California High-Speed Train Project

TECHNICAL MEMORANDUM

HIGH-SPEED TRAIN SERVICE PLAN — FULL BUILD NETWORK WITH LINKS TO SACRAMENTO AND SAN DIEGO

DRAFT

Prepared by: _____Foster Nichols_____ 1/10/2009
Date

Checked & Edited by: Paul Mosier_____ 1/12/2009
Date

Approved by: _____ _____
Date

Released by: _____ _____
Date

Revision	Date	Description

CONTENTS

FIGURES

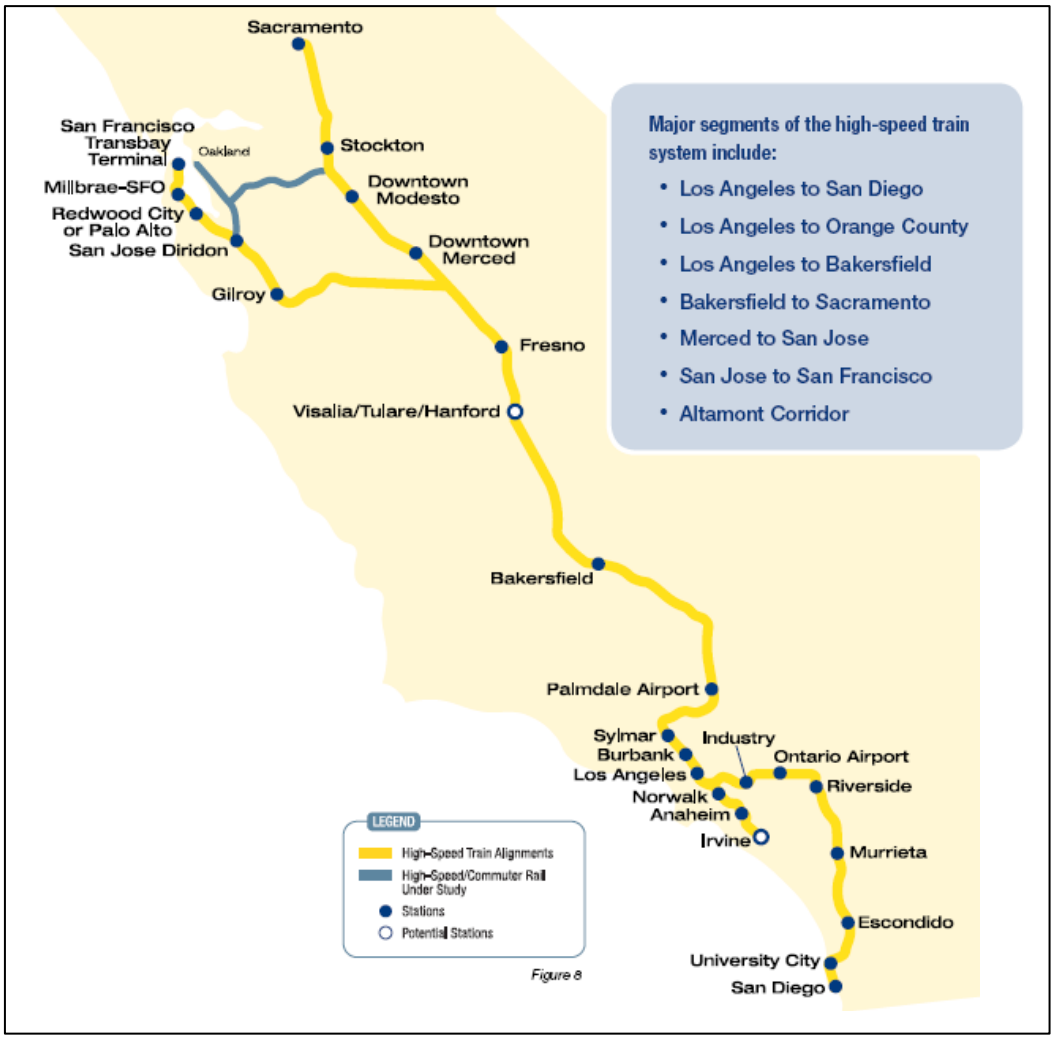
TABLES

HIGH-SPEED TRAIN SERVICE PLAN – FULL BUILD NETWORK

1. INTRODUCTION

A concept level service plan and hypothetical timetable for the full build-out of the California High Speed Train (HST) project has been developed, including high-speed train service on a four-leg network, with links serving the Bay Area and San Francisco peninsula, Sacramento and the northern Central Valley, Anaheim and Irvine in Orange County via the LOSSAN Corridor, and Riverside and San Diego via the Inland Empire and Interstate 15 corridors. A map of the full-build network is shown below.

FIGURE 1 – FULL-BUILD HIGH-SPEED TRAIN NETWORK



This memorandum provides a description of the type and quantity of rail service that will be needed to accommodate the forecast level of ridership estimated for the year 2030. This Full-Build Service Plan is more detailed than those that had been available previously. It builds off of the Phase 1 Service Plan prepared in November 2008 and is intended to serve several purposes:

- Confirm the level of service assumptions (travel times and service frequencies between station pairs) used to develop the estimates of system ridership and revenue
- Validate the operational feasibility of the desired level of service at a conceptual level
- Identify operable patterns of train service, particularly the general requirements for non-stop or limited-stop trains to pass slower trains that need to make a greater number of stops along the route (i.e., the locations and frequencies of occurrence of these "overtakes" at various times of day)
- Provide a basis for estimating the number of required train sets and overall rolling stock fleet requirements for the full build-out
- Provide a basis for estimating platform track and storage track capacity needed beyond the requirements identified in the Phase 1 Service Plan to support operations at the end terminal stations, including Sacramento and San Diego
- Provide a basis for sizing train storage and maintenance facilities throughout the HST network
- Provide a basis for planning passenger-handling operations at HST stations, which can be used to help size and configure station facilities.

2. ANALYTIC METHODOLOGY

PB developed a spreadsheet-based "static" model of high-speed train operations, customized for the California HST network, to formulate and analyze concept level operating plans for full build-out. This was the same model that was utilized to determine the service plan for Phase 1. The model utilizes train performance calculations taken from prior detailed "dynamic" simulation modeling results to identify the running time characteristics of the various types of service and train stopping patterns that are expected to operate on the HST 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 confidently perform "pattern analysis" of the various express, limited stop and all-stop local services that are envisioned. The service plan provides a combination of different train stopping patterns, in order to offer non-stop or limited stop service to travelers between major stations or over relatively long distances, while preserving direct train service at reasonable intervals at each intermediate station to all other stations on the network. In order to provide both frequent and rapid service to all the geographic travel markets along the HST network, non-stop trains will need to bypass stopping trains at certain times and locations along the network. The condition where a faster or non-stop train passes a slower-moving or stopping train running in the same direction is know as an "overtake." Since the HST system is envisioned as a 2-track railroad with one track used for train movement in each direction, additional tracks will need to be provided at various locations – in the vicinity of intermediate stations – to permit overtakes to occur.

The objective of the pattern analysis is to identify a reasonable mix of service patterns that achieves the desired level of service at each station while minimizing both conflicts between trains and the required number of overtakes. The train types and stopping patterns that comprise the Full-Build Service Plan are described in Appendix A1.

The primary outputs of the spreadsheet model include a hypothetical timetable for the Full-Build Service Plan showing train arrival and departure times at each station in the network, as well as the stringline (time-distance) diagrams. These are presented in Appendices A2 and A3 for the Full-Build plan.

The spreadsheet model provides the ability for trains to be "linked" with subsequent trains and assigned to specific train sets. The resulting train set equipment cycles, tabulated in Appendix A4, form the basis for estimating the size of the required rolling stock fleet.

The model also includes a module that compares the forecast level of system ridership with the quantity of service delivered, allocating riders to specific trains and calculating estimated load factors (projected number of riders per train divided by train seating capacity), using station specific boarding and alighting passenger (detail) estimates and peaking factors derived from the ridership forecasts. This analysis is summarized in Appendix A5, which includes graphs of estimated peak and off-peak train loads, by line segment, for each train type.

This Full-Build Service Plan, while contributing to confident approximations at the conceptual level, does not yet represent a detailed operating plan for the system, even though the train timetables and stringline diagrams give the impression of a high level of precision. This conceptual plan analysis is based on optimal ideal operations with trains running exactly on schedule. It does not analyze any randomization, delays or perturbations to the normal schedule and does not address the time required to recover from track blockages or the impacts of delay conditions on the network. A full detailed operating plan supported by dynamic computer simulation modeling of train movements throughout the system will be developed in a subsequent task later in the project, at which time an actual proposed timetable can be confidently prepared and approved.

3. ASSUMPTIONS AND GENERAL PRINCIPLES

The following assumptions and general principals guided the development of the Full-Build Service Plan:

1. The HST system is assumed to operate on dedicated tracks, independent of any other passenger or freight rail services.
2. Train sets are assumed to comprise units of 200 meters (m) in length, either singly (200 m train with 500 passengers) or operating as pairs (400 m train with 1,000 passengers).
3. Train running times were obtained from simulated train performance calculations, with an additional time factor added to these times. This added time, sometimes referred to as "schedule pad" or "recovery time" accounts for operator performance, external conditions and minor delays, which result in minimal day-to-day fluctuations in train performance – the additional time factor assumed in this analysis is common in passenger train scheduling, permits trains to recover from time lost due to minor causes, and provides an allowance for the system to maintain a high degree of overall on-time performance when operations are normal. The additional time factored into this service plan assumes a recovery time of three and one-half percent for most trains. However, certain "premium" services, such as express trains during peak periods were assumed to operate with a recovery time allowance of as little as one percent.
4. The schedule features "clockface" service patterns and regular intervals between trains (headways), which can be easily remembered and is markedly customer friendly.
5. The schedule features service patterns that repeat every hour, as opposed to patterns that differ somewhat from hour-to-hour providing for more simplified operations – this makes the service more regular and predictable and reduces the number of different types of overtakes required.

