Caltrain/California HSR Blended Operations Analysis

Prepared for:
Peninsula Corridor Joint Powers Board (JPB)

Prepared by:
LTK Engineering Services

March 2012

Caltrain

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Dear Stakeholders,

Caltrain needs to be modernized.

We need to implement Caltrain electrification, procure electric trains and install CBOSS PTC (an advanced signal system). These efforts will allow us to operate an electric rail service that is safer, more efficient and “greener”.

The vision for Caltrain is clear and has been confirmed by the Joint Powers Board and the region. However, funding for modernizing the system has been illusive and the greatest impediment to project advancement.

In 2008, the voters approved Proposition 1A which authorized state funding for high speed rail in California. This was clearly a significant milestone for the state of California, but also for Caltrain.

The high speed rail project, an electrified system, has been defined to use the Caltrain corridor to reach its northern terminus, downtown San Francisco. What this means is that Caltrain and high speed rail can combine local and new resources to advance electrification of the Peninsula rail corridor.

Since the passage of Proposition 1A, Caltrain and high-speed rail have been defining infrastructure needs to provide enhanced local, regional and statewide high speed rail transit service.

Originally envisioned was significant expansion of the existing Caltrain corridor to support a four- track system. However, such an expansion would have significant impacts on local communities that are difficult to justify for the foreseeable future.

In 2011, in response to growing local concerns, US Congresswoman Anna Eshoo, State Senator Joe Simitian and State Assemblyman Rich Gordon, challenged us to rescope the project and minimize impacts. They called for a “blended system” which would have both Caltrain and high speed rail using the existing tracks (primarily a two track system) to the greatest extent possible instead of expanding to a four track system along the entire corridor.

As a first step in exploring the feasibility of a blended system, Caltrain needed to understand if sharing the tracks was operationally feasible and acceptable.

The attached report is an operational analysis conducted by LTK Engineering Services, prepared for Caltrain. The analysis shows that a blended system in the Caltrain corridor is operationally viable. The attached report is a “proof of concept” showing tested service scenarios supporting both Caltrain and high speed rail systems on shared tracks. It is important to know that this report does not define “the” service plan to be implemented. Separate and following this analysis, additional studies and dialogue with stakeholders need be done before specifying what the blended system will ultimately be.

It is with a genuine sense of optimism that I share this report with you. The results of this study give us a reason to begin a new collaborative dialogue on how we might shape the future of our Caltrain corridor for our customers today and tomorrow. I look forward to continuing to work with you in shaping our future.

MJ Scanlon

Michael J. Scanlon

ACKNOWLEDGEMENTS

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0 Executive Summary

This report presents the results of detailed operational analyses of multiple "blended system" solutions for accommodating future Caltrain commuter rail and high speed rail services on the Caltrain Corridor between San Jose and San Francisco. These solutions are based on two services sharing rail tracks along most segments of the Corridor.

The operational analysis was based primarily on a computer simulation model of the Caltrain Corridor, capturing the trains, station stop (dwell) times, tested schedules, track, signals and track junctions (interlockings) of the future system. The computer simulation model software used to conduct the analysis, TrainOps®, is a proprietary software application developed by LTK Engineering Services. The model was customized for application to the Caltrain and high speed rail operations analysis.

The virtual world modeled in the simulation software is different than the current Caltrain system. Key differences include electrification of the Caltrain system, new Caltrain rail cars ("rolling stock") that have electric propulsion and an advanced signal system (CBOSS PTC). With electrification and an advanced signal system in place, the simulation model reflects a Caltrain Corridor with superior performance attributes compared to today's diesel system. This results in the ability to support more train traffic than can be supported today.

In some versions of the simulation model, limited new tracks in select areas of the corridor to support high speed rail stations and passing (overtake) locations to allow high speed rail trains to bypass Caltrain trains were assumed. Versions of the simulation model also varied in terms of simulated Caltrain and high speed rail train speeds, ranging from 79 mph to 110 mph.

The key findings from the simulation model and associated operations analysis are as follows:

- A blended operation on the Caltrain Corridor where Caltrain and high-speed trains are sharing tracks is conceptually feasible.
- An electrified system with an advanced signal system and electric trains increases the ability to support future train growth in the corridor.
- The blended system without passing tracks for train overtakes can reliably support up to 6 Caltrain trains and 2 high speed rail trains per peak hour per direction.
- The blended system with passing tracks for overtakes can reliably support up to 6 Caltrain trains and 4 high speed rail trains per peak hour per direction.
- Supporting high speed rail trains result in non-uniform Caltrain headways.
- Increasing speeds from up to 79 mph to 110 mph decreases travel times for both rail services.

The findings from this analysis should be viewed as a "proof of concept" in analyzing the conceptual feasibility of blended operations. The assumptions in the analysis should be considered as test inputs for analysis and should not be considered as decisions on what the blended system will look like. It is also important to note that the findings are based on a simulation modeling exercise; additional due diligence is needed to ensure that the findings provide sufficient reliability and flexibility for “real world” rail operations.

With a key finding that the Caltrain Corridor blended operations is conceptually feasible; this technical report should be used as a basis for additional discussion by stakeholders for exploring and refining the many blended system alternatives. Subsequent work to be completed include: engineering, identifying maintenance needs, cost estimating, ridership forecasts and environmental clearance.

1 Introduction

This report provides a high level overview and detailed technical assumptions of the feasibility analysis of Caltrain Corridor "blended operations." The blended operations concept reflects Caltrain commuter rail and California High Speed Rail (HSR) trains commingled on the same tracks for much of the Corridor between San Francisco and San Jose. A number of smaller scale infrastructure enhancements have been suggested to enhance the blended operations concept, allowing a greater number of overall trains on the Corridor and/or ensuring that trains operate with virtually no delay due to congestion on the line.

Blended operations being conceptually feasible means identifying future scenarios where the desired level of commuter and high speed rail service can be accommodated and these services can operate with virtually no delays (increased travel time) from terminal to terminal. The basis for assessing the conceptual feasibility of blended operations must include "practical" – as opposed to "theoretical" – assumptions such that any forecasts operational results are achievable under the inevitable day-to-day variations in weather, passenger loads, rolling stock performance, infrastructure availability and the like.

LTK Engineering Services (LTK), working closely with multiple Caltrain departments and California High Speed Rail Program Management staff, was responsible for performing the feasibility analysis of blended operations. LTK was retained by Caltrain for the analysis and worked closely with both future rail operators to ensure concurrence with assumptions and methodologies before advancing the work.

The blended operations analysis used a computer simulation model of the Caltrain Corridor that spanned the territory from Tamien Station, south of San Jose, to the San Francisco terminal at 4th and King. The model replicated the behavior of trains, station stop (dwell) times, schedules, track, signals and track junctions (interlockings), including the dynamic interaction of these entities in the complex railroad operating environment.

