California High-Speed Rail Authority

Federal-State Partnership for Intercity Passenger Rail Program (FSP-National)

Appendix B: California Phase 1 High-Speed Rail Corridor San Francisco to Los Angeles Benefit Cost Analysis Memorandum April 2023

CALIFORNIA High-Speed Rail Authority

Executive Summary

This memorandum summarizes the benefit-cost analysis (BCA) conducted for the California High-Speed Rail Phase 1 System from San Francisco to Los Angeles (Phase 1 HSR System). This BCA was prepared to support the grant application for the Federal-State Partnership for Intercity Passenger Rail Grant (FSP) Program. The analysis was conducted in accordance with the benefit-cost methodology outlined by the U.S. Department of Transportation (USDOT) in the Benefit-Cost Analysis Guidance for Discretionary Grant Programs released in January 2023. Our analysis accounts for **30 years of benefits** after operations begin[1].

KEY TAKEWAYS

The Phase 1 HSR System is transforming California and our nation's transportation infrastructure. The societal benefits generated by the Phase 1 HSR System improvements are estimated to be **$70.6 billion** in discounted 2021 dollars over the lifetime of the system. The total capital costs (net of indirect taxes) are calculated to be **$53.7 billion** in discounted 2021 dollars. The difference in the discounted benefits and costs equals a net present value of **$16.9 billion** in discounted 2021 dollars, resulting in a benefit-cost ratio (BCR) of **1.32**.

The Project improves intercity passenger rail service performance - including on-time performance, safety, competitiveness, reliability, and trip time - and adds capacity to congested corridors. It improves modal integration, builds resiliency to an already strained transport infrastructure, builds new connections to the Central Valley, attracts new users to a cleaner, more sustainable mode of travel, and ensures existing assets are improved to state of good repair. The project will bring improved modal integration to meet current and anticipated demand, as well as generate wider economic benefits and more equitable economic growth and access to opportunities to disadvantaged communities. The project will bring about significant improvements in safety (such as less road crashes), route competitiveness (with the airline industry for example), reliability and on-time performance for both passenger and freight rail, and resilience. The project improves the resiliency of the infrastructure system leaving more room to freight rail to operate on its own and freeing up airline and highways congestion. It will improve safety at highway-rail grade crossings, reduce incidences of rail-related trespassing (both freight and passenger rail), and upgrade infrastructure to achieve a higher level of efficiency and resilience. Benefits include:

- **The project improves travel times, accessibility, and a more equitable access to opportunities to disadvantaged areas.** The project will save travel time and improve reliability to millions of travelers in state-of-the-art stations for residents and visitors. The Project has positive economic impacts along the entire Phase 1 corridor both in areas near historic districts stations, and to other opportunity zones in the Central Valley. The travel time savings and accessibility gains are lifting

[1] 30-year benefit period from 2031 to 2060. Limited operation in the Central Valley starts in 2031, and full Phase 1 starts in 2033.

barriers to opportunity by giving access to jobs in historically unconnected or under-connected communities.

- **Increased accessibility has been shown to increase labor market efficiency and productivity.** Besides the users benefits, the Project has wider economic impacts that reflect the benefits of increased connectivity for firms and workers. These agglomeration benefits are sometimes referred to as wider economic benefits (or 'WEBs'), reflecting the dynamic benefits accruing to a region from increased accessibility between and within labor markets. By bringing businesses (and their employees) closer to each other, agglomeration has been shown to generate better labor matching between employee skills and job requirements, better on-the-job learning, and increased labor specialization. This increased productivity has been shown to result in higher firm profits as well as increased employee wages – at least for the firms and their employees involved in activities that benefit from improved accessibility. Detailed labor market data allow for a detailed analysis of the productivity effect on employees, but the lack of similar data for profits requires an indirect measure of the benefits accruing to firms' owners. In this analysis, increased profits to firms are measured by higher commercial property values – in this case commercial properties adjacent and proximate to rail stations serviced by high-speed rail service. The analysis has quantified the expected impacts on employees and firms in the markets served by the project. Agglomeration impacts accruing to employees are estimated from increases in wages, and the capitalized increase in firm profits is estimated from increases in commercial real estate value.
- **The project improves the service performance, reliability, service frequency, and addresses the state of good repair of all Amtrak routes in California and beyond.** There are trains that travel solely within the state—the Capitol Corridor, San Joaquins, and the Pacific Surfliner—and the benefits of the project to these lines are consequential. Moreover, improvements to existing California routes and stations will have a nationwide impact since California has the most Amtrak stations in the United States. Amtrak lines and customers on cross-country routes and on routes such as California Zephyr (to/from Chicago through Rocky Mountains), Coast Starlight (West Coast to/from Portland and Seattle), Southwest Chief (L.A. to/from Chicago), Sunset Limited (L.A. to/from New Orleans), and Texas Eagle (to/from Chicago via Texas and St. Louis) will all benefit from the service improvements on California Amtrak service brought about by the project.
- **The project has large safety benefits and will eliminate multiple existing Amtrak, BNSF Railway and Union Pacific Railroad at-grade crossings.** The benefits of grade separations alone include improved safety from crashes; travel time savings for residents, commercial trucks, and emergency services; reduced noise (no train horns), decrease in traffic congestion; reduction in emissions from idling vehicles; improved train operations reliability (both for freight and passengers rail operation), and property value uplift. These grade-separation projects will also help provide more equity in access to jobs in historically disadvantaged communities. From Madera to north of Bakersfield, major at-grade crossings will be made separated. This will result in major improvements to both urban and rural areas in the Central Valley, including less cities and neighborhood historically separated by the rail lines. In Northern California, the project will upgrade existing at-grade crossings

to quad gates[2]. Quad gates have been shown to reduce collisions at-grade crossings by 98 percent[3]. In Southern California, key early grade separation projects will include the Doran Street and Rosecrans Avenue/Marquardt Avenue grade crossings. These will deliver safety and environmental benefits even prior to the arrival of high-speed rail. These benefits will be felt across the country along all the long-distance Amtrak routes departing from Los Angeles or San Francisco for cross-country travel.

- **The project addresses climate change and sustainability** by reducing greenhouse gas and criteria air pollutant emissions by transferring trips from road and air to zero-emissions high-speed rail, promoting energy efficiency, increasing transport network resiliency, and recycling and redeveloping existing aging infrastructure.
- **The project improves multimodal efficiency and transport network resiliency**. It promotes multimodal integration for both passenger modes (rail to public transit and active modes) and freight (truck to rail) transport modes; and builds resiliency to the currently strained freight transport infrastructure. It protects and enhances the freight-carrying capacity of existing freight rail providers and reduce conflicts between freight and passenger trains, increasing reliability and travel times of both. This results in freight rail benefits including cost savings to existing rail freight and emission reductions, and pavement damage reductions from truck-to-rail diversion.
- The project provides **equitable economic growth** and **improved access to opportunity** to disadvantaged areas:
  - The project invests in vital infrastructure assets and provides opportunities for families to achieve economic security through rail industry employment and **better access to job opportunities in larger economic centers**. The project provides large positive economic and employment impacts in areas near stations, historic districts and to other opportunity zones including opportunities to disadvantaged areas. These are not quantified as part of the BCA.
  - The project services historically unconnected and under-connected communities in the Central Valley to economic centers in the Bay Area and in Los Angeles. Routes reach underserved communities beyond the core economic centers. The project also incorporates small businesses as part of project completion and includes community engagement efforts.

COSTS

The full capital cost for the Project is expected to be $83.0 billion in undiscounted 2021 dollars through 2033. Based on the construction schedule recently updated in the 2023 Project Update Report and at a

[2] Quad gates are designed to block all lanes of traffic on both sides of the track, and to provide a closure delay on the exit side to allow vehicles that may get stuck between the gates to get off the tracks.

[3] UC Berkeley Safe Transportation Education and Research Center as shown in hsr.ca.gov/about/safety/quad-gates/

7 percent real discount rate, these costs are $57.9 billion in Net Present Value. Total cost net of indirect tax is $53.7 billion. Table ES-1 shows how these costs are allocated across time.

Table ES-1: Phase 1 HSR System Costs by Category and Year

Cost Category in Billions of Dollars	2021 & Prior	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
YOE$ Dollars	8.7	1.2	2.4	4.2	7.6	14.3	21.2	20.9	14.3	6.7	3.1	1.5	0.1	**106.2**
2021$ Undiscounted	8.7	1.1	2.1	3.5	6.2	11.2	16.2	15.6	10.4	4.8	2.2	1.0	0.1	**83.0**
2021$, Discounted 7%	8.7	1.1	1.8	2.9	4.7	8.0	10.8	9.7	6.1	2.6	1.1	0.5	0.0	**57.9**
2021$ net of tax, Discounted 7%	8.1	1.0	1.7	2.7	4.4	7.4	10.0	9.0	5.6	2.4	1.0	0.5	0.0	**53.7**

Source: California High-Speed Rail Authority

(in Billions of Dollars)

Operations and maintenance (O&M) costs are projected to average $1.1 billion per year in 2021 undiscounted dollars in the long term. These costs assume operations and maintenance of the project and account for the annual O&M cost savings derived from the planned integration of San Joaquins Amtrak service and California High-Speed Rail service from Merced to Bakersfield. Over the entire 30-year analysis period these costs accumulate to $31.3 billion in undiscounted 2021 dollars, or $6.3 billion when discounted at 7 percent.

