HIGH-SPEED RAIL: *CONNECTING AND TRANSFORMING CALIFORNIA*

Caltrain / California High Speed Rail Joint Scheduling Working Group

Blended Service Operations: San Francisco to San Jose

2016 Year End Report

December 2016

Contents

Figures

This report describes the work undertaken at the direction of the Joint Scheduling Working Group (JSWG) established between the California High Speed Rail Authority (Authority) and Caltrain.

The aim of the JSWG was to identify the success criteria for both parties and to determine viable service specifications that satisfied these criteria for blended service operation.

Background

Previous analysis to establish the "proof of concept" had been undertaken by LTK Engineering Services on behalf of Caltrain. The results of this analysis is shown in two reports: *Caltrain/California HSR Blended Operation Analysis*, dated March 2012 and; *Caltrain / HSR Blended Service Plan Operations Considerations Analysis* (Requested by Stakeholders), dated June 2013.

During 2015, the Authority engaged the services of SMA Rail Consulting to assess the options for future blended operation of services. This work was only for internal consideration and was undertaken independently of Caltrain.

To build on both of these pieces of work Caltrain and the Authority agreed to establish the JSWG in April 2016. The JSWG comprised senior representatives from both organizations supported by their operational planning consultants, LTK Engineering Services (LTK) for Caltrain and, for the Authority, their Rail Delivery Partners and SMA Rail Consulting.

Methodology

The methodology was developed and agreed upon by the JSWG and is summarized in the diagram below:

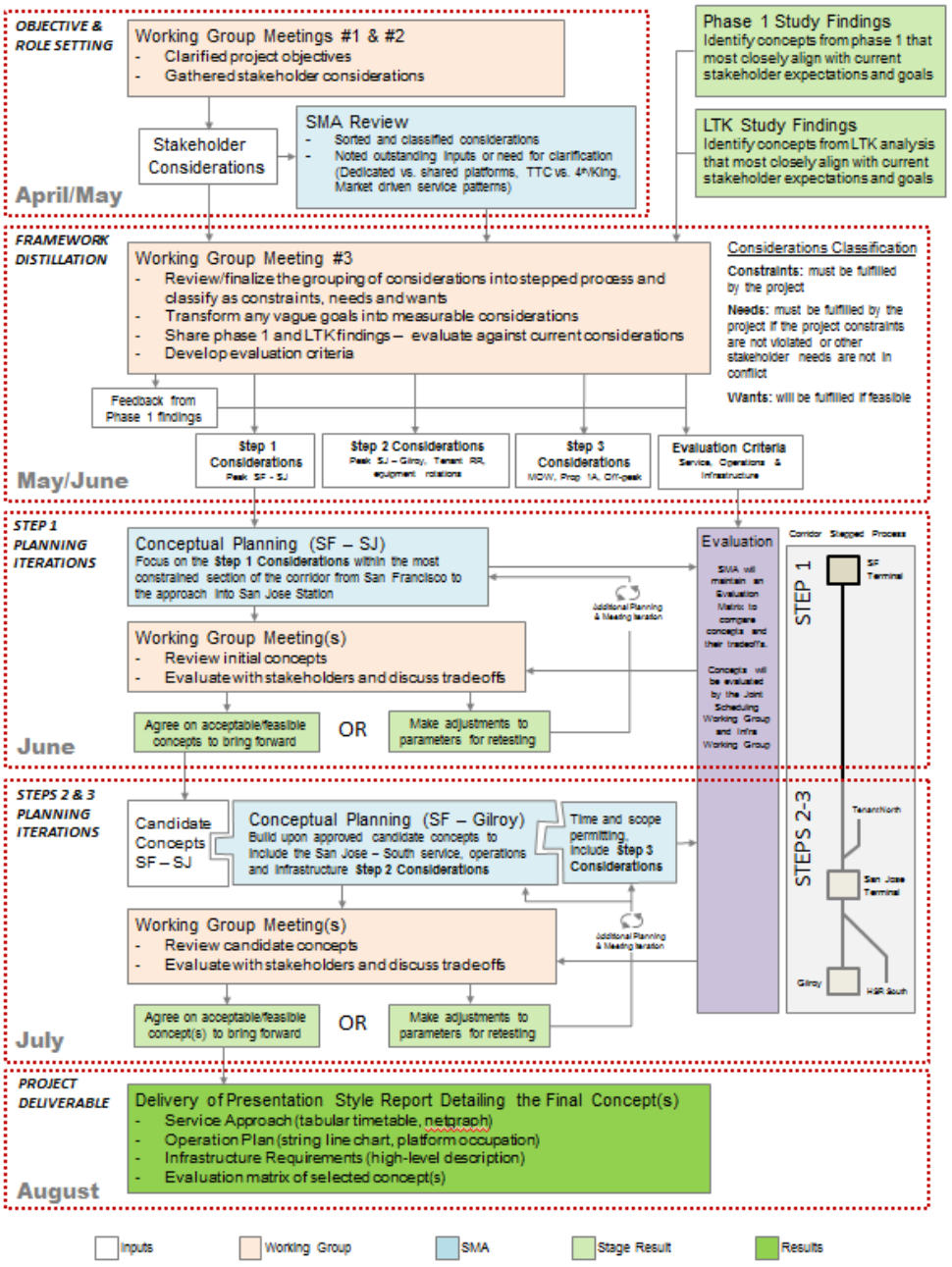


Figure 1 - Analysis methodology

The work undertaken during 2016 has focused on the Objective and Role Setting, Framework Distillation, and Step 1 Planning Iterations. The complexity of these stages and the importance of reaching a clear way forward before proceeding has meant that Steps 2 and 3 remain to be delivered. JSWG agreement will be sought before moving to these steps.

The first main element of the methodology was to establish the Considerations Table to capture the requirements and success measures for Caltrain and for the Authority. Key elements of the table are service plans, service intervals, stopping patterns, journey time expectations, and operational parameters (e.g. dwell times, turn times).

Alongside this work the JSWG identified the infrastructure options to be tested. These were informed by outputs from the Joint Infrastructure Working Group and from the previous work undertaken by LTK. Except for the Baseline case, all options studied assumed the following:

- Peninsula Corridor Electrification Program completed
- Caltrain operating new electrified trains with 6 trains per hour (tph) in peak hours in each direction
- Generic electric high-speed trainset with 4tph in peak hours in each direction
- Standard stopping patterns defined by Caltrain or the Authority
- A planning representation of the Communication Based Overlay Signaling System (CBOSS)
- Alignment improvements to allow for the 110mph passenger speed profile[1]

[1] Appendix 1 shows the passenger speed profiles

A Baseline case was established to enable comparison between the operation of Caltrain services with and without CHSR services. This case used the above assumptions with the exceptions that:

- No high-speed trains would be operating
- Today's 79mph passenger speed profile would apply

Having reviewed the previous work by LTK, the JSWG agreed the North and South passing track cases did not warrant further consideration. The group agreed to carry forward analyses of the Short Middle 4-Track (SM4T), Long Middle 4-Track (LM4T), and the Long Middle 3-Track (LM3T). A further case of No Additional Passing Tracks (NAPT) was also assessed.[2]

A further piece of work was also remitted by JSWG that required an assessment to be made of the capacity and capability of the upgraded signaling system that Caltrain is installing to meet federally mandated positive train control (PTC) protection requirements. In the case for Caltrain, the system is called CBOSS. This work was discharged by a subgroup of the JSWG supported by both LTK and SMA Rail Consulting representatives.[3]

[2] Appendix 2 shows the analysis details
[3] Appendix 3 shows the CBOSS assessment methodology

Results

The results for each scenario are summarized in the table below[4]:

Case	Average total journey time		Average supplemental time	
	Caltrain	CHSR	Caltrain	CHSR
Target	*55 min - 65 min*	*45 min*	*0 min*	*0 min*
Baseline	62.2 min	n/a	0 min	n/a
NAPT	62.5 min	47.1 min	4.8 min	4.5 min
SM4T	65.0 min	44.7 min	7.4 min	2.1 min
LM4T	60.9 min	44.2 min	3.3 min	1.6 min
LM3T	58.6 min	42.7 min	0.9 min	0 min

Figure 2 - Results summary

A methodology was determined to assess the capacity and capability of CBOSS. This methodology was applied in detail to the Baseline case and the No Additional Passing Tracks options in order to validate the assumed planning representation of CBOSS using a generic 3-min corridor headway, with 2-min headway at junctions.

Case	Average total journey time					
	Caltrain			CHSR		
	3-min headway	CBOSS headway	Diff	3-min headway	CBOSS headway	Diff
Baseline	62.2 min	63.0 min	0.8 min	n/a	n/a	n/a
NAPT	62.5 min	63.5 min	1.0 min	47.1 min	48.0 min	0.9 min

Figure 3 - CBOSS headway results summary

[4] Appendix 4 contains the detailed Consideration Table results

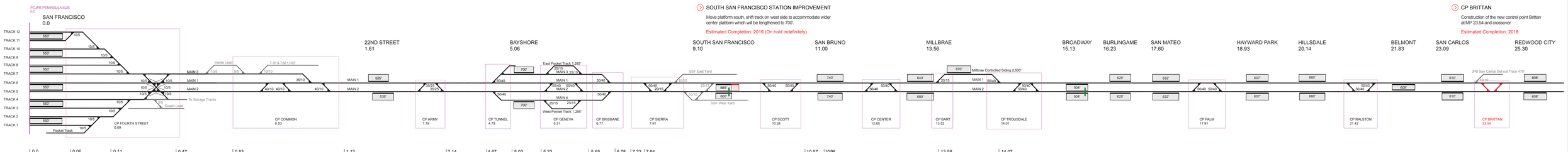
Conclusions

- The No Additional Passing Tracks option holds Caltrain neutral against the Baseline scenario
- The No Additional Passing Tracks option exceeds the CHSR desirable target[5] journey time
- The Short Middle 4-Track option represents a worsenment for Caltrain[6] over the Baseline case, and is at the upper end of the desirable target journey time range
- The Long Middle 4-Track option and Long Middle 3-Track option deliver improvements in average journey time for Caltrain, and are within the desired target range
- The Short Middle 4-Track, Long Middle 4-Track and Long Middle 3-track options all provide average journey times lower than CHSR's desired target.

[5] As captured in the Considerations Table
[6] This results from the forced use of these passing tracks for Caltrain services to enable high-speed trains to pass

Appendix 1

Passenger speed profiles



SOUTH SAN FRANCISCO STATION IMPROVEMENT

Move platform south, shift track on west side to accommodate wider center platform which will be lengthened to 700'.

Estimated Completion: 2019 (On hold indefinitely)

CP BRITTAN

Construction of the new control point Brittan at MP 23.54 and crossover

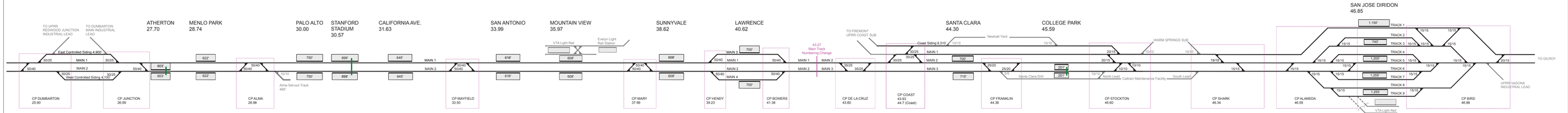
Estimated Completion: 2018

PENINSULA SUB

Passenger	0.0	0.06	0.11	0.47	0.53	1.13	2.14	4.67	5.03	5.33	5.65	6.78	7.23	7.94	10.57	10.98	13.58	14.07
	5 NB, 10 SB Except 15 SB (TK 5,6,7)	10 Except 15 SB (TK 5,6,7)	10, 5 (Coach Lead), 5 (NB Pocket Track) 15 (TK 5,6,7, SB Pocket Track)	25, 5 (Coach & Inside Leads)	40 (M1 & M2), 35 (M3)	75	79	65 (M1 & M2), 50 (M3 & M4)	79 (M1 & M2), 70 (M3 & M4)	79 (M1 & M2), 70 (M3 & M4), 10 (Pocket Tracks)	79 (M1 & M2), 70 (M3 & M4)	79	70	79	65	79	75 (M1 & M2), 50 (Siding)	79
Freight	5		10, 5 (Coach & Inside Leads)	10	40			50 (M1 & M2), 40 (M3 & M4)	50 (M1 & M2), 40 (M3 & M4)	50 (M1 & M2), 40 (M3 & M4), 10 (Pocket Tracks)	50 (M1 & M2), 40 (M3 & M4)	50			50		50 (M1 & M2), 40 (Siding)	50

DRAFT 110 MPH

Passenger	0.0	0.09	0.33	0.50	0.93	1.10	2.10	4.68	4.97	6.85	7.18	7.90	9.09	9.32	10.62	10.90	12.52	12.55	13.49	13.58	13.91	14.00	17.25	17.60	18.38	18.44	19.19	20.23	20.47	21.50	21.58	21.67	22.17	24.68	25.37
	15	20	30	40 (M1 & M2), 35 (M3)	45	75	110	65	110	85	79	110	79	110	80	110	79	110	79	79 (M1 & M2), 50 (Siding)	110 (M1 & M2), 50 (Siding)	110	79	110	100	110	100	110	79	90	110				



	25.90	26.99	39.34	41.38	43.94	45.58	45.66	45.99	46.38	47.10
79	79 (M1 & M2), 30 (Sidings)	79	79 (M1 & M2), 70 (M3 & M4)	79	40 (M1), 79 (M2 & M3), 30 (UPRR Coast Siding)	40	35 (M1), 40 (M2 & M3)	15 (M1), 40 (M2 & M3)	15	35
50	50 (M1 & M2), 25 (Sidings)	50	50 (M1 & M2), 40 (M3 & M4)	50	40, 30 (UPRR Coast Siding)	40 (M1), 25 (M2 & M3)	25	15 (M1), 25 (M2 & M3)	15	15 (TRACK 1), 10 (TRACK 5), 0 (TRACK 2,3,4,6,7,8,9)	35

	25.90	26.99	29.70	30.34	33.97	34.24	37.78	37.89	37.98	38.20	40.24	40.47	41.41	41.97	43.88	43.93	45.60	45.67	45.90	46.30	46.74	46.88
110	110 (M1 & M2), 30 (Sidings)	110	100	110	79	110	85	110	90	110	79	110	79	110	40 (M1), 110 (M2 & M3), 30 (UPRR Coast Siding)	35 (M1), 110 (M2 & M3), 30 (UPRR Coast Siding)	35 (M1), 40 (M2 & M3)	15 (M1), 40 (M2 & M3)	15	35

LEGEND

- Track segment
- Track segment included as reference
- Track segment proposed for removal
- Proposed track segment
- 60/40 — Maximum turnout or crossover speed (60 mph passenger / 40 mph freight)
- 985' — Passenger platform with length (feet)
- 45/40 — AREMA speed used (passenger/freight mph)
- Station hold-out rule in effect
- 20.0 — Approximate mile marker
- Funded project description
- CP HELEN 1.05 — Control point with official milepost
- 79 — 79 mph Passenger speed profile
- 110 — 110 mph Passenger speed profile
- 70 — Freight speed (mph)

PREPARED BY:

sma
sma-usa.com

PENINSULA SUBDIVISION

PCJPB PENINSULA SUBDIVISION (San Francisco Station [0.0]- CP Bird [MP 46.88])

DISCLAIMER

This schematic is a representation of current infrastructure with 79 mph maximum speed limit. For reference, the proposed 110 MPH speed band is shown. Infrastructure and turnouts/crossovers for the 110 MPH speed profile not shown. Speeds of passing tracks assumed to be the same as Main 1 / Main 2 speeds. This drawing is conceptual only and for the convenience of reference. Drawing is not to scale. It should not be relied upon as representation express or implied, of the final length, location or dimensions of any rail subdivision.

DATE: August 29, 2016

Appendix 2

Analysis Details

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Joint Schedule Working Group

Analysis and Outputs - 2016

optimizing railways SMA Rail Consulting + IT, Corp.

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Santa Ana, CA 92705
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Methodology and approach

Discussed: Working Group Meetings #3 - June 3, 2016

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Project Framework

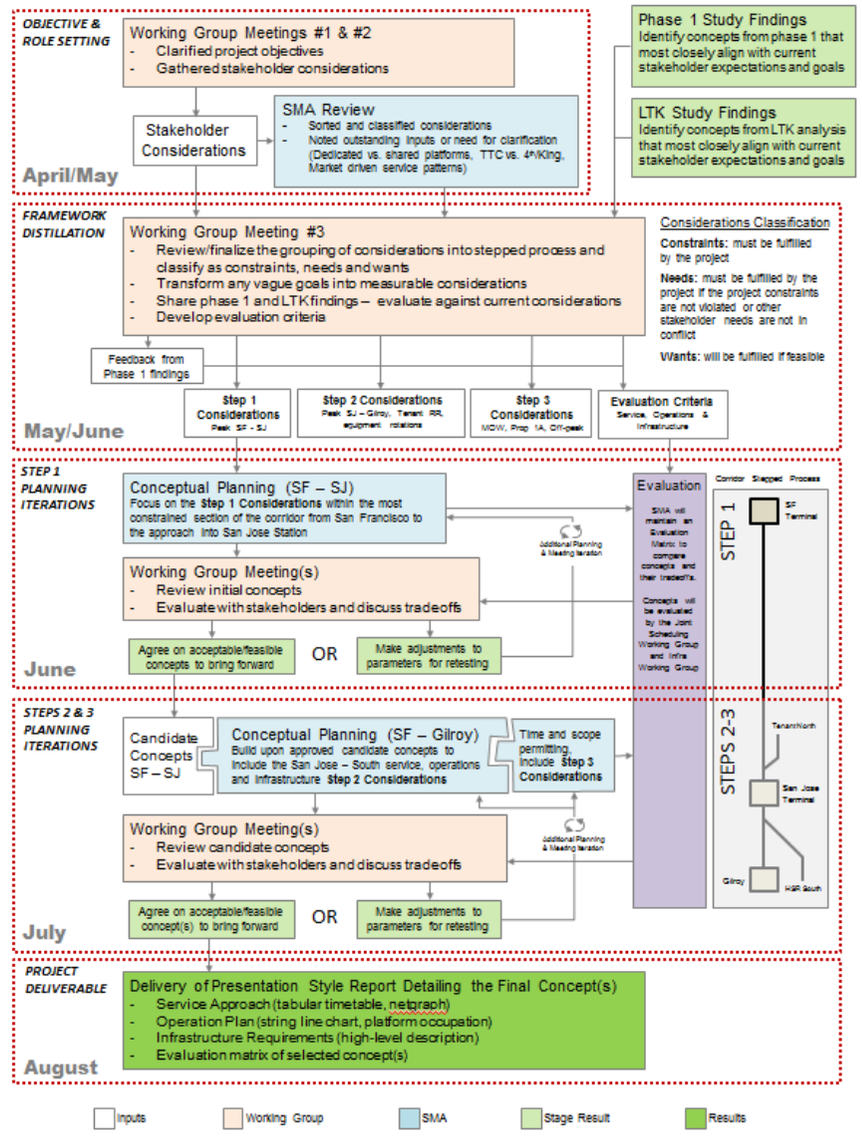
Understand and **agree upon** stakeholder considerations *(request clarity on vague/conflicting goals)*

Classify and **sort** considerations

Develop evaluation criteria

First tackle the **most constrained** part of the system

Build on complexity once fundamental system constraints are satisfied



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Classify Considerations

Constraints:	Stakeholder expectations that must be fulfilled by the project.
Needs:	Stakeholder expectations that must be fulfilled by the project, if the project constraints are not violated or other stakeholder needs are not in conflict.
Wants:	Stakeholder expectations that will be considered once constraints and needs are met and if they are feasible.

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Sequence of Considerations

Step 1: Tackle the most constrained part of the system from San Francisco terminal to the approach into San Jose

Step 2: Build upon concept(s) that satisfy fundamental corridor constraints to include additional complexity of peak operations at San Jose and to the south

Step 3: Increase the robustness of the concept(s) by taking into consideration broader considerations that are an integral part of successful system operations, but not necessary to implementation of peak service

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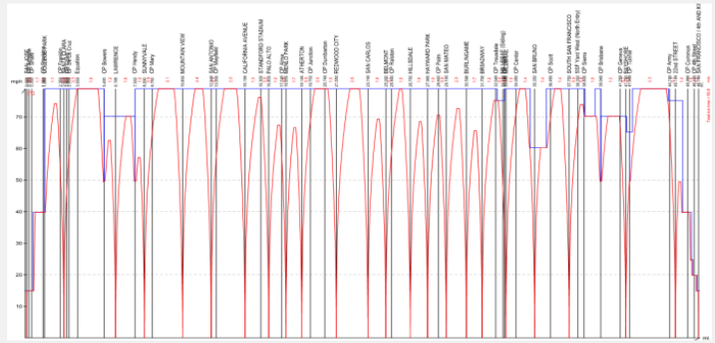
Concept Evaluations

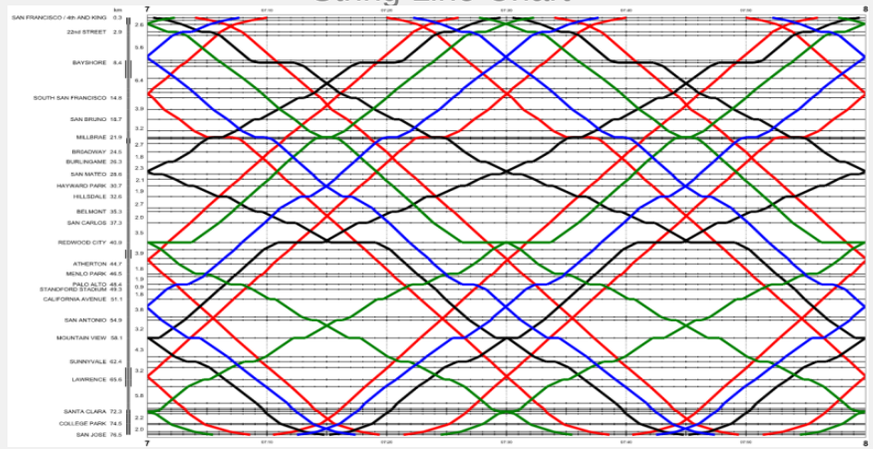
Achievable service concepts are included in the study's evaluation matrix. Key visual outputs are string charts, netgraphs and a chart of detailed service characteristics.

Sample Outputs

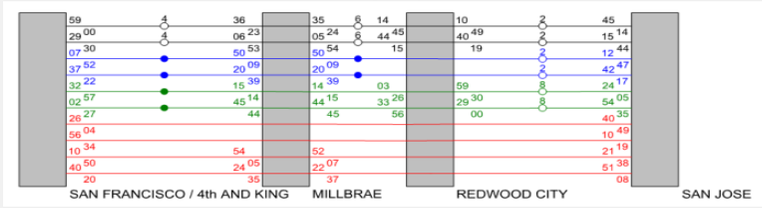
Runtime Calculation



String Line Chart



Netgraph



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Concept Evaluation Matrix

Considerations are broken into two categories for evaluation purposes:

1. Constraints
2. Needs/Wants

Constraints: Either fulfilled ✔ or not ✘

Example:

04-C, Caltrain – Serve all stations, including weekend stations, during the peak

Needs/Wants: Ranges of goal achievement categorized good OK or poor based on stakeholder-defined thresholds

Example:

22-N, Caltrain – Avoid dwelling at any intermediate station for longer than the minimum dwell

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Concept Evaluation Matrix - Example

Need/Want Example:

22-N, Caltrain – Avoid dwelling at any intermediate station for longer than the minimum dwell

Data provided: wherever there is supplemental dwell at a station in the concept, the evaluation will list the train number, station and length of supplemental dwell

Evaluation: stakeholders will develop evaluation criteria based on decided-upon thresholds of acceptability. Some samples are below, for demonstrative purposes only:

Evaluation Basis	Sample Criteria	Application
additional dwell for each station stop occurrence	Acceptable levels of supplemental dwell at each station: 2’ or less “good”, 2’-7’ “OK” and 7’+ “poor”	Any concept that has a train with more than 7’ supplemental dwell at any station would be classified as “poor”
accumulative additional dwell for one entire train run	Acceptable levels of supplemental dwell for one train run: +0 “good”, <10’ “OK” and 10’+ “poor”	Any concept in which every train run has less than 10’ accumulative supplemental dwell would be classified as “OK”
Combination of the above	Acceptable levels of supplemental dwell for one train run: +0 “good”, <10’ “OK” and 10’+ “poor”, AND Acceptable levels of supplemental dwell at each station: 8’ or less “good/OK” and 8’+ “poor”	Any concept in which a single train dwells more than 8’ at a single station would be classified as “poor” even if the accumulative additional dwell for each train run is less than 10’

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Choosing Concepts for Preliminary Evaluation

A multitude of blended service concepts have been tested to date commissioned by Caltrain and CHSRA. For the purpose of discussion, we chose to evaluate those concepts which most closely align with the considerations voiced in the April meetings concerning the 2029 anticipated infrastructure, operations parameters and 10 TPH service goal.

