# California High-Speed Rail Project

# California High-Speed Rail Benefit-Cost Analysis (BCA)

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# Contents

## Figures

## Tables

# 1.0 - Introduction

This report is an economic benefit-cost analysis of each phase of the California High Speed Rail Project (CA HSR) conducted for the California High Speed Rail Authority (Authority). It estimates benefits and costs for the IOS, Bay to Basin, Phase 1 Blended, and Phase 1 Full Build as defined in the 2012 Business Plan. This analysis was completed in support of the 2012 Business Plan, and conducted in accordance with the benefit-cost methodology as recommended by the U.S. DOT in the Federal Register (77 FR 4863).

# 2.0 - Key Analytical Assumptions

## 2.1 - Real Discount Rate

Benefits and costs are typically valued in constant (e.g., 2011) dollars to avoid having to forecast future inflation and escalate future values for benefits and costs accordingly. Even in cases where costs are expressed in future, year of expenditure values, they tend to be built upon estimates in constant dollars, and are easily deflated. The use of constant dollar values requires the use of a real discount rate for present value discounting (as opposed to a nominal discount rate).

A real discount rate measures the risk-free interest rate that the market places on the time value of resources after accounting for inflation. Put another way, the real discount rate is the premium that one would pay to have a resource or enjoy a benefit sooner rather than defer it until later. For example, most people would prefer to be given $10,000 now, as opposed to ten years in the future. This is especially true because that amount of money, if invested now, would likely yield more than $10,000 ten years from now. As such, the values of future resources should be discounted.

For CA HSR investments, dollar figures in this analysis are expressed in constant 2011 dollars. In instances where certain cost or benefit estimates were expressed in dollar values in other (historical) years, the Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) was used to adjust.

Choosing an appropriate discount rate is essential to appropriately assessing the costs and benefits of a project. The higher the discount rate, the lower the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value or economic feasibility of the investment.

The real discount rate this analysis uses for evaluating the CA HSR project is 7.0 percent. This 7 percent discount rate is consistent with U.S. DOT guidance for TIGER II grants and OMB Circular A-4 and A-94.[1]

[1] Office of Management and Budget (1992), *Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. Washington: Office of Management and Budget; (2003) *Circular A-4: Regulatory Analysis*, Washington : Office of Management and Budget.

## 2.2 - Evaluation Period

Benefits and costs are typically evaluated for a period that includes the construction period and an operations period ranging from 20-50 years after the initial project investments are completed. Given the permanence and relatively extended design life of high-speed rail investments, longer operating periods, and thus, evaluation periods are applicable.

For the CA HSR BCA, the evaluation period includes the relevant (post-design) construction period during which capital expenditures are undertaken through 2080. For the purposes of this study, there were four scenarios considered, and depending on the scenario, the construction period varies. Accordingly, this analysis examines all benefits and costs for an analysis period from 2013 to 2080, which is approximately 47 years beyond project completion for the scenario with the longest construction period.

As a simplifying assumption, all benefits and costs are assumed to occur at the end of each year, and all benefits begin in the annual year immediately following the final construction year.

## 2.3 – Project Region and Phasing

The geographic coverage of this CA HSR BCA is considered to be the entire state of California. Thus, benefits are the cumulative effects across the entire state.

This analysis examines each phase of the CA HSR project, comprised of various steps:

- Initial Operating Segment (IOS-South)
- Bay to Basin
- Phase 1 Blended
- Phase 1 Full Build

In order to conduct a BCA, some assumptions about the timing of phasing were made. First, this analysis assumes that the sequence of construction would be as outlined above: 1) IOS , 2)Bay to Basin, 3) Phase 1 Blended and, if it is required to be built, 4) Phase 1 Full Build. The years in which each phase is assumed to be begin operations in this analysis are outlined in Table 1.

**Table 1. California HSR Phasing Assumptions for Benefit-Cost Analysis, First Year of Operations for Sub-phases**

| Sub-phase | Operations Start Year |
|---|---|
| IOS | 2022 |
| Bay to Basin | 2027 |
| Phase 1 Blended | 2029 |
| Phase 1 Full Build | 2034 |

*Source: 2012 Business Plan*

## 2.4 - Travel Demand Sources and Forecast Years for Highway Benefits

### 2.4.1 Travel Demand Models

Following standard industry practices, the benefits calculations are based on the results of the travel demand model and are driven by the impacts of people switching from other modes to HSR. Cambridge Systematics provided travel demand models for the general roadway network, and were able to isolate the impacts of the CA HSR project on existing travelers on the network, as well as changes due to users switching from auto to HSR.

These model estimates were provided for year 2030; for extrapolation purposes, a 1 percent annual growth rate was used for 2010 though 2030, and a 0.5 percent growth rate was used from 2031 onwards. Table 2 shows the travel demand model results for 2011, as well as the selected forecast years of 2040 and 2060. The "Build" scenario results assume that each phase and any preceding phases are built at that time. It is assumed that 7.1 percent of all trips are truck trips, consistent with the California Department of Transportation's Traffic Counts of their State Highway System.[2]

**Table 2. Travel Demand Model for California Highways and Roads, Selected Years**

| | 2011 | 2040 | 2060 |
|---|---|---|---|
| **VMT (Annual)** | | | |
| No Build | 235,000,996,530 | 298,993,415,383 | 330,356,502,264 |
| IOS South | - | 297,076,184,958 | 328,238,162,848 |
| Bay to Basin | - | 295,843,740,239 | 326,876,440,128 |
| Phase 1 Blended | - | 295,375,129,333 | 326,358,674,011 |
| Phase 1 Full Build | - | 294,877,730,746 | 325,809,100,512 |
| **VHT (Annual)** | | | |
| No Build | 7,857,927,512 | 9,997,696,262 | 11,046,410,382 |
| IOS South | - | 9,955,910,294 | 10,005,689,845 |
| Bay to Basin | - | 9,933,052,842 | 9,982,718,106 |
| Phase 1 Blended | - | 9,922,623,450 | 9,972,236,567 |
| Phase 1 Full Build | - | 9,911,315,028 | 9,960,871,603 |

*Source: Cambridge Systematics, 2011*

The travel demand model data reflected in Table 2 only indicates the travel times for the remaining users on the highway network after travelers have shifted from auto to HSR. There are VMT and VHT savings for travelers switching to HSR as well, this data is shown in Table 3 below.

[2] California Department of Transportation (2010), *Business: Traffic Counts, Welcome to the Traffic Data Branch, 2009*, http://traffic-counts.dot.ca.gov/.

Table 3. Travel Demand Model for California Highways and Roads, Selected Years

| | 2011 | 2040 | 2060 |
|---|---|---|---|
| **VMT Savings (Annual)** | | | |
| IOS South | - | 2,007,655,422 | 2,218,249,596 |
| Bay to Basin | - | 3,211,853,528 | 3,548,762,758 |
| Phase 1 Blended | - | 3,674,860,514 | 4,060,337,129 |
| Phase 1 Full Build | - | 4,175,593,700 | 4,613,595,011 |
| **VHT Savings (Annual)** | | | |
| IOS South | - | 55,656,665 | 61,494,803 |
| Bay to Basin | - | 89,796,652 | 99,215,924 |
| Phase 1 Blended | - | 105,324,894 | 116,373,009 |
| Phase 1 Full Build | - | 122,740,059 | 135,614,948 |

*Source: Cambridge Systematics, 2011*

Cambridge Systematics also provided ridership estimates for the system that inform the VMT and VHT figures from Table 2 and Table 3 above. The total system ridership is shown below in

Table 4 for each phase. In this table, ridership indicates the total ridership expected should the selected phase be built out.

Table 4. Total CA HSR Ridership for Selected Phases

| | 2011 | 2040 | 2060 |
|---|---|---|---|
| IOS South | - | 12,280,996 | 13,569,218 |
| Bay to Basin | - | 20,839,379 | 23,025,337 |
| Phase 1 Blended | - | 29,797,195 | 32,922,789 |
| Phase 1 Full Build | - | 34,066,401 | 37,639,815 |

*Source: Cambridge Systematics, 2011*

Finally, the number of riders diverting from the air system was provided:

Table 5. CA HSR Ridership Diverted From Air for Selected Phases

| | 2011 | 2040 | 2060 |
|---|---|---|---|
| IOS South | - | 1,536,569 | 1,697,749 |
| Bay to Basin | - | 4,344,156 | 4,799,839 |
| Phase 1 Blended | - | 5,116,319 | 5,652,998 |
| Phase 1 Full Build | - | 5,868,649 | 6,484,245 |

*Source: Cambridge Systematics, 2011*

# 3.0 - Economic Benefits Included

The following identifies and groups the benefits that are included in the BCA for the CA HSR.

## 3.1 Economic Competitiveness

### 3.1.1 - Travel Time Savings

Travel time savings in this BCA includes two categories: 1) in-vehicle travel time savings for auto passengers and truck drivers who remain on the highway system, and 2) travel time savings for travelers who transfer from auto to HSR.

In standard economic practice, travel time is considered a cost to users, and its value depends on the disutility (cost or disbenefit) that travelers attribute to time spent traveling. A reduction in travel time would translate into more time available for work, leisure, or other activities, which travelers' value.

Travel time savings must be converted from hours to dollars in order for benefits to be aggregated and compared against costs. This is traditionally performed by assuming that travel time is valued as a percentage of the average wage rate, with different percentages for different trip purposes. For this analysis, assumptions for value of time (VOT) estimates were derived from U.S. DOT recommended values as seen in Table 6.[3]

**Table 6. U.S. DOT Recommended Values of Time Used in Analysis**

| Passenger Type | Value of Time (2011 $) |
|---|---:|
| Non-HSR Surface Travel, Intercity | $18.00 |
| Air and HSR Travel, Intercity | $42.10 |
| Truck Driver Value of Time | $24.70 |

*Source: U.S. DOT, 2011*

Historically, wages and salaries have increased, on average, at a higher annual rate than general price inflation. Thus, there is reason to suggest that the VOT should increase yearly as well, reflecting real increases to the VOT. However, this analysis conservatively assumes a constant VOT in real 2011 dollars.

