CALIFORNIA
High-Speed Rail Authority

Service Planning Methodology

2016 BUSINESS PLAN: TECHNICAL SUPPORTING DOCUMENT

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Acronyms

AGV	Automotrice à grande vitesse (high-speed electric train built by Alstom)
HMF	Heavy Maintenance Facility
MPH	Miles per Hour
NTSB	National Transportation Safety Board
O&M	Operations and Maintenance

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1 Purpose for High-Speed Rail Service Plans

The development process of the California High-Speed Rail *2016 Business Plan* includes a refined operations planning framework that was based on the latest ridership forecast data and designed to achieve a balanced service plan reflecting both revenue and non-revenue operations. The plan, which captures service and service costs at an intermediate level of project development, does not yet represent the type of detailed operating plan necessary to provide a commercially driven operating plan.

2 Service Planning Process

The service planning process used in the *2016 Business Plan* is formulated to provide service structure, journey time, and frequencies that can be used in the Travel Demand Forecast Model to produce ridership demand and revenue forecasts. A practical "timetable" for the operating day is developed based on estimated hourly service patterns of revenue service trains for "peak" and "off peak" periods. The timetables are based on train simulator generated running times modified to reflect an operating "pad" (an industry standard practice to account for day to day operating interruptions) and station dwell time. The service plan is then used to calculate specific outputs such as the number of revenue and non-revenue train runs, train mileage, and fleet size for the Operation and Maintenance (O&M) Cost Model. The finished service plan is also the basis for the calculation of feeder bus mileage that is another input for the cost model. The entire process is explained with more detail in this report.

3 Methodology

The service plans developed for the *2016 Business Plan* O&M cost estimate were created in a multi-step process consisting of:

1. Establishing a service structure and frequency to be used in the Travel Demand Forecast Model for each of the designated project milestone years, 2025, 2029, and 2040
2. Development of service plans based on the service levels assumed for the Travel Demand Forecast Model run(s) and fleet manipulation
3. Calculation of the O&M Cost Model inputs:
   - Revenue service train count
   - Daily trainset miles
   - Fleet size
   - Revenue train-to-revenue train turn count
4. Calculation of the feeder bus service revenue miles

3.1 Service Structure and Service Level for the Travel Demand Forecast Model

The first step of the service plan development is to create a service structure and service frequencies for the milestone years and phases that the Travel Demand Forecast Model uses.

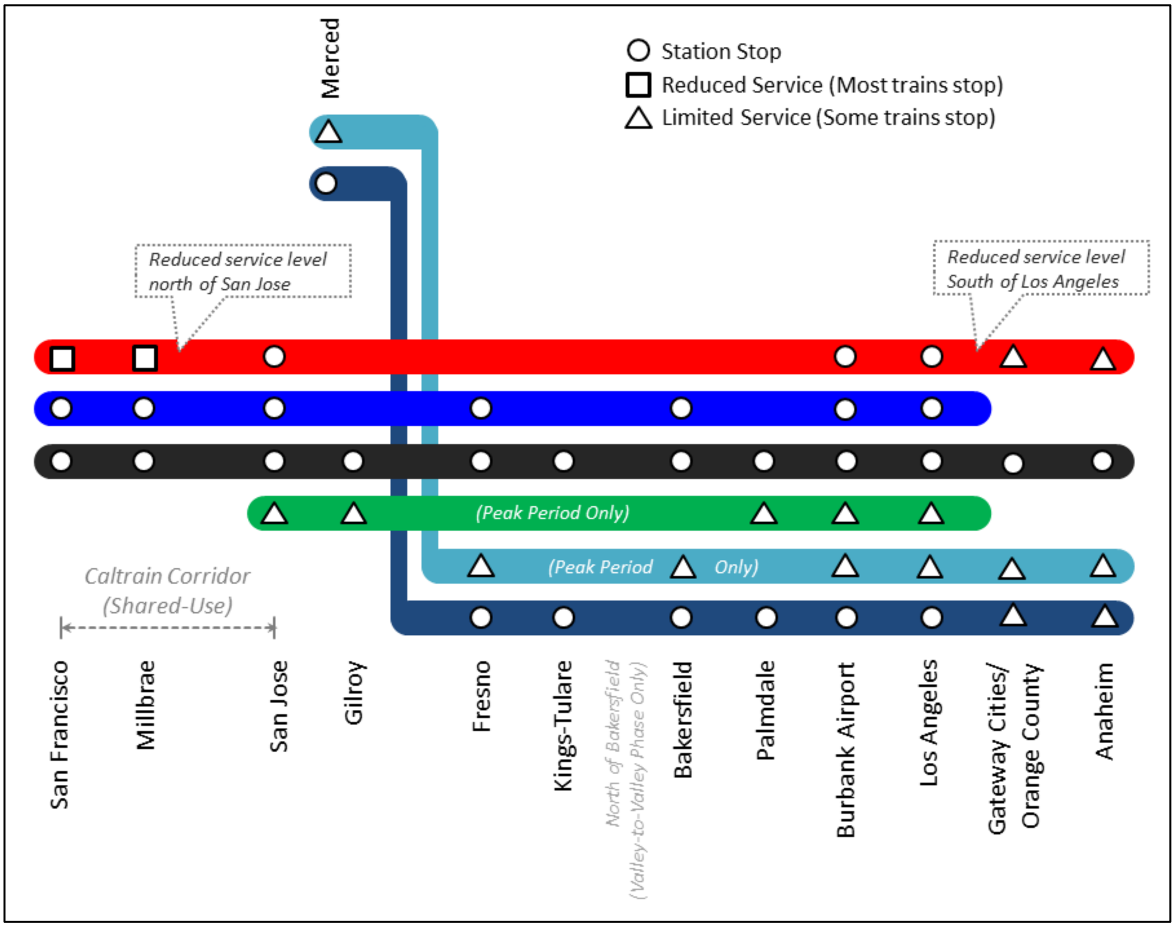
For the *2016 Business Plan*, the following ridership milestone and forecast years were selected to allow for more precise forecasts:

- Silicon Valley to Central Valley line (San Jose to North of Bakersfield) in 2025
- Silicon Valley to Central Valley Extension (San Francisco to Bakersfield) in 2025; this is a second opening segment scenario used to evaluate changes in forecasts and cost estimates if the Silicon Valley to Central Valley line is extended to San Francisco and Bakersfield
- Phase 1 (San Francisco to Anaheim) in 2029 and 2040 (out-year)

A service structure (the combination of stopping patterns normally referred to as local, express and limited stop) and an hourly frequency (the number of trains per hour in each direction) for each stopping pattern in peak and off-peak hours were prepared for the forecast model runs. The service structure pivots off of the hourly service patterns assumed in the service planning work done for the *2014 Business Plan*. Anticipated trip time from the origin station to each of the scheduled stops was calculated using a railroad operations simulation model tool, Train Performance Calculations, for each stopping pattern in order to devise the Travel Demand Forecast Model inputs. The Train Performance Calculation tool is part of specialized software package from Berkeley Simulation's Rail Traffic Controller application.

As an example, the assumed service structure for Phase 1 consists of an all-stop local pattern and variations of limited-stop train patterns similar to the Phase 1 service structure assumed in the *2014 Business Plan* but with improved service to Anaheim, as depicted in Figure 1.

Figure 1 – Service Structure Assumption for the California High-Speed Rail 2016 Business Plan



The service structure illustrated above offers several customer service advantages:

- More frequent express service
- Consistency in the service level at each station throughout the segment and during the service expansion / implementation phases
- Greater operational flexibility for practical application of the commercial service

3.2 Development of California High-Speed Rail Service Plans

The train schedules were developed through a process consistent with the process utilized to support previous California High-Speed Rail Business Plans.

Service plans for the target years of the Travel Demand Forecast Model runs were developed based on the hourly frequency and service structure assumptions used in the model. Using these service assumptions as a template, both peak hour service and off peak hour service were applied to the revenue service hours.

Service plans for the intermediate years reflect the service plans from the previous “milestone” year. For example, the 2025 service plans exist until the system expands to Phase 1 in 2029. The Phase 1 service plan remains consistent from 2029 and beyond. Ramp-up factors, as documented in the Operations and Maintenance Technical Supporting Document, are applied to these service plans to simulate the gradual start-up of high-speed rail service. The O&M inputs presented in the appendix reflect these ramp-up assumptions.

The Travel Demand Forecast Model is sensitive to the frequencies and the trip times between station pairs and it is important that there be consistency between the service levels modeled and the service plan itself. Therefore, service level adjustments were limited to:

- Additional service as required through potential ridership growth and system expansion
- Service designed to accommodate the first and the last hours of the revenue service day that are outside the hourly service pattern used for the ridership forecast

To develop the service plan, a "static" model using standard calculation software was created for the high-speed rail network. This model utilizes train performance calculations taken from prior detailed "dynamic" simulation modeling results to identify the running time of the various types of service and train stopping patterns that are used in the service plans for the California high-speed rail system. The model generates "stringline" (time-distance) diagrams and tabular outputs describing the timing and scheduled operating performance of every train. It provides a level of detail sufficient to perform "pattern analysis" of the various express, limited stop, and all-stop local services that are envisioned. The objective is to identify a service pattern that achieves the desired level of service at each station while minimizing conflicts between trains and the number of instances of train overtakes. The model provides the ability for trains to be "linked" with subsequent trains and assigned to specific trainsets. The resulting trainset equipment cycles form the basis for estimating the size of the required rolling stock fleet.

3.2.1 Early Morning and Late Evening Service

In order to serve all stations with early morning and late evening off peak trains consistent with the ridership forecast assumptions, some trains during this period terminate and start from intermediate stations rather than the end-point stations of the system. In the Phase 1 service plan for instance, the non-stop trains departing from Northern California to Southern California at 0600 would not pass Bakersfield before 0800. This means that intermediate stations would not have any service in the first and the last hours of the revenue-service day and a service gap would be created in a time period when passenger volumes are still anticipated. The addition of short-trip "zone" service addresses the service gap issue and provides the added efficiency of operating revenue trains instead of non-revenue trains to charge and discharge the system.