Caltrain Commissioned Work

Study Year	Speed Limit Caltrain/HSR	TPH	Service Type	Infrastructure	Infra notes
2012	79/79	6 Caltrain / 0 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	79/79	6 Caltrain / 1 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	79/79	6 Caltrain / 2 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	79/79	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	79/79	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Full Midline 4-Track	Baseline + 8.9-mile, 4-track Hayward Park-Redwood City
2012	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Full Midline 4-Track	Baseline + 8.9-mile, 4-track Hayward Park-Redwood City
2012	79/79	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Short Midline 4-Track	Baseline + 5.9-mile, 4-track Hayward Park - San Carlos
2012	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Short Midline 4-Track	Baseline + 5.9-mile, 4-track Hayward Park - San Carlos
2012	79/110	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Full Midline 4-Track	Baseline + 8.9-mile, 4-track Hayward Park-Redwood City
2012	79/110	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Full Midline 4-Track	Baseline + 8.9-mile, 4-track Hayward Park-Redwood City
2012	79/110	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Short Midline 4-Track	Baseline + 5.9-mile, 4-track Hayward Park - San Carlos
2012	79/110	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Short Midline 4-Track	Baseline + 5.9-mile, 4-track Hayward Park - San Carlos
2012	110/110	6 Caltrain / 0 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	110/110	6 Caltrain / 2 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	110/110	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Baseline Infrastructure	*see note below
2012	110/110	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Full Midline 4-Track	Baseline + 8.9-mile, 4-track Hayward Park-Redwood City
2012	110/110	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Full Midline 4-Track	Baseline + 8.9-mile, 4-track Hayward Park-Redwood City
2012	110/110	6 Caltrain / 3 HSR TPH	Skip-stop prototype	Short Midline 4-Track	Baseline + 5.9-mile, 4-track Hayward Park - San Carlos
2012	110/110	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Short Midline 4-Track	Baseline + 5.9-mile, 4-track Hayward Park - San Carlos
2013	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Long-Middle 4-Track	Baseline + 9.1-mile, 4-track segment Hayward Park - Redwood City
2013	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Short-Middle 4-track	Baseline + 6.1-mile, 4-track Hayward Park - San Carlos
2013	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	Middle 3-Track	Baseline + 16-mile, 3-track Hayward-California Ave
2013	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	North 4-track	Baseline + 10.2-mile 4-track Bayshore-Millbrae
2013	79/79	6 Caltrain / 4 HSR TPH	Skip-stop prototype	South 4-track overtake	Baseline + 7.8-mile 4-track San Antonio-Lawrence
2013	79/79	6 Caltrain / 4 HSR TPH	Redwood City HSR stop	Long-Middle 4-Track	Baseline + 9.1-mile, 4-track segment Hayward Park - Redwood City
2013	79/79	6 Caltrain / 4 HSR TPH	TTC as Terminal Station 6 TPH	Long-Middle 4-Track	Baseline + 9.1-mile, 4-track segment Hayward Park - Redwood City
2013	79/79	6 Caltrain / 4 HSR TPH	Dumbarton Rail	Long-Middle 4-Track	Baseline + 9.1-mile, 4-track segment Hayward Park - Redwood City
2013	79/79	6 Caltrain / 4 HSR TPH	Modified schedule to include BB	Long-Middle 4-Track	Baseline + 9.1-mile, 4-track segment Hayward Park - Redwood City

*Baseline Infra: Existing infrastructure, 4 track section CP Sylvan to CP Trousdale, San Bruno grade separation, south terminal project add two platforms at SJ, Santa Clara station project remove hold out rule at station, HSR separated alignment south of CP De La Cruz

CHSRA Commissioned Work

Speed Limit		110 mph				
SF Terminal Station		TTC and 4th/King				
Headway/Separation		2-min near stations and major junctions, 3-min entire corridor				
Turnaround Time (SF)		20 mins for HSR, 15 mins for Caltrain				
Fleet Mix		100% Electric				
	Current	Approach A			Approach B	
Variation Explanation	(323, 227, 231, 135)	Base Concept	2' headway	Bundled	Base Concept	Bundled
Service: Trip Times [min]						
HSR SJ - SF						
Trip Time fastest HSR		41.6	41.6	41.6	42.5	41.6
Supplemental Time fastest HSR		0.0	0.0	0.0	0.9	0.0
Trip Time +Stop		49.2	46.9	46.9	47.1	44.8
Supplemental Time +Stop		4.4	2.1	2.1	2.3	0.0
Average Speed fastest HSR (mph)		69	69	69	68	69
Caltrain SJ - SF						
Trip Time Express	59.0	53.2	50.6	51.7	57.1	57.6
Supplemental Time Express		2.9	0.3	1.4	3.2	0.0
# of Stops	4	5	5	5	8	9
Trip Time Express					72.1	65.8
# of Stops					9	9
Trip Time North Zone Express	86.0	75.2	73.1	88.3		
# of Stops	13	15	15	15		
Trip Time North Zone Express						
# of Stops						
Trip Time South Zone Express	87.0	68.4	68.1	69.4		
# of Stops	16	14	14	14		
Trip Time South Zone Express						
# of Stops						
Trip Time Local	93.0				94.2	102.2
# of Stops	20				23	22
Trip Time fastest SJ - SF	59.0	53	51	52	57	58
fastest Palo Alto - SF	39.0	35	33	33	37	40
Frequency/Interval at SF [min]						
HSR						
Nonstop		30	30	30	30	30
+Stop		30	30	30	30	30
Interval HSR at arr. SJ		10 | 20	12 | 18	08 | 22	14 | 16	03 | 27
Interval HSR at arr. SF		12 | 18	12 | 18	03 | 27	12 | 18	06 | 24
Caltrain						
Express		30	30	30	30 + 30	30 + 30
North Zone Express		30	30	30		
South Zone Express		30	30	30		
Local					30	30
Planned Connections						
Location/ Line				LCL - EXP in Palo Alto	LCL - EXP in Hillsdale	LCL - EXP in Hillsdale
Remarks						
HSR Stopping Pattern		No HSR stop at Palo Alto	No HSR stop at Palo Alto	No HSR stop at Palo Alto	No HSR stop at Palo Alto	No HSR stop at Palo Alto

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Conceptual Planning Evaluation Matrix

CHSRA Commissioned Work

Evaluation based on preliminary criteria

#	Stakeholder	Consideration	Type	Classification	Planning Hierarchy	CHSRA Commissioned Work						
						Approach A Base Concept	Approach A 2' headway	Approach A 20' HSR turns	Approach A HSR Bundled	Approach B Base Concept	Approach B HSR Bundled	Approach C Base Concept
01-C	HSR	4 TPH between San Jose and San Francisco	Service	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
02-C	HSR	stop 2 TPH at Millbrae	Service	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
03-C	Caltrain	run 6 TPH between San Jose and San Francisco	Service	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
04-C	Caltrain	serve all stations, including weekend stations, during the peak	Service	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
05-C	Caltrain	ensure that CBOSS signal system delivers the performance required to operate Caltrain and HSR service/schedule developed as part of this project	Operation	Constraint	Step 1	Assumed signal headway 3 min (section), 2 min (station/junction)						
06-C	HSR	use dedicated platforms at all stations that are served by HSR trains	Operation	Constraint	Step 1	✘	✘	✘	✘	✘	✘	✘
07-C	HSR	have at least 20 minutes to turn a train at a terminal station	Operation	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
08-C	HSR	dwell at least for 2 minutes at intermediate station stops (such as Millbrae, San Jose)	Operation	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
09-C	HSR	use 400m "AGV" trains with the performance characteristics as provided by PB	Operation	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
10-C	Caltrain	have at least 20 minutes to turn a train at a terminal station	Operation	Constraint	Step 1	✔	✔	✘	✘	✘	✘	✘
11-C	Caltrain	dwell at least at each station for the times specified in the Caltrain EMU RFP	Operation	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
12-C	Caltrain	use 8-car EMU's for all their 2029 service between San Francisco and San Jose with the performance defined in Caltrain's EMU RFP	Operation	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
13-C	Caltrain/HSR	limit speed increase to 110-MPH speed profile provided by HSR	Infrastructure	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
14-C	Caltrain/HSR	limit the analysis of new passing tracks to consider only a) Hayward Park to Hillsdale, b) Millbrae 4-track station	Infrastructure	Constraint	Step 1	✘	✘	✘	✘	✘	✘	✔
15-C	Caltrain/HSR	use existing infrastructure together with Caltrain identified capital program improvements as a baseline	Infrastructure	Constraint	Step 1	✔	✔	✔	✔	✔	✔	✔
16-N	Caltrain	provide at least XX trains per hour to all stations during the peak	Service	Need	Step 1	OK	OK	OK	OK	OK	OK	OK
17-N	Caltrain	operate a clock-face/regular interval service	Service	Need	Step 1	good	good	good	good	good	good	good
18-N	Caltrain	achieve an end-to-end run-time for express trains of aprox. 60 minutes	Service	Need	Step 1	good	good	good	good	poor	OK	good
19-N	Caltrain	achieve an end-to-end run-time for local trains of aprox. 70 minutes	Service	Need	Step 1	OK	good	OK	poor	poor	poor	OK
20-N	Caltrain	avoid bunched train service	Service	Need	Step 1	Requires clarification						
21-N	Caltrain	uniform trip times for all services between San Jose and San Francisco	Service	Need	Step 1	OK	OK	OK	poor	poor	poor	OK
22-N	Caltrain	avoid dwelling at any intermediate station for longer than the minium dwell	Service	Need	Step 1	OK	OK	OK	OK	OK	poor	OK
23-N	Caltrain/HSR	primarily use the new TTC station and retain 4th/King as overflow capacity / backup	Infrastructure	Need	Step 1	OK	OK	good	OK	OK	OK	good
24-N	HSR	use tracks 1-4 at 4th/King when using 4th/King	Infrastructure	Need	Step 1	Not yet analyzed, but not seen as an issue						

Why was this constraint consistently unfulfilled?

Assumed existing infra at Millbrae

Planned with 15 minute minimum turnaround for Caltrain

Planned with 3 track section Palo Alto - California Ave.

*Note: used LTK prototype schedule as basis

All-stop local included in Approach B

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Conceptual Planning Evaluation Matrix

Caltrain Commissioned Work

Evaluation based on preliminary criteria

#	Stakeholder	Consideration	Type	Classification	Planning Hierarchy	Caltrain Commissioned Work				
						Approach D Short-Midline 4 Track Overtake 110mph	**Approach E** Short-Middle 4 Track Overtake	**Approach F** Middle 3-Track Overtake	**Approach G** Long-Middle 4 Track Overtake TTC Terminal	**Approach H** Long-Middle 4 Track Overtake BB Service
01-C	HSR	4 TPH between San Jose and San Francisco	Service	Constraint	Step 1	✓	✓	✓	✓	✓
02-C	HSR	stop 2 TPH at Millbrae	Service	Constraint	Step 1	✗	✗	✗	✗	✗
03-C	Caltrain	run 6 TPH between San Jose and San Francisco	Service	Constraint	Step 1	✓	✓	✓	✓	✓
04-C	Caltrain	serve all stations, including weekend stations, during the peak	Service	Constraint	Step 1	✓	✓	✓	✓	✓
05-C	Caltrain	ensure that CBOSS signal system delivers the performance required to operate Caltrain and HSR service/schedule developed as part of this project	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
06-C	HSR	use dedicated platforms at all stations that are served by HSR trains	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
07-C	HSR	have at least 20 minutes to turn a train at a terminal station	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
08-C	HSR	dwell at least for 2 minutes at intermediate station stops (such as Millbrae, San Jose)	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
09-C	HSR	use 400m "AGV" trains with the performance characteristics as provided by PB	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
10-C	Caltrain	have at least 20 minutes to turn a train at a terminal station	Operation	Constraint	Step 1	✓	✓	✓	✗	✓
11-C	Caltrain	dwell at least at each station for the times specified in the Caltrain EMU RFP	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
12-C	Caltrain	use 8-car EMU's for all their 2029 service between San Francisco and San Jose with the performance defined in Caltrain's EMU RFP	Operation	Constraint	Step 1	✓	✓	✓	✓	✓
13-C	Caltrain/HSR	limit speed increase to 110-MPH speed profile provided by HSR	Infrastructure	Constraint	Step 1	✓	✓	✓	✓	✓
14-C	Caltrain/HSR	limit the analysis of new passing tracks to consider only a) Hayward Park to Hillsdale, b) Millbrae 4-track station	Infrastructure	Constraint	Step 1	✗	✗	✗	✗	✗
15-C	Caltrain/HSR	use existing infrastructure together with Caltrain identified capital program improvements as a baseline	Infrastructure	Constraint	Step 1	✗	✗	✗	✗	✗
16-N	Caltrain	provide at least XX trains per hour to all stations during the peak	Service	Need	Step 1	good	good	good	good	good
17-N	Caltrain	operate a clock-face/regular interval service	Service	Need	Step 1	poor	poor	poor	poor	OK
18-N	Caltrain	achieve an end-to-end run-time for express trains of aprox. 60 minutes	Service	Need	Step 1	good	OK	OK	OK	good
19-N	Caltrain	achieve an end-to-end run-time for local trains of aprox. 70 minutes	Service	Need	Step 1	good	good	good	good	good
20-N	Caltrain	avoid bunched train service	Service	Need	Step 1	Requires clarification				
21-N	Caltrain	uniform trip times for all services between San Jose and San Francisco	Service	Need	Step 1	good	good	good	good	good
22-N	Caltrain	avoid dwelling at any intermediate station for longer than the minium dwell	Service	Need	Step 1	good	good	good	good	good
23-N	Caltrain/HSR	primarily use the new TTC station and retain 4th/King as overflow capacity / backup	Infrastructure	Need	Step 1	poor	poor	poor	OK	poor
24-N	HSR	use tracks 1-4 at 4th/King when using 4th/King	Infrastructure	Need	Step 1	Not yet analyzed, but not seen as an issue				

Why was this constraint consistently unfulfilled?

Assumed 4 TPH at Millbrae

*Note: Estimated turns using LTK stringlines

*Note: most concepts used 79 MPH limit

Planned with passing track variations

Planned with separate HSR alignment from CP De la Cruz to San Jose

12 distinct service patterns repeat hourly during AM peak

Planned with 4th/King as SF terminal

sma

Iteration 1 – Existing signaling system

Discussed: Working Group Meeting #4 - July 1, 2016

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Planning Assumptions – Iteration 1

Parameter	Assumption
Headway/ Separation	5 min corridor, 4 min diverging/merging at junctions
Minimum Turnaround Time	HSR: 20 min Caltrain: 20 min
Minimum Dwell Time	HSR: 2 min Caltrain: Between 29 and 48 sec depending on the station Based on LTK Blended Operations Analysis
Rolling Stock	HSR: Generic High Speed Trainset Caltrain: Adapted to EMU RFP train performance and 8 coach train length
Infrastructure	4-track Improvements assumed: Short-Middle 4-Track: CP Palm (MP 17.91 to just after CP Brittan (24.0) Millbrae Station: CP Center (MP 12.65) to CP Trousdale (MP 14.01) Terminal Configurations at San Jose, 4th/King
Speed Limit	110 mph
Terminal Station SF	HSR: TTC Caltrain: 4th & King and TTC

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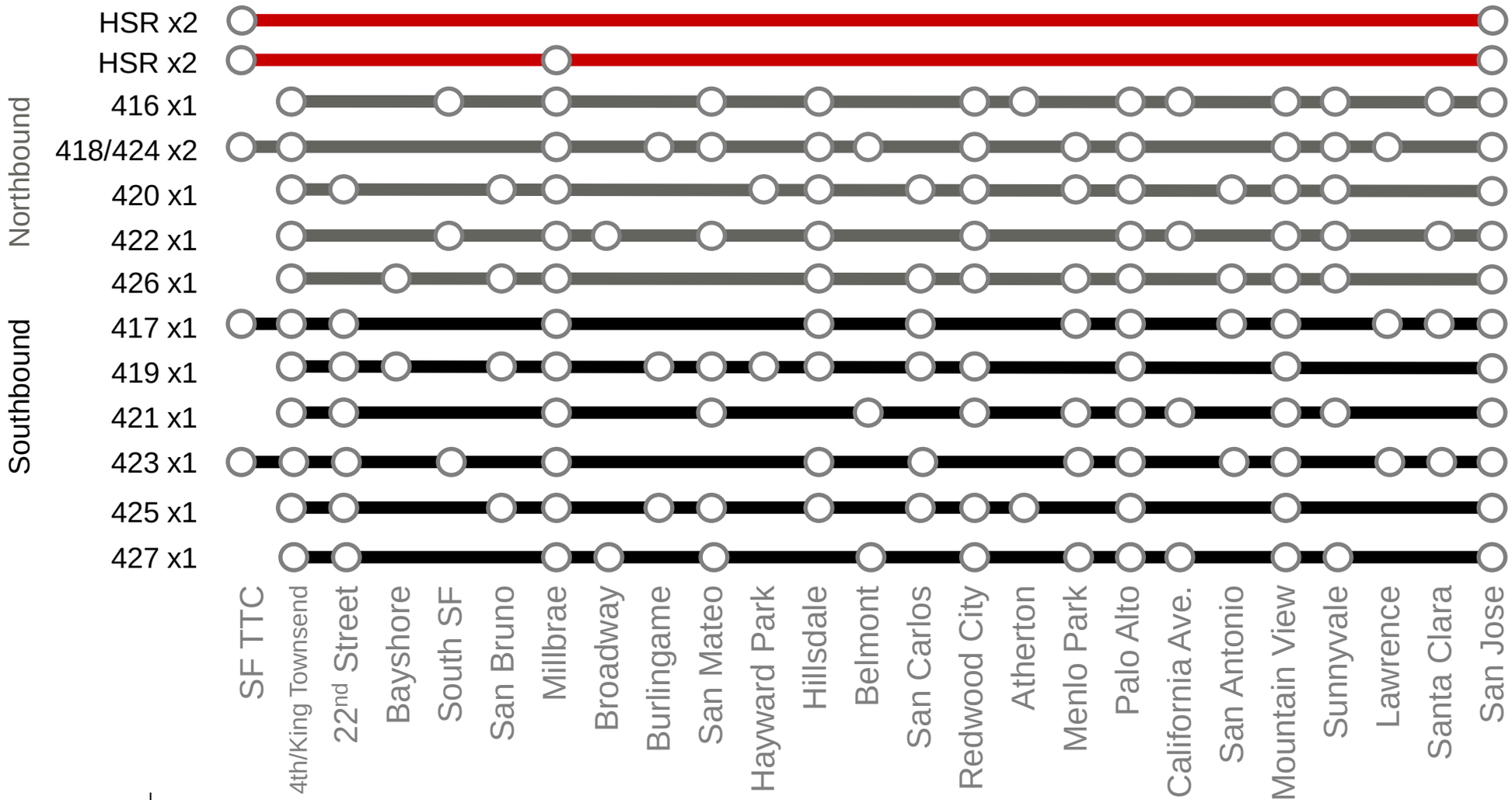
Caltrain Prototypical Skip Stop Pattern

2013 LTK Caltrain-HSR Blended Service Plan Ops Con Report, Table 3



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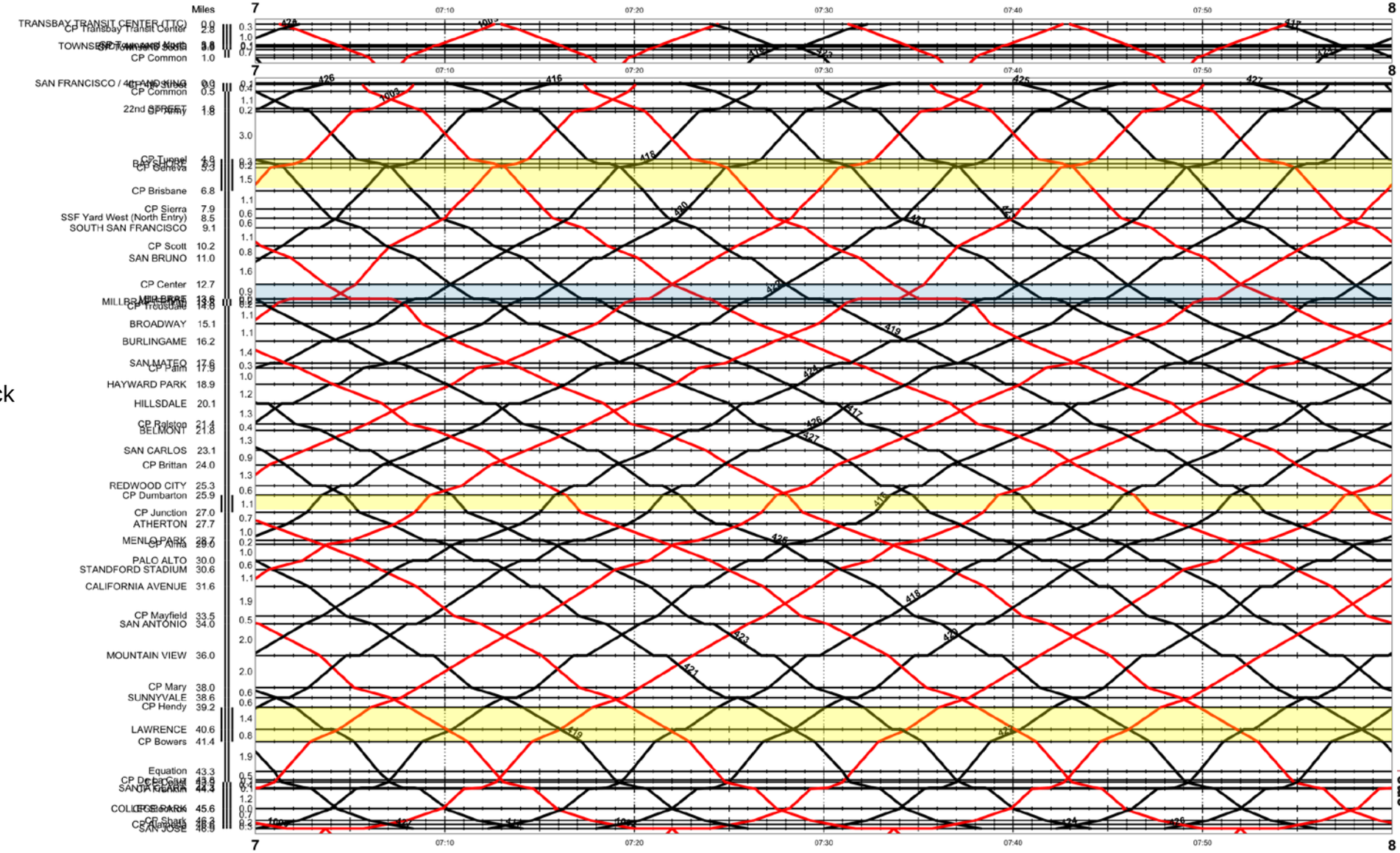
Skip Stop Concept 1.0 – String Line Chart



Concept 1.1 Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 5’, 4’ merging
New 4-track: Millbrae 4-track

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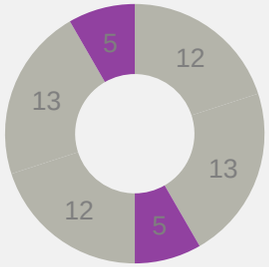
Skip Stop Concept 1.0 – Service Evaluation

SERVICE INTERVAL

Southbound Service Interval at Palo Alto

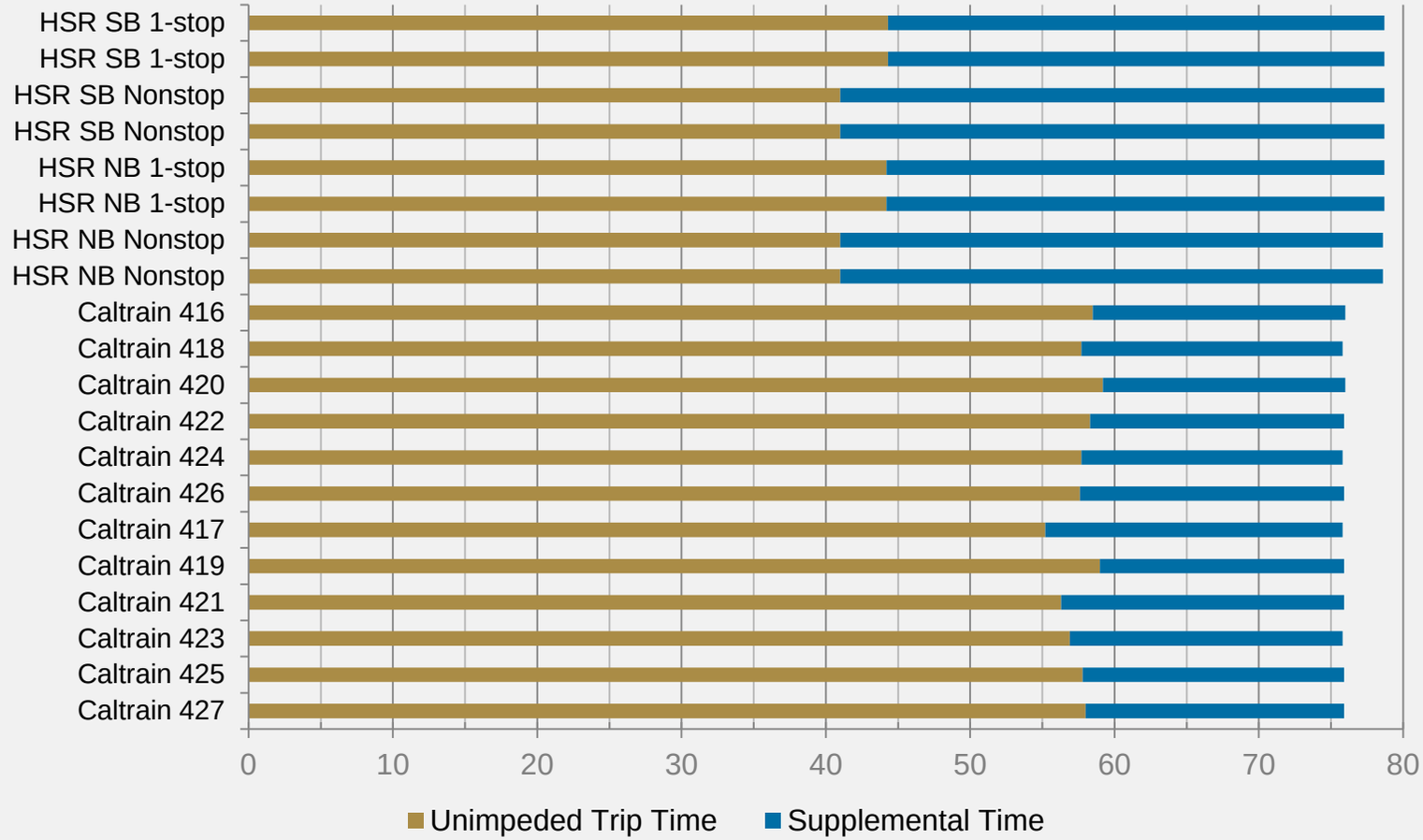
Northbound Service Interval at Palo Alto



AVERAGE TRIP TIME

Caltrain:	75.9 min
HSR Nonstop:	78.7 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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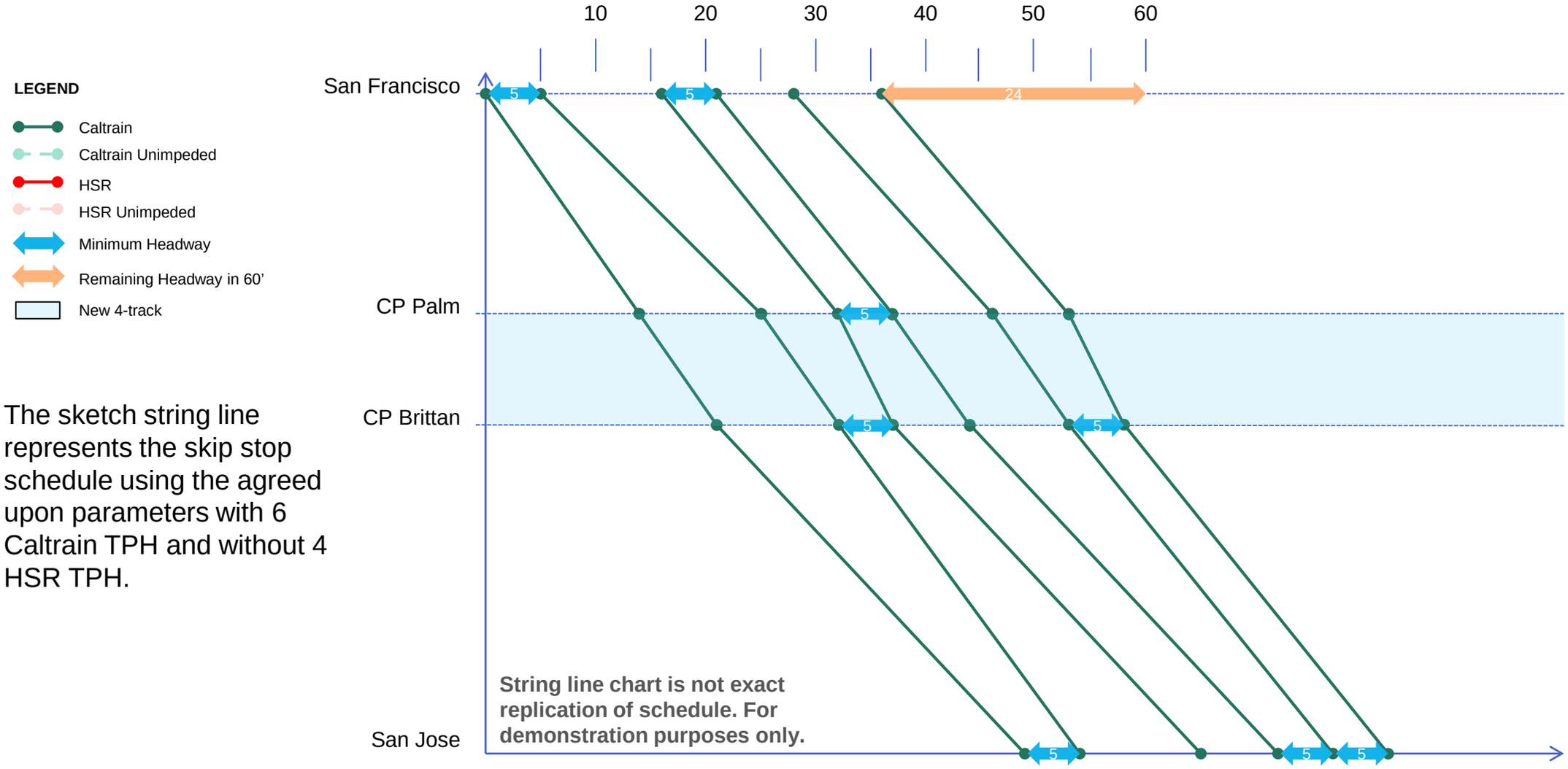
Overtake Analysis – Caltrain Only – Skip Stop



The sketch string line represents the skip stop schedule using the agreed upon parameters with 6 Caltrain TPH and without 4 HSR TPH.