[3] U.S. Department of Transportation (Sept. 2011), *Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis*, Washington : Office of the Assistant Secretary of Transportation for Transportation, Table 4.

Finally, travel time saving calculations require the conversion of VHT into person-hours traveled (PHT), a process that uses the number of occupants per vehicle. All figures of this average vehicle occupancy (AVO) are derived from travel demand model results, which were provided by Cambridge Systematics. These figures were calculated using numbers for total auto trips diverted to HSR, and the total number of person-trips diverted to HSR.

### 3.1.2 - Reliability Benefits

Reliability in travel times is an important element of user benefits from a system like CA HSR. Relative to a highway trip, travelers can generally expect a more reliable trip with trains arriving on time and per a schedule, rather than being subject to the random delays that can occur on the highway network. High speed trains, in particular, have been proven to operate an extremely reliable system.

Because users come to expect, and adjust to, delays on the highway network, there is some extra time 'budgeted' on a trip in order to compensate for the additional time spent. This "buffer time" is that extra lead time and it can be expressed by a concept known as the "Planning Time Index", which is a measure of the amount of actual time spent on a trip after incorporating a certain buffer period above and beyond the standard travel time. This concept is not incorporated in the standard travel demand models, but is typically calculated based on historical data for metropolitan regions.

The Texas Transportation Institute's Urban Mobility Report has measured the Planning Time Index for four cities in California.[4]

**Table 7. Planning Time Indices in California**

| Region | Planning Time Index in Average Conditions |
|---|---|
| Los Angeles | 1.47 |
| Sacramento | 1.26 |
| San Francisco | 1.25 |
| Orange County | 1.40 |

*Source: Texas Transportation Institute, 2010*

A Planning Time Index for Los Angeles of 1.47 means that for the average trip, users would incorporate 47 percent extra "buffer time" into their trip to account for the unreliability of the highway network. Thus, a traveler who believes that his trip may take 20 minutes would add an additional 9.4 minutes as a buffer.

This analysis used a Planning Time Index of 1.30 based on the information above.

Following standard practice, when travelers switch from highway trips to new HSR service, it is assumed that they no longer plan that additional buffer time for the new trip. Knowing the number of trips transferring from automobile to HSR, the average speeds on the highway network, and assuming the

[4] Texas Transportation Institute (2010), *Urban Mobility Report 2010*. Texas A&M University. College Station, p. B53.

HSR trip and highway trip are equivalent distances, it is possible to estimate the buffer time saved. This travel time, when monetized using value of time, represents reliability savings.

### 3.1.3 - Reductions in Vehicle Operating Costs

The proposed CA HSR investments would not only affect travel times, but they also reduce vehicle operating and ownership costs overall. They would do so because as travelers shift towards the HSR service, this reduces the total amount of VMT on the roadway system relative to the "no build" situation. Further, according to the travel demand models, the reduced traffic on the roadway network has ripple effects such that the remaining users on the network also experience reductions in overall VMT. As a result, vehicle and truck operating costs that are linked to VMT would decrease as driving fewer miles reduces the cost of operating a vehicle.

#### *Vehicle Operating Costs - Fuel*

Fuel prices were derived from the U.S. Energy Information Administration (EIA), which provides estimates for the price of fuel through 2035. The Fuel prices and taxes used can be found in the table produced by EIA, titled "Components of Selected Petroleum Product Prices."[5] Prices were derived for the following types of fuel:

- "Motor Gasoline" for passenger vehicle fuel
- "Diesel (transportation sector)" for the price of diesel used by trucks and buses
- "Jet Fuel" for the price of jet fuel (for aviation use)

All dollars were reported in real 2010 dollars by the EIA. These dollar amounts were subsequently converted to real 2011 dollars using the U.S. Bureau of Labor Statistics Consumer Price Index adjustment for "motor fuel" between 2010 and 2011.

Because fuel taxes are considered a pecuniary benefit, or transfer payment, should not be included in benefit calculations of a BCA. Thus, the federal and state taxes estimated by the EIA are subtracted out of the end user fuel prices.

Finally, the EIA only provides estimates through 2035; however the analysis period relevant for this project stretches beyond this timeframe and thus estimated fuel prices in those future years are also necessary. In order to estimate fuel prices that extend beyond 2035, the compound annual growth rate (CAGR) for 2010-2035 was calculated and then used to continue the series through the end of the analysis period.

The following table provides the fuel price, in real 2011 dollars, for selected years.

**Table 8. U.S. EIA Fuel Prices, Real 2011 Dollars**

| Fuel Type | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|

[5] Energy Information Administration (Producer). (2012). Annual Energy Outlook 2012 Early Release. *Components of Selected Petroleum Product Prices, United States, Reference case.* [Microsoft Excel] Retrieved from http://www.eia.gov/oiaf/aeo/tablebrowser/

| | | | | | |
|---|---|---|---|---|---|
| Motor Gasoline | $2.91 | $4.21 | $4.60 | $5.11 | $6.08 |
| Diesel | $2.52 | $4.40 | $4.96 | $5.53 | $6.59 |
| Jet Fuel | $3.67 | $4.16 | $4.57 | $5.51 | $7.02 |

*Source: U.S. EIA; Parsons Brinckerhoff*

Fuel efficiency figures were similarly derived from the U.S. EIA Annual Energy Outlook. [6]

**Table 9. U.S. EIA Fuel Efficiency**

| Vehicle Type | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Automobile, Light Duty Stock (miles per gallon) | 20.50 | 23.40 | 26.80 | 29.51 | 33.25 |
| Truck, Freight Truck (miles per gallon) | 6.70 | 7.40 | 8.10 | 8.53 | 9.24 |
| Aircraft (seat-miles per gallon) | 62.30 | 63.90 | 67.00 | 70.70 | 73.58 |

*Source: U.S. EIA; Parsons Brinckerhoff*

### *Vehicle Operating Costs – Non-Fuel*

Non-fuel operating costs include the cost of operations and maintenance of vehicles, the cost of tires, and vehicle depreciation. A reduction in VMT due to project investments results in cost savings in these categories. The "per VMT" factors of these costs were estimated by a Minnesota DOT study, [7] and used in this analysis (see the table below). Since the original study estimated these values in 2003 dollars, the values for this analysis have been updated to 2011 dollars using a CPI adjustment.[8]

[6] Energy Information Administration (Producer). (2012). Annual Energy Outlook 2012 Early Release. *Transportation Sector Key Indicators and Delivered Energy Consumption* [Microsoft Excel], http://www.eia.gov/oiaf/aeo/tablebrowser/.

[7] Minnesota Department of Transportation (2003), *The Per-mile Costs of Operating Automobiles and Trucks.* (MN/RC 2003-19), http://www.lrrb.org/pdf/200319.pdf, p.22, Table 4.2.

[8] U.S. Bureau of Labor Statistics, Consumer Price Index, All Urban Consumers, U.S. City Average, All Items, Series CUSR0000SA0.

**Table 10. Non-fuel Operating Cost Assumptions**

| Operating Cost Category | Cost per Vehicle-mile Traveled (2011 $) |
|---|---|
| Auto - Maintenance/Repair | 3.9 cents per VMT |
| Auto – Tires | 1.1 cents per VMT |
| Auto – Depreciation | 7.6 cents per VMT |
| Truck – Maintenance / Repair | 12.8 cents per VMT |
| Truck – Tires | 4.3 cents per VMT |
| Truck – Depreciation | 9.8 cents per VMT |

*Source: Minnesota DOT, 2003.*

This analysis uses these average costs per mile values to calculate variable non-fuel vehicle operating costs.

### 3.1.4 - Reductions in the Economic Cost of Oil Imports

Fuel consumption has a cost beyond the actual operating costs and environmental costs of the consumption, and this additional cost is expressed as the economic cost of oil imports. This concept reflects two ideas: a monopsony component and a price shock component.

The monopsony component derives from the following logic; because the U.S. is such a large consumer of oil, an increase in U.S. demand for oil would lead to higher fuel prices (based on supply and demand relationships). The price shock component comes from the fact that when there is a reduction in oil supplies, this leads to higher oil prices which in turn reduces the level of U.S. economic output. As a consequence, reducing oil imports by consuming less fuel reduces the impact of these costs on the U.S. economy.

The National Highway Traffic and Safety Administration discusses this concept, and estimates that each gallon of fuel saved reduces total U.S. imports of refined fuel or crude oil by 0.95 gallons. [9]

The recommended value for NHTSA's estimate of the per-gallon cost of oil imports (both the monopsony and price shock components combined) is $0.295 per gallon (2006 $). When converted to 2011 dollars using the CPI adjustment,[10] this value is $0.329 per gallon (2011 $).

### 3.1.5 – Productivity Benefits

Productivity benefits refer to the idea that travelers are capable of being productive on the new HSR service, whereas they were incapable of the productivity while driving, and less likely to be productive when on an aircraft. For example, an automobile traveler who diverts his or her 90 minute trip to a HSR trip is now capable of using his or her laptop, making phone calls, and continue being productive on the train. While driving, conducting work would be nearly impossible; and completing work would be less likely on the plane. Thus, these productivity benefits are from in-transit productivity.

[9] National Highway Traffic and Safety Administration. (2009). Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks, Final Regulatory Impact Analysis, p.viii-22 – viii-27.

[10] U.S. Bureau of Labor Statistics, Consumer Price Index, All Urban Consumers, U.S. City Average, All Items, Series CUSR0000SA0.

It is assumed that zero percent of automobile travelers are productive in-transit; 33 percent of airline travelers are productive in-transit; and 50 percent of HSR travelers are productive in transit.

Because the number of transfers from other modes onto HSR is estimated from travel demand models, as well as total in-transit travel times, it is possible to calculate the differential in productivity time of those travelers in a world where they do not have HSR versus a world where they do.