An example of the service plan developed in this step is presented in Figure 2.

Figure 2 – Example of Service Plan

Southbound

		Train Number:	291001	291002	291003	291004	291005	291006	291007	291008	291009	291010	291011	291012	291013	291014	291015	291016
		Origin:	PMD	PMD	PMD	PMD	BFD	PMD	FNO	PMD	SJC	FNO	MCD	SJC	SFO	SJC	SFT	SFT
		Destination:	ANA	ANA	LAU	LAU	ANA	LAU	LAU	ANA	LAU	ANA	ANA	LAU	LAU	LAU	ANA	LAU
Code	Station																	
SFT	San Francisco - Transbay	dp.															06:00	06:15
SFO	Millbrae	dp.													06:01		06:16	06:31
SJC	San Jose	dp.									06:00			06:25	06:41	06:37	06:51	07:06
GLY	Gilroy	dp.									06:16			↓	↓	06:58	↓	↓
MCD	Merced	dp.									||		06:56	||	||	||	||	||
FNO	Fresno	dp.							06:30		↓	06:57	07:19	07:15	↓	07:41	↓	07:57
KTR	Kings/Tulare	dp.							↓		↓	07:10	07:33	↓	↓	07:55	↓	↓
TBD	North of Bakersfield	dp.							↓		↓	↓	↓	↓	↓	↓	↓	↓
BFD	Bakersfield	dp.					06:45		07:09		↓	07:41	08:08	07:55	↓	08:26	↓	08:37
PMD	Palmdale	dp.	06:15	06:30	06:45	07:00	07:17	07:30	↓	07:50	08:00	08:14	08:46	↓	↓	08:58	↓	↓
BUR	Burbank Airport	dp.	06:31	06:46	07:01	07:16	07:34	07:46	07:54	08:06	08:17	08:30	09:03	08:40	08:46	09:15	08:56	09:22
LAU	Los Angeles	dp.	06:45	07:00	07:12	07:27	07:48	07:57	08:05	08:20	08:28	08:44	09:16	08:50	08:56	09:26	09:10	09:32
TBD	Gateway Cities/Orange County	dp.	07:06	07:21			08:09			08:41		09:05	09:38				09:31	
ANA	Anaheim	ar.	07:22	07:37			08:25			08:57		09:21	09:54				09:47	

		Train Number:	291017	291018	291019	291020	291021	291022	291023	291024	291025	291026	291027	291028	291029	291030	291031	291032
		Origin:	SFT	MCD	SJC	SFT	SJC	SFT	SFT	MCD	SFT	MCD	SJC	SFT	SJC	SFT	SFT	MCD
		Destination:	LAU	LAU	LAU	ANA	LAU	ANA	LAU	ANA	LAU	LAU	LAU	ANA	LAU	ANA	LAU	ANA
Code	Station																	
SFT	San Francisco - Transbay	dp.	06:30			06:45		07:00	07:15		07:30			07:45		08:00	08:15	
SFO	Millbrae	dp.	06:46			07:01		07:16	07:31		07:46			08:01		08:16	08:31	
SJC	San Jose	dp.	07:21		07:25	07:36	07:42	07:51	08:06		08:21		08:25	08:36	08:42	08:51	09:06	
GLY	Gilroy	dp.	↓		07:42	07:58	↓	↓	↓		↓		08:42	08:58	↓	↓	↓	
MCD	Merced	dp.	||	07:53	||	||	||	||	||	08:40	||	08:53	||	||	||	||	||	09:40
FNO	Fresno	dp.	↓	08:20	↓	08:42	↓	↓	08:57	09:03	↓	09:20	↓	09:42	↓	↓	09:57	10:03
KTR	Kings/Tulare	dp.	↓	08:34	↓	08:55	↓	↓	↓	↓	↓	09:34	↓	09:55	↓	↓	↓	↓
TBD	North of Bakersfield	dp.	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
BFD	Bakersfield	dp.	↓	09:09	↓	09:26	↓	↓	09:37	09:48	↓	10:09	↓	10:26	↓	↓	10:37	10:48
PMD	Palmdale	dp.	↓	09:46	09:26	09:59	↓	↓	↓	↓	↓	10:46	10:26	10:59	↓	↓	↓	↓
BUR	Burbank Airport	dp.	09:27	10:03	09:43	10:15	09:46	09:56	10:22	10:32	10:27	11:03	10:43	11:15	10:46	10:56	11:22	11:32
LAU	Los Angeles	dp.	09:38	10:14	09:53	10:29	09:57	10:10	10:32	10:46	10:38	11:14	10:53	11:29	10:57	11:10	11:32	11:46
TBD	Gateway Cities/Orange County	dp.				10:50		10:31		11:07				11:50		11:31		12:07
ANA	Anaheim	ar.				11:06		10:47		11:23				12:06		11:47		12:23