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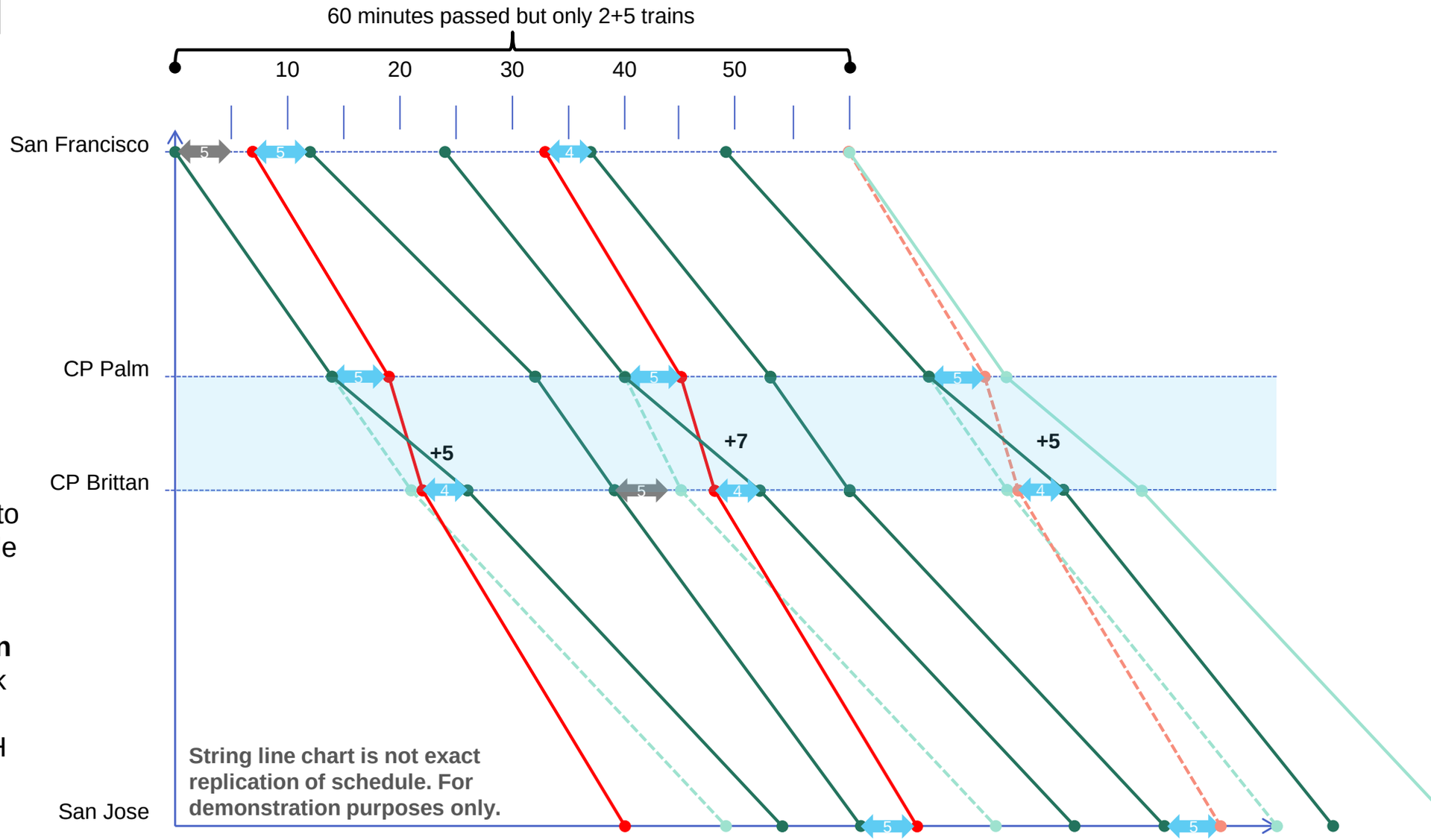
Overtake Analysis



LEGEND

- Caltrain
- Caltrain Unimpeded
- HSR
- HSR Unimpeded
- Minimum Headway
- Remaining Headway in 60'
- New 4-track

The sketch string line demonstrates an attempt to plan the skip stop schedule using the agreed upon parameters **without adding supplemental run time** outside of the 4-track limits. The result is slot space for only 2 HSR TPH and 5 Caltrain TPH.

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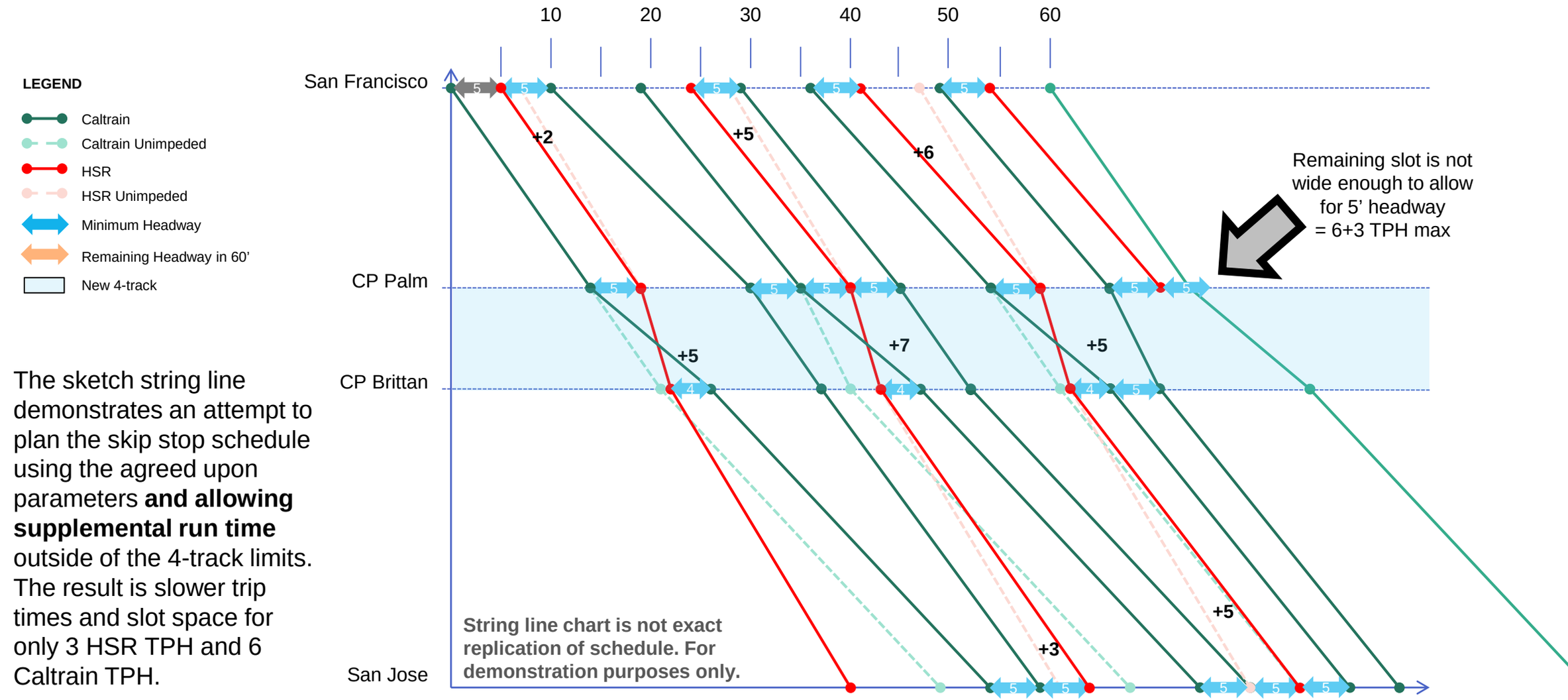
Overtake Analysis - Compressed



The sketch string line demonstrates an attempt to plan the skip stop schedule using the agreed upon parameters **and allowing supplemental run time** outside of the 4-track limits. The result is slower trip times and slot space for only 3 HSR TPH and 6 Caltrain TPH.

sma

Iteration 2 – Enhanced signaling system

Discussed: Working Group Meeting #5 – August 26, 2016

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Planning Assumptions – Iteration 2

Parameter	Assumption
Headway/ Separation	3 min corridor, 2 min diverging/merging at junctions
Minimum Turnaround Time	HSR: 20 min Caltrain: 20 min
Minimum Dwell Time	HSR: 2 min Caltrain: Dwell at least at each station for the times specified in the JPB/CAHSR Blended Operations Studies
Rolling Stock	HSR: Generic High Speed Trainset Caltrain: Adapted to EMU RFP train performance and 8 coach train length
Infrastructure	Millbrae Station: CP Center (MP 12.65) to CP Trousdale (MP 14.01) Terminal Configurations at San Jose, 4th/King 4-track Improvement options assumed: • No additional passing tracks • Short middle 4-track: CP Palm (MP 17.91) to just after CP Brittan (MP 24.00) • Long middle 4-track CP Palm (MP 17.91) to CP Junction (MP 26.99)
Speed Limit	110 mph
Terminal Station SF	HSR: TTC Caltrain: 4th & King and TTC

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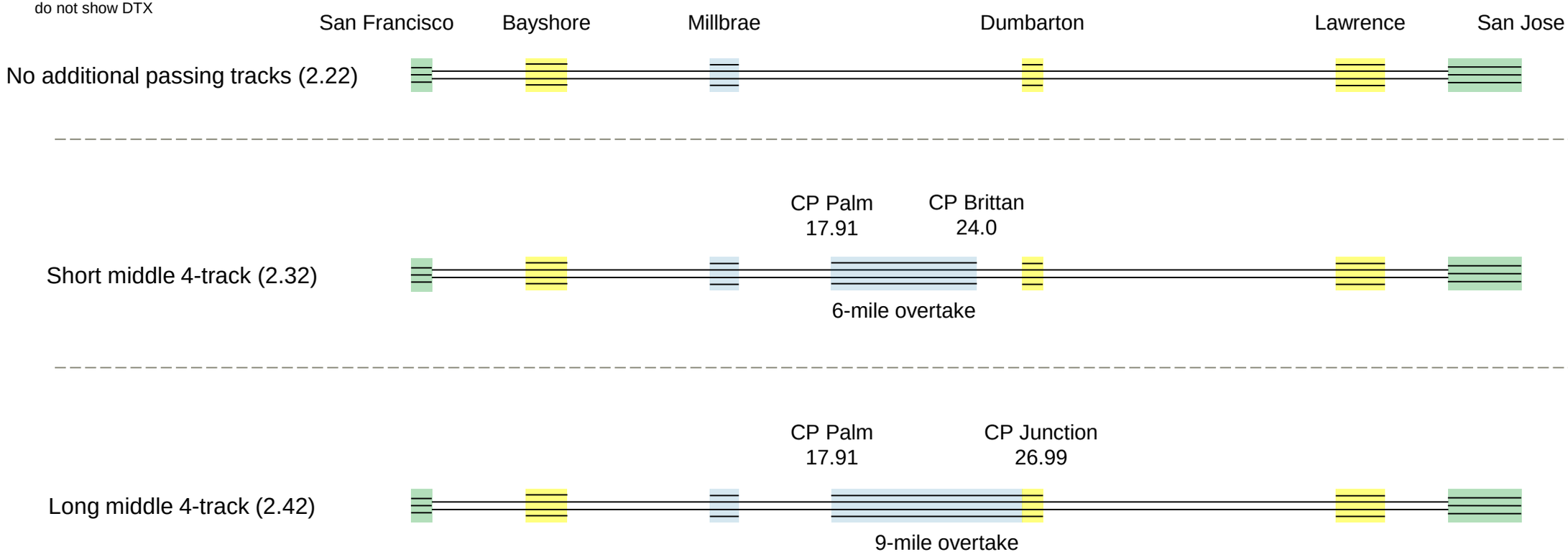
Infrastructure Options – Iteration 2

LEGEND

- New 4-track
- Current 3-track
- Current 4-track

For simplicity, diagrams do not show DTX



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Concept 2.22

Infrastructure Option:

No Additional Passing Tracks

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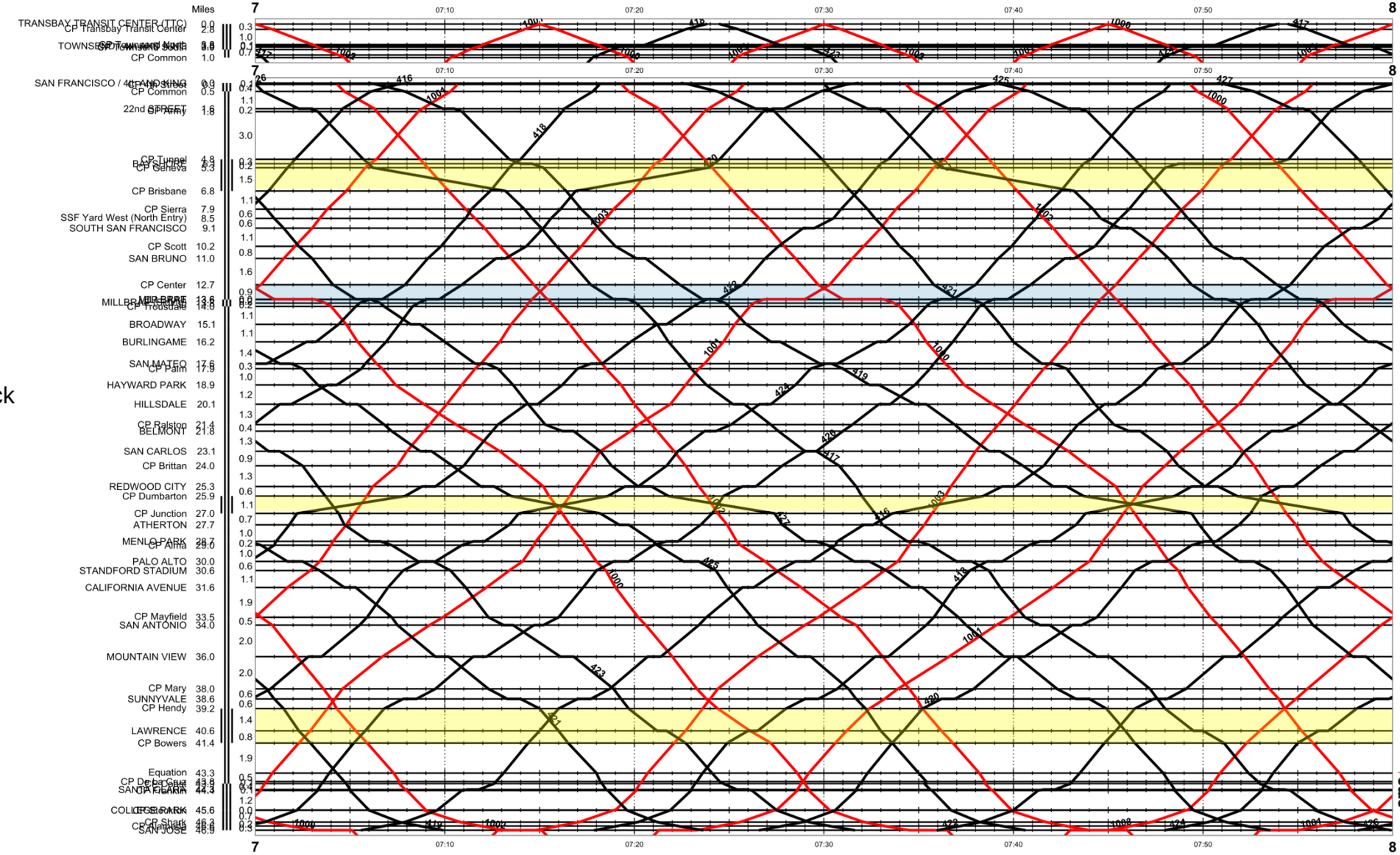
HSR Interval, No Added Passing Tracks (NAPT) String Line Chart



Concept 2.22 Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 3’, 2’
New 4-track: Millbrae 4-track

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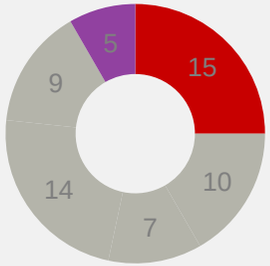
HSR Interval, No Added Passing Tracks (NAPT) Service Evaluation

SERVICE INTERVAL

Southbound Service Interval at Palo Alto

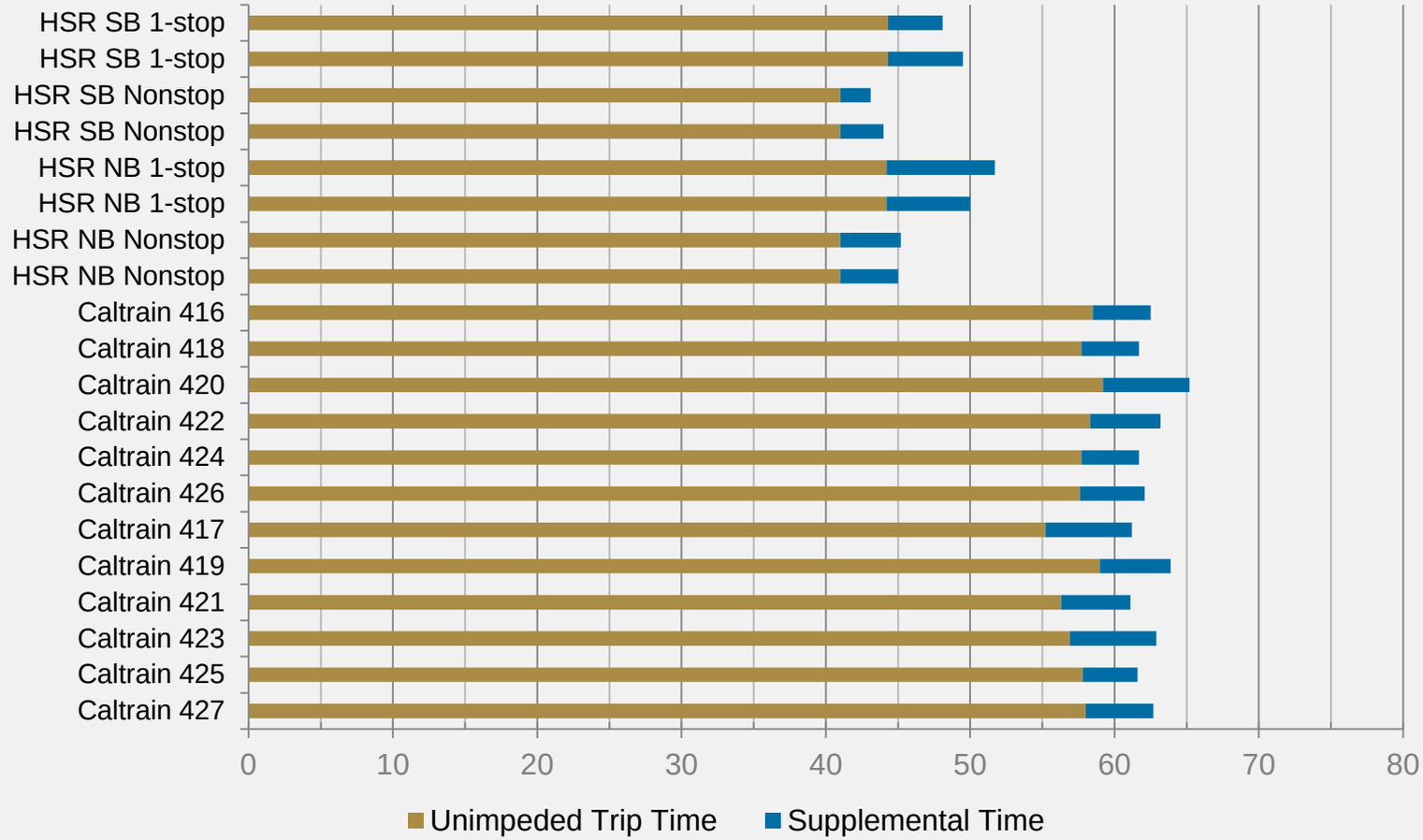


Northbound Service Interval at Palo Alto

AVERAGE TRIP TIME

Caltrain:	62.5 min
HSR Nonstop:	44.3 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Concept 2.32

Infrastructure Option:

Short Middle 4-Track

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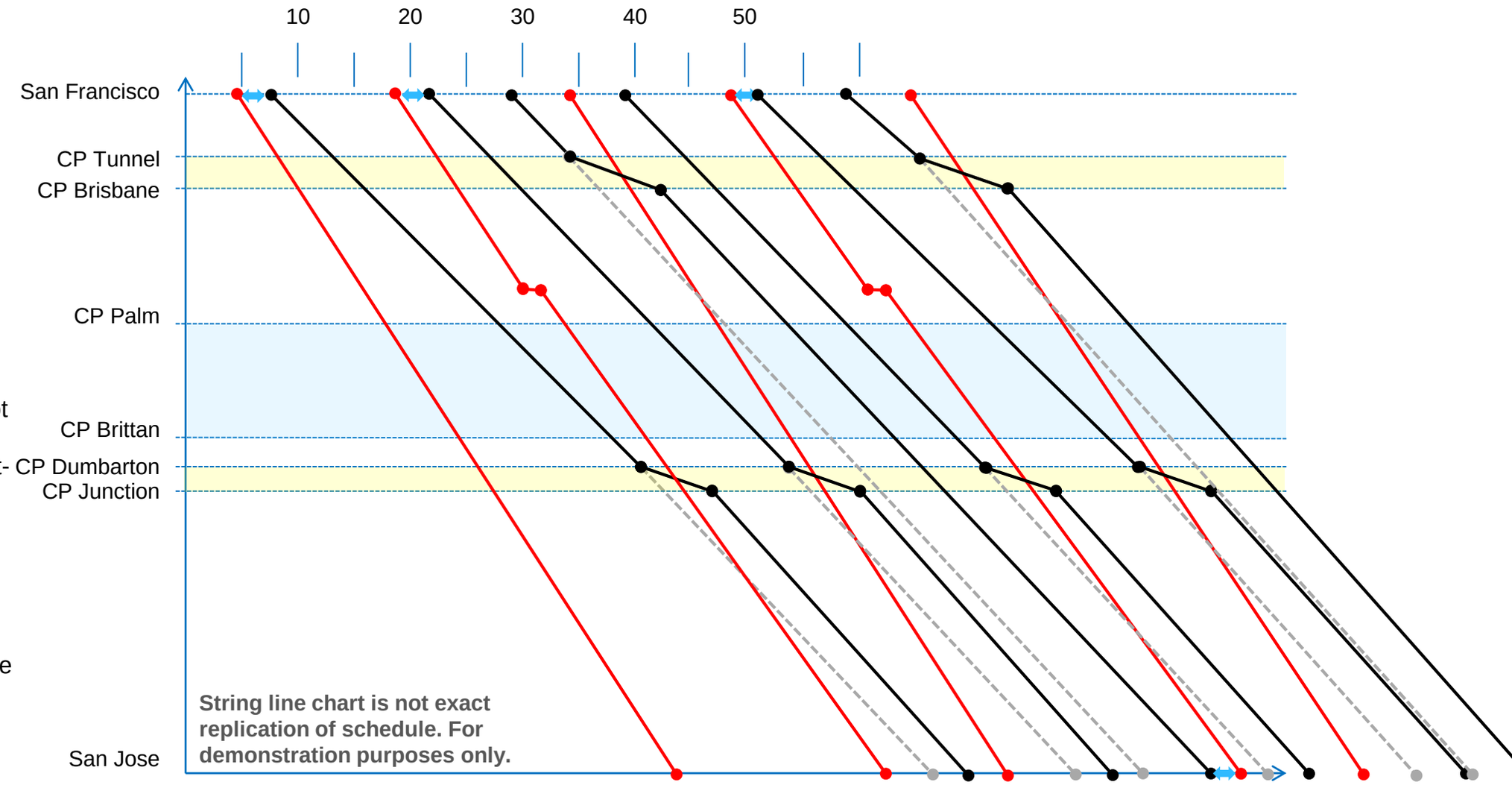
Overtake Analysis



The sketch string line demonstrates an attempt to plan the skip stop schedule using the short-middle 4-track overtake location. Given the parameters used, the more appropriate locations for overtakes are at Brisbane and Dumbarton and not in the short-middle overtake location.

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HSR Interval, Short Middle 4-track (SM4T) String Line Chart

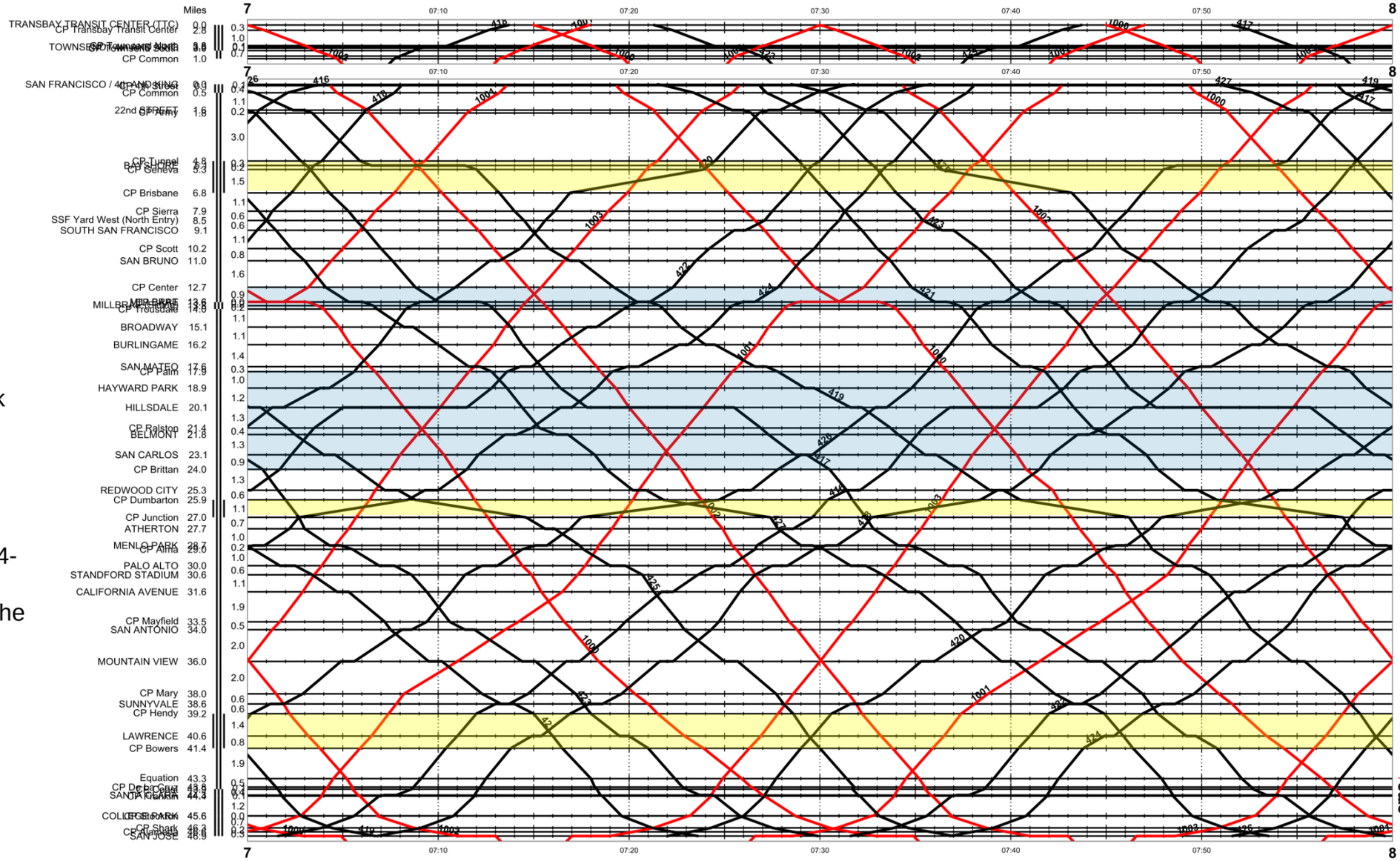
LEGEND

- HSR
- Caltrain
- New 4-track
- Current 4-track

Concept 2.32 Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 3', 2'
New 4-track: Millbrae 4-track
Short middle 4-track section

This concept uses a "forced overtake" in the short-middle 4-track section and, therefore, produces worse results than the concept with no additional overtake locations



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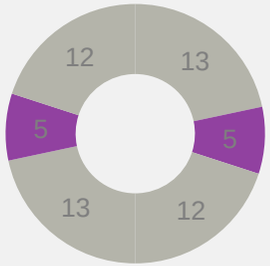
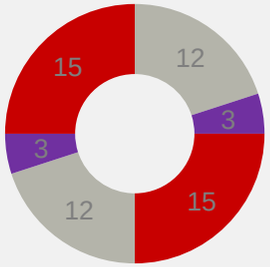
HSR Interval, Short Middle 4-Track (SM4T) Service Evaluation