6. The minimum spacing between trains following each other past a given point (commonly referred to as headway or frequency of service) is set at three minutes, based on the assumed practical capacity design attributes of the signal and train control system.
7. Express trains are given the highest priority in terms of their schedule paths; limited stop trains and those that travel a longer distance along the network have the next highest priority, and all-stop local trains generally have the lowest priority and, therefore, the highest incidence of overtakes.
8. Train overtakes were arranged to utilize station (siding) tracks for express trains to pass local trains making a station stop, while maintaining consistency and reliability in the service stopping patterns. The siding tracks are assumed to be sufficiently long to enable diverging and merging movements from and to the mainline tracks to be made at high speed, with the bulk of deceleration and acceleration for stopping trains occurring on the sidings and not on the mainline tracks. This allows for relatively close spacing of trains approaching overtake locations, reduces delays associated with overtakes, and maximizes overall system capacity and train scheduling flexibility.
9. The service plan assumes that all mainline junctions where branches of the HST network join together (e.g., the junctions south of Merced and in the Redondo Junction vicinity south of Los Angeles Union Station) are fully grade separated (i.e. flyovers), avoiding the need for head-on opposing train movements at the junctions.
10. The Full-Build Service Plan recognizes the need for non-revenue or "deadhead" train movements between terminal stations and the train storage and maintenance facilities; however, these non-revenue train movements have not yet been analyzed in detail.
11. The Full-Build Service Plan assumes that HST service in Orange County is extended southward from Anaheim to Irvine via the LOSSAN corridor, eastward and southward from Los Angeles to San Diego via the Inland Empire and Interstate 15 corridors, and northward from Merced to Sacramento. The potential additional station in the Central Valley at Visalia-Tulare-Hanford, shown in Figure 1, was *not* considered in this analysis. The Full-Build Service Plan also makes no specific assumptions about connecting or integrated high-speed commuter rail service using the Capital or Altamont corridors, as shown in Figure 1.
12. The train performance calculations that were used to generate estimated train running times were based on preliminary assumptions concerning the alignment of HST tracks. To the extent that these alignments are modified as a result of preliminary engineering, estimated running times will also need to be modified to reflect actual physical and operating conditions.
13. The service levels and patterns developed as the basis for the ridership and revenue forecasts were taken as a guideline in the development of this service plan; adjustments were made where necessary to improve the operational efficiency and performance of the system; in all cases the level of service provided at each station remains at or better than the level assumed in the ridership forecasts.
14. HST service is assumed to be operated during the period between approximately 5:00 AM and 12:00 Midnight. Given the length of the Full-Build HST network, the service plan includes a few trains that operate outside of this window to ensure balanced service across the entire network.
15. The Full-Build Service Plan addresses conditions on a typical busy weekday. Estimated passenger loads were calculated for a peak day (busier than average month and busier than average day of the week, at approximately the 90th percentile level). Explicit service plans for weekends and holidays were not prepared.
16. The analysis assumed the station dwell times and minimum terminal layover (turnaround) times indicated in Tables 1 and 2, respectively. Terminal layover time is defined to be the time between the scheduled arrival of a train set at a terminal and the scheduled departure of the same train set in the opposite direction of service. During layover, sufficient time must be

allocated for passenger unloading, train servicing and light maintenance activities such as interior cleaning, inspection and brake testing, provisioning and re-stocking of food service supplies, and passenger boarding. The minimum times provided in Table 2 were used as a guideline; the service plan assumes slightly faster times in a limited number of individual cases where necessary to maintain the smooth flow of trains at a terminal.

TABLE 1 – INTERMEDIATE STATION DWELL TIMES

Code	Station	Scheduled Dwell Time (minutes)
SFO	Millbrae	1.25
RWC	Redwood City	1.25
SJC	San Jose	1.50
GLY	Gilroy	1.25
STN	Stockton	1.25
MOD	Modesto	1.25
MDC	Merced	1.25
FNO	Fresno	1.25
BFD	Bakersfield	1.25
PMD	Palmdale	1.25
SYL	Sylmar	1.25
BUR	Burbank	1.25
LAU	Los Angeles - Union Station	1.50
NSF	Norwalk	1.25
ANA	Anaheim	1.25
COI	City of Industry	1.25
ONT	Ontario	1.25
RIV	Riverside	1.25
MUR	Murrieta	1.25
ESC	Escondido	1.25
UNI	University City	1.25

TABLE 2 – TERMINAL STATION MINIMUM LAYOVER TIMES

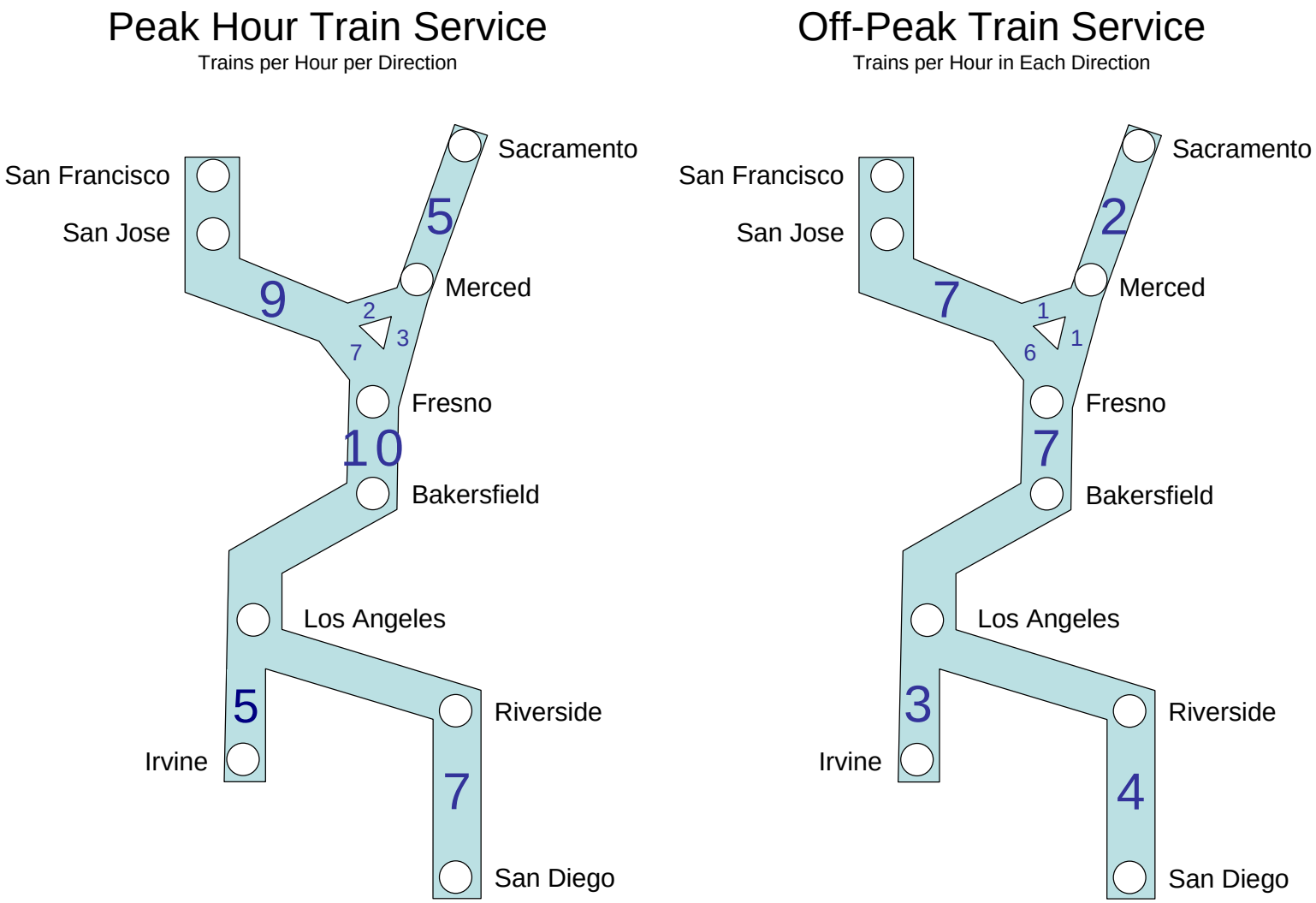
Code	Station	Minimum Scheduled Layover Time (minutes)
SFT	San Francisco –Transbay	30
SAC	Sacramento	40
MCD	Merced	40
LAU	Los Angeles - Union Station	40
IRV	Irvine	40
SAN	San Diego	40

4. FULL-BUILD SERVICE PLAN

DENSITY OF SERVICE BY LINE SEGMENT AND TIME OF DAY

Figure 2 presents the level of train service along various portions of the HST network that is estimated to be required to deliver the appropriate array of choices of train stopping patterns to riders at all stations and satisfy the projected weekday ridership demand in 2030. Weekday ridership demand is assumed to reach peak levels during a three-hour period in the morning and again in the afternoon. Train service density will be greatest during these periods, reverting to a slightly lower level of service during the remainder of the day.

FIGURE 2 – FULL-BUILD SERVICE PLAN – 2030, PEAK HOUR AND OFF-PEAK TRAIN MOVEMENT DENSITY



The portion of the network with the greatest density of train traffic will be the short stretch south of Los Angeles Union Station, between Los Angeles and Redondo Junction, where the service plan calls for as many as twelve high-speed trains per hour in each direction during the morning and afternoon peak hours – equivalent to an average headway of five minutes. The main line through the Central Valley will see ten trains per hour in each direction during the peaks, and seven trains per hour at other times.