Northbound

		Train Number:	292001	292002	292003	292004	292005	292006	292007	292008	292009	292010	292011	292013	292014	292016	292017	292018
		Origin:	GLY	GLY	GLY	GLY	FNO	FNO	BFD	PMD	SFV	SFV	LAU	LAU	LAU	LAU	LAU	LAU
		Destination:	SFT	SFT	SFT	SFT	SFT	SFT	SJC	SFT	SFT	MCD	SFT	SJC	SJC	MCD	SFT	SFT
Code	Station																	
ANA	Anaheim	dp.																
TBD	Gateway Cities/Orange County	dp.																
LAU	Los Angeles	dp.											06:00	06:10	06:17	06:25	06:30	06:35
BUR	Burbank Airport	dp.									06:00	06:08	06:12	06:22	06:29	06:37	06:42	06:47
PMD	Palmdale	dp.								06:10	↓	06:31	↓	↓	06:48	↓	↓	↓
BFD	Bakersfield	dp.							06:28	06:44	↓	07:05	↓	↓	↓	07:26	↓	07:31
TBD	North of Bakersfield	dp.							↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
KTR	Kings/Tulare	dp.							↓	07:13	↓	07:35	↓	↓	↓	↓	↓	↓
FNO	Fresno	dp.					06:37	06:52	07:07	07:32	↓	07:52	↓	↓	↓	08:05	↓	08:10
MCD	Merced	ar.					||	||	||	||	||	08:16	||	||	||	08:28	||	||
GLY	Gilroy	dp.	06:16	06:31	06:46	07:01	07:16	07:31	↓	08:16	↓		↓	↓	08:26		↓	↓
SJC	San Jose	dp.	06:34	06:49	07:04	07:19	07:34	07:49	07:58	08:34	08:04		08:19	08:27	08:42		08:49	09:03
SFO	Millbrae	dp.	07:09	07:24	07:39	07:54	08:09	08:24		09:09	08:39		08:54				09:24	09:38
SFT	San Francisco - Transbay	ar.	07:23	07:38	07:53	08:08	08:23	08:38		09:24	08:54		09:08				09:38	09:53

		Train Number:	292012	292020	292015	292022	292023	292019	292025	292026	292021	292024	292029	292030	292027	292032	292033	292028
		Origin:	ANA	LAU	ANA	LAU	LAU	ANA	LAU	LAU	ANA	ANA	LAU	LAU	ANA	LAU	LAU	ANA
		Destination:	SFT	MCD	SFT	SJC	SJC	MCD	SFT	SFT	SFT	SFT	SJC	SJC	MCD	SFT	SFT	SFT
Code	Station																	
ANA	Anaheim	dp.	06:02		06:19			06:45			07:02	07:19			07:45			08:02
TBD	Gateway Cities/Orange County	dp.	06:19		06:36			07:02			07:19	07:36			08:02			08:19
LAU	Los Angeles	dp.	06:42	06:55	06:59	07:10	07:17	07:25	07:30	07:35	07:42	07:59	08:10	08:17	08:25	08:30	08:35	08:42
BUR	Burbank Airport	dp.	06:55	07:07	07:12	07:22	07:29	07:38	07:42	07:47	07:55	08:12	08:22	08:29	08:38	08:42	08:47	08:55
PMD	Palmdale	dp.	07:13	07:31	↓	↓	07:48	↓	↓	↓	08:13	↓	↓	08:48	↓	↓	↓	09:13
BFD	Bakersfield	dp.	07:42	08:05	↓	↓	↓	08:26	↓	08:31	08:42	↓	↓	↓	09:26	↓	09:31	09:42
TBD	North of Bakersfield	dp.	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
KTR	Kings/Tulare	dp.	08:12	08:34	↓	↓	↓	↓	↓	↓	09:12	↓	↓	↓	↓	↓	↓	10:12
FNO	Fresno	dp.	08:31	08:52	↓	↓	↓	09:06	↓	09:10	09:31	↓	↓	↓	10:06	↓	10:10	10:31
MCD	Merced	ar.	||	09:15	||	||	||	09:29	||	||	||	||	||	||	10:29	||	||	||
GLY	Gilroy	dp.	09:15		↓	↓	09:26		↓	↓	10:15	↓	↓	10:26		↓	↓	11:15
SJC	San Jose	dp.	09:33		09:18	09:27	09:42		09:49	10:03	10:33	10:18	10:27	10:42		10:49	11:03	11:33
SFO	Millbrae	dp.	10:08		09:53				10:24	10:38	11:08	10:53				11:24	11:38	12:08
SFT	San Francisco - Transbay	ar.	10:22		10:08				10:38	10:53	11:22	11:08				11:38	11:53	12:22

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3.3 Calculation of O&M Cost Model Inputs

The service plans are designed to provide direct inputs for the O&M Cost Model for:

- Trainset Mileage
- Fleet Size
- Number of Revenue Trains (for Connecting Buses)
- Revenue Train to Revenue Train Turns (Crew Numbers)
- Feeder Bus Miles

After the service plans were created, all of the equipment was linked to form extended cycles (the planned train schedule assignments for the duration of a service day) to satisfy the terminal requirements (the number of trainsets required to begin revenue service at each terminal station during a calendar day) as well as staging for the morning start-out requirements for each terminal station. These equipment cycles form the basis of the estimate for the total fleet size required by the revenue service. These cycles also dictate the daily system-wide trainset mileage that drives the cost input for rolling stock and infrastructure maintenance used in the O&M Cost Model.

