CALIFORNIA
High-Speed Rail Authority

TECHNICAL SUPPORTING DOCUMENT

2020 Business Plan

SERVICE PLANNING METHODOLOGY

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CALIFORNIA High-Speed Rail Authority

SIGNATURE/APPROVAL SHEET

TO: Joseph Hedges

FROM: Stefan Reul

SUBJECT: Approval of 2020 Business Plan Service Planning Methodology

DESCRIPTION OF ENCLOSED DOCUMENT(S): 2020 Business Plan Service Planning Methodology Report

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Description
AGV	Automotrice à grande vitesse (high-speed electric train built by Alstom)
CVS	Central Valley Segment, early high-speed rail operation between Merced and Bakersfield
HMF	Heavy Maintenance Facility
HSR	High-speed rail
MPH	Miles per hour
NTSB	National Transportation Safety Board
O&M	Operations and Maintenance
TDFM	Travel Demand Forecast Model
TMF	Trainset Maintenance Facility
TPC	Train Performance Calculations
V2V	Silicon Valley to Central Valley Service (San Francisco to Bakersfield)

1 PURPOSE FOR HIGH-SPEED RAIL SERVICE PLANS

The development process of the California High-Speed Rail Authority *2020 Business Plan* includes an operations planning framework that was based on the latest ridership forecast data and designed to achieve a balanced service plan, reflecting 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 commercially driven service.

The service plans are developed to align with the infrastructure to be provided through the capital cost expenditure plan. The service plans aim to optimize utility of the provided infrastructure.

Service plans have been developed to cover three phases of project development: Central Valley (Merced to Bakersfield, December 2028 horizon), Silicon Valley to Central Valley (San Francisco and Merced to Bakersfield, December 2031 horizon) and Phase 1 (San Francisco and Merced to Anaheim via Los Angeles Union Station, December 2033 horizon).

2 SERVICE PLANNING PROCESS

The service planning process used in the *2020 Business Plan* is formulated to provide service structure, journey times and frequencies that can be used in the Travel Demand Forecast Model (TDFM) to produce ridership demand and revenue forecasts. A practical timetable for the operating day was developed based on estimated hourly service patterns of revenue service trains for peak and off-peak periods.

The timetables are based on run times generated by a train simulator, which includes infrastructure-related parameters such as maximum allowable speed and gradients. Industry-standard allowances for day-to-day variance in train operations—such as weather conditions, fluctuation of train performance due to differences in engineers' handling and minor operating interruptions—are then added to these run times. The timetable also includes further allowances for station dwell times and train turn times.

The timetable is used to calculate specific outputs, such as the number of revenue and non-revenue train runs, train mileage and fleet size for the Operations and Maintenance (O&M) Cost Model. The finished timetable is also the basis for the calculation of feeder bus mileage that is another input for the cost model. The entire process is explained in more detail in this report. The timetable does not represent commercially optimized service. The timetable reflects an illustrative plan that can be used to derive reasonable outputs necessary for ridership, revenue and O&M cost modeling.

3 METHODOLOGY

The timetables developed for the *2020 Business Plan* O&M Cost Model were created in a multistep process consisting of:

1. Establishing a service structure and frequency to be used in the TDFM for each of the designated project milestone years: December 2028, December 2031, December 2033 and January 2040.
2. Development of service plans based on the service levels assumed for the TDFM run(s) and fleet manipulation.
3. Calculation of the O&M Cost Model inputs:
    - Revenue service train count;
    - Daily trainset miles;
    - Fleet size; and
    - 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 TDFM

The first step of developing a service plan is to create a service structure and service frequencies for the milestone years and phases that the TDFM uses. For the *2020 Business Plan*, the following ridership milestone and forecast years were selected to allow for more refined forecasts:

- Central Valley in December 2028 (evaluation in separate Central Valley Segment Study);
- Silicon Valley to Central Valley line in December 2031; and
- Phase 1 in December 2033 and 2040 (outer horizon year).

The different services for the three operating scenarios are shown in Figure 3-1 for Valley-to-Valley operation and in Figure 3-2 for the Phase 1 operation of the high-speed rail system.

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. Anticipated trip time from the origin station to each of the scheduled stops for each stopping pattern was calculated using a railroad operations simulation model tool, Train Performance Calculations (TPC). These trip travel times are a key input for the TDFM. The TPC tool is part of specialized software package from Berkeley Simulation's Rail Traffic Controller application.

As an example, the Silicon Valley to Central Valley service patterns are shown in Figure 3-1. Figure 3-2 shows the assumed service structure for Phase 1, which consists of an all-stop local pattern and variations of limited-stop train patterns. These patterns are similar to the Phase 1 service structure assumed in the previous business plans.

Figure 3-1 Service Structure Assumption for the Silicon Valley to Central Valley Line

