California High-Speed Rail Authority

2019 Equivalent Capacity Analysis Report

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Supplemental Report

CALIFORNIA
High-Speed Rail Authority

Prepared by WSP

for the Authority

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ACRONYMS AND ABBREVIATION

Acronym	Abbreviation
ASCE	American Society of Civil Engineers
Authority	California High-Speed Rail Authority
BFL	Meadows Field (Bakersfield) Airport
BTS	Bureau of Transportation Statistics
BUR	Bob Hope (Hollywood Burbank) Airport
FAT	Fresno Yosemite International Airport
HSR	High-Speed Rail
LAX	Los Angeles International Airport
LGB	Long Beach Airport
MRY	Monterey Regional Airport
OAK	Oakland International Airport
ONT	Ontario International Airport
SAN	San Diego International Airport
SFO	San Francisco International Airport
SJC	San Jose International Airport
SMF	Sacramento International Airport
SNA	John Wayne (Orange County) Airport
TDM	Travel Demand Model
YOE	Year of Expenditure

EXECUTIVE SUMMARY

California is facing a transportation infrastructure capacity issue. The state's transportation system is becoming increasingly gridlocked, and it is a problem that will only worsen. The state estimates that its population will grow by an additional 6.5 million people by 2036; by 2050 the population is estimated to grow to a total of 50 million people. These new residents will be using a transportation system that the American Society of Civil Engineers (ASCE)[1] has graded a C, specifically noting that roads are rated a D and aviation infrastructure only slightly better at a C+.[2] In this context of significant forecast population growth, many of the state's highways and airports that are already stretched to the limits of their capacity will struggle to accommodate the new demand.

High-speed rail will dramatically increase the state's transportation capacity and relieve the increasing demands on California's network of highways and airports. Although the investment needed to pay for high-speed rail could be used to add capacity to California's existing transportation network, the investment may not necessarily create the equivalent amount of capacity as that of high-speed rail. This analysis compares the cost of adding to the state's existing network of highways and airports to support the additional intrastate people-carrying capacity as that of high-speed rail.

Table 1 summarizes the 2019 Capacity Analysis Update's analysis, which found that it would cost an estimated $122 billion - $199 billion to provide the equivalent highway and airport capacity that the Phase 1 high-speed rail network would provide.[3] This includes 4,196 highway lane-miles, 91 airport gates and 2 runways to accommodate the same amount of intrastate travel capacity that high-speed rail will support.

Table 1 Highway and Airport Capacity Needed and Cost of Constructing the Equivalent Capacity of the Phase 1 Blended High-Speed Rail System - Year of Expenditure (YOE) Dollars[4]

Mode	Capacity Needed	Cost (YOE)
Highway	4,196 lane-miles	$102 - $165 billion
Airport	91 gates, 2 runways	$21 - $34 billion
Total Cost[5]		**$122 - $199 billion**

Utilizing capital cost estimates from the 2020 Business Plan, Table 2 compares the cost ranges, based on low- and high-cost estimate accuracy, to build Phase 1 of the high-speed rail network or an equivalent highway and airport capacity. An in-depth discussion of the applicability of cost estimate accuracy ranges is detailed in Chapter 5 Results. By providing a cost estimate accuracy range in this 2019 Capacity Analysis Update, the Authority can provide a similar comparison to accuracy ranges presented in the 2018 Business Plan.

[1] American Society of Civil Engineers, 2019 Report Card for California's Infrastructure.

[2] The ASCE assigns grades from A ("Exceptional") through F ("Failing/Critical") based on several criteria, including capacity, condition, public safety, resilience and others.

[3] Phase 1 total cost does not include cost of rolling stock.

[4] For the purposes of this analysis, costs for equivalent highway and airport capacity were assumed to have the same timing as the capital costs for high-speed rail. As such, year of expenditure (YOE) costs were estimated using the same escalation rate, over the same time horizon used for high-speed rail Phase 1 system costs in the 2018 Business Plan and 2019 Project Update Report to the California State Legislature, which assumed a 2033 completion date.

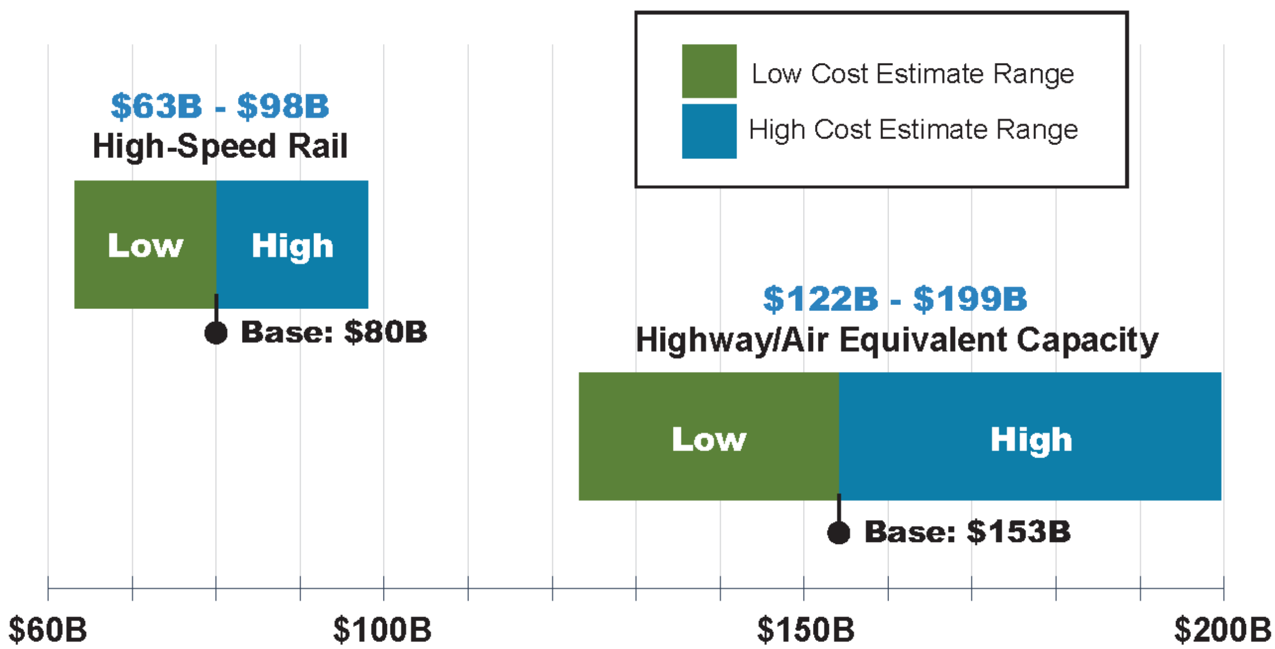
[5] Totals may not match sum due to rounding.