The smaller scale infrastructure enhancements consist of short sections of additional railroad track to be used by faster trains (HSR) to overtake (pass) slower trains (Caltrain). During the morning and evening peak period, the higher volume of both HSR and Caltrain trains means that overtakes happen in both directions at about the same time.

The overall guiding criterion for defining overtake segment options is that operational overtakes should improve integration of HSR and Caltrain services with neither service being routinely delayed at an overtake location by the other service. Other criteria include the following:

- Overtake tracks should be located where their construction and operation limit impacts to adjoining communities,

- Overtake tracks should be sufficiently long to support 7+ minute travel time difference between commuter and HSR trains; and
- Overtake tracks should connect to existing four-track segments of the Caltrain Corridor where possible to minimize capital cost.

The computer simulation model software used to conduct the analysis, TrainOps®, is a proprietary software application developed by LTK Engineering Services. The model was customized for application to the Caltrain and high speed rail operations analysis.

The future "no build" (no action) scenario modeled in the simulation software is different than the current Caltrain system, including differences in propulsion (electrification versus the current diesel propulsion), rail cars (electrified vehicles versus the current diesel locomotive-pulled coaches) and signal system (advanced communications-based system versus a wayside-only system with discrete update locations along the track). With electrification and an advanced signal system in place, the simulation model reflects a Caltrain Corridor with superior performance attributes compared to today's diesel system.

An incremental approach was used in the development of blended operations scenarios. The model started with the "6/0" scenarios (6 Caltrain and 0 HSR trains per peak hour per direction), then layered in additional HSR trains.

HSR frequencies were increased from an initial service level of 1 train per hour per direction to up to 4 trains per hour (bringing total Corridor train volumes to 10 trains per hour per direction). At the same time, Caltrain scheduling strategies (i.e. modifying train stopping patterns) varying maximum operating speeds and assumed infrastructure were also tested, with each scenario changing only one variable (scheduling strategies, train volume, infrastructure or maximum operating speed) at a time so that the impact of the change could be precisely understood.

Where a simulated train volume in a given scenario resulted in unacceptable train congestion and delays for a given infrastructure and a given maximum operating speed, the follow-on simulation scenarios with higher train volumes appropriately included additional infrastructure or changes in maximum operating speeds to eliminate the unacceptable train congestion and delays.

This incremental "three dimensional matrix" of service level, maximum train speed and infrastructure produced a very large number of potential scenarios, which was limited to a number that could actually be simulated in a reasonable time by using the results of initial scenarios to guide the study team in identifying subsequent scenarios that showed promise of blended operations conceptual feasibility. By using "practical" (conservative) input assumptions and appropriate schedule margin ("pad" or "recovery allowance"), the Study team had confidence that simulated blended operations conceptual feasibility can be translated into actual operational feasibility in "real world" conditions.

Included in this report are the details of the simulation modeling effort and the key findings. Chapter 2 provides information about the TrainOps simulation modeling tool used for the analysis. Chapter 3 focuses on the assumptions and inputs into the Caltrain Corridor model and the individual scenarios tested. Chapter 4 details the simulation results specific to individual scenarios as well as overall assessment of the conceptual feasibility of blended operations. Chapter 5 summarizes the key findings and next steps.

The report also includes three appendices. Appendix A includes detailed tables of Caltrain tested schedule changes required for certain future simulation scenarios. Appendix B includes graphical time-distance ("string") charts that reflect the peak period simulated train performance of all of the trains operating in the Caltrain Corridor in each scenario. Appendix C provides a glossary of technical and railroad operational terms for the reader's convenience. Appendix D includes information about stakeholder outreach and public comments on the draft report.

2 TrainOps® Simulation Modeling Tool

Summary: This chapter describes the computer software application (TrainOps) that was used to conduct the simulations for the Caltrain Corridor "blended operations." The software validation process and examples of other rail systems that have used this software application are also described.

2.1 General Description and Capabilities

The TrainOps simulation modeling tool is a proprietary software application developed and enhanced by LTK Engineering Services. TrainOps was specifically enhanced for application to the Caltrain/California HSR Blended Operations Analysis in order to accurately model the specified functionality of an advanced signal system, known as Communications Based Overlay Signal System Positive Train Control (CBOSS PTC) system planned for the Caltrain Corridor.

More generally, TrainOps accurately models the performance of individual trains and the interaction of trains, based on user inputs for rolling stock, track alignment, train control, dispatching and operating plans.

The program provides user-friendly inputs (including the ability to "cut and paste" from spreadsheets) for all relevant system and rolling characteristics, including:

- Route alignment data, including track gradients, horizontal alignment and speed restrictions (which can differ by train class),
- Passenger station locations,
- Train data, including weight, dimensions, propulsion system characteristics, and braking system parameters,
- System train control data, including wayside signaling, cab signaling and Positive Train Control inputs,
- Operations data, such as train consist sizes, train consist manipulations at terminals/yards, operating plan (timetable) inputs, passenger station stopping pattern, and station dwell times.

2.2 Software Validation

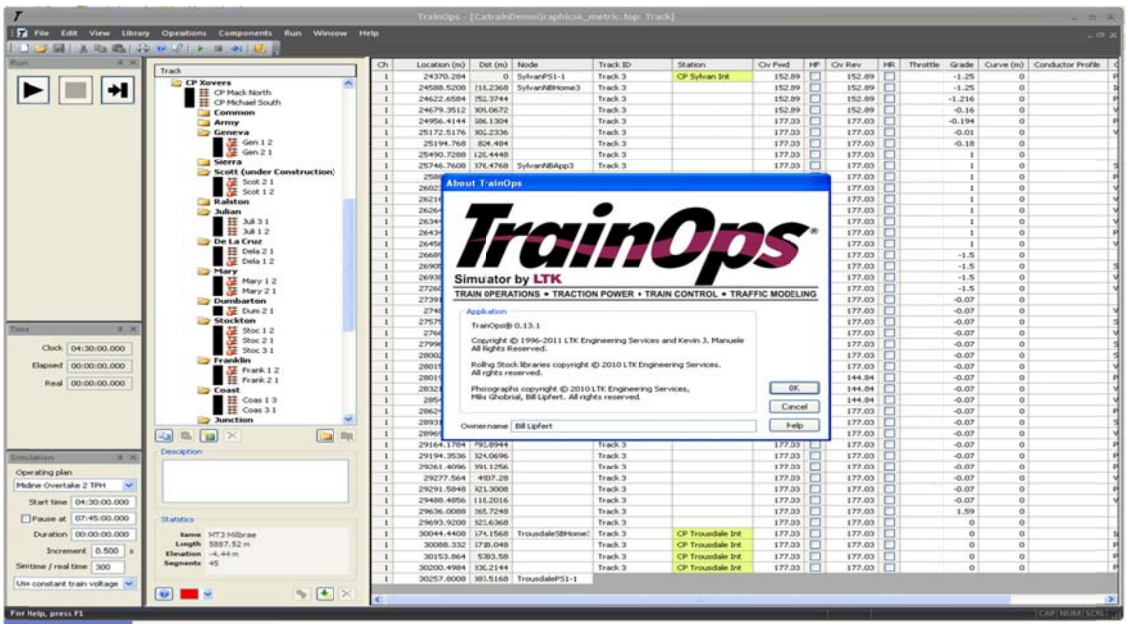
TrainOps was first developed in 1996 by LTK Engineering Services and has been continually enhanced and upgraded in the last 15 years. These enhancements include the addition of new features and ability to model new technologies, as well as adding support for the latest Windows operating systems.

