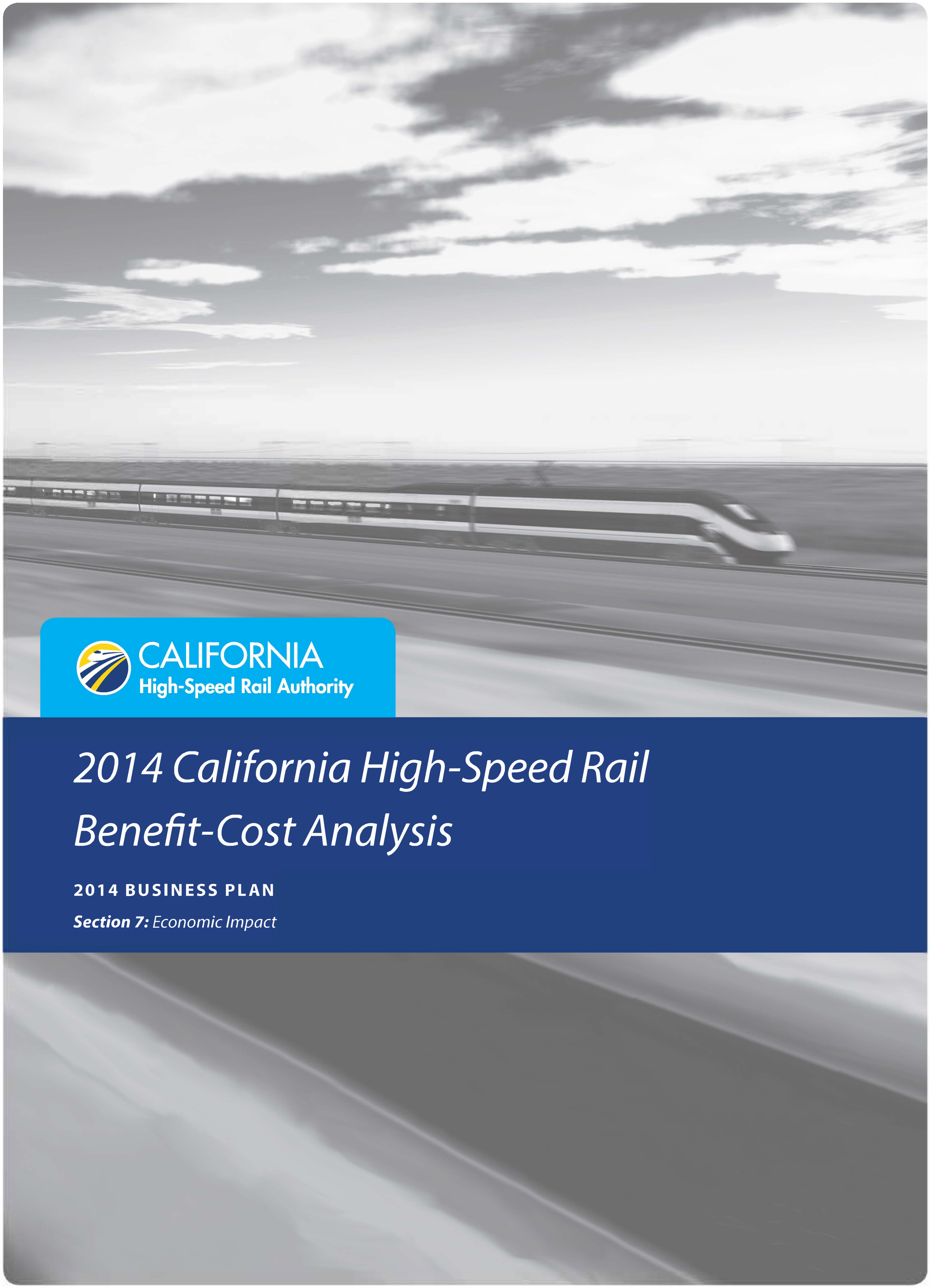

CALIFORNIA
High-Speed Rail Authority

2014 California High-Speed Rail Benefit-Cost Analysis

2014 BUSINESS PLAN

Section 7: *Economic Impact*

California High-Speed Rail System

2014 BUSINESS PLAN
TECHNICAL SUPPORTING DOCUMENT

2014 California High-Speed Rail Benefit-Cost Analysis

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for the California High-Speed Rail Authority

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1 Introduction

This report is an economic benefit-cost analysis (BCA) of each phase of the California High Speed Rail System (CAHSR) conducted for the California High Speed Rail Authority (Authority). It estimates benefits and costs for the IOS, Bay to Basin, and Phase 1 Blended as defined in the 2012 Business Plan. This analysis is an update on and expansion of the BCA conducted for the 2012 Business Plan. This analysis was completed in support of the 2014 Business Plan, and conducted in accordance with the benefit-cost methodology as recommended by USDOT in the 2013 Benefit-Cost Analysis Guidance for Tiger Grant Applicants.

2 Key Analytical Assumptions

All assumptions used in this analysis have been extensively researched and documented; they have also, where possible, been vetted by reputable sources such as academic institutions and federal agencies. With this in mind it is still important to note that changing any of these figures has the potential to impact the results. The sources for inputs that are used were selected to be most applicable for evaluating the California High-Speed Rail System. However, where available, sources of information that could be used as input other than those that are used in the analysis are also documented to show the potential variation in assumptions that may exist.

2.1 Real Discount Rate

Benefits and costs are typically valued in constant (e.g., 2013) 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 CAHSR investments, dollar figures in this analysis are expressed in constant 2013 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 the values to constant year dollars.

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 CAHSR project is 7.0 percent. This 7 percent discount rate is consistent with USDOT guidance for TIGER V grants and OMB Circular A-4 and A-94.[1]

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.

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[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.

For the CAHSR BCA, the evaluation period includes the relevant (post-design) construction period during which capital expenditures are undertaken through 2071. For the purposes of this study, there were three 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 2071, which is 50 years beyond project completion for the scenario with the shortest construction period.