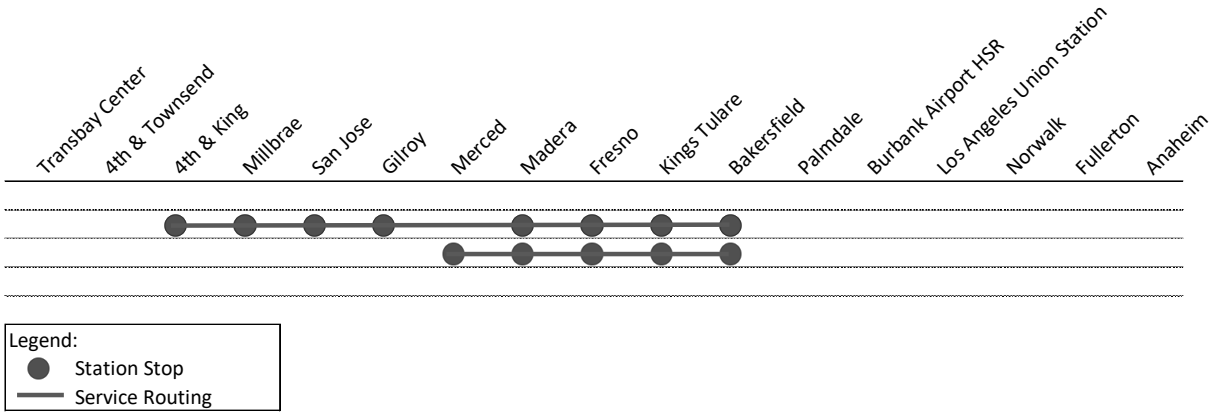
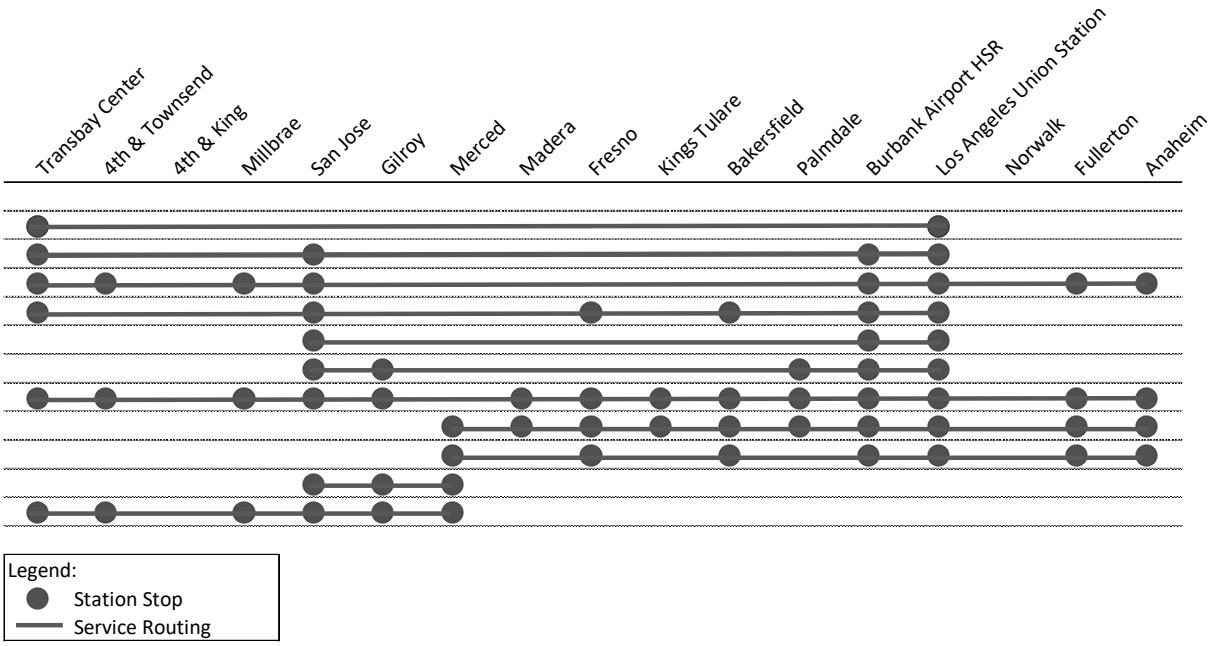


Figure 3-2 Service Structure Assumption for Phase 1



The service structure illustrated above for Phase 1 offers several customer service advantages:

- Ability to travel between any pair of stations without having to change trains;
- Mixture of express service, limited-stop service and all-stop local service, which offers a diverse menu of train services to cover a wide variety travel needs;
- Consistency in the service level at each station throughout the segment and during the service expansion/implementation phases; and
- 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 previous business plans from the California High-Speed Rail Authority.

Service plans for the milestone years of the TDFM runs were developed based on the hourly frequency and service structure assumptions used in the model. Using these service assumptions as a template, separate peak hour and off-peak hour service plans were developed.

Service plans for the intermediate years reflect the service plans from the previous “milestone” year. For example, the December 2031 Silicon Valley to Central Valley line service plan exists until the system expands to Phase 1 in December 2033. The Phase 1 service plan remains consistent from December 2033 and beyond. In past business plans, ramp-up factors were applied to the operating cost for these service plans to simulate the gradual start-up of high-speed rail service levels. However, with the introduction of the Central Valley Segment (CVS), this ramp-up is assumed to take place during the CVS operation and full operating schedules are assumed for the beginning of the December 2031 Silicon Valley to Central Valley and the December 2033 Phase 1 operation. The O&M inputs presented in the appendix reflect the ramp-up assumptions and are documented in the O&M Technical Supporting Document and the *2020 Business Plan*.