The level of service during the business travel peaks at San Francisco Transbay, along the Peninsula Corridor and across Pacheco Pass is nine trains per hour in each direction. The corresponding level of service on the northern section of the Central Valley Line, between Merced and Sacramento, is five trains per hour per direction – with two of these trains operating towards San Francisco and the other three trains operating towards Los Angeles. During off-peak periods, the base level of service provides six trains per hour between San Francisco and Los Angeles (with four of these trains extended to San Diego and two trains extended to Orange County). One train per hour is operated between Sacramento and San Francisco, and between Sacramento and San Diego via Los Angeles.

The service plan provides up to seven trains per hour in each direction along the route between Los Angeles and San Diego and up to five trains per hour per direction between Los Angeles and Orange County (Anaheim and Irvine) during the peak hours. The base level of off-peak service is four trains per hour on the San Diego leg and three trains per hour on the Orange County leg.

STOPPING PATTERNS, SERVICE FREQUENCIES AND TRIP TIMES

When the full California HST network is built out, train service is envisioned to be offered on multiple routes between various origin and destination terminals. The Full-Build Service Plan for 2030 includes service on the following routes, categorized according to the terminals and major stations served:

Route A. San Francisco—Los Angeles—San Diego

Route B. San Francisco—Los Angeles—Orange County (Anaheim/Irvine)

Route C. San Francisco—Sacramento

Route D. Sacramento—Los Angeles—San Diego

Route E. Sacramento—Los Angeles—Orange County (Anaheim/Irvine)

Route F. Los Angeles—San Diego

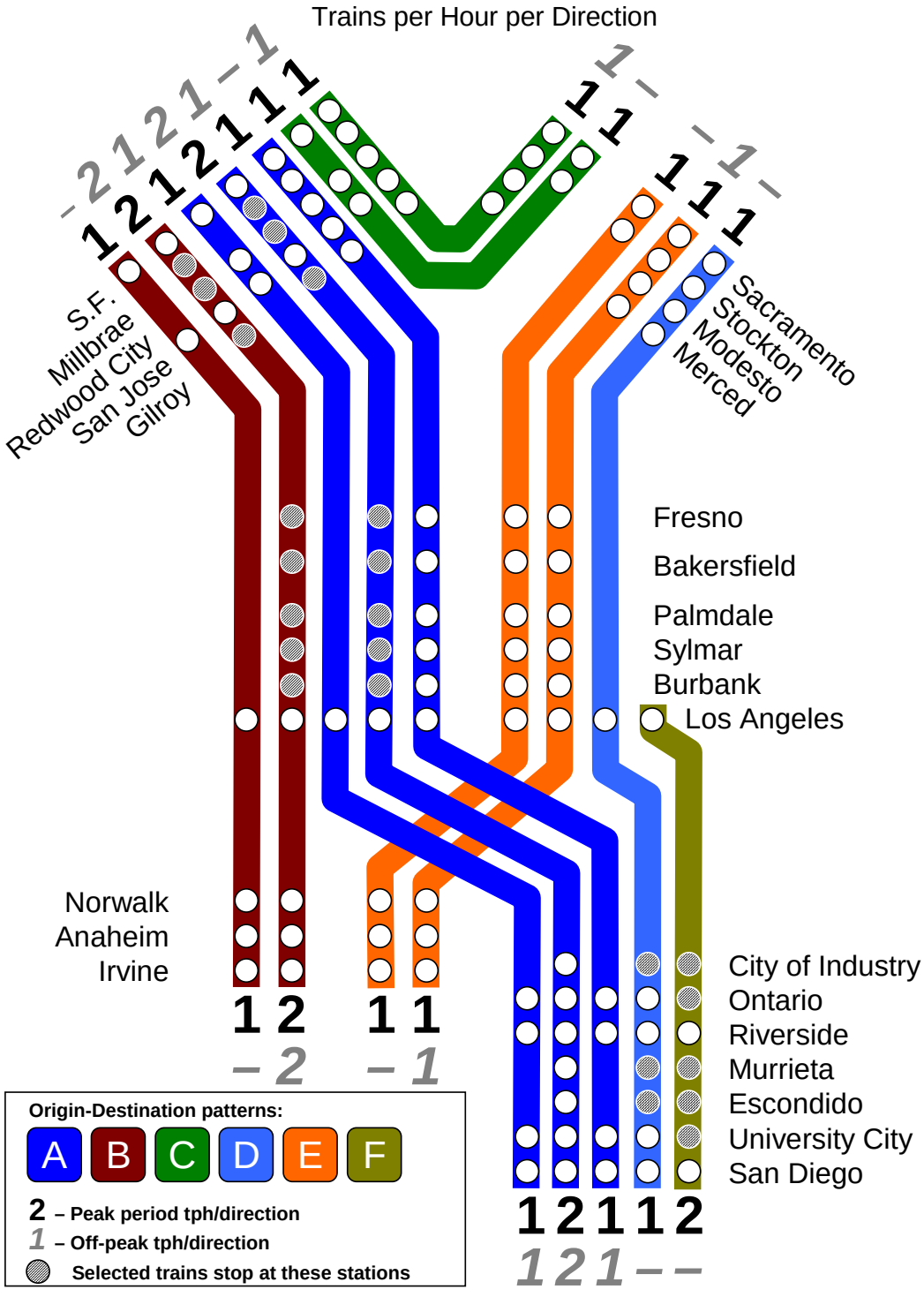
Route G. Los Angeles—Orange County (Anaheim/Irvine)

Most stations and segments of the network are served by more than one route. Trains also are categorized according to the type of service offered, particularly with respect to the number of intermediate stations served. Three basic service types are offered:

- Express service – serves major stations only and skips most intermediate stops, offers fastest trip times between major stations, generally limited to morning and afternoon peaks
- Limited-stop service – skips selected stops along a route, offers some of the trip time benefits of express-style service to intermediate stations as well as the major terminals
- All-stop service – "local" trains that make all stops along a particular route segment, ensures direct service among all stations on the network.

Figure 3 provides an illustration of the types of service and the number of trains of each type operated on each of the HST routes during a typical peak hour and off-peak hour in the year 2030.

FIGURE 3 – FULL-BUILD SERVICE PLAN – 2030, BASIC TRAIN STOPPING PATTERNS



The graphic in Figure 3 shows the variations in the types of trains and stopping patterns that will be available to HST riders, but it generalizes the limited-stop patterns for the sake of presentation clarity. The actual mix of stopping patterns in a typical weekday peak hour and off-peak hour is represented in Table 3, which also identifies the number of trains per hour that would stop at each HST station.

Table 3 shows the 14 stopping patterns that are provided in the northbound direction during the morning peak hour and the eight stopping patterns that are provided in each direction during mid-day off-peak hours. In both cases, each pattern is operated by one train per hour, with the patterns repeating each hour. A more detailed summary of stopping patterns and service levels at various times of day and in both directions of travel is presented in Appendix A1.

TABLE 3 – TRAIN STOPPING PATTERNS – TYPICAL PEAK AND OFF-PEAK HOURS

FULL-BUILD SERVICE PLAN **TRAIN STOPPING PATTERNS**

Typical Peak Hour
(AM Peak Northbound)

Route / Service Type	Stopping Pattern ID	SFT S.F.-Transbay	SFO Millbrae	RWC Redwood City	SJO San Jose	GLY Gilroy	SAC Sacramento	STN Stockton	MOD Modesto	MCD Merced	FNO Fresno	BFD Bakersfield	PMD Palmdale	SYL Sylmar	BUR Burbank	LAU Los Angeles Union	NSF Norwalk	ANA Anaheim	IRV Irvine	COI City of Industry	ONT Ontario	RIV Riverside	MUR Murrieta	ESC Escondido	UNI University City	SAN San Diego
A Bay Area-L.A. Basin Limited Express	1	●		●	●	●										●					●	●			●	●
A Bay Area-L.A.-San Diego Limited	7	●	●	●	●						●	●		●		●				●	●	●	●	●	●	●
A Bay Area-L.A.-San Diego Limited	29	●		●	●	●							●	●		●				●	●	●	●	●	●	●
A Bay Area-Los Angeles All-Stop	4	●	●	●	●	●					●	●	●	●	●	●					●	●			●	●
B Bay Area-Los Angeles Express	2	●			●											●	●	●	●							
B Bay Area-L.A.-Orange County Limited	18a	●	●		●	●					●			●	●	●	●	●	●							
B Bay Area-L.A.-Orange County Limited	21a	●		●	●	●						●	●	●	●	●	●	●	●							
C Sacramento-S.F. All-Stop	14	●	●	●	●	●	●	●	●	●																
C Sacramento-S.F. Limited	39	●		●	●		●	●	●	●																
D Sacramento-L.A.-San Diego Limited	35						●	●	●	●						●					●	●			●	●
E Sacramento-L.A.-Orange County All-Stop	15						●	●	●	●	●	●	●	●	●	●	●	●	●							
E Sacramento-L.A.-Orange County Limited	25						●	●			●	●	●			●	●	●	●							
F Los Angeles-San Diego All-Stop	41															●				●	●	●	●	●	●	●
F Los Angeles-San Diego Express	42															●						●				●
Number of trains stopping at station		9	4	7	9	6	5	5	3	3	5	4	6	6	4	12	5	5	5	3	6	7	3	3	6	7

Off-Peak Hour

Route / Service Type	Stopping Pattern ID	SFT S.F.-Transbay	SFO Millbrae	RWC Redwood City	SJO San Jose	GLY Gilroy	SAC Sacramento	STN Stockton	MOD Modesto	MCD Merced	FNO Fresno	BFD Bakersfield	PMD Palmdale	SYL Sylmar	BUR Burbank	LAU Los Angeles Union	NSF Norwalk	ANA Anaheim	IRV Irvine	COI City of Industry	ONT Ontario	RIV Riverside	MUR Murrieta	ESC Escondido	UNI University City	SAN San Diego
A Bay Area-L.A. Basin Limited Express	1	●		●	●	●										●					●	●			●	●
A Bay Area-L.A.-San Diego Limited	26	●	●	●	●	●					●	●				●				●	●	●	●	●	●	●
A Bay Area-L.A.-San Diego Limited	27	●		●	●	●							●	●	●	●				●	●	●	●	●	●	●
A Bay Area-Los Angeles All-Stop	4	●	●	●	●	●					●	●	●	●	●	●					●	●			●	●
B Bay Area-L.A.-Orange County Limited	16	●	●	●	●	●					●	●				●	●	●	●							
B Bay Area-L.A.-Orange County Limited	17	●		●	●	●							●	●	●	●	●	●	●							
C Sacramento-S.F. All-Stop	14	●	●	●	●	●	●	●	●	●																
E Sacramento-L.A.-Orange County All-Stop	15						●	●	●	●	●	●	●	●	●	●	●	●	●							
Number of trains stopping at station		7	4	7	7	7	2	2	2	2	4	4	4	4	4	7	3	3	3	2	4	4	2	2	4	4

The service plan for the full build-out of the high speed train network as outlined in this document and its attachments provides a level of service at each station that is generally equivalent to the level of service assumed in the development of the estimates of system ridership and revenue.

