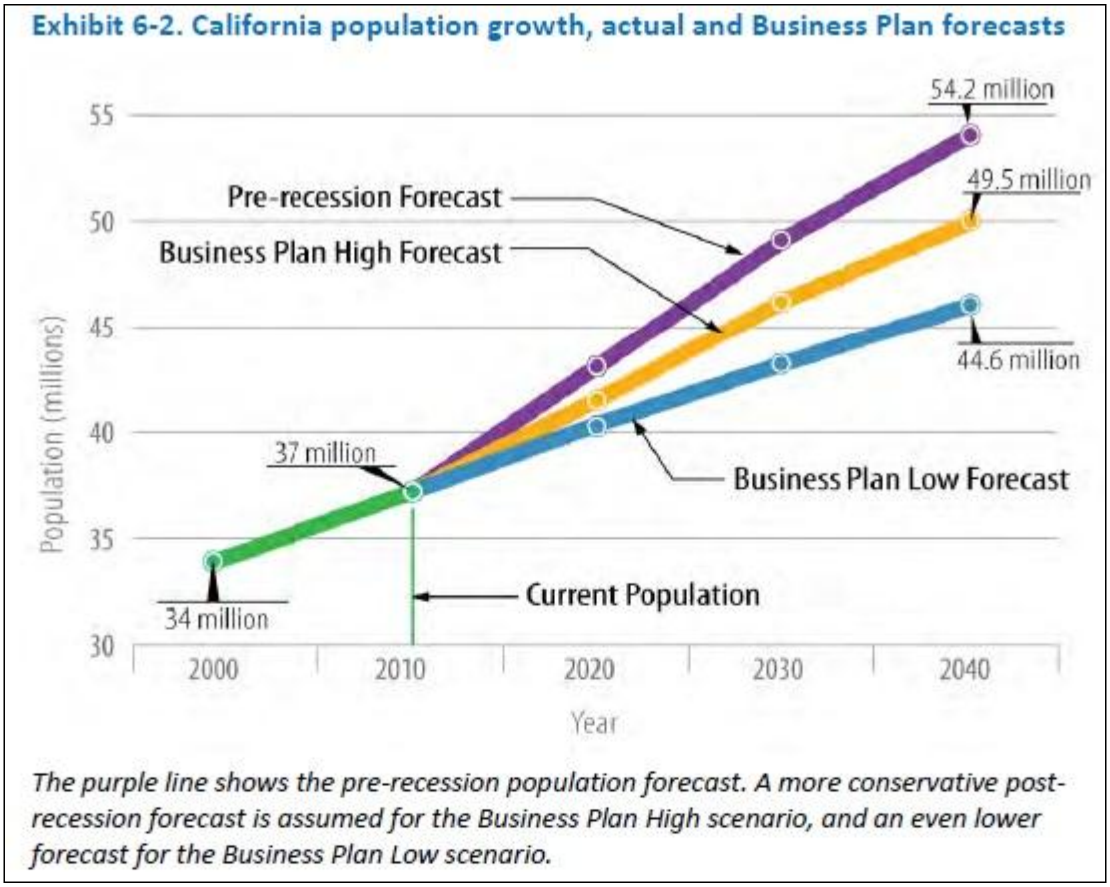



Figure 11. California Population Growth Estimates (California High-Speed Rail Authority, 2011n, p. 6-5)

### 3.2. Current Transportation Congestion and Projections for Increased Future Demand

Even before the population growth of the coming decades takes place, California already has some of the most congested and delayed highways and airports in the country, at least in certain areas. The Rail Authority asserts (California High-Speed Rail Authority, 2011n) that

> Today, our transportation systems are straining to meet current demand. Congestion on our roads results in $18.7 billion annually in lost time and wasted fuel. Air flights between the Los Angeles and San Francisco metropolitan areas—the busiest short-haul market in the U.S.—are the most delayed in the country, with approximately one of every four flights late by close to an hour or more. Continued population and economic growth will place even more demand on mobility systems that are already overburdened. Over the next 30 to 40 years, California is projected to add the equivalent of the current population of the state of New York. There is no question: meeting the demands of that growth will

require *major* investments in transportation infrastructure over the next generation. Those investments will measure in the tens of billions of dollars. The question will not be *if* those investments need to be made, but *how* the investments that will be made can provide the greatest benefit. (p. ES-1)

Similarly, former California Governor Arnold Schwarzenegger's 2007 Strategic Growth Plan (SGP) called for investing $107 billion in new transportation infrastructure (California Department of Transportation, 2007) due to the fact that

The SGP targets a significant decrease in traffic congestion below today's levels. This will occur even while accommodating growth in population and the economy over the decade. Over the next ten years, daily congestion (measured by daily hours of delay) is projected to increase 35% from 558,143 hours in 2005 to 753,000 hours in 2016 based on current trends. With the SGP, congestion levels are estimated to be 454,000 hours daily in 2016, a reduction of more than 100,000 hours (18.7%) below today's levels. Capacity or "throughput" will increase by 15 percent. (p. 1)

Returning to the Rail Authority's assessment of the situation, they assert that "California's transportation system, once the envy of the world and a key driver of economic growth, is facing gridlock" Specifically, the Authority claims regarding highways that

- California's 170,000 miles of roadway are the busiest in the nation. Six California urban areas rank in the 30 most congested in the nation: Los Angeles-Long Beach-Santa Ana, San Francisco-Oakland, San Jose, San Diego, Riverside-San Bernardino, and Sacramento.
- Travel on California's Interstate system is increasing at a rate five times faster than capacity has been added, with vehicle miles traveled increasing by 36 percent between 1990 and 2004, and the number of Interstate lane miles increasing by only 7 percent during that same period. This increase in traffic has significantly increased congestion. (California High-Speed Rail Authority, 2011n, p. 1-1)

As for current California airport congestion, the Authority further asserts that

- The busiest short-haul air market in the country is between the Los Angeles and San Francisco metro areas with hundreds of daily flights and more than 5 million passengers annually. This is larger than the NYC to Washington, D.C. market.
- The LA-San Francisco air route is one of the most delay-prone in the nation, with approximately one out of every four flights delayed by about an hour.
- San Diego-San Francisco, Los Angeles–Sacramento, and Los Angeles-San Jose are also in the top 20 short-haul air travel markets in the nation, representing millions of additional annual passengers.
- Continued airport congestion will have a tremendous negative impact. For example, a recent study of three New York area airports concluded that, in 2008, the total value of lost time to travelers resulting from congestion was $1.67 billion. This same study concluded that for business travelers, the travel time lost cost $676 million. (California High-Speed Rail Authority, 2011n, p. 1-1)

The federal government also sees a strong need for increased transportation capacity for California now and in the coming decades. For example, Federal Railroad Administrator Joseph C. Szabo has stated that “with 20 million more people expected to be in California within the next 40 years, we can’t build enough highways and airport runways to accommodate demand” (California High-Speed Rail Authority, 2011n, p. 1-2). As for air travel demand, the Rail Authority cites “a recent study prepared to support the Bay Area Regional Aviation System Planning (RASP) Update forecasts” that air passenger demand to and from Bay Area commercial airports will “grow from 61 million passengers in 2007 to approximately 101 million passengers in 2035,” leading to severe delays at San Francisco International Airport (SFO) by 2035 unless action is taken to alleviate the situation (California High-Speed Rail Authority, 2011n, p. 1-2). Similar increased air travel predictions for California airports have been made by the Federal Aviation Administration (FAA) in their 2007 report, *Terminal Area Forecast Summary: Fiscal Years 2008-2025*. The FAA asserts that, among the 35 airports in their Operational Evolution Partnership (OEP) (i.e. the largest 35 airports in the country), SFO will experience the second largest (after Washington Dulles) annual enplanement demand growth (2.9%) between 2008-2025 (Federal Aviation Administration, 2007, p. 1). Los Angeles International Airport (LAX) is forecast to experience annual enplanement demand growth of 2.7% during the same period, among the highest growth rates for large airports in the nation (Federal Aviation Administration, 2007, p. 7). Both of these rates of increase significantly exceed the forecasted annual compound growth rate for enplanements from 2007-2025 for large hub airports (2.0%) and all towered airports in the nation (1.9%) (Federal Aviation Administration, 2007, p. 17). LAX will remain the nation's third busiest airport in 2025, and SFO will move from the fourteenth busiest to the ninth busiest airport in the same period (Federal Aviation Administration, 2007, p. 9). It is on the basis of projections such as these that the Rail Authority has concluded that "the state cannot continue meeting the demands of 50 to 60 million residents by taking a 'more of the same' approach" and that "to keep the state moving and to remain economically viable, California will need to add significant new capacity to its transportation network and these investments, no matter what they are, will cost tens of billions of dollars to build and millions of dollars a year to maintain" (California High-Speed Rail Authority, 2011n, p. 1-2).

### 3.3. CHSRA's Proposed Response to California Population, Transportation Challenges

To respond to these population pressures and corresponding intra-state related airport and highway congestion now and in the coming decades, the Rail Authority proposes to build the high-speed rail network that was originally called for in the passage of California's Proposition 1A in 2008, starting with Phase One from the San Francisco Bay area in the north to Los Angeles and Anaheim (in Orange County) to the south, a distance of 520 miles (Table 4). The Authority's 2012 Draft Business Plan asserts that

> "Assuming that such expansions [of airports and highways] would even be feasible, providing the same new capacity as the San Francisco to Los Angeles/Anaheim HSR system would cost California approximately twice as much as the HSR investment. As shown in Exhibit 1-1, building equivalent capacity through road and airport expansions would cost an estimated $114 billion (2010 $), which is equivalent to $171 billion in year-of-expenditure [YOE] dollars. To achieve the same capacity as the HSR system, California would need to construct:
>
> • 2,300 new lane-miles of highway
>
> • 115 additional gates at California airports
>
> • 4 new airport runways (California High-Speed Rail Authority, 2011n, p. 1-3)

| Exhibit 1-1. Comparing the cost of HSR to the cost of highway and airport expansion | | | |
|---|---|---|---|
| Transportation Alternative | Added capacity | Required Investment (2010$) | Required Investment (YOE through 2033) |
| High-speed rail | Full Phase 1<br>San Francisco-Los Angeles/Anaheim<br>520 miles | $65 billion | $98.5 billion |
| Highways and airports | 2,300 new miles of highway<br>115 new airport gates<br>4 new runways | $114 billion | $171 billion |

Table 4. Comparison of Two Main Alternatives (California High-Speed Rail Authority, 2011n, p. 1-3)

And with a few calculations of our own, we can see what the proposed savings are, if we take the Rail Authority's figures at face value:

| Transportation Alternative | Added Capacity | Required Investment (2010 $B) | Required Investment (YOE $B) |
|---|---|---|---|
| High-speed rail | Full Phase 1 | 65.0 | 98.5 |
| | San Francisco-Los Angeles/Anaheim | | |
| | 520 miles | | |
| Highways and airports | 2,326 new lane-miles of highway | 114.0 | 171.0 |
| | 115 new airport gates | | |
| | 4 new runways | | |
| | **Proposed cost savings ($)** | **49.0** | **72.5** |
| | **Proposed avoided cost increases (%)** | **75%** | **74%** |

Table 5. Comparison of the Two Main Alternatives with Savings Calculations

Consequently, the Rail Authority maintains that "the choice California faces is not whether to build both the high-speed rail system *and* undertake a major freeway/airport expansion program, it is which of these two fundamental options is more affordable and what is most consistent with California's environmental, land use, and economic objectives." But the Authority asserts that the second alternative, expanding highways and airports, may be problematic at any price, stating (California High-Speed Rail Authority, 2011n) that

> recent trends suggest that the ability to add significant new highway mileage is limited and could not approach the 2,300 miles noted above. In the last two decades, the state has added less than 1,000 miles in a period when two major federal surface transportation programs significantly increased available highway

> funding for California. Attempts to gain approval for new or expanded runways at San Francisco International Airport have not been successful. Such alternatives run counter to state policies and create noise, air quality, and other livability impacts that engender significant opposition from adjacent communities. In addition, expanding freeways and airports would require extensive right-of-way in California's dense urban areas, would be more costly than HSR, and would conflict with the land use and development goals of most communities. As part of a balanced transportation system, a statewide HSR system can provide additional capacity needed to keep a state with 60 million people moving. (p. 1-3 to 1-4)

It is based upon these contentions by the Rail Authority in their *2012 Draft Business Plan* and its supporting documents from October and November of 2011 that we will take a deeper look at the costs of the two proposed main alternative transportation plans.

### 3.4. Capital Cost Projections for California HSR: Some Historical Background

The Rail Authority's contentions around comparative capital costs in the new business plan (and previous documents) have been criticized on a number of fronts by reputable, non-partisan organizations such as the California State Legislature's Legislative Analyst's Office (LAO), the California State Auditor's Office, and the statutorily mandated (by California Assembly Bill 3034) California High-Speed Rail Peer Review Group (CHSR PRG or, simply, PRG) as well as numerous journalistic outlets and some perhaps more partisan critics (California State Assembly, 2008). Some historical background on California HSR capital cost projections helps to set the stage for the current criticisms.

Proposition 1A, voted into state law by a referendum of California voters on November 4, 2008, called for a total capital construction budget of $40 billion (in 2008 dollars) for the entire California HSR system (i.e. both Phases One and Two, with Phase Two being the connections to Sacramento in the north and San Diego in the south to reach the full 800-mile system extent) (California Secretary of State's Office, 2008a) (Californians for High-Speed Trains, 2008). The new law authorized the state to issue $9.95 in bonds for HSR, of which the net proceeds received from the sale of $9 billion would be made available by the state legislature in future for capital construction costs, with the remaining $950 million to be allocated "to eligible recipients for capital improvements to intercity and commuter rail lines and urban rail systems that provide direct connectivity to the high-speed train system and its facilities, or that are part of the construction of the high-speed train system… or that provide capacity enhancements and safety improvements" (California Secretary of State's Office, 2008a, p. 11). To reach the full capital construction budget of $40 billion, proponents of Proposition 1A envisioned that the federal government would provide funding for a quarter to a third of the budget ($10 to $12 billion) and that public-private partnerships (PPP's) would be formed to provide $4.5 to $7.0 billion in financing (Californians for High-Speed Trains, 2008). Thus, it was believed that $23.5 billion (59%) to $28.0 billion (70%) of the capital budget would be obtained this way, though it was never made clear at the time where the remaining 30-41% of the capital funding would come from. It should also be noted that the LAO estimated at the time that paying off interest on the bonds would result cost an additional $9.5 billion (30 years of average annual payments of $647 million, for a total state cost of $19.4 once all principal and interest were paid), with the additional cost coming from General Fund appropriations required by the new law (California Secretary of State's Office, 2008a, p. 4). In any event, at the time of the passage of Proposition 1A, no funds had been secured other than the aforementioned $9 billion, and there is no evidence of a plan to obtain the "missing" $12.0 to $16.5 billion for capital construction costs.

### 3.5. Capital Cost Projections for California HSR: Current Estimations

The original cost projections were incorporated into the Rail Authority's *2009 Report to the Legislature*, though Phase One (alone) costs were revised upward to $36.4 billion (in 2010 dollars) (California High-Speed Rail Authority, 2011n, p. 3-5). However, with the passage of time, the Rail Authority determined that they had not budgeted sufficiently for the HSR project in this report. A series of studies by contractors (especially the firms Parsons Brinckerhoff and Cambridge Systematics), commissioned by the Rail Authority, led to conclusions incorporated into the *2012 Draft Business Plan*. The new plan proposes that Phase One capital construction costs will now range from $65.2 to $74.2 billion (in 2010 dollars) or from $98.5 to $117.6 billion (in Year-of-Expenditure (YOE) dollars) (California High-Speed Rail Authority, 2011b, p. 6) (California High-Speed Rail Authority, 2011n, p. 1-3 and 3-5). The new plan proposes no budgetary estimations at all for Phase Two, one of the most notable omissions in and a lightning rod for widespread criticism of the plan. Thus the new plan's numbers can be represented as an increase of $28.8 to $37.8 billion (2010 dollars) for Phase One over the 2009 Report's estimates, a capital construction cost growth of 79% to 104%. Taken together with no revised Phase Two cost numbers, this has led to much concern by critics and proponents of HSR alike.