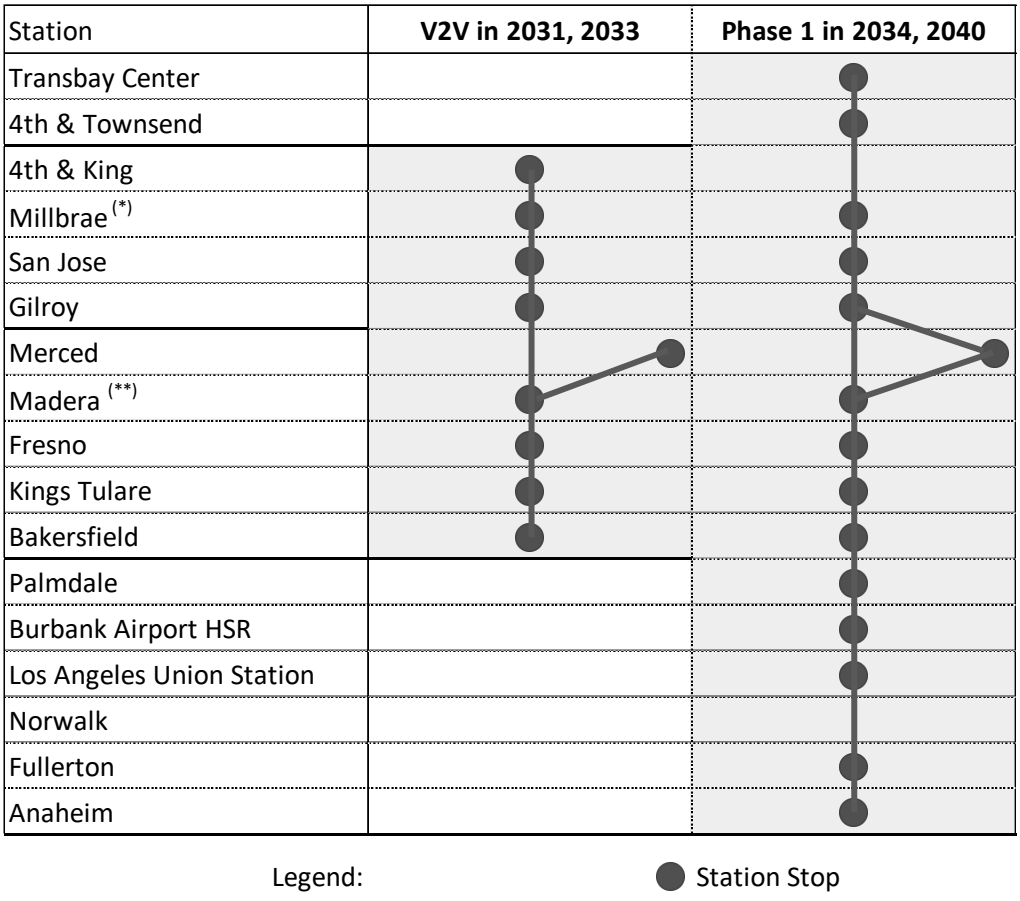
3.2.1 Revised Stopping Patterns in Silicon Valley to Central Valley Service

The Silicon Valley to Central Valley service reflects the following differences as compared to the *2018 Business Plan*:

- Reflection of the CVS early operation between Merced and Bakersfield before Silicon Valley to Central Valley operation commences;
- Early inclusion of Millbrae as a station stop to reflect recent developments in the development of the Millbrae station area planning; and
- Addition of the partial Wye alignment and the station in Merced in the Silicon Valley to Central Valley service plan.

The Silicon Valley to Central Valley service plan reflects elements from the Phase 1 service plans that are assumed at this earlier stage of operation as compared to the *2018 Business Plan*. The resulting service provides a significant increase in train miles that are based on services between San Francisco and Merced and Merced to Bakersfield in addition to the Silicon Valley to Central Valley service (as shown in Figure 3-3).

Figure 3-3 Stations Served for the Silicon Valley to Central Valley and Phase 1 Alternatives



Notes: *Millbrae assumed to be operational by 2030 as a high-speed rail stop.
**Station stop of high-speed rail services in Madera assumed. Station to be provided by others.

The following figures and tables describe the high-speed rail services for the Central Valley Segment, the Silicon Valley to Central Valley operation as well as the Phase 1 service. The service plan assumes six hours of peak operation as well as 12 hours of off-peak operation. Only in Phase 1 service patterns vary between peak and off-peak.

In Silicon Valley to Central Valley (Table 3-3) the San Francisco to Bakersfield operates at 30-minute headways in the peak and hourly in the off-peak hours. The Merced to Bakersfield service operates at hourly headways.

In Phase 1, the service frequencies vary as shown in Table 3-4, with lower frequencies in the off-peak period and reduced service patterns where only six of the 10 peak service patterns operate during the off-peak period.

Figure 3-4 Stopping Patterns by Line for Silicon Valley to Central Valley Service

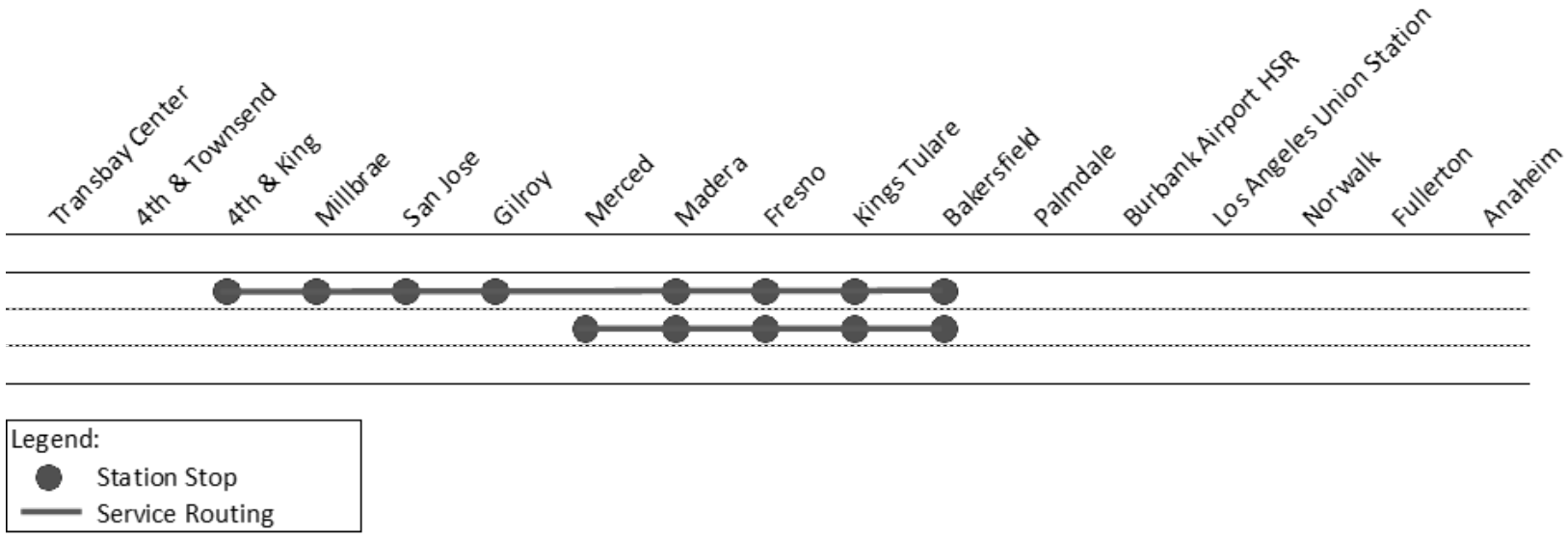


Table 3-1 Service Frequency by Line and Station for Silicon Valley to Central Valley Service