The proposed mix of services offers regular clockface patterns, with each service type leaving at the same time each hour, with relatively limited exceptions. Slightly more service is assumed during the three hour peak periods in the morning and late afternoon than during off-peak hours, consistent with expected ridership peaking.

All-stop service is offered on three routes (San Francisco-San Diego, San Francisco-Sacramento and Sacramento-Irvine) all day long. Express service is offered during the peak periods, with one intermediate stop, between San Francisco and Los Angeles and between San Diego and Los Angeles.

The limited-stop services make up the majority of trains operating on the network and offer a compromise of a relatively fast run time along with connectivity among various groups of intermediate stations along the line. A variety of limited-stop patterns is provided, in order to provide a balanced level of service at all of the intermediate stations. The service plan provides four limited trains per hour in each direction, all day long, between San Francisco and Los Angeles. Two of these trains continue to San Diego, and the other two trains continue to Orange County (Anaheim and Irvine). Each intermediate station in the Bay Area, Central Valley between Fresno and Palmdale and San Fernando Valley is served by at least two limited trains every hour – offering at least two reasonably fast trains an hour to San Francisco and Los Angeles, and one or two limited-stop train each hour to San Diego and to Orange County. An all-stop service provides one additional train per hour between San Francisco and San Diego.

The longer-distance intercity markets in the Bay Area-Los Angeles-San Diego corridor are served by a “limited express” service that operates once per hour, all day long. Clockface “on the hour” departures are envisioned southbound from San Francisco and northbound from Los Angeles. This train makes several stops in the Bay Area and between Los Angeles and San Diego, but it operates as a non-stop express between Gilroy and Los Angeles.

Sacramento and the northern Central Valley would be served by all-stop trains once an hour to San Francisco and Los Angeles-Irvine, supplemented during the morning and afternoon peak periods by one limited stop train per hour to San Francisco and two limited stop trains per hour to Los Angeles (one of which continues to San Diego, with the other continuing to Irvine).

Every station on the HST network is served by at least two trains per hour all day long, and at least three trains per hour during the morning and afternoon peak periods. Major stations, which are estimated to have the largest ridership demand, are served by more trains than intermediate stations with lower estimated ridership.

The service plan attempts to provide direct train service between all pairs of stations at least once per hour. During off-peak hours, certain routes are not served directly (e.g., Sacramento-San Diego). At these times of day, some passengers would need to transfer from one train to another at an intermediate station, such as Los Angeles Union Station, to reach their final destination. Generally, the Full-Build Service Plan offers a full spectrum of direct service options and minimizes the need for passengers to transfer.

The on-board travel time between stations varies, depending on the number of intermediate station stops (which is different for each train type) and the time of day (some trains have additional time built into their peak schedules to allow them to be “overtaken” by express or limited-stop trains while en route). The minimum or “fastest” trip times between selected city pair stations is presented in Table 4, based on the mix of train types and stopping patterns included in the full build-out service plan. For comparison purposes, typical station-to-station trip times also are shown for peak period all-stop service. The latter trip times are longer, due to the higher number of intermediate stops and additional holding time associated with scheduled overtakes.

TABLE 4 – SCHEDULED TRIP TIMES BETWEEN SELECTED STATIONS

FASTEST TRIP TIMES

		San Francisco - Transbay	San Jose	Sacramento	Fresno	Los Angeles Union Station	Anaheim	Irvine	Riverside	San Diego
		SFT	SJC	SAC	FNO	LAU	ANA	IRV	RIV	SAN
SFT	San Francisco-Transbay	--	**0:30**	2:05	1:26	**2:40**	**3:04**	**3:16**	**3:34**	**4:29**
SJC	San Jose	**0:30**	--	1:30	0:55	**2:11**	**2:35**	**2:47**	**3:00**	**3:54**
SAC	Sacramento	2:05	1:30	--	1:06	**2:38**	3:18	3:30	**3:00**	**4:02**
FNO	Fresno	1:26	0:55	1:06	--	1:34	1:58	2:10	**2:18**	**3:19**
LAU	Los Angeles Union Station	**2:40**	**2:11**	**2:38**	1:34	--	0:22	0:34	**0:34**	**1:25**
ANA	Anaheim	**3:04**	**2:35**	3:18	1:58	0:22	--	0:11	--	--
IRV	Irvine	**3:16**	**3:34**	3:30	2:10	0:34	0:11	--	--	--
RIV	Riverside	**3:34**	**3:00**	**3:00**	**2:18**	**0:34**	--	--	--	**0:50**
SAN	San Diego	**4:29**	**3:54**	**4:02**	**3:19**	**1:25**	--	--	**0:50**	--

TYPICAL PEAK PERIOD TRIP TIMES FOR ALL-STOP SERVICE

		San Francisco - Transbay	San Jose	Sacramento	Fresno	Los Angeles Union Station	Anaheim	Irvine	Riverside	San Diego
		SFT	SJC	SAC	FNO	LAU	ANA	IRV	RIV	SAN
SFT	San Francisco-Transbay	--	0:38	2:24	1:36	3:27	3:37	3:49	4:07	5:02
SJC	San Jose	0:38	--	1:44	0:55	2:46	3:03	3:14	3:27	4:24
SAC	Sacramento	2:24	1:44	--	1:15	3:06	3:29	3:41	--	--
FNO	Fresno	1:36	0:55	1:15	--	1:48	2:12	2:24	2:29	3:31
LAU	Los Angeles Union Station	3:27	2:46	3:06	1:48	--	0:21	0:34	0:42	1:44
ANA	Anaheim	3:37	3:03	3:29	2:12	0:21	--	0:10	--	--
IRV	Irvine	3:49	4:07	3:41	2:24	0:34	0:10	--	--	--
RIV	Riverside	4:07	3:27	--	2:29	0:42	--	--	--	1:00
SAN	San Diego	5:02	4:24	--	3:31	1:44	--	--	1:00	--

Notes:

Times expressed in Hours:Minutes, from departure at first station to arrival at second station.

Times based on train performance calculations, plus schedule recovery time of 3.5 percent (except where noted otherwise).

Times in **boldface** type denote station pairs served by peak period express or limited express trains.

Times include station dwell times. All-stop service times include allowance for overtakes where necessary.

[1] Time for peak express service based on schedule recovery time of 1.0 percent (Schedule Pattern 2).

FASTEST TRIP TIMES

		San Francisco - Transbay	San Jose	Sacramento	Fresno	Los Angeles Union Station	Anaheim	Irvine	Riverside	San Diego
		SFT	SJC	SAC	FNO	LAU	ANA	IRV	RIV	SAN
SFT	San Francisco-Transbay	--	***0:27***	2:05	1:31	***2:40***	***3:02***	***3:14***	**3:34**	**4:29**
SJC	San Jose	***0:27***	--	1:30	0:51	***2:11***	***2:34***	***2:46***	**2:59**	**3:54**
SAC	Sacramento	2:05	1:30	--	1:05	**2:38**	3:09	3:21	**3:22**	**4:24**
FNO	Fresno	1:31	0:51	1:05	--	1:33	1:57	2:09	**2:17**	**3:19**
LAU	Los Angeles Union Station	***2:40***	***2:11***	**2:38**	1:33	--	0:21	0:33	**0:31**	**1:24**
ANA	Anaheim	***3:02***	***2:34***	3:09	1:57	*0:21*	--	0:10	--	--
IRV	Irvine	***3:14***	***3:34***	3:21	2:09	*0:33*	0:10	--	--	--
RIV	Riverside	**3:34**	**2:59**	**3:22**	**2:17**	**0:31**	--	--	--	**0:49**
SAN	San Diego	**4:29**	**3:54**	**4:24**	**3:19**	**1:24**	--	--	**0:49**	--

TYPICAL PEAK PERIOD TRIP TIMES FOR ALL-STOP SERVICE

		San Francisco - Transbay	San Jose	Sacramento	Fresno	Los Angeles Union Station	Anaheim	Irvine	Riverside	San Diego
		SFT	SJC	SAC	FNO	LAU	ANA	IRV	RIV	SAN
SFT	San Francisco-Transbay	--	0:38	2:25	1:40	3:28	3:38	3:50	4:10	5:04
SJC	San Jose	0:38	--	1:45	1:00	2:48	3:07	3:19	3:30	4:24
SAC	Sacramento	2:25	1:45	--	1:15	3:12	3:35	3:47	--	--
FNO	Fresno	1:40	1:00	1:15	--	2:00	2:24	2:36	2:30	3:24
LAU	Los Angeles Union Station	3:28	2:48	3:12	2:00	--	0:22	0:34	0:43	1:44
ANA	Anaheim	3:38	3:07	3:35	2:24	0:22	--	0:10	--	--
IRV	Irvine	3:50	4:10	3:47	2:36	0:34	0:10	--	--	--
RIV	Riverside	4:10	3:30	--	2:30	0:43	--	--	--	1:00
SAN	San Diego	5:04	4:24	--	3:24	1:44	--	--	1:00	--

Notes:
Times expressed in Hours:Minutes, from departure at first station to arrival at second station.
Times based on train performance calculations, plus schedule recovery time of 3.5 percent (except where noted otherwise).
Times in **boldface** type denote station pairs served by peak period express or limited express trains.
Times include station dwell times. All-stop service times include allowance for overtakes where necessary.
Italics: Time for peak express service based on schedule recovery time of 1.0 percent (Schedule Pattern 2).