3.3.1 Trainset Mileage

The daily trainset mileage is computed based on the service plan and the associated equipment cycles created to estimate the fleet size. The mileage of the revenue-service movement of the trainsets was derived by adding up all of the revenue-service run mileage included in the service plan. The mileage of the non-revenue movements was added to the revenue-service trainset miles by adding the combined mileage of:

- Non-revenue movements at the beginning of the revenue-service cycle - the distance between a Terminal Station Maintenance Facility where the trainset was stored overnight and the origin station of the first revenue train of the cycle.

- Non-revenue movements at the end of the revenue-train cycle - the distance between the terminus of the final revenue service of the cycle and one of the Terminal Station Maintenance Facilities where the trainset would be stored and maintained for the next revenue-service day.

4 Assumptions

4.1 Infrastructure

- The majority of the high-speed rail network is assumed to be exclusive infrastructure separated from any other conventional heavy rail systems, except for the Caltrain corridor between San Francisco and San Jose and shared track along segments of the Metrolink corridor in Southern California.
- High-speed rail passenger stations are assumed to be located at the following locations:
  - San Francisco Transbay Terminal
  - San Francisco 4th & King[1]
  - Millbrae
  - San Jose Diridon Station
  - Gilroy
  - Merced
  - Fresno
  - Kings/Tulare
  - Interim Terminus North of Bakersfield[2]
  - Bakersfield
  - Palmdale
  - Burbank Airport[3]
  - Los Angeles Union Station
  - Gateway Cities/Orange County
  - Anaheim
- Mid-line stations are assumed to be 4-track stations with two center tracks to be main tracks and two outside tracks to be station platform tracks. Station tracks will be siding tracks of approximately 1,410 feet adjacent to the station platform. The switches to allow trains to diverge from the main tracks to the station tracks are currently designed to handle speeds of 110 MPH. Universal interlockings capable of routing trains to all parts of the station complex must be sited no further than one mile from the turnouts leading to the station tracks.

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[1] The San Francisco 4th & King station is assumed in the Silicon Valley to Central Valley Extension (San Francisco to Bakersfield) scenario only; San Francisco Transbay Terminal is assumed for Phase 1

[2] The interim terminus north of Bakersfield is an interim station assumed in the Silicon Valley to Central Valley line (San Jose to North of Bakersfield) opening phase only

[3] The San Fernando Valley Station presented in the *2014 Business Plan* has been moved to Burbank for the *2016 Business Plan*

- The signal system is assumed to provide a 3-minute minimum signaling headway at 220 MPH, in that 2 trains can operate 3 minutes apart when they are traveling at 220 MPH. It is expected that the timetable headway will maintain minimum 5-minute headway between scheduled trains at intermediate stations.
- Terminal Station Maintenance Facilities are assumed to be built as listed in Table 1. **It should be noted here that the location of these facilities are part of the ongoing environmental approval process so are likely to change before they are finalized. They are listed here as assumptions to develop reference points so that non-revenue crew and mileage inputs can be determined for the O&M Cost Model.**

Table 1 - List of Rolling Stock Maintenance Facility Assumed in Service Plan Development

Preliminary Name	Maintenance Capability	Roll-Out Phase
"Bay Area"[4]	Level II and III	Silicon Valley to Central Valley
"Central Valley HMF"	Level II – V	Silicon Valley to Central Valley
"Palmdale"	Level II and III	Phase 1
"Los Angeles Area"	Level II	Phase 1

4.2 Fleet Specification

- Trainsets with performance characteristics equivalent to the Alstom AGV trainset model were used for the pure run time calculations, and the trip time was based on train performance characteristics described in the trainset specifications and track geometry.
- Trainsets were assumed to be approximately 660 feet in length with 450 passenger seats.
- Each revenue-service train were assumed to be operated in either one trainset or two set configurations based on demand.

4.3 Passenger Service

- The interval of recovery time (scheduled pad) for the high-speed rail trains has been established at seven percent of the pure run time as computed by the Train Performance Calculator in Rail Traffic Controller. The Rail Traffic Controller is a railroad operations simulation model widely used among railroads in the United States and by the National Transportation Safety Board (NTSB).
- System revenue-service hours are anticipated to be from 0600 to Midnight (2400), seven days a week; the five-hour period between 0000 and 0500 is allocated to the maintenance of infrastructure while the one-hour period between 0500 and 0600 is allocated for non-revenue movements and other activities required for the morning service start-up.

