CALIFORNIA
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Ridership and Revenue Forecasting

2016 BUSINESS PLAN: TECHNICAL SUPPORTING DOCUMENT

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CAMBRIDGE SYSTEMATICS

California High-Speed Rail 2016 Business Plan

Ridership and Revenue Forecasting

technical supporting document

prepared for

Parsons Brinckerhoff for the California High-Speed Rail Authority

prepared by

Cambridge Systematics, Inc.

April 8, 2016

www.camsys.com

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Table of Contents

List of Tables

List of Figures

Executive Summary

Cambridge Systematics' (CS) approach to preparing forecasts for use in the California High-Speed Rail Authority's ("the Authority") 2016 Business Plan was predicated on the following concepts:

- The ridership and revenue (R&R) model produces reasonable forecasts with reasonable sensitivities to changing conditions.
- Models are not perfect, and their imperfections need to be understood and reflected in the forecasts used for business planning purposes.
- Future conditions cannot be known with certainty. The forecasts used for business planning purposes need to recognize those uncertainties and present a reasonable range.

The resulting R&R forecasting process involved the following steps. CS:

- Refined the previous Version 2 model by fully incorporating the findings of both new stated-preference and revealed-preference surveys into the rider choice models to create a new model, now called the Business Plan Model Version 3 (BPM-V3). Additionally, a new variable was added to the model that reduced the number of trips that involve a relatively long trip to travel to or from the high-speed rail station, combined with a relatively short trip on the high-speed rail line itself by adding a variable to reflect the disbenefits of those types of trips. Finally, several other small adjustments were made to the model to produce updated forecasts.
- Refined the high-speed rail service plans reflecting the updated strategy for implementation and sequencing of the Phase 1 system; this includes producing forecasts for a line that connects Silicon Valley to the Central Valley (from San Jose to a station north of Bakersfield) for a 2025 opening year, analyzing an extension of that line to San Francisco and Bakersfield also in 2025, and forecasts for the Phase 1 system between San Francisco and Anaheim for 2029 (opening year) and 2040 (out year).
- Updated the conventional passenger rail and urban transit networks to ensure consistency with current and planned routes and service, as outlined in the 2013 California State Rail Plan[1] and plans for individual regional rail operators.[2]
- Incorporated revisions to socioeconomic growth assumptions (population, housing, and employment forecasts) consistent with the California Statewide Travel Demand Model (CSTDM), but customized for the years for which forecasts were needed for the 2016 Business Plan: 2025, 2029, and 2040, as well as developing a range of alternative forecasts for use in the risk analysis.
- Updated the previous risk analysis model that incorporated a range of assumptions for the factors that CS believes will have the greatest influence on high-speed rail ridership and revenue. The ridership and revenue forecasts are expressed in terms of probabilities that were developed using this approach.

[1] 2013 California State Rail Plan, May 2013, available at: http://californiastaterailplan.dot.ca.gov/.

[2] Plans for the Bay Area Rapid Transit District (BART) and the Sonoma-Marin Area Rail Transit (SMART) in the San Francisco Bay Area, and Metrolink in the Southern California region were used.

Summary of Ridership and Revenue Forecasts

Ridership and revenue forecast ranges with the probabilities of achieving certain values are shown in Tables E.1 and E.2, respectively. The values representing different confidence levels, from 1 percent to 99 percent, are highlighted. A 10-percent confidence level means that there is a 10-percent chance that the ridership/revenue will be lower than this value (or a 90-percent chance that it will be higher). The range in revenue for the Silicon Valley to Central Valley line year 2025 forecast between the 10th and 90th percentiles is $560 million, compared to $2,492 million for the Phase 1 year 2040 forecast.

Table ES.1 Range of Annual Ridership by Implementation Step[3]
Millions

	Implementation Step		
Confidence Level That Ridership Will Be Less Than Stated Value	**Silicon Valley to Central Valley line 2025**	**Phase 1 2029**	**Phase 1 2040**
Minimum	1.7	10.2	8.9
1%	3.0	16.3	15.8
10%	4.4	22.9	23.5
25%	5.7	28.7	30.3
Median	7.8	37.5	40.7
75%	10.6	49.1	54.7
90%	13.7	62.0	70.5
99%	20.2	86.6	104.1
Maximum	39.6	137.6	179.1
Base Run (Percentile)	*7.5 (47%)*	*37.1 (49%)*	*42.8 (54%)*

Source: Cambridge Systematics, Inc.

[3] The results are raw model output and do not account for ramp-up.

Table ES.2 Range of Annual Revenue by Implementation Step[4]

Millions, 2015 Dollars

Confidence Level That Ridership Will Be Less Than Stated Value	Implementation Step		
	Silicon Valley to Central Valley line 2025	Phase 1 2029	Phase 1 2040
Minimum	$112	$634	$704
1%	$192	$950	$1,038
10%	$280	$1,303	$1,471
25%	$359	$1,619	$1,852
Median	$484	$2,082	$2,419
75%	$652	$2,691	$3,153
90%	$840	$3,359	$3,963
99%	$1,215	$4,610	$5,606
Maximum	$2,144	$6,628	$9,191
Base Run (Percentile)	*$460 (46%)*	*$2,069 (49%)*	*$2,413 (50%)*

Source: Cambridge Systematics, Inc.

[4] The results are raw model output and do not account for ramp-up.

1.0 Introduction

1.1 Overview

Since 2007, Cambridge Systematics (CS) has been supporting the California High-Speed Rail Authority ("the Authority") by producing ridership and revenue (R&R) forecasts for different high-speed rail service options using a state-of-the-art travel demand model. The "Version 1" model was originally estimated and calibrated using data from the 2000-2001 California Statewide Household Travel Survey and a 2005 Stated-Preference Survey to support alternatives analyses and project-level environmental work.

In 2010 and 2011, CS made numerous enhancements to the original Version 1 R&R model. The updated model was used to support the California High-Speed Rail Draft 2012 Business Plan.[5] After receipt of public comment, the Authority made changes to the high-speed rail scenarios being considered in the draft version of the 2012 Business Plan, and CS updated the model assumptions and prepared forecasts in support of the Final 2012 Business Plan.[6]

In 2012 and 2013, CS made additional enhancements to the R&R model to accommodate the evolving forecasting needs of the Authority. The enhanced model, known as Version 2, represented a major overhaul of all model components. It responded to the recommendations of the Authority's Ridership Technical Advisory Panel (RTAP), and considered comments from the Authority's Peer Review Group (PRG) and the Government Accountability Office (GAO). In addition to model enhancements, CS used a risk analysis approach to prepare and present ridership and revenue forecasts.

In 2014, CS made additional changes to the Version 2 model. The updated version:

- Fully incorporated findings of both stated-preference and revealed-preference surveys into the rider choice models.
- Refined the previous Version 2 model to reduce the number of trips that involve a relatively long trip to travel to or from the high-speed rail station, combined with a relatively short trip on the high-speed rail line itself by adding a variable to reflect the disbenefits of those types of trips.
- Updated the conventional passenger rail and urban transit networks to ensure consistency with current and planned routes and service, as outlined in the 2013 California State Rail Plan[7] and plans for individual regional rail operators.[8]

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[5] Cambridge Systematics, Inc., "California High-Speed Rail 2012 Business Plan, Ridership, and Revenue Forecasting, Draft Technical Memorandum," prepared for Parsons Brinckerhoff for the California High-Speed Rail Authority, October 19, 2011.

[6] Cambridge Systematics, Inc., "California High-Speed Rail 2012 Business Plan, Ridership, and Revenue Forecasting, Final Technical Memorandum," prepared for Parsons Brinckerhoff for the California High-Speed Rail Authority, April 12, 2012.

[7] 2013 California State Rail Plan, May 2013, available at: http://californiastaterailplan.dot.ca.gov/.

[8] Plans for the Bay Area Rapid Transit District (BART) and the Sonoma-Marin Area Rail Transit (SMART) in the San Francisco Bay Area and Metrolink in the Southern California region were used.

- Replaced the San Fernando Valley high-speed rail station with the Burbank Airport high-speed rail station in Phase 1.
- Refined the assumed frequency of service and travel times between several station pairs for each phase, and
- Made several other minor revisions to input variables and recalibrated the model.

The RTAP supported CS' efforts to estimate, calibrate, and validate this new model version, known as the BPM-V3. Documentation of the model and its calibration can be found in the *California High-Speed Rail Ridership and Revenue Model, Business Plan Model Version 3 (BPM-V3) Model Documentation*.

This technical memorandum documents the application of the BPM-V3 to produce ridership forecasts that support the 2016 Business Plan. Section 2.0 summarizes the updates to BPM-V3. Section 3.0 documents the implementation steps evaluated. Section 4.0 describes the assumptions related to the transportation system. Section 5.0 summarizes the evaluation of socioeconomic forecasts. Section 6.0 documents the ridership and revenue forecasts, and Section 7.0 explains the risk analysis approach. Readers interested in learning more about the risk analysis process and the range of forecasts are directed to the *2016 California High-Speed Rail Business Plan - Ridership and Revenue Risk Analysis Technical Report.*

1.2 Scope of Forecasts

CS developed forecasts for two main phases of the project as specified by the Authority:

1. **Silicon Valley to Central Valley (VtoV) –** San Jose to a station north of Bakersfield opening in year 2025:
    a. Silicon Valley to Central Valley Extension – San Francisco to Bakersfield opening in year 2025.
2. **Phase 1: San Francisco and Merced to Los Angeles and Anaheim opening in 2029 and an out-year of 2040.** Ridership and revenue forecasts were prepared for the opening year for each implementation step and a Phase 1 out year. The 2040 forecast would reflect ridership on a mature system that would at the time have more than 10 years of operating history. The 2016 Business Plan lays out an implementation strategy that starts with the Silicon Valley to Central Valley line. Additionally, the Plan also includes a sensitivity analysis to show the impact of extending that line to both San Francisco and Bakersfield. The model results for both of these segments are reported.

1.2.1 Ridership and Revenue Adjustments to Account for "Ramp up"

The ridership and revenue forecasts assume a mature high-speed rail system, where potential passengers are fully aware of the system. In reality, it usually takes some years for a new system to achieve this mature state. The 2016 Business Plan lays out the assumptions to reduce ridership and revenue in the early years of each phase to account for the "ramp up" of ridership and revenue over time.

1.3 Disclaimer

The information and results presented in this technical memorandum are estimates and projections that involve subjective judgments, and may differ materially from the actual future ridership and revenue. This technical memorandum is not intended, nor shall it be construed, to constitute a guarantee, promise, or representation of any particular outcome(s) or result(s). Further, the material presented in this technical memorandum is provided solely for purposes of the Authority's business planning and should not be used for any other purpose.

2.0 Model Updates and Enhancements

Complete details regarding updates and enhancements to the travel demand model used for ridership and revenue forecasts are contained in the *California High-Speed Rail Ridership and Revenue Model – Business Plan Model-Version 3 Model Documentation*. Below is an overview of the improvements made since the 2014 Business Plan.

2.1 Overview of Model Updates

The BPM-V3 has been estimated using data from the 2013-2014 revealed-preference (RP)/stated-preference (SP) survey, in addition to the 2005 RP/SP survey and the 2012-2013 CSHTS data. At the time of release of the 2014 Business Plan, the 2013-2014 RP/SP survey had not been fully incorporated into the forecasts. Over the last two years, CS has completed its analysis of the new survey data, and has fully incorporated it into the forecasts.

Additionally, the BPM-V3 addresses a tendency of the Version 2 Model to forecast some trips with long access and/or egress times, coupled with relatively short trips on the main mode. This characteristic did not show up in the model calibration or validation since most observed trips on conventional rail (CVR) were relatively short; and conversely, most trips by air were relatively long. Since high-speed rail provided competitive service for the full range of distances, trips by high-speed rail were more likely affected by the long access-egress/short main mode issue and, thus, the issue was not identified until model application. Although these trips did not constitute a substantial share of either ridership or revenue, CS added specific variables to the model to discourage these types of trips. By reducing the number of short trips on high-speed rail, the average trip length on high-speed rail increased.