Admittedly, at this point, it should be considered that, unlike Japan or Europe in 2012, this is the United States of America's first real experiment with building a HSR project (not counting Amtrak's slower Acela Express, which averages only about 75 mph along its northeast corridor route, despite a potential maximum speed of 150 mph) (Amtrak, 2010, p. 8-9). Thus a certain learning curve in how to manage all aspects of the project (including appropriate cost projections for an American context) is, perhaps, to be expected. And it does appear that the Rail Authority did some due diligence in creating the revised capital construction cost estimates. These cost increases have been broken down by cost category by the Rail Authority (Figure 12).

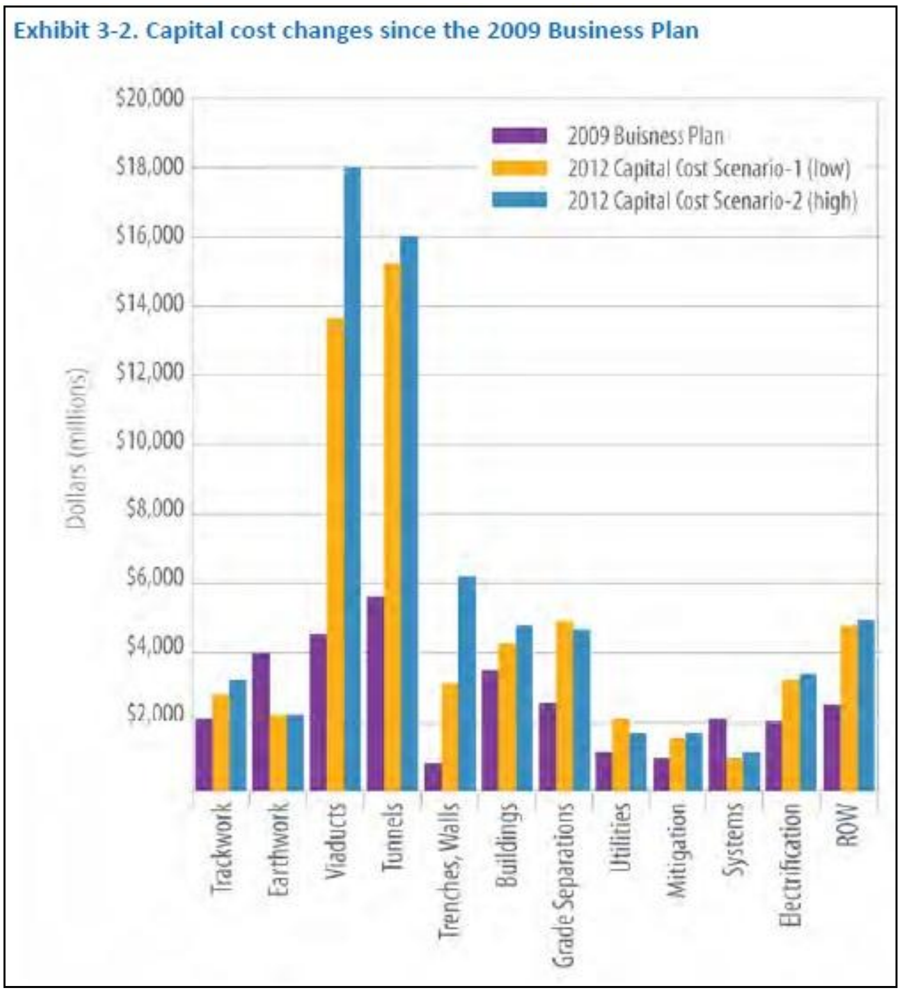



Figure 12. CAHSR 2009-12 Capital Cost Increases (California High-Speed Rail Authority, 2011n, p. 3-6)

Thus we can see that the great majority of the capital construction cost increases (in either the 2012 high or 2012 low scenarios) is due to viaducts and tunnels. As the Rail Authority describes (California High-Speed Rail Authority, 2011n) it

> Eighty to eighty-five percent of this increase is for additional viaducts, tunnels, embankment, and retaining walls/trenches directly attributable to changes in scope and alignment based on stakeholder input, environmental necessity, and improved knowledge of site conditions; the remaining 15 to 20 percent is attributable to increases in composite unit prices. Of the total Full Phase 1 costs, $11 billion are contingency protecting against cost increases. (p. 3-5)

Oddly, at various other points in the *2012 Draft Business Report*, the contingency cost elements of the new Phase One budget are described as amounting to $16 billion, not $11 billion (California High-Speed Rail Authority, 2011n, p. 8-1). This discrepancy is never fully explained (is it a typo? a difference between 2010 and YOE dollars?) in the report. In the absence of a clear explanation, this author assumed (to use higher, more conservative figures) in subsequent calculations that he conducted to evaluate the capital costs of the HSR project that the larger number, $16 billion, was the correct one.

In any case, the report goes on to say that much initial planning for the HSR system by the Rail Authority (which was formed in 1996) predated the mid-2000s California real estate boom, and thus the 2009 report used the older real estate prices rather than revised numbers. And with California adding several million people between 2000 and 2010, and much of that growth along the Phase One project route, at-grade crossings have been replaced in the planning by alignment relocations, bridge elevations, tunnels, or other means of avoiding disruption to existing communities and infrastructure. Also, environmental assessments led to re-routing or other corrective measures. Thus these bases for capital cost increases may, in fact, be very responsible and realistic reassessments necessary for the success of the project and the well-being of the community (California High-Speed Rail Authority, 2011n, p. 3-5 to 3-6).

### 3.6. Capital Cost Projections for California HSR: Comparison with Air / Highway Option

As previously stated, the Rail Authority argues that greatly increased intra-state transportation capacity along the Phase One corridor needs to be built in the next two to three decades, as well as to accommodate further increases in the subsequent several decades. While the Rail Authority provides a fairly detailed accounting of the HSR option (though it is still problematic, as it is missing full cash flow data, a crucial key for benefit-cost analysis), the Authority provides a substantially less detailed accounting of what it characterizes as the primary alternative, a mix of highway and airport expansions. In the Authority's 2009 report, the cost of the air / highway alternative was given as $100 billion (YOE $). This has now risen to $114 billion (2010 $), or $171 billion (YOE $) (California High-Speed Rail Authority, 2011n, p. 1-3), without a complete explanation from the Rail Authority as to the causes of the increase. (The two main interpretations of this omission seem to be either that the Rail Authority had not originally done the due diligence on the air / highways alternative capital costing, or that the new numbers represent an attempt to "cook the books" to make the HSR option look better by comparison than it merits – these contentions will be discussed at somewhat greater length below.) Also, no cash flow data at all is given for when and how California would spend this amount on the equivalent transportation capacity in airports and highways. This makes analysis of the alternative highly problematic, and this has also led to widespread criticism of this part of the *2012 Draft Business Plan*. However, though this author finds these omissions quite troubling and surprising, he has endeavored to create a way to at least attempt to "compare apples to apples" by looking at possible Net Present Value (NPV) estimations of capital construction costs for the HSR system (Option 1) and the air / highway alternative (Option 2), relying heavily on the Rail Authority's rather incomplete supporting document from October 2011, *Cost of Providing the Equivalent Capacity to High-Speed Rail through Other Modes* (hereafter referred to as *COPEC*), in conjunction with the *2012 Draft Business Plan*.

To obtain usable cash-flow data for the HSR system, it has been necessary to stitch together various tables for the two low-cost HSR scenarios which are strewn throughout the current business plan, as no full cash flow for Phase One is provided anywhere in the plan or on the Rail Authority's voluminous website. Also, it has been necessary to look at four principal variations on cash-flow for Phase One. These four variations can be summarized as:

- Low-cost HSR scenario, Initial Operating Segment-South (IOS-S) built first
- Low-cost HSR scenario, Initial Operating Segment-North (IOS-N) built first
- High-cost HSR scenario, IOS-S built first
- High-cost HSR scenario, IOS-N built first

Unfortunately, in yet another omission of crucial data for analysis from the new business plan and its supporting documents, the additional costs of the high-cost scenarios are only given as gross numbers, not in cash-flow format. Once again, this author has been forced by these circumstances to devise a means of modeling this situation without full and comprehensive data. The air / highways alternative has also required various assumptions and estimations about how to work backwards from the gross numbers and combine them with the content of the *COPEC* document to come up with at least some estimation of what might underlie the Rail Authority's option 2 gross capital construction cost numbers.

## 3.7. Capital Cost Comparisons for Options 1 and 2: Proposed Methodology and Problems

In order to have any chance of, hopefully, "comparing apples to apples" for Options 1 and 2, it is necessary to calculate Net Present Values (NPVs) for the two project alternatives. This is due to the fact that NPV calculations take into account the time value of money, which is a crucial element of analysis that is given insufficient attention in the Rail Authority's public documents. For example, $100 today is worth far less than $100 would have been worth in 1900. Similarly, $100 billion today is worth significantly more today, in 2012, than it would be worth in 2033 (which happens to be the proposed end of construction date for Phase One under both low cost scenarios) (California High-Speed Rail Authority, 2011n, p. 8-37). In order to be able to calculate the NPVs, the following five sets of baseline assumptions were made.

### *3.7.1. Inflation*

First, we must choose how to deal with the topic of inflation. In this instance, the Rail Authority has made things fairly easy for us, specifying a 3% annual inflation rate (starting from a baseline of 2010 dollars) for 2010-2033 in the "Funding and Financing" section of their new business plan and in *COPEC* (California High-Speed Rail Authority, 2011n, p. 8-2, 8-14, 8-23, and 8-36) (California High-Speed Rail Authority, 2011c). The Authority then characterizes the aggregate amount of this inflation as "$27.5 billion in construction inflation costs are included in the year-of-expenditure estimate," which does not make sense in that (given the low-cost scenario for IOS-N first), on the next page, it seems clear that the difference due to inflation is $98.5 minus $65.4 equals $33.1 billion. This seems rather more than can be accounted for from the disclaimer that "may not total due to rounding" (California High-Speed Rail Authority, 2011n, p. 8-1 to 8-2). Thus, we will make our own calculations as to the net effects of 3% annual inflation, when necessary. However, NPV calculations, by their nature, transform nominal dollars (inflation-inclusive) into real dollar amounts (excluding inflation) before yielding up an NPV, in order to express things to us in present value dollar amounts.

### *3.7.2. Discount Rates*

Secondly, and more importantly, we must choose how to deal with discount rates. For the most part, the Rail Authority uses a 4% annual real discount rate in its *2012 Draft Business Plan* and its Oct. 2011 *California High-Speed Rail Benefit-Cost Analysis (BCA)* (California High-Speed Rail Authority, 2011n, p. 10-5) (California High-Speed Rail Authority, 2011a, p. 1, p. 2, and p. 20). The Rail Authority bases this determination upon (1) federal Office of Management and Budget (OMB) recommendations, and (2) federal Department of Transportation guidance for transportation project grants such as in the TIGER II grant program. This author concurs with this approach, and has also chosen a 4% real discount rate for his primary means of NPV analysis, especially as this rate is similar to (when rounded to the nearest whole percentage) LIBOR's (London InterBank Offered Rate) Bond Buyer's 20-Bond Index 3.9% current rate (Bankrate.com, 2012). (Bankrate.com describes this rate as "a barometer for yields on tax-free bonds issued by state governments and local municipalities," fitting our analysis well.)

We will subsequently use two more discount rates (a higher one of 11%, based on a theory of high social cost of capital for the HSR project, and a lower one of 2%, based on a theory of low social cost of capital for the HSR project) for purposes of sensitivity analysis as well. This will be discussed further below.

### *3.7.3. Nonexistent Cash-Flow Data for HSR High Capital Cost Scenario 2*

Third, we must choose how to deal with the missing cash-flow data for the two high-cost scenarios for HSR. Unfortunately, the Rail Authority does not provide any cash flow data at all for the high-cost scenarios, an unfortunate omission. The *2012 Draft Business Plan* speaks very little to the high-cost scenario, but does say that "if all environmental and planning decisions currently under consideration were made such that all of the highest capital cost alternatives were selected (Capital Cost Scenario 2)… The total YOE cost increase, if all of the more expensive alternatives were selected, could be an additional $19.1 billion, for a total of $117.6 billion"

(California High-Speed Rail Authority, 2011n, p. 8-2). This indicates a figure based off of the IOS-N first alignment, with its projected $65.4 billion (2010 $) / $98.5 billion (YOE $) budget. The Rail Authority goes on to state that, due to numerous conservative assumptions and calculations (e.g. initial inflation rate is likely to be lower than 3% due to current economic slowdown; population growth rates may be higher than in the new plan, leading to higher ridership rates and corresponding revenues generated; $11 to $16 billion in contingencies budgeted may not all be needed or spent, etc.) that they have already built into the low capital cost scenario, they do not believe the high-cost scenario will happen. But given the Authority's tendency in recent years to greatly underestimate HSR capital costs, the uncertainty around building a true HSR network in the USA for the very first time, and the desire by this author to perform a more thorough analysis of some points than the Rail Authority has presented, some means of modeling the high capital cost scenario for NPV calculation purposes must be devised.

What this author decided to do about the HSR high capital cost scenarios is as follows. Though no alternative cash-flow has been given by the Rail Authority, this author has devised one based upon making assumptions that all the additional cost (the $19.1 billion in YOE $) will be the same amount for either the IOS-N first or IOS-S first scenarios; that the Phase One timetable will remain 2013-2033 for complete construction; and that the high capital cost increases can be modeled by distributing them evenly (accounting for inflation) across the 21-year period, such that the total (in YOE $) equals $19.1 billion. Admittedly, the time-modeling aspect here is questionable, since one Rail Authority supporting report indicates that the high capital cost scenarios might result in Phase One not being complete until 2038, instead of 2033; but in order to have a model simple enough to be able manipulate successfully for the purposes of this Masters Project, the author has decided to allocate all the high capital cost amounts to years in the 2013-33 range nonetheless (California High-Speed Rail Authority, 2011e, p. 13 to 20). In other words, given the IOS-N first alignment, high capital cost scenario, adding $666 million to the first year of construction (2013), then inflating by 3% for the next year ($686 million additional spent in 2014), and again inflating by 3% for the following year ($707 million in 2015), and so on, eventually leads to $19.1 billion (YOE $) in additional capital spending. No doubt, in real life, the costs would not be distributed in such a uniform, linear way; but the Rail Authority has left us little alternative for a better way to model this aspect of the problem.