SERVICE INTERVAL

Southbound Service Interval at Palo Alto



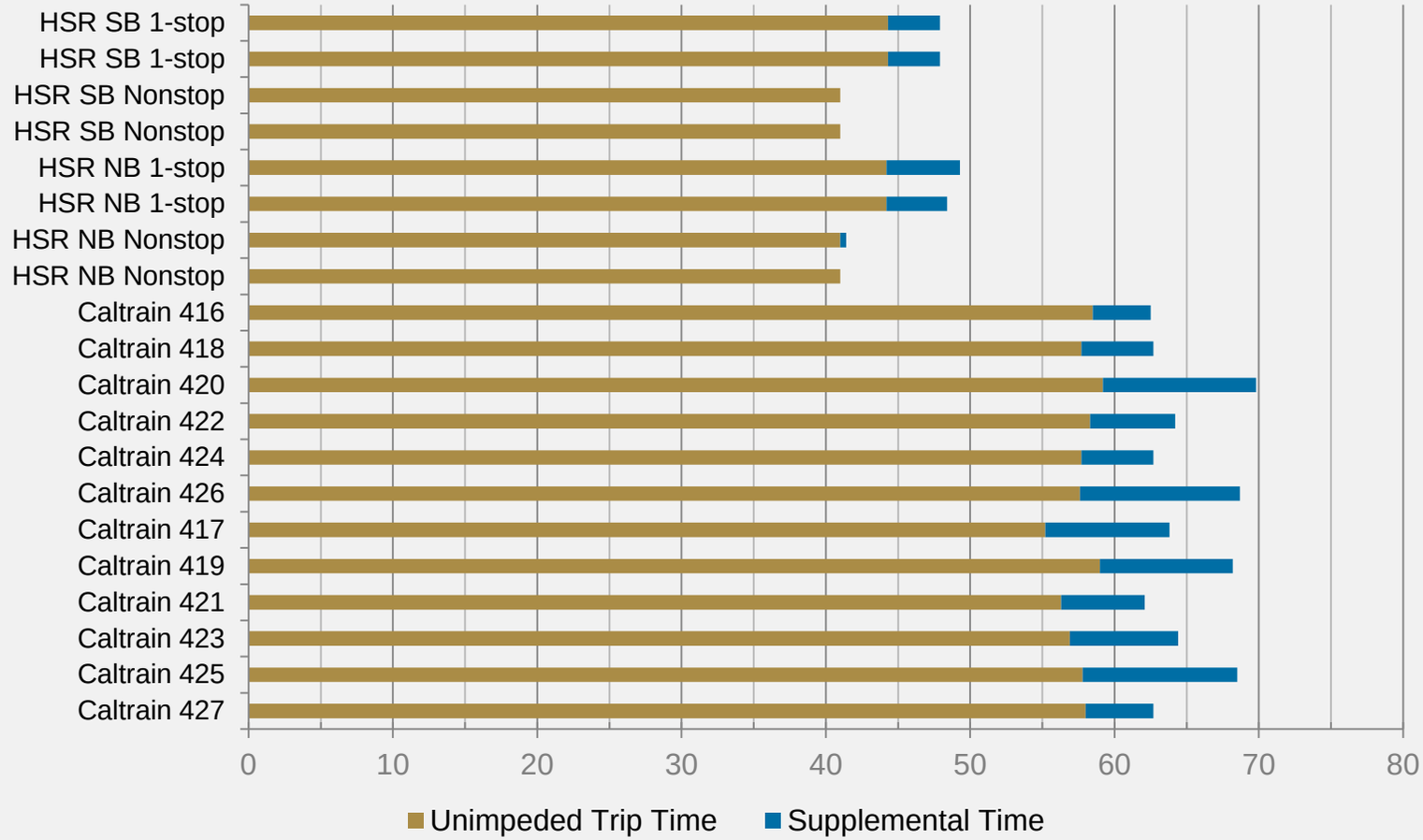
Northbound Service Interval at Palo Alto



AVERAGE TRIP TIME

Caltrain:	65.0 min
HSR Nonstop:	41.1 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Concept 2.42

Infrastructure Option:

Long Middle 4-track

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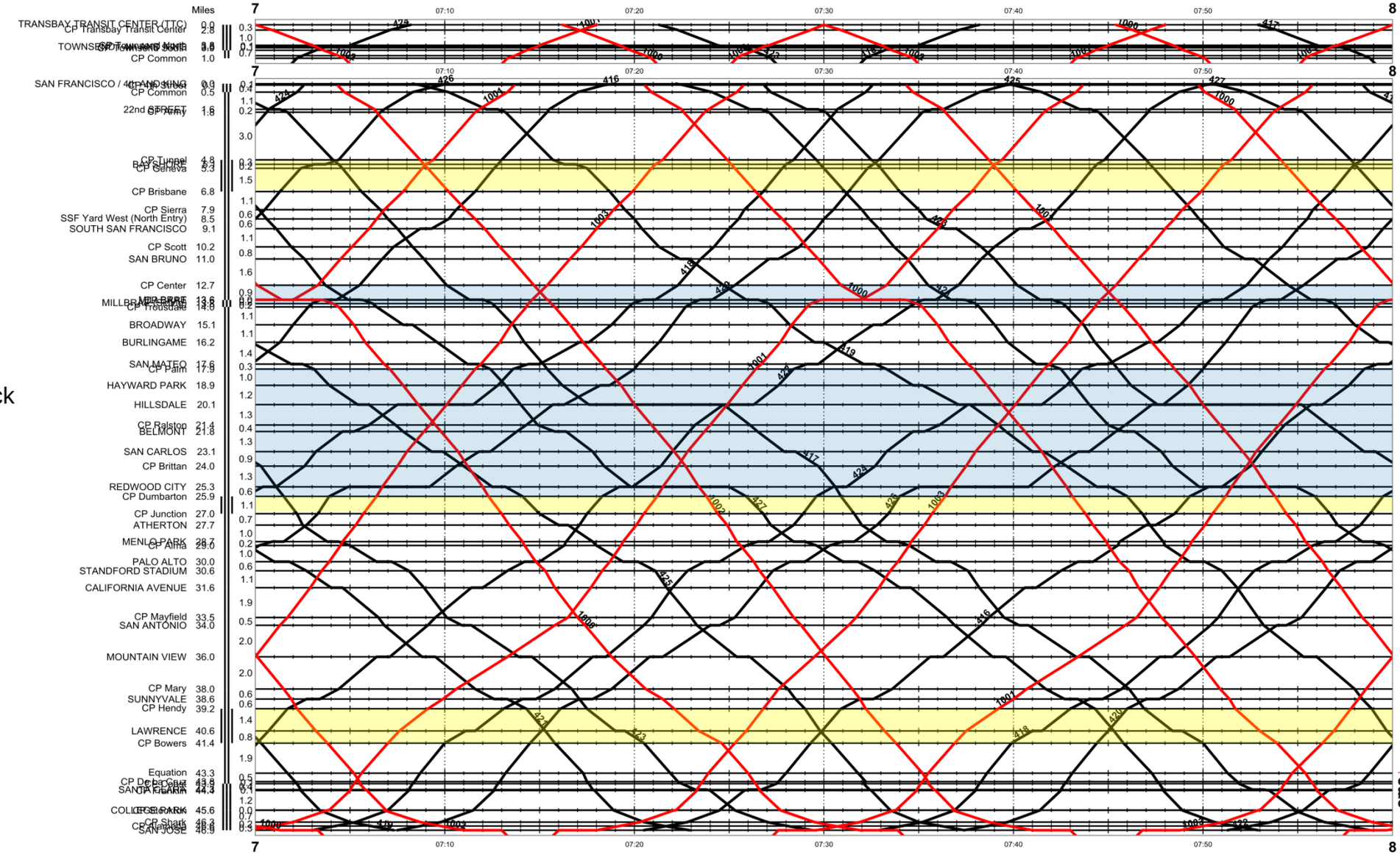
HSR Interval, Long Middle 4-Track (LM4T) String Line Chart



Concept 2.42 Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 3’, 2’
New 4-track: Millbrae 4-track
Long middle 4-track section

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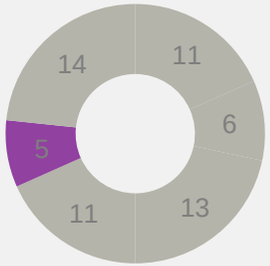
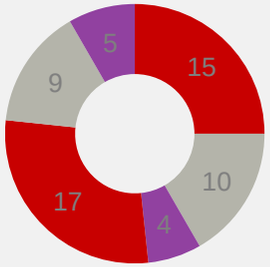
HSR Interval, Long Middle 4-Track (LM4T) Service Evaluation

SERVICE INTERVAL

Southbound Service Interval at Palo Alto



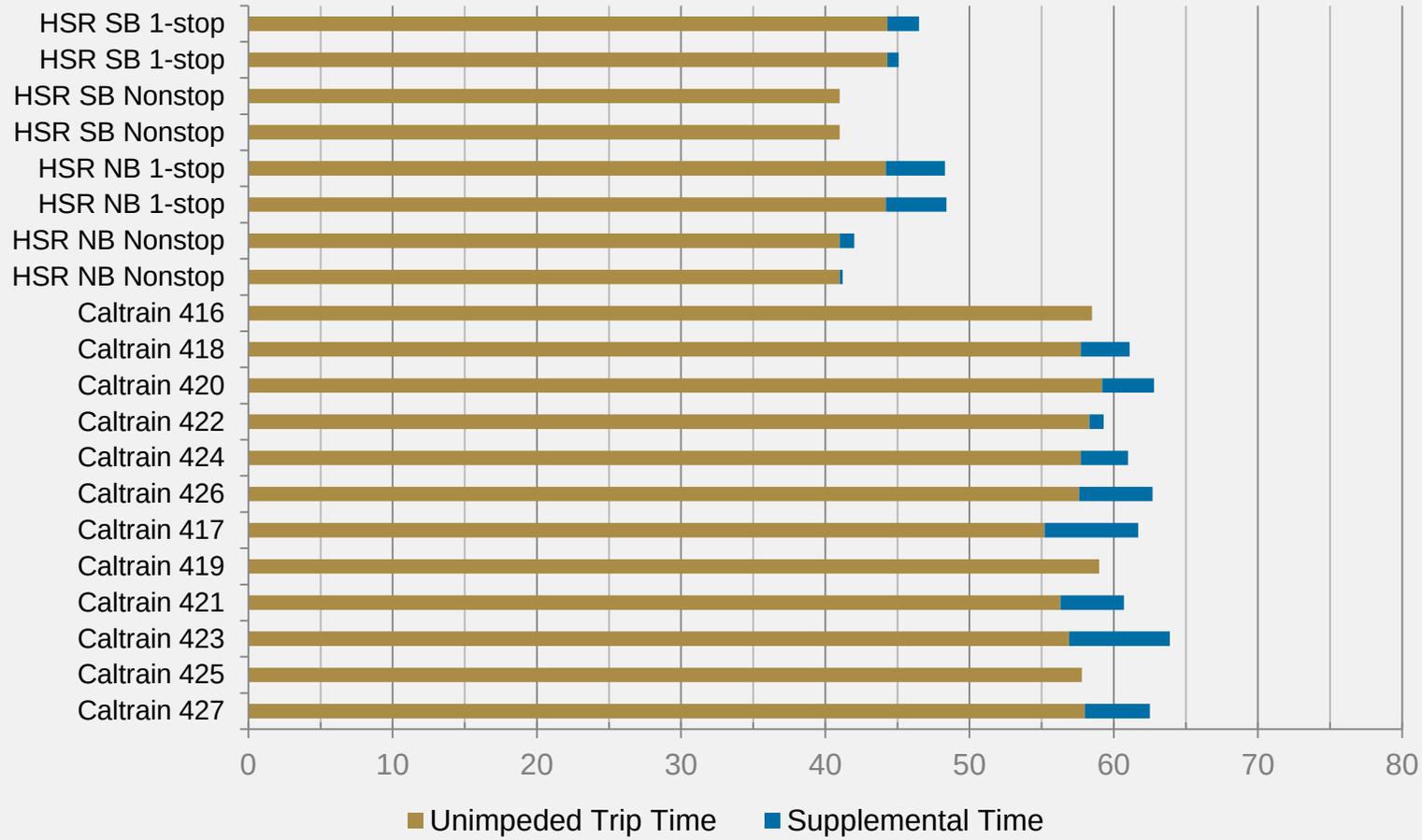
Northbound Service Interval at Palo Alto



AVERAGE TRIP TIME

Caltrain:	60.9 min
HSR Nonstop:	41.3 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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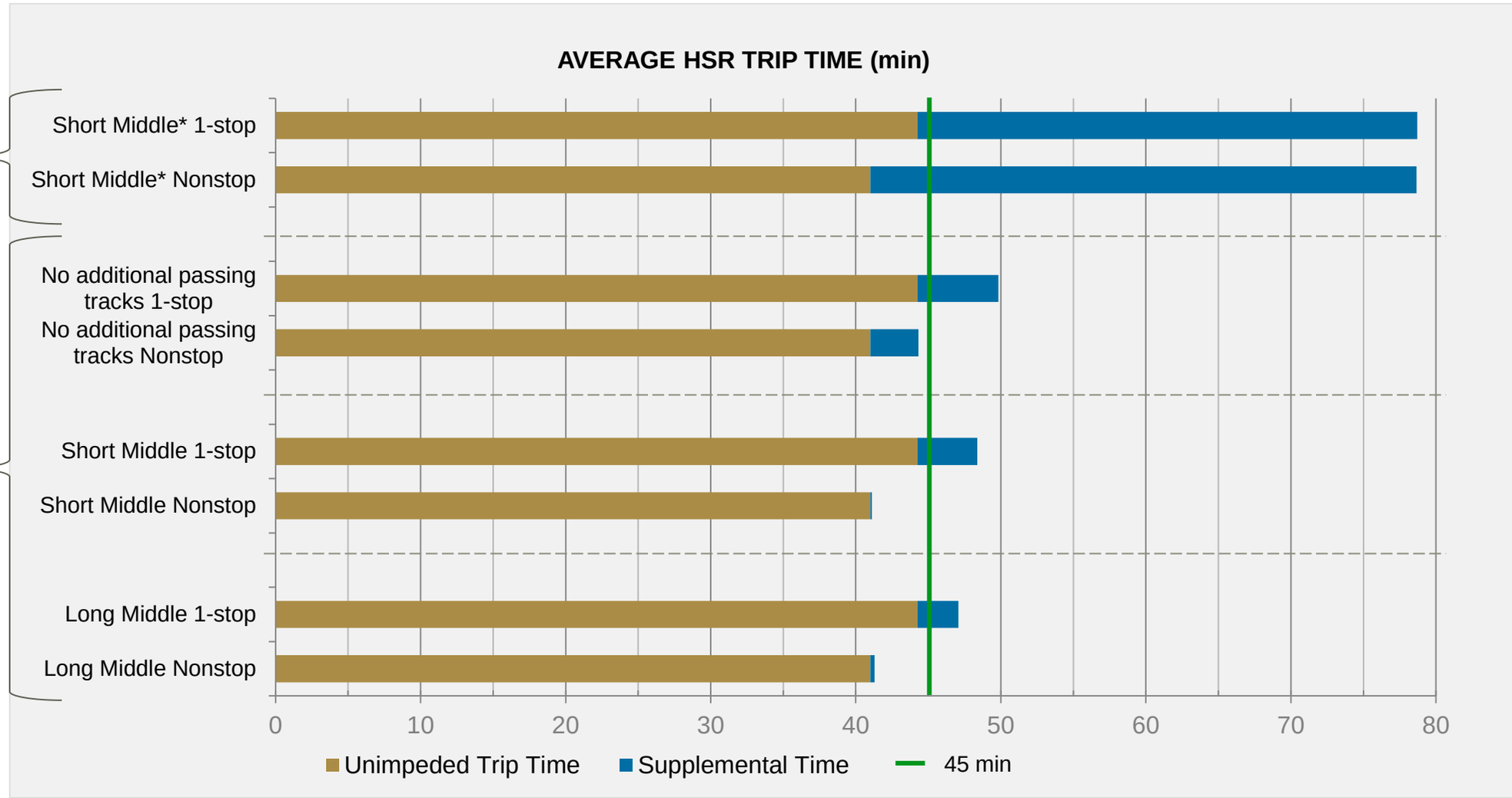
HSR **Interval** Concepts – HSR Evaluation

SIGNAL CAPABILITY

5/4 min headways

3/2 min headways



*Unable to effectively use short-middle 4-track overtake with 5-min headways - resulting in a no build scenario
**Results reflect a forced overtake in the short-middle overtake location

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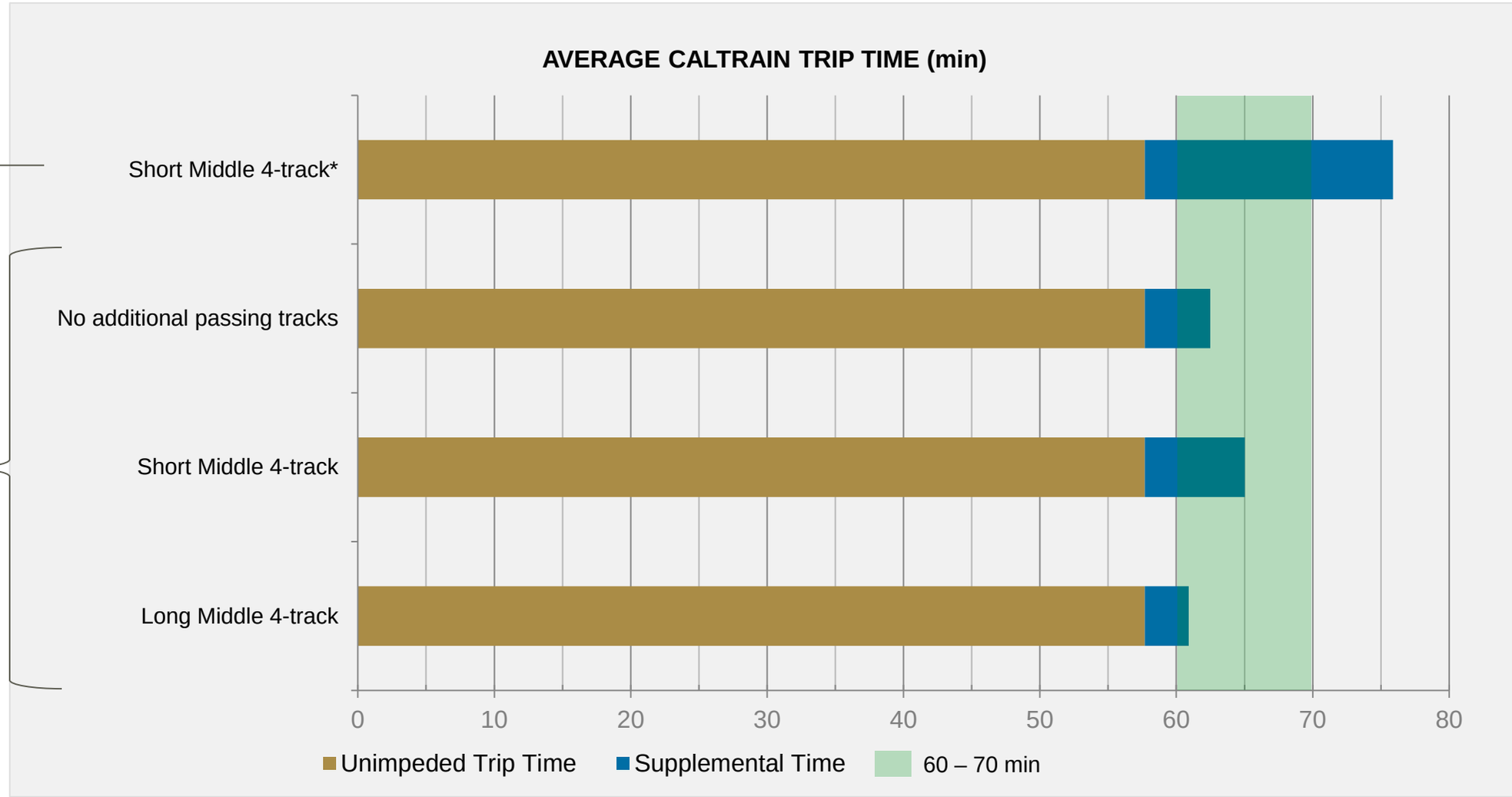
HSR **Interval** Concepts – Caltrain Evaluation

SIGNAL CAPABILITY

5/4 min headways

3/2 min headways



*Unable to effectively use short-middle 4-track overtake with 5-min headways - resulting in a no build scenario
**Results reflect a forced overtake in the short-middle overtake location
All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Concept 2.0

Infrastructure Option:

Existing Infrastructure + Caltrain Identified Capital Program Improvements

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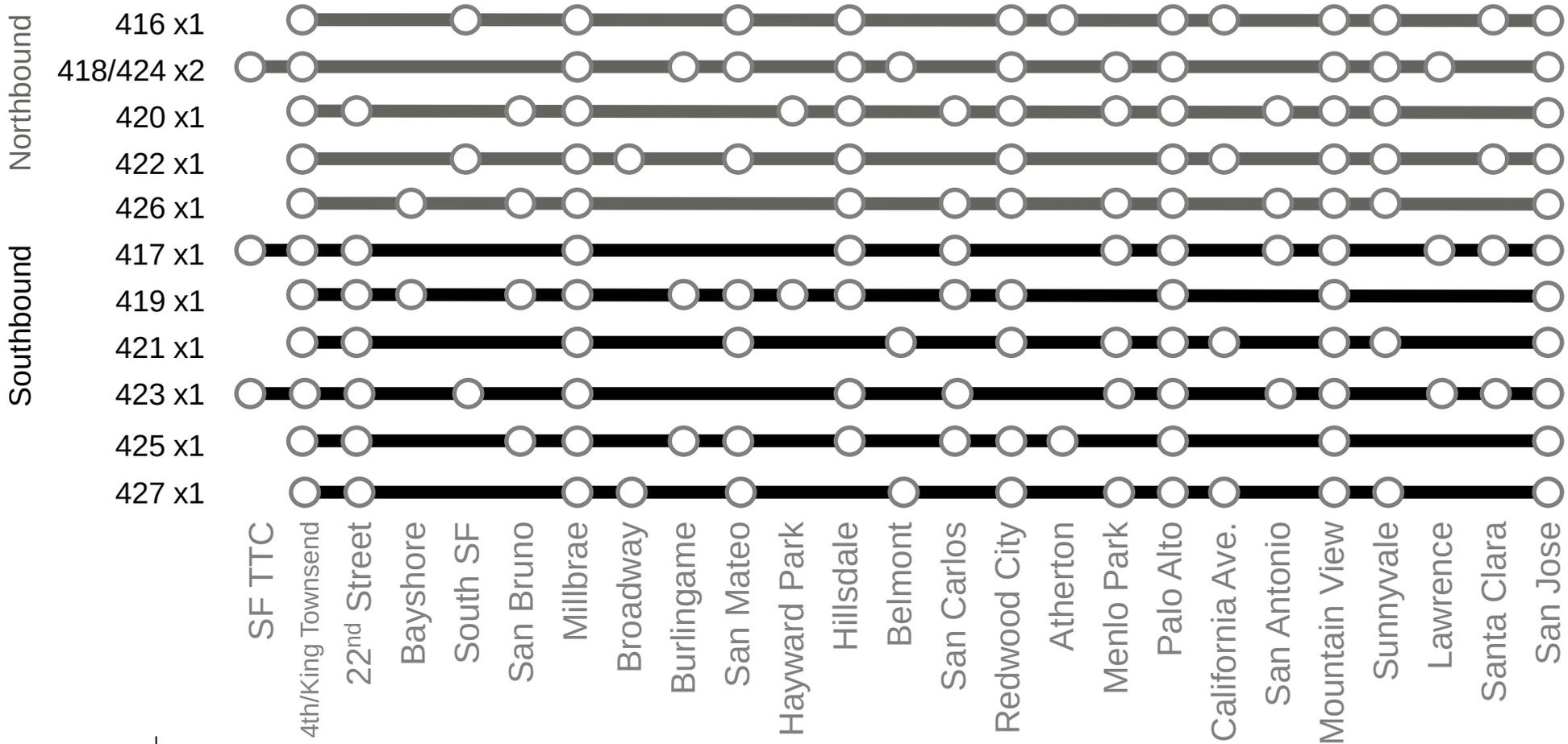
Caltrain Prototypical Skip Stop Pattern

2013 Caltrain-HSR Blended Service Plan Ops Con Report, Table 3



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Planning Assumptions – Concept 2.0

Parameter	Assumption
Headway/ Separation	5 min corridor, 4 min diverging/merging at junctions
Minimum Turnaround Time	Caltrain: 20 min
Minimum Dwell Time	Caltrain: Dwell at least at each station for the times specified in the JPB/CAHSR Blended Operations Studies
Rolling Stock	Caltrain: Adapted to EMU RFP train performance and 8 coach train length
Infrastructure	Existing track layout together with Caltrain identified capital program improvements
Speed Limit	79 mph
Terminal Station SF	Caltrain: 4th & King and TTC

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Caltrain 6TPH, 79 MPH – Service Evaluation

SERVICE INTERVAL

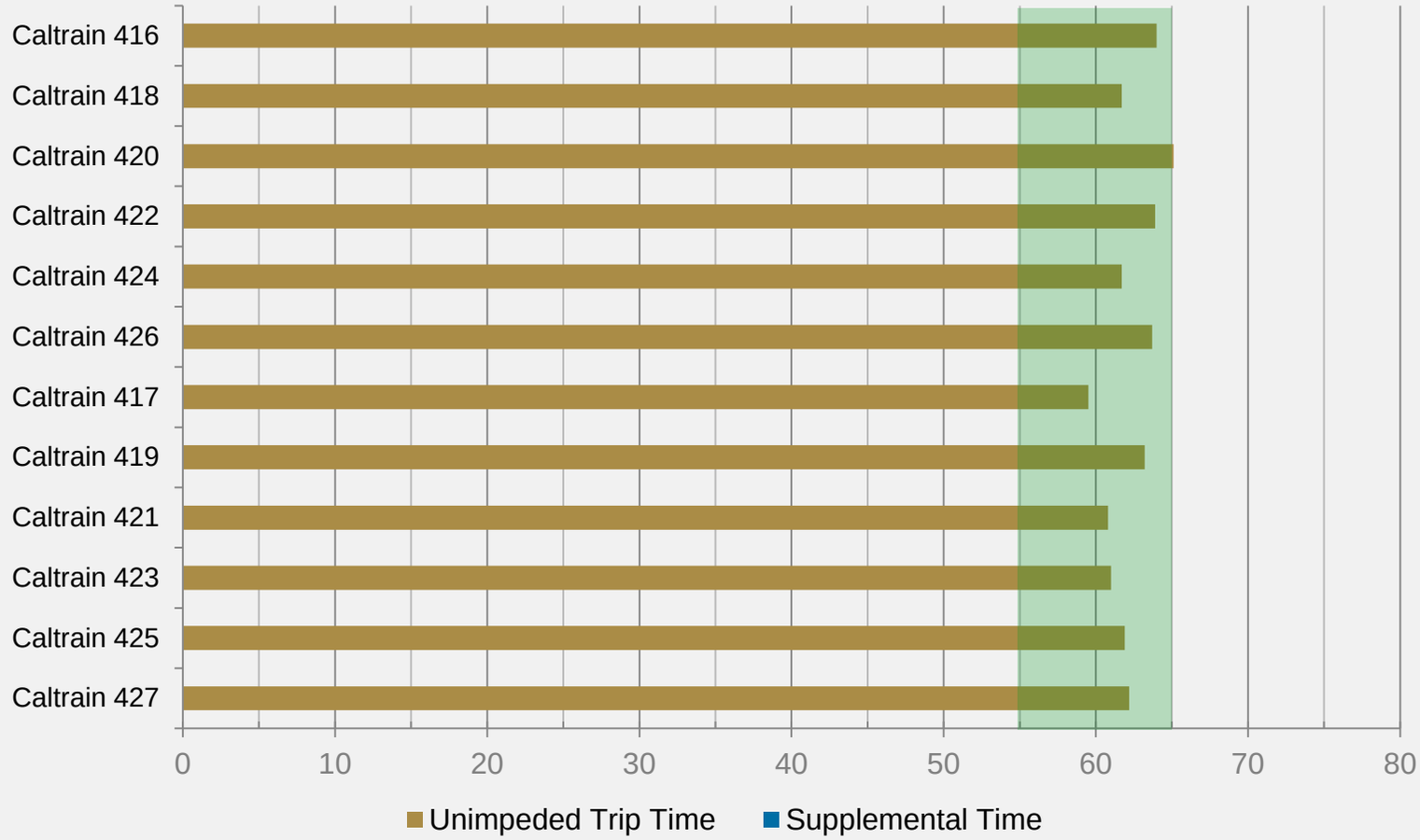
Southbound Service Interval at Palo Alto

Northbound Service Interval at Palo Alto

AVERAGE TRIP TIME

Caltrain:	62.4 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Not for distribution