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

2.3 Project Region and Phasing

The geographic coverage of this CAHSR 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 CAHSR project, comprised of various steps:

- Initial Operating Segment
- Bay to Basin
- Phase 1 Blended

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. 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 Implementation Steps

Implementation Step	Operations Start Year
IOS	2022
Bay to Basin	2027
Phase 1 Blended	2029

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 almost entirely 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 was able to isolate the impacts of the CAHSR project on existing travelers on the network, as well as changes due to users switching from auto and air to HSR.

These model estimates were provided for year the first year of operations for each scenario as well as one further date. Table 2 shows the travel demand model results for the various forecast years. For extrapolation purposes the rate at which the ridership level is forecast to grow is applied. 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

	2022	2027	2029	2040
VMT (Annual)				
No Build	213,909,100,342	223,506,929,552	225,933,161,842	245,507,122.362
IOS	212,453,822,748	221,883,496,756	224,244,599,363	243,482,334,087
Bay to Basin		221,046,623,431	223,374,151,983	242,438,563,565
Phase 1 Blended			222,787,456,577	241,735,045,689
VHT (Annual)				
No Build	5,234,295,681	5,400,188,956	5,433,393,553	5,741,497,445
IOS	5,208,934,780	5,371,897,639	5,403,967,231	5,706,211,767
Bay to Basin		5,356,903,705	5,388,371,764	5,687,510,937
Phase 1 Blended			5,376,780,332	5,673,611,425

Source: Cambridge Systematics, 2013

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.

Table 3. VMT and VHT Savings on California Highways and Roads, Cumulative by Phase, Selected Years

	2022	2030	2040	2060
VMT Savings (Annual)				
IOS	582,11,1038	1,716,668,552	2,024,788,275	2,470,626,486
Bay to Basin		2,468,864,150	3,068,558,797	3,744,224,882
Phase 1 Blended		2,796,917,638	3,772,076,673	4,602,650,386
VHT Savings (Annual)				
IOS	10,144,361	29,916,122	35,285,678	43,055,233
Bay to Basin		43,392,918	53,986,508	65,873,799
Phase 1 Blended		49,874,322	67,886,020	82,833,845

Source: Cambridge Systematics, 2013

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 in Table 4 for each phase for select years. In this table, ridership indicates the total ridership expected should the selected phase be built out. Table 5 shows the estimated number of person trips that are diverted from auto to the HSR system. Table 6 shows the number of riders diverting from the air system.

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

Table 4. Total CAHSR Ridership for Selected Phases and Years

	2022	2030	2040	2060
IOS	4,571,200	13,480,650	15,900,252	19,401,329
Bay to Basin		19,385,436	24,093,920	29,399,161
Phase 1 Blended		24,405,522	34,859,604	42,535,342

Source: Cambridge Systematics, 2013

Table 5. Person Trips Diverted from Auto to CAHSR for Selected Phases and Years

	2022	2030	2040	2060
IOS	3,670,719	10,825,095	12,768,059	15,579,459
Bay to Basin		15,557,390	19,334,742	23,592,060
Phase 1 Blended		19,236,783	27,225,280	33,220,015

Source: Cambridge Systematics, 2013

Table 6. CAHSR Ridership Diverted From Air for Selected Phases and Years

	2022	2030	2040	2060
IOS	229,366	676,409	797,816	973,487
Bay to Basin		1,235,265	1,573,301	1,738,334 1,919,727
Phase 1 Blended		1,453,102	2,040,458	2,254,493 2,489,746

Source: Cambridge Systematics, 2013

3 Economic Benefits Included

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

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 USDOT recommended values. Historically, wages and salaries have increased, on average, at a higher annual rate than general price inflation. Therefore, USDOT allows for 1.6 percent annual growth in the value of time; this analysis does the same (see Table 7).[3]

Table 7. USDOT Recommended Values of Time Used in Analysis (2013 $)

Passenger Type	Value of Time 2013	Value of Time 2030	Value of Time 2040	Value of Time 2060
Non-HSR Surface Travel, Intercity	$19.66	$26.16	$30.66	$41.12
Air and HSR Travel, Intercity	$48.88	$64.02	$75.03	$103.06
Truck Driver Value of Time	$26.82	$35.69	$41.83	$57.46

Source: USDOT, 2013

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 CAHSR. 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.

[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.

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 (Table 8).[4]

Table 8. 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, and assuming the 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 CAHSR 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.

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

3.1.3.1 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 2011 dollars by the EIA. These dollar amounts were subsequently converted to real 2013 dollars using the U.S. Bureau of Labor Statistics Consumer Price Index adjustment for "motor fuel" between 2011 and 2013.

Because fuel taxes are considered a pecuniary benefit, or transfer payment, they 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.

Table 9 provides the fuel price, in real 2013 dollars, for selected years.

Table 9. U.S. EIA Fuel Prices, Real 2013 Dollars

Fuel Type	2011	2020	2030	2040	2050
Motor Gasoline	$3.12	$3.21	$3.83	$4.58	$5.47
Diesel	$3.01	$2.93	$3.30	$3.97	$4.78
Jet Fuel	$2.96	$2.83	$3.45	$4.14	$4.97

Source: U.S. EIA; Parsons Brinckerhoff

[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/

Fuel efficiency figures were similarly derived from the U.S. EIA Annual Energy Outlook (Table 10).[6]

Table 10. U.S. EIA Fuel Efficiency

Vehicle Type	2011	2020	2030	2040	2050
Automobile, Light Duty Stock (miles per gallon)	20.50	24.08	31.33	36.10	41.60
Truck, Freight Truck (miles per gallon)	6.67	7.33	7.98	8.15	8.33
Aircraft (seat-miles per gallon)	62.30	63.86	67.00	71.52	76.35

Source: U.S. EIA; Parsons Brinckerhoff

3.1.3.2 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 (Table 11). Since the original study estimated these values in 2003 dollars, the values for this analysis have been updated to 2013 dollars using a CPI adjustment.[8]

Table 11. Non-fuel Operating Cost Assumptions

Operating Cost Category	Cost per Vehicle-mile Traveled (2013 $)
Auto—Maintenance/Repair	4.8 cents per VMT
Auto—Tires	1.1 cents per VMT
Auto—Depreciation	9.4 cents per VMT
Truck—Maintenance/Repair	15.3 cents per VMT
Truck—Tires	4.4 cents per VMT
Truck—Depreciation	11.7 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

[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.