*3.7.4. Nonexistent Cash-Flow Data for Option 2, Expanding Airports and Highways*

Fourth, we must make some initial decisions to choose how to deal with the missing cash-flow data (and overall time frame, for that matter) for option 2, the airports and highways expansions. First, let us look at the proposed cost breakdown of the airports piece versus the highways piece (Table 6).

| CHSRA *2012 Draft Business Plan* | Capacity Needed | Cost (2010 $) | Cost (YOE) |
|---|---|---|---|
| Highway Component (75%) | 2,326 lane-miles (3 lanes) | $84.6 billion | $126.9 billion |
| Airport Component (25%) | 115 gates & 4 runways | $29.7 billion | $44.6 billion |
| **Total** | | **$114 billion** | **$171 billion** |

Table 6. Option 2 Air & Highway Cost Estimates (California High-Speed Rail Authority, 2011c, p. 4)

Essentially, the Rail Authority foresees that the equivalent intra-state transportation capacity would be delivered by providing three quarters of it through expanded highways and one quarter of it through airport expansions (California High-Speed Rail Authority, 2011c, p. 5). This is based upon the Authority's Travel Demand Model (TDM), which is a highly complex model that has been much criticized outside the Authority. Essentially, the model makes the following assumptions, which echo those made in the 2005 Program Level Environmental Impact Report (EIR) / Environmental Impact Statement (EIS). The Authority assumes that a maximum capacity for the HSR system by its completion in 2033 will need to be (not only to accommodate needs then but also in 2050, 2060, 2070, and so on, given the projected 100-year life of the HSR system) capable of:

- 12 trains per hour in each direction
- 1,000 seats per train
- 19 hours of operation per day
- 70% average load factor for trains (based on international experience and TDM output)

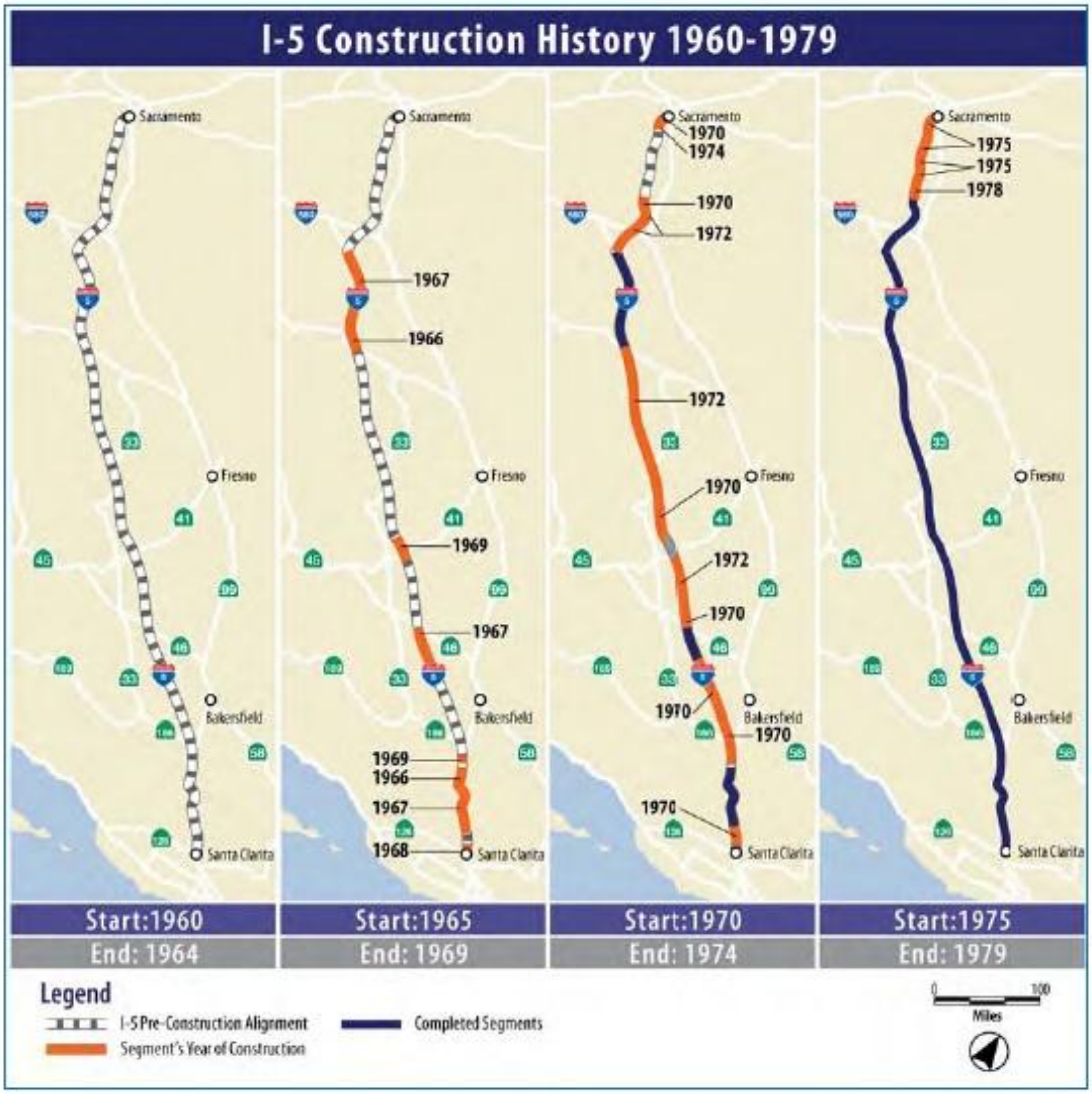
This would lead, in turn, to a needed equivalent air capacity of about 29 million passengers trips per year (or 58 million, if counting both the point of departure in California and point of arrival elsewhere in California) (Table 7) for the one quarter of capacity to be provided by air, and another 87 million passenger trips by highway, for a total of 116 million passenger trips per year.

This is equivalent to the HSR system Phase One capacity of 319,200 passengers per day or 116,508,000 passengers per year (California High-Speed Rail Authority, 2011c, p. 5 to 6).

Due to the complete lack of timelines for the proposed Option 2, we must try to make some potential modeling assumptions from here and see where they take us, and then return later to underlying assumptions for a bit more critical appraisal. First of all, looking at the Airport, Highway, and Total lines in 2010 $, in each case, if we assume that these amounts are spent in equal (adjusted for inflation) amounts every year until the projects are complete, we find that it will take approximately 27 years at 3% inflation to complete these projects. While this author did calculate NPVs for Option 2 on a 27-year, continuous basis, using three different discount rates, it seems better for comparative modeling purposes to condense this to a 21-year construction period (keeping the 2010 $ amounts held constant, though this admittedly reduces the YOE $ amounts somewhat, due to less cumulative inflation applied). This is done for three reasons.

First, this decision yields a bit easier "apples to apples" comparison with HSR if both projects are completed in the same amount of time (2013-33 or 21 years). Second, the resulting somewhat lower YOE $ amounts for Option 2 mean we are making a bit more conservative estimate for the need to expand airports and highways, which seems warranted by the chorus of recent criticism of the Rail Authority's numbers on this point. For example, regarding airports, while current capacities are constrained and congested at LAX and SFO airports, there is room for expansion at Burbank, Ontario, Oakland, etc. And regarding highways, while current capacities are constrained and congested in the Bay Area and the greater Los Angeles area and Orange County, traffic jams are not the norm out in the desert on I-5 in the central California valley. Third, California has built a great highway project before, the I-5 highway system between northern and southern California. The long stretch (of a similar length to the Phase One HSR corridor, though a somewhat different alignment) between Sacramento and Santa Clarita was completed in only 20 years, thus the suggested highway improvements in Option 2 might reasonably be assumed to also be capable of being completed in 20 years (or less), for the most part (Figure 13).

Exhibit 2-7. Interstate-5 construction history 1960–1979




*More than 100 years in the making, implementation of the state road system provides another example of how phasing a large-scale transportation program produces results.*

Figure 13. I-5 Construction History, 1960-1979 (California High-Speed Rail Authority, 2011n, p. 2-26)

However, even armed with these assumptions and decisions on how to model Option 2, numerous questions remain about how many lanes and lane-miles will be needed, and when, for the highways; when the new airport gates and runways will be needed; how construction of the airport and highway expansions might be phased or staggered, much as the HSR system will be; and so on. These questions will be examined in greater detail below, as will the complexity of the airport expansions piece.

### *3.7.5. Questioning a Range of CHSRA Assumptions Inherent in the Option 2 Analysis*

First, we must choose how to deal with a range of assumptions within the Rail Authority's Option 2 numbers which may or may not be supportable by the facts, including proposing some variations on timing / phasing in of Option 2. While we have chosen a time frame of 21 years for the Option 2 capital cost construction elements, there are various ways to look at how this might happen. First, let us take a closer look at highways.

The Rail Authority's October 2011 *COPEC* report illustrates in its Table 9, "Full Cost Estimates" (Appendix I) for the expanded highways, that a total of 775 miles of highway expansions will be built, or a total of 2,326 lane-miles of highway expansions (California High-Speed Rail Authority, 2011c, p. 25). That means that the *total* number of lanes for a given highway, such as I-5, would be expanded by 3 lanes – not 3 lanes in each direction. In other words, California would build 3 lanes in one direction (e.g. going north) and none in the other direction, or 2 lanes going north and 1 going south, etc. This at first seems odd. The authority speaks to this in the *COPEC* report, stating that their estimations yielded an increased capacity need of more than 2 lanes but less than 4 lanes, thus they chose 3 for modeling purposes. This does not seem to this author like the best modeling decision. Highway lanes, in reality, would only be built in pairs: 1 lane in each direction for a total of 2 lanes, or 2 lanes in each direction for a total of 4 lanes, etc. Thus, while this author *did* model some highway cash-flows on the basis of 3 lanes total built across 21 years in even (inflation-adjusted) amounts of money, it seems that better models exist. This author also looked at these other potential models:

- 2 lanes (1 in each direction) built evenly across 21 years
- 4 lanes (2 in each direction) built evenly across 21 years
- 6 lanes (3 in each direction) built evenly across 21 years

However, while cash-flows were modeled for all of these options, none seemed fully satisfactory to the author. For example, the I-5 initial construction from 1960-1979 was not built all at once, simultaneously, everywhere, it was built in segments (like the HSR proposal). And some areas of the 26 highway segments proposed for Option 2 are surely relatively less congested (e.g. the 186-mile rural I-5 segment between SR-152 and SR-99 (i.e. between Merced and Bakersfield)) than others (e.g. the 7.4-mile urban I-5 segment between Burbank and Los Angeles Union Station) (California High-Speed Rail Authority, 2011c, p. 25) (Appendix I). Unfortunately, without further data on comparative congestion conditions on different highway segments, this author has no quantitatively based means to prioritize which segments should be expanded first. An alternative modeling approach was sought, to give some attempt at phasing in highway expansions in a way that reflects gradually increasing transportation demand across time (rather than all at once) and echoes the HSR phasing. Two other models were examined:

- 6 lanes, built in 3 phases of 7 years each, across a total of 21 years, the “2/4/6 model”
- 4 lanes, built in 3 phases of no lanes the first 7 years, followed by 2 lanes each in the subsequent 7 year periods, across a total of 21 years, the “0/2/4 model”

Without yet knowing how CalTrans (the California Department of Transportation) would actually proceed under such circumstances, this piece of the author’s analysis may be less robust. But seeking a model that seems more justifiable than the Rail Authority’s highways model, and would permit further analysis, this author took the decision to emphasize the 0/2/4 model in subsequent NPV analysis of capital construction costs.

Given these five sets of decisions, we are now ready to proceed with our somewhat rough NPV analysis of comparative capital construction costs. We will also briefly address the concept of total cost, which would include projected Operations and Maintenance (O&M) costs. Though a full analysis of O&M costs of both options 1 and 2 will largely be beyond the scope of this paper, a first attempt will be made at estimating O&M cost for the HSR project, at least.

## 3.8. Brief Description of Capital Costs of Options 1 and 2

### *3.8.1. Option 1: High-Speed Rail*

Before delving into the NPV calculations, it is interesting to take note of the sheer size of the program to build the California HSR system. One of the largest infrastructure programs ever undertaken in the United States of America, the HSR system would install 2,200 miles of rail weighing 276,000 tons; lead to construction of 3.5 million square feet of buildings and facilities; install a total of 6,500 miles of electrical wires and cables; and necessitate over 200 grade separations. This last point is due to the fact that 37% to 43% of the Phase One alignment (189-220 miles of track) may be built on elevated structures or in tunnels (California High-Speed Rail Authority, 2011n, p. 3-1). While it is not made clear in the *2012 Draft Business Plan* if these numbers pertain to both Phases One and Two, or only to Phase One, this author has assumed the latter, given the plan’s focus on providing numbers solely for Phase One, by and large.

### *3.8.2. Option 2: Airports and Highways*

As was mentioned previously, the Rail Authority estimates that, in order to provide an equivalent amount (compared to the HSR system) of ostensibly needed intra-state transportation capacity along the Phase One corridor, California would need to instead build 2,300 lane-miles of highways, plus 115 new gates and 4 new runways at statewide airports. These assertions are expanded upon in the *COPEC* report. However, given our chosen frame of analysis (the “0/2/4 model” or asserted “best model”) of Option 2, we are now looking at a situation for highways where no lane-miles of new highways would be built from 2013-2019; 1,550 lane-miles (2 lanes total, or 1 each way) would be built from 2020-2026; and a final 1,550 lane-miles (2 lanes total, or 1 each way) would be built from 2027-2033, for a total of 3,100 lane-miles of expanded highways built across the 21-year period from 2013-2033. The overall effect, from NPV analysis, is to have raised further the cost of the highways piece a bit, given that 4 lanes of highways across 775 miles still costs more than 3 lanes, even with the phased approach. Thus, attention will be given in sensitivity analysis especially also to the “pure” 2-lane approach, where 1 lane each way is built in equal parts across the 21-year period of analysis (the “lowest cost model” for highways).

## 3.9. Proposed Methodology for Modeling the Airport Expansion Option

The situation for airport expansions is also quite complicated to attempt to model, given the total lack of cash-flow numbers from the Rail Authority. First, let us look at the Authority’s basic assertions about needed new airport capacity (Table 7).

Table 4. Summary of Projected Airport Capacity Needs

| Region | Airport | % of Regional Travel | Passengers per Year | Planes per Hour | Gates Needed | Runway Needed? |
|---|---|---|---|---|---|---|
| Los Angeles Basin | BUR | 48% | 10,194,450 | 28 | 20 | YES |
| | ONT | 35% | 7,281,750 | 20 | 14 | YES |
| | LGB | 17% | 3,640,875 | 10 | 7 | NO |
| | | | | | | |
| Bay Area | SJC | 42% | 10,194,450 | 28 | 20 | YES |
| | OAK | 58% | 13,835,325 | 38 | 27 | YES |
| | | | | | | |
| San Diego | SNA | 71% | 4,369,050 | 12 | 9 | NO |
| | SAN | 29% | 1,820,438 | 5 | 4 | NO |
| | | | | | | |
| Monterey | MRY | 100% | 2,548,613 | 7 | 5 | NO |
| | | | | | | |
| San Joaquin Valley | FAT | 51% | 1,456,350 | 4 | 3 | NO |
| | BFL | 49% | 1,456,350 | 4 | 3 | NO |
| | | | | | | |
| Sacramento | SMF | 100% | 1,456,350 | 4 | 3 | NO |
| **Total** | | | **58,254,000[5]** | **160** | **115** | **4** |

Table 7. Projected Airport Capacity Needs (California High-Speed Rail Authority, 2011c, p. 8)

In order to understand this table, we need a few points from the *COPEC* report. First, there is the statement (California High-Speed Rail Authority, 2011c, p. 7) by the Rail Authority that

> Although the Phase 1 system does not reach San Diego or Sacramento, its termini in Anaheim, Merced, and San Francisco still attract some of the passengers that would have flown out of the airports in the Sacramento and San Diego region. Additionally, John Wayne Airport (SNA) is included in the San Diego region even though its [*sic*] located in Santa Ana, just 13 miles from the site of the station in Anaheim. Much of the draw from the San Diego region is actually from SNA, not from San Diego International Airport (SAN). (p. 7)

Thus we understand why SMF, SAN, and SNA have been included in the Authority's Option 2 estimation. The Authority's numbers for increased air travel demand also were generated on the basis of the statement that "since many of these regions have multiple airports, the diverted traffic was assigned to airports based on the relative 2009 levels of intra-state air traffic at each airport as summarized by Cambridge Systematics and Aviation System Consulting" in their report, *Potential Airline Response to High-Speed Rail Service in California* (California High-Speed Rail Authority, 2011c, p. 8). However, what is meant here by "diverted traffic?"