Table 2 Highway and Airport Capacity Needed and Cost of Constructing the Equivalent Capacity of the Phase 1 Blended High-Speed Rail System - Year of Expenditure (YOE) Dollars[6]

Mode	Low	Base	High
High-Speed Rail – Phase 1	$63 billion	$80 billion	$98 billion
Equivalent Highway/Airport Capacity	$122 billion	$153 billion	$199 billion

At $153 billion, this base cost is almost twice as much as the latest baseline cost estimate for the Phase 1 high-speed rail system. Figure 1 compares the cost estimate ranges of the Phase 1 high-speed rail system and the highway/air equivalent capacity investments. As stated in the Authority's 2020 Business Plan, the base capital cost estimate for the Phase 1 system is $80 billion in year of expenditure (YOE) dollars. Furthermore, highway cost estimates are limited to only capital costs, and do not include ongoing operations and maintenance (O&M) costs. These costs would be borne by the state, whereas high-speed rail O&M costs will be fully borne by users of the system through fares.

Figure 1 Estimated Capital Cost Ranges of High-Speed Rail Phase I System and Equivalent Highway and Airport Capacity (YOE$ in Billions)



[6] For the purposes of this analysis, costs for equivalent highway and airport capacity were assumed to have the same timing as the capital costs for high-speed rail. As such, YOE costs were estimated using the same escalation rate, over the same time horizon used for HSR Phase 1 system costs in the 2020 Business Plan which assumed a 2033 completion date.

High-speed rail provides a great deal of intrastate people-carrying capacity at a lower cost. In addition, diverting intrastate travel from highways and airports to high-speed rail provides important benefits, including:

- Relieving congestion on the state's highways;
- Adding transit connectivity and linkages at high-speed rail stations;
- Allowing major airports to focus additional resources to support growing demand for international travel, a major catalyst for ongoing economic development; and
- Advancing the state's environmental goals, such as greenhouse gas emissions reduction, improving air quality and transitioning to a sustainable, low-carbon future.

It is important to note that these highway and airport capital expenditures would also require substantially more land and have much larger impacts on communities than high-speed rail. This analysis does not address the likelihood that such investments could actually be made and is not an assessment of whether the state would choose to build the specific infrastructure identified.

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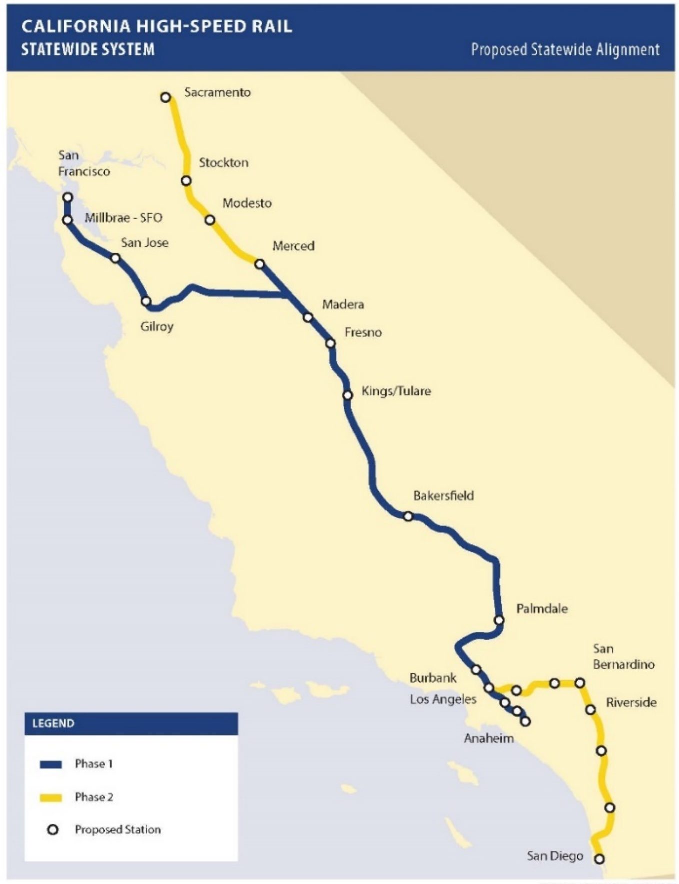
1 BACKGROUND

California high-speed rail system will connect the state's megaregions, contribute to economic development and a cleaner environment, create jobs and preserve agricultural and protected lands. When completed, the Phase 1 system will run from San Francisco to the Los Angeles basin in under three hours at speeds capable of exceeding 200 miles per hour. The system will eventually extend to Sacramento and San Diego, totaling 800 miles with up to 24 stations. Figure 2 depicts the full high-speed rail system.

Figure 2: Phased Implementation of California High-Speed Rail



The Authority is working with regional partners to implement a statewide rail modernization plan that will invest billions of dollars in local and regional passenger rail lines to meet the state's 21st century transportation needs.

When Phase 1 of the high-speed rail system is complete, trips to and from the Central Valley will typically take half the time it currently takes to drive. Trips between San Francisco and Los Angeles will take less than three hours, with options to connect to other modes of transportation. Additionally, shifting trips from flying or driving to high-speed rail postpones the need for additional capacity increases at the busiest and most congested airports as well as roadways. Around the world, countries that have initiated high-speed rail service between two destination cities—such as San Francisco and Los Angeles—saw a considerable mode shift from cars and planes to high-speed rail.