These additional hours of traveler productivity from those users transferring to HSR service can be monetized using values of time discussed above.

### 3.1.6 – Reduction in Parking Infrastructure Needs

When automobile travelers shift to HSR, this reduces the need for parking infrastructure to meet the demands of those vehicles. Since it is estimated how many vehicle trips would transfer from automobile to HSR, the number, and value of those parking spaces can be estimated as well.

It is assumed that for every 365 vehicles taken off the road each year, one less parking space is needed somewhere to suit that vehicle. In other words, one parking space can serve one car for one day for 365 days a year.

Second, it is assumed that 50 percent of the parking demand would be in surface spaces, while the remaining 50 percent would be in structured parking.

Finally, the cost of each parking space is estimated at $300 per surface space, and $1,000 per structured space. These estimates are moderate estimates from a range provided by the Victoria Transportation Institute,[11] Given these assumptions, it is possible to then calculate the reduction in parking infrastructure needs, in dollars.

### 3.1.7 – Airline Operator Savings

As travelers shift modes from air to HSR, this has the effect of relieving congestion and reducing delay in the region's airports. As a result, operators benefit from these delay reductions. The travel demand model section provides estimates for the number of passenger trips diverted from air to HSR under the various scenarios.

Using Bureau of Transportation Statistics and Federal Aviation Administration[12] data for 2010 California departing flights, it was calculated that there were 720,732 departing flights; 72,042,237 departing passengers; and 7,681,411 minutes of delay. This translates to:

- 99.6 passengers per flight
- 10.7 minutes of delay per flight

[11] Victoria Transportation Institute (2009), *Transportation Benefit and Cost Analysis: Techniques, Estimates and Implications. 2nd Edition*. Victoria: Victoria Transportation Institute, Table 6.

[12] U.S. Bureau of Transportation Statistics (2011). *Transtats. Data Library: Aviation, Air Carrier Statistics (Form 41 Traffic) – U.S. Carriers, Airline On-Time Performance Data*, http://www.transtats.bts.gov/databases.asp?Mode_ID=1&Mode_Desc=Aviation&Subject_ID2=0.

This was used to calculate both the reduction in the number of flights due to reduced demand on the aviation system, as well as the decrease in flight delay. It was assumed that for every 99.6 passengers diverting from air to rail, one flight would be removed from the aviation system. Further, every flight on average is responsible for approximately 10.7 minutes of delay. Thus, reducing a flight reduces 10.7 minutes of delay on the airway system.

This reduced aviation flight delay (in aircraft minutes) was monetized using the standard Air Transport Association's[13] estimate of $36.09 non-fuel costs per minute of aircraft delay.

### 3.1.8 – Propagated Air Delay

Aircraft delay does not contain itself to one airport or one region; delay at a given airport is propagated across the entire system. A report by MITRE Corporation for the FAA[14] calculates propagation multipliers that in turn can be used to estimate the amount of delay incurred at other airports in the system due to delay at one airport. In 2008, for SFO, the delay propagation multiplier was 1.55; for LAX it was 1.50.

What this means is that for every 100 hours of delay at LAX, there were 150 hours of delay across the entire system. Thus, the marginal delay propagated to the rest of the system is 50 hours.

This analysis uses a delay propagation multiplier of 1.50, and applies it to the operator delay costs calculated above.

### 3.1.9 – Airline Fuel Savings

Having calculated the number of flights saved due to mode shift to HSR, airline fuel savings can also be estimated. First, consistent with the travel demand model, the average intercity trip is approximately 310 miles. FAA data also indicates that there were approximately 127 seats per flight in 2010 for California departing flights. Combined, these numbers yield the total average number of seat-miles per flight.

Using the EIA's estimate of jet fuel efficiency (seat-miles per gallon) and jet fuel costs discussed previously, both the quantity of fuel and the value of the fuel saved can be calculated.

### 3.1.10 – Air Passenger Delay

In addition to airline operators, passengers in the aviation system also experience costs of delay. When flight delay is reduced, passengers experience air passenger delay benefits.

Flight delay and flight delay savings were already calculated above. A study by NEXTOR[15] calculates passenger delay as it relates to total flight delay, and certain factors can be derived for the overall aviation system:

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[13] Air Transport Association of America (2011), *Economics: Data and Analysis. Annual and Per-minute Cost of Delays to U.S. Airlines*, http://www.airlines.org/Economics/DataAnalysis/Pages/CostofDelays.aspx.

[14] The MITRE Corporation, U.S. Federal Aviation Administration (2010), *Calculating Delay Propagation Multipliers for Benefit-Cost Analysis*. Washington: U.S. Federal Aviation Administration.

[15] National Center of Excellence for Aviation Operations Research (2010), *Total Delay Impact Study: A Comprehensive Assessment of the Costs and Impacts of Freight Delay in the United States*, Washington: U.S. Federal Aviation Administration.

- 1.06 minutes of “non-disrupted passenger” delay per minute of flight delay.
- 31.19 minutes of “disrupted passenger” delay per minute of flight delay.

In this context, “disrupted” passengers refer to those passengers who have their flights canceled or miss a connection due to flight delay. “Non-disrupted” passengers are those passengers who still make their flight and connection, but their flight is delayed and not on schedule.

Using these factors, air passenger delay can be derived from the total flight delay calculated above. This is monetized using value of time assumptions discussed previously.

## 3.2 - Safety

### 3.2.1 – Accident Cost Savings

Reductions in VMT lower the incidence of traffic accidents. The cost savings from reducing the number of accidents include direct savings (e.g., reduced personal medical expenses, lost wages, and lower individual insurance premiums) as well as significant avoided costs to society (e.g., second party medical and litigation fees, emergency response costs, incident congestion costs, and litigation costs). The value of all such benefits – both direct and societal – could also be approximated by the cost of service disruptions to other travelers, emergency response costs to the region, medical costs, litigation costs, vehicle damages, and economic productivity loss due to workers inactivity.

The state-of-the-practice in B/C analyses is to estimate accident cost savings for each of three accident types (fatal accidents, injury accidents, or property damage only accidents) using the change in highway VMT. Some studies perform more disaggregate estimates of the accident cost savings, applying different accident rates to different types of roadways (e.g., interstate, highway, arterial).

This BCA estimates the benefits associated with accident cost savings using 2009 statewide accident data reported by the California Highway Patrol (CHP).[16] The accident figures are statewide averages and represent accidents on interstate highways, state highways, county roads, and arterials. The CHP reports aggregated injury accidents, and this analysis disaggregated the injury accident rates into Maximum Injury Abbreviated Scale (MAIS) categories based on the share of nationwide accident data reported by the National Highway Traffic Safety Administration.[17] Below is the accident rate data used for this study.

Table 11. Accident Rate Assumptions

| Category | Accident Rate (per million VMT) |
|---|---|
| MAIS 6 (fatal) | 0.009486 |
| MAIS 5 (critical) | 0.001290 |
| MAIS 4 (severe) | 0.004975 |
| MAIS 3 (serious) | 0.017158 |

[16] California Highway Patrol (2010), *Statewide Integrated Traffic Records System (SWITRS), 2009 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions*, http://www.chp.ca.gov/switrs/index.html.
[17] National Highway Traffic and Safety Administration (2002*), The Economic Impact of Motor Vehicle Crashes, 2000*, Washington : National Highway Traffic Safety Administration, p. 9.

| | |
|---|---|
| MAIS 2 (moderate) | 0.059418 |
| MAIS 1 (minor) | 0.634997 |
| Property Damage Only | 0.801477 |

*Source: California Highway Patrol, 2010.*

This BCA assumes constant accident rates for the "build" and "no build" scenarios. Thus, the only accident changes would result from changes in VMT, not a structural change to the safety conditions on the roadway network.

Monetized values for fatalities, and accidents categorized on the MAIS scale are reported in the U.S. DOT's guidance for "Treatment of the Economic value of a Statistical Life."[18] Values pertaining to property damage only accidents were reported by the National Highway Traffic and Safety Administration,[19] and have subsequently been updated to 2011 dollars by the U.S. DOT.[20]

**Table 12. Value of a Statistical Life and of Accidents by MAIS Category**

| Category | Value (2011 $) |
|---|---|
| Value of a Statistical Life | $6,200,000 |
| MAIS 6 (fatal) – cost | $3,676,600 |
| MAIS 5 (critical) – cost | $1,649,200 |
| MAIS 4 (severe) – cost | $651,000 |
| MAIS 3 (serious) – cost | $291,400 |
| MAIS 2 (moderate) – cost | $18,600 |
| MAIS 1 (minor) – cost | $12,204 |
| MAIS 0 (property only) –cost | $3,790 |

*Source: U.S. Department of Transportation, 2011*

## 3.3 – Sustainability

The CA HSR project would create environmental and sustainability benefits by reducing air and noise pollution associated with automobile travel as there is a reduction in vehicle-miles travel from mode shifts. Benefits from reduced noise pollution as well as the six standard criteria pollutants are included in this analysis, including: carbon monoxide, nitrous oxide, particulate matter, sulfur dioxide, volatile organic compounds, and carbon dioxide.

### 3.3.1 Auto and Truck Emissions

Per-mile emissions rates were derived from the California Department of Transportation's California Lifecycle Benefit-Cost Analysis Tool (CAL B/C) assuming an average speed of 35 miles per hour for both

[18] Office of the Secretary of Transportation, *Treatment of the Economic Value of a Statistical Life in Departmental Analysis* (2008 revised guidance and 2011 update), (http://ostpxweb.dot.gov/policy/reports.htm)
[19] National Highway Traffic Safety Administration (2002*), The Economic Impact of Motor Vehicle Crashes, 2000*, p. 62, Table 3.
[20] U.S. Department of Transportation (2011), *Tiger Benefit-Cost Analysis (BCA) Resource Guide*, p.3. http://www.dot.gov/tiger/docs/tiger-12_bca-resourceGuide.pdf.

autos and trucks.[21] This tool provides emissions rates for exactly two different years: 2007 and 2027. In order to develop emissions rates for years within this interval as well as beyond 2028, it was necessary to use certain growth rate assumptions.