Rehabilitation and replacement (R&R) costs are expected to total $5.4 billion in 2021 dollars over this same period, or $766 million when discounted at 7 percent. These costs assume rehabilitation and replacement of the full Phase 1 HSR System.

O&M and R&R costs are included in the numerator of the benefit-cost ratio calculation as disbenefits.

BENEFITS

In 2021 dollars, the Phase 1 HSR System is expected to generate **$70.6 billion** in discounted benefits using a 7 percent discount rate to a 2021 base year. The project generates these benefits by providing swift, efficient travel in state-of-the-art stations for residents, generating travel time savings, safety benefits and vehicle operating costs savings for users. Furthermore, travel on the high-speed rail system will divert users from automobiles, and improve Amtrak and freight rail operations, resulting in reduced congestion for the entire network and reduced emissions. In addition to the “static” benefits, an additional layer of WEBs will be engendered: Here firms involved in activities – including manufacturing, trade, agriculture, education, finance, law, media, technology, the arts, management consulting and more – will benefit from increased accessibility between cities along the corridor. The productivity uplift will be reflected directly in higher wages for affected employees, as well as indirectly for firm profits in localized commercial real estate increases. The project also protects and enhances the freight-carrying capacity of the State’s existing freight rail providers and reduce conflicts between freight and passenger trains, increasing reliability and travel times of both.

A summary of the overall impacts and benefits can be seen in Table ES-2.

Table ES-2: Impacts Summary, Values in Millions $2021 Discounted 7%

Impacts	Current Status/Baseline	Project Improvements	Population Affected	Economic Benefit	Value
Users Benefits	**California residents do not have a modern, efficient, and rapid rail service.**	California's Phase 1 High-Speed Rail System will provide swift, efficient travel in state-of-the-art stations for residents and visitors.	State of California; General Population	Travel time savings; Reliability; Transfer time savings; Transit amenities; and Induced ridership benefits	**$24,975**
Safety and Environmental Benefits	**California residents are facing high costs due to highway crashes, increased auto congestion, high vehicle maintenance cost, and high emissions.**	Reduced highway traffic will decrease crashes, congestion, vehicle maintenance costs, and emissions.	State of California; General Population	Vehicle O&M; Safety; Emissions; Congestion; and Pavement damage & noise	**$16,636**
Wider Economic Benefits for Workers	**California economy would benefit from improved accessibility between and within labor markets.**	Increased accessibility will improve labor market efficiency and productivity; workers in specific industries will see increased wages.	State of California	Measuring worker productivity impacts through wage increases	**$17,552**
At-grade Rail Crossing Removals	**California is among the top States with the highest number of reported highway-rail grade crossing accidents/incidents**	The project will eliminate over 100 existing Amtrak, BNSF Railway and Union Pacific Railroad at-grade crossings. These grade-separation projects will also help provide more equity in access to jobs in communities historically segregated by crossings.	State of California; General Population	Safety from crashes, travel time savings at crossings; Travel time savings for emergency services; Reduced noise (no train horns), congestion, emissions from idling vehicles	**$6,676**
Wider Economic Benefits for Firms	**Commercial Property is underdeveloped in areas in the Central Valley around current stations.**	Firms will profit from increased productivity. Commercial space within a radius of the stations will see property value uplift.	State of California; General Population	Measuring firm profits through commercial property value uplift	**$5,996**
Residual Value		California will have a rail infrastructure with substantial value beyond the 30yr benefits period.	State of California; General Population	Transportation assets with a long economic life with large residual value after 30 years	**$3,996**
Freight and Passenger Rail Efficiency Gains	**California freight rail suffer from conflicts between freight and passenger trains. U.S. economy is suffering from freight capacity issue at large ports of entries. U.S. passenger rail system is suffering from poor on-time performance and reliability issues.**	The project protects and enhances the freight-carrying capacity of the State's existing freight rail providers and reduces conflicts between freight and passenger trains, improving reliability and travel times of both.	State of California; U.S. Population	Freight and passenger rail efficiency benefits; improved train operations reliability (both for freight and passengers rail operation)	**$1,813**
Operations & Maintenance and Repair & Rehabilitation		The project requires spending in Operations & Maintenance and Repair & Rehabilitation costs	State of California	O&M and R&R disbenefits	**-$7,052**
TOTAL					**$70,591**

(in Millions of 2021 dollars)

The Phase 1 HSR System will spur economic vitality and improved environmental conditions resulting from commercial activities and employment opportunities from high-speed rail service and operations. The project provides improvements and activity that will result in benefits to the U.S. economy, as well as to state and local businesses along the rail corridor.

This leads to an overall project Net Present Value (NPV) of **$16.9 billion** and a Benefit Cost Ratio (BCR) of **1.32**. A breakdown of benefits and disbenefits by category of expenditures is shown in Table ES-3 below.

Table ES-3: Costs and Benefits Detailed Summary, Monetary Values in Millions

BCA Metric (in Millions)	Discounted (7%)
Total Benefits	**$70,591**
Users Benefits	**$24,975**
Travel and Transfers Time	$12,660
Reliability	$5,372
Stations and Train Amenities Benefits	$4,947
Induced Ridership Benefits	$1,996
Safety and Environmental Benefits	**$16,636**
Vehicle O&M (including fuel)	$8,787
Safety [highway traffic reduction]	$4,995
Emissions Reductions from Auto	$1,381
Emissions Reductions from Air	$222
Airport Delay Savings	$109
Congestion	$1,119
Pavement and Noise	$22
Workers Wider Economic Benefits	**$17,552**
At-Grade Rail Crossing Removals	**$6,676**
Emergency Vehicle Benefits	$4,845
Waiting Time and Emissions Savings	$1,167
Reliability	$532
Safety [at-grade crashes reduction]	$134
Commercial Property Value	**$5,996**
Residual Value	**$3,996**
Freight and Passenger Rail Efficiency Gains	**$1,813**
Operations & Maintenance and Repair & Rehabilitation	**-$7,052**
Operations & Maintenance (O&M)	-$6,287
Repair & Rehabilitation (R&R)	-$766
Total Costs	**$53,667**
Net Present Value (NPV)	**$16,924**
Benefit Cost Ratio (BCR)	**1.32**
Payback Period (Years)	**19**
IRR	**8.8%**

TABLE OF CONTENTS

Tables

Chapter 1: Introduction

A benefit-cost analysis (BCA) was conducted for the Phase 1 HSR System for submission to the U.S. Department of Transportation (USDOT) to support the grant application for the Federal-State Partnership (FSP) for Intercity Passenger Rail Grant Program Grant. The following section describes the BCA framework, evaluation metrics, and report contents.

1.1 BCA Framework

The BCA framework attempts to capture the net welfare change created by a project, including cost savings and increases in welfare (benefits), as well as disbenefits where costs can be identified (e.g., project capital costs), and welfare reductions where some groups are expected to be made worse off as a result of the proposed project. BCA differs from a financial analysis in that all societal costs and benefits, including environmental externalities, are considered; and in that it does not report transfers such as fare revenue or indirect taxes.

The BCA framework involves defining a Base Case or "No Build" Case, which is compared to the "Build" Case. The BCA assesses the incremental difference between the Base Case and the Build Case, which represents the net change in welfare. BCAs are forward-looking exercises which seek to assess the incremental change in welfare over a project life cycle. The importance of future welfare changes is determined through discounting, which is meant to reflect both the opportunity cost of capital as well as the societal preference for the present.

The analysis was conducted in accordance with the benefit-cost methodology as recommended by the USDOT in the January 2023 Benefit-Cost Analysis Guidance update for Discretionary Grant Programs.[4] This methodology includes the following analytical assumptions:

— Defining existing and future conditions under a Base Case as well as under the Build Case;

— Estimating benefits and costs during project construction and operation, including 30 years of operations beyond the Project completion when benefits accrue;

— Using USDOT recommended monetized values for reduced fatalities, injuries, property damage, travel time savings, and emissions, while relying on best practices for monetization of other benefits;

— Presenting dollar values in real 2021 dollars. In instances where cost estimates and benefits valuations are expressed in historical or future dollar years, using an appropriate inflation factor to adjust the values;

[4] U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Applications, January 2023. https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance. Accessed April 2, 2023.