As the *COPEC* report continues, the Rail Authority's analysis assumes that it is, in fact impossible to add capacity at either LAX or SFO, thus their shares of demanded air travel capacity were assigned to the other airports in the region, based on approximate relative shares of current travel. The report continues (California High-Speed Rail Authority, 2011c) that

> Both LAX and SFO have studied expansion possibilities and have found very limited options available to them. Expanding either airport would involve significant eminent domain takings in surrounding communities that are unrealistic in today's environment. The capacity requirements (and costs) are shifted to the other airports in the region. (p. 9)

Given the unrealistic nature of expanding LAX or SFO, we now understand the traffic diversion plan. Indeed, there is also the possibility of opening "new" airports in the Los Angeles area by converting abandoned military airbases into smaller civilian airports, perhaps at least for general aviation purposes, but this author has seen no substantive analysis of this idea, and thus it lies beyond the bounds of this paper (High-Speed Rail Boondoggle, 2012). In any case, between the

*COPEC* report and the Authority's 2005 Programmatic EIR/EIS report, the following assumptions were made about short-haul air travel and airport capacity (California High-Speed Rail Authority, 2011c):

- 70 seats per plane (based on average current plane size for intra-California trips)
- 75% load factor for air travel (based on current high load factors for Southwest Airlines)
- 19 hours of operation per day
- 40 maximum operations per runway per hour
- 525,000 passengers per year per gate
- 1,400 parking spaces per 1,000,000 passengers (p. 9)

Taking these factors together with an analysis of the costs of expanding airports around the state, the Authority came up with the following cost estimates table:

| Airport Code | Airport Name | Gates | Runways | Cost (2010 $) |
|---|---|---|---|---|
| BUR | Burbank-Bob Hope | 20 | 1 | $5,149,000,000 |
| ONT | Ontario Intl. | 14 | 1 | $8,105,000,000 |
| LGB | Long Beach Municipal | 7 | 0 | $344,000,000 |
| | | | | |
| SJC | Norman Y. Mineta San Jose Intl. | 20 | 1 | $9,164,000,000 |
| OAK | Metropolitan Oakland Intl. | 27 | 1 | $1,765,000,000 |
| | | | | |
| SNA | Santa Ana-John Wayne-Orange County | 9 | 0 | $3,321,000,000 |
| SAN | San Diego Intl. | 4 | 0 | $1,181,000,000 |
| | | | | |
| MRY | Monterey Peninsula | 5 | 0 | $267,000,000 |
| | | | | |
| FAT | Fresno Yosemite Intl. Air Terminal | 3 | 0 | $101,000,000 |
| BFL | Bakersfield-Meadows Field | 3 | 0 | $128,000,000 |
| | | | | |
| SMF | Sacramento Intl. | 3 | 0 | $205,000,000 |
| **Total** | | **115** | **4** | **$29,730,000,000** |

Table 8. Equivalent Capacity and Costs by Airport (California High-Speed Rail Authority, 2011c, p. 14)

So far, so good. But this still begs the question: given assertions that there remains some unused capacity (that is, without building new gates or runways) at some California airports, would all these improvements need to be built at once, starting in 2013? Or could there be some more phased implementation plan, such as with the HSR system itself, and with our 0/2/4 model for the highway system? If so, how could this be determined?

While the Rail Authority did not include any information whatsoever about which airports are more or less congested from the above list of 11, and which haves have more, less, or no additional capacity without expansion, we have devised a method by which to at least begin to address this question. *Forbes* magazine, in a June 3, 2008, article by Rebecca Ruiz entitled "America's Most Time-Draining Airports," combed through Federal Aviation Administration (FAA) and Bureau of Transportation Statistics (BTS) stats from 2007 for travel delays for the 100 largest U.S. airports (Ruiz, 2008). In this good article, delay statistics tables are compiled for easy analysis, allowing us to pair them up with the previous table in the following way.

| **Airport Code** | **Airport Name** | **Delay Ranking (#1 = least delayed, #100 = most delayed)** |
|---|---|---|
| SFO | San Francisco Intl. | #95 |
| LAX | Los Angeles Intl. | #86 |
| SAN | San Diego Intl. | #65 |
| OAK | Metropolitan Oakland Intl. | #45 |
| SMT | Sacramento Intl. | #44 |
| SNA | Santa Ana-John Wayne-Orange County | #38 |
| SJC | Norman Y. Mineta San Jose Intl. | #37 |
| ONT | Ontario Intl. | #21 |
| BUR | Burbank-Bob Hope | #16 |
| LGB | Long Beach Municipal | #6 |
| BFL | Bakersfield-Meadows Field | N/A |
| FAT | Fresno-Yosemite Intl. Air Terminal | N/A |
| MRY | Monterey Peninsula | N/A |

Table 9. Eleven California Airports Ranked by Flight Delays (Ruiz, 2008)

Using these figures as a proxy for capacity availability / unavailability, we can prioritize which airports to expand first, starting with the ones with the highest delay figures, and pairing these up with north-south pairings, in phased construction times. We can also simplify the Authority's six aviation regions for the 11 airports of interest into two major regions and one minor region: Northern California (MRY, OAK, SJC, and SMF), Southern California (BUR, LGB, ONT, SAN, and SNA), and Central California (BFL and FAT), respectively. Now, paired accordingly, we find a possible argument for phased airport construction as follows.

| Construction Phase | # of Gates | # of Runways | Airport Improvement Locations | Cost (2010 $) | % of Total Cost |
|---|---|---|---|---|---|
| Phase A | 27 | 1 | So. Cal. Airports (ONT, SAN, SNA) | $14,372,000,000 | 48.34% |
| *54 gates, 2 runways* | 27 | 1 | No. Cal. Airports (OAK) | | |
| Phase B | 20 | 1 | So. Cal. Airports (BUR) | $14,313,000,000 | 48.14% |
| *40 gates, 2 runways* | 20 | 1 | No. Cal. Airports (SJC) | | |
| Phase C | 7 | 0 | So. Cal. Airports (LGB) | $1,045,000,000 | 3.51% |
| *21 gates, 0 runways* | 8 | 0 | No. Cal. Airports (MRY, SMF) | | |
| | 6 | 0 | Central Cal. Airports (BFL, FAT) | | |
| **Totals** | **115** | **4** | | **$29,730,000,000** | **100.00%** |

Table 10. Phases for California Airport Improvements, Based on Delay Data and Region Pairings

Although we are admittedly straining at the limits of what can be reasonably inferred from the incomplete data from the Rail Authority's reports, and due to the author's limited knowledge of what kind of time factors would reasonably be involved in realizing such airport improvements, this at least gives us a fighting chance to phase the improvements into three separate, seven-year sections of the 21-year construction timeline (2013-2033) for HSR, highways, and now, airports. Unfortunately, our proposed schedule front-loads the timing (rather than splitting it quite evenly among all three Phases), which may be an incorrect decision on our part, but as we are guided in prioritization by the delay figures in this regard, and did not want to split improvements within a single airport among more than one Phase, we are left with the device of dividing each Phase's total cost up into seven equal amounts and then accounting for inflation. Doing so (in pre-inflation, 2010 $) yields annual capital construction costs in Phase A of $2,053,142,857, as well as $2,044,714,286 in Phase B, and $149,285,714 in Phase C. And as this completes our discussion of our methodology for basic NPV analysis, we are now ready to go into the results our NPV analyses and add in some sensitivity analysis.

# 4. Findings

### 4.1. Results of NPV Analysis for Capital Construction Cost Options 1 and 2

First, let us look at the results of NPV analysis of Option 1, the HSR project. These results have been summarized in the following table, including three different discount rates for each option: 4% medium (the preferred rate for our analysis), 2% low (based on a theory of low social discount rate, where the widespread public benefits of mass transit to society justify a lower rate), and 11% high (based on a theory of high social discount rate, where the scarcity of public capital today, due to the recession and state and federal budget cuts, means that other competing priorities, such as schools, hospitals, social programs, etc., lead to competition for scarce public spending dollars, driving discount rates potentially higher). We will see that varying the discount rate changes the magnitude of cost savings or losses, but not the order in which the results appear.

| Results of NPV Studies with Sensitivity Analysis | | | | | | |
|---|---|---|---|---|---|---|
| Option 1: California High-Speed Rail, Phase One | | | | | | |
| Project NPV ($B) | Project Length (Years) | Real Discount Rate | Real Inflation Rate | IOS-S or IOS-N First? | High or Low Cost Scenario? | Comments |
| (39.78) | 21 | 4.00% | 3.00% | IOS-S | Low | |
| (50.57) | 21 | 2.00% | 3.00% | IOS-S | Low | |
| (19.28) | 21 | 11.00% | 3.00% | IOS-S | Low | |
| **(39.51)** | **21** | **4.00%** | **3.00%** | **IOS-N** | **Low** | **Least @ 4%** |
| (50.40) | 21 | 2.00% | 3.00% | IOS-N | Low | Least @ 2% |
| (18.92) | 21 | 11.00% | 3.00% | IOS-N | Low | Least @ 11% |
| **(47.69)** | **21** | **4.00%** | **3.00%** | **IOS-S** | **High** | **Most @ 4%** |
| (60.53) | 21 | 2.00% | 3.00% | IOS-S | High | Most @ 2% |
| (23.28) | 21 | 11.00% | 3.00% | IOS-S | High | Most @ 11% |
| (47.42) | 21 | 4.00% | 3.00% | IOS-N | High | |
| (60.37) | 21 | 2.00% | 3.00% | IOS-N | High | |
| (22.91) | 21 | 11.00% | 3.00% | IOS-N | High | |

Table 11. All California HSR Capital Construction Cost NPVs

Thus, building IOS-N first, under the low-cost scenario, is slightly cheaper in NPV terms than building IOS-S first, though the difference in minimal. Similarly, under the high-cost scenario, building IOS-S first is slightly more expensive than building IOS-N first, though only with a small difference. Now let us look at the airport and highway capital construction cost NPVs.

| Results of NPV Studies with Sensitivity Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| Option 2: California Airports and Highways Alternatives | | | | | | | |
| Project NPV ($B) | Project Length (Years) | Real Discount Rate | Real Inflation Rate | Total # Highway Lanes | Highway Phased Constr? | Airports Phased Constr? | Comments |
| **(58.49)** | **27** | **4.00%** | **3.00%** | **3** | **N** | **N** | **Fr. 2012 DBP** |
| (77.11) | 27 | 2.00% | 3.00% | 3 | N | N | |
| (26.88) | 27 | 11.00% | 3.00% | 3 | N | N | |
| **(43.65)** | **27** | **4.00%** | **3.00%** | **2** | **N** | **N** | **Least @ 4%** |
| (57.54) | 27 | 2.00% | 3.00% | 2 | N | N | Least @ 2% |
| (20.06) | 27 | 11.00% | 3.00% | 2 | N | N | Least @ 11% |
| (72.09) | 27 | 4.00% | 3.00% | 4 | N | N | |
| (95.04) | 27 | 2.00% | 3.00% | 4 | N | N | |
| (33.13) | 27 | 11.00% | 3.00% | 4 | N | N | |
| (100.54) | 27 | 4.00% | 3.00% | 6 | N | N | |
| (132.54) | 27 | 2.00% | 3.00% | 6 | N | N | |
| (46.20) | 27 | 11.00% | 3.00% | 6 | N | N | |
| (48.21) | 21 | 4.00% | 3.00% | 2 | N | N | |
| (60.77) | 21 | 2.00% | 3.00% | 2 | N | N | |
| (24.36) | 21 | 11.00% | 3.00% | 2 | N | N | |
| (79.63) | 21 | 4.00% | 3.00% | 4 | N | N | |
| (100.38) | 21 | 2.00% | 3.00% | 4 | N | N | |
| (40.24) | 21 | 11.00% | 3.00% | 4 | N | N | |
| **(111.05)** | **21** | **4.00%** | **3.00%** | **6** | **N** | **N** | **Most @ 4%** |
| (139.99) | 21 | 2.00% | 3.00% | 6 | N | N | Most @ 2% |
| (56.11) | 21 | 11.00% | 3.00% | 6 | N | N | Most @ 11% |
| **(111.05)** | **21** | **4.00%** | **3.00%** | **2/4/6** | **Y** | **N** | **Most @ 4%** |
| (139.99) | 21 | 2.00% | 3.00% | 2/4/6 | Y | N | Most @ 2% |
| (56.11) | 21 | 11.00% | 3.00% | 2/4/6 | Y | N | Most @ 11% |
| (70.72) | 21 | 4.00% | 3.00% | 0/2/4 | Y | N | |
| (94.78) | 21 | 2.00% | 3.00% | 0/2/4 | Y | N | |
| (28.32) | 21 | 11.00% | 3.00% | 0/2/4 | Y | N | |
| **(72.69)** | **21** | **4.00%** | **3.00%** | **0/2/4** | **Y** | **Y** | **Best Est. # ?** |
| (96.09) | 21 | 2.00% | 3.00% | 0/2/4 | Y | Y | |
| (30.59) | 21 | 11.00% | 3.00% | 0/2/4 | Y | Y | |

Table 12. All California Airport and Highway Capital Construction Cost NPVs

This table shows us that the original, *2012 Draft Business Plan* figures (based on 27-year construction periods, and including the expansion of the three highway lanes total) is still significantly more expensive than the HSR options. However, since we prefer to compare only 21-year projects to each other, let us now use the following, more simplified table:

| Results of NPV Studies with Sensitivity Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Option 2: California Airports and Highways Alternatives** | | | | | | | |
| Project NPV ($B) | Project Length (Years) | Real Discount Rate | Real Inflation Rate | Total # Highway Lanes | Highway Phased Constr? | Airports Phased Constr? | Comments |
| **(48.21)** | **21** | **4.00%** | **3.00%** | **2** | **N** | **N** | **Least @ 4%** |
| (60.77) | 21 | 2.00% | 3.00% | 2 | N | N | Least @ 2% |
| (24.36) | 21 | 11.00% | 3.00% | 2 | N | N | Least @ 11% |
| (79.63) | 21 | 4.00% | 3.00% | 4 | N | N | |
| (100.38) | 21 | 2.00% | 3.00% | 4 | N | N | |
| (40.24) | 21 | 11.00% | 3.00% | 4 | N | N | |
| **(111.05)** | **21** | **4.00%** | **3.00%** | **6** | **N** | **N** | **Most @ 4%** |
| (139.99) | 21 | 2.00% | 3.00% | 6 | N | N | Most @ 2% |
| (56.11) | 21 | 11.00% | 3.00% | 6 | N | N | Most @ 11% |
| **(111.05)** | **21** | **4.00%** | **3.00%** | **2/4/6** | **Y** | **N** | **Most @ 4%** |
| (139.99) | 21 | 2.00% | 3.00% | 2/4/6 | Y | N | Most @ 2% |
| (56.11) | 21 | 11.00% | 3.00% | 2/4/6 | Y | N | Most @ 11% |
| (70.72) | 21 | 4.00% | 3.00% | 0/2/4 | Y | N | |
| (94.78) | 21 | 2.00% | 3.00% | 0/2/4 | Y | N | |
| (28.32) | 21 | 11.00% | 3.00% | 0/2/4 | Y | N | |
| **(72.69)** | **21** | **4.00%** | **3.00%** | **0/2/4** | **Y** | **Y** | **Best Est. # ?** |
| (96.09) | 21 | 2.00% | 3.00% | 0/2/4 | Y | Y | |
| (30.59) | 21 | 11.00% | 3.00% | 0/2/4 | Y | Y | |

Table 13. All 21-Year Project NVPs for California Airport and Highway Capital Construction Costs

Again, we see that varying the discount rates does not change the order of the results (in terms of which is the most or least expensive alternative), only the relative savings or losses. The 2-lane project (now based on a 21-year construction schedule) continues to be the least expensive air / highway option, though it is still much more expensive than the low-cost HSR options, and just slightly more expensive than the high-cost HSR options. However, the 2-lane highway option does not seem to this author to be the most realistic option. Rather, in terms of highways, the 0/2/4 option, despite being more expensive, still seems like a more realistic approach to what might actually occur in California. Similarly, the phased-in airport construction, though slightly more expensive than the un-phased airport expansion approach, still seems like a bit more realistic approach than the option without phasing. To simplify matters further, let us look at the results for both Option 1 and Option 2 with only the 4% real discount rate:

| Results of NPV Studies with Sensitivity Analysis | | | | | | |
|---|---|---|---|---|---|---|
| Option 1: California High-Speed Rail, Phase One | | | | | | |
| Project NPV ($B) | Project Length (Years) | Real Discount Rate | Real Inflation Rate | IOS-S or IOS-N First? | High or Low Cost Scenario? | Comments |
| (39.78) | 21 | 4.00% | 3.00% | IOS-S | Low | |
| **(39.51)** | **21** | **4.00%** | **3.00%** | **IOS-N** | **Low** | **Least @ 4%** |
| **(47.69)** | **21** | **4.00%** | **3.00%** | **IOS-S** | **High** | **Most @ 4%** |
| (47.42) | 21 | 4.00% | 3.00% | IOS-N | High | |

Table 14. California HSR Capital Construction Cost NPVs at 4% Real Discount Rate (RDR)

| Results of NPV Studies with Sensitivity Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| Option 2: California Airports and Highways Alternatives | | | | | | | |
| Project NPV ($B) | Project Length (Years) | Real Discount Rate | Real Inflation Rate | Total # Highway Lanes | Highway Phased Constr? | Airports Phased Constr? | Comments |
| **(48.21)** | **21** | **4.00%** | **3.00%** | **2** | **N** | **N** | **Least @ 4%** |
| (79.63) | 21 | 4.00% | 3.00% | 4 | N | N | |
| **(111.05)** | **21** | **4.00%** | **3.00%** | **6** | **N** | **N** | **Most @ 4%** |
| **(111.05)** | **21** | **4.00%** | **3.00%** | **2/4/6** | **Y** | **N** | **Most @ 4%** |
| (70.72) | 21 | 4.00% | 3.00% | 0/2/4 | Y | N | |
| **(72.69)** | **21** | **4.00%** | **3.00%** | **0/2/4** | **Y** | **Y** | **Best Est. # ?** |

Table 15. California Airport and Highway Expansion Capital Construction Cost NPVs at 4% RDR

Once again, we note that, though the lowest cost airports and highway option, 2 lanes, comes very close in cost to the highest cost HSR option, this does not seem like the most likely comparison to make based on our previously stated assumptions. Rather, the best comparison of capital construction costs, in the final analysis, seems to this author to be to take the HSR high-cost, IOS-S first option (NPV of -$47.69 billion) and the 0/2/4 airports and highways option with phased airport construction (NPV of -$72.69 billion) and compare, yielding $25 billion in relative savings by constructing the HSR option instead of the airports and highways option.