This evaluation compares the capital cost of the Phase 1 system to the cost of constructing the equivalent highway and airport capacity.

1.1 Airport and Highway Constraints

When compared to both the nation and the world, California has one of the busiest routes by both flights and passengers. In March 2019, OAG Aviation Worldwide released its annual 'Busiest Routes' report.[7] The report presents data and analysis on the world's busiest air routes by number of flights. The report found that Los Angeles International Airport (LAX) to San Francisco International Airport (SFO) is the 9th ranked busiest domestic route in the world, with a total of 35,365 flights over a 12-month period.[8] Data from the federal Bureau of Transportation Statistics (BTS) shows that more than 13 million people

[7] Official Aviation Guide, 'Busiest Routes – 2019,' March 2019, https://www.oag.com/reports/busiest-routes-2019.

[8] OAG collected data from March 2018 – February 2019.

traveled between the five primary airports in the Los Angeles Basin and the three primary airports within the San Francisco Bay Area.[9] Travel between these two regions is the highest in the country.[10]

California's airports experienced a 15-percent increase in overall intrastate air travel passengers from 2000 to 2017, according to the same BTS data. In addition to serving as hubs for domestic and international travel, LAX and SFO are also the busiest airports in their regions for intrastate air travel. From 2008 through 2017, LAX noted an increase of 21 percent in the number of intrastate air travel passengers, and SFO saw an increase of nearly 28 percent in the number of intrastate air travel passengers.

Federal data also shows significant increases in international arrivals to LAX and SFO. From 2000 to 2017, the number of incoming international passenger arrivals for LAX increased by 43 percent and by 66 percent at SFO.[11] According to the California Travel and Tourism Commission, international visitor spending represents the state's largest export, more than $26 billion in 2017, compared to $20 billion in agricultural exports.[12] However, as demand for both intrastate and international travel increases, California airports are becoming increasingly constrained.

Public policymakers and decision-makers are not only aware of the growing demand on California's airports, but are actively moving toward solutions. SFO launched a $2.4 billion project to increase capacity for larger international jets, as well as an expanded 25-gate terminal, with an anticipated completion in 2021.[13] LAX officials released plans in April 2019 to study the feasibility of adding an estimated 21 new gates.[14] San Diego International Airport is planning a $3-billion redevelopment that will include an additional 11 gates.[15] Regional airports, such as Sonoma County and Fresno Yosemite, are also currently expanding their services.[16]

However, expanding air services does not happen in a vacuum. These expansion efforts must address policy and stakeholder concerns. Long Beach Airport, for example, limits "air carriers to operate up to 41 flights per day while commuter carriers are permitted to operate up to 25 flights per day."[17] Expansion at Long Beach airport as well as other southern California airports, John Wayne (Orange County) and Burbank, is being met with significant opposition.[18] Stakeholder resistance to growth at these airports

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[9] Bay Area airports include: SFO, Oakland, San Jose; Los Angeles Basin airports include: LAX, Burbank, Long Beach, Ontario, Anaheim (John Wayne).

[10] US Department of Transportation, Bureau of Transportation Statistics, Air Carrier Statistics database, T-100 Domestic Segment.

[11] US Department of Transportation, Bureau of Transportation Statistics, Air Carrier Statistics database, T-100 International Segment.

[12] https://industry.visitcalifornia.com/marketing-communications/year-in-review.

[13] SF Gate, "Topping off SFO's $2.4 billion Terminal 1 Project," June 2018, https://www.sfgate.com/chris-mcginnis/article/San-Francisco-Airport-SFO-construction-update-12972541.php.

[14] LAX, Airfield and Terminal Modernization Project, https://www.lawa.org/en/atmp.

[15] KNBC, "San Diego International Airport to Move Some Airlines' Operations," January 2019, https://www.nbclosangeles.com/news/california/San-Diego-International-Airport-to-Move-Some-Airlines-Operations-504376481.html.

[16] California News Wire Services, "Sonoma County Airport Expansion: Board of Supervisors Gets Update," April 30, 2019, https://patch.com/california/petaluma/sonoma-county-airport-expansion-board-supervisors-gets-update; Fresno Yosemite International Airport, Major Facility Expansion Program Planned for Fresno Yosemite International Airport, January 2019, https://flyfresno.com/major-facility-expansion-program-planned-the-airport/.

[17] Long Beach, Municipal Code, 16.43.060 – Compliance with noise budgets, https://library.municode.com/ca/long_beach/codes/municipal_code?nodeId=TIT16PUFAHILA_CH16.43AINOCO.

[18] The Chronicle, "Locals oppose new plans to expand Burbank airport," March 24, 2019, http://hwchronicle.com/locals-oppose-new-plans-to-expand-burbank-airport/; KCAL, "'We are health': Neighbors push back against planned John Wayne Airport Expansion," https://losangeles.cbslocal.com/2019/05/07/concerns-raised-about-john-wayne-airport-expansion/.

may affect future expansion plans. Although some airports, such as Ontario International (ONT), currently have excess capacity, meeting long-term demand across all airports in the region remains costly and challenging due to land constraints, public opposition and funding.

California is investing in highways and local transit to accommodate increasing travel demand. Senate Bill 1, the Road Repair and Accountability Act of 2017, is investing $54 billion to improve roads and relieve congestion. Despite these investments, the ASCE noted that more than $130 billion is needed to bring existing California roads back to a state of good repair, indicating a funding gap of $76 billion.

Los Angeles commuters lose an average of 102 hours to congestion every year—more than any other commuter in a study of major cities worldwide—according to the INRIX 2017 Global Traffic Scorecard.[19] Congestion delays on the state's roadways are so bad that two areas in California, Los Angeles-Long Beach-Anaheim and San Francisco-Oakland, rank one and two in yearly delay per auto commuter at 119 hours and 103 hours, respectively.[20]

In is 2018 California State Rail Plan, Caltrans reviewed five years of Annual Average Daily Traffic (AADT) volumes (2011 to 2015).[21] The analysis of specific locations along I-5 showed increasing traffic volumes that are not limited to only metropolitan areas. The analysis showed increasing traffic volumes in inland counties, such as Merced and Stanislaus (along I-5). For example:

- North-south interstate AADT in Stanislaus County increased 16.2 percent over the same 5 years; and
- East-west interstate AADT in Los Angeles County increased just 4.9 percent over the same period.