As part of the Caltrain/California HSR assignment, TrainOps was enhanced to support the unique functional attributes of Caltrain's planned CBOSS PTC system. Each software enhancement, whether a generic upgrade for general purpose modeling or a project-specific upgrade such as that for CBOSS PTC, is subject to extensive internal QA/QC procedures, including 800+ functional tests.

The purpose of these tests is to ensure that all previously approved software functions continue to operate as specified after the addition of new capabilities. These tests use simplified databases designed to rapidly test each software function. In addition, LTK maintains a large database of regression tests, which consist of complex databases designed to verify the correct interaction of multiple software features. Each regression test has an approved "benchmark" set of results that must be replicated in order for a new release of the TrainOps software to be approved.

Figure 1 shows the initial "launch screen" of the TrainOps software.

Figure 1. TrainOps Software Launch Screen and Route Alignment Input Screen

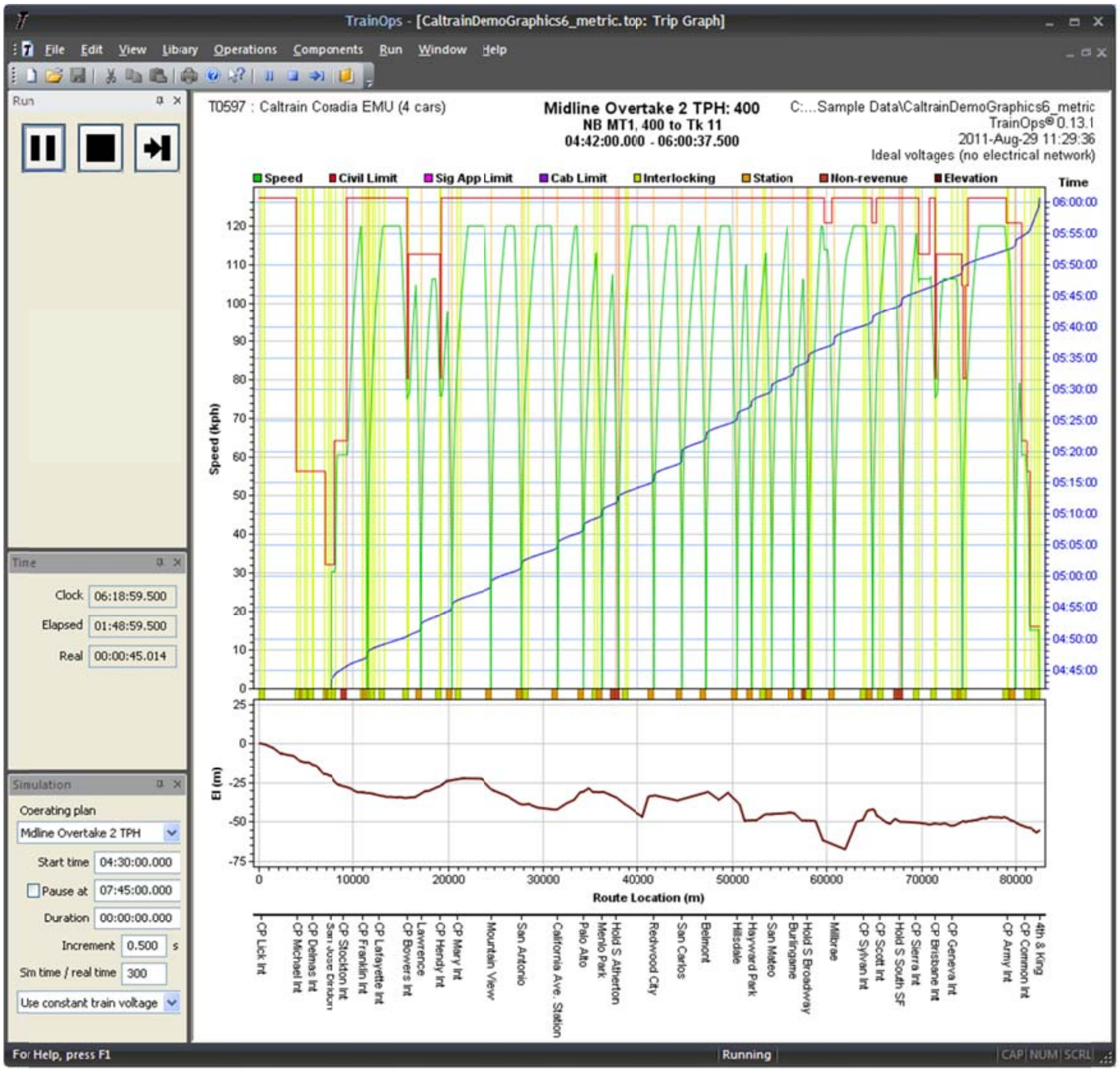


Although TrainOps is not licensed to rail operators or other consulting engineering firms, the software has a long history of successful calibration and application. This history includes application at the following rail systems:

- Mainline Passenger Rail: Amtrak, Denver FasTracks, GO Transit (Toronto), Long Island Rail Road, NJ Transit, SEPTA,
- Heavy Rail: Massachusetts Bay Transportation Authority (Blue, Orange and Red Lines), New York City Transit, and
- Light Rail: Denver, Minneapolis, Phoenix, Portland TriMet, Portland Streetcar, Sacramento, Salt Lake City, Tucson.

Figure 2 shows a typical graphical plot of simulated velocity and simulated travel time.

Figure 2. TrainOps Simulated Velocity



Note: Simulated Velocity (Green); Maximum Authorized Speed (Red); Time versus Distance Plot (Blue); Vertical Profile (Brown)

Traditional TrainOps analyses start with a calibration and validation effort that confirms simulation model results accurately replicate existing conditions on the rail network to be analyzed. TrainOps has been successfully calibrated to existing operations at MBTA, NYCT, NJ Transit, Amtrak and other rail networks.

For the Caltrain/California HSR Blended Operations Analysis, model calibration was not an appropriate use of resources because all model input variables for the Caltrain Corridor (infrastructure, operating plan, vehicles, train control, dwell times) are changing between today's as-in-service condition and the planned future operating condition. This means that once the future simulation scenarios are initiated, there are no calibration database entries remaining on which to leverage the future scenarios.