The BPM-V3 includes four new variables in the mode choice utility functions: 1) auto access time, 2) non-auto access time, 3) auto egress time, and 4) non-auto egress time, with each being divided by total auto distance. These variables appear in the access and egress utility components of the mode choice model. The model also includes an adjustment to divide auto costs by an assumed average auto occupancy of 2.5 for those who travel in groups. Additionally, the forecasts in the 2016 Business Plan reflect updated model inputs for transit networks and high-speed rail system characteristics (e.g., station locations, planned phasing, etc.).

3.0 Phased Implementation Scenarios for the 2016 Business Plan

3.1 Scenario Overview

The business case evaluation assumes that the high-speed rail project will open in phases, from 2025 through 2029, as described below. The Silicon Valley to Central Valley scenarios replace the previous Initial Operating Segment (IOS) evaluated in the 2014 Business Plan. Further detail on the fares and frequencies are provided in Section 3.2.

3.1.1 Silicon Valley to Central Valley Line– Open in 2025

The Silicon Valley to Central Valley line is planned to begin service in 2025, characterized by:

- A north terminal at San Jose and a south terminal at a station north of Bakersfield (Figure 3.1);
- Dedicated coach services will be provided between the Fresno station and the Sacramento region, as well as between the line's southern terminus and locations in the Los Angeles Basin (LA Basin);
- Connections with Amtrak at Fresno to the Bay Area and Sacramento would be coordinated; and
- Potential extensions to the Silicon Valley to Central Valley phase would extend high-speed rail service from San Jose to San Francisco in the north and from the assumed southern terminus to Bakersfield.

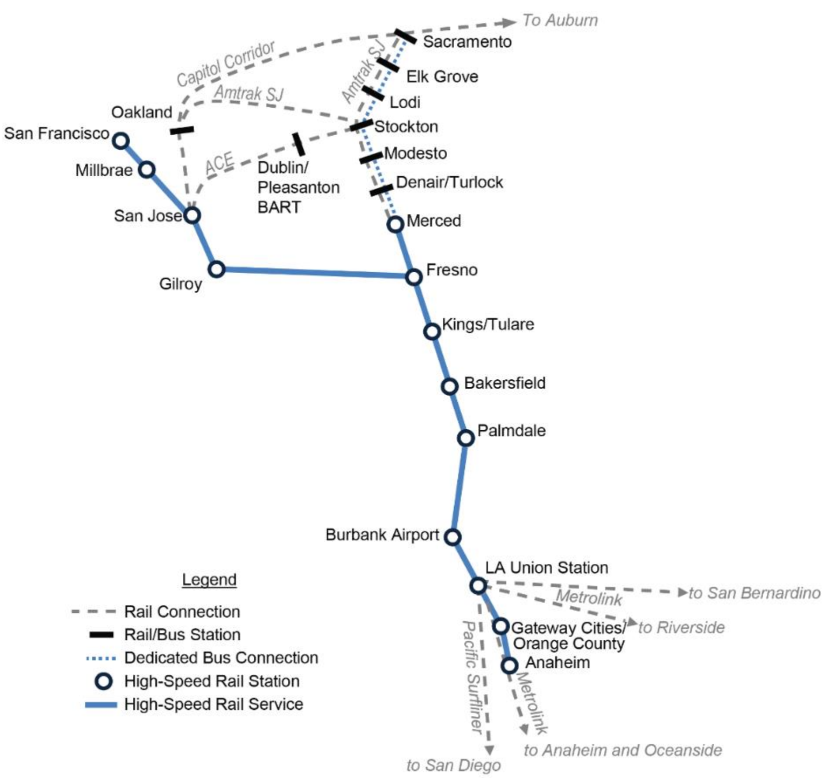
Figure 3.1 Silicon Valley to Central Valley Line

3.1.2 Phase 1

Scheduled to start operations in 2029, Phase 1 completes the high-speed rail system from a north terminal at San Francisco to the south terminal at Anaheim (Figure 3.2), with these characteristics:

- High-speed rail service will operate on Caltrain tracks from San Jose to San Francisco, meaning that congestion on the corridor is taken into account for assumed travel time;
- Dedicated coach services would be provided from Merced to Sacramento;
- Connections with Amtrak at Merced to the Bay Area and Sacramento would be coordinated; and
- Connections with Metrolink feeder service at Los Angeles Union Station (LAUS) to LA Basin destinations would be coordinated.

Figure 3.2 Phase 1



3.2 High-Speed Rail Service Plan Assumptions

High-speed rail fares for all 2016 Business Plan scenarios were identical to those in the 2014 Business Plan escalated from 2013 dollars to 2015 dollars. The fares are based on the formula below, with an $89 maximum in 2015 dollars (see Table 3.1):

- $32.26 + $0.1994 per mile (in 2015 dollars) for interregional fares;
- $23.94 + $0.1662 per mile (in 2015 dollars) for intraregional fares for the SCAG region; and

- $15.51 + $0.1330 per mile (in 2015 dollars) for intraregional fares for MTC and SANDAG regions.

Service assumptions varied by scenario. The details of the service frequencies are described in Table 3.2. The stopping patterns are provided in Appendix A.

Table 3.1 Assumed High-Speed Rail Fares

2015 Dollars

High-Speed Rail Stations	San Francisco (Transbay)	Millbrae	San Jose	Gilroy	Merced	Fresno	Kings/Tulare	Bakersfield	Palmdale	Burbank Airport	Los Angeles Union Station	Gateway Cities/ Orange County	Anaheim
San Francisco (Transbay)		$18	$23	$25	$59	$70	$78	$89	$89	$89	$89	$89	$89
Millbrae			$20	$24	$59	$70	$77	$89	$89	$89	$89	$89	$89
San Jose				$19	$56	$63	$68	$83	$89	$89	$89	$89	$89
Gilroy					$52	$59	$65	$78	$89	$89	$89	$89	$89
Merced						$45	$52	$67	$85	$86	$89	$89	$89
Fresno							$40	$56	$74	$75	$78	$81	$84
Kings/Tulare								$51	$67	$68	$74	$76	$78
Bakersfield[9]									$51	$52	$56	$58	$60
Palmdale										$32	$33	$34	$36
Burbank Airport											$27	$30	$32
Los Angeles Union Station												$27	$30
Gateway Cities/ Orange County													$27
Anaheim													

Source: Cambridge Systematics, Inc.

[9] Fares for the North of Bakersfield station evaluated in the Silicon Valley to Central Valley lines are the same.

Table 3.2 High-Speed Rail Service Plan Assumptions by Scenario

Business Plan Scenario	North Terminus	South Terminus	High-Speed Rail Service Summary[a]	Dedicated Peak Bus Coach Connections[b]		Conventional Rail Connections
				North Terminus	South Terminus	
Silicon Valley to Central Valley Line	San Jose	North of Bakersfield	• 2 peak TPH from San Jose and North of Bakersfield (1 in off-peak)	• 2 peak BPH from Fresno and Sacramento (1 in off-peak)	• 2 BPH from North of Bakersfield and LAUS (1 in off-peak) • 2 BPH from North of Bakersfield and West LA (1 in off-peak) • 2 BPH from North of Bakersfield and Santa Anita (1 in off-peak)	• Coordinated service with Amtrak at Fresno
Silicon Valley to Central Valley Line Extension	San Francisco	Bakersfield	• 2 peak TPH from San Francisco and Bakersfield (1 in off-peak)	• 2 peak BPH from Fresno and Sacramento (1 in off-peak)	• 2 BPH from Bakersfield and LAUS (1 in off-peak) • 2 BPH from Bakersfield and West LA (1 in off-peak) • 2 BPH from Bakersfield and Santa Anita (1 in off-peak)	• Coordinated service with Amtrak at Fresno
Phase 1	San Francisco and Merced	Los Angeles and Anaheim	• 2 peak TPH from San Francisco and Los Angeles (3 in off-peak) • 2 peak TPH from San Francisco and Anaheim (1 in off-peak) • 2 peak TPH from San Jose and Los Angeles (0 in off-peak) • 1 peak TPH from Merced and Los Angeles (0 in off-peak) • 1 peak TPH from Merced and Anaheim (same in off-peak)	• 2 BPH from Sacramento and Merced (1 in off-peak)	None	• Coordinated service with Amtrak at Merced • Metrolink connections at LAUS

[a] TPH – Trains per Hour
[b] BPH - Buses per Hour

4.0 Service Assumptions for Air, Conventional Rail, Highway, and Autos

4.1 Air Service Assumptions

In producing forecasts for previous business plans, CS engaged Aviation System Consulting, LLC (ASC), a California-based expert firm, to develop air service assumptions based on the latest air service patterns in the California Corridor markets. ASC analyzed the past decade of U.S. Department of Transportation (DOT) data on airline service and fare levels, explained the economic factors affecting airline responses to changes in competition and capacity, and helped determine scenarios of potential airline competitive response to the introduction of high-speed rail service. CS and ASC discussed the analytical approach and assumptions developed for the 2012 Business Plan, and concluded that the analysis performed in 2011 is still largely relevant since no significant changes have occurred since then in the airline industry.[10]

The baseline assumption for air fares and assumed headway for all forecast years was that air fares would remain consistent with average fares and frequency of service that was used in the 2014 Business Plan. Table 4.1 provides base airfares and headways between select major airports.

Table 4.1 Air Service Assumptions

Origin Airport	Destination Airport	Assumed Airfare (2015 Dollars)	Assumed Headway (Minutes)
Burbank	San Francisco	$115	480.0
Burbank	Sacramento	$112	150.0
Los Angeles	San Diego	$237	32.0
Los Angeles	San Francisco	$100	23.0
Oakland	San Diego	$111	46.0
Oakland	Los Angeles	$111	44.0
Sacramento	Burbank	$112	150.0
Sacramento	San Francisco	$299	141.0
San Francisco	San Diego	$96	28.0
San Francisco	Burbank	$115	480.0

Source: Aviation System Consulting.

4.2 Conventional Passenger Rail Service Assumptions

CVR service, including travel times, frequency of service, and stations served, were updated to reflect the latest conditions and forecasts from the 2013 California State Rail Plan (CSRP),[11] Metropolitan Planning Organization (MPO) forecasts, and the California Statewide Transportation Demand Model (CSTDM). The

[10] See Appendix B of the "California High-Speed Rail 2012 Business Plan, Ridership and Revenue Forecasting, Final Technical Memorandum, April 12, 2012" for complete details of this evaluation.

[11] 2013 California State Rail Plan, May 2013. Available at: http://californiastaterailplan.dot.ca.gov/.

largest service changes from today include increased conventional rail service on the Altamont Corridor Express and the San Joaquins to connect with high-speed rail, and increased service between San Diego and Los Angeles via connected Coaster and Metrolink service. In the Silicon Valley to Central Valley scenarios, the enhanced San Joaquin trains were assumed to connect from Sacramento and Oakland to high-speed rail at Fresno. In Phase 1, that connection was assumed at Merced. The updated CVR sources are summarized in Table 4.2 and operating frequencies are summarized in Table 4.3.