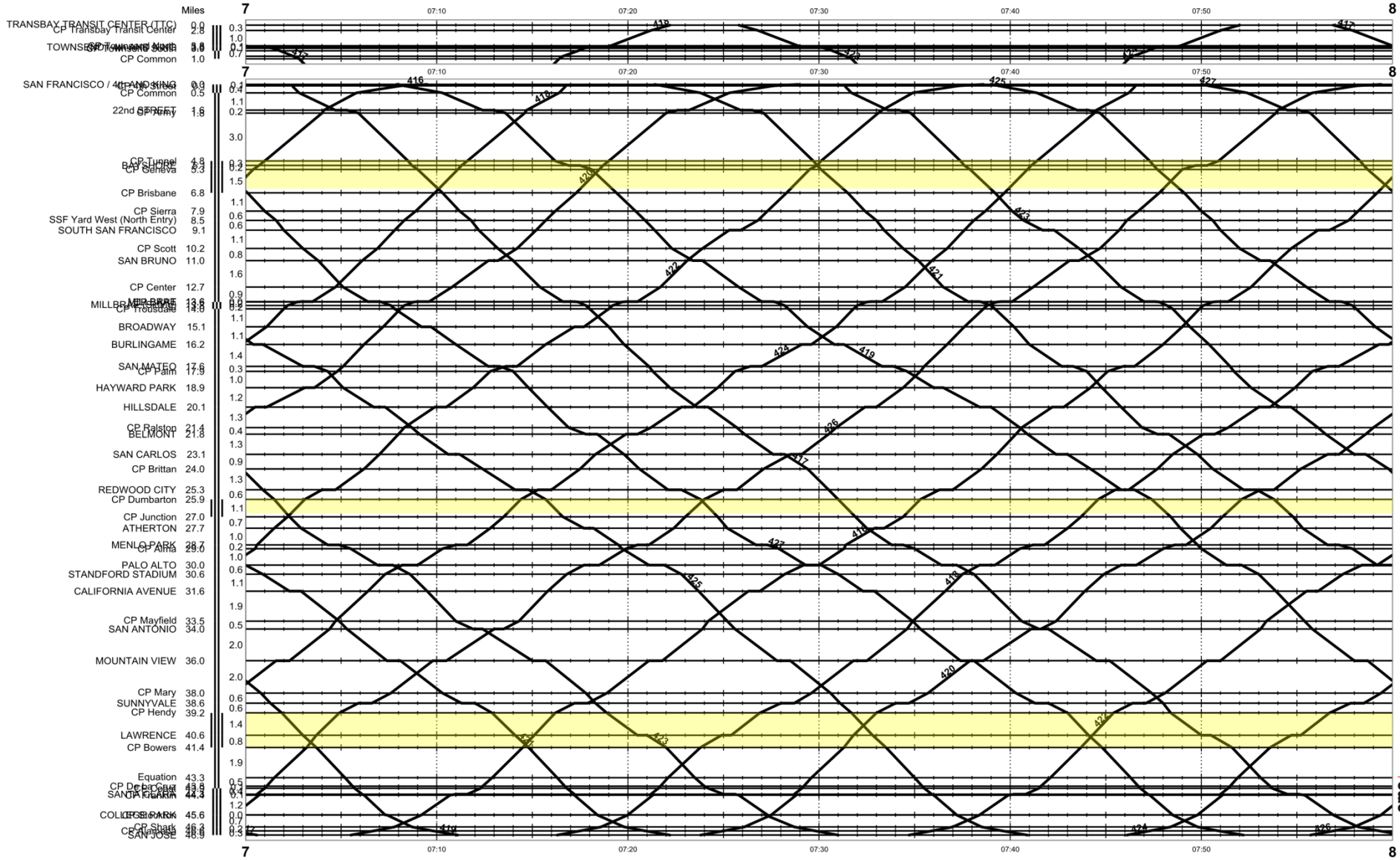
Caltrain 6TPH, 79 MPH – String Line

LEGEND

- HSR
- Caltrain
- New 4-track
- New 3-track
- Current 4-track

Concept Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 5’, 4’



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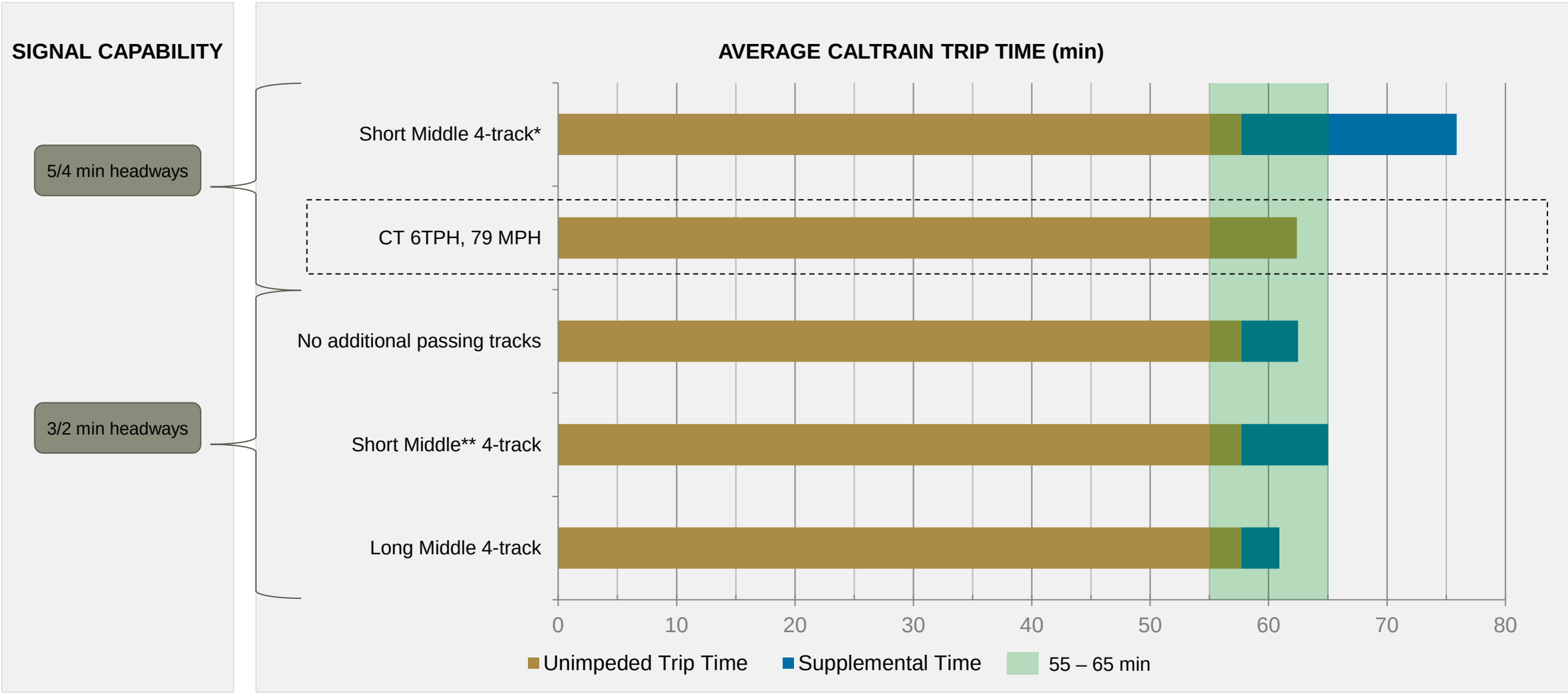
Not for distribution

Caltrain Evaluation



*Unable to effectively use short-middle 4-track overtake with 5-min headways - resulting in a no build scenario
**Results reflect a forced overtake in the short-middle overtake location
All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Concept 2.5B

Infrastructure Option:

Long Middle 3-track

Discussed: Working Group Meeting #6 - October 14, 2016

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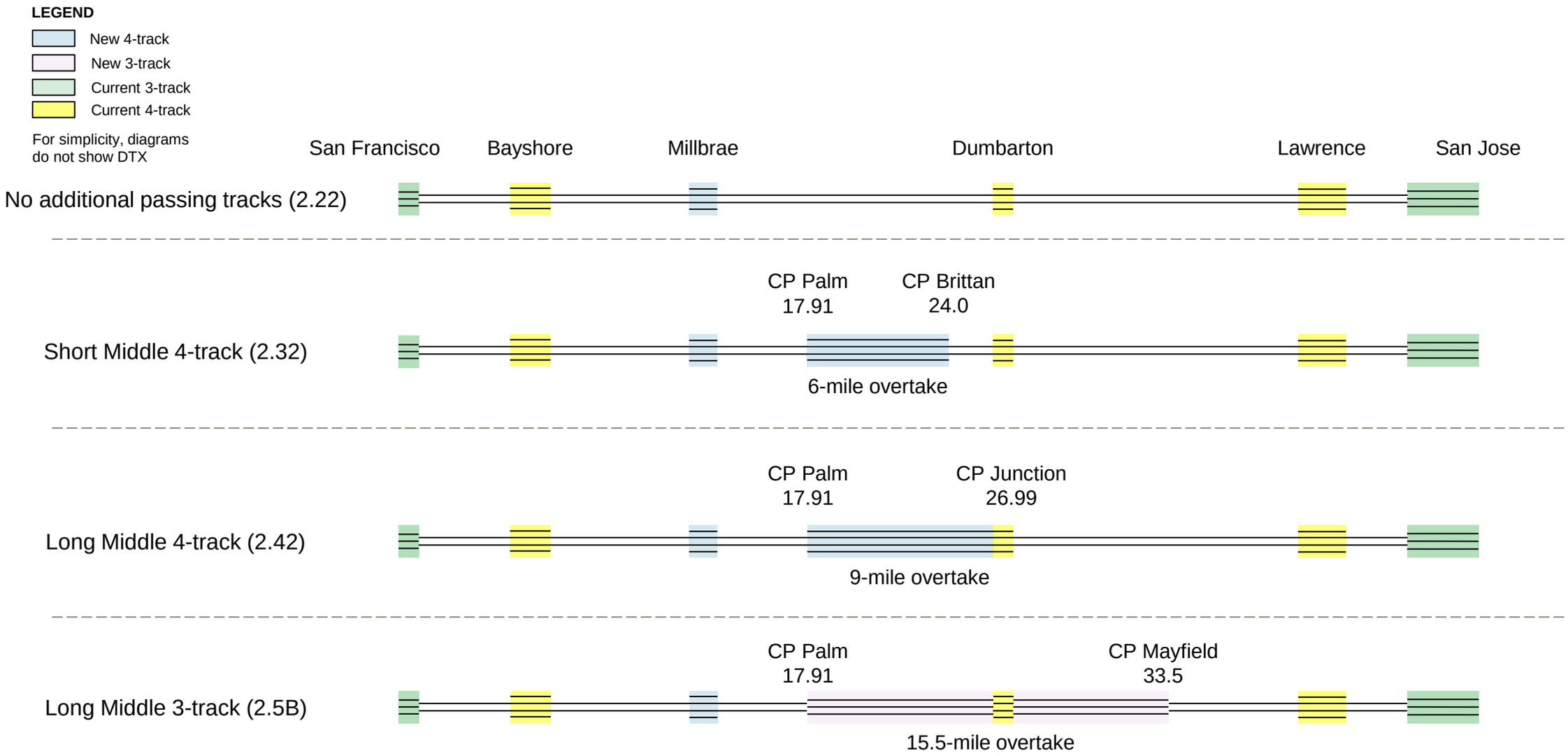
Infrastructure Options



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Planning Assumptions – Iteration 2.0

Parameter	Assumption
Headway/ Separation	3 min corridor, 2 min diverging/merging at junctions
Minimum Turnaround Time	HSR: 20 min Caltrain: 20 min
Minimum Dwell Time	HSR: 2 min Caltrain: Dwell at least at each station for the times specified in the JPB/CAHSR Blended Operations Studies
Rolling Stock	HSR: Generic High Speed Trainset Caltrain: Adapted to EMU RFP train performance and 8 coach train length
Infrastructure	Millbrae Station: CP Center (MP 12.65) to CP Trousdale (MP 14.01) Terminal Configurations at San Jose, 4th/King 4-track Improvement options assumed: • No additional passing tracks • Long-middle 3-Track: CP Palm (MP 17.91) - CP Mayfield (MP 33.50) • Short-middle 4-Track: CP Palm (MP 17.91 to just after CP Brittan (MP 24.00) • Long-middle 4-track CP Palm (MP 17.91) to CP Junction (MP 26.99)
Speed Limit	110 mph
Terminal Station SF	HSR: TTC Caltrain: 4th & King and TTC

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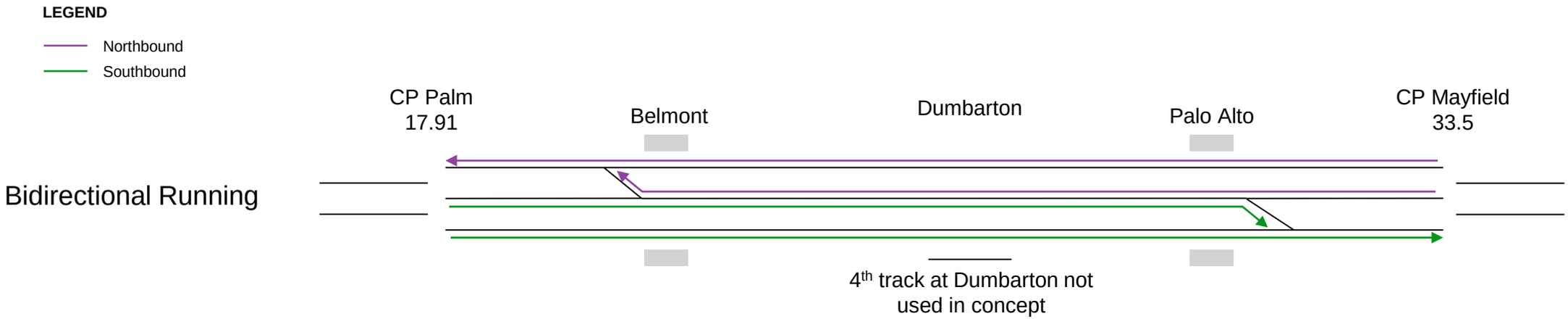
Long-middle 3-track– Configuration



Bidirectional running allows for both northbound and southbound trains to use the third track between Belmont and Palo Alto. In this iteration, we have used a minimum 2 min separation time between two opposing trains on the shared track.

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Long Middle 3-Track (LM3T) - String Line

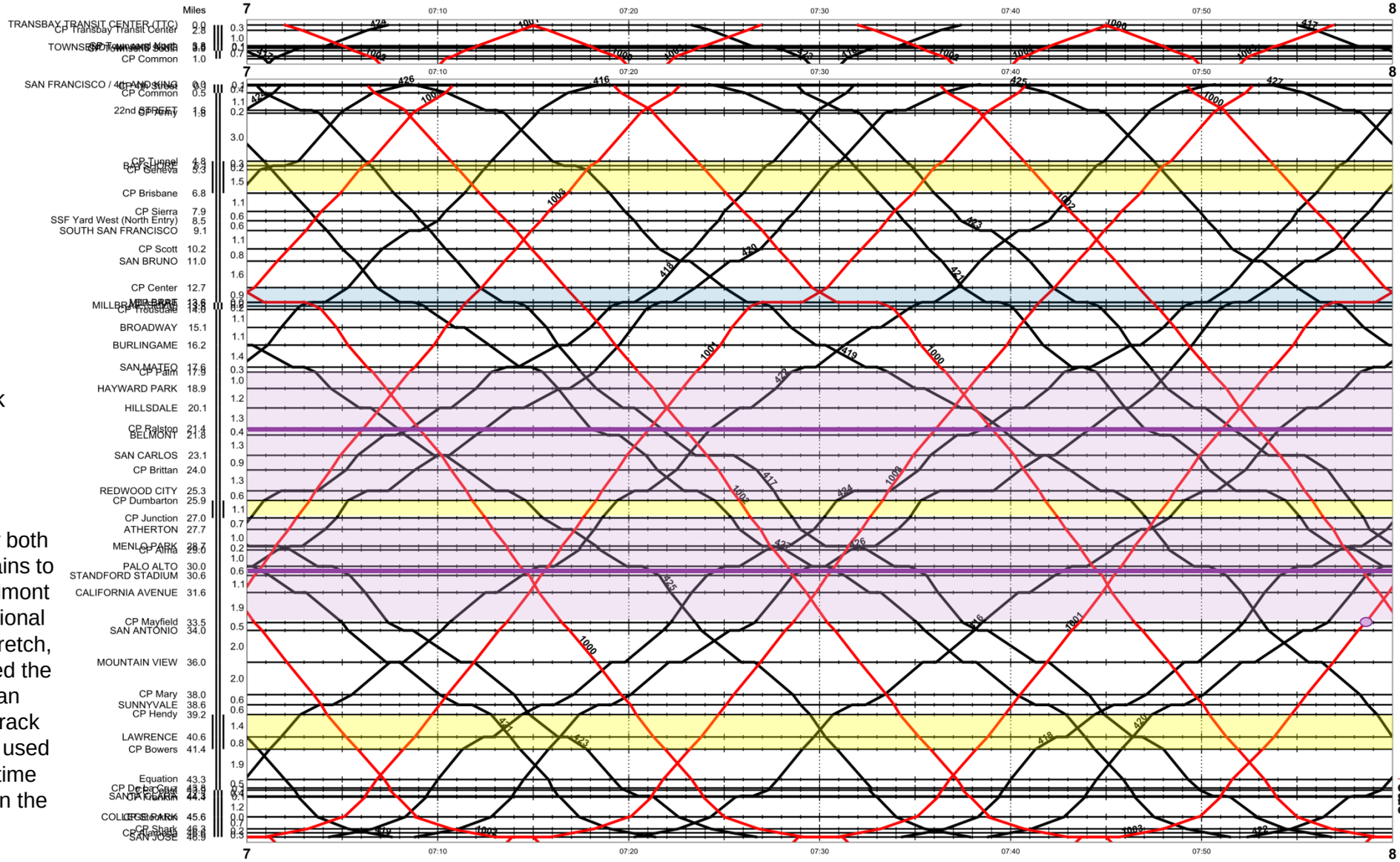
LEGEND

- HSR
- Caltrain
- New 4-track
- New 3-track
- Current 4-track

Concept 2.5B Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 3', 2'
New 4-track: Millbrae 4-track
Long middle 3-track section

Bidirectional running allows for both northbound and southbound trains to use the third track between Belmont and Palo Alto. By adding additional crossovers along the 3-track stretch, some HSR trains that don't need the full length of the 3-track for an overtake can exit the shared track early. In this iteration, we have used a minimum 2 min separation time between two opposing trains on the shared track.



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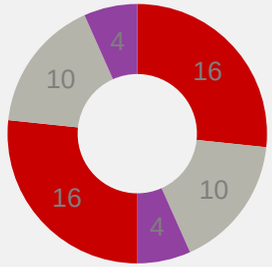
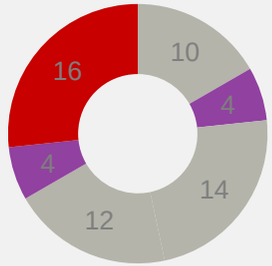
Long Middle 3-Track (LM3T) - Service Evaluation

SERVICE INTERVAL

Southbound Service Interval at Palo Alto



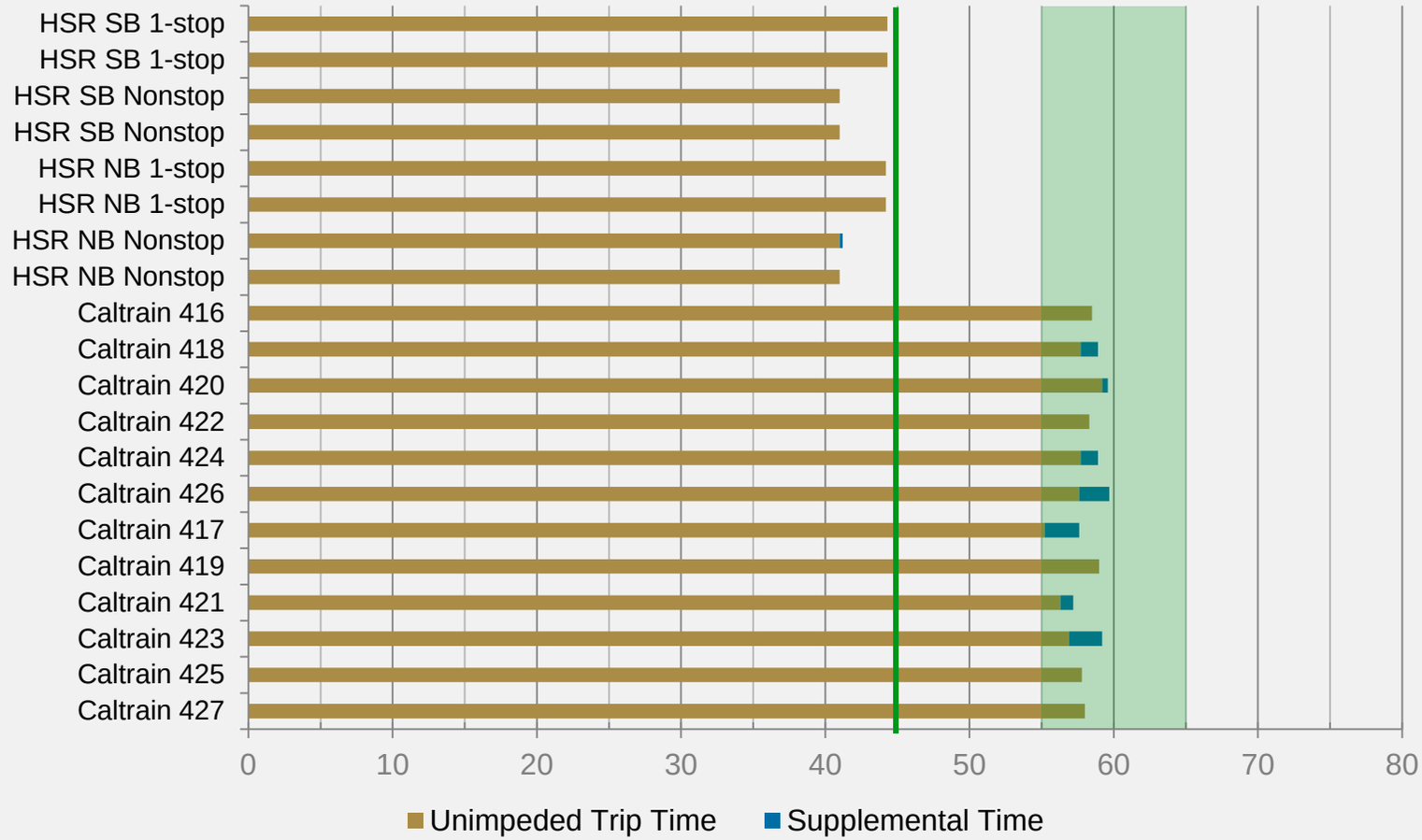
Northbound Service Interval at Palo Alto



AVERAGE TRIP TIME

Caltrain:	58.6 min
HSR Nonstop:	41.1 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Concept Comparison

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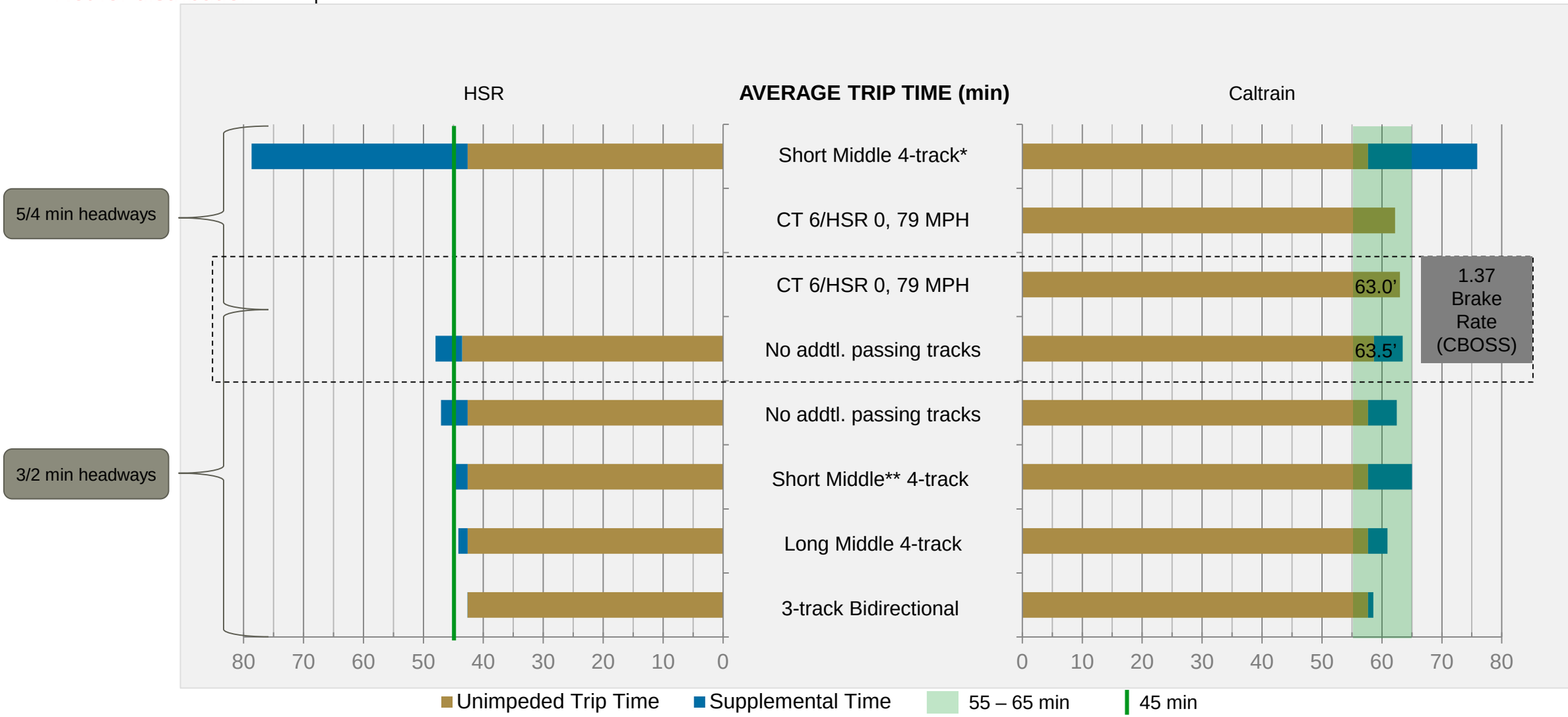
HSR & Caltrain Trip Time Evaluation *DRAFT*



*Unable to effectively use short-middle 4-track overtake with 5-min headways - resulting in a no build scenario
**Results reflect a forced overtake in the short-middle overtake location
Note that HSR can meet 30 min run time from San Francisco to San Jose on unimpeded run
All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

Baseline Parameter References

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JPB/CAHSR Blended Operations Studies
Station Dwell Times

Table 11 – May 2011 Field Observations			
	Average	Min	Max
22nd Street	0:00:51	0:00:33	0:01:21
Bayshore	0:00:55	0:00:28	0:01:55
Belmont	0:00:57	0:00:34	0:01:55
Burlingame	0:00:46	0:00:33	0:01:03
California Ave.	0:00:51	0:00:27	0:01:14
Hayward Park	0:00:40	0:00:30	0:00:52
Hillsdale	0:00:49	0:00:33	0:01:08
Lawrence	0:00:46	0:00:31	0:01:24
Menlo Park	0:00:55	0:00:34	0:01:38
Millbrae	0:00:53	0:00:42	0:01:04
Mountain View	0:01:04	0:00:47	0:01:47
Palo Alto	0:01:19	0:00:41	0:02:23
Redwood City	0:01:07	0:00:41	0:01:50
San Antonio	0:00:44	0:00:31	0:01:10
San Bruno	0:00:45	0:00:32	0:00:56
San Carlos	0:00:57	0:00:30	0:02:48
San Mateo	0:00:53	0:00:39	0:01:05
Santa Clara	0:00:51	0:00:30	0:01:51
South San Francisco	0:00:53	0:00:32	0:01:55
Sunnyvale	0:01:00	0:00:34	0:01:51
Overall Average	0:00:54	0:00:34	0:01:34

Table 12 – Simulated Values with EMU Dwell Time Improvements (Without 6% Schedule Margin)			
	Average	Min	Max
22nd Street	0:00:34	0:00:25	0:00:49
Bayshore	0:00:36	0:00:23	0:01:06
Belmont	0:00:37	0:00:26	0:01:06
Burlingame	0:00:31	0:00:25	0:00:40
California Ave.	0:00:34	0:00:22	0:00:45
Hayward Park	0:00:28	0:00:23	0:00:34
Hillsdale	0:00:33	0:00:25	0:00:43
Lawrence	0:00:32	0:00:24	0:00:50
Menlo Park	0:00:36	0:00:26	0:00:57
Millbrae	0:00:35	0:00:29	0:00:40
Mountain View	0:00:41	0:00:32	0:01:02
Palo Alto	0:00:48	0:00:29	0:01:20
Redwood City	0:00:42	0:00:29	0:01:04
San Antonio	0:00:31	0:00:24	0:00:43
San Bruno	0:00:31	0:00:24	0:00:36
San Carlos	0:00:37	0:00:23	0:01:33
San Mateo	0:00:35	0:00:28	0:00:41
Santa Clara	0:00:34	0:00:24	0:01:04
South San Francisco	0:00:35	0:00:24	0:01:06
Sunnyvale	0:00:38	0:00:26	0:01:04
Overall Average	0:00:36	0:00:22	0:01:33

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JPB/CAHSR Blended Operations Studies Prototypical Schedule

Table 3: Peak 60 Minutes Northbound Service – AM Simulated Schedule

Train:	416	418	420	422	424	426
Tamien Station		7:02a			7:32a	
San Jose Diridon Station	7:00a	7:10a	7:20a	7:30a	7:40a	7:50a
College Park Station*						
Santa Clara Station	7:05a			7:35a		
Lawrence Station		7:18a			7:48a	
Sunnyvale Station	7:11a	7:21a	7:30a	7:41a	7:51a	8:00a
Mountain View Station	7:16a	7:26a	7:35a	7:46a	7:56a	8:05a
San Antonio Station			7:38a			8:08a
California Ave. Station	7:21a			7:51a		
Palo Alto Station	7:25a	7:34a	7:44a	7:55a	8:04a	8:14a
Menlo Park Station		7:36a	7:46a		8:06a	8:16a
Atherton Station	7:28a					
Redwood City Station	7:32a	7:43a	7:51a	8:01a	8:13a	8:21a
San Carlos Station			7:54a			8:24a
Belmont Station		7:47a			8:17a	
Hillsdale Station	7:39a	7:50a	7:58a	8:08a	8:20a	8:28a
Hayward Park Station			8:00a			
San Mateo Station	7:42a	7:53a		8:11a	8:23a	
Burlingame Station		7:56a			8:26a	
Broadway Station				8:15a		
Millbrae Station	7:50a	8:01a	8:08a	8:19a	8:31a	8:37a
San Bruno Station			8:12a			8:41a
South San Francisco Station	7:57a			8:26a		
Bayshore Station						8:45a
22nd Street Station			8:19a			
4th & King Station	8:04a	8:14a	8:23a	8:33a	8:44a	8:52a