Instead, LTK focused on performing sensitivity testing of each model input (using a range of realistic and then extreme inputs), validating that the model responds as expected to each change in input. One such example in this TrainOps QA/QC effort was testing the software's response to different delay times in establishing a new route through an interlocking (control point) in the event that the interlocking had just been occupied by a train on a conflicting route. This type of delay is important in accurately modeling the ends of the overtake tracks. LTK tested the 30 second value agreed to by California HSR and Caltrain to verify that the delay to the second train lasted 30 seconds. LTK also tested "extreme" values (0 seconds and 300 seconds – values not used in the actual analytical simulations that followed) to verify that the model's prediction of delay in the event of a conflicting route responded appropriately for the range of potential inputs.

3 Assumptions and Inputs

Summary: This chapter details the assumptions of the blended operations conceptual feasibility analysis and the inputs to the supporting simulation model. Assumptions and inputs are grouped in this chapter by infrastructure (high speed rail stations and overtake track options, track speed); signal system (train control - including response time to signal system and train headways); rail vehicles (rolling stock); dispatching; and operations (service plans, simulation duration, dwell times and randomization).

The virtual world modeled for the simulation analysis is different from the current Caltrain system. The model assumes an electrified rail corridor (in contrast with today's diesel propulsion) with an advanced signal system known as Communications-Based Overlay Signal System Positive Train Control (CBOSS PTC). The planned future system will enable superior performance from that of today's diesel system.

3.1 Infrastructure

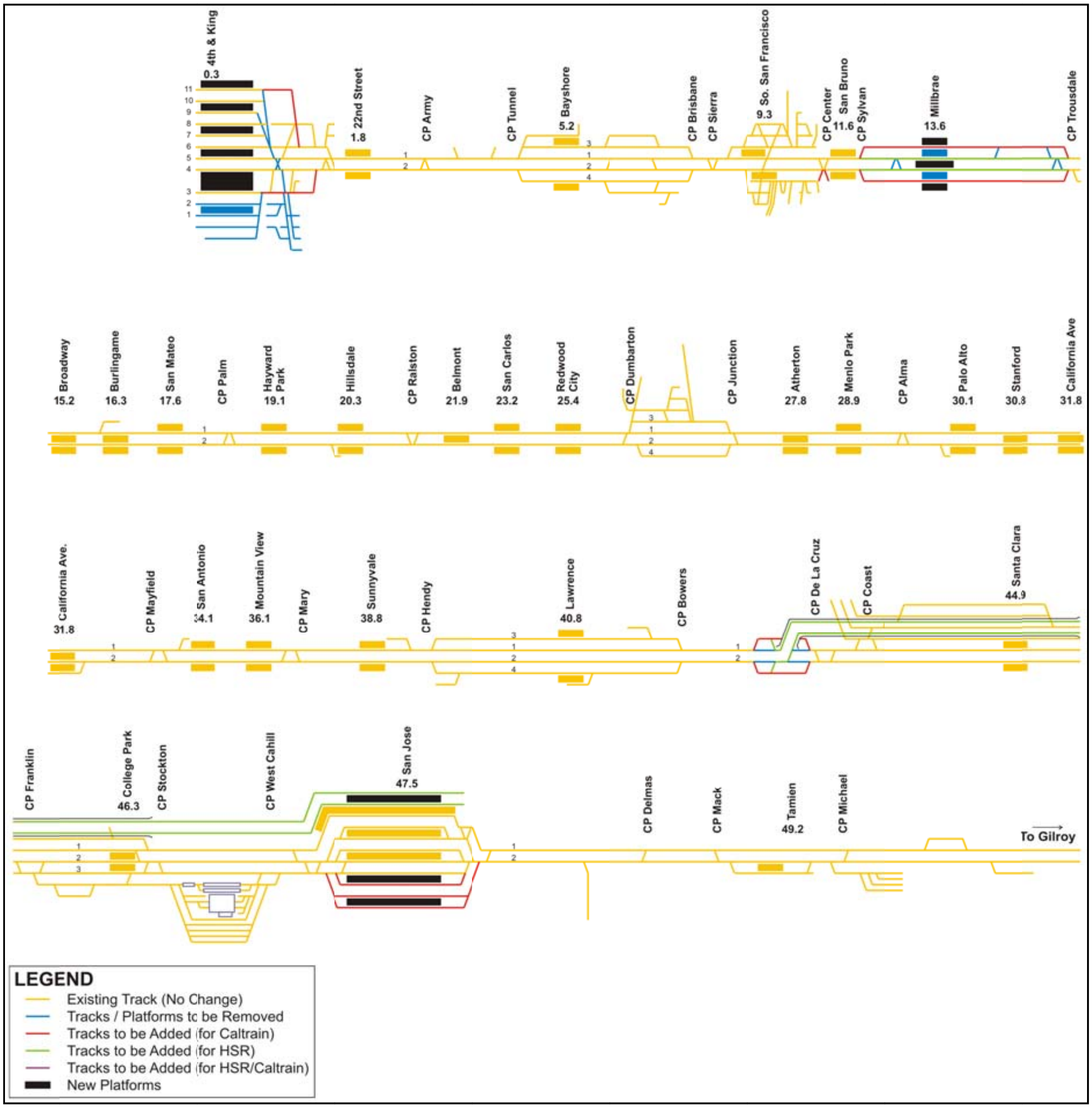
3.1.1 Existing and Under Construction Tracks

The simulation model reflects existing Caltrain tracks and interlockings from 4th and King (North Terminal) to San Jose Diridon (South Terminal) Caltrain stations. It additionally also assumes the following committed track improvements currently being constructed:

- San Bruno Grade Separation Project improvements that will eliminate three highway-rail at-grade crossings,
- South Terminal (San Jose Diridon station) Project which will add two new platforms at this location, and
- Santa Clara Station Project, which will remove the "hold out" rule operations at this location.

Figure 3 shows the assumptions noted above plus HSR-related improvements at North Terminal, at Millbrae and between CP De La Cruz and South Terminal. This in total is referred to as the "Baseline Infrastructure".

Figure 3. Baseline Infrastructure Track Schematic



While California HSR's long-term plan is to continue from 4th & King station to Transbay Terminal in San Francisco, this segment of HSR operation was not assumed in the simulation scenarios. For the purposes of this analysis, which focuses on the operational capabilities of the existing mainline infrastructure between San Francisco and San Jose, all HSR trains were assumed to terminate/originate at the San Francisco (4th & King) Caltrain Station.

3.1.2 High Speed Rail Stations

In order to accommodate HSR service, the simulation assumed additional infrastructure at three existing Caltrain stations where HSR trains will stop. The designs for San Francisco, Millbrae and San Jose Diridon HSR stations developed by HSR to date were incorporated into the simulation database, as described below.