The trend of increasing traffic volumes is also reflected in the increasing amount of time that some freeway segments experience Level of Service (LOS) D – where traffic conditions approach an unstable flow or worse during peak commute periods. Although no longer used by Caltrans, LOS is utilized by local and regional leaders to describe how roadways can accommodate traffic volumes based on physical characteristics of their infrastructure. LOS range from "A," representing uncongested, free flowing conditions, to "F," representing an unstable or breakdown flow conditions."[22]

The planned investments in the state's network of airports and highways will help, but these investments are not sufficient to support the ongoing growth of a state that is the world's 5th largest economy today. High-speed rail will deliver additional capacity, as the following analysis demonstrates, in a more cost-effective way than a similar amount of capacity improvement in airport and highway improvements.

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19 http://inrix.com/scorecard.

20 Texas Transportation Institute 2019 Urban Mobility Report, https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf.

21 AADT volumes obtained from Caltrans' Freeway Performance Measurement System database.

22 Transportation Research Board, "Highway Capacity Manual 2010," http://onlinepubs.trb.org/onlinepubs/trnews/trnews273HCM2010.pdf.

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2 HIGH-SPEED RAIL CAPACITY ASSUMPTIONS

The first step in this capacity cost comparison analysis is developing an estimate of high-speed rail's total "people-carrying" capacity once completed. This system-wide capacity serves as a baseline for determining what would be required on corresponding highway segments and regional airports. The primary assumptions driving the high-speed rail capacity estimate include the potential frequency of trains, seats per train, and average load factor per train, which are:

- 12 trains per hour in each direction;
- 900 seats per train; and
- 70 percent average load factor for trains.

Under these capacity assumptions, a realistic maximum number of passengers that each point on the system can accommodate is 7,560 per hour in each direction. It is important to note that these assumptions do not reflect actual planned service but represent the theoretical capacity of the system regardless of demand conditions or ridership forecasts for a specific time (e.g., the 2018 Business Plan forecasts assume a planned capacity of six trains per hour, 450 seats per train and a 54 percent load factor in the year 2040). The 7,650 passengers per direction reflects the average capacity of the line (i.e., how many passengers could go through that point over the span of an hour).

System capacity was used instead of ridership forecasts for these reasons:

- **Useful life:**
  As with any major transportation infrastructure investment, high-speed rail is an investment with a useful life (50 to 100+ years for high-speed rail). Similarly, freeway and airport projects also represent long-term investments and have useful lives that go well beyond any ridership forecasts. To appropriately reflect that, total capacity provides a more equivalent comparison. The underlying infrastructure provides a given amount of capacity; the ridership levels can fluctuate, with service adjusted to meet that demand.
- **Growth in demand for travel:**
  Over time, demand for travel will grow with population, economic growth and other factors. The high-speed rail system will have the capacity to accommodate this growth in demand. Similarly, additional highway lanes and airport gates and runways would need to be added over time to accommodate the growth (assuming that they are being expanded instead of high-speed rail). If the analysis used demand-based factors, it would be comparing a steady-state of two high-speed rail tracks against other modes, which would be fluctuating and growing over time. Capacity provides an equivalent steady-state comparison between the modes because it is tied to the physical infrastructure being provided, not the number of people using it in any given year.
- **Underlying factors:**
  The detailed ridership forecasts prepared for the program are valuable planning tools that reflect estimates of ridership, given a set of underlying assumptions. However, over the life of the system, the underlying factors that contribute to the assumptions (such as fare levels, economic growth and the rate of actual population growth, among others) can still change. Conversely, the performance of the physical infrastructure (as in the capacity that each type of infrastructure provides) will not change over its lifespan, thus offering a stable and direct comparison.

In this analysis, the blended segments in Northern and Southern California assume four trains per hour. The segments from Burbank to Anaheim in Southern California and between San José and San Francisco on the Peninsula share tracks with other systems and will not operate at the higher speeds of the rest of the system. As a result, these sections will have a lower ultimate carrying capacity.

To estimate capacity needs by alternative modes, it was necessary first to calculate how much capacity was to be provided by airports and how much by highways. The analysis assumes that 80 percent of high-speed rail's capacity would be served by highways and the remaining 20 percent by air travel. This split in needed capacity between air and highway is based on diversion rates assumed in the Travel Demand Model (TDM) used in the 2018 Business Plan to forecast ridership and revenue.[23]

[23] *2018 Business Plan: Technical Supporting Document: Ridership & Revenue Forecasting*; https://www.hsr.ca.gov/docs/about/business_plans/2018_Business_Plan_Ridership_Revenue_Forecasting.pdf.

3 AVIATION CAPACITY COST ANALYSIS

For the aviation component of the analysis, hypothetical capacity improvements (terminal gates, runways, and other associated improvements) were identified at representative airports. The estimation of capital costs, terminal gates and associated capacity improvements are represented in terms of additional passenger terminal areas, rights-of-way (additional physical footprint), parking spaces (on/off site) and primary lanes of access road.

3.1 Capacity Assumptions

The required air capacity (20 percent of 7,650 or 1,512 passengers per hour/direction) was distributed between California airports according to the estimates presented in the Travel Demand Model and overall flight patterns in California. The total number of passengers accommodated is 6,000 because each air trip affects two airports – the origin airport and the destination airport (total passengers per hour multiplied by each direction and again for each origin/destination airport). Since many of these regions have multiple airports, the diverted traffic was assigned to airports based on relative 2018 levels of intrastate air traffic at each airport, based on BTS data.[24]

The methodology is designed to generate a high-level estimate of the capital costs of delivering equivalent aviation capacity at specified airports; it is not meant to be an airport planning exercise and does not consider the detailed feasibility of adding additional capacity at each airport. In addition, the analysis assumes that neither LAX nor SFO will have further potential to add capacity once current and planned improvements are completed. Other regional airports were assigned the additional capacity based on approximate relative shares of current travel.