— Discounting future benefits and costs with a real discount rate of 7 percent,[5] consistent with USDOT January 2023 guidance;

— Operations and maintenance and R&R are disbenefits (rather than a cost); and

— Benefit and cost estimates should reflect real resource use. Transfers such as fare revenues or indirect taxes do not change real resources, so they are not included in our BCA.

1.2 Report Contents

Chapter 2 of this report contains a short description of California's Phase 1 High-Speed Rail System (from San Francisco to Los Angeles), information on the general assumptions made in the analysis, and a description of the base case compared to the build case. Chapter 3 provides a summary of the anticipated project costs and disbenefits. Chapter 4 reviews the expected societal benefits the Phase 1 HSR System will generate, including a review of the assumptions and methodology used to calculate the benefits. Finally, Chapter 5 reports the high-level results of the benefit-cost analysis.

Chapter 2: Project Overview

2.1 Base Case (No Build) and Build Case (the Phase 1 Project)

The Project (Build Case)

The analysis assumes a complete build of the full Phase 1 HSR System in California (Build Case). The Phase 1 HSR System refers to the 500-mile San Francisco/Merced to Los Angeles/Anaheim section of the program approved by California voters in Proposition 1A in 2008. When completed, the Phase 1 HSR System will run from San Francisco to the Los Angeles basin in under three hours at speeds up to 220 miles per hour.

Base Case (No Build)

This report assumes the No Build scenario or Base Case as 'business as usual' for Amtrak to continue its existing services with committed 'state of good repair' investments in their existing services and no additional investment, construction, or eventual service of the Phase 1 HSR System. The analysis considers the annual O&M cost savings derived from the planned integration of San Joaquins Amtrak service and California High-Speed Rail service from Merced to Bakersfield. The analysis also considers the benefits derived from the planned at-grade crossing upgrades for both passenger and freight rail lines, and the benefits from not sharing tracks between Merced and Bakersfield.

[5] With the one exception to this being for carbon dioxide (CO2) emissions, which are discounted at 3 percent per US DOT Guidance.

2.2 General Assumptions

The evaluation period for this project includes a 18-year design and construction period[6], from 2015 to 2033, during which capital expenditures are undertaken, and 30 years of operations within which benefits accrue, from 2031 through 2060[7].

Dollar figures in this analysis are expressed in constant 2021 dollars (2021$). In instances where certain cost estimates or benefit valuations were expressed in dollar values from other historical years, the US Bureau of Economic Analysis Implicit Price Deflator was used to adjust them to 2021 dollars.

The real discount rate used for this analysis was 7 percent[5], consistent with USDOT guidance released in January 2023[4] and OMB Circular A-94.[8]

[6] The construction period assumes a financially unconstrained project schedule consistent with Authority Business Plans and Project Update Reports.

[7] 30-yr. benefit period from 2031 to 2060. Limited operations in the Merced to Bakersfield segment starts in 2031, and full Phase 1 operations starts in 2033.

[8] White House Office of Management and Budget, Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. October 29, 1992. https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/a94/a094.pdf. Accessed March 18, 2022.

Chapter 3: Project Costs

All cost figures have been updated in accordance with the February 2023 estimates from the California HSR Authority 2023 Project Update Report and account for the latest inflation forecasts (February 2023) for construction, operation, and repair costs. While Operations & Maintenance Costs and Repair & Rehabilitation Costs are reported under this 'Project Costs' chapter for clarity purposes, they are disbenefits in the *numerator* of the benefit-cost ratio calculation.

3.1 Capital Costs

The full capital cost for the Phase 1 HSR System is expected to be $83.0 billion in undiscounted 2021 dollars through 2033. The capital costs were updated in February 2023 and reflect the latest assumptions and construction estimates from the California High-Speed Rail Authority as well as the increases in construction costs. At a 7 percent real discount rate, these costs are $57.9 billion. The capital cost net of indirect taxes is $53.7 billion in discounted 2021 dollars.

Table 1: Costs by Category and Year

Cost Category in Billions of Dollars	2021 & Prior	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
YOE$ Dollars	8.7	1.2	2.4	4.2	7.6	14.3	21.2	20.9	14.3	6.7	3.1	1.5	0.1	**106.2**
2021$ Undiscounted	8.7	1.1	2.1	3.5	6.2	11.2	16.2	15.6	10.4	4.8	2.2	1.0	0.1	**83.0**
2021$, Discounted 7%	8.7	1.1	1.8	2.9	4.7	8.0	10.8	9.7	6.1	2.6	1.1	0.5	0.0	**57.9**
2021$ net of tax, Discounted 7%	8.1	1.0	1.7	2.7	4.4	7.4	10.0	9.0	5.6	2.4	1.0	0.5	0.0	**53.7**

Source: California High-Speed Rail Authority
(in Billions of Dollars)

Benefit and cost estimates should reflect real resource use. Transfers such as fare revenues or indirect taxes do not change real resources, so they are not included in the BCA.

The federal and state tax rates applicable to the Capital Cost by category of expenditure, including both labor and material costs, were identified in order to calculate weighted average tax rates for each capital expenditure category. Local taxes were not considered in this analysis due to their complexity and specificity.

Table 2: Weighted Average Indirect Tax Rate – Categories and Calculation

Category	Tax Rate
Labor Cost Indirect Tax Rate	7.65%
Material Cost Indirect Tax Rate	7.25%
Weighted Average Indirect Tax Rate	**7.30%**

Overall, 7.30% of the capital cost for this project are taxes that are transferred to public entities, resulting in capital costs net of indirect taxes (net of transfers) being $53.7 billion in discounted 2021 dollars.

3.2 Operations and Maintenance Costs

Operations and maintenance (O&M) costs are projected to average $1.0 billion per year in the long term at an undiscounted rate. These costs assume O&M of the Phase 1 HSR System. Over the entire 30-year analysis period these costs accumulate to $31.3 billion in undiscounted 2021 dollars, or $6.3 billion when discounted at 7 percent. Table 3 notes the schedule of O&M costs from 2031 to 2060.

The analysis considers the annual O&M cost savings derived from the planned integration of San Joaquins Amtrak service and California High-Speed Rail service from Merced to Bakersfield. Per the 2020 Memorandum of Understanding (MOU)[9] between the California State Transportation Authority (CalSTA), California High-Speed Rail Authority (Authority), and San Joaquin Joint Powers Authority (SJJPA), once the high-speed rail service from Merced to Bakersfield starts operation, the San Joaquins Amtrak service will not run parallel service south of Merced. This will result in net O&M cost savings of $40 million annually, which have been subtracted from the Phase 1 O&M.

Table 3: Schedule of Operations and Maintenance Costs

Year	Net O&M Costs
2031	$14
2032	$36
2033	$783
2034	$909
2035	$1,017
2036	$1,103
2037	$1,136
2038	$1,137
2039	$1,137
2040	$1,139
2041	$1,139
2042	$1,140
2043	$1,140
2044	$1,141
2045	$1,141
2046	$1,142
2047	$1,143
2048	$1,144
2049	$1,144
2050	$1,145
2051	$1,145
2052	$1,146
2053	$1,145
2054	$1,145
2055	$1,146

[9] 2020 Memorandum of Understanding, California State Transportation Authority, California High-Speed Rail Authority, San Joaquin Joint Powers Authority, https://hsr.ca.gov/wp-content/uploads/docs/brdmeetings/2021/brdmtg_012121_Item4_Interim_Service_Plan_MOU_SJJPA.pdf

Year	Net O&M Costs
2056	$1,146
2057	$1,146
2058	$1,146
2059	$1,146
2060	$1,147

(in Millions of Undiscounted 2021 Dollars)

3.3 Repair and Rehabilitation Costs

Rehabilitation and replacement (R&R) costs are expected to total $5.4 billion in 2021 dollars over the 30-year analysis period, or $766 million when discounted at 7 percent. These costs assume R&R of the full Phase 1 HSR System. Table 4 notes the schedule of R & R costs from 2031 to 2060.

Table 4: Schedule of Repair, Rehabilitation and Replacement Costs

Year	R&R Costs
2031	$0
2032	$0
2033	$0
2034	$0
2035	$0
2036	$0
2037	$0
2038	$0
2039	$0
2040	$0
2041	$0
2042	$25
2043	$25
2044	$39
2045	$39
2046	$78
2047	$1,247
2048	$108
2049	$2,251
2050	$109
2051	$61
2052	$137
2053	$137
2054	$134
2055	$119
2056	$60
2057	$117
2058	$73
2059	$101
2060	$579

(in Millions of Undiscounted 2021 Dollars)

O&M and R&R costs are included as disbenefits in the numerator of the Benefit Cost Ratio as per US DOT BCA Guidance (2023).