*Schedule to be determined

This is a prototypical schedule and was developed as a modeling input only. Additional service plans and schedule options will be developed and considered in subsequent stages of the planning process

Table 4: Peak 60 Minutes Southbound Service – AM Simulated Schedule

Train:	417	419	421	423	425	427
4th & King Station	7:00a	7:10a	7:20a	7:30a	7:40a	7:50a
22nd Street Station	7:05a	7:15a	7:25a	7:35a	7:45a	7:55a
Bayshore Station		7:19a				
South San Francisco Station				7:43a		
San Bruno Station		7:27a			7:56a	
Millbrae Station	7:18a	7:30a	7:38a	7:49a	7:59a	8:08a
Broadway Station						8:11a
Burlingame Station		7:34a			8:03a	
San Mateo Station		7:37a	7:44a		8:06a	8:15a
Hayward Park Station		7:39a				
Hillsdale Station	7:27a	7:42a		7:58a	8:10a	
Belmont Station			7:49a			8:20a
San Carlos Station	7:30a	7:45a		8:01a	8:13a	
Redwood City Station		7:51a	7:56a		8:19a	8:27a
Atherton Station					8:22a	
Menlo Park Station	7:39a		8:00a	8:10a		8:31a
Palo Alto Station	7:42a	7:57a	8:03a	8:13a	8:26a	8:34a
California Ave. Station			8:06a			8:37a
San Antonio Station	7:47a			8:18a		
Mountain View Station	7:51a	8:05a	8:12a	8:22a	8:34a	8:43a
Sunnyvale Station			8:16a			8:47a
Lawrence Station	7:57a			8:28a		
Santa Clara Station	8:02a			8:33a		
College Park Station*						
San Jose Diridon Station	8:07a	8:18a	8:29a	8:38a	8:47a	9:00a
Tamien Station	8:14a		8:36a		8:54p	

*Schedule to be determined

This is a prototypical schedule and was developed as a modeling input only. Additional service plans and schedule options will be developed and considered in subsequent stages of the planning process

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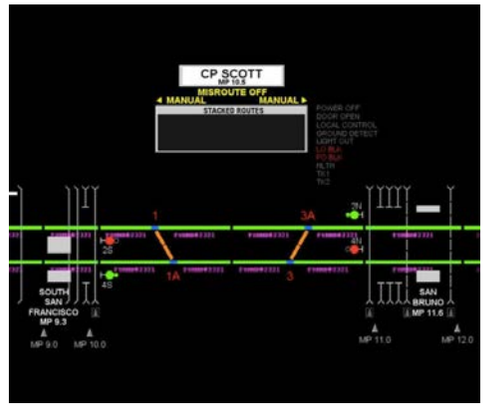
Infrastructure Baseline

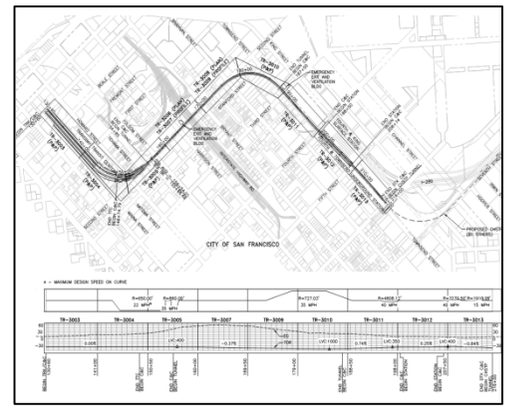
- Existing track layout together with Caltrain identified capital program improvements
- Speed Limits adapted using PB-Supplied Curve Straightening Exercise (using 6" Super-Elevation / 3" Un-balanced)
- Infrastructure adapted using TJPA DTX Track Plan (Oct 2011)



CTC Schematic

Start MP	End MP	Distance ft.	Existing			Increase			Proposed			Un-balanced SE		Existing Number of tracks
			SE inch	Spiral ft.	Speed mph	SE inch	Spiral ft.	Speed mph	SE inch	Spiral ft.	Speed mph	for 79mph	for 110mph	
0.53	0.70	897.6	1.75	62	25	2.25	82	5	4	144	30		2.77	3
1.13	1.30	897.6	3.5	216	40	1.75	67	5	5.25	283	45		2.90	2
1.70	1.96	1372.8	0.75	75	75	0	0	0	0.75	75	75		2.62	2
3.93	4.14	1108.8	1.5	190	79	4	536	31	5.5	726	110		3.03	2
4.88	4.94	316.8	0.5	50	65	0	0	0	0.5	50	65		2.46	2
5.00	5.17	897.6	0.75	260	65	2.5	0	0	3.25	260	65		2.91	4
5.93	6.73	4224.0	1.5	150	79	4	576	31	5.5	726	110		2.87	4
7.05	7.11	316.8	0	0	79	1.25	165	31	1.25	165	110		0.87	2
7.17	7.23	316.8	0	0	79	1.25	165	31	1.25	165	110		0.87	2
7.38	7.91	2798.4	5.5	556	79	0.5	0	0	6	556	79		3.73	2
7.91	8.09	950.4	5.5	485	70	0.5	0	0	6	485	70		1.03	2

Curve Straightening Exercise



Key Map with Speed and Elevation Profile

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Caltrain EMU Rolling Stock: Base Assumptions

The Stadler EMU KISS DD was used as the base Caltrain EMU (6-coach study reference EMU) in the first iteration of conceptual planning.

During the refinement process, various EMU models were tested including the TWINDEXX family of Bombardier Transportation against the RFP requirement: The only EMU that met the All Stop 423 and LIM Type A 227 trip time requirement was the Stadler EMU KISS DD 4-coach option (8 axel powered) trainset.

It was ultimately decided to adapt an 8-coach TWINDEXX EMU with 10 MW performance for use in the study. This trainset slightly underperforms the RFP – which is more conservative and enables planning with greater confidence in scheduling.

Minimal required travel times [hh:mm:ss]	Operating Speed	All Stops 423	LIM Type A 227	LIM Type B 225
RFP Requirement	79 mph Initial Service	00:57:39	00:50:09	00:46:45
6-coach study reference EMU	79 mph Initial Service	01:00:06	00:52:06	00:48:42
4-coach option (8 axle powered)	*79 mph Initial Service*	*00:56:42*	*00:49:54*	*00:47:06*
8-coach option (TWINDEXX)	*79 mph Initial Service*	*00:59:06*	*00:51:24*	*00:48:12*
8-coach 10 MW (TWINDEXX)	*79 mph Initial Service*	*00:58:36*	*00:51:12*	*00:48:06*
RFP Requirement	110 mph Final Service	**00:56:44**	00:47:21	00:42:41
6-coach reference EMU	110 mph Final Service	00:58:48	00:49:24	00:45:24
4-coach option (8 axle powered)	*110 mph Final Service*	*00:54:18*	*00:46:06*	*00:42:54*
8-coach option (TWINDEXX)	*110 mph Final Service*	*00:57:12*	*00:48:12*	*00:44:48*
8-coach 10 MW (TWINDEXX)	*110 mph Final Service*	***00:56:48***	*00:47:48*	*00:44:06*

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Headway and Separation Times

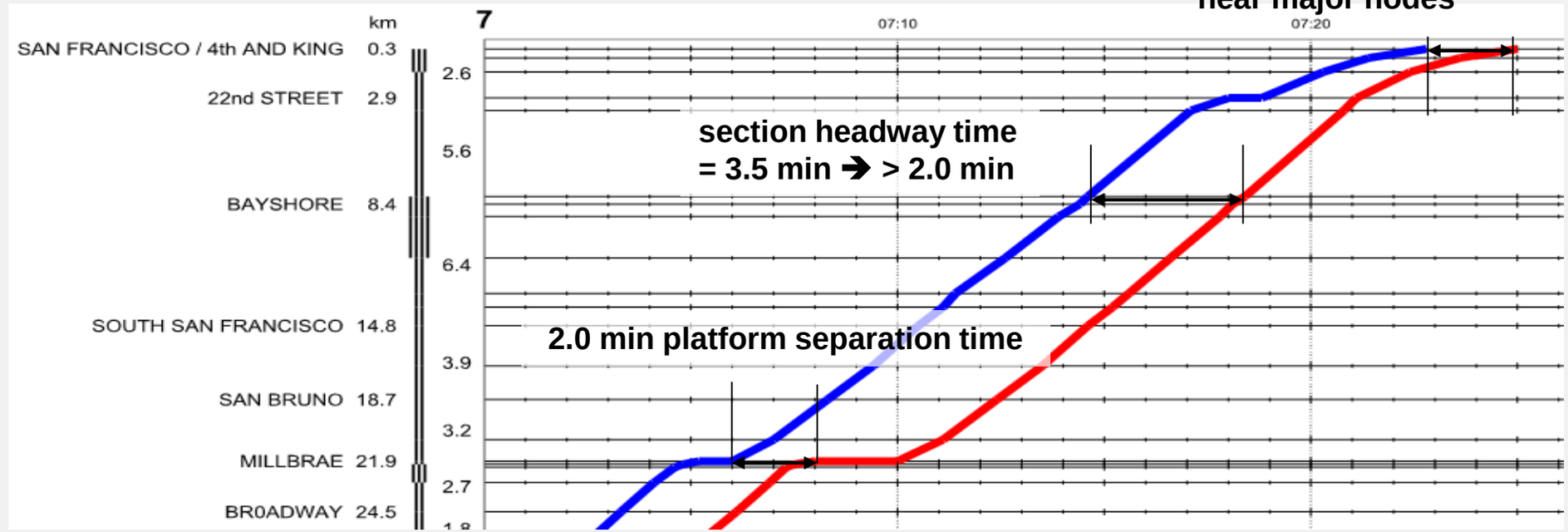
Three headway and separation time limits are defined:

Section headway: time between two trains traveling along the corridor at the same time

Platform separation time: time between departure of first train and arrival of second train at the same platform

Headway near major junctions or nodes: time between two trains as the near major nodes like a terminal station.

Sample EXP – HSR headway times



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Joint Schedule Working Group

Communication Based Overlay Signaling System (CBOSS)

Capacity and capability assessment

optimizing railways SMA Rail Consulting + IT, Corp.

2677 N. Main St., Suite 825
Santa Ana, CA 92705
United States of America

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Assessment Process Coordination

September 9: Participated in a **CBOSS Capabilities Conference Call** with Caltrain/LTK to gain an understanding of anticipated CBOSS signal headway capabilities for 2029 so we could accurately conceptualize the system capabilities in the scheduling process.

September 19: Participated in a second **CBOSS Capabilities Conference Call** where SMA explained to LTK the CBOSS signal headway estimation workbook calculations and methodology. LTK confirmed the methodology was sound and requested minor adjustments to the headway estimation workbook calculations (modification in train length and brake rate).

October 6: Finalized headway estimations and applied headway line to no additional overtake tracks, 2'/3' headway concept.

Found only minor headway infractions in the concept that could easily be resolved by reallocating supplemental time.

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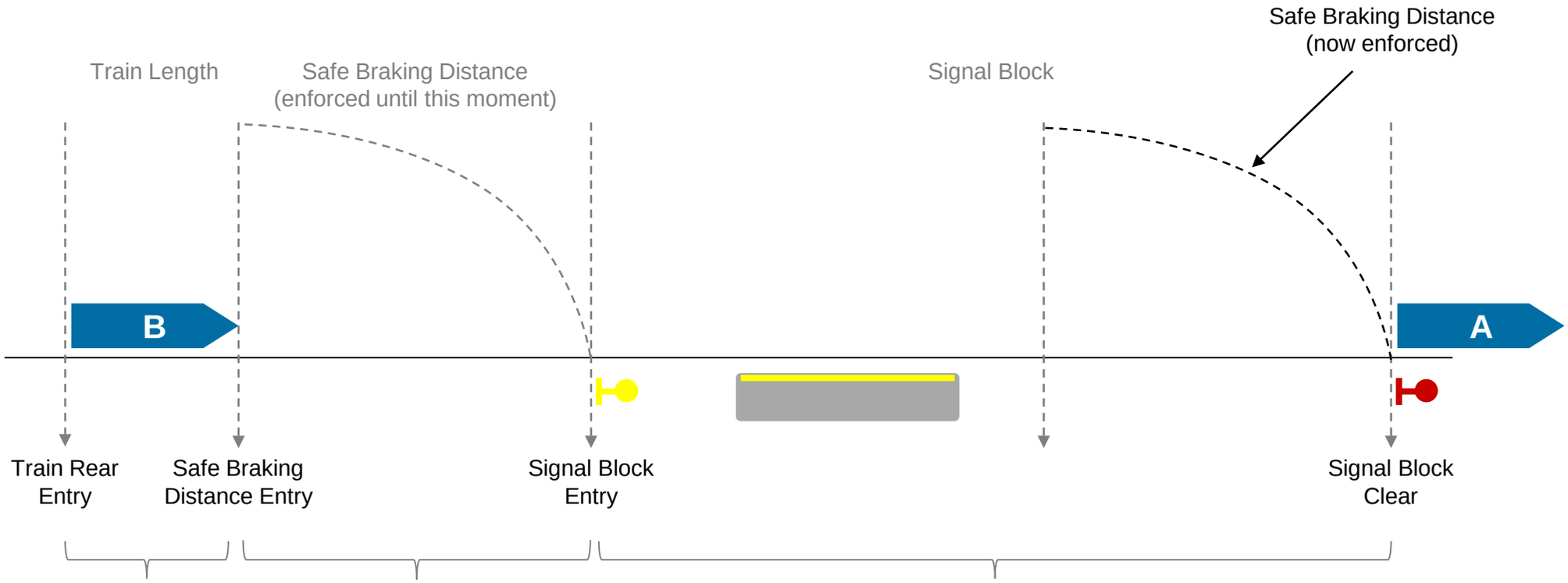
Signal Headway Calculation Diagram

This diagram depicts the very moment that train A clears the signal block and the signal in front of that block changes from red to something better than red.



Train Rear Time + **Safe Braking Distance Time** + **Signal Block + Dwell + Signal Release Time** = **Minimum Headway**

Steps

- Signal blocks were defined in Viriato using Caltrain signal aspect chart (Aug 27, 2015)
- Slight modifications (-.2) were made to signal block MPs to adjust for new Caltrain track chart alignment
- Using Viriato train performance diagrams, which outputs the speed and location of the train by second, the following was defined:
  - The safe braking distance (SBD) at each signal
  - The second at which the train crosses the SBD threshold
  - The second at which the train enters the signal block
  - The second at which the train clears the signal block
  - The second at which the train is one train length away from the SBD – this is called this the “Train Rear Time” (Viriato calculates from the center of the train, thus, the length of the train was added to the SBD)

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Signal Headway Workbook

Signal Headway Workbook contains the estimated headway at each signal for all Caltrain and HSR stopping patterns

Signal Block Start and End

Headway

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Signal Block Start	MP	Signal Block End	MP	Station in Signal Block	MP	Distance (ft)	SBD (mi)	Train Rear Entry (sec)	Train Rear Time (sec)	SBD Entry Time (sec)	SBD Time (sec)	Block Entry Time (sec)	Block Exit Time (sec)	Block Time (sec)	Signal Block Release Time (sec)	Dwell Time (sec)	Total Headway (sec)	Total Headway (min)
2	SAN FRANCISCO	0.00			San Francisco	0.00											0		
3	NL Sig CP 4th Street	0.25	Int Sig SB CP 4th Street	0.40			790	0.05	4	32	36	12	48	75.00	27.00	14.00	0	85.00	1.4
4	Int Sig SB CP 4th Street	0.40	NL Sig CP Common	0.64			1270	0.05	41	25	66	9	75	109.00	34.00	14.00	0	82.00	1.4
5	NL Sig CP Common	0.64	Int Sig 16	1.73	22nd Street	1.61	5760	0.1	77	20	97	12	109	228.25	119.25	14.00	34	199.25	3.3
6	Int Sig 16	1.73	NL Sig CP Army	1.99			1355	0.1	181.75	16	197.75	30.5	228.25	248.25	20.00	14.00	0	80.50	1.3
7	NL Sig CP Army	1.99	Int Sig 31/32 (27/28)	2.92			4910	0.37	180.75	14.5	195.25	53	248.25	291.25	43.00	14.00	0	124.50	2.1
8	Int Sig 31/32 (27/28)	2.92	Int Sig 41/42 (37/38)	3.87			5047	0.92	240.25	9	249.25	42	291.25	324.75	33.50	14.00	0	98.50	1.6
9	Int Sig 41/42 (37/38)	3.87	NL Sig CP Tunnel	4.79			4854	1.23	275.25	5	280.25	44.5	324.75	365.00	40.25	14.00	0	103.75	1.7
10	NL Sig CP Tunnel	4.79	NL Sig CP Geneva	5.33	Bayshore	5.06	2842	1.23	310.25	4	314.25	50.75	365	435.00	70.00	14.00	36	174.75	2.9
11	NL Sig CP Geneva	5.33	Int Sig 63/64 (61/62)	6.14			4267	0.31	371.5	12	383.5	51.5	435	475.00	40.00	14.00	0	117.50	2
12	Int Sig 63/64 (61/62)	6.14	NL Sig CP Brisbane	6.80			3464	0.83	422	12	434	41	475	500.50	25.50	14.00	0	92.50	1.5
13	NL Sig CP Brisbane	6.80	NL Sig CP Sierra	7.93			5972	1.02	453	7	460	40.5	500.5	550.50	50.00	14.00	0	111.50	1.9
14	NL Sig CP Sierra	7.93	Int Sig 91/92 (89/90)	9.00			5665	0.65	515.5	6	521.5	29	550.5	595.25	44.75	14.00	0	93.75	1.6
15	Int Sig 91/92 (89/90)	9.00	Int Sig 99/98 (97/98)	9.85	South San Francisco	9.10	4500	1.02	547.5	6	553.5	41.75	595.25	631.75	36.50	14.00	0	98.25	1.6
16	Int Sig 99/98 (97/98)	9.85	NL Sig CP Scott	10.27			2207	0.92	587.25	5	592.25	39.5	631.75	648.25	16.50	14.00	0	75.00	1.3
17	NL Sig CP Scott	10.27	Int Sig 115/114 (113/114)	11.32	San Bruno	11.00	5539	1.02	600.75	5	605.75	42.5	648.25	745.25	97.00	14.00	31	189.50	3.2
18	Int Sig 115/114 (113/114)	11.32	Int Sig 123/122 (121/122)	12.19			4576	0.37	677.25	11.5	688.75	56.5	745.25	785.50	40.25	14.00	0	122.25	2
19	Int Sig 123/122 (121/122)	12.19	NL Sig CP Center	12.68			2594	0.92	730.25	11	741.25	44.25	785.5	806.50	21.00	14.00	0	90.25	1.5
20	NL Sig CP Center	12.68	SL Sig CP Bart Int Sig 137/138	13.53	Millbrae	13.56	4510	0.92	761.25	6	767.25	39.25	806.5	856.00	49.50	14.00	35	143.75	2.4
21	SL Sig CP Bart Int Sig 137/138	13.53	NL Sig CP Trousdale	14.02			2570	0.74	805.5	6	811.5	44.5	856	919.50	63.50	14.00	0	128.00	2.1
22	NL Sig CP Trousdale	14.02	Int Sig 151/152 (149/150)	15.04			5394	0.43	848.5	16	864.5	55	919.5	963.50	44.00	14.00	0	129.00	2.2
23	Int Sig 151/152 (149/150)	15.04	Int Sig 159/160 (157/158)	15.85	Broadway	15.13	4290	1.02	911.5	8	919.5	44	963.5	996.75	33.25	14.00	0	99.25	1.7
24	Int Sig 159/160 (157/158)	15.85	Int Sig 169/170 (167/168)	16.82	Burlingame	16.23	5098	1.12	946.5	5	951.5	45.25	996.75	1092.75	96.00	14.00	32	192.25	3.2
25	Int Sig 169/170 (167/168)	16.82	Int Sig 175/176	17.50	San Mateo	17.60	3629	0.58	1014.25	14	1028.25	64.5	1092.75	1132.50	39.75	14.00	35	167.25	2.8
26	Int Sig 175/176	17.50	NL Sig CP Palm	17.92			2205	0.65	1087.75	7	1094.75	37.75	1132.5	1193.50	61.00	14.00	0	119.75	2
27	NL Sig CP Palm	17.92	Int Sig 187/188 (185/186)	18.65			3859	0.31	1130.5	14.5	1145	48.5	1193.5	1232.50	39.00	14.00	0	116.00	1.9
28	Int Sig 187/188 (185/186)	18.65	Int Sig 193/194	19.23	Hayward Park	18.93	3034	0.65	1190.5	8	1198.5	34	1232.5	1306.00	73.50	14.00	29	158.50	2.6
29	Int Sig 193/194	19.23	Int Sig 199/200 (197/198)	19.76			2828	0.31	1242	13	1255	51	1306	1335.00	29.00	14.00	0	107.00	1.8
30	Int Sig 199/200 (197/198)	19.76	Int Sig 203/204	20.38	Hillsdale	20.14	3240	0.65	1268.5	28.5	1297	38	1335	1410.00	75.00	14.00	33	188.50	3.1
31	Int Sig 203/204	20.38	Int Sig 211/212 (209/210)	21.05			3563	0.26	1349.5	12.5	1362	48	1410	1445.00	35.00	14.00	0	109.50	1.8
32	Int Sig 211/212 (209/210)	21.05	NL Sig CP Ralston	21.43			1975	0.74	1373.5	30.5	1404	41	1445	1461.00	16.00	14.00	0	101.50	1.7
33	NL Sig CP Ralston	21.43	Int Sig 223/222 (221/222)	22.15	Belmont	21.83	3825	0.92	1410	8	1418	43	1461	1493.00	32.00	14.00	0	97.00	1.6
34	Int Sig 223/222 (221/222)	22.15	Int Sig 229/230 (227/228)	22.83			3588	0.83	1451	5.5	1456.5	36.5	1493	1524.75	31.75	14.00	0	87.75	1.5
35	Int Sig 229/230 (227/228)	22.83	NL Sig CP Brittan	23.53	San Carlos	23.09	3718	0.92	1477	6	1483	41.75	1524.75	1606.25	81.50	14.00	37	180.25	3
36	NL Sig CP Brittan	23.53	Int Sig 249/248 (247/248)	24.72			6270	0.43	1535.75	14.5	1550.25	56	1606.25	1657.75	51.50	14.00	0	136.00	2.3
37	Int Sig 249/248 (247/248)	24.72	Int Sig 255/256 (254)	25.42	Redwood City	25.30	3705	1.02	1608.25	6	1614.25	43.5	1657.75	1732.25	74.50	14.00	42	180.00	3
38	Int Sig 255/256 (254)	25.42	NL Sig CP Dumbarton	25.92			2600	0.1	1686.25	16	1702.25	30	1732.25	1773.25	41.00	14.00	0	101.00	1.7
39	NL Sig CP Dumbarton	25.92	NL Sig CP Junction	27.00			5734	0.37	1731.25	12	1743.25	30	1773.25	1904.25	131.00	14.00	0	187.00	3.1
40	NL Sig CP Junction	27.00	Int Sig 277/276 (275/276)	27.62			3260	0.1	1876.25	16	1892.25	12	1904.25	1952.25	48.00	14.00	0	90.00	1.5
41	Int Sig 277/276 (275/276)	27.62	Int Sig 285/286 (283/284)	28.48	Atherton	27.70	4550	0.58	1893.25	16	1909.25	43	1952.25	1989.25	37.00	14.00	0	110.00	1.8

417 | 419 | 421 | 423 | 425 | 427 | 416 | 418 | 420 | 422 | 424 | 426 | 1000SB0 | 1002SB0 | 1100SB1 | 1102SB1 | 1001NB0 | 1003NB0 | 1101NB1 | 1103NB1 | Headway Comparison | SBTimetable | NBTimetable

Tab for Each Stopping Pattern

sma

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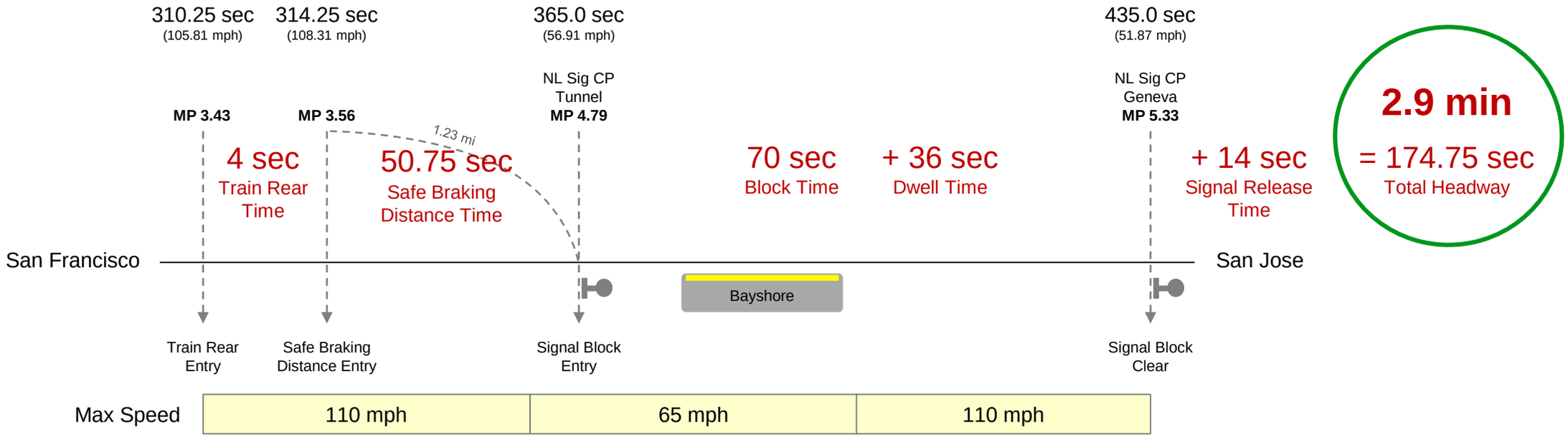
Signal Headway Calculation Detailed

	Signal Block Start	MP	Signal Block End	MP	Station in Signal Block	MP	Distance (ft)	SBD (mi)	Train Rear Entry (sec)	Train Rear Time (sec)	SBD Entry Time (sec)	SBD Time (sec)	Block Entry Time (sec)	Block Exit Time (sec)	Block Time (sec)	Signal Block Release Time (sec)	Dwell Time (sec)	Total Headway (sec)	Total Headway (min)
2	SAN FRANCISCO	0.00			San Francisco	0.00											0		
3	NL Sig CP 4th Street	0.25	Int Sig SB CP 4th Street	0.40			790	0.05	4	32	36	12	48	75.00	27.00	14.00	0	85.00	1.4
4	Int Sig SB CP 4th Street	0.40	NL Sig CP Common	0.64			1270	0.05	41	25	66	9	75	109.00	34.00	14.00	0	82.00	1.4
5	NL Sig CP Common	0.64	Int Sig 16	1.73	22nd Street	1.61	5760	0.1	77	20	97	12	109	228.25	119.25	14.00	34	199.25	3.3
6	Int Sig 16	1.73	NL Sig CP Army	1.99			1355	0.1	181.75	16	197.75	30.5	228.25	248.25	20.00	14.00	0	80.50	1.3
7	NL Sig CP Army	1.99	Int Sig 31/32 (27/28)	2.92			4910	0.37	180.75	14.5	195.25	53	248.25	291.25	43.00	14.00	0	124.50	2.1
8	Int Sig 31/32 (27/28)	2.92	Int Sig 41/42 (37/38)	3.87			5047	0.92	240.25	9	249.25	42	291.25	324.75	33.50	14.00	0	98.50	1.6
9	Int Sig 41/42 (37/38)	3.87	NL Sig CP Tunnel	4.79			4854	1.23	275.25	5	280.25	44.5	324.75	365.00	40.25	14.00	0	103.75	1.7
10	NL Sig CP Tunnel	4.79	NL Sig CP Geneva	5.33	Bayshore	5.06	2842	1.23	310.25	4	314.25	50.75	365	435.00	70.00	14.00	36	174.75	2.9
11	NL Sig CP Geneva	5.33	Int Sig 63/64 (61/62)	6.14			4267	0.31	371.5	12	383.5	51.5	435	475.00	40.00	14.00	0	117.50	2
12	Int Sig 63/64 (61/62)	6.14	NL Sig CP Brisbane	6.80			3464	0.83	422	12	434	41	475	500.50	25.50	14.00	0	92.50	1.5
13	NL Sig CP Brisbane	6.80	NL Sig CP Sierra	7.93			5972	1.02	453	7	460	40.5	500.5	550.50	50.00	14.00	0	111.50	1.9
14	NL Sig CP Sierra	7.93	Int Sig 91/92 (89/90)	9.00			5665	0.65	515.5	6	521.5	29	550.5	595.25	44.75	14.00	0	93.75	1.6
15	Int Sig 91/92 (89/90)	9.00	Int Sig 99/98 (97/98)	9.85	South San Francisco	9.10	4500	1.02	547.5	6	553.5	41.75	595.25	631.75	36.50	14.00	0	98.25	1.6
16	Int Sig 99/98 (97/98)	9.85	NL Sig CP Scott	10.27			2207	0.92	587.25	5	592.25	39.5	631.75	648.25	16.50	14.00	0	75.00	1.3
17	NL Sig CP Scott	10.27	Int Sig 115/114 (113/114)	11.32	San Bruno	11.00	5539	1.02	600.75	5	605.75	42.5	648.25	745.25	97.00	14.00	31	189.50	3.2