These comparative results can be more readily appreciated using the following two tables (note that, in the first one, the NPV's are given as positive numbers (where they actually should be negative numbers) for the sake of simplicity of displaying the costs in bar chart form).

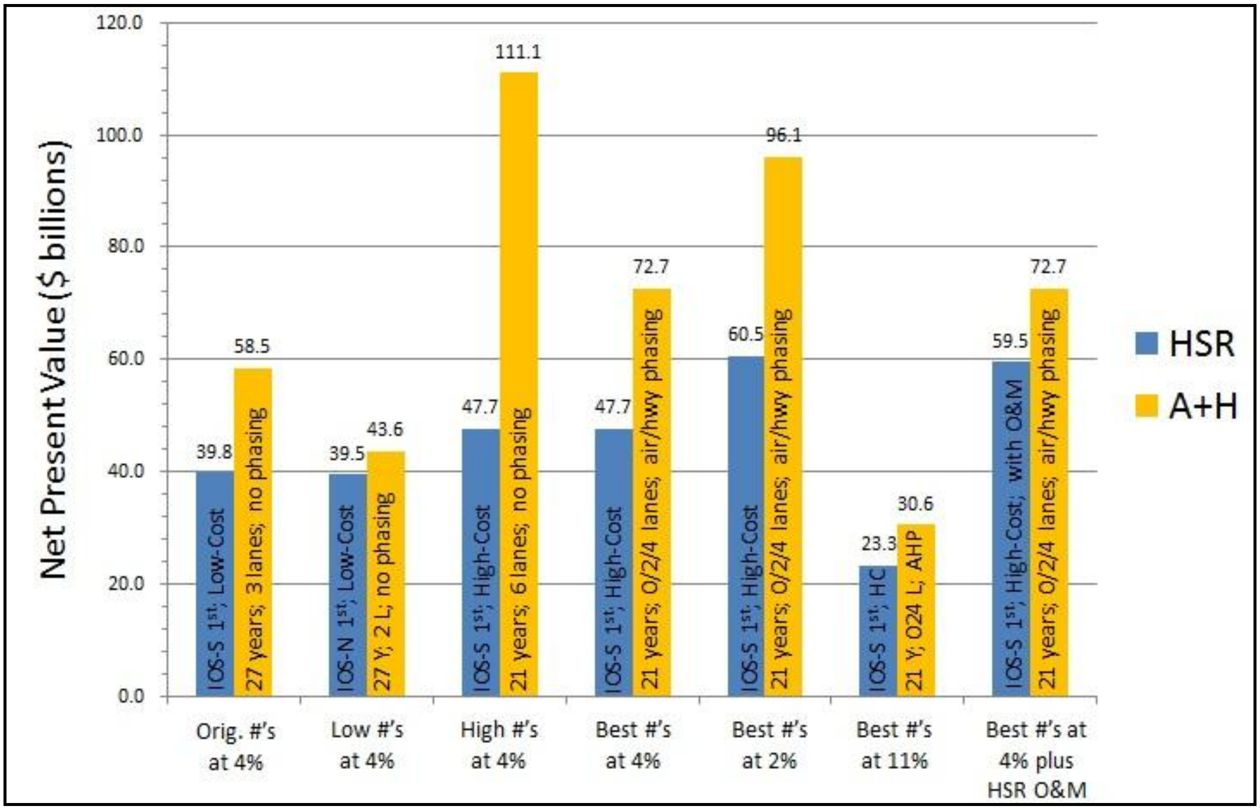



Figure 14. Key Results of Analysis of Options 1 and 2, With Selected Sensitivity Analysis

| Transportation Alternative | Added Capacity | Investment: Orig. NPV (based on 2010 $B) | Investment: Low NPV (based on 2010 $B) | Investment: High NPV (based on 2010 $B) | Investment: Best NPV (based on 2010 $B) |
|---|---|---|---|---|---|
| High-Speed Rail | Full Phase 1 | (39.78) | (39.51) | (47.69) | (47.69) |
| | San Francisco-Los Angeles/Anaheim | *IOS-S First* | *IOS-N First* | *IOS-S First* | *as a proxy for missing* |
| | 520 miles | | | | *local infrastructure* |
| Highways and Airports | 1,000's of new lane-miles of highway | (58.49) | (43.65) | (111.05) | (72.69) |
| | 115 new airport gates | *3 hwy lanes only* | *2 hwy lanes only* | *2/4/6 hwy lanes* | *0/2/4 hwy lanes* |
| | 4 new runways | *no hwy/air phases* | *no hwy/air phases* | *no airport phases* | *hwy/air both phased* |
| | **Proposed cost savings ($)** | **18.71** | **4.13** | **63.37** | **25.00** |
| | **Proposed cost savings (%)** | **47%** | **10%** | **133%** | **52%** |

Table 16. Final Results of NPV Analysis of Comparative Capital Construction Costs

Here we see that the highest number for HSR (NPV of -$47.69 billion for high-cost scenario) is greater than the lowest number for airports and highways (NPV of -$43.65 billion for only 2 highway lanes and no airport phasing for construction). But as this seems an unlikely, if not unrealistic, comparison, the best comparison of capital costs continues to be the one on the far right of Table 16, with the $25 billion in savings.

### 4.2. Additional Sensitivity Analysis: Operations and Maintenance Costs: Methodology

Normally, when evaluating the cost side (cash out) of a project, one uses total costs, not just capital construction costs. That has been made very difficult in this case, since the Rail Authority did not provide full Operations and Maintenance (O&M) cost data for any of the HSR options. And they provided no O&M data whatsoever for the airport and highway expansion options. But this does bring us to an interesting point to consider, before we press on with a bit more sensitivity analysis of the previous results.

In evaluating comparative capital construction costs, we are looking at what the Rail Authority calls "capacity." In other words, the capacity to move people hundreds of miles along high-speed rail networks, or highways, or air networks. However, economists who perform project analysis with net present values tend to prefer a focus on "outputs," to make sure of an "apples to apples" comparison. In other words, if Factory A produces 100 steel widgets, and Factory B produces 100 iron widgets intended for the same type of application, then we probably have equivalent "output" for some comparative analysis. But if Factory B instead produces one gigantic iron widget with a total weight equivalent to all 100 steel widgets made by Factory A, this is likely to be an "apples to oranges" comparison. Or if Factory B instead produces 1,000 automobiles, that is most definitely an "apples to oranges" comparison.

In the context of our own analysis, upon closer inspection, the output from Option 1 is actually not just a capacity to move 116 million people per year by the end of Phase One, it is also an output of 520 miles of track, a great many train sets, the catenary and signaling systems, the new train stations, the viaducts and tunnels and so on. However, the output of the airports and highways is only the highways themselves and the added gates and runways themselves – not the cars, trucks, and buses that ride on those highways and the airplanes that fly in and out of those airports. And these vehicles are obviously essential for generating the capacity to transport the 116 million people per year we just mentioned. (Extensive criticism has been leveled at the Rail Authority for significant over-capacity versus projected increased intra-state travel demand in 2030 and 2040 – but it is also important to bear in mind that the HSR system is designed to last for 100 years, and to continue to be able to handle California's transportation needs in 2050, 2060, and so on. So an extensive look at ridership estimates and travel demands across the next 100 years will have to remain be beyond the limits of this Masters Project, though further investigation along these lines by future researchers would be highly recommended.) However, this author does not have the data necessary to estimate the O&M costs for countless airplanes, cars, trucks, etc. to make a true "total cost" NPV analysis that would include O&M. Indeed, even if the author had such data and the time to work with it, this is a methodologically enormously complex problem. For example, how much of the O&M cost for a car should be allocated to such an NPV analysis? HSR rolling stock will only travel along the Phase One corridor and nowhere else. But a car might traverse I-5 between San Francisco and Los Angeles one day, then travel to Las Vegas, Nevada the next day, then take local trips around Nevada, and so on. The allocation problem would be quite thorny.

Where, then, does that leave us on this question? There is one possible approach for us to investigate here as one last piece of sensitivity analysis coupled with the capital construction costs. The following is the approach that this author has devised. In their October 2011 document, *Estimating High-Speed Train Operating and Maintenance Cost for the CA HSRA 2012 Business Plan*, the Rail Authority gives annual O&M figures for 24 different scenarios from 2020 to 2030 (California High-Speed Rail Authority, 2011e). However, the Authority does not give annual O&M figures beyond that. It only gives O&M figures once every five years, up to 2060. What would be best would be annual figures all the way out to 2080, the end date for the overall NPV project analysis given in the *BCA*, which includes estimated revenues and benefits as well (i.e. a full cash-in and cash-out result, just without any supporting data to back it up). However, this author has made no effort to vet the *BCA's* NPV estimates, as the question of benefits and revenues quickly becomes so large and thorny that, in the absence of any cash-flow data whatsoever on these points from the Rail Authority, evaluation or reproduction of such estimations seems quite difficult if not impossible.

Returning to the *Estimating HST O&M Cost* report, the 24 scenarios listed on pages 13 through 20 correspond to a variety of low capital construction cost versus high capital construction cost estimations, constrained (Phase One unable to be completed by 2033) versus unconstrained (Phase One to be completed by 2033) capital construction scenarios, and three ridership scenarios each (high, medium, and low) for the corresponding O&M costs. To attempt to calculate at least one "total cost" or "full cost" NPV for the HSR system, including both capital and O&M costs, the author has selected “Scenario 22,” the high ridership (and thus both high revenue and high O&M costs) scenario, under the IOS-S first, low capital construction costs, unconstrained capital construction schedule. This allows us to continue to make our comparisons on the basis of the 21-year construction schedule (2013-33), which would be more difficult with the O&M data corresponding to high capital construction costs and/or constrained capital construction schedules, as those scenarios often show completion of HSR Phase One later than 2033 (i.e. full Phase One revenue service starting later than 2034). The data for this aspect of the O&M analysis has been pulled from two tables in the *Estimating HST O&M Cost* report and a supporting table in the *2012 Draft Business Plan*.

**IOS SOUTH - UNCONSTRAINED CONSTRUCTION SCHEDULE - LOW CONSTRUCTION COSTS**
**HIGH, MEDIUM, AND LOW RIDERSHIP, REVENUE, AND OPERATING AND MAINTENANCE COSTS**
**SCENARIOS 22, 23, AND 24**

**SERVICE PARAMETERS**

| | Route Miles | Revenue Service Start | HST Trainset Miles (in millions per year) | | | Dedicated Coach Hours (in millions per year) | | |
|---|---|---|---|---|---|---|---|---|
| | | | High | Medium | Low | High | Medium | Low |
| IOS South | 300 | 2021 | 10.5 | 9.0 | 7.3 | 1.1 | 0.9 | 0.7 |
| Bay to Basin | 450 | 2026 | 21.8 | 18.1 | 14.8 | 0.3 | 0.2 | 0.2 |
| Phase 1 | 540 | 2034 | 36.9 | 31.1 | 25.6 | 0.3 | 0.2 | 0.2 |

Note: HSR Trainset Miles and Dedicated Coach Hours are for Year 2040

Table 17. O&M Scenarios Overview for Analysis (California High-Speed Rail Authority, 2011e, p. 20)

**HIGH RIDERSHIP, REVENUE, AND O&M COSTS - Scenario 22**

| | | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ridership** | **(in millions)** | - | 5.2 | 7.0 | 8.9 | 10.7 | 12.7 | 16.4 | 17.9 | 19.5 | 21.1 | 22.7 | 34.0 | 43.9 | 45.0 | 46.2 | 47.4 | 48.5 |
| **Revenue** | **(in 2010 $$)** | - | 369 | 497 | 627 | 759 | 894 | 1,199 | 1,311 | 1,425 | 1,541 | 1,660 | 2,101 | 2,712 | 2,780 | 2,851 | 2,923 | 2,996 |
| **Revenue** | **(in YoE $$)** | - | 511 | 708 | 920 | 1,148 | 1,393 | 1,924 | 2,167 | 2,426 | 2,703 | 2,998 | 4,400 | 6,583 | 7,824 | 9,299 | 11,052 | 13,136 |
| **O&M Costs** | **(in 2010 $$)** | 150 | 243 | 290 | 347 | 389 | 436 | 562 | 613 | 655 | 678 | 750 | 967 | 1,196 | 1,240 | 1,263 | 1,259 | 1,271 |
| Ops. and Maint. Of Equipment | | - | 125 | 164 | 210 | 245 | 284 | 327 | 365 | 395 | 409 | 461 | 623 | 785 | 804 | 828 | 857 | 876 |
| Maint. Of Infrastructure | | - | 30 | 30 | 30 | 30 | 30 | 45 | 46 | 48 | 51 | 54 | 93 | 119 | 136 | 131 | 100 | 90 |
| Stations | | - | 21 | 21 | 21 | 21 | 21 | 34 | 34 | 34 | 34 | 34 | 59 | 59 | 59 | 59 | 59 | 59 |
| Insurance | | - | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| General and Administration | | - | 20 | 24 | 29 | 32 | 36 | 43 | 47 | 50 | 52 | 57 | 80 | 99 | 103 | 104 | 104 | 105 |
| Contingency | | - | 22 | 26 | 32 | 35 | 40 | 47 | 52 | 55 | 57 | 63 | 88 | 109 | 113 | 115 | 114 | 116 |
| Caltrain Fare Reimbursement | | - | - | - | - | - | - | 40 | 44 | 47 | 51 | 55 | - | - | - | - | - | - |
| Start-up Training | | 150 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **O&M Costs** | **(in YoE $$)** | 202 | 337 | 414 | 509 | 589 | 679 | 901 | 1,012 | 1,115 | 1,190 | 1,354 | 2,026 | 2,903 | 3,490 | 4,119 | 4,763 | 5,570 |

Table 18. O&M Scenario 22 for our NPV Analysis (California High-Speed Rail Authority, 2011e, p. 20)

**Exhibit 7-2. Cost categories and unit cost assumptions (2009$)**

| Category of Cost | Unit Cost | Basis |
|---|---|---|
| Train operations and maintenance | $20 per trainset mile, plus $83.33 per revenue service hour for feeder coach service | Operating crew costs from comparable U.S. operations and labor practices, electricity cost from power demand simulations and California large user rates with green surcharge, and train maintenance cost from French HSR experience. Feeder service cost based on review of similar systems in California and elsewhere in the U.S. |
| Maintenance of infrastructure | $200,000 per route mile | French HSR experience adapted to California requirements and benchmarked against other HSR systems |
| Stations | $4,100,000 per station per year | U.S. staffing for high-volume, access-controlled stations and reserved seating ticketing practices |
| Administration and support | 10% of O&M costs excluding contingency | Standard industry allowance to cover management, accounting, sales, marketing, and control center |
| Insurance | $25,000,000 per year | Review of insurance costs for rail passenger service in the U.S. |
| Contingency | 10% of total O&M costs | Contingency applied to account for unknowns |
| Inflation | 3% per year, price base date of 2010 | Long-term year-over-year percentage increase for the Consumer Price Index in the region |

Table 19. Explanations of O&M Cost Categories (California High-Speed Rail Authority, 2011n, p. 7-3)

This is a fairly good start for our O&M analysis. And when examining the O&M figures more closely, we see that they tend to level off on an annual basis after Phase One is completed in 2033 and ridership finishes “ramping up” across a few years by about 2040. This can be more easily illustrated in the following figure.