Several of the aviation assumptions in the previous analysis prepared in 2012 were based on the Statewide California High-Speed Train Program EIR/EIS (2005). These assumptions were updated based on available data and research on current air traffic by airport and airline industry information. The following assumptions were used to estimate the equivalent aviation capacity:

- 125 seats per plane (based on average current plane size for intra-California trips);[25]
- 74 percent load factor for air travel (based on BTS data);
- 500,000 passengers per year per gate (based on existing airport data); and
- 500 to 1,350 parking spaces per 1,000,000 passengers (based on airport design guidelines).[26]

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24 https://www.bts.gov/.

25 It is possible that airlines could deal with increases in future demand by shifting to larger planes in the long term, although estimating this future size is considered somewhat speculative compared to the current estimate based on existing data.

26 Airport Passenger Terminal Planning and Design, Volume 1: Guidebook (2010); low end of ranges provided in 2010 used to account for increased usage of rideshare services and the resulting decline in parking demand in recent years.

Table 3 Summary of Projected Airport Capacity Needs

Airport	% of Regional Travel	Passengers/Hours	Gates Needed	Runway Needed?
Los Angeles Basin — 43% of Total Diverted Air Travel by Region				
Burbank	29%	700	11	No
Ontario	19%	500	7	No
Long Beach	17%	450	7	No
Orange County	35%	900	13	No
Bay Area – 41% of Total Diverted Air Travel by Region				
Oakland	53%	1,300	19	Yes
San Jose	47%	1,200	17	Yes
San Diego – 6% of Total Diverted Air Travel by Region				
San Diego	100%	400	6	No
San Joaquin Valley – 3% of Total Diverted Air Travel by Region				
Fresno	92%	200	3	No
Bakersfield	8%	10	1	No
Sacramento – 5% of Total Diverted Air Travel by Region				
Sacramento	100%	300	5	No
Monterey – 2% of Total Diverted Air Travel by Region				
Monterey	100%	100	2	No
Total[27]	**—**	**6,000**	**91**	**2**

Based on the above assumptions, found in Table 3, delivering the equivalent airport capacity as that of 20 percent of high-speed rail's capacity would require approximately 91 new gates and two new runways.

27 Totals may not match sum due to rounding.

3.2 Cost Updates

Aviation cost updates to the previous 2012 analysis combine research on actual recent capital improvement costs at California airports with historical construction cost indices to generate order-of-magnitude airport capital costs for several types of improvements. These categories include:

- Runways – for airports requiring the highest levels of equivalent capacity (Burbank, Oakland and San José), costs of additional runways include:
  - Land acquisition;
  - Right of way;
  - Site preparation;
  - Runway construction;
  - Taxiway construction; and
  - Navigational aids.[28]
- Gates – each additional gate required is assumed to require the following cost categories:
  - Passenger terminal facilities;
  - Apron and apron site preparation; and
  - Passenger loading bridge.
- Parking – additional parking (500 to 1,350 spaces per 1 million originating passengers per year depending on the number of annual passengers) was assumed to be structured parking.
- Additional costs include:
  - Environmental mitigation – 3 percent of construction costs;
  - Preliminary engineering / environmental review – 2.5 percent of total costs;
  - Program and design management – 5 percent of total costs;
  - Final design – 5 percent of total costs;
  - Construction and procurement management – 5 percent of total costs;
  - Agency costs – 1 percent of total costs;
  - Risk management – 6 percent; and
  - Contingency – 25 percent.

Airport cost estimates are documented in Appendix B.

[28] Navigational aids including "Distance Measuring Equipment (DME), Non-Directional Beacons (NDB), Tactical Air Navigation (TACAN) systems, Very High Frequency (VHF) Omni-Directional Range (VOR) systems, VOR Test Facilities (VOT), and certain combinations of these systems." https://www.faa.gov/air_traffic/flight_info/aeronav/aero_data/7900.2D-NAVAID/.

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4 HIGHWAY CAPACITY COST ANALYSIS

The required highway capacity to accommodate 7,560 passengers per hour was divided into required lanes and assigned to specific highway segments according to the estimates from the 2005 EIR/EIS document and standard Caltrans planning assumptions.