Table 4 (above) displays estimated timetable travel times between selected city pairs. For example, when reading the first row of the first table, the numbers shown represent the trip time between: San Francisco and San Jose (27 minutes); San Francisco and Fresno (1 hour, 31 minutes); and San Francisco and Los Angeles (2 hours, 40 minutes).

By contrast, the proposed peak all-stop local trains represent the longest travel times between selected city pairs; providing service between San Francisco and Los Angeles in three hours, twenty-eight minutes, and between Los Angeles and San Diego in one hour, forty-four minutes.

As the HST project studies continue to progress, and as both the operating plan and the ridership estimates are refined, it will be possible to make informed benefit and cost tradeoffs to develop the most appropriate mix of limited, express and all-stop services, which will affect the trip times between stations and the frequency of service offered at each station for each route.

TRAIN SCHEDULE DEVELOPMENT

The process of formulating a feasible train schedule for the various combinations of stopping patterns, train origins and destinations and service frequencies entailed overlaying the various patterns in a graphical template known as a "stringline" – which is a diagram with clock time on the horizontal axis and location along the rail system on the vertical axis. Each train movement is represented by a line that traces its path along the network in both time and distance. The stringline for a non-stop train has a steeper slope than that of a multiple-stop train. Stringlines in the same direction of flow are not permitted to intersect one another except at locations where there are additional tracks (at passenger stations) available for faster trains to bypass slower or stopped trains. These overtake locations generally are located on the central portion of the HST line – at the Gilroy, Fresno, Bakersfield and Palmdale stations – where non-stop trains are permitted to bypass or "overtake" trains operating in the same direction and stopping at the station. During the off-peak hours, the only scheduled overtakes are at Bakersfield. During the morning and afternoon peak hours, additional overtakes of a limited number of trains are indicated at Sylmar and at either Merced or Modesto. It is worthy of note that, with the Full-Build service levels and consistent stopping patterns, the conceptual analysis revealed that trains are able to run in sequence (without overtakes) north of Gilroy and between Los Angeles and San Diego. This attribute is subject to further study and validation, and will be examined in detail when the full dispatch computer simulation is performed.

Stringline diagrams were constructed in the spreadsheet model by starting with the highest priority trains (express trains running on clockface schedules), and then adding the other stopping patterns and frequencies in a priority order, adjusting the starting times of each subsequent group of trains to minimize the number of required overtakes and to make sure that all overtakes, when required, occur at the appropriate intermediate station locations. Additional station dwell time was added to the schedules of trains being overtaken, as necessary, to ensure that the minimum three minute separation between trains is maintained.

Hypothetical timetables and a description of the various train types and stopping patterns are presented in the appendix. A timetable for the Full-Build Service Plan is presented in Appendix A2. This same schedule is represented in stringline format in Appendix A3, which shows the patterns of train movements during the morning peak, mid-day period, afternoon peak and late evening period.

Table 5 shows the number of scheduled trains, for each stopping pattern/train type, within the morning peak, mid-day, afternoon peak and late evening periods. Limited-stop services are aggregated within each route for ease of presentation. The daily weekday schedule includes a total of 339 revenue trains.

TABLE 5 – REVENUE TRAINS BY TIME PERIOD AND TRAIN TYPE

Route	Stopping Pattern ID	Train Type	Daily Trains (both directions)				
			Morning Peak 3 Hrs	Mid-Day 7 Hrs	Afternoon Peak 3 Hrs	Late Evening 3+ Hrs	**Total Daily**
A SFT-SAN	1	Bay Area-L.A. Basin Limited Express	9	14	6	8	**37**
	26-27	Bay Area-L.A.-San Diego Limited	—	28	—	6	**34**
	7-9-28-29	Bay Area-L.A.-San Diego Limited	10	—	10	—	**20**
	4	Bay Area-L.A.-San Diego All-Stop	11	14	6	6	**37**
B SFT-IRV	2	Bay Area-L.A.-Orange County Express	6	—	6	—	**12**
	16-17	Bay Area-L.A.-Orange County Limited	—	28	—	2	**30**
	18-19-20-21	Bay Area-L.A.-Orange County Limited	12	—	14	—	**26**
C SFT-SAC	14	Sacramento-S.F. All-Stop	8	14	6	6	**34**
	39	Sacramento-S.F. Limited	6	—	6	—	**12**
D SAC-SAN	35	Sacramento-L.A.-San Diego Limited	6	—	6	—	**12**
E SAC-IRV	15	Sacramento-L.A.-Orange County All-Stop	8	14	6	6	**34**
	25	Sacramento-L.A.-Orange County Limited	6	—	6	—	**12**
F LAU-SAN	41	Los Angeles-San Diego All-Stop	9	—	6	4	**19**
	42	Los Angeles-San Diego Express	6	—	6	1	**13**
G LAU-IRV	43	Los Angeles-Orange County All-Stop	2	—	2	3	**7**
TOTAL			**99**	**112**	**86**	**42**	**339**

Annual operating costs for HST service, in large measure, are estimated based on the number of train-miles of assumed service operated. Table 6 presents the annual train-miles associated with the Full-Build Service Plan. This estimate is based on full daily service for 250 weekdays per year, plus 115 weekend days and holidays with a reduced level of service.

TABLE 6 – DAILY AND ANNUAL TRAIN-MILES

	Daily Train-Miles	Daily Train-Miles (200m equivalent)	Days/ Year	Annual Train-Miles (200m equivalent)
Weekday	146,650	246,800	250	61,700,000
Weekend & Holiday	120,700	150,900	115	17,300,000
Total	--	--	365	*79,000,000

* Average annual train miles per 200 meter trainset is estimated at approximately 373,000, assuming a Phase 1 fleet requirement of 212 trainsets including spares (assumed spare ratio of 10%).

5. FLEET REQUIREMENTS

EQUIPMENT CYCLES

The concept level train schedule presented in Appendix A1 indicates 339 total daily revenue train movements. An analysis was undertaken to estimate the number of individual train sets required to operate this schedule, allowing for adequate layover times at the end terminals. Trains arriving at a terminal station are assumed to lay over at the platform for a certain period of time, for passenger alighting train servicing/inspection and passenger boarding, then depart in the opposite direction as the next available departing revenue train. This analysis generally adhered to the minimum terminal layover times presented in Table 2 (30 minutes at San Francisco Transbay Terminal, 40 minutes elsewhere). In certain cases, shorter layover times were assumed in order to keep the number of trainsets to a reasonable minimum and to avoid inordinately long layovers, which would occupy terminal station or yard tracks for extended periods of time. Except during the late evening time period, train sets are generally available at the major terminals to provide "protection" for short connections from potentially delayed trains. These additional equipment sets would be culled from the 400 m all-stop and limited trains operating during the morning peak period that continue during the mid-day period as 200 m trains.

The train turns at the endpoint terminals are balanced during the mid-day and late evening off-peak hours. During the peaks, additional directional service is offered, so a relatively small number of trains are designated for mid-day yard storage in lieu of making a revenue turn.

A total of 107 equipment cycles are estimated to be required to operate the 339 daily trains in the 2030 Full Build schedule, comprising a mix of 200 m and 400 m train sets. Most trainsets are able to make three-to-four one-way trips between the Bay Area/Sacramento and southern California over the course of a service day. The equipment cycles and terminal layover times for each trainset and each layover point are presented in Appendix A3.

At San Francisco-Transbay, San Diego and Irvine, arriving trains generally turn for the next available train after their allotted layover time has concluded. As a result, train sets typically operate a variety of stopping patterns and serve multiple origin and destination points over the course of a service day. For example, an express train leaving San Francisco in the morning could turn at Irvine for all-stop train to Sacramento, then become a limited-stop train to San Diego and end up the day with a local run to Los Angeles Union Station. At Sacramento, trains arriving from Los Angeles generally turn for trains headed to the Bay Area, and *vice versa*, which provides the best arrangement of layover times at the Sacramento terminal station.

The frequency of train service tapers at the start and end of the service day, reflecting the relatively lower level of demand during the very early morning and late evening hours. Two equipment cycles begin in the 5:00 AM hour at Merced rather than Sacramento, providing the first train in the morning to both San Francisco and Los Angeles. Similarly, an early morning train is assumed to start from Bakersfield and operate north to San Francisco. Overnight storage of these three trainsets is assumed to be provided at the planned maintenance facility near Merced. The Bakersfield train would operate as a non-revenue or "deadhead" train between Merced and Bakersfield. To balance the daily equipment cycles, the last three trains out in the late evening would run Los Angeles-Merced, San Francisco-Merced and San Francisco-Bakersfield, with these three trains ending up at the Merced maintenance facility for overnight storage. In addition to providing early morning and late night service to intermediate stations on the HST network, these trains can be used by the HST system operator to cycle different train sets on a daily basis to and from the major maintenance

facility at Merced, where heavy scheduled maintenance, repair and overhaul will be performed on the HST fleet on a periodic, rotating basis.

During the major part of the day, Los Angeles Union Station will function primarily as a run-through station. However, several equipment cycles originate in the morning at Los Angeles, with trains operating towards all four terminals – San Francisco, Sacramento, San Diego and Irvine. Similarly, towards the end of the service day, the same number of equipment cycles terminate at Los Angeles, minimizing the number of trains operating on the network after midnight. In addition, the "extra" peak trains that operate between Los Angeles and San Diego (up to two per hour in each direction) are assumed to lay over and turn at the station platforms in Los Angeles.