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 2013 dollars using the CPI adjustment,[10] this value is $0.340 per gallon.

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 continuing 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.

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 in 2010 dollars, the values for this analysis have been updated to 2032 dollars, $321 and $1,068

[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.

respectively, using a CPI adjustment.[11]These estimates are moderate estimates from a range provided by the Victoria Transportation Institute,[12] 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[13] 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

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[14] estimate of $38.56 (2012 $) 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[15] 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.

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

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

[13] 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.

[14] 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.

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

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 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[16] calculates passenger delay as it relates to total flight delay, and certain factors can be derived for the overall aviation system:

- 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.

3.1.11 Agricultural Productivity Loss

Changes in the quantity of agricultural land have the effect of reducing the productive use of that land for agriculture. From a societal perspective, acquiring land for project use can be viewed as a trade-off between the agricultural value added of the land and the benefits of the project.

The amount of agricultural value added to the economy from affected farms is a contribution to the economy. When that agricultural output is diminished as farms are lost to right of way, there is a societal loss in the form of agricultural output and associated value added.

[16] 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.

The Regional Consultants for each project environmental section provided estimates of the quantity of agricultural land being taken over the period of time for each phase of the project, shown in Table 12.

Table 12. Agricultural Land Takings for California High Speed Rail

Phase	Agricultural Land Takings During Phase (acres)
IOS	6,632
Bay to Basin	4,189
Blended	11
Total	10,832

Source: CHSRA Regional Consultant Estimates, 2013

This analysis seeks to capture the value added to the economy, which is a closer indication of the societal effect that this land has. For purposes of this analysis, the U.S. Department of Agriculture (USDA) agricultural productivity measure of "net value added" is used, a definition consistent with Organization for Economic Cooperation and Development. Net value added is the sector's contribution to the National economy and is the sum of the income from production earned by all factors-of-production, regardless of ownership.

The USDA reports that in 2011, total California agricultural net value added as $23,648,537,000.[17] Furthermore, the USDA reports that there were 25,400,000 acres of agricultural land in California in 2011.[18] Combined, these to figures give an average net value added per acre of $931.04 in 2011 dollars or $964.25 in 2013 dollars.

Finally, the value is a value for a single year. Thus, this disbenefit is experienced for the life of the project to reflect the opportunity cost of the agricultural value added no longer being experienced. As a disbenefit, it is reported as a negative value.

The Authority has worked with local jurisdictions to develop a program to acquire agricultural easements with at least a 1:1 ratio with the land that will be taken from willing sellers. The program is intended to preserve at least as much agricultural land in perpetuity as will be required for the system's right-of-way. Although there is some potential economic value from these preservation efforts, the valuation of the easement is uncertain and to avoid overestimating, any *benefits* associated with the program are not included in the benefit-cost ratio. However, the *costs* of the program are included as part of the mitigation costs.

3.1.12 Wetland Loss

Changes in the quantity of wetlands will have effects on the environment and the environmental contribution of those wetlands—this is known as ecosystem services. These services include greenhouse gas mitigation, nitrogen mitigation, and wildlife recreation value of the wetlands.

[17] U.S. Department of Agriculture. State Fact Sheets, California, Farm Financial Indicators, http://www.ers.usda.gov/data-products/state-fact-sheets/state-data.aspx?reportPath=/StateFactSheets/StateFactSheets&StateFIPS=06

[18] U.S. Department of Agriculture, *2011 State Agriculture Overview, California*, http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_CA.pdf

The wetlands being taken by the project are measured in units of acres. This information is taken directly from project-specific data provided by the Authority's Regional Consultants.

One method of valuing the cost of wetlands is identifying the mitigation costs, which to a degree reflect what society is willing to pay for wetland preservation. These values range from the tens of thousands of dollars per acre, to millions per acre, depending on the scale, scope, and specific features of a project.[19] Wetland mitigation costs exhibit significantly high variance, and they also reflect factors not pertaining to societal benefits such as right of way, acquisition, and engineering. A study by Texas A&M looks specifically at the value of wetland services through various studies and meta analysis, finding total per-acre values to be between $1,000 and $22,000 in 1990 dollars.[20]

This analysis' default values are consistent with a Duke University report by W. A. Jenkins, et. al. , which identifies three types of services that wetland ecosystems provide: greenhouse gas mitigation, nitrogen mitigation, and wildlife recreation.[21] This study was chosen because it reports values on a "per-year" basis, while other studies provide total values. Because wetland services are distributed through all years in the analysis period, it is recommended to have annualized values and studies often do not indicate the length of time associated with their total valuations.

The value used in this analysis is from the "societal value" of the wetlands as reported by Jenkins, et. al., as seen in Table 13.

Table 13. Value of Wetland Services (2008 $/ha/year)

Wetland Ecosystem Service Provided	Societal Value (2008 $/ha/year)
GHG Mitigation	$213
Nitrogen Mitigation	$1,268
Wildlife Recreation	$16
Total	$1,497

Source: Duke University, Jenkins, et. al., 2008

The values in Table 13 are initially reported in 2008 dollars, and on a per hectare basis. When converted to 2013 dollars, and on a per acre basis, this value becomes $646 per acre. Thus, a valuation of $656 per acre is used in this analysis.

Like agricultural land, this valuation is only for a single year. Thus, this disbenefit is experienced for the life of the project to reflect the opportunity cost of the wetland ecosystem services no longer being experienced. As a disbenefit, it is reported as a negative value.