The CAL B/C documentation indicates that growth rates for CO, NOX, PM10, and VOC are exponential, so the 2007 to 2027 compound annual growth rate (CAGR) was used to interpolate and extrapolate as necessary. [22]

Growth for SOX and CO2 were shown by CAL B/C to exhibit linear growth. Thus, a linear rate is used for these two emissions categories.

Finally, after 2047, emissions rates are assumed “flat-line.” The flat-line represents both a leveling out of emissions rates, as well as a prudent observation of the uncertainty in estimating rates that far into the future.

The following tables show per-mile emissions rates in selected years:

**Table 13. Auto Emissions Rates (grams per VMT), Assuming 35 mph.**

| Emissions Type | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| CO | 3.1354 | 1.7193 | 0.8818 | 0.4523 | 0.3030 |
| NOX | 0.3128 | 0.1536 | 0.0697 | 0.0316 | 0.0197 |
| PM | 0.0346 | 0.0354 | 0.0363 | 0.0372 | 0.0378 |
| SOX | 0.0040 | 0.0039 | 0.0038 | 0.0037 | 0.0036 |
| VOC | 0.2554 | 0.1520 | 0.0854 | 0.0480 | 0.0339 |
| CO2 | 386.9 | 384.0 | 380.7 | 377.5 | 375.6 |

*Source: California Department of Transportation, 2011; Parsons Brinckerhoff*

[21] California Department of Transportation (2010) California Life-cycle Benefit/Cost Analysis Model v4.1 [Microsoft Excel]. http://www.dot.ca.gov/hq/tpp/offices/eab/benefit_files/Cal-BCv4-1.xls

[22] California Department of Transportation. (2009). California Life-cycle Benefit/Cost Analysis Model, Technical Supplement to User's Guide (Vol. 3). Sacramento: California Department of Transportation.

Table 14. Truck Emissions Rates (grams per VMT), Assuming 35 mph.

| Emissions Type | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| CO | 4.3010 | 2.2250 | 1.0698 | 0.5143 | 0.3315 |
| NOX | 8.3562 | 4.1628 | 1.9193 | 0.8849 | 0.5561 |
| PM | 0.3378 | 0.1827 | 0.0923 | 0.0466 | 0.0310 |
| SOX | 0.0131 | 0.0133 | 0.0135 | 0.0137 | 0.0138 |
| VOC | 0.7999 | 0.4736 | 0.2645 | 0.1477 | 0.1042 |
| CO2 | 1,358 | 1,379 | 1,403 | 1,427 | 1,442 |

*Source: California Department of Transportation, 2011; Parsons Brinckerhoff*

The value of non-CO2 emissions was derived from the National Highway Traffic and Safety Administration's CAFE standards for MY2012-MY2016.[23] As these values were reported in 2007 dollars, this analysis converted them into real 2011 dollars using a CPI deflator.[24] The resulting values are shown in the table below.

Table 15. Cost of Emissions per Ton

| Emissions Type | Emissions Costs (2011 $ per metric ton) |
|---|---|
| NOX | $ 5,660 |
| PM | $ 309,697 |
| SOX | $ 33,106 |
| VOC | $ 1,389 |

*Source: California Department of Transportation, Cal B/C*

The per-ton costs of carbon emissions were derived from the Interagency Working Group on the Social Cost of Carbon[25] as well as the analysis conducted by the U.S. DOT in the Tiger Benefit –Cost Analysis Resource Guide.[26] The values used for this analysis were discounted at a 3 percent rate as recommended by the U.S. DOT.

[23] National Highway Traffic and Safety Administration (March 2010), *Corporate Average Fuel Economy for MY2012-MY2016 Passenger Cars and Light Trucks*, http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf, page 403, Table VIII-8.

[24] Bureau of Labor Statistics, Consumer Price Index, All Urban Consumers, U.S. City Average, All Items, Series CUSR0000SA0.

[25] U.S. Environmental Protection Agency, Interagency Working Group on Social Cost of Carbon (2010), *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf, p.2., Table 19,

[26] U.S. Department of Transportation, *Tiger Benefit-Cost Analysis (BCA) Resource Guide*, http://www.dot.gov/tiger/docs/tiger-12_bca-resourceGuide.pdf, p.6.

Next the social cost of carbon was converted from 2007 dollars to 2011 dollars using a CPI adjustment.[27] Finally, values beyond year 2050 were extrapolated using the compound annual growth rate (CAGR) from 2040 to 2050. The table below shows the social cost of carbon for selected years as used in this analysis.

**Table 16. Social Cost of Carbon at 3 percent Discounting (2011 $)**

| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Social Cost of CO2 | $23.76 | $28.53 | $38.58 | $42.53 | $48.71 |

*Source: U.S. EPA, 2010; Parsons Brinckerhoff*

### 3.3.2 Auto Noise Pollution

By reducing VMT, there are environmental benefits to society in the form of noise reduction. On a per-VMT basis, these values were estimated based on a Federal Highway Administration cost allocation study report.[28]

An urban/rural split of 50/50 percent was used to create a weighted average of the FHWA values for those environments. When calculating the impact of truck, a conservative estimate was made by employing the values for 40 kip 4-axle single unit trucks to all trucks. All values were adjusted from the study's 2000 values to 2011 dollars using a CPI adjustment.[29]

For automobiles, the per-mile cost of noise was calculated as 0.12 cents per VMT. For trucks, this value was estimated at 1.96 cents per VMT.

### 3.3.3 Aviation Emissions Savings

The quantity of fuel saved in the aviation system due to HSR mode-shifts was previously quantified to calculate fuel savings. That same quantity of fuel saved can subsequently be converted into emissions to calculate the aviation emissions savings that result from CA HSR. The following emissions factors for aviation, published by the United Nations[30], allow the flight and fuel savings to be converted into emissions:

[27] U.S. Bureau of Labor Statistics. Consumer Price Index, All Urban Consumers, U.S. City Average, Motor Fuel. Series CUUR0000SETB. 1982-1984=100, 2010=239.178; 2011=302.619.

[28] Federal Highway Administration, *Addendum to the 1007 Federal Highway Cost Allocation Study*, http://www.fhwa.dot.gov/policy/hcas/addendum.htm, Table 13.

[29] Bureau of Labor Statistics, Consumer Price Index, All Urban Consumers, U.S. City Average, All Items, Series CUSR0000SA0.

[30] Intergovernmental Panel on Climate Change (2000), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* . *Framework Convention on Climate Change*, Kanagawa, Japan : U.N. Intergovernmental Panel on Climate Change.

Table 17. Emissions Factors for Aviation, Average Aircraft Takeoff/Landing Cycle and Cruising

| Emission Type | Emissions per takeoff/landing cycle (kg / flight) | Emissions during cruising (kg / ton fuel) |
|---|---|---|
| **SO2** | 0.80 | 1.00 |
| **CO** | 8.10 | 7.00 |
| **CO2** | 2680 | 3150 |
| **NOX** | 10.2 | 11.0 |
| **VOC** | 2.60 | 0.70 |

*Source: United Nations Intergovernmental Panel on Climate Change, 2000.*

Emissions from takeoff/landing cycles refer to the fact that the process of takeoff plus the process of landing has its own unique emissions factors. This occurs on a per-flight basis. The cruising portion of the flight has emissions factors pertaining to the fuel usage, which was calculated previously. The same monetization factors used for auto emissions were used to monetize savings in aviation emissions.

# 4.0 - Economic Benefits Not Included

The following is a summary of other potential benefits that are excluded from the BCA. The ensuing discussion describes these possible benefits and explains the rationale for their exclusion.

## 4.1 - Fares

Fares are an economic transfer from users to the HSR operator. Because they are a pecuniary transfer, they represent neither an economic benefit nor an economic cost of the project. In this BCA, fares are excluded from both the benefit and O&M cost tabulations.

## 4.2 – Land Use Impacts / Land Value Impacts

This BCA does not incorporate or monetize the land use impacts that the CA HSR project may cause. Because of the improved connectivity between urban areas, and the impacts that new stations may have on their surrounding environments, it is possible that land values may change to reflect the improvements in accessibility. Furthermore, changes in travel times may influence employment and housing patterns, creating land-use impacts throughout the region. Such changes were not included in this BCA, but are discussed in the rest of the Business Plan.

## 4.3 – Improved Economic Productivity

Improved travel times and reduction in time-distances along the CA HSR corridor may create shifts in employment patterns and allow workers access to more job markets that were not previously feasible. As a result, workers may seek employment in higher output work that puts their labor to the highest and best use. This has the effect of increasing overall economic productivity in the region as workers can be gainfully employed in a broader geographic job market. Such impacts, however, were excluded from this BCA as they would require detailed labor market analysis beyond the scope of the data available. Nonetheless, such impacts are discussed in the wider economic impacts analysis in this Business Plan.

## 4.4 – Improved Service to Urban Rail Corridors

By completion of the Phase 1 Blended system, there are expected improvements in the urban corridors near Los Angeles and the Bay Area. The local regional passenger rail systems, Caltrain and Metrolink, would have improved right of ways due to the improvements that are part of CA HSR. As a result, those systems stand to benefit from improved O&M costs, and riders on those systems benefit in many of the ways that CA HSR riders benefit (travel time, vehicle O&M costs, etc). However, the travel demand modeling in this analysis only examines the impact of CA HSR. Thus, benefits accruing to Caltrain, Metrolink, and their riders are not included in this analysis.

# 5.0 - Economic Costs Included and Assumptions

In the benefit-cost analysis, the term 'cost' refers to the additional resource costs or expenditures required to implement, perpetuate, and maintain the investments associated with CA HSR.

The BCA uses project costs that have been estimated for CA HSR on an annual basis, and expressed in real 2011 dollars.

## 5.1 - Initial Project Investment Costs

Initial project investment costs include engineering and design, construction, acquisition of right-of-way, vehicles, other capital investments, and contingency factors.