San Jose Diridon Station

In the vicinity of the San Jose Diridon station, the design includes dedicated high speed tracks and station platforms. The dedicated two-track HSR alignment continues northward and merges into middle of the Caltrain mainline north of CP De La Cruz. It was assumed in the model that the two Caltrain tracks were spread apart with the HSR tracks accessing the existing Corridor alignment between the Caltrain tracks. The HSR tracks were assumed to merge into the Caltrain tracks using #32.7 turnout geometry, supporting 80 MPH diverging movements for HSR.

Millbrae Station

At Millbrae Station, a four-track configuration is assumed in the simulation model with two station tracks dedicated to HSR trains and two station tracks dedicated to Caltrain trains. The simulation model assumes 80 MPH diverging #32.7 high speed turnouts for HSR to access the 3rd and 4th main tracks, both north and south of Millbrae.

San Francisco (4th and King) Station

At the San Francisco (4th & King) terminal station in San Francisco, dedicated HSR station tracks with extended station platforms are assumed. This requires modifications to the terminal's interlocking layout.

3.1.3 Overtake Track Options

Overtake (passing) locations provide additional tracks to what exists today in limited segments of the corridor to be used by high speed rail trains to bypass Caltrain trains stopping at stations.

The overall guiding criterion for defining overtake segment options is that operational overtakes (one same-direction train passing another) should improve integration of commuter and high speed rail services with neither service being routinely delayed at an overtake location by the other service. Other criteria include:

- Overtake tracks should be located where their construction and operation limit impacts to adjoining communities;
- Overtake tracks being sufficiently long to support 7+ minute travel time difference between commuter and HSR trains; and
- Overtake tracks connecting to existing four-track segments where possible to minimize capital cost.

To achieve a delay-free overtake, the 4-track section contains a minimum of three Caltrain station stops for each train. Since the Caltrain future operating plan tested in this analysis features a skip-stop zone express type operation, the need for each train to make at least three station stops requires that an overtake section include at least five station locations. Making three out of five station stops allows for both delay free overtakes and consistency with the tested skip-stop operating plan.

In some cases, scheduling delay-free overtakes of commuter trains by HSR requires that additional stops be added to Caltrain in order to create the required 7+ minute travel time difference. These additional stops are undesirable because they increase Caltrain trip times as a result of additional scheduled station stops within the overtake segments.

The minimum 7 minutes of HSR travel time advantage is comprised of:

- 3:00 minimum following move headway (Caltrain is ahead of HSR),
- 0:30 route reestablishment time at overtake diverging interlocking,
- 0:30 route reestablishment time at overtake merging interlocking, and
- 3:00 minimum following move headway (Caltrain is behind HSR)

Four potential overtake locations have been conceptually defined. They are as follows and reflected in Figure 4:

1 The *North Overtake* assumes a 10.2-mile long 4-track segment of tracks from milepost 5 to milepost 15.2. It includes four Caltrain stations and one high speed rail station. They are Bayshore, South San Francisco, San Bruno and Millbrae. The existing 4-track configuration at Bayshore is utilized.

2 The *Full Midline Overtake* assumes a 8.9-mile long 4-track segment of tracks from milepost 18.3 to milepost 27.2. It includes five stations – Hayward Park, Hillsdale, Belmont, San Carlos and Redwood City, all of which are served only by Caltrain. While it is understood that Redwood City is being considered by California High Speed Rail as a possible mid-Peninsula station stop, HSR trains were not programmed to stop there in the simulations. The existing 4-track configuration south of Redwood City is utilized.

3 The *Short Midline Overtake* assumes a 5.9-mile long 4-track segment of tracks from milepost 18.3 to milepost 24.2. It includes four Caltrain stations, Hayward Park, Hillsdale, Belmont and San Carlos, all of which are served only by Caltrain. This option was explored to see what could be achieved if the overtake location was terminated north of Redwood City, avoiding 3rd and 4th track in a portion of the corridor where right of way constraints become more limiting.

4 The *South Overtake* assumes a 7.8-mile long 4-track segment of tracks from milepost 33.8 to milepost 41.6. It includes four Caltrain stations, San Antonio, Mountain View, Sunnyvale and Lawrence, all of which are served only by Caltrain. While it is understood that Mountain View is being considered by California High Speed Rail as a possible mid-Peninsula station stop, HSR trains were not programmed to stop there in the simulations. The existing 4-track configuration at Lawrence is utilized.

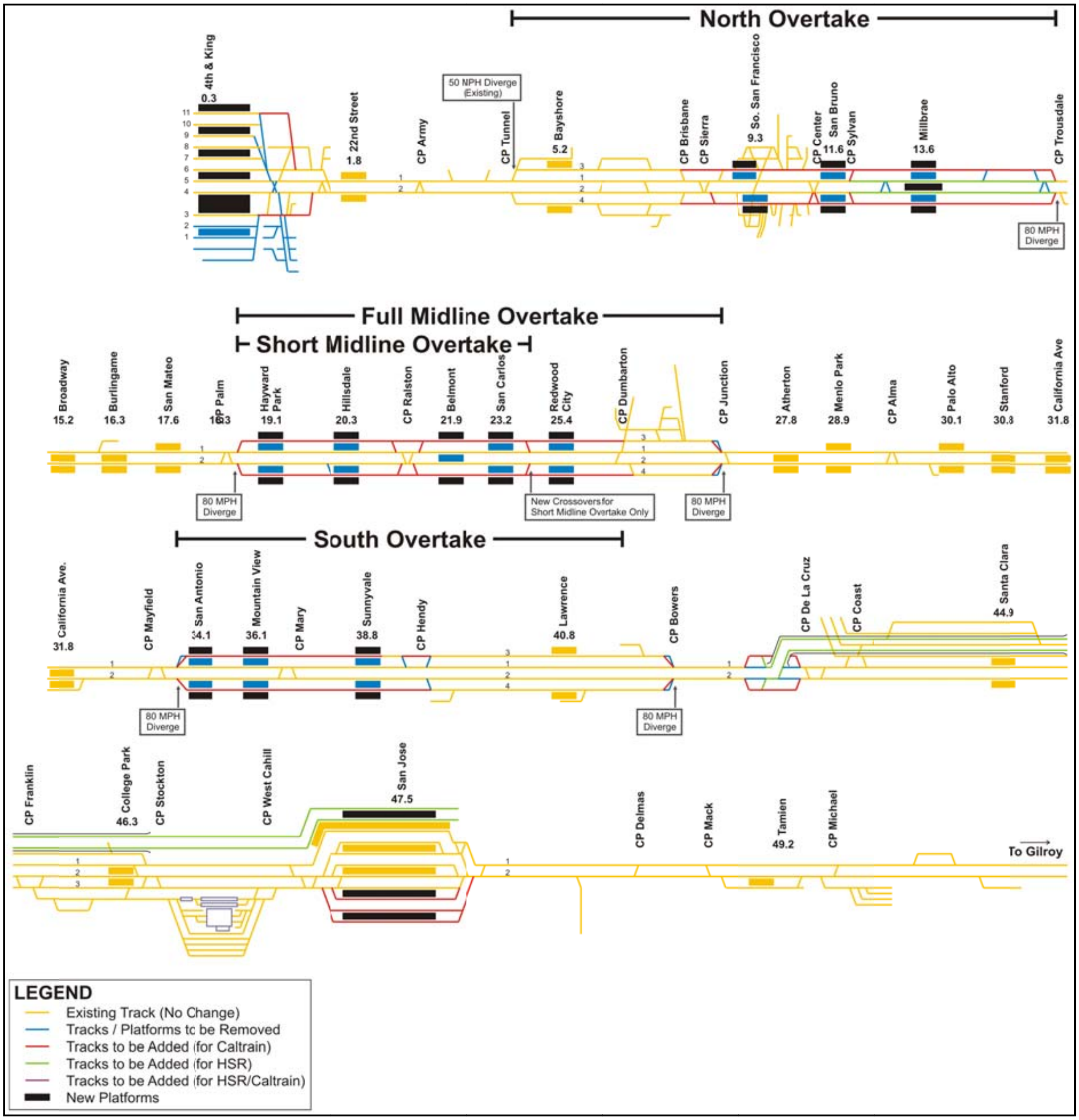
In addition to the 4-track options, a 3-track option is also being considered. Four tracks allow two dedicated tracks for high speed rail for a limited segment of the corridor – one track per direction. Three tracks allow one dedicated track for high speed rail for a limited segment of the corridor – one track that must be shared in both directions.