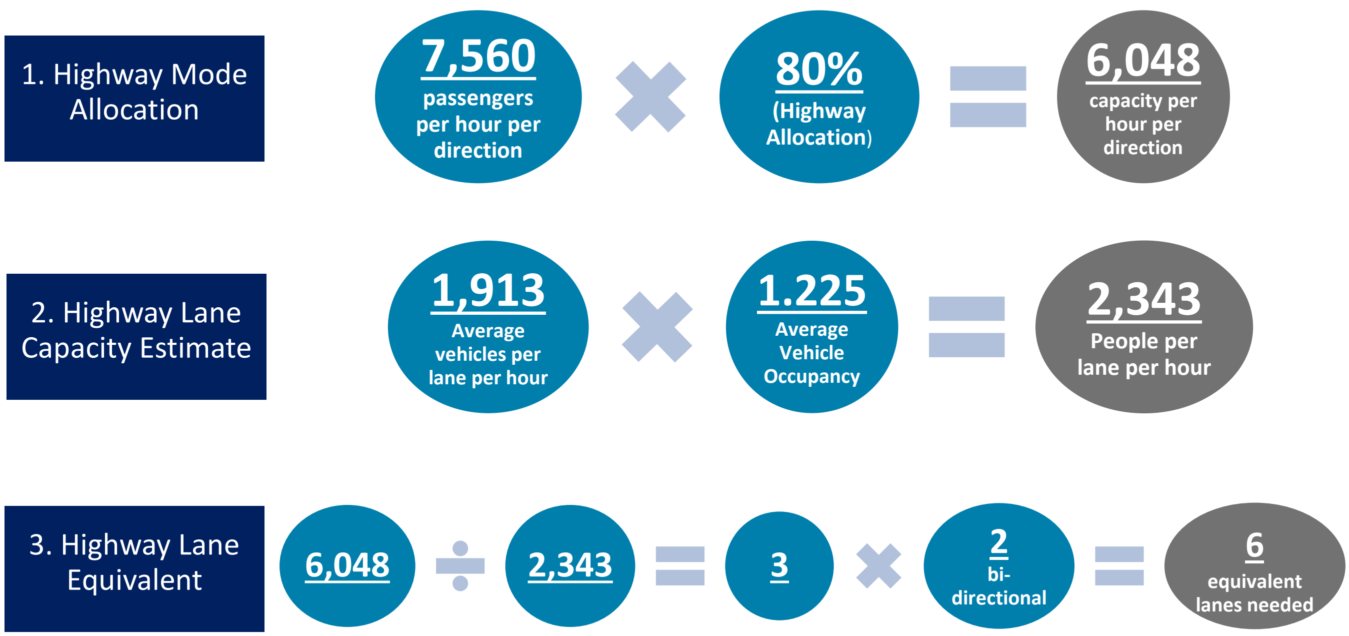
4.1 Capacity Assumptions

The following assumptions were used for estimating highway capacity at any location based on Caltrans planning assumptions:

- 1,913 cars per lane per hour; and
- 1.225 passengers per car.

To accommodate the capacity estimate using the vehicle occupancy and lane capacity assumptions described above, each non-blended highway segment would require a total of six lanes. Figure 3 details the underlying calculations to arrive at this result.

Figure 3 High-Speed Rail/Highway Capacity Conversion Calculations – Non-Blended Segments



For highway segments corresponding with blended high-speed rail segments on the San Francisco Peninsula and in Southern California, the equivalent capacity requirement was reduced by two-thirds, reducing the required lanes from six to two. The total lane-miles required to match the capacity for high-speed rail assigned to highways is 4,196 lane miles.

Table 4 shows the major highway segments that correspond to the high-speed rail network, based on the 2005 EIR/EIS analysis.

Table 4 Summary of Highway Segments, North to South

Highway Corridor	Segment (From–To)	Miles	Lane–Miles
US-101	San Francisco to SFO (blended)	11.3	22.6
US-101	SFO to Redwood City (blended)	13.8	27.6
US-101	Redwood City to I-880 (blended)	19.7	39.4
I-880	US-101 to San Jose (blended)	0.9	1.8
US-101	San Jose to Gilroy (blended)	31.2	62.4
US-101	Gilroy to SR-152	1.4	8.4
SR-152	US-101 to I-5	40.8	244.8
SR-152	I-5 to SR-99	42.8	256.8
I-80	San Francisco to I-880	9.2	55.2
I-880	I-80 to I-238	13.8	82.8
I-580	I-880 to I-5 (via I-238)	52.7	316.2
I-880	I-238 to Fremont/Newark	14.5	87.0
I-880	Fremont/Newark to US-101	12.4	74.4
I-5	SR-152 to SR-99	186	1,116.0
SR-99	Merced to SR-152	21.5	129.0
SR-99	SR-152 to Fresno	33.4	200.4
SR-99	Fresno to Tulare/Visalia	46.4	278.4
SR-99	Tulare/Visalia to SR-58	68.9	413.6
I-5	SR-99 to SR-14	65.0	390.0
I-5	SR-14 to I-405	2.5	15.0
I-5	I-405 to Burbank	15.3	91.8
I-5	Burbank to Los Angeles Union Station (LAUS) (blended)	7.4	14.8
SR-14	Palmdale to I-5	34.8	208.8
I-5	LAUS to I-10 (blended)	0.8	1.6
I-5	I-10 to Norwalk (blended)	20.7	41.4
I-5	Norwalk to Anaheim (blended)	8.1	16.2
Total	**—**	**775**	**4,196**

4.2 Cost Updates

The previous analysis used the per-mile costs from recent Caltrans projects to arrive at average costs for urban and rural highway lanes. Segments of highway that were primarily urban or suburban in the 2005 Caltrans study were grouped together as urban highways while rural highways were evaluated separately. As of 2011, Caltrans recommended an urban lane-mile cost range of $30 million to $50 million per lane-mile, so the 2012 Capacity Analysis Report used an average of $40 million per lane-mile. For rural lanes, Caltrans recommended $6 million to $10 million per lane-mile, so the 2012 Capacity Analysis Report used an average of $8 million per lane-mile.

For this 2019 Capacity Analysis Update, the previous methodology was revised using a slightly different approach. The 2005 EIR/EIS identified specific highway segments that would need to have lanes added to accommodate California high-speed rail demand in a No-Build scenario and estimated the costs of those improvements. These cost estimates were generated in a highly detailed manner, with unit costs for segment-specific needs, including major infrastructure elements such as interchange improvements and bridges, local topography, urban land constraints and other factors.

The 2012 Capacity Analysis Report simply classified each segment as urban or rural and applied a high-level cost per lane-mile provided by Caltrans, as described above. Based on a review of the 2005 EIR/EIS, discussions with highway cost estimators and consultation with Caltrans, the cost estimate methodology in this 2019 Capacity Analysis Update uses the detailed, segment-specific costs from the 2005 EIR/EIS and escalates them based on a review of historical highway cost indices. Although the environmental study is several years old, escalating these cost estimates using an escalation factor provides a more refined estimate over the high-level cost per-lane-mile approach.

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5 RESULTS

Based on the assumptions and calculations described, high-speed rail provides a more cost-effective transportation investment. Providing the equivalent capacity via highways and airports would require numerous individual projects spread across the state at a higher cost. In addition, these individual investments would not provide the same intrastate connectivity that high-speed rail would achieve between San Francisco and the Los Angeles Basin via the Central Valley.

The results of the current analysis note that a comparable highway/airport infrastructure investment would cost an estimated $122 - $199 billion in year of expenditure dollars, as shown in Table 5. This investment is nearly double the 2018 estimated costs of the entire Phase 1 high-speed rail system.