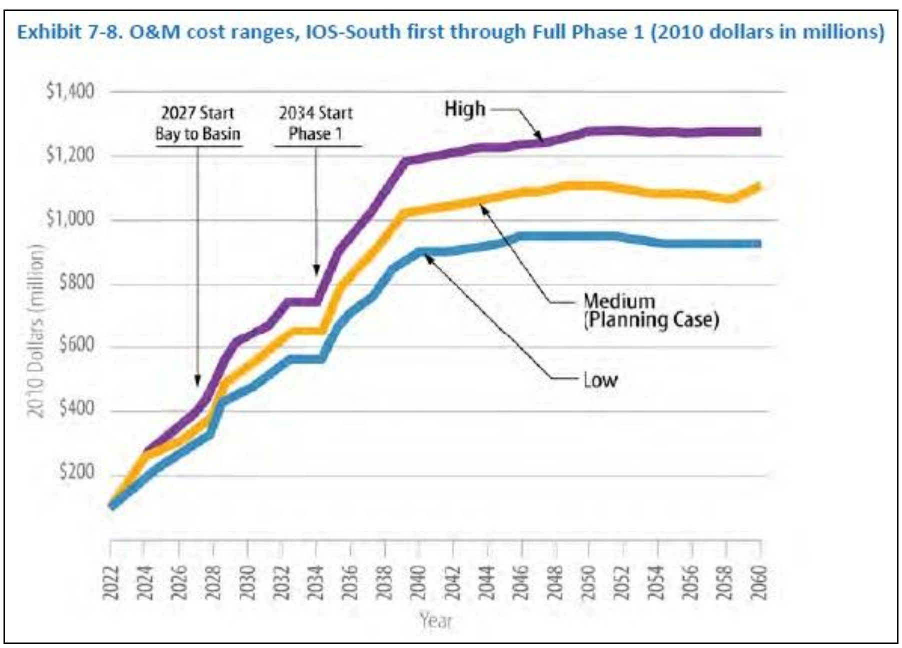



Figure 15. O&M Cost Ranges, IOS-S 1st, Low Capital Costs (California High-Speed Rail Authority, 2011n, p. 7-6)

Taking Tables 17 and 18 together, we fill in the missing O&M data for 2031-2034, 2036-2039, 2041-2044, 2046-2049, 2051-2054, and 2056-2059 by creating linear interpolations between each five-year increment. Though there is no guarantee, of course, that the O&M costs in these missing years behave in a linear fashion, when looking at Figure 15 above, this seems to be as reasonable an alternative to obtain an approximation of the missing data as can be devised. Thus we now have something we can work with for the basic component of the O&M NPV analysis.

However, when examining Chapter 7, "Operating and Maintenance Costs," of the *2012 Draft Business Plan*, more closely, we see that a full and complete look at O&M includes two parts: O&M per se (captured in the above table), and Capital Asset Renewal (CAR), which is not included in the O&M figures above (California High-Speed Rail Authority, 2011n, p. 7-6). Essentially, HSR system assets placed in service (the trains, rail infrastructure, stations, and systems) wear out at varying times and must then be renewed or replaced (Table 20).

**Exhibit 7-9. Component design life—track structures and systems**

| Component | Years |
|---|---|
| Civil structures | 100 |
| Track system | 30–60 |
| Facilities/yards/sidings | 30–60 |
| Signal/communication system | 15 |
| Traction power system | 30 |
| Catenary system | 30 |
| Stations | 50 |

Table 20. HSR System Component Design Life (California High-Speed Rail Authority, 2011n, p. 7-6)

On a section-by-section basis of the HSR project, the Rail Authority developed incremental capital asset renewal cost estimates to replace things beyond minor components (which are included in the basic O&M data). This is calculated based on when the asset it placed into service, its useful life, and the extent to which that asset is used or consumed in the course of train operations. Incremental annual capital asset renewal activities begin for some HSR system components in each section after about the first five years of operations of that section of the HSR system. Thus we have pulled CAR data in five-year increments (the only CAR data available to us) from the following table.

Exhibit 7-12. Trainset replacement assumptions for IOS-North or IOS-South (2010 dollars in millions)

| Segment | Opening | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 |
|---|---|---|---|---|---|---|---|---|---|
| IOS-N | 2022 | $2.8 | $38.3 | $48.5 | $48.5 | $42.0 | $15.8 | $14.0 | $14.0 |
| Bay to Basin | 2027 | — | — | $68.3 | $74.3 | $74.3 | $74.3 | $18.7 | $15.8 |
| Phase 1 | 2034 | — | — | — | $71.9 | $72.6 | $72.6 | $72.6 | $8.5 |
| Total | | $2.8 | 38.3 | $116.8 | $194.7 | $188.9 | $162.7 | $105.4 | $38.3 |

Table 21. HSR Capital Asset Renewal Estimates (California High-Speed Rail Authority, 2011n, p. 7-7)

By combining the CAR data from this table with the aforementioned basic O&M data, we now have the ability to calculate a "total cost" NPV for a HSR system scenario. Rather than go through all 24 scenarios given in the *Estimates of HST O&M Costs* report, we have chosen one scenario to execute some sensitivity analysis on this point as follows.

### 4.3. Additional Sensitivity Analysis: Operations and Maintenance Costs: NPV Results

We will now calculate a "total cost" NPV for the HSR system on the basis of the following assumptions. First, the HSR capital construction project will be completed by 2033, the "unconstrained construction schedule" variant. Second, the HSR capital construction project will feature the IOS-South alignment first. Third, the HSR capital construction project will be the "low cost" variant (the one preferred by the Rail Authority, though we may later supplement our analysis with the "high cost" variant as well). Fourth, to be a bit conservative on O&M costs by pushing the basic O&M costs as high as they can go in terms of ridership projections, we choose the high ridership/revenue/O&M cost variant (instead of the medium or low ones): 36.9 million riders of the HSR system by 2034, the first full year of revenue service for the entire Phase One corridor. Fifth, we stick with our basic 4% real discount rate. Sixth, we conduct the NPV analysis from 2010-2060, a 51-year period of analysis, since 2060 is the last year for which any O&M and CAR cash-flow data (even in five-year increments) is available. And here are our results.

| HSR Project Evaluation Option | NPV Results ($B) |
|---|---|
| Capital Cost-Only NPV (without O&M or CAR) | ($39.78) |
| Total Cost NPV (with O&M and CAR) | ($51.55) |
| Project Cost NPV Increase | ($11.77) |

Table 22. HSR Project NPV Cost Comparisons for Capital Cost-Only versus "Total Cost"

Unsurprisingly, including O&M and CAR in our total project cost NPV does increase that cost significantly, by almost $12 billion in NPV terms. However, when compared with the preferred means (the 0/2/4 highways option and phased airports option) of NPV analysis of capital costs *only* for California's Option 2, the expanded airports and highways, the HSR total cost is still lower than the airports and highways capital cost:

| Project Evaluation Option | NPV Results ($B) |
|---|---|
| HSR Total Cost NPV (with O&M and CAR) | ($51.55) |
| Airports & Highways Capital Cost NPV (without O&M or CAR) | ($72.69) |
| Project Cost NPV Savings | $21.14 |

Table 23. HSR and Airports/Highways Project Options: Additional NPV Comparisons

Thus, the HSR project's total cost still appears significantly more attractive (to the tune of $21 billion) than the airports and highways project based on capital construction costs alone. (And even if we adjust this for the HSR high-cost variant, part of our aforementioned "best" model for HSR, the total cost including O&M is just under $60 billion, and thus still between $12 and $13 billion less than the BAU scenario (Figure 14, far right columns).) And this is a very interesting conclusion, since the capital construction cost for the HSR system includes acquiring the rolling stock that will fly down the railroads at up to 220 mph, while the capital construction cost for the airports and highways obviously does *not* include purchasing countless airplanes, cars, trucks, buses, etc. – which would actually be purchased by numerous airlines, shipping companies, private citizens, and so on. But it still would be interesting to know what would happen if we put a single item of "cash in" on the capital side for the HSR system. Namely, what would happen if we took the Rail Authority's *BCA* report's 2080 liquidation number (a.k.a.

"residual value") for the HSR system assets (which is given by the Rail Authority as $19.4 billion in 2010 $), moved it to 2060 instead (adjusting for inflation, of course, but not otherwise manipulating the figure – this is not entirely justified by the facts, as a different amount of depreciation should be in effect in 2060 than in 2080, and different real estate value projections as well, but as we have no data to do such a manipulation, we go with the number we have from *BCA*), based on the low capital construction cost scenario (California High-Speed Rail Authority, 2011a, p. 26)? The following results occur:

| **Project Evaluation Option** | **NPV Results ($B)** |
|---|---|
| HSR Total Cost NPV (with O&M and CAR but no residual values) | ($51.55) |
| HSR Total Cost NPV (with O&M, CAR, and residual values) | ($48.82) |
| Change in HSR Project Total Cost NPV | $2.73 |

Table 24. HSR Total Cost NPVs with and without Possible Liquidation Values

While it is interesting to see how the HSR project appears to become even more affordable (by almost $3 billion) in NPV terms by factoring in liquidation values for the HSR land, rolling stock and so on, we should not assign too much weight to this result. This is due to the fact that we again risk confusing "output" comparisons in terms of "apples to apples." In other words, we have not calculated any liquidation values for all the airplanes, airport terminals, airport land, cars, trucks, highway land, and so on – or even for just the new highway lanes, airport gates, and airport runways. So it appears to this author safer to focus on cost comparisons for the purposes of this masters project that do not include any cash-in items, even for liquidation values.

# 5. Implications and Conclusion

### 5.1. Recommendations for California

Based on this author's methodology and research results, his recommendations for the state of California are as follows. Based on the data in hand, and the NPV analyses completed herein, we assert that the California High-Speed Rail system *should* be built. There are several problems with this analysis, to be sure – but if a decision had to be made today (and in Sacramento, there is exactly that sort of pressure currently to decide whether or not to release funds for the ICS to begin in 2012 or 2013), the HSR system looks like a good alternative to solely expanding airports and highways, and one that will have a substantially lower NPV for capital construction costs, and probably a substantially lower NPV even when O&M and Capital Asset Renewal costs are included as well. The capacity delivered by HSR in 2040 is likely to be more than is actually needed by California at that time, and perhaps by a large margin. But population growth predictions may yet go back up as the economy recovers; the HSR system is being built to last for 100 years, so potentially to the early-to-mid 22$^{nd}$ century; and diversion of traffic to HSR from air and highways may, in fact, become far greater than has been forecast when "peak oil" starts to hit in the coming decades (for there is only a finite supply of petroleum on this planet versus our exponentially growing population in the USA and around the world). Environmental, economic, and congestion relief benefits (among others) will likely be far greater for HSR than the air and highways alternative, based on extensive previous international experience – though the American (and particularly the Californian) "love affair" with the automobile may be something of a countervailing pressure in that equation.

### 5.2. Problems, Next Steps, and Suggested Further Research

The problems that should be solved by subsequent researchers on this topic are manifold. First, full cash-flow data for all major scenarios and permutations thereof is essential to give better, more complete results. Also, more granular cash-flow data would be helpful, such as to break it out by rolling stock, tracks, catenary system, etc. – this would also allow for more sophisticated sensitivity analysis. Full cash-flow data for the "high-cost" HSR scenarios would be extremely helpful, as would full cash-flow data for airport and highway expansions. Data about the potential availability of closed military airports in southern California to be reopened as civilian airports (either for general aviation or for passenger service) could be helpful as well. Data about the revenues from and benefits of highways and airports should also be obtained. A more thorough study of what CalTrans thinks about the need for and scheduling of expanded airports and highways would also be of great use. It is believed that much of this data may already lie (at least in some form) in the hands of the Rail Authority and its chosen contractors. All of that data should be released to researchers and the public immediately, for the sake of transparency and accountability of public funds and projects. Of course, politics is ever a force in major transportation projects, and thus, barring new and more extensive legal requirements for data releases and reporting, little hope is held out that the Rail Authority will do this.

In addition, further research on the possibilities of restructuring the Rail Authority (such as making it part of CalTrans, as is one of the suggested options from the LAO) to be more accountable and have greater staff support and less reliance on contractors would also be of great benefit from a research perspective. An analysis of how the HSR might be able to earn carbon allowances / credits under California's new AB32 law, the Carbon Cap-and-Trade System, would also be of great interest and could impact the bottom line for profitability of the HSR system. Naturally, research on how best to fund the system (such as PPP funding options, a new round of federal grants, a new dedicated transportation tax (e.g. gasoline tax) at the state and/or federal levels to fund HSR, etc.) would be great importance and value. Finally, the creation of complete project analysis NPVs (with all relevant cash-in and cash-out benefits) for the HSR system and the airports / highways option would be highly desirable, to be sure, and could then be compared with the rather opaque summary numbers from the Rail Authority's *BCA*, which have no supporting data available for evaluation thereof.

But while many such possible further avenues of California HSR research are thus available, it is the hope of this author that he has made a contribution to moving the conversation forward on how best to evaluate the relevant intra-state transportation project alternatives along the Phase One corridor through the above comparative capital construction cost analysis in Net Present Value terms. For high-speed rail indeed represents to this author an intriguing and important possibility to help solve a significant portion of California's – and the country's – transportation, energy, and environmental problems, a possibility very much deserving of further study and one that is too promising to ignore.