The North, Full Midline and Short Midline Overtakes were analyzed in the simulation model. Analysis of alternative overtake configurations was paused at this point because the Full Midline Overtake (given Caltrain's tested schedule) shows greater promise in enhancing Corridor capacity and minimizing impacts to Caltrain operations.

Further analysis of all overtake options is required to understand the location options for the overtake tracks along the Caltrain Corridor.

A complete assessment of all of the overtake options will be conducted and provided in a subsequent report.

Figure 4. Track Schematic Showing Baseline Infrastructure with Potential Overtake Trackage



3.1.4 Interlockings

All existing track junctions (interlockings) were assumed to remain in the simulation scenarios. New conceptual interlockings were implemented in the simulation model at San Francisco (4th & King) station in San Francisco, at the Millbrae station, and near CP De La Cruz. Interlockings requiring single #20 turnouts, which support 45 mph diverging movements to another track, were assumed to extend 400 feet from interlocking home signal to home signal. Interlockings requiring single #32.7 high speed turnouts, which support 80 mph diverging movements to another track, were assumed to extend 800 feet from interlocking home signal to home signal.

3.1.5 Track Speed

Two maximum passenger train operating speeds have been tested: (1) up to 79 mph and (2) up to 110 mph for both Caltrain and high speed rail trains. Today, Caltrain trains operate up to 79 mph.

In order to operate trains up to 110 mph, Caltrain's track structure will need to be upgraded to a higher Federal Railroad Administration (FRA) track class with more stringent maintenance tolerances. This will require system-wide infrastructure improvements.

The specific tested speeds are as follows:

- 79/79: Caltrain and HSR trains operating at up to 79 mph along the corridor;
- 79/110: Caltrain and HSR trains operating at up to 79 mph for most of the corridor, except HSR trains operate at up to 110 MPH on the overtake tracks; and
- 110/110: Caltrain and HSR trains operating at up to 110 mph along the corridor.

In all three tested scenarios, optimal corridor throughput was achieved by having Caltrain and HSR trains operate at the same operating speeds to the greatest extent possible on shared tracks. When both operators are running close to the same speed, it allows for a "free flow" of train traffic for the tested service level maximizing corridor throughput.

In the 79/79 and 110/110 scenario, both Caltrain and HSR trains are operating at similar speeds along the whole corridor.

In the 79/110 scenario, Caltrain and HSR trains travel at similar speeds of up to 79mph on the shared tracks but on the overtake tracks used by HSR trains, HSR trains travel faster, up to 110 mph. Higher speeds on the overtake tracks enhances the corridor throughput by allowing the HSR trains to more efficiently pass the Caltrain trains. Since the differing speed is exclusive to the HSR dedicated tracks only, there are no impacts to the "free flow" of train traffic maximized by sustaining similar speeds of both systems on the shared tracks along most of the corridor.

3.2 Train Control

3.2.1 Base Assumptions

Caltrain's existing wayside signaling system is assumed as the base of the train control system in the simulation model. The existing system does not have cab signaling or automatic train control.

The existing system generally features three-block, four-aspect control lines, meaning that two trains must be separated by three signal blocks (each about 4,000 to 5,000 feet long) for the following train to experience green ("Clear") signal aspects. The system has automatic signals, indicators along the side of the track that cannot be controlled by the dispatcher and respond automatically to track occupancy status ahead on the Caltrain Corridor.

3.2.2 CBOSS PTC Signal System Overlay Assumptions

In addition to the based train control system, the simulation model assumes an overlay advanced signal system. The advanced signal system is called CBOSS PTC (Communication-Based Overlay Signal System Positive Train Control).

CBOSS PTC, to be implemented by 2015, brings federally mandated safety benefits and performance enhancements to the Caltrain Corridor. PTC is associated with the safety attributes related to collision prevention, civil speed restrictions and roadway worker protection zones. CBOSS is associated with the attributes of the system related improved performance and capacity enhancement.

Unlike most other PTC systems under development in North America, CBOSS PTC is being designed to provide important capacity benefits on the Caltrain Corridor. These benefits emanate from two distinct features of the system. Firstly, CBOSS PTC allows trains on the Caltrain Corridor to approach signals at stop based on their individual braking performance capabilities rather than the “worst case” braking of all trains operating on the Corridor. Secondly, CBOSS PTC provides continuous updates to the train engineer about the occupancy status of the track ahead, rather than providing intermittent information only at wayside signal locations.

The overall capacity of the corridor is governed by the minimum supportable headway (in terms of time) at which the signal system permits two trains to operate at maximum speed. The capacity of each corridor segment is defined by a location-specific minimum supportable headway, with this being a function of train speed, signal layout, station spacing, train stopping patterns and train dwell times at station. The longest resulting interval between trains on the corridor defines overall Caltrain Corridor capacity.

3.2.3 Response Time

Caltrain worked with CHSR in defining appropriate signal system/CBOSS PTC response times assumed in the simulation model. Recognizing that CBOSS PTC is an overlay system, the response time of both systems must be added together to determine the overall response time for sequential actions of the two systems (signal system/CBOSS PTC).

The following are the simulation parameters:

- Response time for signal system/CBOSS PTC - automatic territory – 6 seconds
- Response time for signal system/CBOSS PTC - interlocking territory (fleeting routes) – 14 seconds
- Response time for signal system/CBOSS PTC - interlocking territory (train waiting for conflicting route to clear) – 30 seconds

The 30 second time for reestablishment of a new route includes provisions for loss-of-shunt time, switch movement time, central control communication time, route establishment time and CBOSS PTC processing time.