Table 5 Equivalent Highway and Airport Capacity Needed and Estimated Cost - Year of Expenditure (YOE) Dollars[29]

Mode	Capacity Needed	Cost (YOE)
Highway	4,196 lane-miles	$102–$165 billion
Airport	91 gates, 2 runways	$21–$34 billion
Total Cost[30]	**—**	**$122–$199 billion**

For the purposes of this analysis, costs for equivalent highway and airport capacity were assumed to have the same timing as the capital costs for high-speed rail. As such, YOE costs were estimated using the same escalation rate, over the same time horizon used for high-speed rail Phase 1 system costs in the 2018 Business Plan and 2019 Project Update Report to the California State Legislature. The 2012 analysis generated a YOE range of $158 billion to $186 billion. Factors that contributed to the differences in estimates between the initial study and this updated analysis include:

- **Increased construction costs:** construction cost estimates were based on a combination of research on actual airport capital improvements in California, input from Caltrans on highway construction costs, and construction and building cost indices from several sources, including:
  - Engineering News-Record (ENR) Construction Cost Index (CCI) and Building Cost Index (BCI);
  - Caltrans Historical Highway Construction Price Index Report; and
  - Federal Highway Administration (FHWA) National Highway Construction Cost Index (NHCCI) 2.0.
- **Changes in diversion rates by mode:** the previous analysis assumed that 75 percent of system capacity would be allocated to highways and 25 percent allocated to airports, based on factors from the travel demand model as of 2011. Based on diversion rates from the most recent travel demand model used to estimate ridership and revenue for the 2018 Business Plan,[31] these rates were adjusted to 80 percent highway and 20 percent airports. This change reduced the equivalent airport capacity required, from 115 gates and 4 runways in the 2012 analysis to 91 gates and 2 runways in this 2019 Capacity Analysis Update. Although this modification to the

[29] YOE costs were estimated using the same escalation rate used for high-speed rail Phase 1 system costs in the 2018 Business Plan, which assumes a 2033 completion date.

[30] Totals may not sum due to rounding.

[31] https://www.hsr.ca.gov/docs/about/business_plans/2018_Business_Plan_Ridership_Revenue_Forecasting.pdf.

diversion rate increases capacity required of the highway system, it did not increase the lane-miles required relative to the previous analysis. This is because the equivalent highway capacity in lane-miles does not have a linear relationship with high-speed rail capacity. The highway capacity calculation reflects a threshold upon which a new lane is required on the identified segments based on lane capacity estimates (resulting from average vehicle occupancy (AVO) and vehicles per lane per hour (VPLPH) assumptions). As such, the shift in diversion allocation reduced the necessary airport capacity requirement slightly but did not increase the additional highway capacity proportionally because the additional lanes required by 75 percent diversion can accommodate the increased capacity required by 80 percent diversion.

- **Additional blended segments:** the 2012 analysis assumed blended segments from San Francisco to San José and from Los Angeles to Anaheim. As of 2018, the segments from Burbank to Los Angeles and San José to Gilroy have been added to the total amount of blended distance in the system. This increase reduced the equivalent capacity calculation for the corresponding highway segments, resulting in a reduction in required lane-miles to 4,196 in this 2019 Capacity Analysis Update from 4,295 in the 2012 analysis.
- **Inclusion of cost estimate accuracy ranges:** the 2012 analysis showed a cost range for equivalent highway capacity based on a full Phase 1 high-speed rail network versus one that included blended segments. The 2019 Capacity Analysis Update assumes a Phase 1 system with blended segments, as defined in the 2018 Business Plan. However, this 2019 update now presents an estimating cost range based on industry accepted standards from the Association for the Advancement of Cost Engineering (AACE). All estimates now are presented in ranges using this method, not just highways.

Table 6 shows the cost estimate classifications used by AACE to present potential cost accuracy. In the Capital Cost Basis of Estimate Report technical supporting document for the 2018 Business Plan[32], the Authority "predominantly" utilized a Class 3 estimate, based on the level of design maturity in the sections that have been advanced to a 15-percent design level.[33] In the technical report, the Authority used the higher end of the expected accuracy range, showing a potential of cost increases of up to 30 percent and possible cost decreases of up to 20 percent.

[32] https://www.hsr.ca.gov/docs/about/business_plans/2018_Business_Plan_Basis_of_Estimate.pdf.

[33] The exceptions are the Central Valley estimate, which is considered a Class 1 estimate, and the San Francisco to San Jose to Gilroy and Palmdale to Burbank estimates, which would be considered as Class 4 estimates that have to rely on a conceptual level of design.

Table 6 AACE Cost Estimate Classification Matrix[34]

Estimate Class	Level of Project Definition	End Usage	Methodology	Expect Accuracy Range
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	Low: -20% to -50% High: +30% to +100%
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	Low: -15% to -30% High: +20% to +50%
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	Low: -10% to -20% High: +10% to +30%
Class 2	30% to 70%	Control or Bid/Tender	Detailed Unit Cost with Forced Detailed Take-Off	Low: -5% to -15% High: +5% to +20%
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	Low: -3% to -10% High: +3% to +15%

For this 2019 Capacity Analysis Update, a Class 5 estimating range is used. Class 5 estimates are based on limited information typically applied to strategic business planning estimates for purposes such as initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, and long-range capital planning. Class 5 estimates range from potential increases of 30 percent to 100 percent; as well as potential decreases from 20 percent to 50 percent. The results for this analysis utilizes a conservative range, assuming the lower ends of this estimate class showing potential cost increases of up to 30 percent and cost decreases of up to 20 percent.

Although overall construction costs increased since the 2011-2012 timeframe of the previous analysis, the impacts of the updated diversion rates and additional blended segments slightly offset the effect of construction cost escalation over the period.

[34] Association for the Advancement of Cost Engineering, Cost Estimate Classification System – as applied in Engineering, Procurement, and Construction for the Process Industries, 2005, https://www.costengineering.eu/Downloads/articles/AACE_CLASSIFICATION_SYSTEM.pdf.

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6 COMPARISON TO PREVIOUS WORK

This section provides a comparison to the previous 2012 Capacity Analysis Report. In 2012, the Authority published a capacity analysis estimating highway and airport costs based on available information at that point in time. This 2019 Capacity Analysis Update provides current highway and airport capital costs, as well as revises high-speed rail operating assumptions for the blended segments that operate at lower operating speeds and reduced capital costs.