Silicon Valley to Central Valley (V2V) Service Pattern	Southbound	Northbound	Transbay Center	4th & Townsend	4th & King	Millbrae	San Jose	Gilroy	Merced	Madera	Fresno	Kings Tulare	Bakersfield	Palmdale	Burbank Airport HSR	Los Angeles Union Station	Norwalk	Fullerton	Anaheim
Southbound V2V-04M	22				22	22	22	22		22	22	22	22						
Southbound V2V-02M	17								17	17	17	17	17						
Southbound Total Day	39				22	22	22	22	17	39	39	39	39						
Northbound V2V-04M		21			21	21	21	21		21	21	21	21						
Northbound V2V-02M		17							17	17	17	17	17						
Northbound Total Day		38			21	21	21	21	17	38	38	38	38						
Total Day (Both Directions)	39	38			43	43	43	43	34	77	77	77	77						
Peak (Both Directions)	18	18			24	24	24	24	12	36	36	36	36						
Off-Peak (Both Directions)	21	20			19	19	19	19	22	41	41	41	41						

Table 3-2 Service Frequency by Station Pair for Silicon Valley to Central Valley Service

From Origin Station to Destination Station	Transbay Center	4th & Townsend	4th & King	Millbrae	San Jose	Gilroy	Merced	Madera	Fresno	Kings Tulare	Bakersfield	Palmdale	Burbank Airport HSR	Los Angeles Union Station	Norwalk	Fullerton	Anaheim
Transbay Center																	
4th & Townsend																	
4th & King				22	22	22		22	22	22	22						
Millbrae			21		22	22		22	22	22	22						
San Jose			21	21		22		22	22	22	22						
Gilroy			21	21	21			22	22	22	22						
Merced								17	17	17	17						
Madera			21	21	21	21	17		39	39	39						
Fresno			21	21	21	21	17	38		39	39						
Kings Tulare			21	21	21	21	17	38	38		39						
Bakersfield			21	21	21	21	17	38	38	38							
Palmdale																	
Burbank Airport HSR																	
Los Angeles Union Station																	
Norwalk																	
Fullerton																	
Anaheim																	