[4] A facility will exist in the Gilroy area for the Silicon Valley to Central Valley line segment and another facility is expected to open when the system expands to San Francisco

- When possible, the conceptual schedule features passenger-friendly and operationally-flexible "clock face" patterns with train departures at regular headways and at the same minute after each hour.
- Train schedules consist of two kinds of clock face patterns: one for the peak period and the other for the midday off-peak period.
- There were assumed to be two (2) 3-hour peak periods in each revenue service day. The peak hours are meant to accommodate the size of the system and the variety of peak demand times.
- The service during the early morning start-up period and the late evening shut-down period may be different from service patterns during other times of the day in order to capture short-distance regional trip demands while offering fast service between terminal stations and intermediate stations.
- Overtakes between faster trains and slower trains occur at intermediate stations in order to allow faster trains to achieve scheduled trip time; no overtakes occur at intermediate stations north of Gilroy or south of Palmdale.
- Minimum dwell time at intermediate stations is 180 seconds in both Silicon Valley to Central Valley options and 90 seconds in Phase 1.
- Minimum and desirable layover/turnaround times for a train set between revenue trips at terminal stations are 30 minutes and 40 minutes, respectively.

4.4 Fleet Requirements

- All trainsets required for revenue-service operations are assumed to be stored at nearby trainset maintenance facilities, tail tracks at terminal stations, or platform tracks at the passenger stations.
- The total fleet requirement of the system is approximately 10 percent more than the actual number of trainsets required to operate the revenue service in order to provide maintenance spares and revenue service "protect" trains. This is an international industry standard in high-speed passenger rail systems.
- In addition to the "protect" trains, a few trainsets are assumed to be reserved to respond to the high demand days in the peak traveling seasons. The number of trainsets for the high demand response varies but it is assumed that at least one scheduled revenue-service train in every 2 hours can operate in double-consist configuration.
- Furthermore, several trainsets are assumed to be reserved as "hot standby". These trainsets are provided to "protect" revenue service during disruptions or unforeseen events. The number of trainsets reserved as "hot standby" varies in each phase.

5 Feeder Bus Service Planning

5.1 Introduction

During initial stages of its implementation, the high-speed rail system would not provide direct high-speed train service to some of the major urban areas - such as the Sacramento area and the Los Angeles Basin area. The proposed high-speed train service would end at San Jose and a station north of Bakersfield creating interim end-of-the-line stations there. While certain conventional rail connections - such as Caltrain – would be available between the opening Silicon Valley to Central Valley line segment and major urban areas, the limited frequency of such connections would not be able to provide connections to/from each high-speed train arriving at/leaving from these interim end-of-the-line stations. In fact, there are no transit options between the North of Bakersfield interim station and the Los Angeles Basin area. In order to fill this connectivity gap, the high-speed rail service will be supplemented with feeder bus connections between the opening Silicon Valley to Central Valley line segment and certain major urban areas during the initial stages of implementation.

Feeder bus connections were included in the Travel Demand Forecast Model run specifications. The Travel Demand Forecast Model accounts for these feeder bus connections in estimating the ridership for the high-speed rail system; it also forecasts bus revenue based on the number of passengers using the feeder bus to access and egress the high-speed rail system. Table 2 presents feeder bus revenue by forecast year and the number of bus revenue miles as calculated through the service planning process. It is important to note that the feeder bus service levels have not yet been optimized.

Table 2 - Estimated Feeder Bus Annual Fare Revenue and Revenue Vehicle Miles

Year	Bus Revenue in 2015$ (Silicon Valley to Central Valley Line)	Bus Revenue Vehicle Miles (Silicon Valley to Central Valley Line)	Bus Revenue in 2015$ (Silicon Valley to Central Valley Extension)	Bus Revenue Vehicle Miles (Silicon Valley to Central Valley Extension)
2025	$5,227,364	7,624,525	$6,047,356	6,956,683
2029	<$100,000	1,842,885	<$100,000	1,842,885
2040	<$100,000	2,168,100	<$100,000	2,168,100

The significant drop in feeder bus revenue when the Phase 1 system opens is due to a reduction in the feeder bus service offered. Given the minimal service frequencies of the San Joaquin Amtrak trains between Sacramento and Fresno and the absence of transit connecting the North of Bakersfield station and the Los Angeles Basin, there are minimal transit options available that connect to the Silicon Valley to Central Valley line. As a result, before the high-speed rail system expands to Phase 1 a feeder bus will run frequently enough to meet each high-speed rail train in Fresno and the station north of Bakersfield. Phase 1 feeder bus service is reduced as the system extends its reach and is consistent with bus service levels in the *2014 Business Plan*; additional information on the feeder bus connections can be found in the sections below.

5.2 Travel Demand Forecast Model Run Specification

Feeder bus connections were included in the Travel Demand Forecast Model run specifications for each implementation step. The specifications included stopping patterns, run times, and service frequencies for each feeder bus connection.

5.2.1 Feeder Bus Connections

The Travel Demand Forecast Model run specifications for the Silicon Valley to Central Valley line and Phase 1 implementation steps include the following proposed feeder bus connections as summarized in Table 3.