Table 4.2 Source of CVR Operating Plan Forecasts

Source of Forecast	CVR Operators
California State Rail Plan	Amtrak San Joaquin Capitol Corridor Pacific Surfliner Altamont Corridor Express Caltrain Coaster MetroRail
MPO Plans	BART SMART Metrolink
California Statewide Transportation Demand Model	Muni LRT VTA LRT Sacramento LRT SANDAG LRT Sprinter

Table 4.3 CVR Operating Plan Service Frequencies

	2025 / 2029-2040[a]
Caltrain	
Gilroy – San Jose	11 / 11
Tamien/San Jose – San Francisco (4th and King/SF Transbay)	68 / 68
Capitol Corridor Route	
Auburn – Oakland	2 / 2
Sacramento – Oakland	3 / 3
Sacramento – San Jose	11 / 11
San Joaquin Route	
Sacramento – Merced connection to high-speed rail via San Joaquin Route	10 / 10
Sacramento – Bakersfield via San Joaquin Route	- / -
Oakland – Bakersfield via San Joaquin Route	- / -
Oakland – Merced connection to high-speed rail via San Joaquin Route	10 / 10
Stockton – Merced connection to high-speed rail via San Joaquin Route	1 / 1
Merced – Bakersfield via San Joaquin Route	6 / 6
Ace Route	
San Jose – Stockton via ACE Route	4 / 4
San Jose – Merced connection to high-speed rail via ACE and Union Pacific Railroad (UPRR) Route	2 / 2
San Jose – Merced connection to high-speed rail via ACE and BNSF Railway (BNSF) Route	4 / 4
Pacific Surfliner	
San Luis Obispo – Los Angeles	2 / 2
Goleta – Los Angeles	3 / 3
Los Angeles – San Diego	18 / 18
Metrolink (Ventura and Orange County Lines) and COASTER	
East Ventura[p] – Los Angeles	20 / 20
Los Angeles – Irvine/Laguna Niguel	5 / 5
Los Angeles – Oceanside	2 / 2
Los Angeles – San Diego (Metrolink COASTER “through” commuter service)	5 / 5
Riverside – San Diego (Metrolink-COASTER “through” commuter service)	0 / 2
Oceanside – San Diego	17 / 17
Metrolink – Other Lines	
Antelope Valley Line (LAUS – Palmdale)	19 / 19
San Bernardino Line (LAUS – San Bernardino)	23 / 23
Riverside Line (LAUS – Riverside)	6 / 6
91/Perris Valley Line (LAUS – Riverside-Perris)	7 / 7
Burbank Airport Line (LAUS – Burbank Airport)	7 / 7
IEOC (San Bernardino-Riverside-Irvine-Laguna Niguel/Mission Viejo)	10 / 10
OC Intracounty Line (Fullerton – Laguna Niguel/Mission Viejo)	5 / 5

Source: Cambridge Systematics, Inc.

[a] This column denotes the number of conventional passenger rail trains per day in each direction for the Silicon Valley to Central Valley lines in 2025 and for Phase 1 between 2029 and 2040.

Fare assumptions for all CVR lines are consistent with on-line published fares in 2011. Consistent with previous assumptions, the peak period was assumed to be three hours during each of the a.m. and p.m. peak periods, and 10 hours for the off-peak period.

4.2.1 Highway Network

CS used the same highway network assumptions as those used for the CSTDM for each respective forecast year.[12] CS averaged AM and PM peak congested travel times derived from the CSTDM for use when peak travel times were needed in the mode choice model. Similarly, CS averaged midday and off-peak congested speeds for when off peak travel times were needed.

Auto terminal times represent the average time to access one's vehicle at each end of the trip and are added to the congested travel time to get the total congested travel time skim. They are based on the area type of the trip ends and are assessed at both the origin and destination of the trip.

Travel times for the modeled forecast years were obtained by interpolating between the closest forecast years.

Auto costs (besides operating costs) comprise tolls and parking costs. Toll costs were imported from networks developed for the CSTDM. Tolls corresponding to single-occupancy vehicles were assumed in the auto skims. Peak and off-peak tolls were averaged where costs differed. The parking costs developed for the 2010 base year scenario were used for all future year scenarios.

4.2.2 Automobile Operating Cost

The approach for forecasting auto operating costs for the 2016 Business Plan is consistent with the methodology used for the 2014 Business Plan, with updates to the cost projections. The auto operating costs used for the different forecast years are summarized in Table 4.4, with details regarding forecasts for the fuel and nonfuel components of operating cost provided below. The ranges and probability distribution used in the risk analysis model is described in Section 6.3.

Table 4.4 Auto Operating Costs
2015 Dollars

Forecast Year	Range (Cents per Mile)
2025	26
2029	26
2040	24

Source: Cambridge Systematics, Inc.

[12] For more information regarding the CSTDM model development and assumptions, see the documentation provided on the California DOT (Caltrans) web site: http://www.dot.ca.gov/hq/tsip/otfa/cstdm/cstdm_documentation.html.

Fuel Component of Auto Operating Costs

Forecasts of future fuel costs are a function of the cost of fuel and vehicle fuel economy. Each of these is discussed below.

Motor gasoline price forecasts. The gasoline price forecast was based on the U.S. Energy Information Administration's (EIA) 2011 Annual Energy Outlook (AEO). CS updated the projected motor gasoline prices in California based on the 2013 AEO, which extends through 2040. The EIA provides average motor gasoline price forecasts for three different scenarios: 1) reference, 2) low, and 3) high. CS extrapolated the forecasts to 2050 using the projected average annual growth rate from 2020 to 2040. Historically, California's retail gasoline prices have been higher than the U.S. average; the overall average for California prices over the U.S. average prices over the 2000 to 2012 time period has been 12 percent. CS developed a forecast of California gasoline prices by taking the forecasts from EIA and increasing them by 12 percent. For the base model run, CS assumed the reference case forecast, adjusted to California.

Fuel Economy Forecasts. The forecasts for the 2016 Business Plan considered the adopted Corporate Average Fuel Economy (CAFE) standards for light-duty vehicles for model year 2012 to 2016, as well as fuel economy projections based on the 2013 AEO forecasts, which included the adopted fuel efficiency standards for model year 2017 through model year 2025. The EIA provided forecasts for two cases:

1. **Reference Case.** The AEO2013 Reference case includes the final CAFE standards adopted in October 2012 for model years 2017 through 2025, with subsequent CAFE standards for years 2026 to 2040 vehicles calculated using 2025 levels. In 2010, California accepted compliance with Federal greenhouse gas (GHG) emission standards as meeting similar state standards and incorporated the national standards into their motor vehicle emissions program.[13,14] CS interpreted this to mean that, in the future, national and California standards will be the same.

2. **Extended Policy.** The Reference case assumes that the CAFE standards are held constant at model year 2025 levels in subsequent model years, although the fuel economy of new light-duty vehicles would continue to rise modestly over time. The Extended case modifies the assumption assuming continued increases in CAFE standards after model year 2025. CAFE standards for new light-duty vehicles are assumed to increase by an annual average rate of 1.4 percent.

The fuel economy projections for the Reference and Extended policy case are for the entire "on-the-road" fleet of vehicles (not only new vehicles). The average annual growth rate from 2035 to 2040 for the Reference case is 1.1 percent.

Combined Estimate of Fuel Operating Costs. While the lowest auto operating cost could be achieved by combining the high fuel efficiency with the low gasoline price, and the highest cost could be achieved by assuming the reverse, it is more reasonable to assume that high prices will coincide with high fuel economy, and low prices with low fuel economy. While fuel economy is not nearly as volatile as fuel prices, it is reasonable to assume that, over a long period of time, high prices will drive the demand for better fuel

[13] U.S. Environmental Protection Agency (EPA) (http://yosemite.epa.gov/opa/admpress.nsf/1e5ab1124055f3b28525781f0042ed40/6f34c8d6f2b11e5885257822006f60c0!OpenDocument).

[14] California Air Resources Board, Statement of the California Air Resource Board Regarding Future Passenger Vehicle Greenhouse Gas Emission Standards, May 21, 2010.

economy.[15] Therefore, CS used the Reference case with the Reference motor fuel price forecasts to develop auto operating costs for use in our ridership and revenue forecasting.

Non-Fuel Component of Auto Operating Costs

Non-fuel operating costs[16] were consistent with those in the Version 2 model for the 2014 Business Plan forecasts. The 2014 Business Plan used 7.5 cent per mile non-fuel cost. Since the non-fuel operating costs are likely to be less volatile than fuel prices, they were kept a constant amount, modified only by inflation over time (as opposed to fuel costs which were updated based on data from the EIA). The value of the non-fuel costs was rounded to 8 cents per mile in 2005 dollars, which equates to 9 cents per mile in 2015 dollars.

[15] Research studies have found and press articles have reported that when gasoline prices increase, the market share of fuel-inefficient cars decrease, and the reverse occurs for fuel-efficient vehicles (Klier, Linn, 2008; Li, Timmis, Von Haefen, 2009; Busse, Knittel, Zettelmeyer, 2009; CNN, 2012; and AOL Auto, 2012).

[16] Non-fuel costs include maintenance and repair, motor oil, parts, and accessories.

5.0 Socioeconomic Forecast

5.1 Overview

Updated long-range socioeconomic projections were developed to support the ridership and revenue forecasts for the 2014 Business Plan. These same forecasts were used in the 2016 Business Plan. CS projections reflect our professional judgment as to a reasonable range of county-level population, household, and employment levels through 2040. The projections are based upon our critical evaluation of county-level socioeconomic estimates and forecasts from many sources, including:

- **Federal agencies.** U.S. Census Bureau.
- **State agencies.** California Department of Finance (DOF); California Employment Development Department (EDD).
- **MPOs.** Metropolitan Transportation Commission (MTC), Sacramento Area Council of Governments (SACOG), San Diego Association of Governments (SANDAG), Southern California Association of Governments (SCAG), and the San Joaquin Valley MPOs.
- **Third Parties within California.** CSTDM, California Economic Forecast Project (CEF), Center for Continuing Study of the California Economy, University of California Los Angeles (UCLA) (Anderson School), and University of Southern California (Price School).
- **Third Parties outside California.** Moody's Analytics (Economy.com) and Woods & Poole, Inc.

For most sources, CS assembled and reviewed forecasts from multiple publication years beginning in the early 2000s (and as early as 1965 for one source). This history allowed an assessment of each source's accuracy versus actual conditions over many years. Overall, CS found that the U.S. Census Bureau's population and household projections were reasonably accurate. Other sources, mostly prepared by California-based organizations, tended to over-predict population, households, and employment.

The CSTDM forecasts served as the starting point for the high-speed rail socioeconomic forecasts because they had been recently updated to reflect adopted MPO forecasts at the time (as of early summer 2013).[17] They also were the only dataset that provided forecasts at the individual traffic analysis zone (TAZ) level. All the other forecasts were either at the state or county level. Making forecasts at more disaggregate geographic detail, such as a TAZ, is a challenging process and can require considerable project resources. Using the CSTDM forecasts was a reasonable choice based on the level of analysis and effort that had already been expended for that project. These forecasts are still relevant today.

CS used the other forecasts and their underlying assumptions to explore a range of plausible population, household, and employment growth scenarios on statewide and regional bases. CS considered the prior accuracy; stability (magnitude of changes of a given forecast source over time); rigor (explanation of underlying data, assumptions, and models); and robustness (internal consistency between population, housing, income, and employment components) of each source when developing and analyzing these

[17] CSTDM socioeconomic forecasts for the MTC, SACOG, SANDAG, and SCAG regions were generally developed and adopted by the MPOs between early 2010 and late 2012. Forecasts for the rest of California, including the San Joaquin Valley, appear to have been developed from 2003 to 2008 and adopted no later than early 2010.

scenarios. CS also compared the scenarios to historic relationships between population, housing, and employment growth in California and the nation.

The information suggests that CSTDM forecasts represent a likely high end of the future statewide socioeconomic growth. The CSTDM forecast assumes a statewide annual population growth rate of 1.01 percent between 2010 and 2040 which is above growth projections from other sources and observed trends over the past several years. The CSTDM forecast also assumes an average population growth rate higher than the employment growth rate, which is counter to California's historic trends between World War II and the recent recession. Beyond statewide trends, the CSTDM forecasts incorporate somewhat buoyant growth assumptions for the San Joaquin Valley.[18] These statewide and regional assumptions produce valley-wide forecasts that are higher than other sources. Therefore, CS used the CSTDM forecasts as the high estimate for statewide socioeconomic forecasts.