Figure 3-5 Stopping Patterns by Line for Phase 1 Peak Service

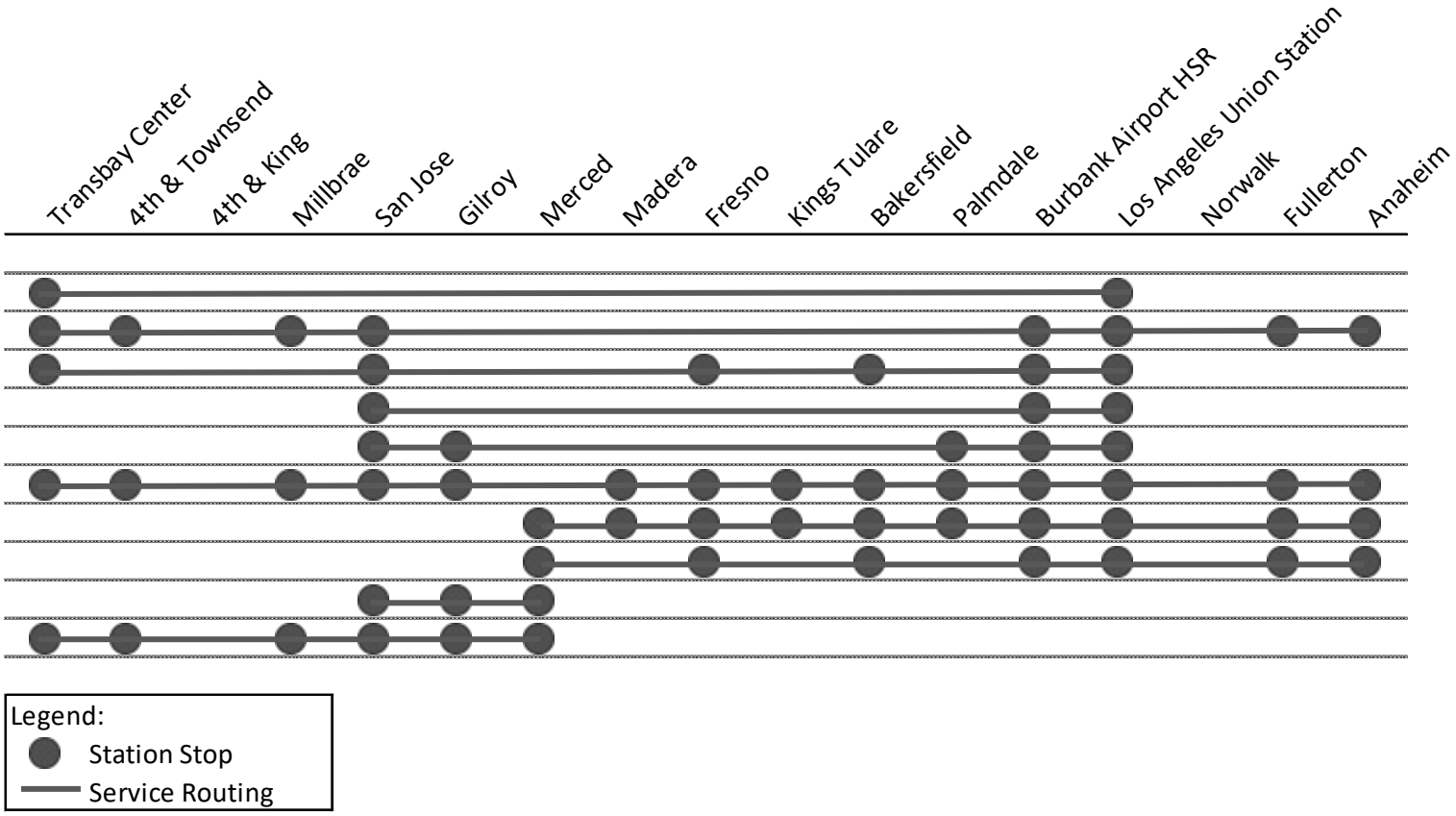


Figure 3-6 Stopping Patterns by Line for Phase 1 Off-Peak Service

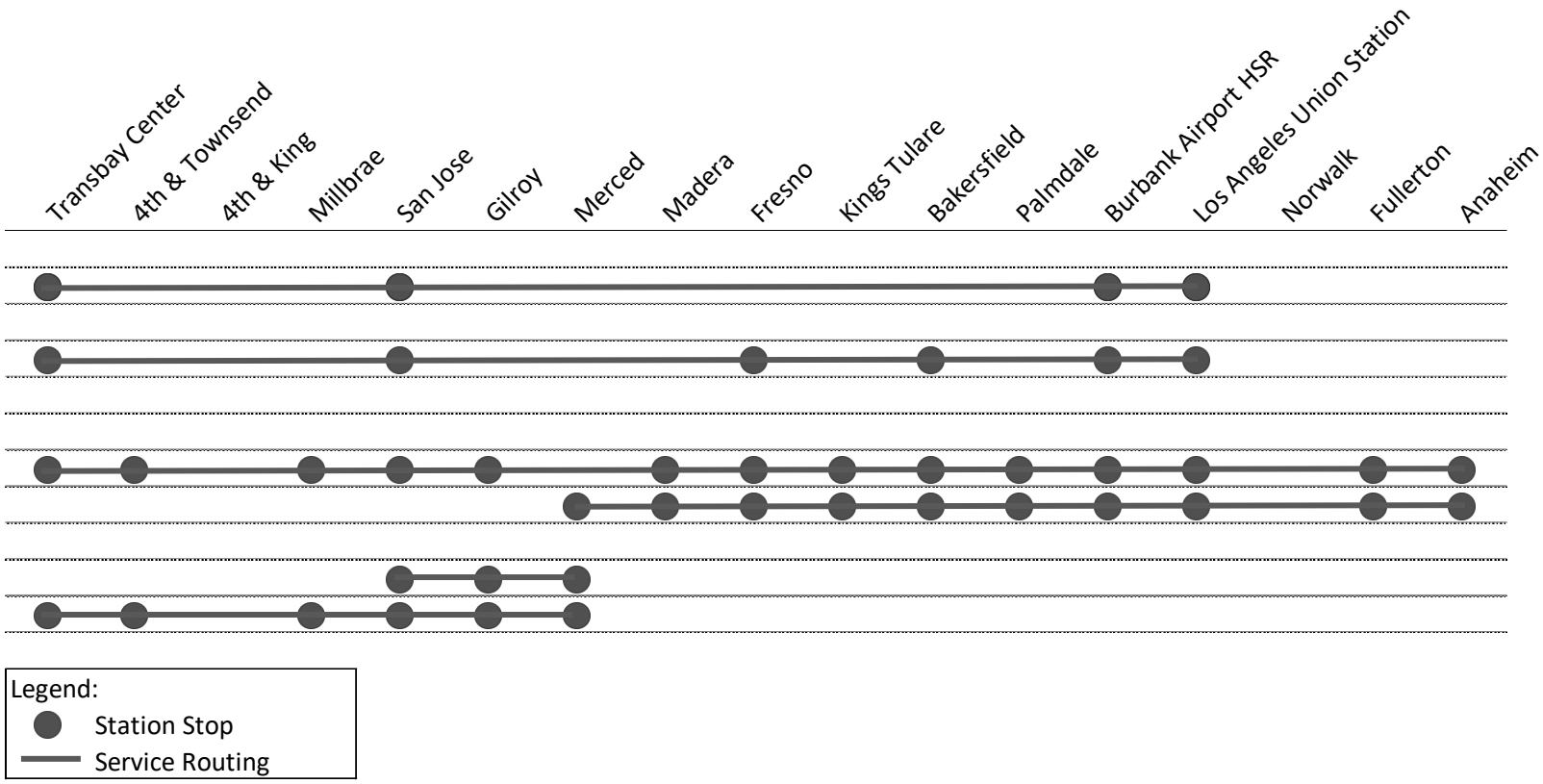


Table 3-3 Service Frequency by Line and Station for Phase 1 Service

Phase 1 Service Pattern	South-bound	North-bound	Transbay Center	4th & Townsend	4th & King	Millbrae	San Jose	Gilroy	Merced	Madera	Fresno	Kings Tulare	Bakersfield	Palmdale	Burbank Airport HSR	Los Angeles Union Station	Norwalk	Fullerton	Anaheim
Southbound PH1-00	6		6													6			
Southbound PH1-01	10		10				10								10	10			
Southbound PH1-02	6		6	6		6	6								6	6		6	6
Southbound PH1-03	16		16				16				16		16		16	16			
Southbound PH1-04	6						6								6	6			
Southbound PH1-05	6						6	6						6	6	6			
Southbound PH1-06	16		16	16		16	16	16		16	16	16	16	16	16	16		16	16
Southbound PH1-07	15								15	15	15	15	15	15	15	15		15	15
Southbound PH1-08	6								6		6		6		6	6		6	6
Southbound PH1-09	8						8	8	8										
Southbound PH1-10	10		10	10		10	10	10	10										
Southbound Total Day	105		64	32		32	78	40	39	31	53	31	53	37	81	87		43	43
Northbound PH1-00		6	6													6			
Northbound PH1-01		10	10				10								10	10			
Northbound PH1-02		6	6	6		6	6								6	6		6	6
Northbound PH1-03		16	16				16				16		16		16	16			
Northbound PH1-04		6					6								6	6			
Northbound PH1-05		6					6	6						6	6	6			
Northbound PH1-06		15	15	15		15	15	15		15	15	15	15	15	15	15		15	15
Northbound PH1-07		15							15	15	15	15	15	15	15	15		15	15
Northbound PH1-08		6							6		6		6		6	6		6	6
Northbound PH1-09		7					7	7	7										
Northbound PH1-10		10	10	10		10	10	10	10										
Northbound Total Day		103	63	31		31	76	38	38	30	52	30	52	36	80	86		42	42
Total Day (Both Directions)	105	103	127	63		63	154	78	77	61	105	61	105	73	161	173		85	85
Peak (Both Directions)	54	54	54	30		30	72	36	36	24	48	24	48	36	84	96		48	48
Off-Peak (Both Directions)	51	49	73	33		33	82	42	41	37	57	37	57	37	77	77		37	37

Table 3-4 Service Frequency by Station Pair for Phase 1 Service

From Origin Station to Destination Station	Transbay Center	4th & Townsend	4th & King	Millbrae	San Jose	Gilroy	Merced	Madera	Fresno	Kings Tulare	Bakersfield	Palmdale	Burbank Airport HSR	Los Angeles Union Station	Norwalk	Fullerton	Anaheim
Transbay Center		32		32	58	26	10	16	32	16	32	16	48	54		22	22
4th & Townsend	31			32	32	26	10	16	16	16	16	16	22	22		22	22
4th & King																	
Millbrae	31	31			32	26	10	16	16	16	16	16	22	22		22	22
San Jose	57	31		31		39	17	16	32	16	32	22	60	60		22	22
Gilroy	25	25		25	39		17	16	16	16	16	22	22	22		16	16
Merced	10	10		10	18	18		15	21	15	21	15	21	21		21	21
Madera	15	15		15	15	15	15		31	31	31	31	31	31		31	31
Fresno	31	15		15	31	15	21	30		31	53	31	53	53		37	37
Kings Tulare	15	15		15	15	15	15	30	30		31	31	31	31		31	31
Bakersfield	31	15		15	31	15	21	30	52	30		31	53	53		37	37
Palmdale	15	15		15	21	21	15	30	30	30	30		37	37		31	31
Burbank Airport HSR	47	21		21	59	21	21	30	52	30	52	36		81		43	43
Los Angeles Union Station	53	21		21	59	21	21	30	52	30	52	36	80			43	43
Norwalk																	
Fullerton	21	21		21	21	15	21	30	36	30	36	30	42	42			43
Anaheim	21	21		21	21	15	21	30	36	30	36	30	42	42		42	

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3.3 Calculation of Operations and Maintenance Cost Model Inputs