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[19] WSDOT Project Mitigation Cost Case Studies. http://www.wsdot.wa.gov/NR/rdonlyres/E4C452AE-2D0E-4B0F-825F-D5AE3D93742C/0/ExecutiveSummary.pdf

[20] Woodward and Wui, 2001. The Economic Value of wetland services Meta-Analysis. Ecological Economics, 37: 257-270. http://jberg.myweb.uga.edu/docs/Woodward&Wui_ValueofWetlandsServices.pdf

[21] Jenkins, W.A., B.C. Murray, R.A. Kramer, and S.P. Faulkner. 2010. Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley. Ecological Economics, 69(15): 1051-1061.; also available at http://www.nicholas.duke.edu/ecosystemservices/msvalley/at_download/paper p. 32

Similar to the agricultural takings, the Authority also has a wetland mitigation program designed to recreate or preserve taken wetlands in other parts of the state. The wetlands that are being preserved/created are generally of higher quality than those that are taken. However, only the costs of these preservation efforts are included while the benefits are not, to avoid potentially overestimating benefits from these programs.

3.2 Safety

3.2.1 Car Crash Cost Savings

Reductions in VMT lower the incidence of traffic crashes. The cost savings from reducing the number of crashes 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 car crash cost savings for each of three car crash types (fatal crashes, injury crashes, and property damage only crashes) using the change in highway VMT. Some studies perform more disaggregate estimates of the car crash cost savings, applying different crash rates to different types of roadways (e.g., interstate, highway, arterial).

This BCA estimates the benefits associated with car crash cost savings using 2010 statewide crash data reported by the California Highway Patrol (CHP).[22] The car crash figures are statewide averages and represent crashes on interstate highways, state highways, county roads, and arterials. The CHP reports aggregated injury crashes, and this analysis disaggregated the injury crash rates into Maximum Injury Abbreviated Scale (MAIS) categories based on the share of nationwide crash data reported by the National Highway Traffic Safety Administration.[23] Table 14 describes the crash rate data used for this study.

Table 14. Car Crash Rate Assumptions

Category	Crash Rate (per million VMT)
MAIS 6 (fatal)	0.0084
MAIS 5 (critical)	0.0013
MAIS 4 (severe)	0.0048
MAIS 3 (serious)	0.0167
MAIS 2 (moderate)	0.0579
MAIS 1 (minor)	0.6190
Property Damage Only	0.7715

Source: California Highway Patrol, 2011.

[22] California Highway Patrol (2011), *Statewide Integrated Traffic Records System (SWITRS), 2010 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions*, http://www.chp.ca.gov/switrs/index.html.

[23] National Highway Traffic and Safety Administration (2002*), The Economic Impact of Motor Vehicle Crashes, 2000,* Washington : National Highway Traffic Safety Administration, p. 9.

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

Monetized values for fatalities, and crashes categorized on the MAIS scale (Table 15) are reported in USDOT's guidance for "Treatment of the Economic value of a Statistical Life."[24] Values pertaining to property damage only crashes were reported by the National Highway Traffic and Safety Administration,[25] and have subsequently been updated to 2012 dollars by USDOT.[26]

Table 15. Value of a Statistical Life and of Crashes by MAIS Category

Category	Value (2013 $)
Value of a statistical life	$9,233,293
MAIS 6 (fatal)—cost	$9,233,293
MAIS 5 (critical)—cost	$5,475,343
MAIS 4 (severe)—cost	$2,456,056
MAIS 3 (serious)—cost	$969,496
MAIS 2 (moderate)—cost	$433,965
MAIS 1 (minor)—cost	$27,700
MAIS 0 (property only)—cost	$3,476

Source: U.S. Department of Transportation, 2013

3.3 Sustainability

The CAHSR 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 (reactive organic gases)[27], and carbon dioxide.

3.3.1 Auto, Truck, and Plane Emissions

The sustainability team used the same methodology and assumptions for the 2014 business plan update as were used for the 2013 SB 2019 greenhouse gas (GHG) report to the legislature (Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels)[28]. The team calculated GHG and criteria pollutant emissions diverted through operation of high-speed rail and GHG and criteria pollutant emissions associated with consumption of electricity to run the system.

[24] Office of the Secretary of Transportation, *Treatment of the Economic Value of a Statistical Life in Departmental Analysis* (2008 revised guidance and 2013 update), (http://www.dot.gov/regulations/economic-values-used-in-analysis)

[25] National Highway Traffic Safety Administration (2002*), The Economic Impact of Motor Vehicle Crashes, 2000,* p. 62, Table 3.

[26] U.S. Department of Transportation (2013), *Tiger Benefit-Cost Analysis (BCA) Resource Guide*, p.3. http://www.dot.gov/sites/dot.gov/files/docs/BCA_OnlineSupplement_May22_2013.pdf

[27] The EPA formerly defined the regulated organic compounds in outdoor air as "Reactive Organic Gases" (ROG). This terminology clarified its meaning as being limited to reactive chemicals. However, EPA later changed that terminology to Volatile Organic Compounds (VOC). Volatile Organic Compounds (VOCs): Technical Overview

http://www.epa.gov/iaq/voc2.html

[28] Available at http://hsr.ca.gov/docs/about/legislative_affairs/HSR_Reducing_CA_GHG_Emissions_2013.pdf

The team used the following inputs:

- VMT Diverted
- Plane Trips Diverted
- Energy Use for Traction Power and Facilities
- Construction Schedule and Equipment

In addition, for this report, the Authority used the following data sets and assumptions:

- Emission factors generated through EMFAC 2011 PL (issued by the California Air Resources Board) with Pavley and low carbon fuel standard (LCFS) applied.
- VMT reductions/emissions as calculated and extrapolated from the travel demand model
- Updated power emissions from EPA's eGRID2012, Version 1.0 and ARB's statewide emission inventory data, reflecting 2009 emissions.
- Updated power emissions based on ARB grid emissions estimates for 2020
- Updated power emissions based on a solar-wind mix of energy supply for 2022-2060
- Plane emissions for each analysis year developed from the most current version of FAA's Emission and Dispersion Modeling System (EDMS), and including the full plane cycle (per ARB's Inventory) GHG emissions.
- Construction Emissions based on ARB's Off-Road emission model, construction schedule and equipment