Table 3 - Feeder Bus Connections

Proposed High-Speed Rail Station Connection Point	Implementation Step: Silicon Valley to Central Valley	Implementation Step: Phase 1
Fresno High-Speed Rail (Silicon Valley to Central Valley line and Silicon Valley to Central Valley Extension) Merced High-Speed Rail (Phase 1)	• Sacramento	• Sacramento
North of Bakersfield or Bakersfield High-Speed Rail	• Los Angeles Basin	• None

In order to efficiently serve the large geographic area of the Los Angeles Basin, more than one feeder bus connection route was assumed. The Los Angeles Basin area was provided with three feeder bus routes – the first one terminating at Los Angeles Union Station, the second one terminating at West Los Angeles, and third one terminating at Santa Anita. Further details for each of these routes are included in the following sections.

5.2.2 Stopping Pattern

Stopping patterns for each connection were determined based on the location of major transportation connections and/or the size and location of major population centers or urban areas.

Table 4 - Location of Mid-Line Bus Stops

Feeder Bus Connection	Location of Bus Stop
Sacramento	Sacramento (Amtrak Station) Elk Grove (Amtrak Thruway bus stop) Lodi (Amtrak Station) Stockton (Amtrak Station) Modesto (Amtrak Station) Denair/Turlock (Amtrak Station) Fresno (Amtrak Station)
Los Angeles Basin (Los Angeles Union Station)	Burbank Airport Los Angeles Union Station
Los Angeles Basin (West Los Angeles)	Van Nuys West Los Angeles
Los Angeles Basin (Santa Anita)	Santa Anita

5.2.3 Run Times

Run times for each feeder bus connection were based on auto travel times between each consecutive bus stop.

5.3 Ridership

The feeder bus service levels have not been optimized to account for ridership levels projected by the Travel Demand Forecast Model. However, based on the service plans assumed that feed the Travel Demand Forecast Model, initial forecasts suggest that ridership is significantly higher during the Silicon Valley to Central Valley line phase. This is because the Silicon Valley to Central Valley line opening segment connects with Amtrak San Joaquin service in the north and extends only as far south as the station located north of Bakersfield, making the high-speed rail feeder bus the best transit option to connect the high-speed trains to Southern California.

As high-speed rail expands to the Phase 1 system in 2029, feeder bus ridership drops significantly as the Los Angeles basin is well served by high-speed rail directly.

5.4 Revenue and Fare

In the *2014 Business Plan*, one of the objectives of the Travel Demand Forecast Model runs was to allow comparison of ridership under various implementation steps with the same set of end-to-end fares. High-speed rail fares were set to be competitive with airfares and other modes of travel were assumed to maintain overall fare levels between regions as described in the *2014 Business Plan*. The fares were specified in 2005$ in the Travel Demand Forecast Model. In order to escalate the revenue to current year dollars, an escalation factor was applied based on the California Consumer Price Index.

High-speed rail fares in the *2016 Business Plan* utilize a generally consistent approach and remain competitive with airfares in the market. In 2015$, an $89 average fare from San Francisco to Los Angeles trip is used in the modeling. Similarly, feeder bus fares were set to be competitive with other modes of travel. More specifically, the feeder bus fares for the Sacramento area buses remain consistent with the *2014 Business Plan* assumptions, while the Los Angeles Basin buses have increased. The Travel Demand Forecast Model assumes a $9.87 feeder bus fare between Sacramento and Fresno/Merced and $1.23 for connections at the mid-line bus stops (all in 2015$). The bus fares for the Bakersfield area to Los Angeles Basin connection are assumed to be $12.33 in the *2016 Business Plan*, consistent with fares listed for the Amtrak Thruway bus between Bakersfield and Los Angeles for the existing Amtrak San Joaquin service.

Table 5 presents the incremental fare for using the feeder bus connections, as specified in the Travel Demand Forecast Model run specifications.

Table 5 - Incremental Fares

Bus Origin	Connection High-Speed Rail Station	Incremental Fares (in 2015 $)
Los Angeles Basin (Silicon Valley to Central Valley scenarios only)	North of Bakersfield (Silicon Valley to Central Valley line) Bakersfield (Silicon Valley to Central Valley Extension)	$12.33
Sacramento Area	Fresno (Both Silicon Valley to Central Valley scenarios) Merced (Phase 1)	$9.87
Stockton/Modesto/Denair/Merced	Fresno (Both Silicon Valley to Central Valley scenarios) Merced (Phase 1)	$1.23

The total feeder bus revenues are included in Table 2.

5.5 Service Levels

Feeder bus service levels assumed for the Silicon Valley to Central Valley line opening phase in 2025 are set to meet every high-speed train in Fresno and North of Bakersfield. As mentioned above, few transit options exist that connect to the Silicon Valley to Central Valley line segment from the Sacramento area in Northern California or the Los Angeles Basin area in Southern California.