The service plans are designed to provide direct inputs for the Operations and Maintenance (O&M) Cost Model for:

- Trainset mileage;
- Fleet size;
- Number of revenue trains;
- Crew numbers; and
- Feeder bus miles.

After the service plans were developed, all equipment was linked to form extended cycles[1] to satisfy the terminal requirements,[2] 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, which affects energy costs as well as rolling stock and infrastructure maintenance costs 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 trainsets was derived by adding up:

- Revenue movements included in the service plan;
- Non-revenue movements at the beginning of the service day—the distance between a TMF where the trainset was stored overnight and the origin station of the first revenue train of the cycle; and
- Non-revenue movements at the end of the service day—the distance between the terminus of the final revenue service of the cycle and the TMF where the trainset would be stored and maintained for the next day.

[1] The planned train schedule assignments for the duration of a service day.

[2] The number of trainsets required to begin revenue service at each terminal station during a calendar day.

4 ASSUMPTIONS

The assumptions used in the service planning process are related to infrastructure, fleet parameters, proposed service and fleet requirements.

4.1 Infrastructure

The northern part of the system between San Francisco and Gilroy will operate on infrastructure shared with Caltrain and its tenants with operating speeds up to 110 MPH in the Silicon Valley to Central Valley and Phase 1 systems.

The central section of the system between Gilroy and Burbank will be dedicated high-speed infrastructure separated from any other conventional heavy-rail systems, and trains can reach operating speeds up to 220 MPH on this central section.

The southern part of the system, between Burbank and Anaheim, will operate on infrastructure shared with Metrolink, Amtrak and BNSF, with operating speeds up to 125 MPH.

High-speed rail passenger stations are assumed to be at the following locations:[3]

- San Francisco Salesforce Transit Center;
- San Francisco 4th and Townsend;
- San Francisco 4th & King;[4]
- Millbrae;
- San José Diridon Station;
- Gilroy;
- Merced;
- Madera (high-speed rail service assumed to stop; station to be provided by third parties);
- Fresno;
- Kings/Tulare;
- Bakersfield;
- Palmdale;
- Burbank Airport;
- Los Angeles Union Station;
- Gateway Cities/Orange County;[5] and
- Anaheim.

Mid-line stations are assumed to be four-track stations with two center through tracks and two outside platform tracks. Station tracks will be siding tracks of approximately 1,410 feet adjacent to the station platform. Universal interlockings capable of routing trains to all parts of the station complex will be provided.

[3] The list of stations shown is not definitive and may be subject to change as the program continues to develop. The final set of stations operated on the network will meet Prop 1A requirements.

[4] San Francisco 4th & King station to be used only until the opening of the Downtown Extension and Salesforce Transit Center station.