Based on this analysis, CS incorporated two components of socioeconomic growth, and then combined them in a matrix of distributions.

1. Statewide population, household, and employment forecasts; and
2. Share of California population in San Joaquin Valley counties (Table 5.2):
    a. Distribution 1 follows the CSTDM forecasts.
    b. Distribution 2 follows the valley-wide average distribution from recent statewide forecasts, with excess population, employment, and household-related employment shifted to the Bay Area, the Sacramento region, and Southern California.
    c. Distribution 3 reflects a further shifting of population, household, and employment growth from the San Joaquin Valley to all other California regions. It assumes that the San Joaquin Valley will see 2010 to 2050 growth patterns that are closer to statewide averages (for population and households) and long-term historical patterns for jobs.

For the 2016 Business Plan, CS used the mid-range socioeconomic forecasts with Distribution 2 for the San Joaquin Valley. Table 5.1 shows the statewide socioeconomic forecasts (in millions) for each decade and travel model years. Table 5.2 shows the share of statewide population, households, and employment assumed for San Joaquin Valley in Distribution 2.

[18] For this analysis, the San Joaquin Valley includes San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Kings, and Kern Counties.

Table 5.1 Statewide Socioeconomic Forecasts for Ridership and Revenue Risk Analysis Model
Millions

	Mid-Range Forecasts		
Year	**Population**	**Households**	**Employment**
2010	37.309	12.607	16.078
2020	40.790	13.891	18.331
2025	43.142	14.698	19.258
2029	44.359	15.116	19.703
2030	44.655	15.218	19.811
2040	47.951	16.447	21.138

Note: Ridership and revenue model forecast years are indicated by bold font in the "year" column.

Table 5.2 Share of Statewide Socioeconomic Forecasts in San Joaquin Valley Counties

	Distribution 2		
Year	**Population**	**Households**	**Employment**
2010	10.66%	9.66%	9.33%
2020	11.11%	10.23%	9.57%
2025	11.33%	10.41%	9.96%
2029	11.51%	10.57%	10.09%
2030	11.55%	10.61%	10.12%
2040	12.00%	11.17%	11.07%

Note: Ridership and revenue model forecast years are indicated by bold font in the "year" column.

6.0 Ridership and Revenue Forecast Results for Business Plan Phases

6.1 Summary of Assumptions

Table 6.1 summarizes the input assumptions for each high-speed rail operating plan and forecast year.

Table 6.1 Summary of High-Speed Rail Assumptions for Each Modeled Business Plan Phase

	Year 2025	Year 2025	Year 2029	Year 2040
High-speed rail Phase	Silicon Valley to Central Valley Line	Silicon Valley to Central Valley Line Extension	Phase 1	Phase 1
Highway Network	Year 2025[a]	Year 2025[a]	Year 2029[a]	Year 2040[a]
Auto Travel Time	Year 2025[b]	Year 2025[b]	Year 2029[b]	Year 2040[b]
Auto Parking	Year 2010	Year 2010	Year 2010	Year 2010
Air Travel Time	Year 2012[c]	Year 2012[c]	Year 2012[c]	Year 2012[c]
Air Service Frequency	Year 2012[c]	Year 2012[c]	Year 2012[c]	Year 2012[c]
Air Reliability	Year 2010[d]	Year 2010[d]	Year 2010[d]	Year 2010[d]
Parking Cost at Airport	Year 2010	Year 2010	Year 2010	Year 2010
CVR Service Plans	SRP Year 2025 Build High-speed rail[e]	SRP Year 2025 Build High-speed rail[e]	SRP Year 2040 Build High-speed rail[e]	SRP Year 2040 Build High-speed rail[e]
CVR Fares	Year 2010	Year 2010	Year 2010	Year 2010
CVR Reliability	Year 2010[f]	Year 2010[f]	Year 2010[f]	Year 2010[f]
Parking Cost at CVR Station	Year 2010	Year 2010	Year 2010	Year 2010
High-speed rail Service Plan	2016 BP for VtoV	2016 BP for VtoV Extension	2016 BP for Phase 1	2016 BP for Phase 1
High-speed rail Fares	2014 BP (83% of airfare)	2014 BP (83% of airfare)	2014 BP (83% of airfare)	2014 BP (83% of airfare)
High-speed rail Reliability	2014 BP (99%)	2014 BP (99%)	2014 BP (99%)	2014 BP (99%)
High-speed rail Parking Cost	2014 BP	2014 BP	2014 BP	2014 BP
Urban/Light Rail Service Plans	Year 2020	Year 2020	Year 2035	Year 2035
Other Transit Lines	Year 2010	Year 2010	Year 2010	Year 2010
Socioeconomic Data	Year 2025	Year 2025	Year 2029	Year 2040
Auto Operating Cost	26 cents/mile	26 cents/mile	26 cents/mile	24 cents/mile
Air Fares	Year 2009	Year 2009	Year 2009	Year 2009

[a] The high-speed rail master highway network was developed based on the CSTDM highway network for each respective forecast year. Thus, the highway "build" assumptions are consistent with those used for the CSTDM.

[b] The auto travel times for peak and off-peak were developed by loading the CSDTM AM peak and off-peak congested speeds for year 2020 and 2040 on to the corresponding year high-speed rail highway network, and then skimming the high-speed rail network to obtain peak and off-peak travel times. Travel times for the modeled forecast years were obtained by interpolating between the closest forecast years. The main mode auto times reflect an average of peak and off-peak travel times.

[c] Air service frequency and travel times remain consistent with the 2014 Business Plan, which were developed in 2011 by CS and ASC.

[d] Air reliability remains consistent with Bureau of Transportation Statistics published data for year 2010 (http://www.transtats.bts.gov/OT_Delay/OT_DelayCause1.asp?pn=1).

[e] The CVR service plan, including travel times, frequency of service, and stations served, are based on the 2013 California State Rail Plan (SRP). Assumptions for CVR operators not specifically mentioned in the SRP are based on MPO forecasts.

[f] CVR reliability remains consistent with year 2010 reliability assumptions developed from information published by each CVR operator.

6.1 Summary of Ridership and Revenue Forecasts

The base case ridership and revenue forecasts are shown in Tables 6.2. Ridership is presented in millions of annual passengers for each implementation step starting with the Silicon Valley to Central Valley line in year 2025 and Phase 1 in years 2029 and 2040. Annual revenue is reported in millions of 2015 dollars for the same implementations steps and forecast years.

Table 6.2 Annual Ridership and Revenue by Implementation Step
Millions

	Implementation Step			
	VtoV 2025	V2V Extension 2025	Phase 1 2029	Phase 1 2040
Ridership	7.5	13.2	37.1	42.8
Revenue (in 2015 dollars)	$460	$717	$2,069	$2,413

Source: Cambridge Systematics, Inc

6.2 Ridership and Revenue Forecast Comparisons by Implementation Step and Year

A comparison of forecasts for the Silicon Valley to Central Valley line in year 2025, the Silicon Valley to Central Valley Extension year 2025, Phase 1 year 2029, and Phase 1 year 2040 annual trips by major market is shown in Table 6.3. These values are shown for illustrative purposes to provide a sense of how ridership and revenue varies by project phase for particular region pairs and at particular stations. CS prepared these comparisons for a model run that represents the base case (medium level) for all of the factors that were used in the risk analysis. These values are likely to be close to, but not necessarily identical to those that represent the 50th percentile confidence-level forecast. These values also represent a mature system that have not been reduced to account for the time it takes for customers to become fully familiar with anew service.

The Silicon Valley to Central Valley line is assumed to provide less frequent high-speed rail service compared to Phase 1. The Silicon Valley to Central Valley line provides two peak trains per hour (TPH) between San Jose and a station north of Bakersfield. Dedicated coach services are assumed to be provided to Sacramento and the Los Angeles Basin. However, the coach service results in longer travel times to the Los Angeles Basin relative to Phase 1. The markets forecasted to have the highest high-speed rail mode shares include the longer-distance markets and those involving the MTC region.[19] For example, the MTC to SCAG market will have the highest mode share at 7.0 percent, followed by MTC to the San Joaquin Valley at 5.2 percent.

The lower high-speed rail mode share in the MTC to San Joaquin Valley market is partially explained by the size of the market, which has about twice the number of total person trips as MTC to SCAG (43 vs 21 million). The MTC to San Joaquin Valley market is also dominated by autos, which are forecasted to carry about 93 percent of the overall demand. The MTC to SCAG market, on the other hand, has a well-

[19] Mode share is defined as the percentage of the total travel market riding a particular mode. It is calculated by dividing the total person trips on high-speed rail by the sum of the person trips on all modes (auto person trips, conventional rail person trips, air person trips, and high-speed rail person trips).

established air market compared to MTC to San Joaquin Valley. In longer-distance markets, high-speed rail diverts a smaller share from autos and a greater share from air travel. While the absolute number of high-speed rail riders in the MTC to San Joaquin Valley market is forecasted to be higher, the mode share is lower because high-speed rail is not as competitive in shorter-distance markets where autos are the dominant mode.

The Silicon Valley to Central Valley Extension adds two new stations (San Francisco and Millbrae) and assumes a station in downtown Bakersfield instead of a station north of Bakersfield. These extensions provide greater accessibility to high-speed rail service in the MTC region and in the Bakersfield area. The mode share for MTC to SCAG and MTC to San Joaquin Valley markets increases to 10.2 percent and 7.2 percent, respectively. Like the Silicon Valley to Central Valley run, the lower high-speed rail mode share forecasted for the MTC to San Joaquin Valley market is due to the size of the total travel market.

Extending high-speed rail system to Phase 1 (where it stretches from San Francisco and Merced to Los Angeles and Anaheim) provides more access to the most populous areas in the State. Compared to the Silicon Valley to Central Valley line, the high-speed rail mode share triples (28 percent) between MTC and SCAG. Similar increases in mode share also are forecasted for other longer-distance markets. The extension of high-speed rail service to both San Francisco and Anaheim increases high-speed rail travel on the system as those extensions add new opportunities for people to access stations closer to them within the State’s largest metropolitan areas.