The overall project capital investment costs are typically treated in one of two basic ways. The first, and most common, is to treat the project costs as up-front costs coinciding with the actual project expenditures on a pay-as-you go basis. This approach excludes financing costs from long-term borrowing as part of the investment expenditures subject to present value calculations.

An alternative approach would consider the proposed financial plan for the investments, when the plan involves long-term debt that is repaid over time with interest, and account for the financing costs as the debt is repaid. The two approaches yield essentially the same results for the discounted present value of the project investment costs.[31] As a result, the pay-as-you-go assumption is usually adopted in recognition that a detailed financial plan typically would not yet be available at the time when a BCA of project alternatives is undertaken.

To understand why debt service costs over time for financed investments equate to the same present value as up-front, pay-as-you-go investments, note that debt service amounts are expressed in nominal dollars, and calculated using a nominal interest rate that includes both real and inflationary components. Because BCAs typically account for all dollar amounts in constant dollars of a single year (e.g., 2011 dollars), it is necessary to convert the stream of debt service payments into constant dollars. However, once inflation is extracted from the nominal debt service payments, the remaining debt

[31] A small difference may result from financing costs such as the underwriter's fees which would not be part of pay-as-you-go investment.

service is simply a stream of principal repayments and real interest payments.[32] Converting this stream of real debt service payments to its present value using a real discount rate cancels out the real interest paid over time, leaving the sum of the principal payments — the original level of investment. Put another way, the long term real cost of capital for public highway investments in a relatively risk free environment is essentially equal to the real discount rate.

### 5.2 - Annual Operating and Maintenance Costs

The annual cost of operating and maintaining the proposed CA HSR are included in the analysis. Operations and maintenance activities apply to several assets, including track, rolling stock, stations, overhead, customer service, staff and other operations. Operating and maintenance costs are assumed to begin at the start of the year immediately following the completion of a sub-phase. This is consistent with benefits beginning at that time as well.

O&M costs were provided as estimates for all years, given each individual phase. The operating costs reported were the net operating costs, or the costs above and beyond the "no build" scenario, which presumes continuation of existing Amtrak San Joaquin service and its associated costs. The operating costs do not net out the operating costs of other Amtrak lines that may change service with the introduction of CA HSR. Doing so would decrease the net O&M costs for this project.

### 5.3 - Life Cycle Costs

Life cycle costs were also provided as estimates for all years, given each individual phase. These lifecycle costs reflect rehabilitation and replacement above and beyond regular O&M costs.

### 5.4 – Residual Value

Real estate is an asset that has, historically, little depreciation. In many cases, it may appreciate over time. This BCA assumes that the right of way purchases are real assets purchased by the Authority that have a zero-depreciating value over the entire analysis period. Since this analysis ends in year 2080, whatever value is remaining attributed as a one-time, one year cost-offset (or negative cost). This reflects the fact that the agency has tangible value in the real estate remaining. This offset, is however, discounted at the corresponding discount rate when calculating the benefit-cost ratio.

## 6.0 - Economic Costs Excluded

### 6.1 - Construction Delay

During the period of project construction there are expected to be some impacts on the roadway network due to construction, especially in and about urban areas. This would create additional delay on the roadway system during the period of construction, thereby offsetting against some travel time

[32] Assuming the project can secure debt with a solid credit rating such that there is no material risk component also factored into the borrowing interest rate. An interest rate premium for risk could result in a higher net present value cost for the project under debt financing than pay-as-you go. However, the use of tax-exempt debt with lower nominal interest rates than taxable debt may offset the real increase attributable to credit risk.

savings. However, the impacts are likely to be localized, and the entirety of the CA HSR project minimizes urban grade crossings. These impacts are not included in this analysis, and are assumed to be negligible in proportion to overall travel time savings.

## 7.0 - Key Benefit-Cost Evaluation Measures

There are three common benefit-cost evaluation measures, each tailored to compare benefits and costs from different perspectives.

### 7.1 Net Present Value

The benefit-cost analysis converts potential gains and losses from the proposed investment into monetary units and compares them on the basis of economic efficiency, i.e., net present value (NPV). For example, NPV = PVB (present value of benefits) - PVC (present value of costs); where:

$$PVB = \sum_{t=0}^{T} B_t / (1+ r)^t; \text{ and } PVC = \sum_{t=0}^{T} C_t / (1 + r)^t$$

Equation 1

And the NPV of a project can be represented as:

$$NPV = \sum_{t=0}^{T} (B_t - C_t)/ (1+r)^t,$$

Equation 2

where $B_t$ and $C_t$ are the benefits and costs, respectively, of a project in year t; r is the real discount rate; and T is the time horizon (evaluation period). In essence, NPV gives the magnitude of the project's economic feasibility in terms of net benefits (benefits minus costs) discounted to present values using the real discount rate assumption. Under this criterion, a scenario with an NPV greater than zero may be considered "economically feasible." The NPV provides some perspective on the overall dollar magnitude of benefits not reflected by the other two measures.

### 7.2 Economic Rate of Return

The Economic Rate of Return (ERR) is the discount rate that makes the present value of all benefits just equal to the present value of all costs, i.e., the real discount rate at which the project's NPV is zero and it's benefit-cost is unity. The ERR measures the social or economic return on investment. As an evaluation measure, it allows comparison of the proposed investment package with other similar packages and/or alternative uses of investment funds that may have different costs, different benefit flows, and/or different timing. Note that the ERR is interpreted as a real rate of return (after accounting for inflation), since the assumption is that benefits and costs are expressed in constant dollars. As such, it should not be directly compared with investment returns calculated from inflated or nominal future year dollars. In some cases, a threshold value for the ERR may be established where exceeding that threshold results in the determination of an economically justified project.

### 7.3 Benefit/Cost Ratio

The evaluation also estimates the benefit-cost ratio; where the present value of incremental benefits divided by the present value of incremental costs yields the benefit-cost ratio (B/C Ratio), i.e., B/C Ratio = PVB / PVC. In essence, the B/C Ratio expresses the relation of discounted benefits to discounted costs as a measure of the extent by which a project's benefits either exceed or fall short of their associated costs. For example, a B/C ratio of 1.5 indicates that the project generates $1.5 of benefits per $1 of cost. As such, a ratio greater than 1 is necessary for the project to be economically worthwhile (feasible). The B/C Ratio can be useful when the objective is to prioritize or rank projects or portfolios of projects with the intent to decide how to best allocate an established capital budget, assuming equivalent classification of benefits and costs.

## 8.0 – CA HSR BENEFIT-COST ANALYSIS RESULTS

### 8.1 - Results in Brief

There were two "scenarios" conducted for this analysis. They are:

- low capital cost
- high capital cost

All scenarios presume a 7 percent discount rate. The results for each scenario are outlined below in Table 18, and presume the completion of each step and the ones preceding it:

Table 18. Benefit Cost Analysis Summary Results

| Scenario | Net Present Value (NPV) | Economic Rate of Return (ERR) | Benefit Cost Ratio (B/C) |
|---|---|---|---|
| **Low Capital Costs** | | | |
| IOS South | $30.0 billion | 12.9% | 2.13 |
| Bay to Basin | $34.9 billion | 13.5% | 2.25 |
| Phase 1 Blended | $36.9 billion | 12.9% | 2.11 |
| Phase 1 Full Build | $38.4 billion | 12.6% | 2.02 |
| **High Capital Costs** | | | |
| IOS South | $20.2 billion | 11.7% | 1.88 |
| Bay to Basin | $32.0 billion | 12.2% | 1.96 |
| Phase 1 Blended | $32.3 billion | 11.7% | 1.85 |
| Phase 1 Full Build | $33.6 billion | 11.5% | 1.79 |

## 8.2 - Benefits by Category

**Table 19. Summary of Benefits and Costs, IOS South (Discounted 2011 $)**

| | Low Capital Cost | (High Capital Cost |
|---|---|---|
| **Benefits** | | |
| **Roads and Highways** | | |
| Highway User Travel Time Savings | $7,501,274,004 | $7,501,274,004 |
| Highway User Fuel Savings | $2,759,335,197 | $2,759,335,197 |
| Highway User Non-fuel O&M Savings | $1,548,410,624 | $1,548,410,624 |
| Oil Import Savings | $325,033,505 | $325,033,505 |
| Reduction in Pavement Damages | $41,474,264 | $41,474,264 |
| Highway CO2 Emissions Savings | $445,722,478 | $445,722,478 |
| Highway Non CO2 Emissions Savings | $346,355,005 | $346,355,005 |
| Noise Savings | $49,810,416 | $49,810,416 |
| Road Fatality Reductions | $1,593,688,861 | $1,593,688,861 |
| Road Injury Reductions | $1,633,531,082 | $1,633,531,082 |
| Vehicle Property Damage Reductions | $871,052 | $871,052 |
| **HSR Mode Shift Benefits** | | |
| Travel Time Savings for Auto Transfers to HSR | $11,255,183,865 | $11,255,183,865 |
| Transfers to HSR Fuel Savings | $2,427,678,062 | $2,427,678,062 |
| Transfers to HSR Non-Fuel O&M Savings | $1,745,361,099 | $1,745,361,099 |
| HSR Mode Shift reliability benefits | $4,853,248,006 | $4,853,248,006 |
| Productivity Increases from Auto Transfers to HSR | $5,627,591,933 | $5,627,591,933 |
| Reductions in Parking Infrastructure Needs | $91,979,946 | $91,979,946 |
| **Aviation Benefits** | | |
| Productivity Increases from Air Transfers to HSR | $361,376,111 | $361,376,111 |
| Operator Savings from Delay Reductions (non-fuel) | $45,855,851 | $45,855,851 |

| | Low Capital Cost | (High Capital Cost |
|---|---|---|
| Fuel Savings, aviation | $426,134,900 | $426,134,900 |
| Air System Savings from Propagated Delay | $22,927,925 | $22,927,925 |
| Air Passenger Travel Time Savings / Delay Reduction | $25,596,915 | $25,596,915 |
| Aviation CO2 Reductions | $48,324,099 | $48,324,099 |
| Aviation Non-CO2 Emissions Reductions | $68,507,425 | $68,507,425 |
| **Total Benefits** | **$43,245,272,624** | **$43,245,272,624** |
| **Costs** | | |
| Capital Costs | $17,496,220,689 | $20,281,662,451 |
| Life Cycle Costs | $106,351,046 | $106,351,046 |
| O&M Costs | $2,670,232,066 | $2,670,232,066 |
| ROW Residual Value Offset | -$13,710,036 | -$14,293,645 |
| *Subtotal Costs before ROW Offset* | $20,272,803,801 | $23,058,245,563 |
| **Grand Total Discounted Costs** | $20,259,093,766 | $23,043,951,918 |