Using the data sets, models, and assumptions above, the Authority calculated the GHG and criteria pollutant emissions reductions associated with mode shift from cars and planes to the high-speed rail system (VMT reduction and plane trip reduction) and the GHG and criteria pollutant emissions associated with the use of electricity to power operations (traction power and facilities). This methodology is consistent with the industry recommended practice for quantifying GHG emissions for transit, as well as CEQA and NEPA guidance for criteria pollutant emissions. The value of non-CO2 emissions was derived from the National Highway Traffic and Safety Administration's CAFE standards for MY2012–MY2016.[29] As these values were reported in 2007 dollars, this analysis converted them into real 2013 dollars using a CPI factor.[30] The resulting values are shown in Table 16.

[29] 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.

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

Table 16. Cost of Emissions per Ton

Emissions Type	Emissions Costs (2013$ per metric ton)
NOX	$5,862
PM10	$3,584
SOX	$33,791
VOC/ROG	$1,417

Source: National Highway Traffic and Safety Administration

The per-ton costs of carbon emissions were derived from the Interagency Working Group on the Social Cost of Carbon[31] as well as the analysis conducted by USDOT in the Tiger Benefit—Cost Analysis Resource Guide.[32] The values used for this analysis were discounted at a 3 percent rate as recommended by USDOT.

Next the social cost of carbon was converted from 2007 dollars to 2013 dollars using a CPI adjustment.[33] Finally, values beyond year 2050 were extrapolated using the compound annual growth rate (CAGR) from 2040 to 2050. Table 17 shows the social cost of carbon for selected years as used in this analysis.

Table 17. Social Cost of Carbon at 3 percent Discounting (2013 $)

	2011	2020	2030	2040	2050
Social Cost of CO2	$24.61	$29.55	$36.85	$44.04	$50.45

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.[34]

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 trucks, 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 2013 dollars using a CPI adjustment.[35]

For automobiles, the per-mile cost of noise was calculated as 0.13 cents per VMT. For trucks, this value was estimated at 2.04 cents per VMT.

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[31] 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,

[32] 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.

[33] 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.

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

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

3.3.3 Train Noise Pollution

The introduction of new trains will increase some noise pollution levels along the corridor, thus offsetting some of the auto noise pollution benefits. In order to estimate the impacts of noise, a valuation per train mile is necessary. This valuation comes from a study commissioned by the European Commission,[36] which provides externality values for different transport modes including passenger rail (Table 18).

Table 18. Unit Values for Marginal Costs of Different Network Types (€ct/vkm)

	Urban	Suburban	Rural
Passenger Train—Day	23.65	20.61	2.57
Passenger Train—Night	77.99	34.40	4.29

Source: European Commission, 2008

The values range depending on time of day and land use. On the low range, they are 2.57 euro cents per train km, and on the high end they are 77.99 euro cents per train km. This analysis, acknowledging the uncertainty of these ranges, uses the mid-point of this range of 37.71 euro cents per train km.

To convert for use in this analysis, an exchange rate of 1.38 euro per US Dollar is applied. Finally, the valuations must be converted on a per-mile basis. Thus, 37.71 euro cents per train km translates to $0.3348 per mile (2013 $).

The $0.3348 per train-mile value is applied to the train miles of the project as reported by the operations and service planning for the system. Finally, because the additional train noise is considered a disbenefit to society, it is reported as a negative value.

3.3.4 Emissions from Construction

This analysis also considers emissions from construction. Construction emissions estimates were provided by the environmental analysis teams and are reported as tons per year of construction for the period 2013-2023, these were then extrapolated through 2028 using miles of track constructed in each phase These emissions for NOX, PM, VOC, SOX, and CO2 are valued using the same values above for highway and aviation emissions in Table 16 and Table 17.

Because these are negative values to society, this category is calculated as a negative benefit, or "disbenefit."

[36] M. Maibach, et al. (2008), *Handbook on Estimation of External Cost in the Transport Sector, CE Delft Table 22 p 69*, http://ec.europa.eu/transport/themes/sustainable/doc/2008_costs_handbook.pdf

3.3.5 Tree Program Benefits

The Authority anticipates a tree planting program as part of its mitigation efforts. The ecosystem services rendered by trees planted are expected to offset the greenhouse gases associated with construction of the system. The benefits calculated include reduced greenhouse gas (GHG) levels including GHG sequestered by the trees and reductions in GHG associated with reduced energy use.

The estimates of greenhouse gas emissions (tons of CO2 equivalent) were estimated and provided by the environmental/sustainability team. These CO2 equivalent emissions are valued in this analysis at the same value for CO2 emissions from highway vehicles, as seen in Table 17 and the previous discussion on the social cost of carbon.

4 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 CAHSR 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 2012 Business Plan.

4.3 Improved Economic Productivity

Improved travel times and reduction in time-distances along the CAHSR 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 the 2012 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 CAHSR. 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 CAHSR riders benefit (travel time, vehicle O&M costs, etc). However, the travel demand modeling in this analysis only examines the impact of CAHSR. Thus, benefits accruing to Caltrain, Metrolink, and their riders are not included in this analysis.

5 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 CAHSR.

The BCA uses project costs that have been estimated for CAHSR on an annual basis, and expressed in real 2012 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, mitigation costs, 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.[37] 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 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., 2013 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 service is simply a stream of principal repayments and real interest payments.[38] 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 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 CAHSR are included in the analysis. Operations and maintenance activities apply to several assets, including maintenance of infrastructure, maintenance of rolling stock, stations operations, on-board staff, overhead and administrative staff, and

[37] 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.

[38] 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.

other operational staff and costs. 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 CAHSR. Doing so would decrease the net O&M costs for this project. The O&M costs are presented in the Business Plan

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. The lifecycle costs are presented in the Business Plan.