Table 6.3 Comparison of Annual Ridership (Millions) and Revenue (Millions, 2015 Dollars) by Major Market for Medium Level Forecast Year Scenarios

		Year 2025 VtoV Medium Level			Year 2025 VtoV Ext. Medium Level			Year 2029 Ph1 Medium Level			Year 2040 Ph1 Medium Level		
	Market	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share
SACOG	SACOG	–	–	0.00%	–	–	0.00%	–	$0.00	0.00%	–	$0.00	0.00%
	SANDAG	0.0	$1.00	1.10%	0.0	$1.25	1.29%	0.1	$8.72	7.92%	0.1	$10.13	8.10%
	MTC	0.0	$0.39	0.04%	0.5	$8.75	0.76%	0.7	$13.30	1.05%	0.8	$16.16	1.10%
	SCAG	0.2	$14.28	2.35%	0.2	$20.07	3.09%	1.0	$84.43	11.82%	1.1	$98.84	12.20%
	San Joaquin Valley	0.1	$8.51	0.86%	0.2	$11.63	1.06%	0.2	$13.76	1.63%	0.3	$17.71	1.60%
	Other regions	0.1	$1.70	0.39%	0.1	$2.52	0.49%	0.1	$3.86	0.57%	0.1	$4.65	0.60%
SANDAG	SANDAG	–	–	0.00%	–	–	0.00%	–	–	0.00%	–	–	0.00%
	MTC	0.1	$9.48	3.16%	0.2	$13.44	4.31%	0.7	$65.89	18.94%	0.8	$75.06	19.70%
	SCAG	–	–	0.00%	–	–	0.00%	2.6	$72.40	2.02%	2.8	$78.89	2.00%
	San Joaquin Valley	0.1	$5.05	2.61%	0.1	$5.92	3.08%	0.5	$37.62	13.61%	0.6	$46.47	13.70%
	Other regions	0.0	$1.87	0.89%	0.0	$2.33	1.11%	0.2	$13.49	5.79%	0.2	$15.53	6.00%
MTC	MTC	0.2	$4.30	0.61%	1.8	$40.86	4.80%	2.1	$46.33	5.30%	2.3	$51.24	5.40%
	SCAG	1.5	$121.61	6.96%	2.2	$186.21	10.18%	6.3	$555.79	27.89%	7.1	$628.22	29.00%
	San Joaquin Valley	2.2	$146.89	5.15%	3.1	$206.34	7.16%	4.1	$266.17	9.28%	5.1	$329.82	9.10%
	Other regions	0.7	$17.13	1.51%	2.0	$49.65	4.15%	2.2	$60.52	4.46%	2.5	$69.79	4.50%
SCAG	SCAG	–	–	0.00%	–	–	0.00%	5.9	$181.22	3.41%	6.4	$197.58	3.30%
	San Joaquin Valley	0.6	$34.53	1.77%	0.8	$43.51	2.23%	5.6	$368.03	15.52%	6.7	$438.80	14.90%

	Market	Year 2025 VtoV Medium Level			Year 2025 VtoV Ext. Medium Level			Year 2029 Ph1 Medium Level			Year 2040 Ph1 Medium Level		
		High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share	High-Speed Rail Rider	High-Speed Revenue	High-Speed Rail Share
	Other regions	0.3	$23.40	0.98%	0.4	$31.05	1.28%	1.5	$115.34	4.68%	1.7	$130.53	4.90%
San Joaquin Valley	San Joaquin Valley	0.7	$37.43	2.95%	1.0	$55.89	4.41%	1.9	$101.46	8.07%	2.5	$132.93	7.50%
	Other regions	0.5	$30.07	2.00%	0.6	$33.93	2.22%	0.7	$42.88	2.78%	0.9	$51.61	2.70%
Other regions	Other regions	0.1	$2.71	0.38%	0.1	$3.65	0.47%	0.1	$5.51	0.55%	0.1	$6.72	0.50%
Long-Distance Total		7.5	$460.35	1.09%	13.2	$717.00	1.92%	36.5	$2,056.71	5.08%	42.2	$2,400.70	5.10%
MTC (< 50 miles)	MTC (< 50 miles)	–	–	–	0.0	$0.46	–	0.5	$8.23	0.00%	0.5	$9.54	0.00%
SCAG (<50 miles)	SCAG (< 50 miles)	–	–	–	–	–	–	0.1	$3.27	0.00%	0.1	$2.94	0.00%
Short-Distance Total[b]		–	–	–	0.0	$0.46	–	0.6	$11.50	0.00%	0.6	$12.48	0.00%
Total		**7.5**	**$460.35**	**1.09%**	**13.2**	**$717.46**	**1.92%**	**37.1**	**$2,069.00**	**5.08%**	**42.8**	**$2,413.18**	**5.10%**

[a] With the exception of the SCAG and MTC regions, only long-distance trips (trips made to locations 50 or more miles from a traveler's home) are shown in the table. In the SCAG and MTC regions, separate summaries of intraregional trips made to locations less than 50 miles from the travelers' homes also are shown.

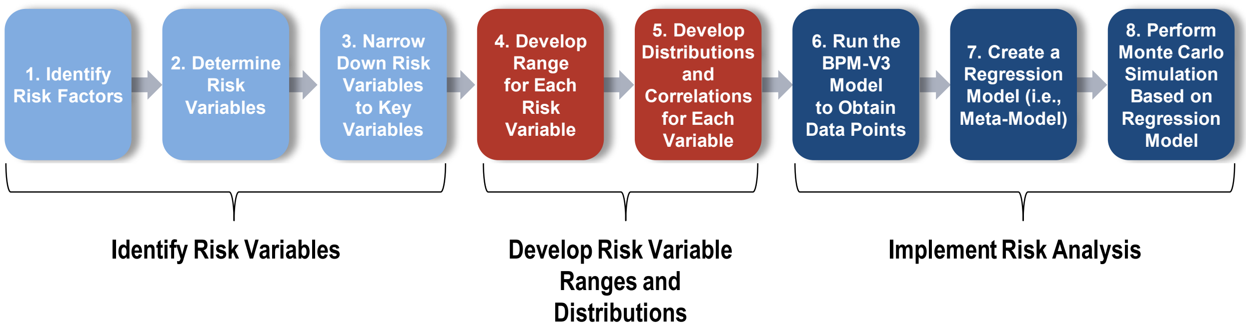
[b] Only short-distance auto, high-speed rail, and conventional rail modes are shown in this table.

7.0 Risk Analysis

7.1 Approach

An eight-step risk analysis approach was employed to forecast a range of revenue and ridership forecasts for the 2016 Business Plan, as shown in Figure 7.1 and detailed below.

Figure 7.1 Risk Analysis Approach



Step 1. Develop a list of possible risk factors to be considered for the revenue and ridership risk analysis.

- Risk factors are defined as any circumstance, event, or influence that could affect high-speed rail revenue and ridership.
- A panel of experts developed a set of potential risk factors that could impact future high-speed rail ridership and revenue.
- The identified risk factors differed between forecast years (e.g., the uncertainty and impact of high-speed rail bus connections to actual high-speed rail service is a concern for earlier years, while the likelihood of significant autonomous vehicle use affecting high-speed rail ridership is not likely until 2040).

Step 2. Identify risk variables for each risk factor.

- Risk variables are actual variables and constants that can be adjusted in the BPM-V3. As an example, auto operating cost (i.e., cost, in dollars, per vehicle mile driven) is a risk variable that can be adjusted in the model. To address the possibility that fuel cost and fuel efficiency may be higher or lower than predicted, auto operating cost may be increased or reduced in the risk analysis to test how these two risk variables affect ridership and revenue.
- The risk variables have been chosen to represent one or more risk factors identified in Step 1.

Step 3. Narrow risk variables to key variables for inclusion within each forecast year of analysis.

- Sensitivity runs of the BPM-V3 were performed for each risk variable that allowed for a quantitative comparison of the impacts of each risk variable on ridership and revenue.

- Based on the range and known sensitivity of the risk variables under consideration, a final set of 10 risk variables were selected for inclusion for each forecast year.

Steps 4 and 5. Develop a range and distribution for each of the 10 risk variables.

- The uncertainty associated with each risk variable was quantified by assigning a range and distribution for each variable. For example, based on the research on each risk factor affecting auto operating cost, such as fuel cost and fuel efficiency, auto operating cost in year 2025 is predicted to range from $0.15 per mile to $0.31 per mile, with a most likely value of $0.20 per mile.

- For each risk variable, the minimum, most likely, and maximum values for each forecast year were developed based on currently available research and analysis. The research and analysis are documented in the *2016 California High-Speed Rail Business Plan - Ridership and Revenue Risk Analysis Technical Report*.

- The shape of the distribution for each variable determined the likelihood of the variable's value, within the set range, under random sampling. For example, it is very unlikely that auto operating cost will be the minimum value of $0.15 per mile or the maximum value of $0.31 per mile, but more likely it will be close to $0.20 per mile. The auto operating cost distribution is defined such that the most likely value will be selected, via the Monte Carlo simulation, at a higher rate than the extreme values, and thus the simulated model runs will be more representative of potential future outcomes.

Steps 6 and 7. Run the BPM-V3 using a defined set of risk variable values to obtain data points for estimation of two sets of Regression Models (i.e., Meta-Models) that regress the 10 risk variables on either high-speed rail revenue or ridership.

- The set of BPM-V3 specified model runs were developed to:
  - Test for the presence of two variable interaction effects;
  - Estimate nonlinearity of model variables;
  - Adequately capture the boundaries of the solution space; and
  - Ensure that data points do a good job of representing the interior of the solution space.

The risk variable values were defined based on the minimum, most likely, and maximum values developed in Step 5.

Step 8. Perform a Monte Carlo simulation by running the regression model 50,000 times with varying levels of the input variables based on the distributions assigned to the variables.

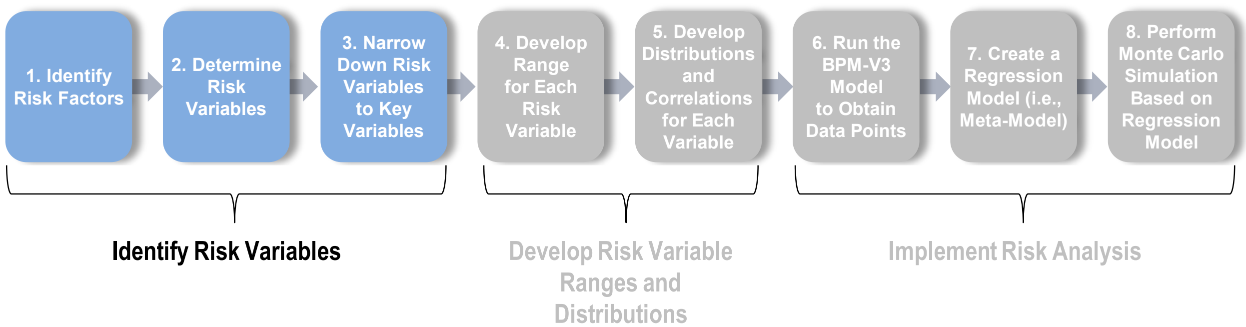
- The simulation results in probability distributions of high-speed rail revenue and ridership; and
- The results of the simulation were analyzed to determine the relative contribution of each risk factor on revenue and ridership.

The rest of this section is divided into three sections that provide insight into the steps taken to produce the simulation results: Identification of Risk Variables (*Steps 1 to 3*), Development of Risk Variable Ranges and Distributions (*Steps 4 to 5*), and Risk Analysis implementation (*Steps 6 to 8*).

7.2 Identification of the Risk Variables

This section details the steps taken to identify the risk variables included in the risk analysis, as shown in Figure 7.2 below.

Figure 7.2 Eight-Step Risk Analysis Approach: Identifying Risk Variables (Steps 1 to 3)



To develop a set of potential risk factors (*Step 1*), CS held a series of meetings with the Rail Delivery Partner (RDP) and Authority staff to brainstorm and identify potential risks that sought to answer the following question: What real-world risks could impact ridership and revenue in 2025, 2029, and 2040? As a result, the list of risk factors identified differed depending on the operating plan and forecast year under consideration. For example, the uncertainty and impact of conventional rail and high-speed rail bus connections to high-speed rail service is a concern for earlier years, while the likelihood of significant autonomous vehicle use affecting high-speed rail ridership is not likely until 2040.

This list of potential risk factors generated was used to identify risk variables (i.e., assumptions built into the BPM-V3 model) that could represent each risk factor (*Step 2*). The risk variables identified for each risk factor were determined by answering the following questions: What model inputs and variables drive these risks? How does one account for these risks in the model? Next, sensitivity runs of the BPM-V3 model were run for each risk variable that allowed for a quantitative comparison of the impacts of each risk variable on ridership and revenue. Based on this sensitivity analysis, the risk variables that were determined to have the greatest effect on high-speed rail ridership and revenue and the highest potential uncertainty for each forecast year were selected for inclusion (*Step 3*). A set of 10 risk variables was included in the risk analysis for each forecast year, as shown in Table 7.1. This table also documents the risk factors that are represented by each risk variable.