Table 20. Summary of Benefits and Costs, Bay to Basin (Discounted 2011 $)

| | Low Capital Cost | High Capital Cost |
|---|---|---|
| **Benefits** | | |
| **Roads and Highways** | | |
| Highway User Travel Time Savings | $10,496,379,584 | $10,496,379,584 |
| Highway User Fuel Savings | $4,066,459,019 | $4,066,459,019 |
| Highway User Non-fuel O&M Savings | $2,274,962,502 | $2,274,962,502 |
| Oil Import Savings | $465,738,397 | $465,738,397 |
| Reduction in Pavement Damages | $60,878,135 | $60,878,135 |
| Highway CO2 Emissions Savings | $664,199,620 | $664,199,620 |
| Highway Non CO2 Emissions Savings | $499,186,340 | $499,186,340 |
| Noise Savings | $72,660,320 | $72,660,320 |
| Road Fatality Reductions | $2,315,885,945 | $2,315,885,945 |
| Road Injury Reductions | $2,373,783,094 | $2,373,783,094 |
| Vehicle Property Damage Reductions | $1,265,778 | $1,265,778 |
| **HSR Mode Shift Benefits** | | |
| Travel Time Savings for Auto Transfers to HSR | $15,945,664,847 | $15,945,664,847 |
| Transfers to HSR Fuel Savings | $3,494,844,357 | $3,494,844,357 |
| Transfers to HSR Non-Fuel O&M Savings | $2,509,516,008 | $2,509,516,008 |
| HSR Mode Shift reliability benefits | $7,026,279,462 | $7,026,279,462 |
| Productivity Increases from Auto Transfers to HSR | $7,972,832,424 | $7,972,832,424 |
| Reductions in Parking Infrastructure Needs | $131,212,069 | $131,212,069 |
| **Aviation Benefits** | | |
| Productivity Increases from Air Transfers to HSR | $843,354,662 | $843,354,662 |
| Operator Savings from Delay Reductions (non-fuel) | $107,015,224 | $107,015,224 |
| Fuel Savings, aviation | $1,026,862,712 | $1,026,862,712 |
| Air System Savings from Propagated Delay | $53,507,612 | $53,507,612 |

| | Low Capital Cost | High Capital Cost |
|---|---|---|
| Air Passenger Travel Time Savings / Delay Reduction | $59,736,315 | $59,736,315 |
| Aviation CO2 Reductions | $116,911,614 | $116,911,614 |
| Aviation Non-CO2 Emissions Reductions | $159,034,184 | $159,034,184 |
| **Total Benefits** | **$62,738,170,225** | **$62,738,170,225** |
| **Costs** | | |
| Capital Costs | $23,769,496,937 | $27,953,769,556 |
| Life Cycle Costs | $196,288,605 | $196,288,605 |
| O&M Costs | $3,905,959,414 | $3,905,959,414 |
| ROW Residual Value Offset | -$17,967,513 | -$19,173,002 |
| *Subtotal Costs before ROW Offset* | $27,871,744,957 | $32,056,017,575 |
| **Grand Total Discounted Costs** | $27,853,777,443 | $32,036,844,574 |

Table 21. Summary of Benefits and Costs, Phase 1 – Blended, (Discounted 2011 $)

| | Low Capital Cost | High Capital Cost |
|---|---|---|
| **Benefits** | | |
| **Roads and Highways** | | |
| Highway User Travel Time Savings | $11,698,175,896 | $11,698,175,896 |
| Highway User Fuel Savings | $4,506,002,365 | $4,506,002,365 |
| Highway User Non-fuel O&M Savings | $2,517,897,454 | $2,517,897,454 |
| Oil Import Savings | $512,184,360 | $512,184,360 |
| Reduction in Pavement Damages | $67,369,122 | $67,369,122 |
| Highway CO2 Emissions Savings | $739,682,624 | $739,682,624 |
| Highway Non CO2 Emissions Savings | $550,132,012 | $550,132,012 |
| Noise Savings | $80,327,889 | $80,327,889 |
| Road Fatality Reductions | $2,558,703,516 | $2,558,703,516 |
| Road Injury Reductions | $2,622,671,103 | $2,622,671,103 |
| Vehicle Property Damage Reductions | $1,398,493 | $1,398,493 |
| **HSR Mode Shift Benefits** | | |
| Travel Time Savings for Auto Transfers to HSR | $17,967,990,289 | $17,967,990,289 |
| Transfers to HSR Fuel Savings | $3,857,043,357 | $3,857,043,357 |
| Transfers to HSR Non-Fuel O&M Savings | $2,767,890,384 | $2,767,890,384 |
| HSR Mode Shift reliability benefits | $7,895,446,713 | $7,895,446,713 |
| Productivity Increases from Auto Transfers to HSR | $8,983,995,145 | $8,983,995,145 |
| Reductions in Parking Infrastructure Needs | $162,222,146 | $162,222,146 |
| **Aviation Benefits** | | |
| Productivity Increases from Air Transfers to HSR | $959,923,323 | $959,923,323 |
| Operator Savings from Delay Reductions (non-fuel) | $121,806,891 | $121,806,891 |
| Fuel Savings, aviation | $1,175,872,400 | $1,175,872,400 |
| Air System Savings from Propagated Delay | $60,903,446 | $60,903,446 |

| | Low Capital Cost | High Capital Cost |
|---|---|---|
| Air Passenger Travel Time Savings / Delay Reduction | $67,993,081 | $67,993,081 |
| Aviation CO2 Reductions | $133,874,919 | $133,874,919 |
| Aviation Non-CO2 Emissions Reductions | $180,848,423 | $180,848,423 |
| **Total Benefits** | **$70,190,355,350** | **$70,190,355,350** |
| **Costs** | | |
| Capital Costs | $28,840,533,543 | $33,502,031,881 |
| Life Cycle Costs | $207,015,999 | $207,015,999 |
| O&M Costs | $4,244,421,099 | $4,244,421,099 |
| ROW Residual Value Offset | -$30,644,273 | -$36,748,253 |
| *Subtotal Costs before ROW Offset* | *$33,291,970,642* | *$37,953,468,980* |
| **Grand Total Discounted Costs** | **$33,261,326,368** | **$37,916,720,727** |

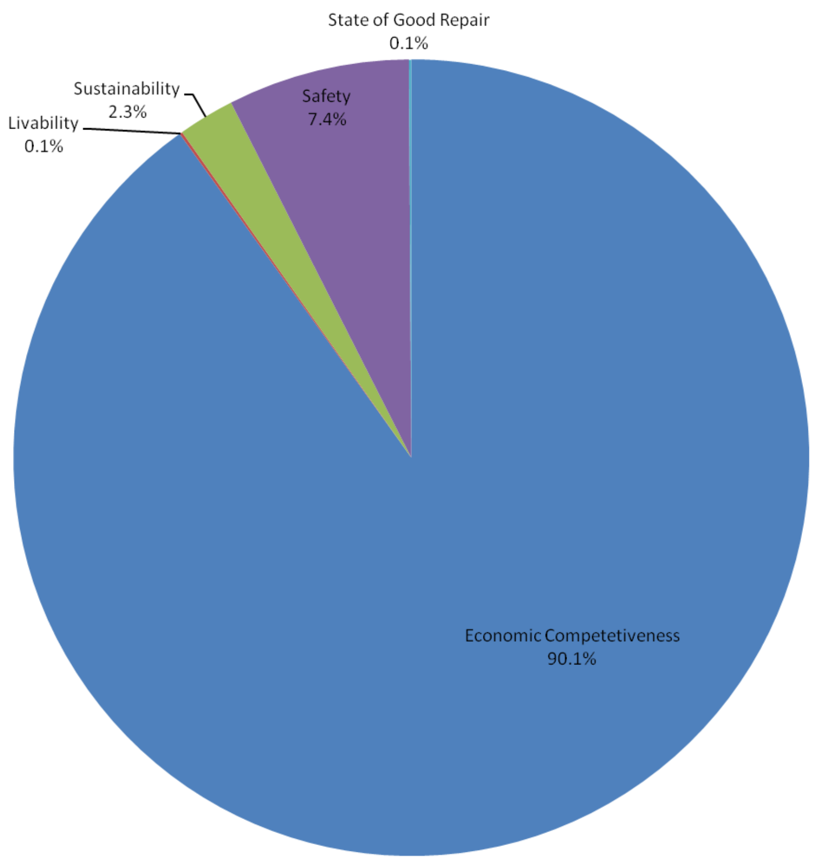
Table 22. Summary of Benefits and Costs, Phase 1 – Blended, (Discounted 2011 $)