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 2071, whatever value is remaining is 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 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 around urban areas. This would create additional delay on the roadway system during the period of construction, thereby offsetting against some travel time savings. However, the impacts are likely to be localized, and the entirety of the CAHSR 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 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 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 CAHSR Benefit-Cost Analysis Results

8.1 Results in Brief

All scenarios presume a 7 percent discount rate. The results for each scenario are outlined in Table 19, and presume the completion of each step and the ones preceding it:

Table 19. Benefit Cost Analysis Summary Results

Scenario	Net Present Value (NPV, 2013 $)	Economic Rate of Return (ERR)	Benefit Cost Ratio (B/C)
IOS	$25,715,914,611	12.2%	2.23
Bay to Basin	$38,223,901,450	12.6%	2.35
Phase 1 Blended	$45,902,781,948	12.5%	2.33

8.2 Benefits by Category

Table 20. Summary of Benefits and Costs, IOS

Category	Discounted 2013 $
Benefits	
Roads and Highways	
Highway User Travel Time Savings	$8,890,488,343
Highway User Fuel Savings	$1,806,363,849
Highway User Non-fuel O&M Savings	$1,683,534,333
Oil Import Savings	$251,017,469
Reduction in Pavement Damages	$38,437,731
Highway CO2 Emissions Savings	$101,841.510
Highway Non CO2 Emissions Savings	$16,737,921
Noise Savings	$44,730,617
Road Fatality Reductions	$1,766,779,006
Road Injury Reductions	$1,791,513,912
Vehicle Property Damage Reductions	$665,039
HSR Mode Shift	
Travel Time Savings for Auto Transfers to HSR	$19,393,903,111
Transfers to HSR Fuel Savings	$1,508,725,285
Transfers to HSR Non-Fuel O&M Savings	$1,812,200,574
HSR Mode Shift reliability benefits	$3,116,402,253
Productivity Increases from Auto Transfers to HSR	$3,880,315,648
Reductions in Parking Infrastructure Needs	$106,023,279
Aviation	
Productivity Increases from Air Transfers to HSR	$277,261,453
Operator Savings from Delay Reductions (non-fuel)	$19,161,724
Fuel Savings, aviation	$134,623,132
Air System Savings from Propagated Delay	$9,580,862
Air Passenger Travel Time Savings/Delay Reduction	$19,638,923
Aviation CO2 Reductions	$16,694,999
Aviation Non-CO2 Emissions Reductions	$6,979,133
Other Externalities	
CO2 Reductions from Tree Program	$1,902,004
Construction Emissions Disbenefit	-$29.768,877
Train CO2 Emissions	-$8,405,607
Value of Lost Wetlands	-$22,281,282
Agricultural Productivity Loss	-$72,996,794
Train Noise Disbenefit	-$13,840,642
Total Benefits	**$46,548,228,907**
Costs	
Capital Costs	$17,832,842,345
Life Cycle Costs	$317,467,407
O&M Costs	$2,713,361,526
ROW Residual Value Offset	-$31,356,982
Subtotal Costs before ROW Offset	*$20,863,671,278*
Grand Total Discounted Costs	**$20,832,314,296**

Table 21. Summary of Benefits and Costs, Bay to Basin

Category	Discounted 2013 $
Benefits	
Roads and Highways	
Highway User Travel Time Savings	$12,719,639,873
Highway User Fuel Savings	$2,511,561,243
Highway User Non-fuel O&M Savings	$2,334,507,050
Oil Import Savings	$341,632,660
Reduction in Pavement Damages	$53,330,298
Highway CO2 Emissions Savings	$143,392,890
Highway Non CO2 Emissions Savings	$22,275,736
Noise Savings	$62,300,728
Road Fatality Reductions	$2,466,855,996
Road Injury Reductions	$2,501,391,980
Vehicle Property Damage Reductions	$928,557
HSR Mode Shift	
Travel Time Savings for Auto Transfers to HSR	$28,077,717,195
Transfers to HSR Fuel Savings	$2,090,492,967
Transfers to HSR Non-Fuel O&M Savings	$2,512,924,429
HSR Mode Shift reliability benefits	$4,450,212,735
Productivity Increases from Auto Transfers to HSR	$5,508,616,583
Reductions in Parking Infrastructure Needs	$146,102,467
Aviation	
Productivity Increases from Air Transfers to HSR	$492,299,556
Operator Savings from Delay Reductions (non-fuel)	$33,132,503
Fuel Savings, aviation	$237,611,836
Air System Savings from Propagated Delay	$16,566,252
Air Passenger Travel Time Savings/Delay Reduction	$34,870,456
Aviation CO2 Reductions	$29,699,132
Aviation Non-CO2 Emissions Reductions	$11,144,490
Other Externalities	
CO2 Reductions from Tree Program	$1,902,004
Construction Emissions Disbenefit	-$37.153,882
Train CO2 Emissions	-$11,546,257
Value of Lost Wetlands	-$32,484,945
Agricultural Productivity Loss	-$105,584,847
Train Noise Disbenefit	-$19,705,525
Total Benefits	**$66,594,634,162**
Costs	
Capital Costs	$24,249,895,896
Life Cycle Costs	$437,504,578
O&M Costs	$3,722,742,461
ROW Residual Value Offset	-$39,410,223
Subtotal Costs before ROW Offset	$28,410,142,936
Grand Total Discounted Costs	$28,370,732,712