# 6. References


Allen, M. (2008, September 24). Fast train called just the ticket for job growth. *San Diego Business Journal*. Retrieved February 27, 2012, from http://www.sdbj.com/industry_article.asp?aID=81935272.1054346.1685918.5681378.7722524.820&aID2=129677

American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5 (2009, February 17). Retrieved November 10, 2010, from http://www.gpo.gov/fdsys/pkg/PLAW-111publ5/html/PLAW-111publ5.htm

Amos, P., Bullock, D., & Sondhi, J. (2010, July). *High-speed rail: The fast track to economic development?* Beijing, People's Republic of China: World Bank. Retrieved March 4, 2012, from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/07/26/000334955_20100726032714/Rendered/PDF/558560WP0Box341SR1v08121jul101final.pdf

Amtrak. (2010, September 27). *A vision for high-speed rail in the Northeast Corridor*. Retrieved February 27, 2012 from http://www.amtrak.com/servlet/ContentServer?c=Page&pagename=am%2FLayout&cid=1241245669222

Bailey, E. (2008, October 15). Backers push bullet-train measure as a dramatic change in California transportation. *Los Angeles Times*. Retrieved February 27, 2012, from http://www.latimes.com/news/local/la-me-fasttrain15-2008oct15,0,5022325,full.story

Ballotpedia. (2012). *California Proposition 1A, high-speed rail act (2008)*. Retrieved February 27, 2012, from http://ballotpedia.org/wiki/index.php/California_Proposition_1A,_High-Speed_Rail_Act_(2008)

Bankrate.com. (2012). *LIBOR, other interest rate indices*. Retrieved March 19, 2012 from http://www.bankrate.com/rates/interest-rates/libor.aspx

Bogren, S. (2012). A national tour of innovative passenger rail finance. *Rail Magazine, Vol. 29*. Retrieved February 27, 2012, from http://web1.ctaa.org/webmodules/webarticles/articlefiles/RAIL_29_Tour.pdf

Brown, S. (2010, May). Revolutionary rail. *Scientific American, Vol. 302* (Issue 5). Retrieved February 27, 2012, from http://www.scientificamerican.com/article.cfm?id=revolutionary-rail

Cabanatuan, M. (2008, October 20). New way of life needed to run high-speed rail. *San Francisco Chronicle*. Retrieved February 27, 2012, from http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2008/10/19/BA5N13IO71.DTL&tsp=1

California Chamber of Commerce. (2012, January). *High-speed rail in California: Using limited funds in cost-efficient manner should be a priority*. Retrieved February 27, 2012, from http://www.calchamber.com/governmentrelations/issuereports/documents/2012-reports/highspeedrail_2012.pdf

California Department of Transportation. (2007, May). *Governor Arnold Schwarzenegger's strategic growth plan: Transportation investments for mobility and quality of life.* Retrieved March 16, 2012, from http://www.dot.ca.gov/docs/strategicgrowth.pdf

California Department of Transportation. (2008, November). *California transportation plan 2035: Fact sheet.* Retrieved March 16, 2012, from http://www.dot.ca.gov/dist05/planning/sys_plan_docs/ctp/CTP2035_FactSheet_11-17-08.pdf

California Department of Transportation. (2011, January). *California transportation financing summary: Fiscal year 2011-12*. Retrieved March 16, 2012, from http://www.dot.ca.gov/docs/2011-12Transportation_FinPkgComplete.pdf

California Department of Transportation & San Francisco County Transportation Authority. (2010, May 4). *Revised project proposal report for the Presidio parkway public-private partnership project*. Retrieved March 16, 2012, from http://www.catc.ca.gov/programs/DB-P3/P3/Presidio_Prkwy_Prjct_Prpsl_Rprt_May4.pdf

California Department of Transportation. Division of Transportation Planning. Economic Analysis Branch. (2011). *Transportation funding in California*. Retrieved March 16, 2012, from http://www.dot.ca.gov/hq/tpp/offices/eab/fundchrt_files/Transportation_Funding_in_California_2011.pdf

California Environmental Protection Agency. Air Resources Board. (2012). *Cap-and-trade program*. Retrieved March 2, 2012, from http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

California High-Speed Rail Authority. (2008a). *What is Proposition 1A?* Retrieved March 2, 2012, from http://www.cahighspeedrail.ca.gov/CHSRTemplate_STDwoBanner.aspx?pageid=8504

California High-Speed Rail Authority. (2011a, October). *California high-speed rail benefit-cost analysis (BCA).* Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/c58241b2-7f49-49d0-befe-769c756ad973.pdf

California High-Speed Rail Authority. (2011b, October). *Cost changes from 2009 report to 2012 business plan capital cost estimates*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/02fa2469-ef00-4eb0-ac78-74edff7b4fc3.pdf

California High-Speed Rail Authority. (2011c, October). *Cost of providing the equivalent capacity to high-speed rail through other modes*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/3fad5c4a-f462-4f2b-836c-5e45d1e379a4.pdf

California High-Speed Rail Authority. (2011d, October). *Economic impact analysis report.* Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/734332d3-26f3-4ed5-beaf-7a640f058094.pdf

California High-Speed Rail Authority. (2011e, October). *Estimating high-speed train operating and maintenance cost for the CA HSRA 2012 business plan*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/976a2a29-ab0b-4dff-a153-bf1ca7b219c2.pdf

California High-Speed Rail Authority. (2011f, December 21). *Executive update*. Retrieved March 2, 2012, from http://www.cahighspeedrail.ca.gov/12212011_jobs.aspx

California High-Speed Rail Authority. (2011g, November 3). *Funding plan*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/281/d89c18ef-f90b-4cd8-8fcd-0f4ffd93e0a9.pdf

California High-Speed Rail Authority. (2011h, October). *International case studies*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/dd9040b5-8ef3-4df8-82b5-a204481ba5dd.pdf

California High-Speed Rail Authority. (2011j, November 1). *Press Release: High-speed rail releases new business plan: Voter-approved system will create 100,000 jobs in next 5 years, more than 1 million jobs over life of project*. Retrieved March 2, 2012, from http://www.cahighspeedrail.ca.gov/pr_11012011.aspx

California High-Speed Rail Authority. (2011k, October 4). *Press release: High-speed rail to release business plan Nov. 1*. Retrieved March 2, 2012, from http://www.cahighspeedrail.ca.gov/10042011-bp.aspx

California High-Speed Rail Authority. (2011m, June 2011). *Ridership and revenue model: Development, application, and project-level EIR/EIS forecasts*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/dce0ae33-6717-43a0-bf82-a2e7825c6996.pdf

California High-Speed Rail Authority. (2011n, November 1). *2012 draft business plan*. Retrieved February 27, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/c7912c84-0180-4ded-b27e-d8e6aab2a9a1.pdf

California High-Speed Rail Authority. (2011p). *2012 draft business plan fact sheet*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/6e05bd66-4317-46df-9891-4aea706fae01.pdf

California High-Speed Rail Authority. (2012a). *Interactive map*. Retrieved March 2, 2012, from http://www.cahighspeedrail.ca.gov/trip_planner.aspx

California High-Speed Rail Authority. (2012b). *Project vision and scope*. Retrieved March 2, 2012, from http://www.cahighspeedrail.ca.gov/project_vision.aspx

California High-Speed Rail Peer Review Group. (2011a). *Peer Review Group's comments on the Legislative Analyst's Office report on the California high-speed rail project*. Retrieved February 27, 2012, from http://www.cahsrprg.com/files/legislativeanalysist.pdf

California High-Speed Rail Peer Review Group. (2011b, May 11). *California High-Speed Rail Peer Review Group Testimony before the Senate Select Committee on High-Speed Rail*. Retrieved February 27, 2012, from http://www.cahsrprg.com/files/Testimony.pdf

California Public Interest Research Group Education Fund. (2010, June). *Next stop: California: The benefits of high-speed rail around the world and what's in store for California*. Retrieved March 19, 2012, from https://www.uspirg.org/reports/usf/next-stop-california

California Secretary of State's Office. (2008a). *Official voter information guide: Supplemental: California general election: Tuesday, November 4, 2008*. Retrieved March 2, 2012, from http://voterguide.sos.ca.gov/past/2008/general/pdf-guide/suppl-complete-guide.pdf

California Secretary of State's Office. (2008b). *Proposition 1A - Safe, Reliable, High-Speed Passenger Train Bond Act: November 6, 2008*. Retrieved March 2, 2012, from http://voterguide.sos.ca.gov/past/2008/general/title-sum/prop1a-title-sum.htm

California State Assembly. (2007-2008 Session: August 26, 2008). Assembly bill 3034: Chapter 267, Statutes of 2008. Retrieved March 2, 2012, from http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_3001-3050/ab_3034_bill_20080826_chaptered.html

California State Auditor. Bureau of State Audits. (2010, April). *High-speed rail authority: It risks delays or an incomplete system because of inadequate planning, weak oversight, and lax contract management* (Report 2009-106). Sacramento, CA: California State Auditor's Office. Retrieved February 27, 2012, from http://www.bsa.ca.gov/pdfs/reports/2009-106.pdf

California State Auditor. Bureau of State Audits. (2012a, January 24). *Fact sheet: High-speed rail authority follow-up* (Report 2011-504). Sacramento, CA: California State Auditor's

Office. Retrieved February 27, 2012, from http://www.bsa.ca.gov/pdfs/factsheets/2011-504.pdf

California State Auditor. Bureau of State Audits. (2012b, January 24). *High-speed rail authority follow-up* (Report 2011-504). Sacramento, CA: California State Auditor's Office. Retrieved February 27, 2012, from http://www.bsa.ca.gov/pdfs/reports/2011-504.pdf

California State Auditor. Bureau of State Audits. (2012c, January 24). *Report 2011-504 Highlights – January 2012*. Sacramento, CA: California State Auditor's Office. Retrieved February 27, 2012, from http://www.bsa.ca.gov/reports/highlights/2011-504

California State Auditor. Bureau of State Audits. (2012d, January 24). *Report 2011-504 Summary – January 2012*. Sacramento, CA: California State Auditor's Office. Retrieved February 27, 2012, from http://www.bsa.ca.gov/reports/summary/2011-504

California, State of.  (2012). *State Constitution: Article 16: Public Finance*. Retrieved February 27, 2012, from http://www.leginfo.ca.gov/.const/.article_16

Californians for High-Speed Trains. (2008). *Prop. 1A will create over 500,000 desperately needed jobs in California communities*. Retrieved February 27, 2012, from http://www.californiahighspeedtrains.com/

Cambridge Systematics Inc. (2011, October 19). *California high-speed rail 2012 business plan: Ridership and revenue forecasting: Draft technical memorandum*. Retrieved February 29, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/321/739f2a3b-1d66-4c59-9e2e-3541581dbcbd.pdf

Camino, F. (2008, March 6). Traffic and congestion costs every Los Angeles citizen $1,561 annually. *Metro Rider LA*. Retrieved February 27, 2012, from http://MetroRiderLA.com

Cox, J. (2012, March 18). High-speed rail link to L.A. gains momentum. *Bakersfield Californian*. Retrieved March 25, 2012, from http://www.fresnobee.com/2012/03/18/2765484/rail-link-to-la-gains-momentum.html

Cruickshank, R. (2008a, November 5). All aboard! *California High Speed Rail Blog*. Retrieved February 27, 2012, from http://cahsr.blogspot.com/2008/11/all-aboard_05.html

Cruickshank, R. (2008b, September 12). Green dividend of high-speed rail for California. *California High Speed Rail Blog*. Retrieved February 27, 2012, from http://www.californiaprogressreport.com/2008/09/the_green_divid.html

Cruickshank, R. (2008c, November 6). Next steps. *California High Speed Rail Blog*. Retrieved February 27, 2012, from http://cahsr.blogspot.com/2008/11/next-steps.html

Cruickshank, R. (2008d, September 23). Prop 1A as economic stimulus. *California High Speed Rail Blog*. Retrieved February 27, 2012, from http://cahsr.blogspot.com/2008/09/prop-1a-as-economic-stimulus.html

Del Mar Times. (2008, October 16). High-speed rail proposition worth support. *Del Mar Times*. Retrieved February 27, 2012, from http://www.delmartimes.net/opinion/249596-high-speed-rail-proposition-worth-support

Economist. (2012, March 10). Going nowhere fast: Even California, America's last big hope for high-speed trains, is reconsidering. *The Economist*. Retrieved March 16, 2012, from http://www.economist.com/node/21549960

Freemark, Y. (2011, February 16). Florida governor Rick Scott rejects funding for Tampa-Orlando intercity rail project. *The Transport Politic*. Retrieved March 19, 2012, from http://www.thetransportpolitic.com/2011/02/16/florida-governor-rick-scott-rejects-funding-for-tampa-orlando-intercity-rail-project

Fresno Bee. (2008, October 7). High-speed rail pays off: New study says Valley will greatly benefit from building system. *Fresno Bee*. Retrieved February 27, 2012, from http://www.fresnobee.com/opinion/story/918219.html

Geddes, R. R. (2012). Public-private partnerships in passenger rail. *Rail Magazine, Vol. 29*. Retrieved February 27, 2012, from http://web1.ctaa.org/webmodules/webarticles/articlefiles/RAIL_29_PPP.pdf

Gould, P. (2008, October 6). Election 2008: State Proposition 1A. *MoreMarin.com*. Retrieved February 27, 2012, from http://www.moremarin.com/buzzhome/2008/10/election-2008-.html

High-Speed Rail Boondoggle. (2012). *About high-speed rail boondoggle*. Retrieved February 27, 2012, from http://owl.english.purdue.edu/owl/resource/560/06/

Imperial Valley News. (2008, August 27). Schwarzenegger puts taxpayer protections into high-speed rail bond on ballot. *Imperial Valley News*. Retrieved February 27, 2012, from http://imperialvalleynews.com/index.php?option=com_content&task=view&id=2494&Itemid=1

Kantor, S. (2008, September). *Economic impact of the California high-speed rail in the Sacramento / Central Valley area*. Retrieved February 27, 2012, from www.californiahighspeedtrains.com/docs/HST%20Central%20Valley%20Report.pdf

Kempton, W. (2011, May 2). *Letter to Mr. Roelof van Ark*. California High-Speed Rail Peer Review Group. Retrieved February 27, 2012, from http://www.cahsrprg.com/files/Letter.pdf

Kopp, Q. (2008, November 5). Statement on voter approval of Proposition 1A from Quentin Kopp, Chairman, California High-Speed Rail Authority. *Market Watch*. Retrieved February 27, 2012, from http://www.marketwatch.com/news/story/Statement-Voter-Approval-Proposition-1A/story.aspx

Legislative Analyst's Office. California State Legislature. (2009). *The high-speed rail authority*. Sacramento, CA: Legislative Analyst's Office. Retrieved February 27, 2012, from http://www.lao.ca.gov/handouts/transportation/2009/High_Speed_Rail_Authority_03_17_09.pdf

Legislative Analyst's Office. California State Legislature. (2011a, November 29). *High-speed rail authority: The draft 2012 business plan and funding plan*. Sacramento, CA: Legislative Analyst's Office. Retrieved February 27, 2012, from http://www.lao.ca.gov/handouts/transportation/2011/HSRA_Business_Funding_plan_11_29_11.pdf

Legislative Analyst's Office. California State Legislature. (2011b, November 15). *Strategy for reviewing the draft 2012 high-speed rail authority business plan*. Sacramento, CA: Legislative Analyst's Office. Retrieved February 27, 2012, from http://www.lao.ca.gov/handouts/transportation/2011/2012_HSRA_Business_Plan_11_15_11.pdf

Los Angeles Times. (2008, October 2). Yes on California bonds. *Los Angeles Times*. Retrieved February 27, 2012, from http://www.latimes.com/business/la-ed-endorsements2-2008oct02,1,7037801.story

Merced Sun Star. (2008, October 8). Our view: High-speed rail pays off. *Merced Sun Star*. Retrieved February 27, 2012, from http://www.californiahighspeedtrains.com/docs/Press/MercedSunStarEditorial.pdf

Mercury News. (2008, October 12). Yes on 1A: It puts Silicon Valley and California on the fast track. *Mercury News*. Retrieved February 27, 2012, from http://www.mercurynews.com/opinion/ci_10755831

Miranda, N. (2012, January 4). Budget deficit tops legislature's 2012 priority list. *KGO-TV/DT*. Retrieved March 16, 2012, from http://abclocal.go.com/kgo/story?section=news/politics&id=8490904

Moyer, M. (2009, August). The third way: High hopes for high-speed rail. *Scientific American, Vol. 301* (Issue 2). Retrieved February 27, 2012, from http://www.scientificamerican.com/article.cfm?id=high-hopes-for-high-speed-rail

Mufson, S. (2008, October 20). As fuel prices fall, will push for alternatives lose steam? *Washington Post*. Retrieved February 27, 2012, from http://www.washingtonpost.com/wp-dyn/content/article/2008/10/19/AR2008101902073.html

Nussbaum, P. (2010, September 28). Amtrak proposes Northeast Corridor high-speed service. *Philadelphia Inquirer*. Retrieved November 10, 2010, from http://www.philly.com/philly/news/103930949.html

Orange County Business Council. (2008, October). *Economic impact of high-speed trains for Orange County*. Retrieved February 27, 2012, from http://www.californiahighspeedtrains.com/docs/HST-%20Orange%20Co%20Report.pdf

Porcari, J. (2012, January 3). Letter to Mr. Roelof van Ark. California High-Speed Rail Authority. Retrieved February 27, 2012, from http://www.cahighspeedrail.ca.gov/assets/0/152/302/9f61175c-f0a9-4bc6-87bd-4e541d558038.pdf

Project Vote Smart. (2008). *California state key votes: Key votes for AB 3034*. Retrieved February 27, 2012, from http://www.votesmart.org/issue_keyvote.php?type=billnumber&state_id=CA&search_2=AB+3034&go3.x=11&go3.y=12

Purdum, T. S. (2000, June 23). Los Angeles subway reaches end of the line. *New York Times*. Retrieved February 27, 2012, from http://query.nytimes.com/gst/fullpage.html?res=9C00E4D71F31F930A15755C0A9669C8B63