2.9 min
= 174.75 sec
Total Headway

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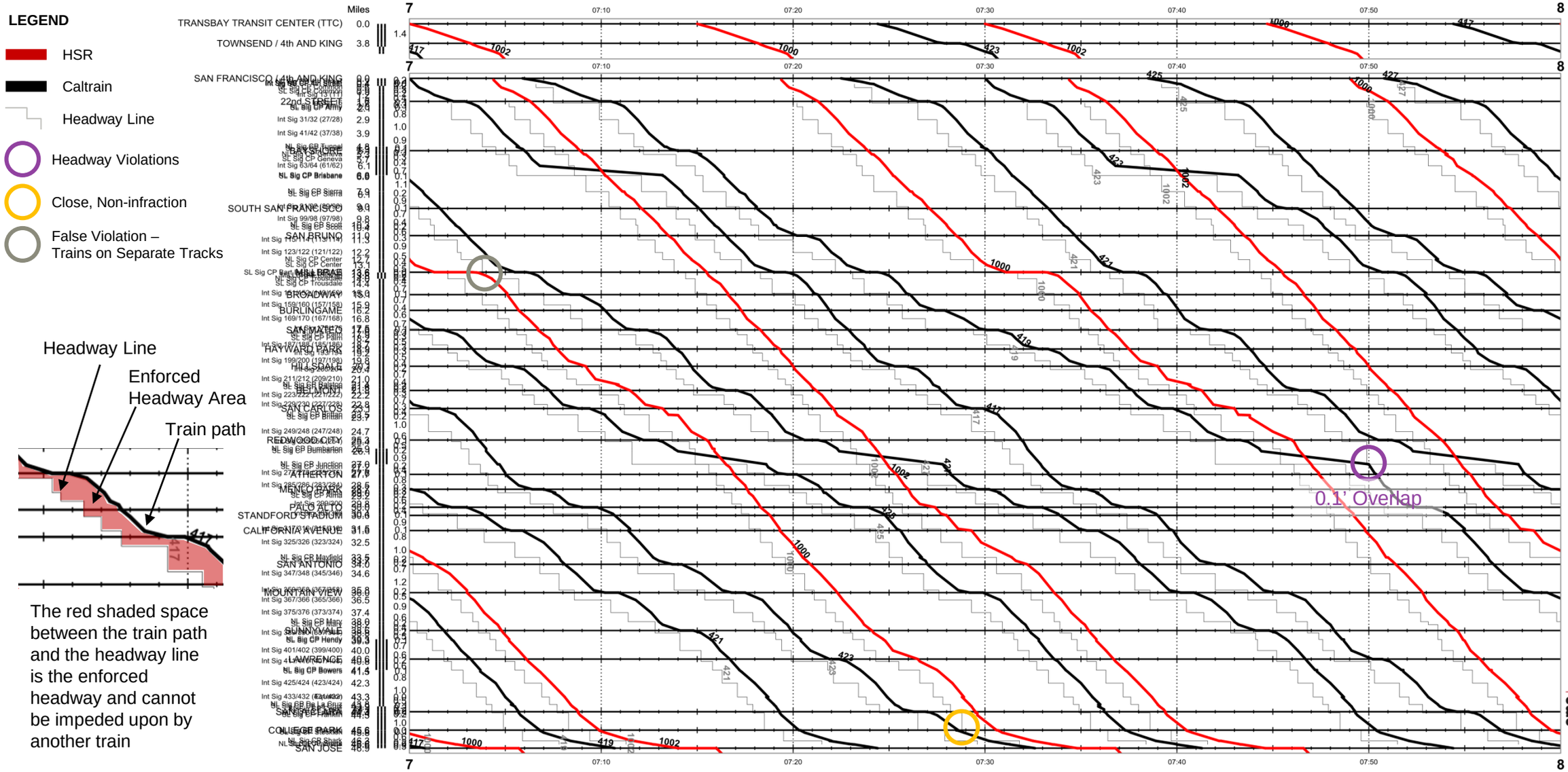
Signal Headway Calculation Application

No additional passing tracks, 2’/3’ Headways - Southbound



The red shaded space between the train path and the headway line is the enforced headway and cannot be impeded upon by another train

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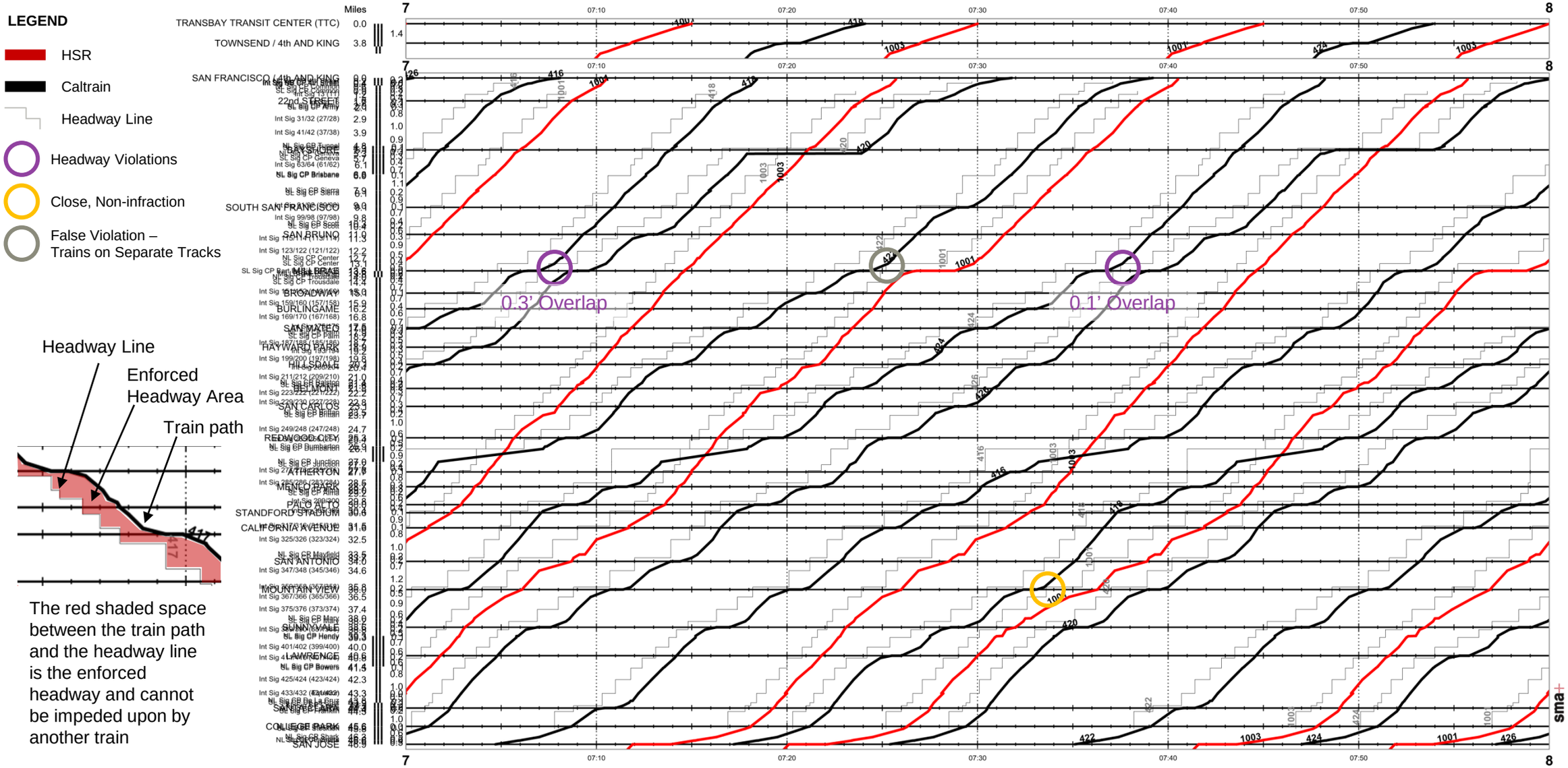
Not for distribution

Signal Headway Calculation Application

No additional passing tracks, 2’/3’ Headways - Northbound



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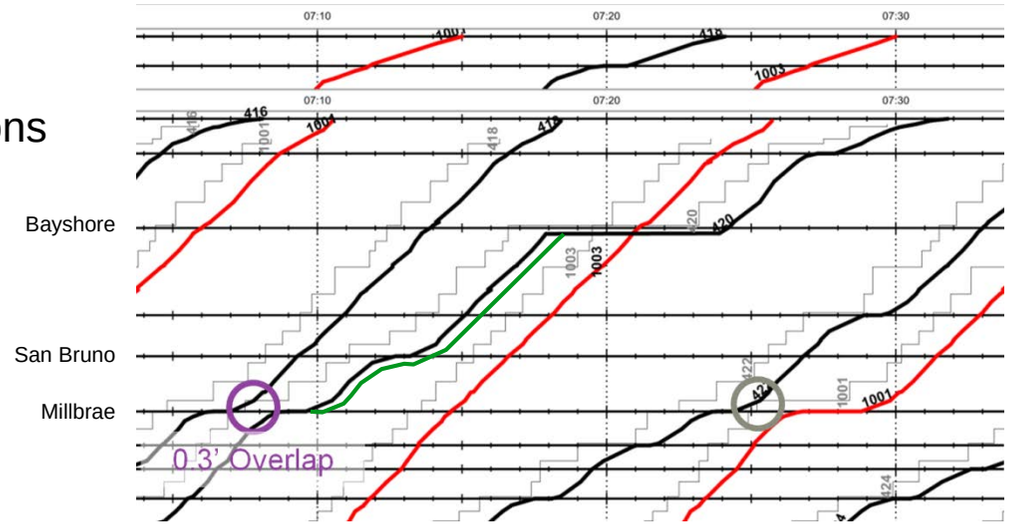
Signal Headway – Violation Explanation

Headway Violations

Instances where a train impedes on another train's headway line, thus violating the enforced headway



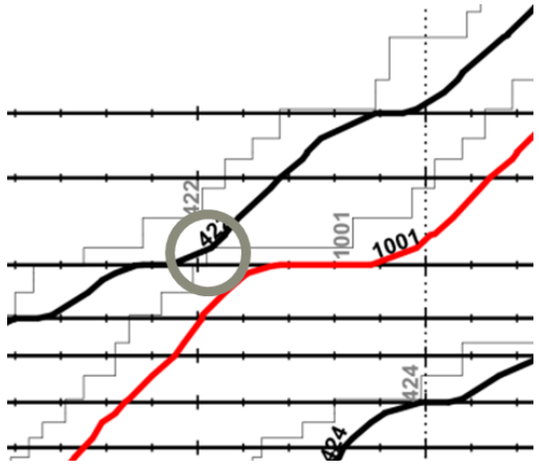
When evaluating the no-build concept headway estimations there were three instances where a train's headway was violated. These infractions ranged between 0.1' and 0.3'. In the example to the right we demonstrate how this infraction could be eliminated through the addition of minimal supplemental run time added to the train.

- The black line represents 420's current train run
- The green line represents a roughly adjusted 420 train run

The adjusted train run results in no headway violation. If the train adds ~.3' in dwell at Millbrae it can continue on a parallel route and arrive at Bayshore ~.3' later than the current schedule without violating any additional headway lines.

False Violation

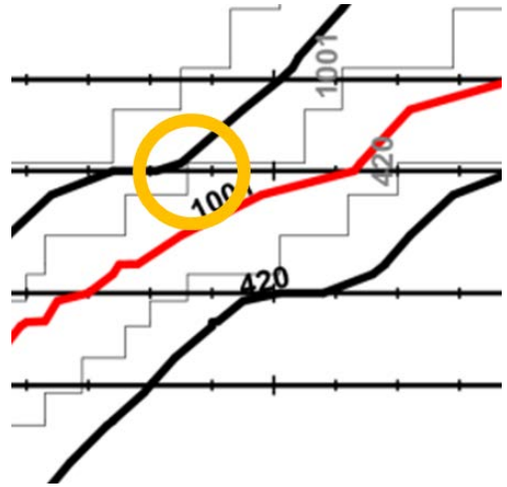
Instances where it may look like a train violates a headway line, but the two trains are on separate tracks



Close, Non-infraction

Instances where it may look like a train violates a headway line, but the train doesn't actually cross the headway line

In these instances minor adjustments to the train run may be advised in order to improve conceptual robustness



Appendix 3

CBOSS Assessment

CBOSS Concepts

1.37 Brake Rate

Concept 2.0C

Infrastructure Option:

Baseline with CBOSS headways

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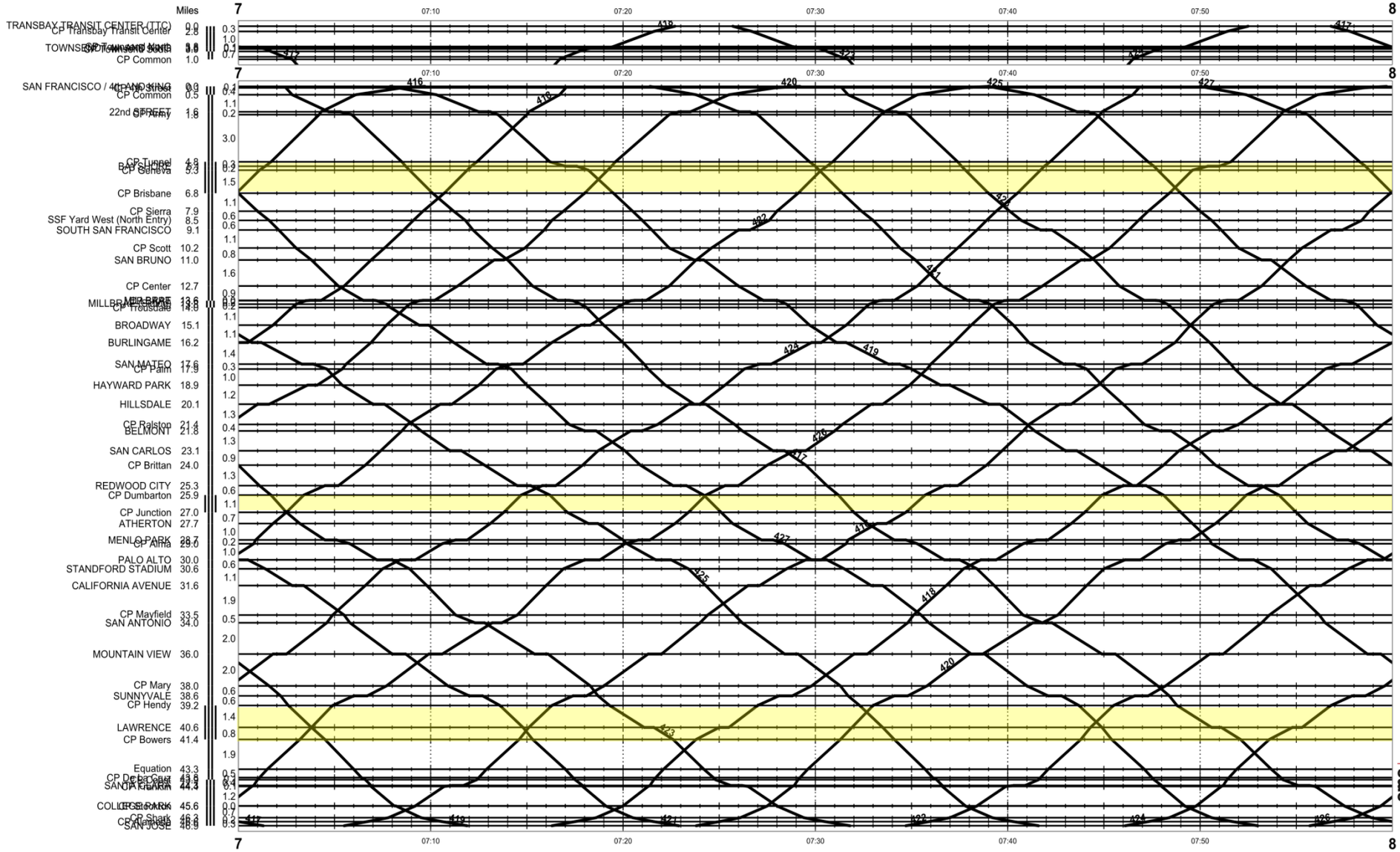
CBOSS 6 CT/0 HSR, 79 MPH – String Line



LEGEND

- HSR
- Caltrain
- New 4-track
- New 3-track
- Current 4-track

Concept 2.0C Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 5’, 4’
Speed Limit: 79 mph
Brake Rate: 1.37

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CBOSS 6 CT/0 HSR, 79 MPH – Service Evaluation

SERVICE INTERVAL

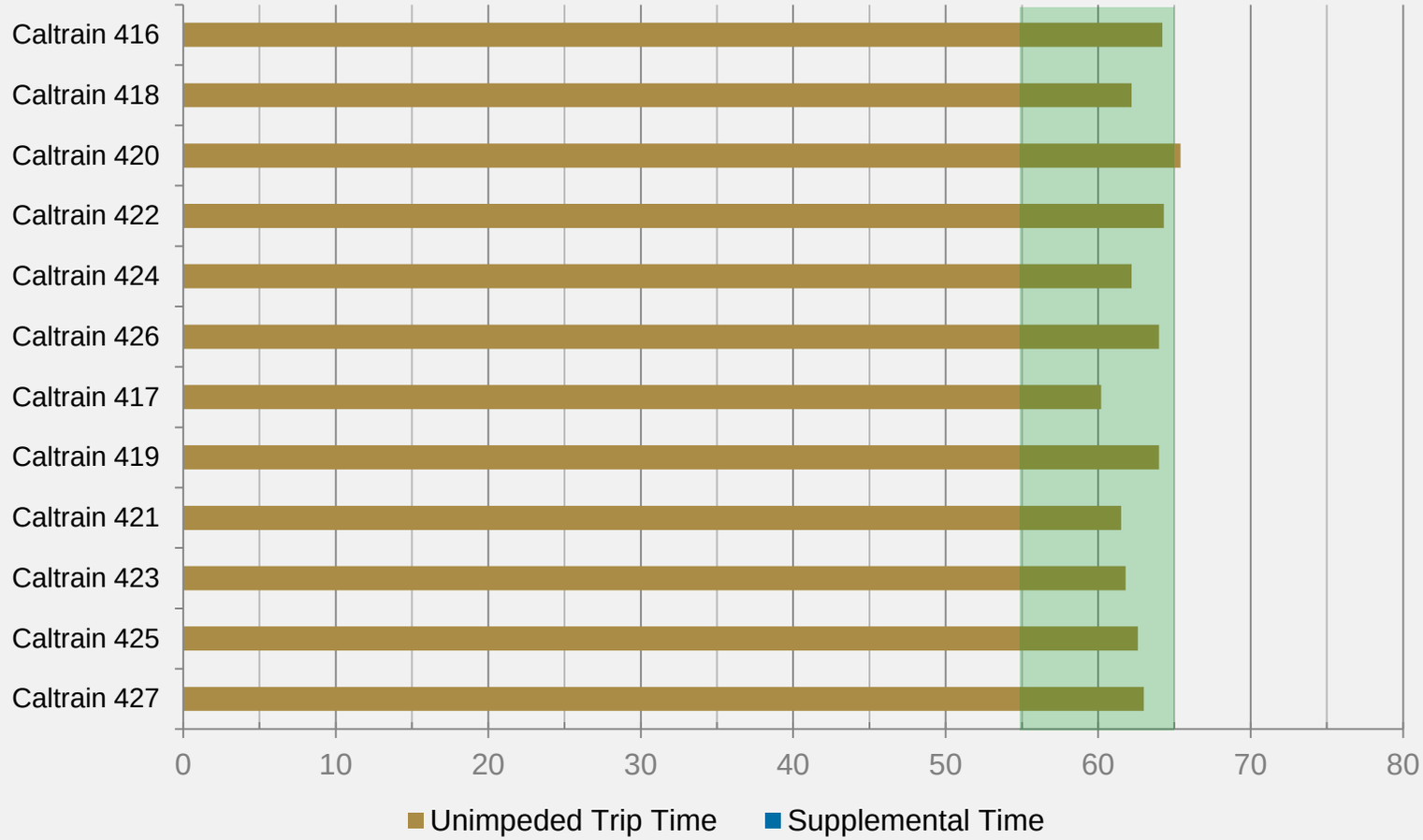
Southbound Service Interval at Palo Alto

Northbound Service Interval at Palo Alto

AVERAGE TRIP TIME

Caltrain:	63.0 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

Concept 2.22C:

Infrastructure Option:

No additional passing tracks with CBOSS headways

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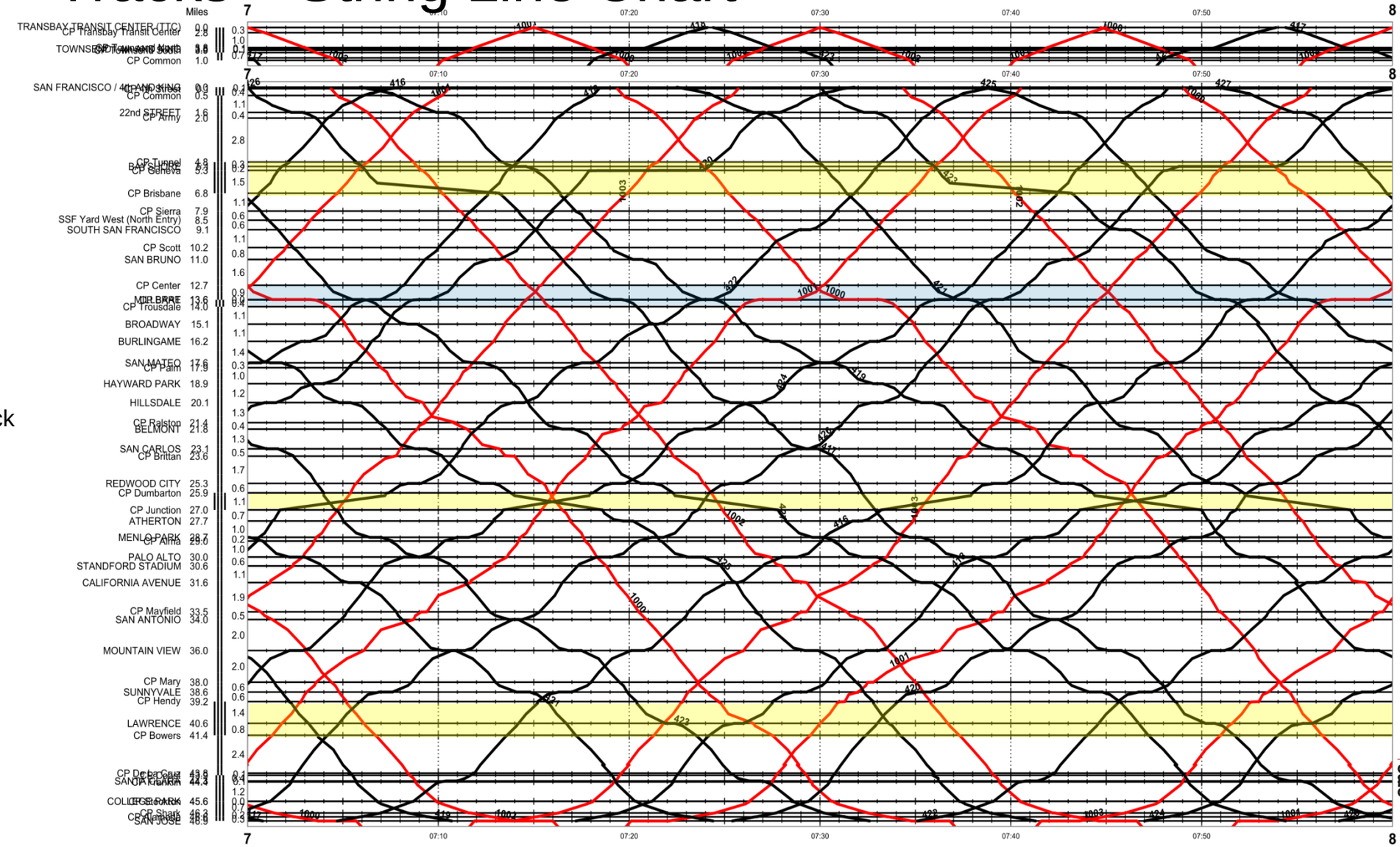
CBOSS 6 CT/4 HSR, No Additional Overtake Tracks – String Line Chart



Concept 2.22C Attributes

Caltrain Service: skip-stop
HSR Service: interval
Headways: 3’, 2’
Speed Limit: 110 mph
New 4-track: Millbrae 4-track
Brake Rate: 1.37

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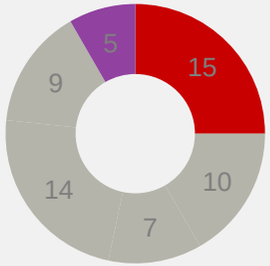
CBOSS 6 CT/4 HSR, No Additional Overtake Tracks – Service Evaluation

SERVICE INTERVAL

Southbound Service Interval at Palo Alto

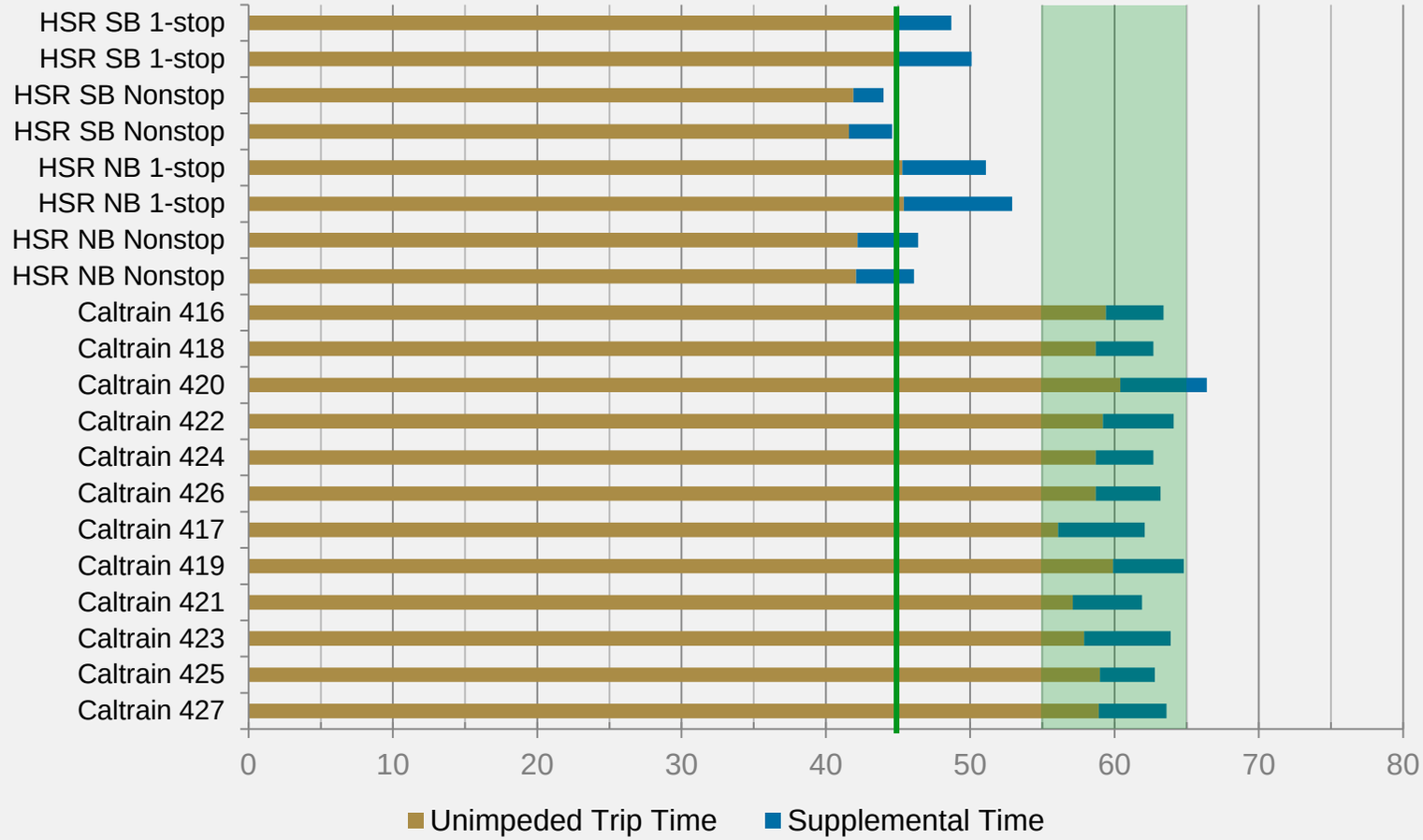


Northbound Service Interval at Palo Alto

AVERAGE TRIP TIME

Caltrain:	63.5 min
HSR Nonstop:	45.3 min

TRIP TIME (min)



*All Caltrain trip times are San Jose – 4th&King/Townsend. Additional ~4.2' to TTC

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Appendix 4

Consideration Table Results

2029 Peninsula Corridor Service, Operations and Infrastructure Considerations Table

CONSIDERATIONS CLASSIFICATION

Constraints: Stakeholder expectations that must be fulfilled by the project.