Like the previous analysis, this cost reflects the equivalent capacity based on Phase I of the high-speed rail system. The change from the 2012 analysis is due to four primary factors:

- Updated construction cost estimates due to escalation;
- Changes in diversion rates by mode;
  - The 2012 analysis assumed 75 percent of system capacity would be allocated to highways and 25 percent allocated to airports; and
  - The 2019 analysis assumes 80 percent of system capacity allocated to highways and 20 percent allocated to airports.
- Addition of blended high-speed rail operational segments;
  - The previous analysis assumed blended segments from San Francisco to San José and from Los Angeles to Anaheim.
  - In 2018, the segments from Burbank to Los Angeles and San José to Gilroy have been added to the total amount of blended distance in the system. This increase reduced the equivalent capacity calculation for the corresponding highway segments, resulting in a reduction in required lane-miles to 4,196 in the current update from 4,295 in the 2012 analysis.
- Inclusion of cost estimate accuracy ranges.

Table 7 provides a comparison of the capacity changes between the 2012 Capacity Analysis Report and the 2019 Capacity Analysis Update. The 2012 Capacity Analysis Report provided a range of estimates, based on the use of blended or nonblended segments, for both highway lane miles and cost in year of expenditure; the 2019 Capacity Analysis Update provides a cost range based on industry standard estimate ranges.

The 2012 Capacity Analysis Report estimated the capacity needed for highway lane-miles is 4,295 to 4,652. The 2019 Capacity Analysis Update notes a decreased need of 99 lane-miles. In addition, airport infrastructure needs decreased by 18 gates and 1 runway within the state. However, estimated baseline costs have potentially increased up to $8 billion for highway costs from the 2012 Capacity Analysis Report.

Table 7 Comparison of Capacity Needed and Cost of Providing Equivalent Capacity between 2012 and 2019 Analyses

Mode	Capacity Needed 2012	Capacity Needed 2019	Cost (YOE) 2012	Cost (YOE) 2019
Highway	4,295 - 4,652 lane-miles	4,196 lane-miles	$119 - $146 billion	$102 - $165 billion
Airport	115 gates and 4 runways	91 gates and 2 runways	$39 - $41 billion	$21 - $34 billion

Table 8 compares the total cost between the 2012 Capacity Analysis Report and the 2019 Capacity Analysis Update in year of expenditure (YOE) dollars, identifying a new cost range of up to $199 billion.

Table 8 Total Cost Comparison between 2012 Capacity Analysis Report and 2019 Capacity Analysis Update

Cost	2012 Analysis	2019 Analysis
Total[35]	**$158 - $186 billion**	**$122 - $199 billion**

35 Totals may not match sum due to rounding.

Appendix A 2017 CALIFORNIA INTRASTATE AIR TRAVEL FOR AIRPORTS ANALYZED – TOTALS (ORIGIN AND DESTINATION FLIGHTS)

Airport	Flight	Seats	Seats/Flight	Origin and Destination Passengers	Passengers/Flight
BUR	27,377	3,467,500	127	2,424,934	89
ONT	18,499	2,116,510	114	1,578,028	85
LGB	14,314	2,122,094	148	1,465,413	102
OAK	45,871	6,419,636	140	4,777,905	104
SJC	48,221	5,926,648	123	4,219,639	88
SNA	28,423	3,757,616	132	2,970,504	105
SAN	55,656	6,969,987	125	5,368,009	96
MRY	5,693	313,985	55	228,325	40
FAT	8,567	580,477	68	404,288	47
BFL	1,185	68,143	58	34,323	29
SMF	43,767	5,310,836	121	4,114,201	94

Appendix B SUMMARY OF ESTIMATED AIRPORT COSTS (MILLIONS, 2018$ AND YOE$)

Airports	Per Unit	BUR	ONT	LGB	SJC	OAK	SNA	SAN	MRY	FAT	BFL	SMF	Total[36]
Gates	—	11	7	7	17	19	13	6	2	3	1	5	**91**
New Runways	—	0	0	0	1	1	0	0	0	0	0	0	**2**
Passenger Terminal Facilities Cost/Unit	6,976 $/m2	—	—	—	—	—	—	—	—	—	—	—	—
Passenger Terminal Facilities	—	139	171	136	341	195	219	97	29	25	15	58	**1,425**
Apron Cost/Unit	$1.2M/ea	—	—	—	—	—	—	—	—	—	—	—	—
Aprons Total	—	14	10	8	22	25	18	7	2	4	1	6	**118**
Cost/Jetway	$0.6M/ea.	—	—	—	—	—	—	—	—	—	—	—	—
Jetway Total	—	8	5	5	12	14	10	4	1	2	1	3	**65**
Cost/Parking Space	$45,000/ea	—	—	—	—	—	—	—	—	—	—	—	—
Parking Total	—	175	114	106	272	308	159	32	11	29	1	71	**1,277**
Cost/Runway	$36M/ea.	—	—	—	—	—	—	—	—	—	—	—	—
Runway Total	—	—	0	0	36	36	36		0	0	0	0	**109**
Developed Land Clearing	—	—	0	0	4,554	513	3,416	1,072	1	0	0	0	**9,556**
Utility Cost	—	—	0	0	263	6	106	23	0	0	0	0	**397**
ROW Cost	—	—	0	0	1,851	93	463	141	15	0	0	0	**2,562**
Env. Mitigation	—	10	9	8	165	33	119	37	1	2	1	4	**388**
Prog. Implementation	—	88	79	67	1,917	312	1,159	360	16	16	5	36	**4,054**
Contingency	—	87	77	66	1,879	306	1,136	353	15	15	5	35	**3,974**
Total - 2018$	—	521	465	395	11,312	1,840	6,840	2,127	92	93	27	213	**23,924**
Total - YOE$	—	597	532	452	12,956	2,107	7,834	2,435	105	106	31	244	**27,400**

Note: For the purposes of this analysis, costs for equivalent highway and airport capacity were assumed to have the same timing as the capital costs for high-speed rail. As such, YOE costs were estimated using the same escalation rate, over the same time horizon used for high-speed rail Phase 1 system costs in the 2020 Business Plan, which assumed a 2033 completion date.

[36] Totals may not match sum due to rounding.