[5] For timing purposes, Fullerton has been used in this analysis.

The signal system is assumed to provide a two-minute 45-second minimum signaling headway at 220 MPH.

Trainset Maintenance Facilities will be built as listed Table 4-1. It should be noted here that the locations of these facilities are part of the ongoing environmental approval process and so may 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 Operations and Maintenance Cost Model.

Table 4-1 List of Rolling Stock Maintenance Facility Assumed in Service Plan Development

Preliminary Name	Maintenance Capability	Roll-Out Phase
Bay Area	Level III	Silicon Valley to Central Valley
Central Valley HMF	Level V	Silicon Valley to Central Valley
Los Angeles Area	Level III	Phase 1
Anaheim	Level I (stabling only)	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. 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 was assumed to be operated in one trainset configuration but can be expanded to two train sets if future demand indicates the need to double the seat capacity.

4.3 Passenger Service

Pure run times have been computed by the Train Performance Calculator in Rail Traffic Controller.[6] For a non-stop run between San Francisco and the Los Angeles Union Station, the pure run time meets the Proposition 1A requirement for the time to not exceed two hours 40 minutes.

To allow for minor variances associated with the daily operation of train services, a recovery time, known as “pad,” is applied to the pure run times. A pad of 5 percent is applied on the newly constructed, dedicated high-speed sections, and a pad of 10 percent is applied on sections where high-speed services share the track with other train operators. System revenue-service hours are anticipated to be from 0600 to midnight (0000), seven days per week. The five-hour period between 0000 and 0500 is allocated to the maintenance of infrastructure, and the one-hour period between 0500 and 0600 is allocated for non-revenue movements and other activities required for the morning service start-up.

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 off-peak period.

There were assumed to be two, three-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

[6] Rail Traffic Controller is a railroad operations simulation model widely used among railroads in the United States and by the National Transportation Safety Board.

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 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 to allow faster trains to achieve scheduled trip time. In some instances, the train being overtaken or overtaking may incur additional station dwell time or scheduled trip time to accommodate the overtake at intended locations.

Minimum dwell time at intermediate stations is two minutes except at Los Angeles Union Station, where a dwell of five minutes is applied for through services. Minimum turnaround time for a trainset between revenue trips at a terminal station is 20 minutes.

4.4 Fleet Requirements

All trainsets required for revenue-service operations are assumed to be stored at nearby Trainset Maintenance Facilities or on platforms or tail tracks at intermediate 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 to provide maintenance spares and revenue service “protect” trains. This is an international industry standard in high-speed passenger rail systems.

It is anticipated that service plans will continue to be developed in conjunction with the Early Train Operator, and that this will impact fleet sizes. The adopted approach for this business plan cycle should be considered reasonable and conservative.

5 FEEDER BUS SERVICE PLANNING

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. When the Silicon Valley to Central Valley line opens, the proposed high-speed train service would end at 4th & King in San Francisco and at Bakersfield, creating interim end-of-the-line stations.

5.1 Filling the Connectivity Gap

Although certain conventional rail connections, such as the Amtrak San Joaquins Service, would be available between the opening of the 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 currently very limited transit options between Bakersfield and the Los Angeles Basin area. To fill this connectivity gap, the high-speed rail service will be supplemented with feeder bus connections when opening the Central Valley Segment as well as the Silicon Valley to Central Valley line segment providing connectivity between the Merced and Bakersfield termini 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 TDFM accounts for these feeder bus connections in estimating the ridership for the high-speed rail system, and the TDFM forecasts bus revenue based on the number of passengers using the feeder bus to access and egress the high-speed rail system.

Given the limited service frequencies of the San Joaquins Amtrak trains between Sacramento and Merced and the absence of other transit connecting the Bakersfield and the Los Angeles Basin, a bus service is needed to supplement the connectivity and to connect to the Central Valley Segment Service and the Silicon Valley to Central Valley service. 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 Merced and in Bakersfield.

In the Phase 1 system, only the connection in Merced is assumed as a high-speed rail connecting bus service, where high-speed rail service will service southern California locations following the introduction of high-speed services to Burbank, Los Angeles, Fullerton and Anaheim, where passengers can connect to the Metrolink and Los Angeles – San Diego – San Luis Obispo (LOSSAN) networks.

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 5-1.

Table 5-1 Feeder Bus Connections by Implementation Step

Proposed Connection Point	Silicon Valley to Central Valley	Phase 1
Merced High-Speed Rail	Sacramento	Sacramento
Bakersfield High-Speed Rail	Los Angeles Basin	None

Three feeder bus routes are envisioned to efficiently serve major population and employment centers around the large geographic area of the Los Angeles Basin:

- The first route provides service to the San Fernando Valley along Interstate 5 and to Central Los Angeles (terminating at Los Angeles Union Station);
- The second provides service to the San Fernando Valley along Interstate 405 and to the Westside (terminating in West Los Angeles); and
- The third provides service to the San Gabriel Valley (terminating in Santa Anita).

Further details for each of these routes are included in the following sections.

5.2.2 Stopping Patterns

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 5-2 Location of Mid-Line Bus Stops

Feeder Bus Connection	Location of Bus Stop
Sacramento Line	Sacramento (Amtrak Station)
Sacramento Line	Elk Grove (Amtrak Thruway bus stop)
Sacramento Line	Lodi (Amtrak Station)
Sacramento Line	Stockton (Amtrak Station)
Sacramento Line	Modesto (Amtrak Station)
Sacramento Line	Denair/Turlock (Amtrak Station)
Sacramento Line	Merced (High-Speed Rail Station)
Los Angeles Basin – Los Angeles Union Station Line	Burbank Airport
Los Angeles Basin – Los Angeles Union Station Line	Los Angeles Union Station
Los Angeles Basin – West Los Angeles Line	Van Nuys
Los Angeles Basin – West Los Angeles Line	West Los Angeles
Los Angeles Basin – Santa Anita Line	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 TDFM but are designed to provide across-the-platform connectivity to high-speed rail services. However, based on the service plans that feed the TDFM, 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 only with limited Amtrak San Joaquins service in the north and extends south only to 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 2034, feeder bus ridership drops significantly as only the Merced to Sacramento bus line remains in service and the ridership to and from the Los Angeles Basin uses Metrolink, LOSSAN and other transit services to connect with high-speed rail services.