Table 7.1 Variables Included in Risk Analysis for Each Analysis Year

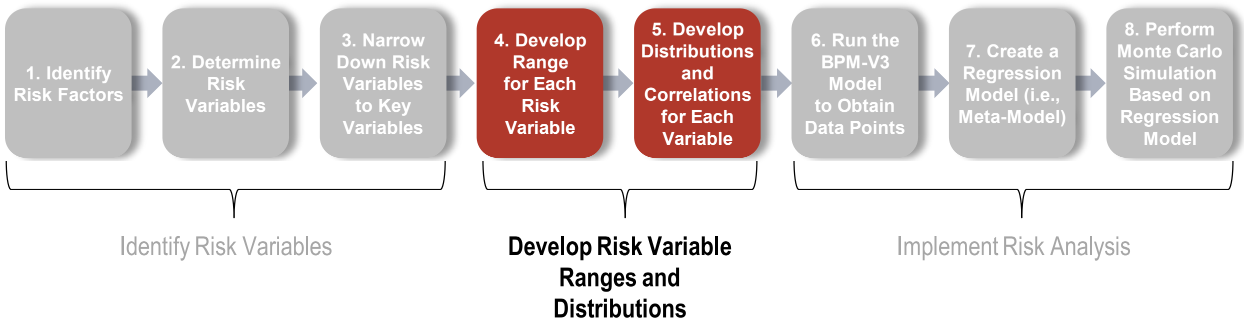
Number	Risk Variable	Reasons for Considering Model Variable and Risk Factors Represented
1	Business High-Speed Rail Mode Choice Constant	The mode constants capture the unexplained variation in traveler mode choices after system variables and demographics are taken into account. Unexplained variation may include factors, such as comfort aboard trains, opinions regarding high-speed rail, need for a car at the destination, level of familiarity with high-speed rail, etc.
2	Commute High-Speed Rail Mode Choice Constant	
3	Recreation/Other High-Speed Rail Mode Choice Constant	
4	Business/Commute Trip Frequency Constant	The trip frequency constants capture the unexplained variation in the number of long-distance trips that travelers will take after accounting for household demographics and the accessibility of available destinations. Also, risks associated with the state of the economy are accounted for within the trip frequency constant risk variable.
5	Recreation/Other Trip Frequency Constant	
6	Auto Operating Costs	This variable reflects the inherent risks in forecasting future: fuel costs, fuel efficiencies, adoption of alternative fuels/electric vehicles, maintenance costs, changes in gas taxes, potential impacts of cap and trade on fuel costs, market penetration of autonomous connected vehicles, and higher shares of "shared use" vehicles.
7	High-Speed Rail Fares	A number of issues could affect actual fares charged to travelers, especially as the system is being opened: institution of discount/premium fares (advance purchase, peak/off-peak, first/second class seating); adjustments needed to respond to changing auto operating costs or air fares; yield management strategies; etc.
8	High-Speed Rail Frequency of Service	With final service plans expected to be developed by a private operator that has not been brought on board yet, there is uncertainty around the amount of service that will be provided based on the markets and strategies that the operator may employ.
9a (Year 2025)	Availability and Frequency of Service of Conventional Rail and High-Speed Rail Buses that Connect with High-Speed Rail	Access to and egress from the system include connections with both conventional rail services and high-speed rail buses (as well as many other modes). Levels of conventional rail service are assumed based on the State Rail Plan, but there is some risks that the State Rail Plan does not develop on-time or as expected. Similarly, the amount of connecting bus service could be different than currently assumed. These connections are most critical in the early years of the program when the high-speed rail system does not yet connect the whole State.
9b (Year 2029)	Airfares	Airfares change and fluctuate over time. Some possible reasons that airlines may change airfares from currently forecasted levels include changes in fuel or personnel costs or airport landing fees, changes in equipment or efficiency such as NextGen technology, competitive response to high-speed rail to maintain air market shares, acceptance of high-speed rail as a replacement for inefficient, short-haul air service, etc.

Number	Risk Variable	Reasons for Considering Model Variable and Risk Factors Represented
10a (Year 2025 and Year 2029)	Coefficient on Transit Access-Egress Time/Auto Distance Variable	Between some regions in California, especially in the Silicon Valley to Central Valley scenario, individuals who wish to travel primarily by transit to reach their destination must transfer from a high-speed rail bus or conventional rail system before or after traveling on high-speed rail. International experience has shown that there is uncertainty around how the need to make these transfers affects overall high-speed rail ridership. The model includes a variable that makes high-speed rail less attractive for trips that require a long access or egress trip in relation to the time spent on high-speed rail. The variation in this variable was used as a way to estimate the uncertainty around the affect of these transfers on high-speed rail ridership and revenue.
9c (Year 2040)	Number and Distribution of Households throughout the State	The forecasted number of statewide households can fluctuate for a variety of reasons, such as inherent uncertainty with population forecasts, national and statewide economic cycles, impacts of natural disasters such as continuing draught, changes in U.S. immigration policy, etc. The uncertainty of population forecasts and the divergence between different forecasts increases the further out that the forecasts make predictions. For example, based on a review of nine forecasts for 2020, the differences in predicted California population were only 840,000, while the differences for 2040 were 2.4 million between the lowest and highest forecasts. The risk analysis addresses the increased uncertainty in the later years.
10b (Year 2040)	Auto Travel Time	The introduction of autonomous vehicles is represented by decreases in auto travel times included within the model.

7.3 Development of Risk Ranges and Distributions

To conduct the risk analysis, the uncertainty surrounding each risk variable must be quantified by assigning a range and distribution for each variable. As shown in Figure 7.3, determining the ranges of the risk variables corresponds to *Step 4*, and developing the distributions corresponds to *Step 5* of the risk analysis approach.

Figure 7.3 Eight-Step Risk Analysis Approach: Develop Risk Variable Ranges and Distributions (Steps 4 to 5)



The absolute minimum and absolute maximum value of the variable sets the range of the variable's forecasted value, while the most likely represents the peak of the variable's distribution. For each risk variable, the absolute minimum, most likely, and absolute maximum values were driven by independent research and analysis.

The shape of the distribution determines the likelihood of the variable's value, within the set range, under random sampling. The most likely value has the greatest likelihood of occurring within the Monte Carlo simulation. The shape of the distribution can be triangular, PERT, uniform, or another form. The shape of the distribution around the minimum, most likely, and maximum values of each risk variable was determined based on the level of uncertainty surrounding each of the three data points.

Tables 7.2, 7.3, and 7.4 identify the ranges of values and distribution for each risk variable for years 2025, 2029, and 2040, respectively. The "base run" values are presented for comparison purposes, but they are not directly used within the risk analysis.[20] More information on the research and methodology for developing the minimum, most likely, and maximum value can be found in the *2016 California High-Speed Rail Business Plan - Ridership and Revenue Risk Analysis Technical Report*.

[20] The "base run" is the revenue for the year and scenario forecast using the BPM-V3 model with the base input variable values.

Table 7.2 Year 2025 Silicon Valley to Central Valley Risk Variable Ranges and Distributions

Risk Variable	Base	Absolute Minimum	Most Likely	Absolute Maximum	Distribution
High-speed rail Constant	High-speed rail Calibrated Constant (Assumes Wait + Terminal Time = 25 min)	CVR bundled Constant + Assumed Wait + Terminal Time = 45 min	High-speed rail Calibrated Constant (Assumes Wait + Terminal Time = 25 min)	High-speed rail Calibrated Constant + (HSR Constant – CVR Constant) + Assumed Wait + Terminal Time = 15 min	Includes two components: Unexplained Variation and terminal and wait time Unexplained Variation: 50% Correlation between purposes; Distribution = Shape 4 PERT Terminal/Wait Time: 100% Correlation between purpose; Distribution = Triangle
Business/Commute Trip Frequency Constant *(Annual business/commute round trips per person)*	2.16	1.30	2.16	3.35	Includes two components: Unexplained Variation and Economic Cycle Unexplained Variation: 50% Correlation between purposes; Distribution = Shape 4 PERT Economic Cycle: 100% Correlation between purpose; Distribution = Triangle
Recreation/Other Trip Frequency Constant *(Annual recreation/other round trips per person)*	5.76	4.76	5.76	6.84	
Auto Operating Cost *($/mile in 2015 dollar)*	$0.26	$0.15	$0.20	$0.31	Distribution = Shape 5 PERT
High-speed Rail Fares *(Decimal Factor Difference from Base Fare)*	1.0	0.846	1.0	1.275	Distribution = Triangle
High-speed Rail Frequency of Service *(Roundtrips per day)*	22	14	22	76	Distribution = Triangle
Availability and Frequency of Service of Conventional Rail and High-speed rail Buses that connect with High-speed rail	Scenario 3 = 2025 CVR as defined in SR Plan, w/ high-speed rail buses	Scenario 1 (10%) = 2015 CVR, no high-speed rail buses;	Scenario 2 (50%)= 2025 CVR except for SJV frequency set to maximum of current capacity, 75% high-speed rail buses; 50%	Scenario 3 (40%) = 2025 CVR as defined in SR Plan, w/ high-speed rail buses	Distribution = multinomial. There are three scenarios (1, 2, and 3) with a probability assigned to each scenario. Only one of the three scenarios is chosen for each draw of the Monte Carlo simulation. Note: The scenarios do not represent the minimum, most likely, and maximum values.
Coefficient on Transit Access-Egress Time/Auto Distance Variable	Calibrated Transit Penalty variable based on Air and CVR RP data	Transit Penalty set to equal auto penalty based on International Experience	Calibrated Transit Penalty variable based on Air and CVR RP data	Calibrated Transit Penalty variable based on Air and CVR RP data	Distribution = Shape 4 PERT

Table 7.3 Year 2029 Phase 1 Risk Variable Ranges and Distributions

Risk Variable	Base	Absolute Minimum	Most Likely	Absolute Maximum	Distribution
High-speed rail Constant	High-speed rail Calibrated Constant (Assumes Wait + Terminal Time = 25 min)	CVR bundled Constant + Assumed Wait + Terminal Time = 45 min	High-speed rail Calibrated Constant (Assumes Wait + Terminal Time = 25 min)	High-speed rail Calibrated Constant + (HSR Constant – CVR Constant) + Assumed Wait + Terminal Time = 15 min	Includes two components: Unexplained Variation and terminal and wait time Unexplained Variation: 50% Correlation between purposes; Distribution = Shape 4 PERT Terminal/Wait Time: 100% Correlation between purpose; Distribution = Triangle
Business/Commute Trip Frequency Constant *(Annual business/commute round trips per person)*	2.20	1.37	2.20	3.62	Includes two components: Unexplained Variation and Economic Cycle Unexplained Variation: 50% Correlation between purposes; Distribution = Shape 4 PERT Economic Cycle: 100% Correlation between purpose; Distribution = Triangle
Recreation/Other Trip Frequency Constant *(Annual recreation/other round trips per person)*	5.76	4.76	5.76	6.84	
Auto Operating Cost *($/mile in 2015 dollars)*	$0.26	$0.14	$0.19	$0.30	Distribution = Shape 5 PERT
High-speed Rail Fares *(Decimal Factor Difference from Base Fare)*	1.0	0.846	1.0	1.275	Distribution = Triangle
High-Speed Rail Frequency of Service *(Roundtrips per day)*	98	44	98	152	Distribution = Triangle
Airfares *(Decimal Factor Difference from Base Fare)*	1.0	1.0	1.2	1.33	Distribution = Triangle
Coefficient on Transit Access-Egress Time/Auto Distance Variable	Calibrated Transit Penalty variable based on Air and CVR RP data	Transit Penalty set to equal auto penalty based on International Experience	Calibrated Transit Penalty variable based on Air and CVR RP data	Calibrated Transit Penalty variable based on Air and CVR RP data	Distribution = Shape 4 PERT