Needs: Stakeholder expectations that must be fulfilled by the project, if the project constraints are not violated or other stakeholder needs are not in conflict.

Wants: Stakeholder expectations that will be considered if they are feasible.

#	Stakeholder	Consideration	Concept 1.1		Concept 2.0		CBOSS Analysis (1.37 brake rate) Concept 2.0C		CBOSS Analysis (1.37 brake rate) Concept 2.22C		Concept 2.22		Concept 2.32		Concept 2.42		Concept 2.5B	
			Approach G 110mph, Short-Middle 4 Track Overtake 6 CT/4 HSR 4/5-min Headways		**Approach G** 79 mph, no additional passing tracks 6 CT/0 HSR 2/3-min Headways		**Approach G** 79 mph, no additional passing tracks 6 CT/ 0 HSR CBOSS derived headways		**Approach G** 110 mph, no additional passing tracks 6 CT/4 HSR, HSR Interval CBOSS derived headways		**Approach G** 110 mph, no additional passing tracks 6 CT/4 HSR, HSR Interval 2/3-min Headways		**Approach G** 110mph, Short-Middle 4 Track Overtake 6 CT/4 HSR, HSR Interval 2/3-min Headways		**Approach G** 110mph, Long-Middle 4 Track Overtake 6 CT/4 HSR, HSR Interval 2/3-min Headways		**Approach G** 110mph, Long-Middle 3 Track Overtake - Bidirectional 6 CT/4 HSR, HSR Interval 2/3-min Headways	
01-C	HSR	4 TPH between San Jose and San Francisco	✓		✗	No HSR	✗	No HSR	✓		✓		✓		✓		✓	
02-C	HSR	stop 2 TPH at Millbrae	✓		✗	No HSR	✗	No HSR	✓		✓		✓		✓		✓	
03-C	Caltrain	run 6 TPH between San Jose and San Francisco	✓		✓		✓		✓		✓		✓		✓		✓	
04-C	Caltrain	serve all stations, including weekend stations, during the peak	✓		✓		✓		✓		✓		✓		✓		✓	
05-C	Caltrain	ensure that signal system delivers the performance required to operate Caltrain and HSR service/schedule developed as part of this project	✓	5 min Headway/Separation	✓	5 min Headway/Separation	✓	5 min Headway/Separation	?	3 min corridor/2 min junction Headway/Separation	?	3 min corridor/2 min junction Headway/Separation	?	3 min corridor/2 min junction Headway/Separation	?	3 min corridor/2 min junction Headway/Separation	?	3 min corridor/2 min junction Headway/Separation
07-C	HSR	have at least 20 minutes to turn a train at a terminal station	✓	TTC: 31' | 31' | 37' | 37'	✗	No HSR	✗	No HSR	✓	TTC: 30' | 30' | 30' | 29'	✓	TTC: 30' | 30' | 30' | 30'	✓	TTC: 28' | 28' | 30' | 30	✓	TTC: 27' | 28' | 30' | 30	✓	TTC: 29' | 29' | 36' | 36'
08-C	HSR	dwell at least for 2 minutes at intermediate station stops (such as Millbrae, San Jose)	✓	2 minute HSR dwell time at Millbrae assumed	✗	No HSR	✗	No HSR	✓	2 minute HSR dwell time at Millbrae assumed	✓	2 minute HSR dwell time at Millbrae assumed	✓	2 minute HSR dwell time at Millbrae assumed	✓	2 minute HSR dwell time at Millbrae assumed	✓	2 minute HSR dwell time at Millbrae assumed
09-C	HSR	use 400m "AGV" trains with the performance characteristics as provided by PB	✓	EMU, PB_AGV	✗	No HSR	✗	No HSR	✓	EMU, PB_AGV	✓	EMU, PB_AGV	✓	EMU, PB_AGV	✓	EMU, PB_AGV	✓	EMU, PB_AGV
10-C	Caltrain	have at least 20 minutes to turn a train at a terminal station	✓	TTC: 22' | 22' 4th and King: 24' | 25' | 48' | 49' SJ: 22' | 22' | 22' | 22' | 28' | 28'	✓	TTC: 34' | 33' 4th and King: 30' | 22' | 29' | 22' SJ: 24' | 25' | 24' | 23' | 23' | 24'	✓	TTC: 34' | 33' 4th and King: 29' | 22' | 29' | 21' SJ: 22' | 23' | 23' | 24' | 24' | 24'	✓	TTC: 31' | 30' 4th and King: 34' | 38' | 42' | 43' SJ: 23' | 23' | 23' | 25' | 25' | 25'	✓	TTC: 31' | 31' 4th and King: 35' | 39' | 42' | 43' SJ: 24' | 25' | 25' | 27' | 27' | 27'	✓	TTC: 38' | 38' 4th and King: 27' | 28' | 46' | 46' SJ: 25' | 28' | 29' | 29' | 32' | 37'	✓	TTC: 43' | 44' 4th and King: 28' | 29' | 31' | 32' SJ: 28' | 29' | 30' | 30' | 34' | 34'	✓	TTC: 49' | 51' 4th and King: 30' | 32' | 34' | 35' SJ: 22' | 22' | 29' | 29' | 29' | 31'
11-C	Caltrain	Dwell at least at each station for the times specified in the JPB/CAHSR Blended Operations Studies	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis	✓	Caltrain dwell times based on Caltrain LTK Blended Operations Analysis
12-C	Caltrain	use 8-car EMU's for all their 2029 service between San Francisco and San Jose with the performance defined in Caltrain's EMU RFP	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length	✓	EMU, 8-Car Consist, Adapted to EMU RFP train performance and 8 coach train length
13-C	Caltrain/HSR	limit speed increase to 110-MPH speed profile provided by HSR	✓	110 MPH speed profile used	✗	79 MPH speed profile used	✗	79 MPH speed profile used	✓	110 MPH speed profile used	✓	110 MPH speed profile used	✓	110 MPH speed profile used	✓	110 MPH speed profile used	✓	110 MPH speed profile used
14-C	Caltrain/HSR	limit the analysis of new passing tracks to consider only a) JPB/CAHSR Blended Operations Studies short-middle 4-track section, b) Millbrae 4-track station	✓	Short-middle 4 Track Overtake not utilized Millbrae 4 Track utilized	✓	No build	✓	No build	✓	Short-middle 4 Track Overtake not utilized Millbrae 4 Track utilized	✓	Short-middle 4 Track Overtake not utilized Millbrae 4 Track utilized	✓	Short-middle 4 Track Overtake utilized Millbrae 4 Track utilized	✗	Long-middle 4 Track Overtake utilized Millbrae 4 Track utilized	✗	Long-middle 3 Track Overtake utilized Millbrae 4 Track utilized
15-C	Caltrain/HSR	use existing track layout together with Caltrain identified capital program improvements as a baseline	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)	✓	2016 Caltrain Track Charts Capital Improvements incorporated (South Terminal Phase III, South SF Station, South Terminal Phase II)
06-N	HSR	use dedicated platforms at all stations that are served by HSR trains	Assumed 4-track improvements at Millbrae		No HSR		No HSR		Assumed 4-track improvements at Millbrae		Assumed 4-track improvements at Millbrae		Assumed 4-track improvements at Millbrae		Assumed 4-track improvements at Millbrae		Assumed 4-track improvements at Millbrae	
51-N	HSR	avoid adding supplemental dwell or run-time to HSR trip times	**TOTAL SUPP TIME: 288.4'** SB 1-stop: +34.4' SB Nonstop: +37.7' NB 1-stop: +34.5' NB Nonstop: +37.6		No HSR		No HSR		**TOTAL SUPP TIME: 35.6'** SB 1-stop: +5.2', +3.8' SB Nonstop: +3.0', +2.1' NB 1-stop: +5.8', +7.5' NB Nonstop: +4.0', +4.2'		**TOTAL SUPP TIME: 35.6'** SB 1-stop: +5.2', +3.8' SB Nonstop: +3.0', +2.1' NB 1-stop: +5.8', +7.5' NB Nonstop: +4.0', +4.2'		**TOTAL SUPP TIME: 16.9'** SB 1-stop: +3.6', +3.6' SB Nonstop: +0.0', +0.0' NB 1-stop: +4.2', +5.1' NB Nonstop: +0.0', +0.4'		**TOTAL SUPP TIME: 12.5'** SB 1-stop: +2.2', +0.8 SB Nonstop: +0.0', +0.0' NB 1-stop: +4.1', +4.2' NB Nonstop: +1.0', +0.2		**TOTAL SUPP TIME: 0.2'** SB 1-stop: +0.0', +0.0 SB Nonstop: +0.0, +0.0 NB 1-stop: +0.0, +0.0 NB Nonstop: +0.0, +0.2	
53-N	HSR	achieve 45 min TTC - San Jose trip time	SB 1-stop: 78.7' SB Nonstop: 78.7' NB 1-stop: 78.7' NB Nonstop: 78.6'		No HSR		No HSR		SB 1-stop: 50.1', 48.7' SB Nonstop: 44.6', 44.0' NB 1-stop: 52.9', 51.1' NB Nonstop: 46.1', 46.4'		SB 1-stop: 49.5', 48.1' SB Nonstop: 44.0', 43.1' NB 1-stop: 50.0', 51.7' NB Nonstop: 45.2', 45.0'		SB 1-stop: 47.9', 47.9" SB Nonstop: 41.0', 41.0' NB 1-stop: 48.4', 49.3' NB Nonstop: 41.0', 41.4'		SB 1-stop: 46.5', 45.1' SB Nonstop: 41.0', 41.0' NB 1-stop: 48.3', 48.4' NB Nonstop: 42.0', 41.2'		SB 1-stop: 44.3', 44.3' SB Nonstop: 41.0', 41.0' NB 1-stop: 44.2', 44.2' NB Nonstop: 41.0', 41.2'	
16-N	Caltrain	Provide as many trains per hour to all stations during the peak as in the prototypical skip stop schedule from the JPB/CAHSR Blended Operations Studies	schedule based on prototype skip stop		schedule based on prototype skip stop		schedule based on prototype skip stop		schedule based on prototype skip stop		schedule based on prototype skip stop		schedule based on prototype skip stop		schedule based on prototype skip stop		schedule based on prototype skip stop	
17-N	Caltrain	operate a clock-face/regular interval service	6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly		6 NB and 6 SB train types repeat hourly	
20-N	Caltrain	avoid bunched train service	SB 22nd St: 6 - 12 - 12 - 6 - 12 - 12 SB Palo Alto: 6 - 12 - 12 - 6 - 12 - 12 SB San Jose: 6 - 12 - 12 - 6 - 12 - 12 NB Palo Alto: 12 - 13 - 5 - 12 - 13 - 5		SB 22nd St: 14 - 8 - 10 - 11 - 10 - 8 SB Palo Alto: 8 - 8 - 14 - 8 - 7 - 15 SB San Jose: 11 - 9 - 10 - 11 - 8 - 11 NB Palo Alto: 9 - 7 - 13 - 10 - 9 - 12		SB 22nd St: 8 - 14 - 7 - 10 - 11 - 10 SB Palo Alto: 15 - 7 - 8 - 15 - 8 - 7 SB San Jose: 11 - 11 -9 -10 -11 - 8 NB Palo Alto: 12 - 9 - 8 - 13 - 9 - 9		SB 22nd St: 8 - 17 - 6- 10 - 12 - 7 SB Palo Alto: 15 - 10- 7- 14 - 9 - 5 SB San Jose: 10 - 14 - 8 - 9 - 13 - 6 NB Palo Alto: 10 - 10 - 8 - 12 - 10 - 10		SB 22nd St: 8 - 17 - 5- 11 - 12 - 7 SB Palo Alto: 15 - 10- 7- 14 - 9 - 5 SB San Jose: 10 - 14 - 8 - 9 - 13 - 6 NB Palo Alto: 10 - 9 - 11 - 10 - 10 - 10		SB 22nd St: 23 - 3 - 4 - 22 - 5 - 3 SB Palo Alto: 13 - 5 - 12 - 13 - 5 - 12 SB San Jose: 17 - 6 - 8 - 16 - 6 - 7 NB Palo Alto: 12 - 3 - 15 - 12 - 3 - 15		SB 22nd St: 14 - 3 - 15 - 10 - 7 - 11 SB Palo Alto: 11 - 6 - 13 - 11 - 5 - 14 SB San Jose: 15 - 7 8 - 15 - 6 - 9 NB Palo Alto: 15 - 10 - 4 - 17 - 9 - 5		SB 22nd St: 10 - 16 - 3 - 13 - 13 - 5 SB Palo Alto: 16 - 10 - 4 - 16 - 10 - 4 SB San Jose: 11 - 14 - 5 - 11 - 14 - 5 NB Palo Alto: 10 - 5 - 14 - 12 - 5 - 16	
21-N	Caltrain	Uniform trip times for all services with end-to-end trip times of approximately 55-65 minutes between San Jose and 4th & King and up to 70 minute scheduled trip time for trains terminating at TTC	4th&King/Townsend - SJ 417: 75.8' 416: 76.0' 419: 75.9' 418: 75.8' 421: 75.9' 420: 76.0' 423:75.8' 422: 75.9' 425: 75.9' 424: 75.8' 427: 75.9' 426: 75.9'		4th&King/Townsend - SJ 417: 59.5' 416: 63.5' 419: 63.2' 418: 61.3' 421: 60.8' 420: 65.1' 423: 61.0' 422: 63.4' 425: 61.9' 424: 61.3' 427: 62.2' 426: 63.3'		4th&King/Townsend - SJ 417: 60.2' 416: 64.2' 419: 64.0' 418: 62.2' 421: 61.5' 420: 65.4' 423: 61.8' 422: 64.3' 425: 62.6' 424: 62.2' 427: 63.0' 426: 64.0'		4th&King/Townsend - SJ 417: 62.1' 416: 63.4' 419: 64.8' 418: 62.7' 421: 61.9' 420: 66.4' 423: 63.9' 422: 64.1' 425: 62.8' 424: 62.7' 427: 63.6' 426: 63.2'		4th&King/Townsend - SJ 417: 61.2' 416: 62.5' 419: 63.9' 418: 61.7' 421: 61.1' 420: 65.2' 423: 62.9' 422: 63.2' 425: 61.6' 424: 61.7' 427: 62.7' 426: 62.1'		4th&King/Townsend - SJ 417: 63.8' 416: 62.5' 419: 68.2' 418: 62.7' 421: 62.1' 420: 69.8' 423: 64.4' 422: 64.2' 425: 68.5' 424: 62.7' 427: 62.7' 426: 68.7'		4th&King/Townsend - SJ 417: 61.7' 416: 58.5' 419: 59.0' 418: 61.1' 421: 60.7' 420: 62.8' 423: 63.9' 422: 59.3' 425: 57.8' 424: 61.0' 427: 62.5' 426: 62.7'		4th&King/Townsend - SJ 417: 57.6' 416: 58.5' 419: 59.0' 418: 58.9' 421: 57.2' 420: 59.6' 423: 59.2' 422: 58.3' 425: 57.8' 424: 58.9' 427: 58.0' 426: 59.7'	
22-N	Caltrain	avoid dwelling at any intermediate station for longer than the minium dwell	no additional dwell		no additional dwell		no additional dwell		426: +4.5 Bayshore		426: +4.5 Bayshore		417: +7.1' Hillsdale, +1.5' Millbrae 416: +4.0' Hillsdale 419: +4.3' Bayshore 426: +4.5' Bayshore		417: +6.5' Hillsdale 418: +3.4' Hillsdale 420: +3.6' Redwood City 421: +4.4' Redwood City 422: +1.0' Hillsdale 423: +7.0' Hillsdale 424: +3.3' Hillsdale 426: +5.1' Redwood City 427: +4.5' Redwood City		417: +1.4' San Carlos, +1.0' Menlo Park 418: +1.2' Redwood City 420: +0.4' Redwood City 421: +0.5' Redwood City 423: +1.3' San Carlos, +1.0 Menlo Park 424: +1.2 Redwood City 426: +2.1' Redwood City	
50-N	Caltrain	avoid adding supplemental run-time to Caltrain trip times	417: +20.6' 416: +17.5' 419: +16.9' 418: +18.1' 421: +19.6' 420: +16.8' 423: +18.9' 422: +17.6' 425: +18.1' 424: +18.1' 427: +17.9' 426: +18.3'		no supplemental run-time		no supplemental run-time		417: +6.0' 416: +4.0' 419: +4.9' 418: 4.0' 421: +4.8' 420: +6.0' 423: +6.0' 422: +4.9' 425: +3.8' 424: +4.0' 427: +4.7' 426: +0'		417: +6.0' 416: +4.0' 419: +4.9' 418: 4.0' 421: +4.8' 420: +6.0' 423: +6.0' 422: +4.9' 425: +3.8' 424: +4.0' 427: +4.7' 426: +0'		417: +0.0' 416: +0.0' 419: +4.9' 418: +5.0' 421: +5.8' 420: +10.6' 423: +7.5' 422: +5.9' 425: +10.7' 424: +5.0' 427: +4.7' 426: +6.6'		417: +0.0' 416: +0.0' 419: +0.0' 418: +0.0' 421: +0.0' 420: +0.0' 423: +0.0' 422: +0.0' 425: +0.0' 424: +0.0' 427: +0.0' 426: +0.0'		417: +0.0' 416: +0.0' 419: +0.0' 418: +0.0' 421: +0.0' 420: +0.0' 423: +0.0' 422: +0.0' 425: +0.0' 424: +0.0' 427: +0.0' 426: +0.0'	
52-N	Caltrain	avoid adding supplemental dwell or run-time to Caltrain trip times	**TOTAL SUPP TIME: 218.4'** 417: +20.6' 416: +17.5' 419: +16.9' 418: +18.1' 421: +19.6' 420: +16.8' 423: +18.9' 422: +17.6' 425: +18.1' 424: +18.1' 427: +17.9' 426: +18.3'		no supplemental time		no supplemental time		**TOTAL SUPP TIME: 57.6'** 417: +6.0' 416: +4.0' 419: +4.9' 418: +4.0' 421: +4.8' 420: +6.0' 423: +6.0' 422: +4.9' 425: +3.8' 424: +4.0' 427: +4.7' 426: +4.5'		**TOTAL SUPP TIME: 57.6'** 417: +6.0' 416: +4.0' 419: +4.9' 418: +4.0' 421: +4.8' 420: +6.0' 423: +6.0' 422: +4.9' 425: +3.8' 424: +4.0' 427: +4.7' 426: +4.5'		**TOTAL SUPP TIME: 88.1'** 417: +8.6' 416: +4.0' 419: +9.2' 418: +5.0' 421: +5.8' 420: +10.6' 423: +7.5' 422: +5.9' 425: +10.7' 424: +5.0' 427: +4.7' 426: +11.1'		**TOTAL SUPP TIME: 38.8'** 417: +6.5' 416: +0.0' 419: +0.0' 418: +3.4' 421: +4.4' 420: +3.6' 423: +7.0' 422: +1.0' 425: +0.0' 424: +3.3' 427: +4.5' 426: +5.1'		**TOTAL SUPP TIME: 10.5'** 417: +2.4' 416: +0.0' 419: +0.0' 418: +1.2' 421: +0.9' 420: +0.4' 423: +2.3' 422: +0.0' 425: +0.0' 424: +1.2' 427: +0.0' 426: +2.1'	
23-N	Caltrain/HSR	use TTC as HSR terminal station and TTC and 4th/King as Caltrain terminal station	6 TPH TTC, 4 TPH 4th/King		No HSR		No HSR		6 TPH TTC, 4 TPH 4th/King		6 TPH TTC, 4 TPH 4th/King		6 TPH TTC, 4 TPH 4th/King		6 TPH TTC, 4 TPH 4th/King		6 TPH TTC, 4 TPH 4th/King	

	Concept 1.1				Concept 2.0				CBOSS Analysis (1.37 brake rate)							
									Concept 2.0C				Concept 2.22C			
	Approach G 110mph, Short-Middle 4 Track Overtake 6 CT/4 HSR 4/5-min Headways				**Approach G** 79 mph, no additional passing tracks 6 CT/0 HSR 2/3-min Headways**				**Approach G** 79 mph, no additional passing tracks 6 CT/ 0 HSR CBOSS derived headways**				**Approach G** 110 mph, no additional passing tracks 6 CT/4 HSR, HSR Interval CBOSS derived headways			
			Supplemental				*Supplemental*				*Supplemental*				*Supplemental*	
Caltrain	*Run-time*	*vs 2.0*	*Run-time*	*Dwell*	*Run-time*		*Run-time*	*Dwell*	*Run-time*		*Run-time*	*Dwell*	*Run-time*	*vs 2.0C*	*Run-time*	*Dwell*
Average	75.9	(12.9)	18.2	0.0	62.2		0.0	0.0	63.0		0.0	0.0	63.5	(0.5)	4.4	0.4
Total		(155.1)	218.4	0.0			0.0	0.0			0.0	0.0		(6.2)	53.1	4.5
CHSR																
Average	78.7		36.1		n/a				n/a				48.0		4.5	
Total			288.4												35.6	
Train																
416	76.0	(11.8)	17.5	0.0	63.5		0.0	0.0	64.2		0.0	0.0	63.4	0.8	4.0	0.0
417	75.8	(15.6)	20.6	0.0	59.5		0.0	0.0	60.2		0.0	0.0	62.1	(1.9)	6.0	0.0
418	75.8	(13.6)	18.1	0.0	61.3		0.0	0.0	62.2		0.0	0.0	62.7	(0.5)	4.0	0.0
419	75.9	(11.9)	16.9	0.0	63.2		0.0	0.0	64.0		0.0	0.0	64.8	(0.8)	4.9	0.0
420	76.0	(10.6)	16.8	0.0	65.1		0.0	0.0	65.4		0.0	0.0	66.4	(1.0)	6.0	0.0
421	75.8	(14.3)	19.6	0.0	60.8	2/3-min assumed headway base case	0.0	0.0	61.5	CBOSS derived headway base case	0.0	0.0	61.9	(0.4)	4.8	0.0
422	75.9	(11.6)	17.6	0.0	63.4		0.0	0.0	64.3		0.0	0.0	64.1	0.2	4.9	0.0
423	75.8	(14.0)	18.9	0.0	61.0		0.0	0.0	61.8		0.0	0.0	63.9	(2.1)	6.0	0.0
424	75.8	(13.6)	18.1	0.0	61.3		0.0	0.0	62.2		0.0	0.0	62.7	(0.5)	4.0	0.0
425	75.9	(13.3)	18.1	0.0	61.9		0.0	0.0	62.6		0.0	0.0	62.8	(0.2)	3.8	0.0
426	75.9	(11.9)	18.3	0.0	63.3		0.0	0.0	64.0		0.0	0.0	63.2	0.8	0.0	4.5
427	75.9	(12.9)	17.9	0.0	62.2		0.0	0.0	63.0		0.0	0.0	63.6	(0.6)	4.7	0.0
SB1*	78.7		34.4										50.1		5.2	
NB2*	78.7		37.7										52.9		5.8	
SB3	78.7		34.5										44.6		3.0	
NB4	78.6		37.6										46.1		4.0	
SB5*	78.7		34.4										48.7		3.8	
NB6*	78.7		37.7										51.1		7.5	
SB7	78.7		34.5										44.0		2.1	
NB8	78.6		37.6										46.4		4.2	

* stops at Millbrae

** the same results are achieved with any signalling configuration delivering 4/5-min headways or better

	Concept 2.22				Concept 2.32				Concept 2.42				Concept 2.5B			
	Approach G 110 mph, no additional passing tracks 6 CT/4 HSR, HSR Interval 2/3-min Headways				**Approach G** 110mph, Short-Middle 4 Track Overtake 6 CT/4 HSR, HSR Interval 2/3-min Headways				**Approach G** 110mph, Long-Middle 4 Track Overtake 6 CT/4 HSR, HSR Interval 2/3-min Headways				**Approach G** 110mph, Long-Middle 3 Track Overtake - Bidirectional 6 CT/4 HSR, HSR Interval 2/3-min Headways			
			Supplemental				*Supplemental*				*Supplemental*				*Supplemental*	
	Run-time	*vs 2.0*	*Run-time*	*Dwell*	*Run-time*	*vs 2.0*	*Run-time*	*Dwell*	*Run-time*	*vs 2.0*	*Run-time*	*Dwell*	*Run-time*	*vs 2.0*	*Run-time*	*Dwell*
Average	62.5	(0.3)	4.4	0.4	65.0	(2.8)	5.6	1.8	60.9	1.3	0.0	3.3	58.6	3.7	0.0	0.9
Total		(3.3)	53.1	4.5		(33.6)	66.9	21.4		15.5	0.0	39.0		43.8	0.0	10.5
CHSR																
Average	47.1		4.5		44.7		2.1		44.2		1.6		42.7		0.0	
Total			35.6				16.9				12.5				0.2	
Train																
416	62.5	1.0	4.0	0.0	62.5	1.0	0.0	4.0	58.5	5.0	0.0	0.0	58.5	5.0	0.0	0.0
417	61.2	(1.7)	6.0	0.0	63.8	(4.3)	0.0	8.6	61.7	(2.2)	0.0	6.5	57.6	1.9	0.0	2.4
418	61.7	(0.4)	4.0	0.0	62.7	(1.4)	5.0	0.0	61.1	0.2	0.0	3.4	58.9	2.4	0.0	1.2
419	63.9	(0.7)	4.9	0.0	68.2	(5.0)	4.9	4.3	59.0	4.2	0.0	0.0	59.0	4.2	0.0	0.0
420	65.2	(0.1)	6.0	0.0	69.8	(4.7)	10.6	0.0	62.8	2.3	0.0	3.6	59.6	5.5	0.0	0.4
421	61.1	(0.3)	4.8	0.0	62.1	(1.3)	5.8	0.0	60.7	0.1	0.0	4.4	57.2	3.6	0.0	0.9
422	63.2	0.2	4.9	0.0	64.2	(0.8)	5.9	0.0	59.3	4.1	0.0	1.0	58.3	5.1	0.0	0.0
423	62.9	(1.9)	6.0	0.0	64.4	(3.4)	7.5	0.0	63.9	(2.9)	0.0	7.0	59.2	1.8	0.0	2.3
424	61.7	(0.4)	4.0	0.0	62.7	(1.4)	5.0	0.0	61.0	0.3	0.0	3.3	58.9	2.4	0.0	1.2
425	61.6	0.3	3.8	0.0	68.5	(6.6)	10.7	0.0	57.8	4.1	0.0	0.0	57.8	4.1	0.0	0.0
426	62.1	1.2	0.0	4.5	68.7	(5.4)	6.8	4.5	62.7	0.6	0.0	5.1	59.7	3.6	0.0	2.1
427	62.7	(0.5)	4.7	0.0	62.5	(0.3)	4.7	0.0	62.5	(0.3)	0.0	4.7	58.0	4.2	0.0	0.0
SB1*	49.5		5.2		47.9		3.6		46.5		2.2		44.3		0.0	
NB2*	50.0		5.8		48.4		4.2		48.3		4.1		44.2		0.0	
SB3	44.0		3.0		41.0		0.0		41.0		0.0		41.0		0.0	
NB4	45.2		4.0		41.0		0.0		42.0		1.0		41.0		0.0	
SB5*	48.1		3.8		47.9		3.6		45.1		0.8		44.3		0.0	
NB6*	51.7		7.5		49.3		5.1		48.4		4.2		44.2		0.0	
SB7	43.1		2.1		41.0		0.0		41.0		0.0		41.0		0.0	
NB8	45.0		4.2		41.4		0.4		41.2		0.2		41.2		0.2	

* stops at Millbrae