| | Low Capital Cost | High Capital Cost |
|---|---|---|
| **Benefits** | | |
| **Roads and Highways** | | |
| Highway User Travel Time Savings | $12,637,002,565 | $12,637,002,565 |
| Highway User Fuel Savings | $4,849,437,577 | $4,849,437,577 |
| Highway User Non-fuel O&M Savings | $2,703,676,654 | $2,703,676,654 |
| Oil Import Savings | $546,375,512 | $546,375,512 |
| Reduction in Pavement Damages | $72,336,834 | $72,336,834 |
| Highway CO2 Emissions Savings | $801,848,813 | $801,848,813 |
| Highway Non CO2 Emissions Savings | $588,876,651 | $588,876,651 |
| Noise Savings | $86,227,062 | $86,227,062 |
| Road Fatality Reductions | $2,746,136,102 | $2,746,136,102 |
| Road Injury Reductions | $2,814,789,505 | $2,814,789,505 |
| Vehicle Property Damage Reductions | $1,500,937 | $1,500,937 |
| **HSR Mode Shift Benefits** | | |
| Travel Time Savings for Auto Transfers to HSR | $19,616,938,954 | $19,616,938,954 |
| Transfers to HSR Fuel Savings | $4,144,335,229 | $4,144,335,229 |
| Transfers to HSR Non-Fuel O&M Savings | $2,969,208,660 | $2,969,208,660 |
| HSR Mode Shift reliability benefits | $8,597,748,249 | $8,597,748,249 |
| Productivity Increases from Auto Transfers to HSR | $9,808,469,477 | $9,808,469,477 |
| Reductions in Parking Infrastructure Needs | $195,167,003 | $195,167,003 |
| **Aviation Benefits** | | |
| Productivity Increases from Air Transfers to HSR | $1,041,750,369 | $1,041,750,369 |
| Operator Savings from Delay Reductions (non-fuel) | $132,190,115 | $132,190,115 |
| Fuel Savings, aviation | $1,288,448,470 | $1,288,448,470 |
| Air System Savings from Propagated Delay | $66,095,057 | $66,095,057 |

| | Low Capital Cost | High Capital Cost |
|---|---|---|
| Air Passenger Travel Time Savings / Delay Reduction | $73,789,037 | $73,789,037 |
| Aviation CO2 Reductions | $146,431,414 | $146,431,414 |
| Aviation Non-CO2 Emissions Reductions | $196,032,126 | $196,032,126 |
| **Total Benefits** | **$76,124,812,372** | **$76,124,812,372** |
| **Costs** | | |
| Capital Costs | $32,875,187,507 | $37,638,769,229 |
| Life Cycle Costs | $270,344,550 | $270,344,550 |
| O&M Costs | $4,636,282,770 | $4,636,282,770 |
| ROW Residual Value Offset | -$45,578,932 | -$45,712,875 |
| *Subtotal Costs before ROW Offset* | $37,781,814,827 | *$42,545,396,549* |
| **Grand Total Discounted Costs** | $37,736,235,896 | **$42,499,683,674** |

Approximately 90.1 percent of all CA HSR Phase 1 Blended benefits are attributable to economic competitiveness. Safety is the next largest category at 7.4 percent, and the remaining three categories comprise less than 3 percent. While the absolute numbers change across scenarios, the proportion by category remains almost identical across both scenarios. The (discounted) present values of benefits that were quantified are shown in Figure 1.

**Figure 1. Benefit Shares by DOT Category – Discounted Present Value (2011 $), All Scenarios (approximate)**




## 8.3 - Costs over Time

Figure 2 to Figure 3 present the capital expenditures over time, expressed in constant 2011 dollars before present value discounting.

**Figure 2. Capital and Rehabilitation Expenditures in 2011 Dollars before Present Value Discounting, Phase 1 Blended, Low Cost**

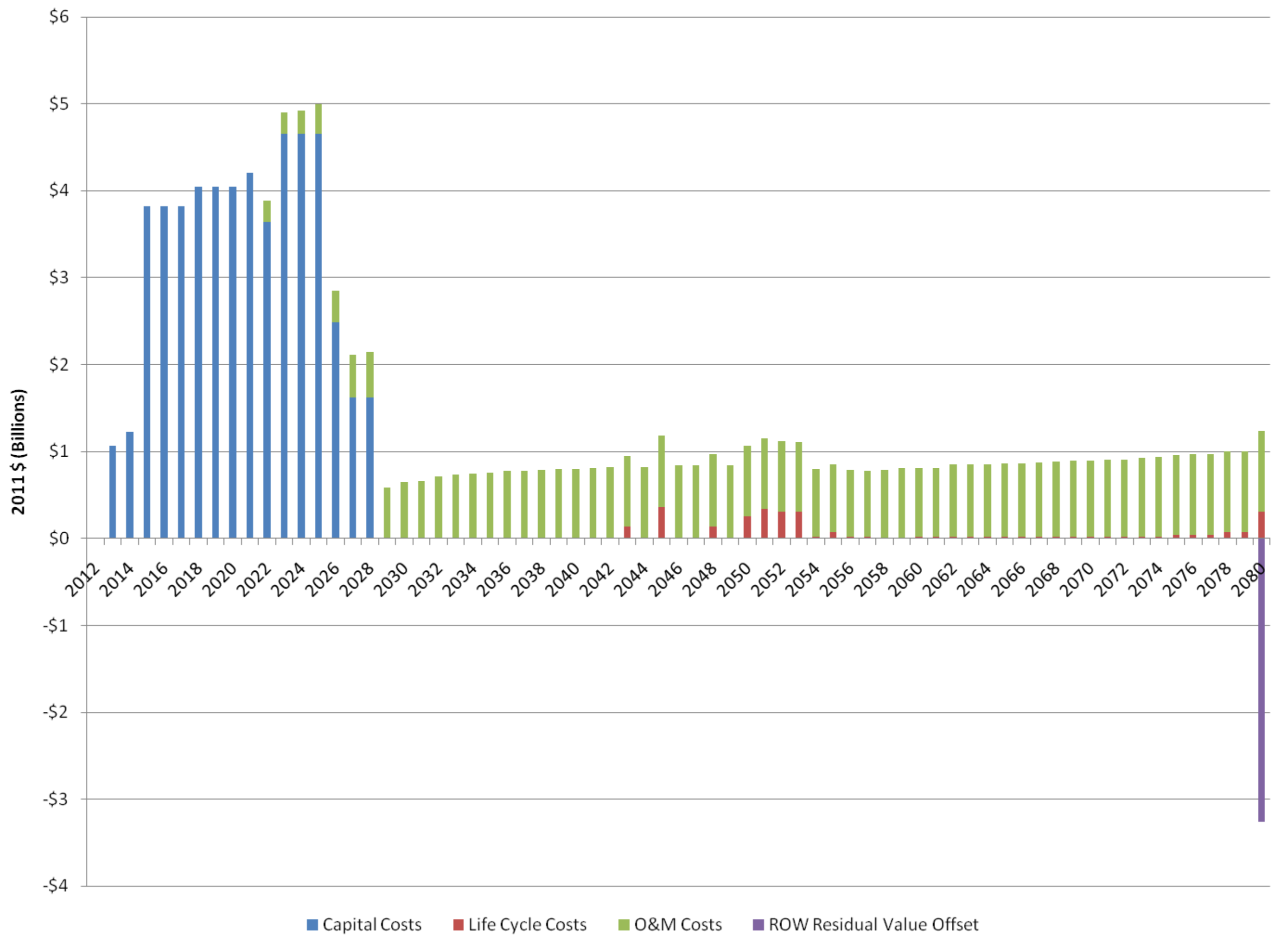
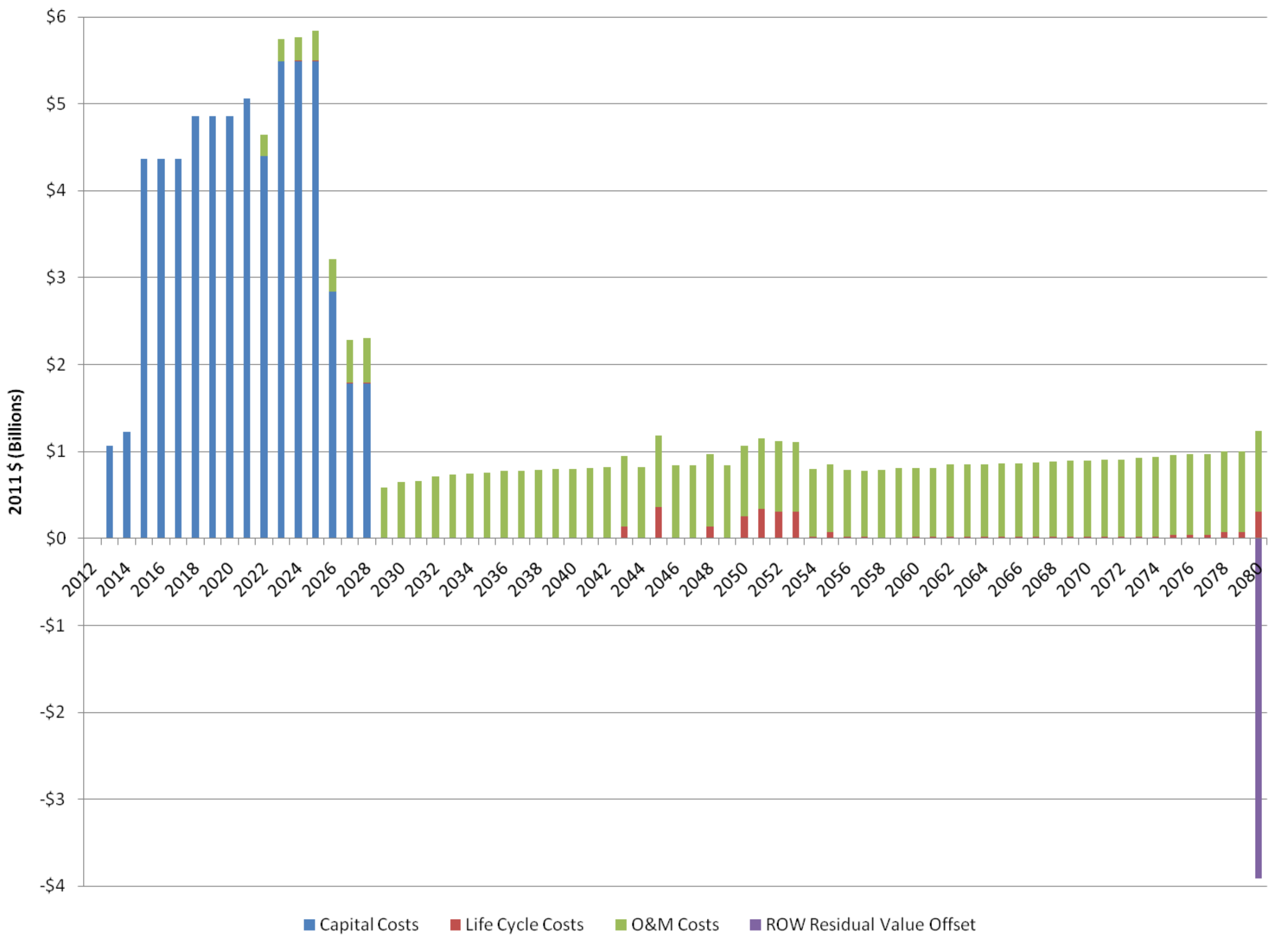