Chapter 4: Project Benefits

The total value of the benefits generated by the Phase 1 HSR System improvements within the analysis period are calculated to be $69.7 billion in discounted 2021 dollars[10]. The project generates these benefits by providing swift, efficient travel in state-of-the-art stations for residents and visitors, and safety benefits from at-grade crossing upgrades. The project also generates societal benefits from commercial property value growth not already accounted for in travel time savings and significant wider economic benefits (or WEBs) also not accounted for in accessibility benefits. The Phase 1 HSR System will divert users from automobiles, resulting in reduced congestion and emissions as well as improved fuel savings and safety. The project protects and enhances the freight-carrying capacity of the State's existing freight rail providers and reduces conflicts between freight and passenger trains, increasing reliability and travel times of both. Table 5 below summarizes the benefits.

Table 5: Phase 1 High-Speed Rail System Benefits

Benefit (Disbenefit) Category	Description	Monetized
Travel Time Savings	Riders will travel more swiftly and efficiently on the high-speed rail system	√
Travel Reliability	Reduction in travel buffer time for high-speed rail riders due to mode diversion from auto to rail and air to rail	√
Vehicle Operating Cost Savings	Cost savings to due to mode diversion from auto to rail	√
Safety	Cost savings to due to mode diversion from auto to rail	√
Reduced Road Damage	Cost savings to roadway users due to mode diversion from auto to rail	√
Reduced Congestion	Cost savings to roadway users due to mode diversion from auto to rail and cost savings to air travelers due to mode diversion from air to rail	√
Reduced Road Noise	Cost savings due to mode diversion from auto to rail	√
Reduced Emissions	Reduced emissions due to mode diversion from auto to rail and from air to rail	√
Transit Amenities	Cost savings with improvements to stations and vehicles	√

[10] Total project cost is $53.7 billion in discounted 2021 dollars.

Benefit (Disbenefit) Category	Description	Monetized
Commercial Property Value Uplift	Property value increases around alignment and high-speed rail stations	√
Wider Economic Benefits	Agglomeration benefits from increased connectivity	√
At-grade Crossing Removals	Safety from at-grade crash reductions, reduced emissions, travel time savings, and travel reliability benefits to roadway users	√
Residual Value	Value of capital assets at the end of their useful life	√
Benefits to Induced Riders	Benefits to riders making trips that otherwise would not have been made without high-speed rail	√
Transfer Time Reduction	Reduction in travel transfer time for certain rail riders	√
(High-Speed Rail Operations and Maintenance Costs)	Operations and maintenance costs attributable to the high-speed rail service	√
(Repair & Rehabilitation Costs)	Repair and rehabilitation costs attributable to the high-speed rail service	√

The benefits of traditional transportation projects are commonly defined as reductions in transportation costs (such as travel time reductions, vehicle cost savings, accident reductions, air emission and greenhouse gas reductions). However, the California high-speed rail project is unprecedented in its size and the connectivity it adds to one of the country's largest state economies. The analysis herein shows that the Build scenario will generate benefits well beyond its direct users benefits to society at large. In general, very large transport projects that improve overall accessibility (i.e., improve business's ability to provide goods and services and people's ability to access education, employment, and services) and reduce transportation costs (including travel time, vehicle operating costs, road and parking facility costs, accidents, and pollution damages) also tend to increase economic productivity, benefitting impacted workers' wages and impacted firms' profits.

4.1 Demand Projections

The size of the benefits (and disbenefits) is often linked to the size of the expected demand for the project. For traditional passenger rail transportation projects, a large portion of the benefits are driven by the impacts of people switching from their current existing modes to the new rail system. Deutsche Bahn E.C.O. provided travel demand projections for the California transportation network and modeled

the impacts of the Phase 1 HSR System on existing travelers on the network, as well as changes due to users switching from auto and air to high-speed rail.

The table below shows the forecasted passenger demand for high-speed rail coming from auto, air, existing rail (existing Amtrak passenger rail service) and induced as a result of building California's Phase 1 High-Speed Rail System. The table compares the ridership in 2040 (after ramp-up) to the final year of analysis (2060). The high-speed rail ridership model estimates about 35.7 million riders in the final year of analysis. The system is expected to take the majority of its ridership from existing auto users (83.6%).

Table 6: Build Demand Projections

Forecasted HSR Passenger	Year 2040		Final Year of Analysis (2060)	
	Ridership	Percent of Total	Ridership	Percent of Total
Ridership from Auto	28,229,620	83.65%	29,872,128	83.65%
Ridership from Air	1,159,596	3.44%	1,225,440	3.43%
Ridership from CVR[1]	2,097,055	6.21%	2,227,332	6.24%
Induced	2,259,706	6.70%	2,388,084	6.69%
TOTAL	**33,745,976**	**100.00%**	**35,712,984**	**100.00%**

(1) Conventional rail (CVR) refers to the existing Amtrak passenger rail service.

Induced trips include the generation of new trips: Users choose to make trips they previously would not have made, because travel costs are lower. It includes both entirely new travelers (such as those who didn't have a car or were afraid of flying) and existing travelers who will travel more frequently now that they can get to their destination faster.

The table below notes the vehicle miles traveled (VMT) savings per trip and annually resulting from California Phase 1 high-speed rail service. The table compares the data in year 2040 to the final year of analysis (2060). The analysis estimates 3.4 billion annual VMT savings in year 2040 compared to 3.6 billion annual VMT savings in the final year of analysis (2060).

Table 7: Vehicle Miles Traveled (VMT) Savings

Variable	Year 2040		Final Year of Analysis (2060)	
	No Build	Build	No Build	Build
Average VMT Savings per trip	-	122	-	121
Total Annual VMT Savings	-	3,446,658,324	-	3,620,222,849

4.2 Users Benefits

A large portion of the benefits are derived from travel time savings and other direct impacts on users. Overall, these benefits are estimated to be **$25.0 billion** in discounted $2021 benefits.

4.2.1 Travel Time Savings

Travel time is considered a cost to users, and its value depends on the disutility that travelers attribute to time spent traveling. A reduction in travel time translates into more time available for work, leisure, or other activities.

Table 8: Value of Time (VoT) Savings Assumptions and Sources

Variable	Unit	Value	Source
VoT - High-Speed Rail – Personal	2021$ per person hour	$45.30	USDOT BCA Guidance, 2023
VoT - High-Speed Rail – Business	2021$ per person hour	$79.30	USDOT BCA Guidance, 2023

The table below summarizes travel time savings benefits for riders diverted from auto and air, as well as existing rail services. The table notes the hours saved as well as realized monetary benefits. In 2040, the

Phase 1 HSR System will realize $629.4 million in discounted benefits related to travel time savings. Over the 30-year period of operations analyzed, it will realize $12.7 billion in discounted benefits related to travel time savings.

Table 9: Travel Time Savings

Benefit	Year 2040			Project Life Cycle		
	Hours (Millions)	Undiscounted	Discounted (7%)	Hours (Millions)	Undiscounted	Discounted (7%)
Auto	36.6	2,162.3	597.9	1,024.1	60,456.4	11,992.5
Air	-0.2	-9.7	-2.7	-4.6	-270.1	-53.5
CVR	2.1	123.8	34.2	59.6	3,516.4	709.9
Total	**38.6**	**2,276.4**	**629.4**	**1,079.0**	**63,702.7**	**12,648.9**

(Millions of 2021 dollars)

4.2.2 Transfer time savings

Quantified transfers that are avoided are the ones that are made by existing conventional rail passengers in Bakersfield where passengers currently have to transfer to intercity buses; whereas in Phase 1 they will have a direct trip into the Los Angeles area. The model runs for the no-build for 2030 have 766,000 annual trips on the buses to/from Bakersfield, and 44.5% of the 766,000 trips on the buses in the new build scenario are transferring from the rail service. This translates into 347,015 avoided transfers in 2040.

Table 10: Passenger Transfer Reduction Inputs

Variable	Year 2040		Project Life Cycle	
	No Build	Build	No Build	Build
Transfers Avoided at Bakersfield	-	347,015	-	10,163,954
Average Minutes Saved	-	5.0	-	5.0

Over the 30-year period of operations analyzed, the system will realize $11 million in discounted benefits related to transfer time savings.

Table 11: Passenger Transfer Reduction Travel Time Saving Benefits

Benefit	Year 2040			Project Life Cycle		
	Hours	Undiscounted	Discounted (7%)	Hours	Undiscounted	Discounted (7%)
Bakersfield Transfer Reductions	28,918	$1.71	$0.47	846,996	$50	$11

(Millions of 2021 dollars)

4.2.3 Reliability

Reliability in travel times is an important element of user benefits from a system like California high-speed rail. 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 "Travel 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. The Texas Transportation Institute provides the average Travel Time Index for various regions across the country based on congestion levels.

In California, these regional indices range from a low of 1.15 in Fresno and Bakersfield to 1.51 in the Bay Area and 1.52 in the Los Angeles. This figure reflects a ratio of congested travel time compared to the time required to for the same trip at uncongested speeds. A value of 1.5, for example, means that a 30-minute free-flow trip would require 45 minutes during peak periods of congestion.