Table 7.4 Year 2040 Phase 1 Risk Variable Ranges and Distributions

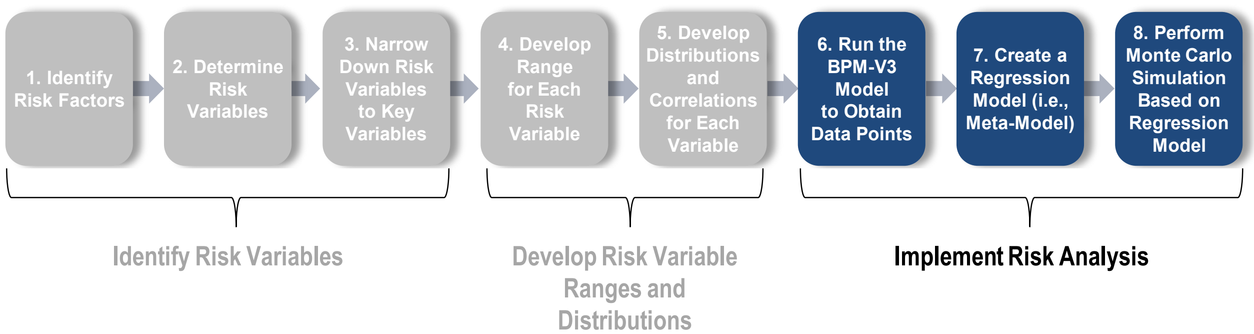
Risk Variable	Base	Absolute Minimum	Most Likely	Absolute Maximum	Distribution
High-speed rail Constant	High-speed rail Calibrated Constant (Assumes Wait + Terminal Time = 25 min)	CVR bundled Constant + Assumed Wait + Terminal Time = 45 min	High-speed rail Calibrated Constant (Assumes Wait + Terminal Time = 25 min)	High-speed rail Calibrated Constant + (HSR Constant – CVR Constant) + Assumed Wait + Terminal Time = 15 min	Includes two components: Unexplained Variation and terminal and wait time Unexplained Variation: 50% Correlation between purposes; Distribution = Shape 4 PERT Terminal/Wait Time: 100% Correlation between purpose; Distribution = Triangle
Business/Commute Trip Frequency Constant *(Annual business/commute round trips per person)*	2.45	1.45	2.45	3.97	Includes two components: Unexplained Variation and Economic Cycle Unexplained Variation: 50% Correlation between purposes; Distribution = Shape 4 PERT Economic Cycle: 100% Correlation between purpose; Distribution = Triangle
Recreation/Other Trip Frequency Constant *(Annual recreation/other round trips per person)*	6.23	5.06	6.23	7.54	
Auto Operating Cost *($/mile in 2015 dollars)*	$0.24	$0.13	$0.21	$0.36	Composed of various components with PERT = Shape 5, uniform and triangular distributions
High-speed Rail Fares *(Decimal Factor Difference from Base Fare)*	1.0	0.647	1.0	1.881	Distribution = Triangle
High-speed Rail Frequency of Service *(Roundtrips per day)*	98	44	98	152	Distribution = Triangle
Number and Distribution of Households throughout the State *(Total Households in Millions)*	16.447	14.977	16.128	17.840	Distribution = Shape 4 PERT
Auto Travel Time	Congested times based on High Household Growth Rate	Congested times based on High Household Growth Rate	Freeway free-flow travel times weighted at 6% (congested weight = 94%)	Freeway free-flow travel times weighted at 80% (congested weight = 20%)	Arterial travel time index = .5*Freeway index, with 100% correlation Composed of various components with uniform and triangular distributions

7.4 Implementation of Risk Analysis

To fully understand the uncertainty in the high-speed rail forecasts of revenue and ridership, the full range of values for the risk variables was analyzed. To capture this full range, a Monte Carlo simulation of the BPM-V3 model is desired, but due to the BPM-V3's complexity, it is infeasible to run the model thousands of times. Therefore, regression meta-models were developed to approximate the relationships between BPM-V3 revenue and ridership and model inputs and variables based on actual model runs. The regression model can be run very quickly (i.e., tenths of a second), while the BPM-V3 model takes hours to run.[21] Based on the model runs that were conducted, it is possible to test the regression meta-model's ability to replicate the results of the original model. The meta-models that were developed were able to replicate the results of the BPM-V3 model very well, indicating that the regression model forecasts of ridership and revenue match closely with the BPM-V3 forecasts of ridership and revenue given the same input values.

As shown in Figure 7.4, there are three steps that comprise the risk analysis implementation. The regression meta-model is developed from a set of full BPM-V3 runs (*Step 6*). The independent variables of the regression model are the risk analysis variables, and the dependent variable is either high-speed rail revenue or ridership. Each full BPM-V3 model run acts as one data point for use in estimating the regression models (*Step 7*). A Monte Carlo simulation, of 50,000 draws, is then run using the ridership and revenue regression meta-models and different combinations of values of the risk variables, with the values being drawn from the assigned risk variable distributions (*Step 8*). The revenue and ridership output from these runs is then used to develop the revenue and ridership range and probability of occurrence.

Figure 7.4 Eight-Step Risk Analysis Approach: Implement Risk Analysis (Steps 6 to 8)



7.4.1 BMP-V3 Model Runs

An experimental design was developed to determine the number of full BPM-V3 model runs needed for estimating the regression meta-models and the combination of variable values that compose each BPM-V3 model run. The analysis used a combination of a Fractional Factorial design and a Sampling design.

[21] It takes approximately 12 hours to run the BPM-V3 model using a one-thread set-up. It takes one hour to run the BPM-V3 model using a 12-thread set-up, which is the maximum possible threads that can be run on one standard computer.

The final experimental design included 59 full model runs for each operating plan and forecast year, as follows:

- 27 model runs using fixed minimum, most likely, and maximum values of risk variables specified using a three-level Resolution III fractional factorial design.
- 27 model runs sampled uniformly from low, mid, and high ranges of the risk variables, using a random sampling design. These runs ensured that the interior of the solution space was well represented and not biased toward the edges.
- 5 model runs representing extreme scenarios of full upside (3 runs) and full downside (2 runs); that is, all inputs in these runs were set to values that would either be toward the very favorable or very unfavorable end of the spectrum of high-speed rail revenue and ridership. The runs correspond to the following percentiles for each risk variable: 10, 25, 75, 90, and 100.[22]

Thus, the final experiment design includes both the Fractional Factorial design to help understand extreme values and tails of distributions, and the Sampling design which helps fill in the space in the middle of the distribution where most results lie. Additional details of the development of the experimental design process are discussed in the *2016 California High-Speed Rail Business Plan - Ridership and Revenue Risk Analysis Technical Report*.

7.4.2 Final Revenue and Ridership Regression Models

The forecast ridership and revenues from the 59 BPM-V3 runs were used as data points for developing the meta-model linear regression equations of the log of revenue as a function of the 10 risk variables. All models have r-squared values above 0.9, indicating that the regression models (for ridership and revenue) fit the BPM-V3 data points very well, and all of the signs and magnitudes of model coefficients are sensible.

7.4.3 Revenue Results of the Monte Carlo Simulation

A Monte Carlo simulation using the regression meta-model outlined above was run 50,000 times using different combinations of values of the risk variables, with the values being drawn from the assigned risk variable distributions. It is important to note that some risk factors include multiple components that are sampled in the Monte Carlo analysis. For example, values are sampled from both the uncertainty component distribution and the terminal/wait time component distribution for the High-Speed Rail Mode Choice Constant risk variable. Setting a positive correlation between two risk variable components results in the Monte Carlo simulation having a higher probability of sampling from the same point on the distribution (e.g., a 100-percent positive correlation would result in two risk variables always being chosen from the same percentile point on the distribution).

The revenue output from these 50,000 Monte Carlo runs was used to develop the revenue range and probability of occurrence, as shown in Table 7.5. Revenue listed in the table does not include adjustments due to ramp-up. Short-distance trips of less than 50 miles in length within SCAG and MTC contribute approximately $12 million (2015 dollars) in revenue in year 2029 and 2040. This short-distance revenue was

[22] The 0th percentile run was not added because the experimental design included this run already, where all inputs are set to the “min” value, and the Minimum value always corresponded to the absolute minimum, unfavorable value for high-speed rail revenue or ridership.

added to the year 2029 and year 2040 long-distance revenue for all probability levels to obtain total high-speed rail revenue.

The "base run" is the revenue for the year and scenario forecast using the BPM-V3 model with the base input variable values. The percentages shown are where the original base revenue falls on the continuum of revenue forecasts produced by the various risk models.

Table 7.5 Year 2025 – 2040 High-Speed Rail Revenue Range and Probability of Occurrence[23]
2015 Dollars

Probability	Revenue (Millions of 2015 Dollar)		
	2025 VtoV	2029 Phase 1	2040 Phase 1
Minimum	$112	$634	$704
1%	$192	$950	$1,038
10%	$280	$1,303	$1,471
25%	$359	$1,619	$1,852
Median	$484	$2,082	$2,419
75%	$652	$2,691	$3,153
90%	$840	$3,359	$3,963
99%	$1,215	$4,610	$5,606
Maximum	$2,144	$6,628	$9,191
Base Run	*$460 (46%)*	*$2,069 (49%)*	*$2,413 (50%)*

Source: Cambridge Systematics, Inc.

7.4.4 Ridership Results of the Monte Carlo Simulation

A Monte Carlo simulation using the ridership regression meta-model was applied to the same 50,000 runs developed for the revenue analysis. The ridership output from these runs was used to develop the ridership range and probability of occurrence, as shown in Table 7.6. Ridership listed in the table does not included adjustments due to ramp-up. Short-distance trips of less than 50 miles in length within SCAG and MTC contribute 0.6 million in ridership in years 2029 and 2040. This short-distance ridership was added to the year 2029 and year 2040 long-distance ridership for all probability levels to obtain total high-speed rail ridership. The "base run" is the ridership for the year and scenario forecast using the BPM-V3 model with the base input variable values. The percentages shown are where the original base ridership falls on the continuum of ridership forecasts produced by the various risk models.

[23] The results are raw model output and do not account for ramp-up.

Table 7.6 Year 2025 2040 High-Speed Rail Ridership Range and Probability of Occurrence[24]

Probability	Ridership (Millions)		
	2025 VtoV	2029 Phase 1	2040 Phase 1
Minimum	1.7	10.2	8.9
1%	3.0	16.3	15.8
10%	4.4	22.9	23.5
25%	5.7	28.7	30.3
Median	7.8	37.5	40.7
75%	10.6	49.1	54.7
90%	13.7	62.0	70.5
99%	20.2	86.6	104.1
Maximum	39.6	137.6	179.1
Base Run	*7.5 (47%)*	*37.1 (49%)*	*42.8 (54%)*

Source: Cambridge Systematics, Inc.

7.4.5 Contribution to Risk Variance

One feature of the risk analysis approach taken here is that the probability distribution of forecasts of high-speed rail ridership and revenue result from the underlying uncertainty in several variables that have direct impacts on high-speed rail ridership and revenue. Each of those variables contributes to the uncertainty in different ways, which can be quantified by examining the variance in the forecasts. The contribution of the variance of each risk variable component is shown in Table 7.7. The contribution to risk variance for each variable considers two features: the risk variable distribution and the impact that a unit change in a risk variable has on revenue or ridership, which comes directly from the regression coefficients. The wider a risk variable's distribution range, the bigger its contribution to risk variance, all else being equal. Likewise, the bigger the impact a variable has on revenue or ridership, the bigger its contribution to risk variance, all else being equal.

The high-speed rail constants' unexplained variation contributes the most to the variance in the revenue distribution. This result reflects the large distribution on this risk variable component, as well as the large sensitivity of this variable to high-speed rail revenue and ridership. There is a significant amount of uncertainty associated with how travelers will view high-speed rail, because there is no way to observe and collect data related to it until high-speed rail opens. The next set of variables that contributes the most to the variance in high-speed rail revenue is the trip frequency constants' unexplained variation. On the other hand, the level of uncertainty associated with the high-speed rail attributes and auto costs is much lower, because they are controllable in the case of the former, or there is a large amount of existing data to rely on in the case of the latter.

[24] The results are raw model output and do not account for ramp-up.