As defined earlier, the San Jose Diridon station marks the northern interim terminal in the Silicon Valley to Central Valley line segment. Conventional rail such as Caltrain runs frequent enough service from other parts of the Bay Area to San Jose that feeder bus service is assumed to not be necessary. The Amtrak San Joaquin conventional rail service connects the Sacramento area to the Central Valley and is a logical transit option to connect to the Silicon Valley to Central Valley line at Fresno. However, Amtrak San Joaquin service is limited and feeder bus service is assumed to meet high-speed trains at Fresno as an alternate option.

The North of Bakersfield interim southern terminal has no alternate transit connection options. Potential riders from the Los Angeles Basin area that want to access high-speed rail by transit will rely on feeder bus connections to meet high-speed trains at the North of Bakersfield station until the high-speed rail system expands to Southern California. As a result, each of the three Los Angeles feeder bus lines runs frequently enough to meet each high-speed train at the interim North of Bakersfield station.

Phase 1 feeder bus service levels are reduced significantly and service assumptions remain generally consistent with the *2014 Business Plan*. As the Phase 1 system extends to Palmdale, Burbank, and further south, Metrolink will conveniently connect the Los Angeles Basin to several high-speed rail stations. As a result, the Los Angeles Basin feeder bus is removed from the Travel Demand Model in Phase 1. There still remains some feeder bus service in the Sacramento area to connect the region to the Merced terminal in the Central Valley.

In the *2016 Business Plan*, the service levels assumed in the ridership forecast were also used to calculate daily revenue bus mileage. The total number of annual revenue miles of feeder bus connection service was then calculated by multiplying the trip length with the total number of daily feeder bus connections, an annualization factor (365), and a factor to account for roundtrip service (2).

The derived estimates for revenue vehicle miles were then used as input in the O&M Cost Model, which then applied the per mile cost to calculate the total operating and maintenance cost for feeder bus connections. Additional details for this step are available in the Operations and Maintenance Cost Model Technical Supporting Document.

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Appendix 1 Inputs to O&M Cost Model

2016 Business Plan Service Plan Input for O&M Cost Model (Silicon Valley to Central Valley line through Phase 1)

Item	Year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Total Number of Revenue Service Trips	Single Consist Daily Runs	30	32	34	36	197	203	212	220	232	232	232	232	232	232	232	232	232	232
	Double Consist Daily Runs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Trainset Miles	Daily Single Consist Miles	3,140,659	3,338,645	3,508,407	3,678,169	29,357,180	30,251,410	31,529,638	32,807,867	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859
	Daily Double Consist Miles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Revenue to Revenue Service Turns	SF Transbay	0	0	0	0	41	42	44	46	48	48	48	48	48	48	48	48	48	48
	San Jose	10	10	11	11	3	4	4	4	4	4	4	4	4	4	4	4	4	4
	Merced	0	0	0	0	11	11	12	12	13	13	13	13	13	13	13	13	13	13
	Interim North of Bakersfield	8	9	9	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	LA Union Sta.	0	0	0	0	35	36	37	39	41	41	41	41	41	41	41	41	41	41
	Anaheim	0	0	0	0	24	25	26	27	28	28	28	28	28	28	28	28	28	28

Item	Year	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
Total Number of Revenue Service Trips	Single Consist Daily Runs	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232
	Double Consist Daily Runs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Trainset Miles	Daily Single Consist Miles	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859
	Daily Double Consist Miles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Revenue to Revenue Service Turns	SF Transbay	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	San Jose	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Merced	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Interim North of Bakersfield	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	LA Union Sta.	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
	Anaheim	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28

2016 Business Plan Service Plan Input for O&M Cost Model (Silicon Valley to Central Valley Extension through Phase 1)

Item	Year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Total Number of Revenue Service Trips	Single Consist Daily Runs	30	32	34	36	197	203	212	220	232	232	232	232	232	232	232	232	232	232
	Double Consist Daily Runs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Trainset Miles	Daily Single Consist Miles	3,809,204	4,042,936	4,248,509	4,454,082	29,357,180	30,251,410	31,529,638	32,807,867	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859
	Daily Double Consist Miles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Revenue to Revenue Service Turns	SF Transbay	0	0	0	0	41	42	44	46	48	48	48	48	48	48	48	48	48	48
	SF 4th & King	7	7	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	San Jose	0	0	0	0	3	4	4	4	4	4	4	4	4	4	4	4	4	4
	Merced	0	0	0	0	11	11	12	12	13	13	13	13	13	13	13	13	13	13
	Bakersfield	9	10	10	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	LA Union Sta.	0	0	0	0	35	36	37	39	41	41	41	41	41	41	41	41	41	41
	Anaheim	0	0	0	0	24	25	26	27	28	28	28	28	28	28	28	28	28	28

Item	Year	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
Total Number of Revenue Service Trips	Single Consist Daily Runs	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232
	Double Consist Daily Runs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Trainset Miles	Daily Single Consist Miles	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859	34,537,859
	Daily Double Consist Miles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Revenue to Revenue Service Turns	SF Transbay	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
	SF 4th & King	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	San Jose	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Merced	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Bakersfield	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	LA Union Sta.	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
	Anaheim	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28