Table 12: Reliability Assumptions and Sources

Variable	Unit	Value	Source
Travel Time Savings - Auto	PHT	2,048,120,940	ETO Travel Demand Model
California Travel Time Index	factor	1.40	Texas Transportation Institute, Weighted Average of CA Regions on HSR Line
Reduction in Trip Buffer Time	PHT	407,169,999	Calculation

The table below shows the reliability benefits generated from the Project. In year 2040, $238 million in discounted benefits related to productivity and reliability will be realized.

Table 13: Reliability Benefits

Benefit	Year 2040		Project Life Cycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Reliability Time Savings	$860	$238	$24,038	$4,768

(Millions of 2021 dollars)

Over the life cycle of the project, $4.77 billion discounted benefits will be realized from the reduced buffer times.

An additional $0.6 billion of reliability benefits will be realized from the improved operation at the multimodal transit stations served by the project, and improve reliability for all transit users, not just the project users.

Overall, the project is expected to generate $5.37 billion discounted benefits from the reduced buffer times of both CA HSR users and of the overall multimodal transit station users. [11]

[11] $4.77 billion in reliability benefits from project users and $0.60 billion in reliability benefits from other transit station users.

4.2.4 Facility and vehicle amenities

The Phase 1 HSR System will increase benefits derived from improvements to station facilities and to train vehicles. A list of the station benefits and their benefit values per trip are listed below. All values are from the USDOT Guidance January 2023 update.

Table 14: Facility Improvement Benefits Assumptions and Sources

Variable	Unit	Value
Clocks	2021$ / trip	$0.06
Electronic Real-Time Information Displays	2021$ / trip	$0.86
Information/Emergency Button	2021$ / trip	$0.11
PA System	2021$ / trip	$0.10
Platform/Stop Seating Availability	2021$ / trip	$0.13
Platform/Stop Weather Protection	2021$ / trip	$0.13
Restroom Availability	2021$ / trip	$0.10
Retail/Food Outlet Availability	2021$ / trip	$0.06
Staff Availability	2021$ / trip	$0.18
Step-free Access to Station/Stop	2021$ / trip	$0.20
Step-free Access to Vehicle	2021$ / trip	$0.07
Surveillance Cameras	2021$ / trip	$0.32
Temperature Controlled Environment	2021$ / trip	$0.62
Ticket Machines	2021$ / trip	$0.07
Timetables	2021$ / trip	$0.48
Bike Facilities	2021$ / trip	$0.10
Car Access Facilities	2021$ / trip	$0.11
Elevator	2021$ / trip	$0.07
Escalators	2021$ / trip	$0.04
On-Site Ticket Office	2021$ / trip	$0.09
Taxi Pickup/Dropoff	2021$ / trip	$0.05
Waiting Room	2021$ / trip	$0.20

Source: USDOT BCA Guidance, 2023

The project will increase benefits derived from improvements to train vehicles. A list of these benefits and their benefit values per trip are listed below. All figures are taken from USDOT Guidance January 2023 update.

Table 15: Vehicle Improvement Benefits Assumptions and Sources

Variable	Unit	Value
Electronic Real-Time Information Displays	2021$ / trip	$0.22
Handrails	2021$ / trip	$0.31
Luggage Storage	2021$ / trip	$0.09
PA System	2021$ / trip	$0.39
Surveillance Cameras	2021$ / trip	$0.63
Temperature Control	2021$ / trip	$0.47
Wheelchair Space	2021$ / trip	$0.04
Food Service Availability	2021$ / trip	$0.03
Restroom Availability	2021$ / trip	$0.19

Source: USDOT BCA Guidance, 2023

The rail station facility upgrades will benefit all users at the stations, not just the planned high-speed rail users; existing and planned public transit users at the multimodal stations served by high-speed rail will experience the station improvements.

As a result of station and vehicle improvements, the Phase 1 HSR System will realize monetary benefits over its life cycle. In year 2040, the project will realize $220 million in discounted benefits related to station and vehicle improvements. Over the life cycle of the project, $4.9 billion in discounted benefits will be realized related to station and vehicle improvements.

Table 16: Mobility and Community Connectivity Benefits

Benefit	Year 2040		Project Life Cycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Rail Station Facility	$683.42	$188.97	$20,358.68	$4,321.84
Rail Vehicle Amenities	$111.93	$30.95	$3,140.38	$625.36
Total	**$795.35**	**$219.92**	**$23,499.06**	**$4,947.20**

(Millions of 2021 dollars)

4.2.5 Induced ridership

The benefits experienced by new travelers – trips that didn't exist before – are shown in the table below. Induced trips include the generation of new trips: Users choose to make trips they previously would not have made, because travel costs are lower. It includes both entirely new travelers (such as those who didn't have a car or were afraid of flying) and existing travelers who will travel more frequently now that they can get to their destination faster.

Table 17: Induced Benefits Inputs

Variable	Unit	Value	Source
Forecasted HSR Passenger Ridership (Induced) - Project Life Cycle	Ridership	63,064,290	Authority Travel Demand Model

Average Benefit per Non-Induced Passenger Trip	2021$ / trip	$188	Calculation

Over the life cycle of the project, $2.0 billion in discounted benefits will be realized through induced ridership.

Table 18: Induced Benefits

Benefit	Year 2040		Project Life Cycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Induced Ridership Benefits	$335.2	$92.7	$11,376	$1,996

(Millions of 2021 dollars)

4.3 Safety and Environmental Benefits

Safety and environmental benefits are estimated to be **$16.6 billion** in discounted $2021 benefits. Additional safety benefits from at-grade separation are shown in section 4.5 At-grade Crossing Upgrade Benefits.

4.3.1 Auto vehicle operating cost savings

Vehicle operating cost savings includes the cost of fuel, as well as maintenance, repair, and replacement of tires, and the depreciation of the vehicle over time. Consumption rates per vehicle mile travelled (VMT) are used to calculate the vehicle operating cost savings. Estimates of VMT and unit costs for each component of vehicle operating cost are applied to the consumption rates to calculate the total vehicle operating cost. The assumptions used in the estimation of vehicle operating costs are presented in Table 19.

Table 19: Vehicle Operating Cost Savings Assumptions and Sources

Variable	Unit	Value	Source
Vehicle Operating Costs - Light Duty Vehicles	2021$ / trip	$0.46	USDOT BCA Guidance, 2023

The table below summarizes the savings related to operating and maintaining personal automobile vehicles as a result of the Project. In year 2040, the Project will realize $438 million in discounted savings related to personal vehicle operations and maintenance costs. Over the life cycle of the project, $8.8 billion in discounted savings will be realized related to personal vehicle operations and maintenance.

Table 20: Vehicle Operating Cost Savings

Benefit	Year 2040		Project Life Cycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Vehicle O&M Costs - Auto	$1,585	$438	$44,220	$8,787

(Millions of 2021 dollars)

4.3.2 Safety benefits from highway traffic reduction

Reductions in VMT lower the incidence of traffic crashes, generating significant benefit in the form of cost savings. 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, and incident congestion 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 assumptions used in the estimation of safety benefits are summarized below.

Table 21: Safety Benefits Assumptions and Sources

Variable	Unit	Value	Source
Fatal Crash	2021$	$13,046,800	US DOT Guidance, January 2023
Injury Crash	2021$	$307,800	US DOT Guidance, January 2023
Property Damage Only Crash	2021$	$4,800	US DOT Guidance, January 2023

During operations, the Project will reduce fatal crashes, injury crashes and property damage crashes. In year 2040, 2,378 crashes will be avoided. Over the project's life cycle, a total of $4,995 million in safety related benefits will be realized—in addition to the safety benefits realized by at-grade crossing upgrades presented in Table 22.

Table 22: Safety Benefits from Highway Traffic Reduction

Benefit	Year 2040			Project Life Cycle		
	Casualties Avoided	Undisc.	Disc. (7%)	Casualties Avoided	Undisc.	Disc. (7%)
Fatal Crashes	48	$630	$174	1,346	$17,559	$3,489
Injury Crashes	860	$265	$73	23,985	$7,382	$1,467
Property Damage Crashes	1,470	$7	$2	41,001	$197	$39
Total	**2,378**	**$901**	**$249**	**66,332**	**$25,138**	**$4,995**

(Millions of 2021 Dollars)

4.3.3 Emissions benefits

The project will create environmental and sustainability benefits by reducing air and noise pollution associated with automobile travel and air travel as there is a reduction in vehicle-miles travel from mode shifts. Less cars on the road and less planes taking off and landing at major congested airports will provide environmental benefits.

Four forms of emissions were identified, measured, and monetized, including: nitrous oxide (NOx), particulate matter (PM2.5), sulfur dioxide (SO_2), and carbon dioxide (CO_2).