**Figure 3. Capital and Rehabilitation Expenditures in 2011 Dollars before Present Value Discounting, Phase 1 Blended, High Cost**




## 8.4 Cumulative Benefits and Costs

Figure 4 and Figure 5 present cumulative present value of benefits with the cumulative present value of costs over time for the two scenarios for Phase 1 Blended. These discounted benefits and costs show at which point the benefits exceed costs. For the four scenarios, they are as follows:

- Low Capital Cost: between 2032 and 2033
- High Capital Cost: between 2034 and 2035

**Figure 4. Cumulative Benefits and Costs in 2011 Dollars (Discounted at 7 percent), Phase 1 Blended, Low Cost**

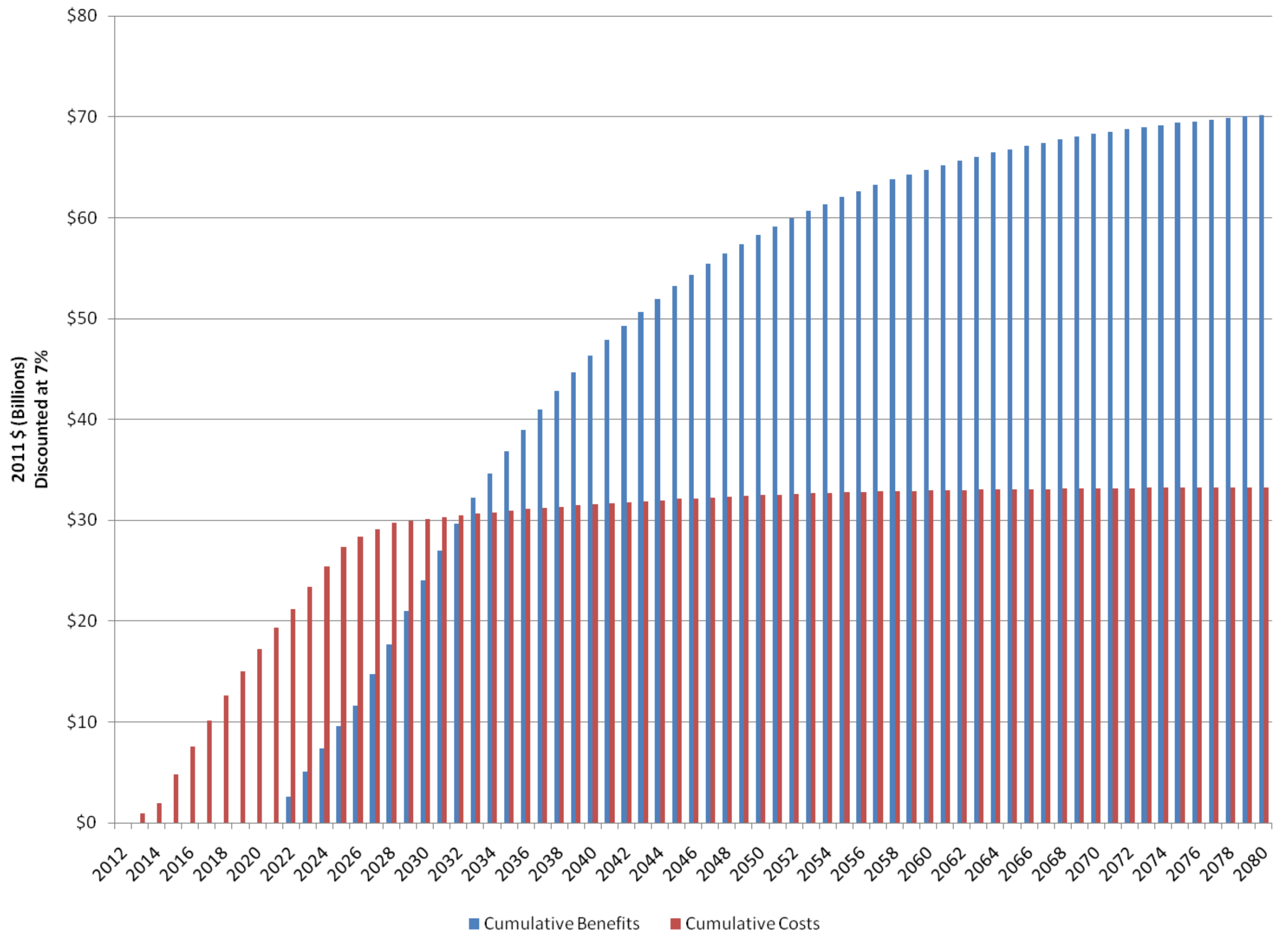
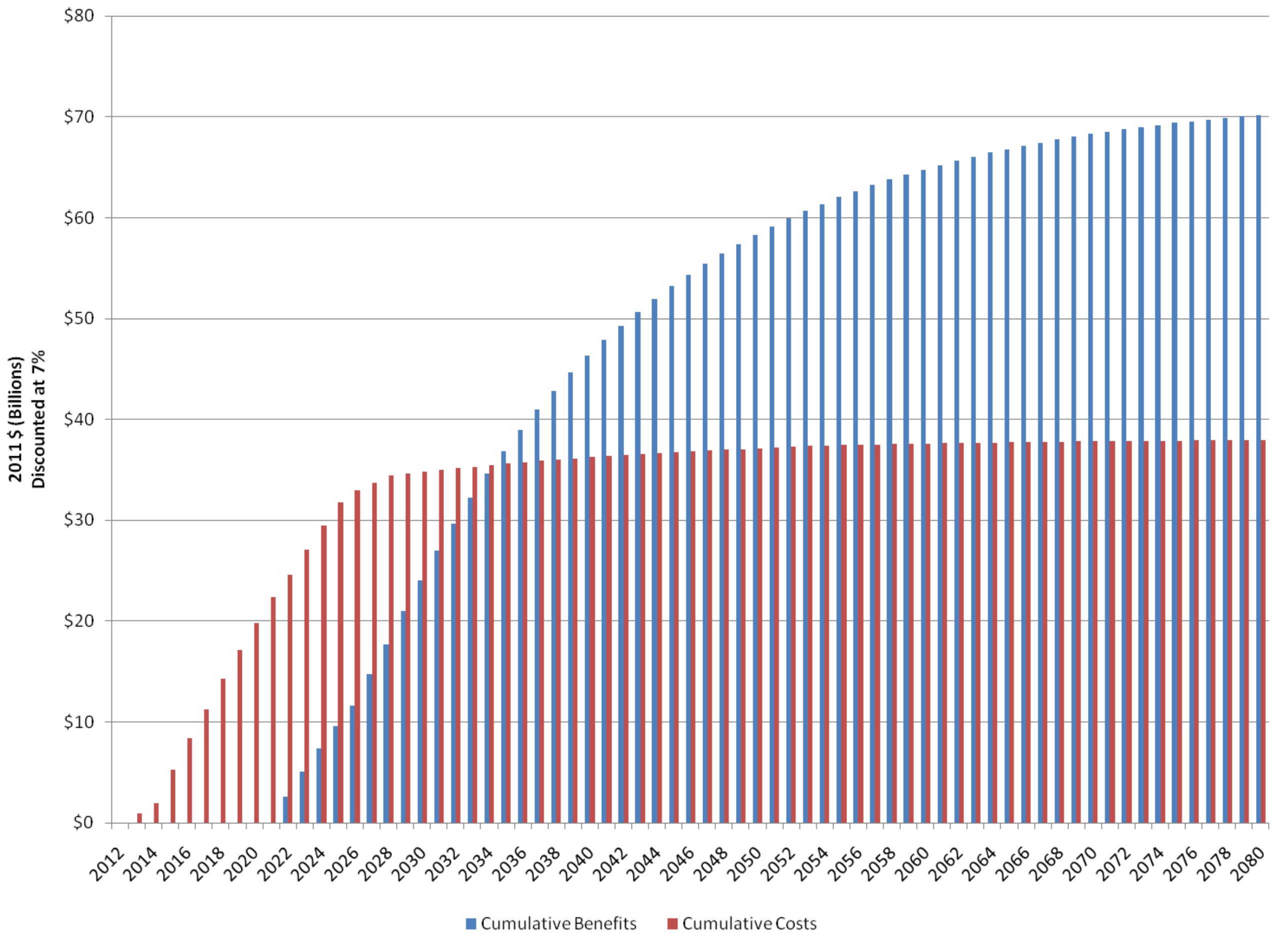


Figure 5. Cumulative Benefits and Costs in 2011 Dollars (Discounted at 7 percent), Phase 1 Blended, High Cost




## 9.0 Conclusion

This analysis shows that the anticipated quantifiable benefits from the CA HSR project exceed their anticipated costs regardless of the phasing or the high/low cost scenarios presented. It is important to note this analysis does not include all of the potential benefits that HSR investments would contribute to the region. The value of providing a transportation service that is the first of its kind in the United States, in one of America's most populous states, is a substantial structural change to the transportation and land use system that would bring economic benefits for the future.