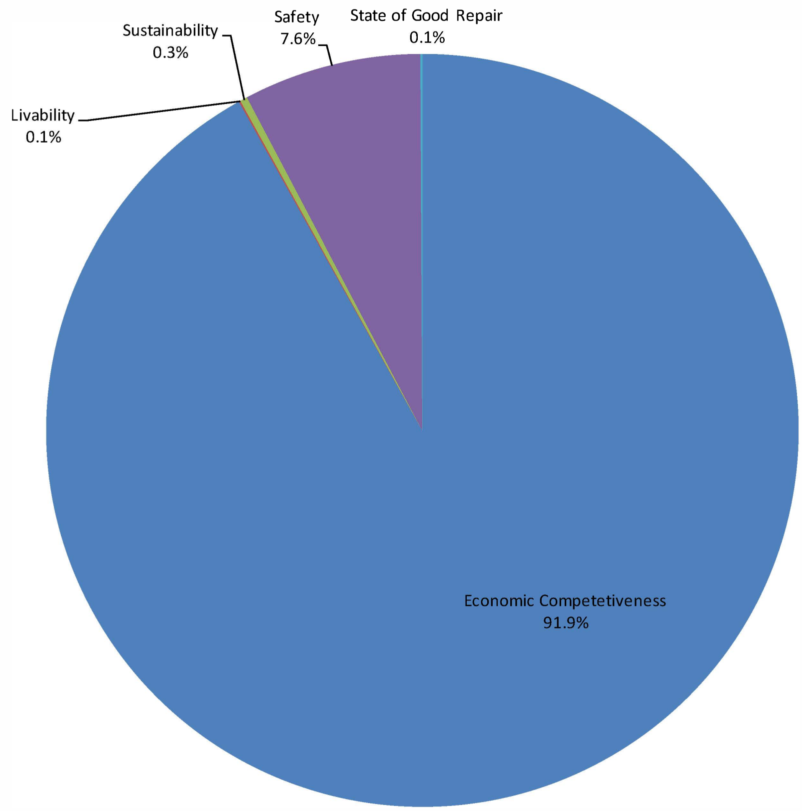
Table 22. Summary of Benefits and Costs, Phase 1—Blended

Category	Discounted 2013 $
Benefits	
Roads and Highways	
Highway User Travel Time Savings	$15,401,014,406
Highway User Fuel Savings	$2,936,841,406
Highway User Non-fuel O&M Savings	$2,723,819,341
Oil Import Savings	$394,596,282
Reduction in Pavement Damages	$62,257,511
Highway CO2 Emissions Savings	$168,794,040
Highway Non CO2 Emissions Savings	$25,423,047
Noise Savings	$72,999,171
Road Fatality Reductions	$2,897,302,893
Road Injury Reductions	$2,937,865,134
Vehicle Property Damage Reductions	$1,090,583
HSR Mode Shift	
Travel Time Savings for Auto Transfers to HSR	$34,652,801,576
Transfers to HSR Fuel Savings	$2,439,669,880
Transfers to HSR Non-Fuel O&M Savings	$2,931,990,888
HSR Mode Shift reliability benefits	$5,338,191
Productivity Increases from Auto Transfers to HSR	$6,549,859,810
Reductions in Parking Infrastructure Needs	$187,843,739
Aviation	
Productivity Increases from Air Transfers to HSR	$610, 095,403
Operator Savings from Delay Reductions (non-fuel)	$40,599,995
Fuel Savings, aviation	$293,683,807
Air System Savings from Propagated Delay	$20,299,998
Air Passenger Travel Time Savings/Delay Reduction	$43,214,146
Aviation CO2 Reductions	$36,825,157
Aviation Non-CO2 Emissions Reductions	$13,421,488
Other Externalities	
CO2 Reductions from Tree Program	$1,902,004
Construction Emissions Disbenefit	-$45,952,349
Train CO2 Emissions	-$16,550,325
Value of Lost Wetlands	-$40,493,015
Agricultural Productivity Loss	-$105,657,366
Train Noise Disbenefit	-$31,883,767
Total Benefits	**$80,541,866,770**
Costs	
Capital Costs	$29,437,155,658
Life Cycle Costs	$546,049,368
O&M Costs	$4,725,424,166
ROW Residual Value Offset	-$69,544,370
Subtotal Costs before ROW Offset	*$34,708,629,192*
Grand Total Discounted Costs	**$34,639,084,822**

Approximately 92.3 percent of all CAHSR Phase 1 Blended benefits are attributable to economic competitiveness. Safety is the next largest category at 7.2 percent, and the remaining three categories comprise less than 1 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.

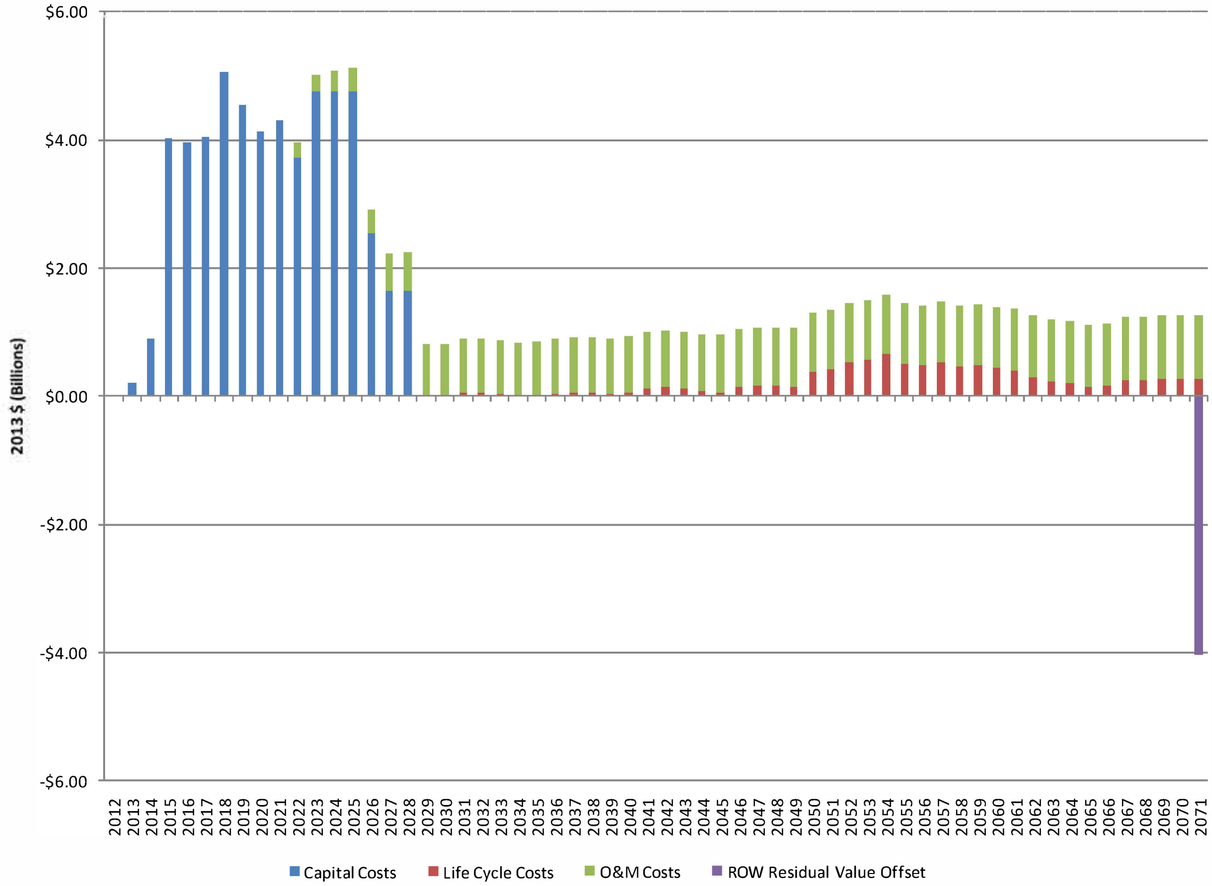
Figure 1. Benefit Shares by DOT Category—Discounted Present Value (2013 $), All Scenarios (approximate)