The assumptions used in the estimation of emissions reduction benefits are summarized in Table 10.

Table 23: Emissions Benefits Assumptions

Variable	Unit	Value	Source
CO2 emissions	2021$ / metric ton	$56 (2022) - $88 (2050)	US DOT Guidance, 2023
NOx emissions	2021$ / metric ton	$16,600 (2022) - $18,900 (2050)	US DOT Guidance, 2023
PM2.5 emissions	2021$ / metric ton	$796,700 (2022) - $907,600 (2050)	US DOT Guidance, 2023
SOx emissions	2021$ / metric ton	$44,300 (2022) - $51,300 (2050)	US DOT Guidance, 2023
Emissions per VMT	Grams per VMT	Varies by year, vehicle type, speed, and emission type	EPA and California Air Resources Board EMFAC Database

The project will realize substantial auto emission reductions benefits over its life cycle. 1.29 million tons of emissions will be avoided in year 2040 from auto. $57.2 million in discounted benefits will be realized in 2040 for auto alone. As a result of 35.1 million tons of auto emissions being reduced over the life cycle of the project, $1.4 billion in discounted auto emissions benefits will be realized.

Table 24: Auto Emissions Benefits

Emission Reduction Benefit	Year 2040			Project Life Cycle		
	Tons	Undisc.	Discounted [1]	Tons	Undisc.	Discounted [1]
CO2 Reduction[12]	1,290,828	$98.10	$55.95	35,070,274	$2,872.22	$1,356.53
NOx Reduction	103	$1.95	$0.54	2,426	$45.86	$10.22
PM2.5 Reduction	3	$2.40	$0.66	61	$55.76	$12.48
SOx Reduction	6	$0.29	$0.08	188	$9.64	$1.81
Total Reduction	**1,290,939**	**$102.74**	**$57.23**	**35,072,950**	**$2,983**	**$1,381**

(Millions of 2021 Dollars)

[1] Discounted at 7 percent with an exception for carbon dioxide (CO2) emissions, which are discounted at 3 percent per US DOT Guidance

The project will also realize substantial airplane emission reductions benefits over its life cycle. 155 thousand tons of emissions will be avoided in year 2040 from air traffic reduction alone. $9.3 million in discounted benefits will be realized in 2040 for air alone. As a result of 4.3 million tons of air emissions being reduced over the life cycle of the project, $222 million in discounted air emissions benefits will be realized.

[12] Carbon dioxide (CO2) emissions are discounted at 3 percent per US DOT Guidance.

Table 25: Air Emissions Benefits

Emission Reduction Benefit	Year 2040			Project Life Cycle		
	Tons	Undisc.	Discounted [1]	Tons	Undisc.	Discounted [1]
CO2 Reduction[12]	154,823	$11.77	$6.71	4,335,044	$354	$168.10
NOx Reduction	176	$3.33	$0.92	4,940	$93.37	$19.23
PM2.5 Reduction	6	$5.10	$1.41	157	$142.92	$29.43
SOx Reduction	18	$0.94	$0.26	512	$26.24	$5.40
Total Reduction	**155,023**	**$21.14**	**$9.30**	**4,340,653**	**$617**	**$222**

(Millions of 2021 Dollars)

[1] Discounted at 7 percent with an exception for carbon dioxide (CO2) emissions, which are discounted at 3 percent per US DOT Guidance

Overall, the project will realize substantial emission reductions benefits over its life cycle. 1.4 million tons of emissions will be avoided in year 2040 from auto and air combined (1.29 million tons from auto plus 155 thousand tons from air), and $66.5 million in discounted benefits will be realized in 2040 alone, combining air and auto emissions savings. As a result of 39.4 million tons of emissions being reduced over the life cycle of the project, $1.6 billion in discounted emissions benefits will be realized (1.38 billion from auto plus 222 million from air).

The decrease in airport traffic will generate an additional $100 million in airport delay reduction and congestion relief benefits in discounted $2021 dollars over the lifecycle of the project.

4.3.4 Noise, congestion, and pavement costs

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 USDOT BCA Guidance from January 2023. The table below notes the assumptions and values based on congestion reduction benefits as well as auto average noise cost.

Table 26: Noise, Congestion, and Pavement Costs Assumptions

Variable	Unit	Value	Source
Auto Average Noise Cost	2021$ / VMT	$0.00068	USDOT BCA Guidance Jan 2023
Congestion Reduction Benefits	2021$ / VMT	$0.05860	USDOT BCA Guidance Jan 2023
Auto Average Pavement Cost	2021$ / VMT	$0.00046	FHWA, Cost Allocation Study, 2000

As a result of the Phase 1 HSR System, benefits over its life cycle will be realized for automobile noise, congestion, and pavement damage. In year 2040, the project will realize $56.9 million in discounted benefits related to noise, congestion, and pavement damage. Over its life cycle, the Phase 1 HSR System will realize $1.1 billion in discounted benefits related to auto noise, congestion, and pavement damage.

Table 27: Noise, Congestion, and Pavement Costs Benefits

Benefit	Year 2040		Project Life Cycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)

Noise - Auto	$2.34	$0.65	$65.37	$12.99
Congestion - Auto	$201.97	$55.85	$5,633.25	$1,119.42
Pavement Damage - Auto	$1.58	$0.44	$43.95	$8.73
TOTAL	**$205.89**	**$56.93**	**$5,742.56**	**$1,141.15**

(Millions of 2021 Dollars)

4.4 Wider Economic Benefits for Workers and Firms

Besides externalities and users benefits, the project has positive wider economic impacts – the WEBs introduced earlier - that reflect the benefits of increased connectivity for firms and workers. For firms in industries that benefit from the improved connectivity, the project will increase wages for workers and profits for firms. The impact on wages can be assessed from observing previous impacts from existing high-speed rail service, notably the Amtrak Acela service. The impact on firm profits is much harder to discern directly and must be gauged from observed commercial real estate impacts on properties around rail stations which become more valuable due to the improved connectivity[13]. These agglomeration benefits reflect the benefits accruing to a region from increased accessibility between labor markets. Improved connectivity between businesses (and their employees) in different locations should result in better labor matching between employee skills and job requirements, better on-the-job learning, and increased labor specialization[14].

The increased connectivity will increase the profits of firms that can benefit from greater inter-city accessibility. It has been shown that these are primarily industries contained within professional services, where teams can be more easily formed across locations and where face-to-face interactions facilitate exchange of ideas, learning and innovation. These profits in turn are "shared" with employees, in part to reduce turnover and maintain the benefits of the increased productivity within the firm[15].

In order to estimate what these impacts, an analysis was conducted of observed impacts from a comparable service, the Amtrak Acela service linking Boston to Washington, DC which has been in operation for over twenty years. The analysis identifies the impact of the service on both employees and firms in professional services in markets which obtained improved inter-city connectivity from Acela, namely:

- Estimated worker impacts with increased wages for managerial occupation, and

[13] Roback, J., 1982. "Wages, Rents, and the Quality of Life". *Journal of Political Economy,* Vol. 90, No. 6, pp. 1257-1278

[14] The topic of agglomeration is core principle of urban economics as well as labor economics and was arguably introduced by Adam Smith and later Alfred Marshall. A comprehensive discussion can be found in numerous strands of research, summarized in Glaeser, E., 2008. *Cities, Agglomeration and Spatial Equilibrium.* New York: Oxford University Press.

[15] Blanchflower, D. G., A. Oswald and P. Sanfrey, 1996. "Wages, Profits and Rent-Sharing". *Quarterly Journal of Economics.* Vol. 111 No. 1, pp. 227-251.

- Estimated capitalized increase in firm profits in commercial real estate value (office, retail, and industrial).[16]

The reason for focusing on real estate property impacts instead of the actual profits of firms is due to the very limited availability of profit data for non-publicly traded firms. As mentioned, increased profits will be capitalized into commercial real estate properties, notably those with easy access to train stations served by the high-speed rail service.

Over its life cycle, the project will bring long term wage increases for residents, and property value growth for commercial properties along the corridor and near stations. The project will realize $17.55 billion in discounted benefits related to wider economic benefits from workers wage increases, and $6.0 billion in commercial property value benefits across the main rail stations. These do not include residential property value increases which are already accounted for in users benefits.

The premise of WEBs is therefore that projects that improve overall accessibility and reduce transportation costs (including travel time, vehicle operating costs, road and parking facility costs, accident, and pollution damages) will tend to facilitate inter-city connections between firms, thereby engendering the impacts on innovation, labor specialization, learning and labor market matching between workers and tasks. Care was taken to avoid double counting impacts that are already counted in travel time and vehicle cost savings, emission, or safety benefits, as well as not counting impacts that are mere transfers. The following section describes the process for quantifying the WEBs included in the current economic analysis.