3.2.4 Determining Minimum Train Intervals

As designed, CBOSS PTC will allow for trains to safely operate closer together than today's wayside signal system. The TrainOps software was used to determine this improvement in signal system capacity. The result of the simulation exercise determined that the minimum supportable headway would decrease from approximately six minutes (realized under the current wayside signal system) to approximately three minutes.

A simulation with two Caltrain trips that depart the terminal at an initial "trial" train interval (headway) of 1:30 (one and half minutes) and then stop and dwell at each station for 30 second dwells was created to assess the minimum system headway under CBOSS PTC.

As the trains are delayed by the CBOSS PTC system, the headway increases to the minimum supportable headway between trains, which is a function of the longest signal block clearing time and CBOSS PTC braking profile on the corridor. The results in Table 1 and Table 2 indicate that a headway of just over three minutes can be scheduled for identical all-stops trains without encountering delay. Figure 5 displays time versus distance plots of the two sets of trains, showing their CBOSS PTC-enforced headway increasing from the initial "trial" train interval to the true minimum supportable train interval of just over three minutes as they operate through the Corridor.

For sections along the Corridor with a higher signal density (shorter signal block lengths), such as from Redwood City to San Jose, the supportable headway is closer.

Included in Table 3 and Table 4, are simulation results showing two trains departing the terminals at a headway of 3:15. Figure 6 shows the time versus distance plot of the two pairs of trains as well. In this case, the trains operate with just one second of delay along the entire corridor, indicating that a headway of 3:16 represents the unimpeded minimum supportable headway for all-stops trains on the Corridor under CBOSS PTC. As the blended simulations show, due to the CBOSS PTC profile-based braking to the stop target ahead, variations in stopping patterns become the primary contributing factor to supportable headways along the corridor.

3.2.5 Passing Track Signal Spacing

In sections of new 3rd and 4th main track, automatic signal spacing averaging 3,000 to 4,000 feet was assumed, which is somewhat shorter than the current Caltrain automatic signal block length. Automatic signal block layouts were developed with uniform length, based on constraining fixed interlocking signal locations.

Table 1 – Minimum Supportable Caltrain Corridor CBOSS PTC Headway - Northbound Trains				
Station	**Lead**	**Following**	**Headway**	**Running Delay to Following Train**
San Jose Diridon Station	0:00:00	0:01:30	0:01:30	0:00:00
Santa Clara Station	0:04:44	0:06:57	0:02:13	0:00:43
Lawrence Station	0:09:06	0:11:25	0:02:19	0:00:49
Sunnyvale Station	0:12:19	0:15:11	0:02:52	0:01:22
Mountain View Station	0:15:51	0:18:43	0:02:52	0:01:22
San Antonio Station	0:18:47	0:21:39	0:02:52	0:01:22
California Ave. Station	0:22:02	0:24:55	0:02:53	0:01:23
Palo Alto Station	0:24:45	0:27:38	0:02:53	0:01:23
Menlo Park Station	0:27:05	0:29:58	0:02:53	0:01:23
Atherton Station	0:29:16	0:32:09	0:02:53	0:01:23
Redwood City Station	0:32:31	0:35:35	0:03:04	0:01:34
San Carlos Station	0:35:40	0:38:44	0:03:04	0:01:34
Belmont Station	0:38:02	0:41:06	0:03:04	0:01:34
Hillsdale Station	0:40:44	0:43:49	0:03:05	0:01:35
Hayward Park Station	0:43:01	0:46:05	0:03:04	0:01:34
San Mateo Station	0:45:25	0:48:30	0:03:05	0:01:35
Burlingame Station	0:48:00	0:51:04	0:03:04	0:01:34
Broadway Station	0:50:05	0:53:11	0:03:06	0:01:36
Millbrae Station	0:52:47	0:55:54	0:03:07	0:01:37
San Bruno Station	0:56:08	0:59:14	0:03:06	0:01:36
South San Francisco Station	0:58:58	1:02:05	0:03:07	0:01:37
Bayshore Station	1:04:00	1:07:06	0:03:06	0:01:36
22nd Street Station	1:08:10	1:11:16	0:03:06	0:01:36
4th & King Station	1:13:31	1:16:38	0:03:07	0:01:37

Table 2 – Minimum Supportable Caltrain Corridor CBOSS PTC Headway - Southbound Trains				
Station	**Lead**	**Following**	**Headway**	**Running Delay to Following Train**
4th & King Station	0:00:00	0:01:30	0:01:30	0:00:00
22nd Street Station	0:04:44	0:07:48	0:03:04	0:01:34
Bayshore Station	0:08:59	0:12:03	0:03:04	0:01:34
South San Francisco Station	0:13:57	0:17:01	0:03:04	0:01:34
San Bruno Station	0:16:51	0:19:55	0:03:04	0:01:34
Millbrae Station	0:20:10	0:23:15	0:03:05	0:01:35
Broadway Station	0:22:52	0:25:56	0:03:04	0:01:34
Burlingame Station	0:25:06	0:28:10	0:03:04	0:01:34
San Mateo Station	0:27:35	0:30:39	0:03:04	0:01:34
Hayward Park Station	0:29:58	0:33:02	0:03:04	0:01:34
Hillsdale Station	0:32:16	0:35:20	0:03:04	0:01:34
Belmont Station	0:34:58	0:38:03	0:03:05	0:01:35
San Carlos Station	0:37:19	0:40:23	0:03:04	0:01:34
Redwood City Station	0:40:27	0:43:32	0:03:05	0:01:35
Atherton Station	0:43:44	0:46:48	0:03:04	0:01:34
Menlo Park Station	0:45:55	0:49:00	0:03:05	0:01:35
Palo Alto Station	0:48:16	0:51:21	0:03:05	0:01:35
California Ave. Station	0:50:56	0:54:00	0:03:04	0:01:34
San Antonio Station	0:54:11	0:57:16	0:03:05	0:01:35
Mountain View Station	0:57:09	1:00:13	0:03:04	0:01:34
Sunnyvale Station	1:00:42	1:03:48	0:03:06	0:01:36
Lawrence Station	1:03:54	1:07:00	0:03:06	0:01:36
Santa Clara Station	1:08:10	1:11:18	0:03:08	0:01:38
San Jose Diridon Station	1:13:38	1:16:46	0:03:08	0:01:38