The HST fleet will not be captive to a particular service territory or storage and maintenance facility. Train schedulers will be able to route individual train sets to particular overnight and mid-day yard locations, including the major maintenance shop at Merced, for specialized maintenance activities that may be concentrated at a single location or to balance maintenance schedules among the various HST maintenance facilities.

REVENUE TRAINSETS

A total of 107 train sets are estimated to be required to operate the 339 daily train schedule in revenue service. Each train set comprises a base configuration, 200 meters in length and seating approximately 500 passengers. Some of these train sets will be doubled in length to accommodate peak passenger loadings up to 1,000 passengers per train. An additional eighty-five 200 m units are required to "fill out" the 400 m trainsets that serve the peak periods (and all-day limited express services), as shown in Table 7. The determination of requirements for 200 m versus 400 m train lengths was based on estimated train-specific passenger loadings on the various routes during the peak, peak shoulder and off-peak hours and will be refined as the ridership estimates are updated. The loading assumptions are described and displayed graphically in Appendix A4.

TABLE 7 – REVENUE TRAIN SETS REQUIRED AT EACH TERMINAL TO START WEEKDAY MORNING TRAIN SERVICE

Terminal	200 m Sets	400 m Sets	Total
San Francisco – Transbay	6	24	30
Sacramento	3	14	17
Merced	--	3	3
Los Angeles Union Station	2	16	18
Irvine	9	8	17
San Diego	2	20	22
Total	22	85	107

FLEET REQUIREMENTS

The total number of 200 meter trainset units required to operate the 2030 Full-Build Service Plan is a function of several factors:

- The train schedule and equipment cycles developed for the service plan, which drive the number of required revenue train sets
- Estimated station-to-station ridership by time of day, which drives the determination of whether train sets need to be 200 meters or 400 meters long
- The fleet maintenance philosophy, maintenance plan and terminal operating plans, which drive the number of spare equipment sets needed to allow for periodic and non-scheduled maintenance and repair activities, and to protect reliable operations at the major terminals.

The Full-Build Service Plan described in this document requires 107 revenue train sets. The estimated proportion of 200 meter and 400 meter sets is indicated in Table 8, along with an allowance for spare train sets, resulting in an overall fleet requirement for 212 total 200-meter units. The allowance of 10 percent spares in the mid range of spare ratios for U.S. and international intercity and high-speed rail fleets. A lower spare ratio could be justifiable if an aggressive preventive maintenance program is adopted, which invests in the facilities, spare parts inventories and labor force needed to progressively replace train set components on a regular schedule before component failure occurs or life expectancy is reached. Conversely, a decision in favor of a more traditional maintenance philosophy that undertakes more limited periodic inspections and relies more on reactive repair and replacement of components as they wear out, would tend to increase the required spare ratio – as would the desire for spare ready equipment sets to ensure a very high level of equipment availability. The fleet requirement numbers will need to be modified as the operating plan, demand projections, and maintenance plan are refined. The figures presented in Table 8 can serve as placeholders for preliminary sizing and planning of HST storage and maintenance facilities.

TABLE 8 – HIGH-SPEED TRAIN FLEET REQUIREMENTS

Terminal	Train Sets	200 m Equivalent Units
200 m Revenue Train Sets	22	22
400 m Revenue Train Sets	85	170
Subtotal	107	192
Spare Equipment (Assume 10 percent)		20
Total		212

6. TRAIN STORAGE REQUIREMENTS

The number of trainsets estimated to be stored at each terminal location during both the overnight period and the mid-day off-peak period was calculated for the Full-Build Service Plan based on the equipment cycles presented in Appendix A3. The 107 revenue trainset consists required for the Full-Build operation in 2030 includes a mixture of 200m and 400m trainsets, distributed among the four terminals for overnight storage as follows:

TABLE 9 – OVERNIGHT TRAIN STORAGE REQUIREMENTS

(Revenue Trainsets)

Location	200 m Sets	400 m Sets	Total Trainsets	200 m Equivalents	400 m Yard Tracks*	Add'l Tracks for Maneuvering and Future Expansion	Total No. of Required Tracks
San Francisco	6	24	30	54	27	TBD (3 – 5)	TBD
Sacramento	3	14	17	31	16		
Merced	--	3	3	6	3		
Los Angeles	2	16	18	34	17		
Anaheim / Irvine	9	8	17	25	13		
San Diego	2	20	22	42	21		
Total	22	85	107	192	96		

* Additional tracks will be required at most locations for train maneuvering and to support required maintenance functions.

The overnight train storage requirements influence the sizes of the required storage yards capacities significantly. Train storage yards can be configured in several different ways, depending upon the size and shape of the available property for yard storage. Yards could be configured as a series of double-ended 400m tracks capable of storing either one 400m train or two 200m trains. Or, yards could comprise a combination of 400m and 200m long tracks. The storage yards are assumed to be located in reasonable proximity to the terminal stations, to minimize the extent of non-revenue or "deadhead" train movements, although the yards do not need to be immediately adjacent to the stations. Detailed operations analysis of the terminal stations, storage yards and connecting trackage have not yet been performed but are planned to be undertaken at a future stage of project development. Utilization of tracks in terminal stations to supplement overnight storage capacity will be examined during this analysis.

All 107 trainset consists are projected to be in active revenue during both the morning and afternoon peak periods. The mid-day off-peak train schedule (between approximately 11:00 AM and 3:00 PM) can be operated with 93 revenue trainsets. The remaining 14 trainsets (all 400m long) will be stored in the terminal stations and nearby yards, along with an additional 200 m sets culled from trains that need to be 400m long to meet peak demand but which can be reduced to 200 m long during the mid-day period to reduce the quantity of off-peak empty seat-mileage. The number of required mid-day storage tracks, by location, is presented in the following table.

TABLE 10 – MID-DAY TRAIN STORAGE REQUIREMENTS

(Revenue Trainsets)

Location	200 m Extra Sets	400 m Sets	Total Trainsets	200 m Equivalents	400 m Yard Tracks
San Francisco	14	3	17	20	10
Sacramento	6	9	15	24	12
Merced	--	--	--	--	--
Los Angeles	6	5	11	16	8
Anaheim / Irvine	6	5	11	16	8
San Diego	8	5	13	18	9
Total	40	27	67	94	47

APPENDIX A – FULL-BUILD SERVICE PLAN DESCRIPTION

A1. TRAIN TYPES AND STOPPING PATTERNS

This appendix describes the basic characteristics of the draft California High-Speed Train (HST) Full Build-Out Service Plan. , which assumes a 1.0-3.5% allowance for schedule pad or recovery time, consistent with the intent of the HST system to operate at a very high level of precision. In this service plan, the express services operating between San Francisco and Los Angeles with one intermediate stop at San Jose would have a scheduled run time of 2 hours and 40 minutes, with a recovery time allowance of one percent. All other trains in this variation of the plan would have a recovery time allowance of three and one half percent.

This full build-out service plan, with direct service links to Sacramento and San Diego, was composed of the following train types and service patterns:

Express Services

1. Route B (Bay Area-Orange County) – Pattern #2
   San Francisco-Los Angeles-Irvine "Express" service

   - San Jose is the only intermediate stop between San Francisco and Los Angeles
   - Trip time between San Francisco and Los Angeles of 2 hours, 40 minutes
   - Southbound trains depart San Francisco at 5:30 AM, 6:30 AM, 7:30 AM, 3:30 PM, 4:30 PM, and 5:30 PM.
   - Northbound trains depart Irvine at 4:53 AM, 5:53 AM, 6:54 AM, 2:53 PM, 3:53 PM, and 4:53 PM so that the trains can depart Los Angeles at the bottom (:30) of the hour.
   - These are assumed to be the highest-priority trains for railroad dispatching purposes and are assumed to operate with a high degree of precision and reliability – as a result, the estimated timetable times include a recovery time factor of 1.0 percent instead of the 3.5 percent factor used for all other trains

2. Route F (Los Angeles-San Diego) – Pattern #42
   Los Angeles-San Diego "Express" service

   - Riverside is the only intermediate stop between Los Angeles and San Diego
   - Trip time between Los Angeles and San Diego of 1 hours, 25 minutes
   - Southbound trains depart Los Angeles at 6:07 AM, 7:07 AM, 8:07 AM, 3:07 PM, 4:07 PM, and 5:07 PM.
   - Northbound trains depart San Diego at 6:17 AM, 7:17 AM, 8:17 AM, 3:17 PM, 4:17 PM, 5:17 PM and 6:17 PM.

3. Route A (Bay Area-San Diego) – Pattern #1
   San Francisco-Los Angeles-San Diego "Limited Express" service

   - Clockface departure on the hour southbound from San Francisco between 5:00 AM and 9:00 PM

   - Clockface hourly departures northbound from San Diego at 24 minutes past the hour, and departures from Los Angeles at the top of the hour.

   - This train has the characteristics of an express train (no intermediate stops) in the Central and San Fernando Valleys, and the characteristics of a limited-stop train (skips selected stations) in the Bay Area and between Los Angeles and San Diego.

   - Trip times:

San Francisco—Los Angeles	2 hours, 53 minutes
San Francisco—San Diego	4 hours, 29 minutes
Los Angeles—San Diego	1 hour, 34 minutes

   - Expected to be a popular option for travelers between the Bay Area and the Los Angeles basin.

Limited-Stop Services – Peak Periods

The Full-Build Service Plan includes four limited stop trains between San Francisco and Los Angeles in each direction of travel, in each hour of the peak period. Each of the four trains has a unique stopping pattern, but, together, they provide a balanced schedule of trains providing relatively fast and frequent service to every station within this corridor. Because of the need to weave these trains in and around the other express, limited and all-stop trains that operate on the network during the peak periods, the individual stopping patterns differ in the morning peak period and afternoon peak period, and they also are different in the northbound direction than in the southbound direction. While this makes the details of the service cumbersome to describe, the effect on the overall rhythm of train service at each station is relatively minor, as can be seen in the hypothetical timetables presented in Appendix A2.