5.4 Revenue and Fares

In the *2020 Business Plan*, one of the objectives of the TDFM runs was to allow a 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.

High-speed rail fares in the *2020 Business Plan* utilize a generally consistent approach with the *2018 Business Plan* and remain competitive with airfares in the market. Indexed to June 2019, the model assumes that an average fare from San Francisco to Los Angeles is $100. Similarly, feeder bus fares were set to be competitive with other modes and remain consistent with the *2018 Business Plan* assumptions. The TDFM assumes a $10.96 feeder bus fare between Sacramento and Madera/Merced and $1.36 for connections at the mid-line bus stops (all dollars indexed to June 2019). The bus fares for the Bakersfield area to Los Angeles Basin connection are assumed to be $13.70 in the *2020 Business Plan*, consistent with fares listed for the Amtrak Thruway bus between Bakersfield and Los Angeles for the existing Amtrak San Joaquins service.

Table 5-3 presents the incremental fare for using the feeder bus connections, as specified in the TDFM run specifications.

Table 5-3 Incremental Fares

Bus Origin	Connection to High-Speed Rail	Incremental Fares (in June 2019 $)
Los Angeles Basin (Silicon Valley to Central Valley only)	Bakersfield	$13.70
Sacramento Area	Merced	$10.96
Stockton/Modesto/Denair/Merced	Merced	$1.36

5.5 Service Levels

Feeder bus service levels assumed for the Silicon Valley to Central Valley (V2V) line opening phase in December 2031 are set to meet every high-speed train in Merced and Bakersfield. With the exception of the San Joaquins Amtrak trains in Merced, few existing transit options connect the Silicon Valley to Central Valley line segment from the Sacramento area in northern California. Only the Amtrak Thruway bus connects current San Joaquins service between Bakersfield and the Los Angeles Basin area in southern California.

As defined earlier, the 4th and King station in San Francisco marks the northern interim terminal in the Silicon Valley to Central Valley line segment. This station in downtown San Francisco is close enough to other transit infrastructure that feeder bus service is assumed to be unnecessary. Amtrak's San Joaquins 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 Merced. However, the Amtrak San Joaquins service will remain limited, and feeder bus service is assumed to meet high-speed trains at Merced as a supplemental option.

Bakersfield currently has limited transit connection options to southern California. 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 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 Bakersfield station.

Phase 1 feeder bus service levels are reduced significantly and service assumptions remain generally consistent with the *2018 Business Plan*. As the Phase 1 system extends to Palmdale, Burbank and farther south, Metrolink will connect the Los Angeles Basin to several high-speed rail stations. As a result, the Los Angeles Basin feeder bus lines are removed from the TDFM in Phase 1. Feeder bus service is continued in the Sacramento area during Phase 1 to connect the region to the Merced terminal in the Central Valley.

In the *2020 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 calculated by multiplying the trip length with the total number of daily feeder bus connections and an annualization factor (365).

The derived estimates for revenue vehicle miles were then used as an input in the Operations and Maintenance Cost Model, which 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.

APPENDIX A INPUTS TO OPERATIONS AND MAINTENANCE COST MODEL

Table A-1 *2020 Business Plan* Service Plan Input for Operations and Maintenance Cost Model (Silicon Valley to Central Valley Line – Phase 1) Years 2031 through 2044

Item	Type/Station	2031*	2032	2033*	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Total Revenue Service Trips	Single Consist Daily Runs	77	77	77/208	208	208	208	208	208	208	208	208	208	208	208
Total Revenue Service Trips	Double Consist Daily Runs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Trainset Miles	Annual Single Consist Miles	640,301	7,683,615	9,538,393	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950
Total Trainset Miles	Annual Double Consist Miles	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Service Turns**	SF Transbay	0	0	0/47	47	47	47	47	47	47	47	47	47	47	47
Service Turns**	SF 4th & King	16	16	16/0	0	0	0	0	0	0	0	0	0	0	0
Service Turns**	San José	0	0	0/9	9	9	9	9	9	9	9	9	9	9	9
Service Turns**	Merced	15	15	15/30	30	30	30	30	30	30	30	30	30	30	30
Service Turns**	Bakersfield	29	29	29/0	0	0	0	0	0	0	0	0	0	0	0
Service Turns**	LA Union Station	0	0	0/26	26	26	26	26	26	26	26	26	26	26	26
Service Turns**	Anaheim	0	0	0/30	30	30	30	30	30	30	30	30	30	30	30

Note: *Numbers include partial years and reflect Silicon Valley to Central Valley operation from 12/01/2031 until 11/30/2033 and beginning of Phase 1 operation on 12/01/2033. **Number of Revenue to Revenue Service Turns.

Table A-2 *2020 Business Plan* Service Plan Input for Operations and Maintenance Cost Model (Silicon Valley to Central Valley Line – Phase 1) Years 2045 through 2060

Item	Type/Station	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
Total Revenue Service Trips	Single Consist Daily Runs	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208
Total Revenue Service Trips	Double Consist Daily Runs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Trainset Miles	Annual Single Consist Miles	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950	29,940,950
Total Trainset Miles	Annual Double Consist Miles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Service Turns**	SF Transbay	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Service Turns**	SF 4th & King	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Service Turns**	San José	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Service Turns**	Merced	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Service Turns**	Bakersfield	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Service Turns**	LA Union Station	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Service Turns**	Anaheim	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Note: **Number of Revenue to Revenue Service Turns.

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