8.3 Costs over Time

Figure 2 presents the costs incurred over time, expressed in constant 2013 dollars before present value discounting.

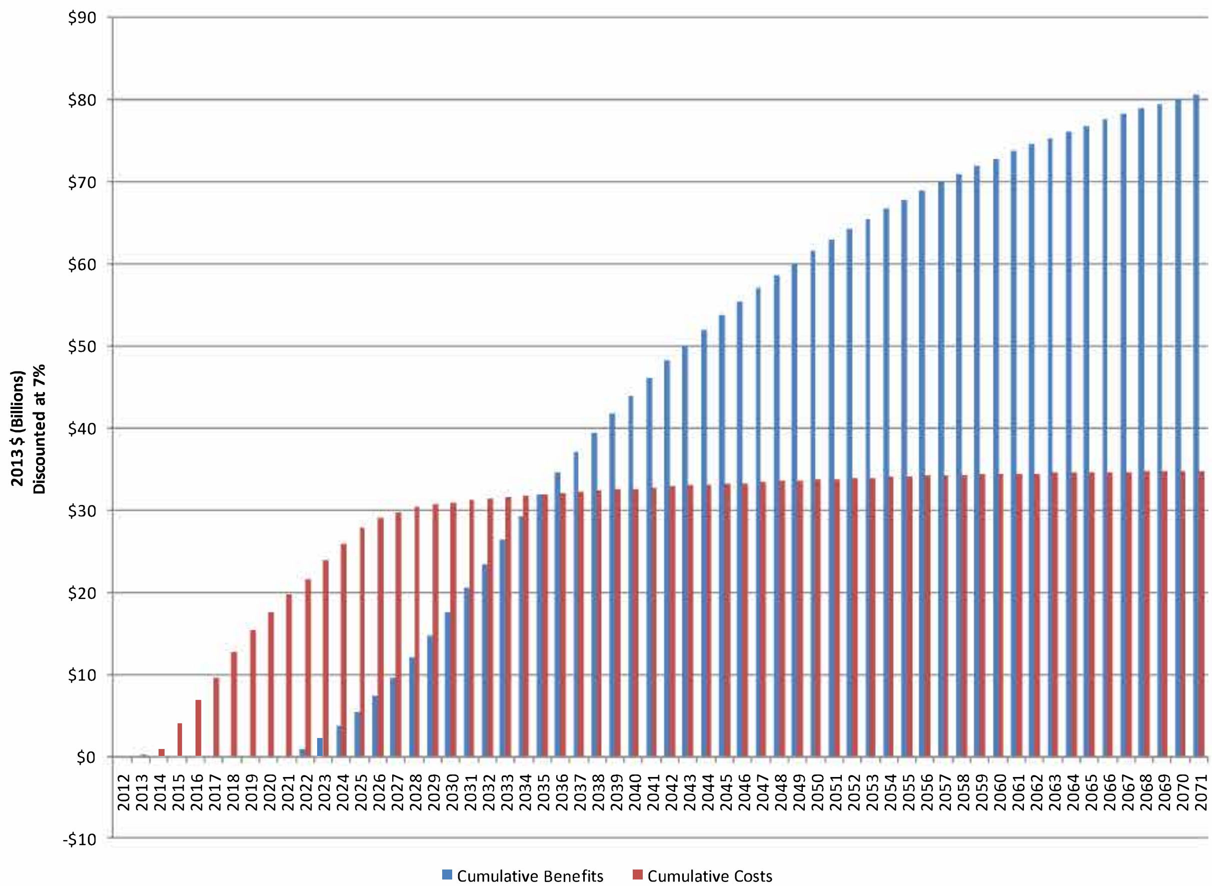
Figure 2. Capital and Rehabilitation Expenditures in 2013 Dollars before Present Value Discounting, Phase 1 Blended,



8.4 Cumulative Benefits and Costs

Figure 3 presents cumulative present value of benefits with the cumulative present value of costs over time for Phase 1 Blended. These discounted benefits and costs show at which point the benefits exceed costs, this occurs between 2034 and 2035

Figure 3. Cumulative Benefits and Costs in 2013 Dollars (Discounted at 7 percent), Phase 1 Blended



9 Conclusion

This analysis shows that the anticipated quantifiable benefits from the CAHSR project exceed their anticipated costs for each of the system's phases. 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.