Generally, the four limited stop trains operate as a coordinated group. All four trains serve the Bay Area, south Central Valley, San Fernando Valley and Los Angeles. These trains leave the stations at San Francisco and Los Angeles in closely-spaced pairs, immediately following the Limited Express departures at the top of the hour, and again 30 minutes later immediately following the departures of the peak Express trains. One pair of these trains is extended southward to San Diego. The other pair of trains operates to Anaheim and Irvine. Each intermediate station is served by two or three of these trains, and passengers at any station have the choice of at least one direct train to San Diego and Orange County, and at least two limited-stop trains to San Francisco and Los Angeles. Major stations such as San Francisco, Los Angeles and San Jose, are served by all four trains. The characteristics of the various limited stopping patterns are described below, including peak period Limited service to and from Sacramento. Not all of these patterns are operated in both directions and in both the morning and afternoon peak periods.

XXX Local south of LAU

The following table indicates the stopping patterns that are active during the weekday morning and afternoon peak periods in the southbound and northbound directions of travel:

Peak Period Limited-Stop Services

Southerly Terminus	AM Peak Southbound	AM Peak Northbound	PM Peak Southbound	PM Peak Northbound
San Diego (Route A)	Pattern 28	Pattern 7	Pattern 28	Pattern 7
	Pattern 29	--	Pattern 29	Pattern 9
Irvine (Route B)	Pattern 18	Pattern 18a	Pattern 20	Pattern 18a
	Pattern 21	Pattern 19	Pattern 21	Pattern 19
	--	Patterns 20 & 21a (early morning starts)	--	--

4. Route A (Bay Area-San Diego) – Patterns #28 & #7
   San Francisco-Los Angeles-San Diego Limited

   - One train per hour per direction
   - Southbound departures from San Francisco at :08 past the hour (Pattern 28) – skips Bakersfield, Sylmar and Burbank stations – trains are held for an overtake at Fresno
   - Northbound departures from San Diego at :47 past the hour in the AM peak and :44 past the hour in the PM peak (Pattern 7) – trains depart Los Angeles Union Station at :33 past the hour – skips Burbank and Palmdale stations – no northbound overtakes en route

5. Route A (Bay Area-San Diego) – Patterns #29 & #9
   San Francisco-Los Angeles-San Diego Limited

   - One train per hour southbound in AM peak, both directions in PM peak
   - Southbound departures from San Francisco at :03 past the hour in the AM peak and :04 past the hour in the PM peak (Pattern 29) – skips Fresno, Bakersfield and Burbank stations – PM peak trains are held for an overtake at Sylmar; AM peak trains are not overtaken en route
   - Northbound departures from San Diego at :49 past the hour in the PM peak only (Pattern 9) – trains depart Los Angeles Union Station at :35 past the hour – skips Fresno and Millbrae stations – no northbound overtakes en route – Pattern 9 does not operate in AM peak

6. Route B (Bay Area-Orange County) – Patterns #18, 18a & 20
   San Francisco-Los Angeles-Irvine Limited

   - One train per hour southbound in AM and PM peaks, two trains per hour per northbound in AM peak, one train per hour northbound in PM peak
   - Southbound AM peak departures from San Francisco at :37 past the hour (Pattern 18) – skips Bakersfield and Sylmar stations – no overtakes en route
   - Southbound PM peak departures from San Francisco at :37 past the hour (Pattern 20) – skips Palmdale and Burbank stations – no overtakes en route

- Northbound AM peak departures from Irvine at :31 past the hour and from Los Angeles at :07 past the hour (Pattern 18) – skips Burbank, Sylmar, Bakersfield and Redwood City stations – trains are held for an overtake at Gilroy

- Northbound PM peak departures from Irvine at :31 past the hour and from Los Angeles at :07 past the hour (Pattern 18a) – skips Sylmar, Bakersfield and Redwood City stations – no overtakes en route

7. Route B (Bay Area-Orange County) – Patterns #21 & #19
   San Francisco-Los Angeles-Irvine Limited

   - One train per hour per direction

   - Southbound AM and PM peak departures from San Francisco at :33 past the hour (Pattern 21) – skips Millbrae and Redwood City stations (PM peak also skips Fresno station) – no overtakes en route

   - Northbound AM peak departures from Irvine at 6:59 from Los Angeles at 5:35, 6:35 and 7:35 AM (Pattern #21a) – skips Palmdale and Millbrae stations – latter two trains also skip Palmdale and are held for an overtake at Bakersfield

   - Northbound departures in AM and PM peaks from Irvine at :27 past the hour and from Los Angeles at :03 past the hour (Pattern #19) – skips Burbank, Bakersfield, Fresno and Millbrae stations – latter two PM peak trains are held for overtake at Sylmar

8. Route B (Bay Area-Orange County) – Patterns #21a & #20
   San Francisco-Los Angeles-Irvine Limited – Additional Orange County services in AM peak in lieu of San Diego start-outs (distances too great to originate these trains in San Diego at a reasonable hour)

   - Northbound AM peak departures from Irvine at 6:59 AM and from Los Angeles at 5:35, 6:35 and 7:35 AM (Pattern #21a) – skips Palmdale and Millbrae stations – latter two trains also skip Palmdale and are held for an overtake at Bakersfield

   - Northbound AM peak departure from Los Angeles at 5:33 AM (Pattern #20) – skips Burbank, Palmdale and Gilroy – no overtake en route

9. Route C (Bay Area-Sacramento) – Pattern #39
   Bay Area-Sacramento Limited

   - One train per hour in each direction, only during 3-hour morning and afternoon peak periods

   - Train skips Millbrae, Gilroy, Merced and Modesto stations

   - Trip time of 2 hours, 5 minutes between San Francisco and Sacramento, 20 minutes faster than the all-stop train

   - Departures from San Francisco at 6:48 PM, 7:48 PM, 8:48 AM, 4:27 PM, 5:27 PM and 6:42 PM

   - Departures from Sacramento at 5:20 AM, 6:20 AM, 7:20 AM, 4:19 PM, 5:19 PM and 6:19 PM.

   - No overtakes between Merced and San Francisco.

10. Route D (Sacramento-San Diego) – Pattern #35
    Sacramento-Los Angeles-San Diego Limited

    - One train per hour in each direction, only during 3-hour morning and afternoon peak periods
    - Train skips Southern Central Valley and San Fernando Valley stations (Fresno, Bakersfield, Palmdale, Sylmar and Burbank)
    - Trip time of 2 hours, 5 minutes between Sacramento and Los Angeles, 20 minutes faster than the all-stop train
    - Departures from Sacramento at 5:20 AM, 6:20 AM, 7:20 AM, 4:19 PM, 5:19 PM and 6:19 PM.
    - Departures from San Diego at 6:48 PM, 7:48 PM, 8:48 AM, 4:27 PM, 5:27 PM and 6:42 PM
    - No overtakes en route

11. Route E (Sacramento-Orange County) – Pattern #25
    Sacramento-Los Angeles-Orange County Limited

    - One train per hour in each direction, only during 3-hour morning and afternoon peak periods
    - Train skips Burbank, Bakersfield, Merced and Modesto stations
    - Trip time of 2 hours, 5 minutes between San Francisco and Sacramento, 20 minutes faster than the all-stop train
    - Departures from Sacramento at 5:20 AM, 6:20 AM, 7:20 AM, 4:19 PM, 5:19 PM and 6:19 PM.
    - Departures from Irvine at 6:48 PM, 7:48 PM, 8:48 AM, 4:27 PM, 5:27 PM and 6:42 PM
    - Northbound trains are held for overtakes at Palmdale

Limited-Stop Services – Off-Peak Periods

The following four limited stop trains operate as a coordinated group, each running once per hour in each direction. All four trains serve the Bay Area, south Central Valley, San Fernando Valley and Los Angeles. These trains leave the stations at San Francisco and Los Angeles in closely-spaced pairs, immediately following the Limited Express departures at the top of the hour, and again 30 minutes later. One pair of trains is extended southward to San Diego. The other pair of trains operates to Anaheim and Irvine. Within each pair of Limited trains, one train focuses on Central Valley stops (Fresno and Bakersfield), skipping the stops in the San Fernando Valley, while the other pair of Limited trains stops at Palmdale, Sylmar and Burbank and skips the Central Valley stations. The terminal stations and major intermediate stations, such as San Jose, are served by all four trains. The other intermediate stations are served by two of the four trains (including one San Diego train and one Irvine train). The characteristics of each of the four trains are as follows:

12. Route A (Bay Area-San Diego) – Pattern #27
    San Fernando Valley Off-Peak Limited – Limited stop service between San Francisco and Los Angeles stopping at stations in the San Fernando Valley and the Santa Clara/Silicon Valley area, while generally bypassing Central Valley stations (Pattern #17)

    - 30-minute headways in both direction for travel between 8:00 AM and 3:00 PM, and again between 6:00 PM and 9:00 PM.
    - Southbound departure from San Francisco at :03 and :33 of the hour; northbound departure from Los Angeles at :10 and :40 of the hour.
    - No overtakes occur en route
    - Two northbound trips, departing Los Angeles at 8:10 AM and 9:10 AM, provide service to the Millbrae station.
    - Northbound trains departing Los Angeles at :40 of the hour reduce speed between Palmdale and Bakersfield to increase travel time by 2 minutes in order to minimize the dwell time of local trains overtaken at Bakersfield.
    - Reduced service to 60-minute headways after 7:00 PM

13. Route B (Bay Area-Orange County) – Pattern #17
    San Fernando Valley Off-Peak Limited

    - Same stopping pattern north of Los Angeles as previous train type (Pattern #27)
    - South of Los Angeles, service operates to Norwalk, Anaheim and Irvine instead of San Diego

14. Route A (Bay Area-San Diego) – Pattern #26
    Central Valley Off-Peak Limited – Limited stop service between San Francisco and Los Angeles stopping at all stations north of Bakersfield while skipping Palmdale and the San Fernando Valley stations.