4.4.1 Measuring firm profits through commercial property value uplift

The capitalized increase in firm profits is reflected in commercial real estate value. The analysis excludes residential property value uplift which are already accounted for in users' benefits calculations. The impact on commercial property values reflects the value of proximity to inter-city rail connectivity – in this case commercial properties adjacent and proximate to rail stations serviced by high-speed rail service. Commercial properties adjacent and near rail stations being served by improved rail service will become more valuable due to this proximity.

AVOIDING DOUBLE COUNTING

The project will lead to subsequent changes in the value as well as use of surrounding property (land and the buildings on them). Changes in property values are a direct measure of shifts in demand for a location, and in this case, it reflects the higher value of proximity to some firms. Given that the premium is driven by higher profits and profit impacts are not analyzed separately, there is no double-counting. The real estate impact is the capitalization of increased profits (which are unobserved) into real estate

[16] The analysis involved micro-data on workers and commercial properties and used statistical techniques to control for any confounding effects by isolating the effects on "treated" locations served by Acela and "control" locations, adjacent and with similar characteristics but not served by Acela.

values (which are observed). In this BCA, firm profits benefits are assumed to be captured by **commercial** property value uplift only.

COMMERCIAL PROPERTY VALUE BENEFITS

The increased connectivity of intercity services improves the productivity of certain employees and increases firm profits. Standard economic theory as well as empirical research such as Blanchflower (op. cit.) strongly suggests that the benefits are shared: there is a sharing of the benefit between owners (which we estimate through commercial real estate effects) and workers (which we estimate through wages).

The estimate of firms profit impact is based on commercial real estate value located in "treated" Amtrak stations served by Acela compared to similar Amtrak stations in cities not served by Acela (the control stations). It is estimated that the value of commercial real estate near stations served by Acela are on average 15% more expensive compared to similar commercial real estate near Amtrak stations not served by Acela.

Historical property values within a 20 min walk around the stations were obtained from the *CoStar* database, and the 15% property value uplift was applied as a one-time benefit.

The uplift of commercial (office and retail) property value near the stations in San Francisco, San Jose, Los Angeles, SFO and Fresno is estimated at **$5.996 billion** in discounted benefits and is applied as a one-time benefit. Benefits by station area are shown in the following table.

Table 28: Wider Economic Benefits for Firms by Station Area

Station	One-time uplift in $2021 Undiscounted	Discounted (7%)
San Francisco (2 stations)	$10,271	$5,221
San Jose Station	$704	$358
Los Angeles Station	$505	$257
Millbrae/SFO Station	$168	$85
Fresno Station	$147	$75
Total	**$11,795**	**$5,996**

(Millions of 2021 dollars)

4.4.2 Measuring worker productivity impacts through wage increases

The increased connectivity of intercity services—such as Acela in the Northeastern U.S.—improve the productivity of certain employees and increase firm profits. Standard economic theory as well as empirical research such as Blanchflower (op. cit.) strongly suggests that some of the benefits will flow to the employees of the firm. In essence, there is a sharing of the benefit between owners (which we estimate through real estate effects) and workers.

Our estimate of worker wage impacts is based on micro-data of individual workers located in "treated" labor markets served by Acela compared to similar workers in the same industries in labor markets not

served by Acela (the control markets). It is estimated that the WEBs accruing to management workers in markets served by Acela have on average $3,000 higher annual wages in $2021 compared to similar workers in comparison markets not served by Acela. The industries where these effects are found are those contained in management services, and the wage uplift was applied to California labor market in markets served by the project.

Historical wages and employment data for Management Occupation in California metropolitan areas served by the project were obtained from the U.S. Bureau of Labor and Statistics (BLS), and a $3,000 annual wage uplift was applied to workers in the Management labor category (864,240 workers in 2021). Table 29 shows the results of the California workers WEBs analysis. Over its life cycle, the project will realize **$17.55 billion** in discounted benefits related to workers wider economic benefits.

Table 29: Wider Economic Benefits for Workers

Benefit	Project Life Cycle	
	Undiscounted	Discounted (7%)
Wage uplift	$89,044	$17,552

(1) Productivity Impacts from Agglomeration Benefits

(Millions of 2021 dollars)

Table 30: Wider Economic Benefits for Workers by metro area

Metro Area	Number of jobs in Management Occupations (2021)	Undiscounted 2021 WEBs Wage Uplift Benefits from Management Occupation
All combined	**864,240**	**$3,297,939,840**
LA-Long Beach-Anaheim	410,750	$1,567,422,000
San Francisco-Oakland-Hayward	218,400	$ 833,414,400
San Jose-Sunnyvale-Santa Clara	114,460	$ 436,779,360
Riverside-SB-Ontario	74,020	$ 282,460,320
Fresno	18,110	$ 69,107,760
Bakersfield	13,620	$51,973,920
Merced	3,160	$12,058,560
Modesto	9,650	$36,824,400
Madera	2,070	$7,899,120

(2021 dollars)

4.5 At-grade Crossing Upgrade Benefits

Overall, the updates to the at-grade crossings are estimated to generate **$6.7 billion** in discounted $2021 benefits. Benefits of grade separations include:

- Improved safety from at-grade crossing crash reduction
- Reduced noise (no train horns)
- Decrease in traffic congestion and travel time savings
- Reduction in emissions from idling vehicles

- Improved reliability
- Reduction in temporary loss of emergency services
- Improved train operations reliability (both freight and passengers)

The project addresses safety issues with existing at-grade crossings by eliminating the conflicts passing trains have with vehicles, bicyclists, and pedestrians. Combined, there are 91 existing at-grade crossings that are being eliminated by the project. Among these are 28 crossing terminations (street will be closed at the given site), 37 overheads (street will pass over rail tracks) and 26 underpasses (street will pass under rail tracks). The overall system will also upgrade over 68 existing at-grade crossings to 4 Quadrant Gates ("Quad Gates").

In the Central Valley, where trains will be capable of running at speeds in excess of 200 miles per hour, the high-speed rail system is being built fully grade separated. Many existing grade crossings with existing freight service will be eliminated. Along the approximately 119 miles from Madera to north of Bakersfield, there will be a number of existing BNSF Railway and Union Pacific Railroad at-grade crossings eliminated. In total, 59 at-grade crossing will be updated in the Central Valley alone. This will result in major improvements to both urban and rural areas in the Central Valley, including less segregated cities and neighborhood historically separated by the rail lines.

In Northern California, the blended system will upgrade over 67 existing at-grade crossing to Quad Gates.[17] Quad Gates have been shown to reduce collisions at-grade crossings by 98 percent.[18]

In Southern California, key early grade separation projects will include Doran Street and Rosecrans Avenue/Marquardt Avenue grade crossings. These will deliver safety and environmental benefits prior to the arrival of high-speed rail.

Table 31: At-grade Crossing Upgrade Benefits

Rail Crossing Eliminations Benefits	Year 2040		Project Life Cycle	
	Undiscounted	Discounted (7%)	Undiscounted	Discounted (7%)
Travel Time	$170	$47	$5,394	$1,157
Emissions	$1	$0	$48	$10
Safety	$20	$5	$594	$134
Reliability	$78	$22	$2,479	$532
Loss of Emergency Services	$710	$196	$22,588	$4,845
TOTAL	**$979**	**$271**	**$31,103**	**$6,676**

(Millions of 2021 dollars)

[17] Quad gates are designed to block all lanes of traffic on both sides of the track, and to provide a closure delay on the exit side to allow vehicles that may get stuck between the gates to get off the tracks.

[18] UC Berkeley Safe Transportation Education and Research Center as shown in hsr.ca.gov/about/safety/quad-gates/

Overall, the at-grade crossings updates are estimated to generate $6.7 billion in discounted $2021 benefits.

During operations, the at-grade crossings removals will reduce fatal crashes, injury crashes and property damage crashes. In year 2040, 390 crashes will be avoided at at-grade crossings. Over the project's life cycle, a total of $134 million in safety related benefits will be realized—in addition to the safety benefits realized by reduction in auto traffic.

Table 32: Safety Benefits from At-Grade Crossing

Benefit	Year 2040			Project Life Cycle		
	Casualties Avoided	Undisc.	Disc. (7%)	Casualties Avoided	Undisc.	Disc. (7%)
Fatal Crashes	1.4	$18.6	$5.2	42.9	$559.4	$125.8
Injury Crashes	3.6	$1.1	$0.3	109.1	$33.6	$7.6
Property Damage Crashes	7.9	$0.0	$0.0	237.7	$1.1	$0.3
Total	**13.0**	**$20.0**	**$5.0**	**389.8**	**$594.0**	**$134.0**

(Millions of 2021 Dollars)

4.6 Freight and Passenger Rail Efficiency Gains

Overall, the Freight and Passenger Rail Efficiency Gains are estimated to generate $1.8 billion in discounted $2021 benefits.