Randolph, S. (2008, October). *California high-speed rail: Economic benefits and impacts in the San Francisco Bay area*. Retrieved February 27, 2012, from http://www.californiahighspeedtrains.com/docs/HST%20Bay%20Area%20Report.pdf

Romero, P. J. (2008, October 8). *Unlocking the gridlock in Los Angeles County's transportation system: The local economic benefits of high-speed rail*. Retrieved February 27, 2012, from http://www.californiahighspeedtrains.com/docs/HST-%20Los%20Angeles%20Report.pdf

Ruiz, R. (2008, June 3). America's most time-draining airports. *Forbes.com*. Retrieved March 16, 2012, from http://www.forbes.com/2008/06/02/aviation-travel-delays-biz-logistics-cx_rr_0603travel.html

Sahr, R. (2008). *Consumer price index (CPI) conversion factors to convert to 2007 dollars*. Retrieved March 16, 2012, from http://oregonstate.edu/cla/polisci/faculty-research/sahr/cv2007x.pdf

Sampson, R. (2012a). Finance: The crucial component of multi-faceted rail contracts. *Rail Magazine, Vol. 29*. Retrieved February 27, 2012, from http://web1.ctaa.org/webmodules/webarticles/articlefiles/RAIL_29_Finance.pdf

Sampson, R. (2012b). Made in America. *Rail Magazine, Vol. 29*. Retrieved February 27, 2012, from http://web1.ctaa.org/webmodules/webarticles/articlefiles/RAIL_29_Made_in_America.pdf

Samuelson, R. (2010, October 29). High-speed pork: Why fast trains are a waste of money. Newsweek. Retrieved February 27, 2012, from http://www.newsweek.com/2010/10/29/why-high-speed-trains-don-t-make-sense.html

San Diego Institute for Public Policy Research. (2008, September). *San Diego regional economic impact study of the California high-speed train project*. Retrieved February 27, 2012, from http://www.californiahighspeedtrains.com/docs/HST-%20San%20Diego%20Report.pdf

San Diego Union-Tribune. (2008, September 21). Prop. 1A: No, no, no: Rail measure may be biggest boondoggle ever. *San Diego Union-Tribune*. Retrieved February 27, 2012, from http://www.signonsandiego.com/uniontrib/20080921/news_lz1ed21top.html

San Francisco Bay Guardian. (2008, October 8). Yes, yes, yes: Proposition 1A high-speed rail bond. *San Francisco Bay Guardian*. Retrieved February 27, 2012, from http://www.sfbg.com/entry.php?entry_id=7262

San Francisco Chronicle. (2008, October 8). Yes on Proposition 1A: A 21st century vision. *San Francisco Chronicle*. Retrieved February 27, 2012, from http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2008/10/08/EDF113D47B.DTL

Sheehan, T. (2012, February 28). High-speed rail project likely delayed until 2013. *Fresno Bee*. Retrieved March 16, 2012, from http://www.fresnobee.com/2012/02/28/2740638/rail-project-delayed-construction.html

Taylor, C. J. (2012). Selling the value of high-speed rail. *Rail Magazine, Vol. 29*. Retrieved February 27, 2012, from http://web1.ctaa.org/webmodules/webarticles/articlefiles/RAIL_29_HSR.pdf

Thronson, E. (2011, May 10). *High-speed rail is at a critical juncture*. Sacramento, CA: Legislative Analyst's Office. Retrieved February 27, 2012, from http://www.lao.ca.gov/reports/2011/trns/high_speed_rail/high_speed_rail_051011.aspx

Todorovich, P., & Hagler, Y. (2009, September 17). *Where high-speed rail works best*. New York, NY: America 2050. Retrieved March 4, 2012, from http://www.america2050.org/pdf/Where-HSR-Works-Best.pdf

Todorovich, P., & Hagler, Y. (2011, January). *High-speed rail in America*. New York, NY: America 2050. Retrieved March 4, 2012, from http://www.america2050.org/pdf/HSR-in-America-Complete.pdf

Todorovich, P., Schned, D., & Lane, R. (2011, September). *High-speed rail: International lessons for U.S. policy makers*. Cambridge, MA: Lincoln Institute of Land Policy. Retrieved March 4, 2012, from https://www.lincolninst.edu/pubs/dl/1948_1268_High-Speed%20Rail%20PFR_Webster.pdf

Trigg, T., & Levinn, J. (2010, April 25). *Transit-oriented development in the greater Richmond, Virginia region: A client-based masters project with GRTC Transit System*. Retrieved February 27, 2012, from DukeSpace at http://dukespace.lib.duke.edu/dspace/handle/10161/2146

United States. Department of Transportation. Bureau of Transportation Statistics. (2012). *National transportation statistics*. Retrieved February 27, 2012, from http://www.bts.gov/publications/national_transportation_statistics

United States. Department of Transportation. Federal Aviation Administration. (2007). *Terminal area forecast summary: Fiscal years 2008-2025*. Retrieved March 16, 2012, from http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/taf_reports/media/TAF%20Summary%20Report%20FY%202008-2025.pdf

United States. Department of Transportation. Federal Railroad Administration. (2009a). *A Vision for high-speed rail in America: Highlights of strategic plan: April 16, 2009*. Retrieved February 27, 2012, from http://www.fra.dot.gov/Downloads/RRdev/hsrspfacts.pdf

United States. Department of Transportation. Federal Railroad Administration. (2009b). *Vision for high-speed rail in America: High-speed rail strategic plan*. Retrieved November 10, 2010, from http://www.fra.dot.gov/downloads/Research/FinalFRA_HSR_Strat_Plan.pdf

United States. Department of Transportation. Federal Railroad Administration. (2012). *High-speed and intercity passenger rail: A vision of high-speed rail in Americ*a. Retrieved February 27, 2012, from http://www.fra.dot.gov/rpd/passenger/31.shtml

United States. Government Accountability Office. (2009, March). *High-speed passenger rail: Future development will depend on addressing financial and other challenges and establishing a clear federal role*. (Report # GAO-09-317). Retrieved November 10, 2010, from http://www.gao.gov/new.items/d09317.pdf

United States Public Interest Research Group Education Fund. (2010, Fall). *A track record of success: High-speed rail around the world and its promise for America*. Retrieved March 19, 2012, from https://www.uspirg.org/reports/usf/track-record-success

United States Public Interest Research Group Education Fund. (2011, Summer). *High-speed rail: Public, private or both? Assessing the prospects, promise and pitfalls of public-private partnerships*. Retrieved March 19, 2012, from https://www.uspirg.org/reports/usp/high-speed-rail-public-private-or-both

University of California at Berkeley. Institute of Governmental Studies. (2008). *Proposition 1A would lay down the track for California high-speed rail*. Retrieved February 27, 2012, from http://igs.berkeley.edu/library/hot_topics/2008/Nov2008Election/Prop1Amain.html

Vartabedian, R. (2012, March 8). A collision of visions on bullet train: The high-speed rail line would transform California lifestyles for the better, backers say. *Los Angeles Times*. Retrieved March 25, 2012, from http://www.latimes.com/news/local/la-me-bullet-vision-20120308,0,3644887,full.story

Vartabedian, R., & Weikel, D. (2012, January 17). New doubts about bullet train. *Los Angeles Times*. Retrieved February 27, 2012, from http://articles.latimes.com/2012/jan/17/local/la-me-bullet-exaggeration-20120117

Walters, D. (2008, October 28). Riding blind on the bullet train. *Orange County Register*. Retrieved February 27, 2012, from http://www.ocregister.com/articles/plan-project-kopp-2208154-authority-state

Witt, J. R. (2010). High-speed transportation: California is leading the way in green transportation and job creation. *California Transportation Journal, Vol. 2010,* Issue 1. Retrieved March 16, 2012, from http://www.dot.ca.gov/ctjournal/2010-1/hi-speed_rail.html

World Book. Online Reference Center. (2012). *Los Angeles subway system*. Retrieved February 27, 2012, from http://0-www.worldbookonline.com.helin.uri.edu/wb/media?id=bt199167&st=basketball

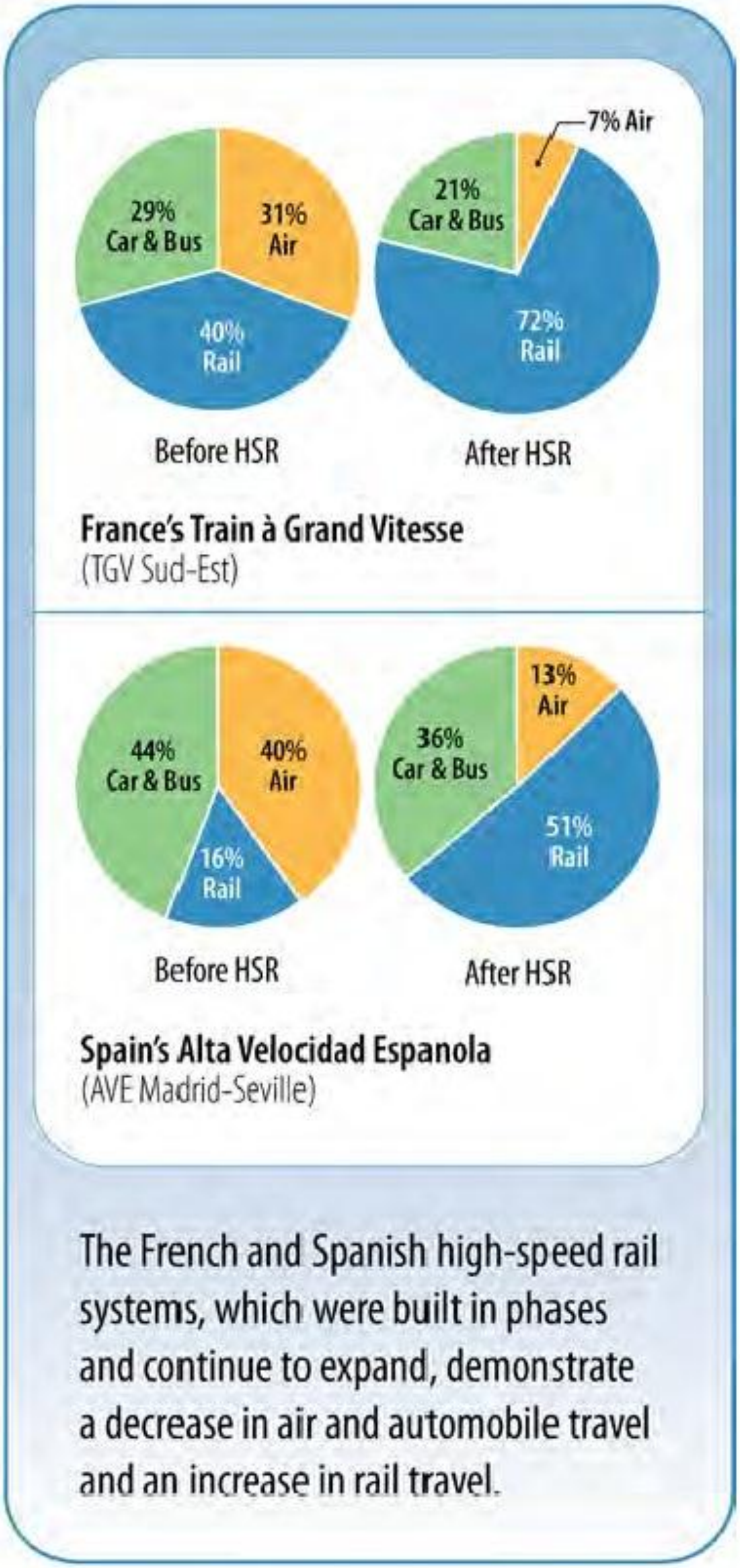
Yogerst, J. (2011, October). T+L's most dangerous U.S. airports: Airline safety is on the rise, but near accidents are still more common than you might think. Retrieved March 16, 2012, from http://www.travelandleisure.com/articles/tls-most-dangerous-us-airports

# 8. Appendix

## Appendix I

| Section 9, Full Cost Estimate; Table 6, Summary of Highway Segments & Costs (2010 $) | | | | | | |
|---|---|---|---|---|---|---|
| Cost of Providing Equivalent Capacity, Oct. 2011, by CHSRA - Page 25 (from 2005 Program Level EIS/EIR) | | | | | | |
| ***# lanes =*** | ***3*** | | | | | |
| **Highway Corridor** | **Segment (From–To)** | **Urban/ Rural** | **Miles** | **Lane-Miles** | **Cost per Lane-Mile (2010 $)** | **Total Costs (2010 $)** |
| *Bay Area to Merced* | | | | | | |
| US-101 | San Francisco to SFO | Urban | 11.3 | 33.9 | $75,737,000 | $2,567,484,300 |
| US-101 | SFO to Redwood City | Urban | 13.8 | 41.4 | $47,272,000 | $1,957,060,800 |
| US-101 | Redwood City to I-880 | Urban | 19.7 | 59.1 | $46,436,000 | $2,744,367,600 |
| I-880 | US-101 to San Jose | Urban | 0.9 | 2.7 | $68,020,000 | $183,654,000 |
| US-101 | San Jose to Gilroy | Urban | 31.2 | 93.6 | $30,439,000 | $2,849,090,400 |
| US-101 | Gilroy to SR-152 | Urban | 1.4 | 4.2 | $27,233,000 | $114,378,600 |
| SR-152 | US-101 to I-5 | Rural | 40.8 | 122.4 | $11,480,000 | $1,405,152,000 |
| SR-152 | I-5 to SR-99 | Rural | 42.8 | 128.4 | $14,071,000 | $1,806,716,400 |
| I-80 | San Francisco to I-880 | Urban | 9.2 | 27.6 | $41,416,000 | $1,143,081,600 |
| I-880 | I-80 to I-238 | Urban | 13.8 | 41.4 | $51,185,000 | $2,119,059,000 |
| I-580 | I-880 to I-5 (via I-238) | Rural | 52.7 | 158.1 | $29,736,000 | $4,701,261,600 |
| I-880 | I-238 to Fremont/Newark | Urban | 14.5 | 43.5 | $44,874,000 | $1,952,019,000 |
| I-880 | Fremont/Newark to US-101 | Urban | 12.4 | 37.2 | $41,612,000 | $1,547,966,400 |
| *Merced to Bakersfield* | | | | | | |
| I-5 | SR-152 to SR-99 | Rural | 186.0 | 558.0 | $9,804,000 | $5,470,632,000 |
| SR-99 | Merced to SR-152 | Rural | 21.5 | 64.5 | $12,489,000 | $805,540,500 |
| SR-99 | SR-152 to Fresno | Urban | 33.4 | 100.2 | $25,964,000 | $2,601,592,800 |
| SR-99 | Fresno to Tulare/Visalia | Urban | 46.4 | 139.2 | $19,969,000 | $2,779,684,800 |
| SR-99 | Tulare/Visalia to SR-58 | Urban | 68.9 | 206.7 | $22,044,000 | $4,556,494,800 |
| *Bakersfield to Los Angeles* | | | | | | |
| I-5 | SR-99 to SR-14 | Rural | 65 | 195.0 | $21,981,000 | $4,286,295,000 |
| I-5 | SR-14 to I-405 | Urban | 2.5 | 7.5 | $109,828,000 | $823,710,000 |
| I-5 | I-405 to Burbank | Urban | 15.3 | 45.9 | $28,677,000 | $1,316,274,300 |
| I-5 | Burbank to L.A. Union Station | Urban | 7.4 | 22.2 | $57,303,000 | $1,272,126,600 |
| SR-14 | Palmdale to I-5 | Urban | 34.8 | 104.4 | $23,704,000 | $2,474,697,600 |
| *Los Angeles to Anaheim* | | | | | | |
| I-5 | L.A. Union Station to I-10 | Urban | 0.8 | 2.4 | $271,834,000 | $652,401,600 |
| I-5 | I-10 to Norwalk | Urban | 20.7 | 62.1 | $60,231,000 | $3,740,345,100 |
| I-5 | Norwalk to Anaheim | Urban | 8.1 | 24.3 | $75,534,000 | $1,835,476,200 |
| ***Totals*** | | | **775.3** | **2,325.9** | | **$57,706,563,000** |

**Appendix II**




Source: California High-Speed Rail Authority, 2011n, p. ES-5.