    - 30-minute headways in both direction for travel between 8:00 AM and 3:00 PM, and again between 6:00 PM and 9:00 PM.
    - Southbound departure from San Francisco at :08 and :38 of the hour; northbound departure from Los Angeles at :03 and :33 of the hours
    - No overtakes occur en route

15. Route B (Bay Area-Orange County) – Pattern #16
    Central Valley Off-Peak Limited

    - Same stopping pattern north of Los Angeles as previous train type (Pattern #26)
    - South of Los Angeles, service operates to Norwalk, Anaheim and Irvine instead of San Diego

All-Stop Services

16. Route A (Bay Area-San Diego) – Pattern #4
    Bay Area-Los Angeles "all-stop" service

    - All day, hourly service with clockface schedule.
    - Southbound departure from San Francisco at :14 past the hour during AM peak period, :15 past the hour at other times; northbound departure from San Diego at :29 or :33 past the hour (departure at Los Angeles at :05 or :09 past the hour)
    - During peak period, southbound trains are overtaken at Gilroy; most off-peak southbound trains are overtaken at Bakersfield
    - Northbound peak and off-peak trains are overtaken at Bakersfield
    - Peak period northbound trains skip Burbank station
    - All trains make limited stops south of Los Angeles (skipping City of Industry, Murrieta and Escondido stations) – this improves trip times to San Diego for stations in the Central and San Fernando Valleys; all-stop local service between Los Angeles and San Diego is provided by other trains

17. Route C (San Francisco-Sacramento) – Pattern #14
    San Francisco-Sacramento all-stop service

    - All-day, hourly service with semi-clockface schedule
    - Southbound/eastbound departure from San Francisco at approximately :50 past the hour throughout the day
    - Westbound departure from Sacramento at :40 past the hour
    - No overtakes occur en route

18. Route E (Sacramento-Orange County) – Pattern #15
    Sacramento-Los Angeles-Irvine All-Stop

    - All day, hourly service with semi-clockface schedule
    - Southbound departures from Sacramento at :12 past the hour during the AM peak and :04 past the hour at other times; northbound departures from Irvine at approximately :10 past the hour and from Los Angeles at approximately :45 past the hour
    - Southbound trains are overtaken at Bakersfield; almost all northbound trains are overtaken at Palmdale; AM peak northbound trains have a second overtake at either Sylmar or Fresno
    - First train in the morning originates at Merced; last train in the late evening terminates at Merced

19. Route F (Los Angeles-San Diego) – Pattern #41
    Los Angeles-San Diego all-stop service

    - Operates during peak periods to provide supplemental capacity to meet ridership demand in LA-SD corridor; also operates in selected early morning and late evening slots to fill gaps in the schedule of longer-distance limited trains

    - Departure times from Los Angeles and from San Diego are irregular, depending upon available capacity slots

20. Route G (Los Angeles-Orange County) – Pattern #43
    Los Angeles-Irvine all-stop service

    - Operates at the beginning and end of the service day to fill gaps in the schedule

    - Southbound in the morning peak from Los Angeles to Irvine, departing Los Angeles at 6:26 and 7:51 AM

    - Northbound in the afternoon peak and evening hours, at approximate 30 minute intervals, departing Irvine at 5:30, 5:54, 6:27, 6:54 and 7:54 PM.

    - These trains are timed to provide convenient transfer connections at Los Angeles Union Station to other trains, including limited-stop trains heading northward to San Francisco

The Full-Build Service Plan provides a total of 339 revenue trains, a significant increase above the 260 daily trains provided in the Phase1 Service Plan.

A graphical representation and tabulation of key characteristics of the stopping patterns described above is presented in Appendix A1. A hypothetical daily timetable for this service plan is presented in Appendix A2. This same schedule is presented in stringline (time-distance) diagram format in Appendix A3. Equipment cycles are presented in Appendix A4, which is the basis for estimating the number of required revenue trainsets.

The following wide format tables and graphics, summarizing the Full-Build Service Plan, are presented on the following pages:

A1. TRAIN TYPES AND STOPPING PATTERNS

- Listing and graphical representation of service types and stopping patterns, including end-to-end run times for each stopping pattern (these trip time estimates do not include intermediate overtakes or additional time other than the specified recovery time)

A2. HYPOTHETICAL TIMETABLE

- Southbound System Timetable
- Northbound System Timetable

A3. STRINGLINE DIAGRAMS

- Morning Peak Period
- Mid-Day Period
- Afternoon Peak Period
- Evening and Late Night Period

A4. EQUIPMENT CYCLES

- Equipment Cycles Tabulation

[SUGGEST OMITTING REMAINING TEXT FROM DRAFT TECH MEMO on 1-9-09]

A5. ESTIMATED TRAIN LOADS BY LINE SEGMENT

In order to estimate train consists and fleet requirements, and verify that the capacity of the service plan for the full build-out approximately matches demand, the estimated daily ridership in 2030 of 307,000 trips was factored to develop an approximation of demand by hour for the peak hour, peak shoulder hour and off-peak periods. Ridership projections for daily boardings at each station, and annual region-to-region trips factored down to average daily travel, were used to derive a station-to-station daily trip table, which is presented in Table A5.1 below. The assumed peaking factors are presented in Table 9.

TABLE A5.1 – ESTIMATED DAILY STATION-TO-STATION RIDERSHIP IN 2030 – FULL BUILD NETWORK

[Table to be inserted]

TABLE A5.2 – RIDERSHIP PEAKING FACTORS

RIDERSHIP PEAKING FACTORS
(Applied to Average Daily Station-to-Station Trips)

Origin-Destination Market	[A] Seasonal Peaking Factor	[B] Day-of Week Factor	[C] Peak Hour Factor	[D] Shoulder Hour Factor	[E] Average Off-Peak Hour Factor	[F] Directional Peaking Factor		[G] Avg. Daily to Peak Hour Factor [A x B x C x F]	[H] Avg. Daily to Shoulder Hour Factor [A x B x D x F]	[J] Avg. Daily to Avg. Off-Peak Hour Factor [A x B x E]
Inter-regional	1.15	1.20	0.09	0.07	0.046	Peak direction	1.0	0.12	0.10	0.06
						Reverse-peak direction	1.0	0.12	0.10	0.06
Within MTC territory	1.05	1.10	0.12	0.08	0.033	Peak direction	1.2	0.17	0.11	0.04
						Reverse-peak direction	0.8	0.11	0.07	0.04
Within SCAG territory	1.05	1.10	0.12	0.08	0.039	Peak direction	1.1	0.15	0.10	0.05
						Reverse-peak direction	0.9	0.12	0.08	0.05

Notes:
Average daily boardings assumed to be equal to annual boardings divided by 339.
Seasonal peaking factor converts from Average Day to Average Day in Peak Month.
Day-of-week factor converts from Average Day in Peak Month to Peak Day in Peak Month.
Off-peak period assumed to comprise 10 hours; average off-peak hour assumed to include one-tenth of total daily off-peak ridership.

For the peak hour, average peak shoulder hour and average off-peak hour, station-to-station ridership was allocated among the available trains operating during those hours. Where choices among both express and local trains exist, a higher percentage of trips is allocated to the faster express services. Within each hour, overall demand is constrained by trainset seating capacity. Where the initial allocation of trips resulted in some trains being over capacity, a portion of the affected station-to-station loads were re-assigned to trains with available seating capacity operating within the same hour.

The graphs on the following pages show the estimated passenger loadings on the various train types for each station-to-station segment. In all cases, passenger loads can be kept within the 1,000 seat capacity of a 400 m trainset. The express services require 400 m trainsets all day long. The all-stop local trains, selected limited stop trains, and the Anaheim-Merced local trains all have passenger loads between 500 and 1,000 passengers, necessitating 400 m trainsets. All off-peak trains other than the hourly expresses have passenger loads under 500 and can be accommodated on 200 m trainsets.

Describe which services require 400 m train sets:

- Peak Express services
- Bay Area-Los Angeles Basin Limited Express
-

FIGURE A5.1 – ESTIMATED PASSENGER LOADS IN 2030 – EVENING PEAK HOUR SOUTHBOUND – ROUTE [A] – SAN FRANCISCO—SAN DIEGO

[Segment load graphs to be inserted]

- Routes A & F – San Francisco—Los Angeles—San Diego
    - Evening Peak Hour Southbound
    - Evening Peak Shoulder Hour Southbound
    - Evening Peak Hour Northbound
    - Evening Peak Shoulder Hour Northbound
    - Average Off-Peak Hour
- Routes B & G – San Francisco— Los Angeles—Irvine
    - Evening Peak Hour Southbound
    - Evening Peak Shoulder Hour Southbound
    - Evening Peak Hour Northbound
    - Evening Peak Shoulder Hour Northbound
    - Average Off-Peak Hour
- Route C – San Francisco—Sacramento
    - Evening Peak Hour towards Sacramento
    - Evening Peak Shoulder Hour towards Sacramento
    - Evening Peak Hour towards San Francisco
    - Evening Peak Shoulder towards San Francisco
    - Average Off-Peak Hour
- Route D – Sacramento—San Diego
    - Evening Peak Hour Southbound
    - Evening Peak Shoulder Hour Southbound
    - Evening Peak Hour Northbound
    - Evening Peak Shoulder Hour Northbound
    - Average Off-Peak Hour
- Route E – Sacramento—Irvine
    - Evening Peak Hour Southbound
    - Evening Peak Shoulder Hour Southbound
    - Evening Peak Hour Northbound
    - Evening Peak Shoulder Hour Northbound
    - Average Off-Peak Hour