The CA HSR Phase 1 Project protects and enhances the freight-carrying capacity of the State's existing freight rail providers and reduce conflicts between freight and passenger trains, increasing reliability and travel times of both. This results in freight rail benefits including

- Existing rail freight cost savings, and
- External costs savings (emission reductions, pavement from truck diversion.

There are several underlying societal benefits of making freight rail more efficient:

Reduced Carbon Emissions: One of the most significant benefits of making freight rail more efficient is the reduction in carbon emissions. Freight trains are more fuel-efficient than trucks and shifting goods from trucks to trains can significantly reduce greenhouse gas emissions.

Improved Traffic Safety: Freight trains are much safer than trucks on the road and reducing the number of trucks on the highways can lead to fewer accidents, less traffic congestion, and improved road safety for all.

Increased Economic Productivity: A more efficient freight rail system can lead to increased economic productivity, as goods can be moved more quickly and cost-effectively, allowing businesses to operate more efficiently.

Cost Savings: Shippers can save money by using rail transportation instead of truck transportation, especially over long distances. Rail transportation is typically less expensive than truck transportation because it is more fuel-efficient, can carry more goods at once, and requires fewer drivers.

Reduced Road Maintenance Costs: Fewer trucks on the highways means less wear and tear on the roads, which can lead to lower road maintenance costs for municipalities and governments.

Overall, making freight rail more efficient has a significant positive impact on the environment, public safety, the economy, and infrastructure maintenance costs.

In the Central Valley, BNSF will benefit from replacing San Joaquin passenger service with HSR service and free up capacity on BNSF plus the grade separation benefits. The project south of Los Angeles will provide benefits for BNSF and the section between Gilroy and Control Point Lick will benefit UP.

Although freight transport contributes significantly to the productivity of the U.S. economy, it also involves sizable costs to society. Those costs include wear and tear on roads and bridges; delays caused by traffic congestion; injuries, fatalities, and property damage from accidents; and harmful effects from exhaust emissions. No one pays those external costs directly—neither freight haulers, nor shippers, nor consumers. The unpriced external costs of transporting freight by truck (per ton-mile) are around eight times higher than by rail.[19] Existing rail cost savings were estimated assuming a 1% efficiency gain to rail freight rate; and external costs savings (including pavement damage, congestion, safety (accidents), and emissions reductions) assuming a 1.5% diversion to rail due to rail efficiency gains.

Table 33: Freight and passenger rail efficiency benefits inputs

Data input	Value	Source
Truck External Costs ($2014)	2.62–5.86 cents / ton-mile	Pricing Freight CBO Working Paper[19]
Rail External Costs ($2014)	0.30–0.82 cents / ton-mile	Pricing Freight CBO Working Paper
Freight rail rate ($2021)	$0.041 / ton-mile	Association of American Railroads[20]
Proportion diverted to rail	1.5%	KPMG and Texas Freight Rail Study[21]
Efficiency cost savings for rail	1%	Texas Freight Rail Study

Table 34: Freight and passenger rail efficiency benefits

Benefit	Year 2040	Project Life Cycle	
	Undiscounted	Undiscounted	Discounted (7%)
Existing rail cost savings	$49	$1,572	$337
External cost savings	$216	$6,879	$1,475
TOTAL	**$266**	**$8,451**	**$1,813**

(Millions of 2021 dollars)

4.7 Residual Value

The useful life of the asset under construction is expected to go well beyond the 30-year period of benefits accrual. Rolling stock, rail stations, tunnels and bridges under construction will continue to be used and benefit the state of California past the 30-year period used to compute benefits. The residual capital value (RCV) is calculated by determining the percentage of useful life remaining beyond the

[19] Pricing Freight Transport to Account for External Costs CBO Working Paper https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/workingpaper/50049-Freight_Transport_Working_Paper-2.pdf

[20] Association of American Railroads https://www.aar.org/data/average-u-s-freight-rail-rates-since-deregulation/#!

[21] Port of Corpus Christi Rail Yard Project BCA Appendix C https://ftp.dot.state.tx.us/pub/txdot-info/rail/tiger3/port_corpus/cost_benefit.pdf

analysis period and multiplying that percentage by the construction cost for that component. The design life is estimated at 60 years for capital costs items such as stations, and 100 years for longer-term expenditures such as tunnels and bridges, according to engineer estimates taking into account annual repair, rehabilitation and replacement, and reinvestments in the system.

With a 30-year benefit analysis period and 60 to 100-years design life, a percent of the remaining capital value is viewed as a cost offset or "negative cost" and is applied to the last year of the analysis period as a negative value. The residual value of the project improvements is valued at $4.0 billion in 2021 discounted dollars, as show in the table below.

Table 35: Residual Value Estimation of Benefits

Benefit	Final Analysis Year – 2060	
	Undiscounted	Discounted (7%)
Phase 1 System Remaining Capital Value in Final Year	$55,922	$3,996
Total Residual Value Benefits	**$55,922**	**$3,996**

(Millions of 2021 dollars)

The assumptions used in the estimation of residual value benefits are presented in the following table.

Table 36: Residual Value Capital Cost Assumptions

Asset Name	Expected Life Span	Last Purchase Year	Residual Value in Final Analysis Year - Undiscounted	Residual Value in Final Analysis Year – Discounted (7%)
Long-Term Capital Costs	100	2031	$47,858	$3,420
Regular-Term Capital Costs	60	2031	$8,063	$576
Total		**2031**	**$55,922**	**$3,996**

(in Millions of Undiscounted 2021 Dollars)

Chapter 5: Summary of Results

5.1 Evaluation Measures

The benefit-cost analysis converts potential gains (benefits) and losses (costs) from the Phase 1 HSR System into monetary units and compares them. The following common benefit-cost evaluation measures are included in this BCA:

- Net Present Value (NPV): All benefits and costs over the project life cycle are discounted to the present, and the costs are subtracted from the benefits to yield an NPV. If benefits exceed costs, the NPV is positive, and the project may be considered to be economically justified.
- Benefit Cost Ratio (BCR): In this measure, the present value of benefits (including negative benefits such as O&M costs) is placed in the numerator of the ratio and the present value of costs is placed in the denominator. If benefits exceed costs, the NPV is above 1.0 and the project may be considered to be economically justified.
- Internal Rate of Return (IRR): The IRR is the discount rate which makes the NPV from a project equal to zero. In other words, it is the discount rate at which a project break even. Generally, the greater the IRR, the more desirable a project.
- Payback Period: The payback period refers to the period of time required to recover the funds expended on a project. When calculating the payback period, the time value of money (discounting) is not taken into account.

5.2 BCA Results

The table below presents the evaluation results for the Phase 1 HSR System. Results are presented in $2021 dollars, discounted at 7 percent.

The total value of the benefits generated by the project improvements within the analysis period are calculated to be **$70.6 billion** in discounted 2021 dollars. The total capital costs are calculated to be **$53.7 billion** in discounted 2021 dollars. The difference in the discounted benefits and costs equals a net present value of **$16.9 billion** in discounted 2021 dollars, resulting in a benefit-cost ratio (BCR) of **1.32**.

The evaluation of the Phase 1 HSR System's benefits and costs are summarized below. Results are presented in undiscounted and discounted at 7 percent. All benefits and costs were estimated in constant 2021 dollars over an analysis period of 30 years following project completion.

Table 37: Benefit-Cost Analysis Results

BCA Metric (in Millions)	Discounted (7%)
Total Benefits	**$70,591**
Users Benefits	**$24,975**
Travel and Transfers Time	$12,660
Reliability	$5,372
Stations and Train Amenities Benefits	$4,947
Induced Ridership Benefits	$1,996
Safety and Environmental Benefits	**$16,636**
Vehicle O&M (including fuel)	$8,787
Safety [highway traffic reduction]	$4,995
Emissions Reductions from Auto	$1,381
Emissions Reductions from Air	$222
Airport Delay Savings	$109
Congestion	$1,119
Pavement and Noise	$22
Workers Wider Economic Benefits	**$17,552**
At-Grade Rail Crossing Removals	**$6,676**
Emergency Vehicle Benefits	$4,845
Waiting Time and Emissions Savings	$1,167
Reliability	$532
Safety [at-grade crashes reduction]	$134
Commercial Property Value	**$5,996**
Residual Value	**$3,996**
Freight and Passenger Rail Efficiency Gains	**$1,813**
Operations & Maintenance and Repair & Rehabilitation	**-$7,052**
Operations & Maintenance (O&M)	-$6,287
Repair & Rehabilitation (R&R)	-$766
Total Costs	**$53,667**
Net Present Value (NPV)	**$16,924**
Benefit Cost Ratio (BCR)	**1.32**
Payback Period (Years)	**19**
IRR	**8.8%**

(in Millions of 2021 dollars unless otherwise noted)