Table 7.7 Contribution of High-Speed Rail Revenue Variance of Each Risk Variable Component

Risk Variable	Risk Variable Component	2025 VtoV	2029 Phase 1	2040 Phase 1
High-Speed Rail Constant – Business	Unexplained Variation[a]	35.3%	32.0%	32.2%
High-Speed Rail Constant – Commute	Unexplained Variation[a]	13.9%	14.1%	14.0%
High-Speed Rail Constant – Recreation/Other	Unexplained Variation[a]	38.4%	40.3%	37.8%
Terminal & Wait Time	Business[b] Commute[b] Recreation/Other[b]	1.4%	1.5%	1.5%
Trip Frequency Constant – Business/ Commute	Unexplained Variation[c]	2.3%	3.4%	3.6%
	Economic Cycle[d]	1.3%	2.1%	2.6%
Trip Frequency Constant – Recreation/Other	Unexplained Variation[c]	2.2%	1.9%	2.4%
	Economic Cycle[d]	1.3%	2.1%	2.5%
Base Auto Operating Costs	n/a	0.2%	0.8%	0.6%
High-Speed Rail Fares	n/a	1.5%	0.0%	0.6%
High-Speed Rail Headway	n/a	1.9%	1.5%	1.3%
High-Speed Rail Connecting Service	n/a	0.0%	n/a	n/a
High-Speed Rail Access/Egress by Transit Variable	Index Variable	0.4%	0.3%	n/a
Airfares	n/a	n/a	0.0%	n/a
Number and Distribution of Statewide Households	n/a	n/a	n/a	0.2%
Automated Vehicle Market Penetration	Penetration	n/a	n/a	0.2%
Automated Vehicle Effect on Auto Travel Times	Alpha, Beta	n/a	n/a	0.0%
Automated Vehicle Fuel Economy		n/a	n/a	0.0%
Shared Use Vehicle Share		n/a	n/a	0.3%
Shared Use Vehicle Cost per Mile		n/a	n/a	0.4%

[a] 50 percent correlation for random draws from distributions in Monte Carlo simulation.

[b] 100 percent correlation for random draws from distributions in Monte Carlo simulation.

[c] 50 percent correlation for random draws from distributions in Monte Carlo simulation.

[d] 100 percent correlation for random draws from distributions in Monte Carlo simulation.

Overall, the range and distribution in revenue and ridership reflect the uncertainty associated with a number of the most important determinants across the forecast years. The variables were carefully examined and researched before assigning appropriate distributions to them. The demand model used for forecasting was constructed from and closely matches the results of a complex travel model system that has been vetted with industry experts over the course of several years.

Appendix A. High-Speed Rail Operating Plans

A.1 Silicon Valley to Central Valley Line – 2025

A.1.1 Dedicated Bus Connections – North

Sacramento Bus
6 Peak Hours

Pattern#	**2**
Frequency	30
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
Fresno Amtrak	260
Fresno HSR	**270**
# of Buses	*12*
Transfer time at Merced	15

Sacramento Bus
10 Off-Peak Hours

Pattern#	**2**
Frequency	60
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
Fresno Amtrak	260
Fresno HSR	**270**
# of Buses	*10*
Transfer time at Merced	15

A.1.2 High-Speed Rail Patterns

Train
6 Peak Hours

Pattern #	10
Frequency	30
Run times from start in minutes	
San Jose	**0**
Gilroy	18
Fresno	62
Visalia	83
North Shafter	**118**
# of trains	12

Train
10 Off-Peak Hours

Pattern #	10
Frequency	60
Run times from start in minutes	
San Jose	**0**
Gilroy	18
Fresno	62
Visalia	83
North Shafter	**118**
# of trains	10

A.1.3 Dedicated Bus Connections – South

LA Basin Bus
6 Peak Hours

<table>
<tr><td>Transfer Time at Bakersfield</td><td>15</td><td>15</td><td>15</td></tr>
<tr><td>Pattern#</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Frequency</td><td>30</td><td>30</td><td>30</td></tr>
<tr><td colspan="4">Run times from start in minutes</td></tr>
<tr><td>North of Bakersfield</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Burbank Airport</td><td>152</td><td>| |</td><td>| |</td></tr>
<tr><td>Los Angeles Union Station</td><td>180</td><td>| |</td><td>| |</td></tr>
<tr><td>Van Nuys</td><td></td><td>160</td><td>| |</td></tr>
<tr><td>West Los Angeles</td><td></td><td>180</td><td>| |</td></tr>
<tr><td>Santa Anita</td><td></td><td></td><td>180</td></tr>
<tr><td># of Buses</td><td>12</td><td>12</td><td>12</td></tr>
</table>

LA Basin Bus
10 Off-Peak Hours

<table>
<tr><td>Transfer Time at Bakersfield</td><td>15</td><td>15</td><td>15</td></tr>
<tr><td>Pattern#</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Frequency</td><td>60</td><td>60</td><td>60</td></tr>
<tr><td colspan="4">Run times from start in minutes</td></tr>
<tr><td>North of Bakersfield</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Burbank Airport</td><td>152</td><td>| |</td><td>| |</td></tr>
<tr><td>Los Angeles Union Station</td><td>180</td><td>| |</td><td>| |</td></tr>
<tr><td>Van Nuys</td><td></td><td>160</td><td>| |</td></tr>
<tr><td>West Los Angeles</td><td></td><td>180</td><td>| |</td></tr>
<tr><td>Santa Anita</td><td></td><td></td><td>180</td></tr>
<tr><td># of Buses</td><td>10</td><td>10</td><td>10</td></tr>
</table>

A.2 Silicon Valley to Central Valley Extension – 2025

A.2.1 Dedicated Bus Connections – North

Sacramento Bus	
6 Hour Peak Revenue-Service Day	
Pattern #	2
Frequency	30
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
Fresno Amtrak	260
Fresno HSR	270
# of Buses	12
Transfer time at Fresno	15

Sacramento Bus	
10 Hour Revenue-Service Day	
Pattern #	2
Frequency	60
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
Fresno Amtrak	260
Fresno HSR	270
# of Buses	10
Transfer time at Fresno	15

A.2.2 High-Speed Rail Patterns

Train	
6 Peak Hours	
Pattern #	10
Frequency	30
Run times from start in minutes	
San Francisco	**0**
Millbrae	16
San Jose	52
Gilroy	70
Fresno	114
Visalia	135
Bakersfield	**173**
# of trains	12

Train	
10 Off-Peak Hours	
Pattern #	10
Frequency	60
Run times from start in minutes	
San Francisco	**0**
Millbrae	16
San Jose	52
Gilroy	70
Fresno	114
Visalia	135
Bakersfield	**173**
# of trains	10

A.2.3 Dedicated Bus Connections – South

LA Basin Bus			
6 Hour Peal Revenue-Service Day			
Transfer Time at Bakersfield	15	15	15
Pattern #	1	2	3
Frequency	30	30	30
Run times from start in minutes			
Bakersfield	**0**	**0**	**0**
Burbank Airport	132	||	||
Los Angeles Union Station	160	||	||
Van Nuys		140	||
West Los Angeles		160	||
Santa Anita			160
# of Buses	12	12	12

LA Basin Bus			
10 Hour Revenue-Service Day			
Transfer Time at Bakersfield	15	15	15
Pattern #	1	2	3
Frequency	60	60	60
Run times from start in minutes			
Bakersfield	**0**	**0**	**0**
Burbank Airport	132	||	||
Los Angeles Union Station	160	||	||
Van Nuys		140	||
West Los Angeles		160	||
Santa Anita			160
# of Buses	10	10	10

A.3 Phase 1– 2029

A.3.1 Dedicated Bus Connections – North

Sacramento Bus
6 Peak Hours

Pattern#	**2**
Frequency	30
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
# of Buses	*12*
Transfer time at Merced	15

Sacramento Bus
10 Off-Peak Hours

Pattern ID	**2**
Frequency	60
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
# of Buses	*10*
Transfer time at Merced	15

A.3.2 High-Speed Rail Patterns

Train
6 Peak Hours

Pattern #	10	12	20	11	31	42	50		62
Frequency	60	60	60	60	60	60	60		60
Run times from start in minutes									
San Francisco	**0**	**0**	**0**			**0**			
Millbrae	16	16	16			16			
San Jose	48	48	48	0	0	48			
Gilroy	↓	↓	↓	↓	18	66			
Merced	||	||	||	||	||	||	*0*		*0*
Fresno	↓	↓	107	↓	↓	110	25		25
Kings/Tulare	↓	↓	↓	↓	↓	126	41		↓
Bakersfield	↓	↓	148	↓	↓	157	72		66
Palmdale	↓	↓	↓	↓	117	194	109		↓
Burbank Airport	185	185	208	137	146	223	138		126
Los Angeles	**194**	**194**	**217**	**146**	**155**	**232**	**147**		**135**
Gateway Cities/Orange County		224				262			165
Anaheim		235				273			176
# of Trains	6	6	6	6	6	6	6		6

Train
10 Off-Peak Hours

Pattern #	10		20			42		52	
Frequency	30		60			60		60	
Run times from start in minutes									
San Francisco	**0**		**0**			**0**			
Millbrae	16		16			16			
San Jose	48		48			48			
Gilroy	↓		↓			66			
Merced	||		||			||		*0*	
Fresno	↓		107			110		25	
Kings/Tulare	↓		↓			126		41	
Bakersfield	↓		148			157		72	
Palmdale	↓		↓			194		109	
Burbank Airport	185		208			223		138	
Los Angeles	**194**		**217**			**232**		**147**	
Gateway Cities/Orange County						262		177	
Anaheim						273		188	
# of Trains	20		10			10		10	

A.4 Phase 1 – 2040

A.4.1 Dedicated Bus Connections – North

Sacramento Bus
6 Peak Hours

Pattern#	**2**
Frequency	30
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
# of Buses	*12*
Transfer time at Merced	15

Sacramento Bus
10 Off-Peak Hours

Pattern ID	**2**
Frequency	60
Run times from start in minutes	
Sacramento	**0**
Elk Grove	10
Lodi	35
Stockton	60
Modesto	120
Turlock/Denair	155
Merced	200
# of Buses	*10*
Transfer time at Merced	15

A.4.2 High-Speed Rail Patterns

Train
6 Peak Hours

Pattern #	10	12	20	11	31	42	50		62
Frequency	60	60	60	60	60	60	60		60
Run times from start in minutes									
San Francisco	**0**	**0**	**0**			**0**			
Millbrae	16	16	16			16			
San Jose	48	48	48	0	0	48			
Gilroy	↓	↓	↓	↓	18	66			
Merced	||	||	||	||	||	||	*0*		*0*
Fresno	↓	↓	107	↓	↓	110	25		25
Kings/Tulare	↓	↓	↓	↓	↓	126	41		↓
Bakersfield	↓	↓	148	↓	↓	157	72		66
Palmdale	↓	↓	↓	↓	117	194	109		↓
Burbank Airport	185	185	208	137	146	223	138		126
Los Angeles	**194**	**194**	**217**	**146**	**155**	**232**	**147**		**135**
Gateway Cities/Orange County		224				262			165
Anaheim		235				273			176
# of Trains	6	6	6	6	6	6	6		6

Train
10 Off-Peak Hours

Pattern #	10		20			42		52	
Frequency	30		60			60		60	
Run times from start in minutes									
San Francisco	**0**		**0**			**0**			
Millbrae	16		16			16			
San Jose	48		48			48			
Gilroy	↓		↓			66			
Merced	||		||			||		*0*	
Fresno	↓		107			110		25	
Kings/Tulare	↓		↓			126		41	
Bakersfield	↓		148			157		72	
Palmdale	↓		↓			194		109	
Burbank Airport	185		208			223		138	
Los Angeles	**194**		**217**			**232**		**147**	
Gateway Cities/Orange County						262		177	
Anaheim						273		188	
# of Trains	20		10	4	1	10		10	