Table 3 – Simulation of Northbound Trains - With 3:15 Departing Headway				
Station	**Lead**	**Following**	**Headway**	**Running Delay to Following Train**
San Jose Diridon Station	0:00:00	0:03:15	0:03:15	0:00:00
Santa Clara Station	0:04:44	0:07:59	0:03:15	0:00:00
Lawrence Station	0:09:06	0:12:21	0:03:15	0:00:00
Sunnyvale Station	0:12:19	0:15:34	0:03:15	0:00:00
Mountain View Station	0:15:51	0:19:06	0:03:15	0:00:00
San Antonio Station	0:18:47	0:22:02	0:03:15	0:00:00
California Ave. Station	0:22:02	0:25:17	0:03:15	0:00:00
Palo Alto Station	0:24:45	0:28:00	0:03:15	0:00:00
Menlo Park Station	0:27:05	0:30:20	0:03:15	0:00:00
Atherton Station	0:29:16	0:32:31	0:03:15	0:00:00
Redwood City Station	0:32:31	0:35:46	0:03:15	0:00:00
San Carlos Station	0:35:40	0:38:55	0:03:15	0:00:00
Belmont Station	0:38:02	0:41:17	0:03:15	0:00:00
Hillsdale Station	0:40:44	0:43:59	0:03:15	0:00:00
Hayward Park Station	0:43:01	0:46:16	0:03:15	0:00:00
San Mateo Station	0:45:25	0:48:40	0:03:15	0:00:00
Burlingame Station	0:48:00	0:51:15	0:03:15	0:00:00
Broadway Station	0:50:05	0:53:21	0:03:16	0:00:01
Millbrae Station	0:52:47	0:56:02	0:03:15	0:00:00
San Bruno Station	0:56:08	0:59:23	0:03:15	0:00:00
South San Francisco Station	0:58:58	1:02:13	0:03:15	0:00:00
Bayshore Station	1:04:00	1:07:15	0:03:15	0:00:00
22nd Street Station	1:08:10	1:11:25	0:03:15	0:00:00
4th & King Station	1:13:31	1:16:47	0:03:16	0:00:01

Table 4 – Simulation of Southbound Trains With 3:15 Departing Headway				
Station	**Lead**	**Following**	**Headway**	**Running Delay to Following Train**
4th & King Station	0:00:00	0:03:15	0:03:15	0:00:00
22nd Street Station	0:04:44	0:07:59	0:03:15	0:00:00
Bayshore Station	0:08:59	0:12:14	0:03:15	0:00:00
South San Francisco Station	0:13:57	0:17:12	0:03:15	0:00:00
San Bruno Station	0:16:51	0:20:06	0:03:15	0:00:00
Millbrae Station	0:20:10	0:23:25	0:03:15	0:00:00
Broadway Station	0:22:52	0:26:07	0:03:15	0:00:00
Burlingame Station	0:25:06	0:28:21	0:03:15	0:00:00
San Mateo Station	0:27:35	0:30:50	0:03:15	0:00:00
Hayward Park Station	0:29:58	0:33:13	0:03:15	0:00:00
Hillsdale Station	0:32:16	0:35:31	0:03:15	0:00:00
Belmont Station	0:34:58	0:38:13	0:03:15	0:00:00
San Carlos Station	0:37:19	0:40:34	0:03:15	0:00:00
Redwood City Station	0:40:27	0:43:42	0:03:15	0:00:00
Atherton Station	0:43:44	0:46:59	0:03:15	0:00:00
Menlo Park Station	0:45:55	0:49:10	0:03:15	0:00:00
Palo Alto Station	0:48:16	0:51:31	0:03:15	0:00:00
California Ave. Station	0:50:56	0:54:11	0:03:15	0:00:00
San Antonio Station	0:54:11	0:57:26	0:03:15	0:00:00
Mountain View Station	0:57:09	1:00:24	0:03:15	0:00:00
Sunnyvale Station	1:00:42	1:03:57	0:03:15	0:00:00
Lawrence Station	1:03:54	1:07:09	0:03:15	0:00:00
Santa Clara Station	1:08:10	1:11:26	0:03:16	0:00:01
San Jose Diridon Station	1:13:38	1:16:54	0:03:16	0:00:01

Figure 5. Time-Distance "String" Chart Showing Northbound and Southbound All-Stops Trains Dispatched at Initial 1:30 Headway

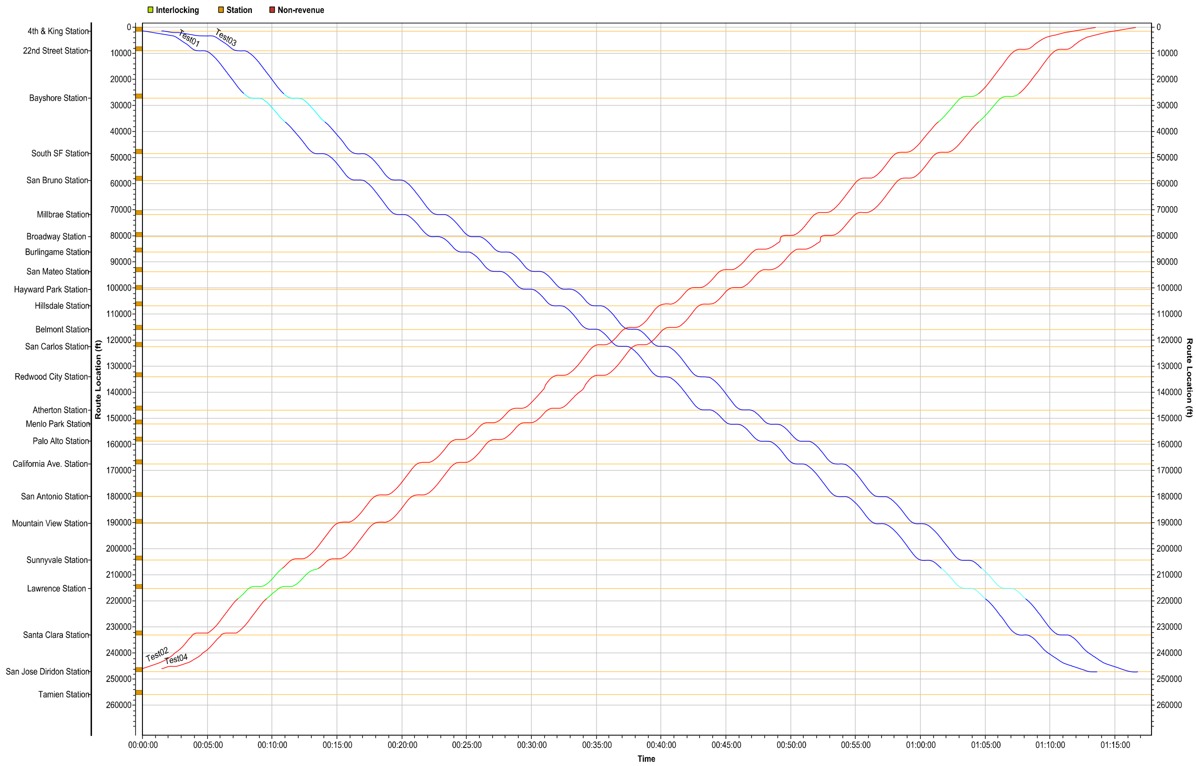
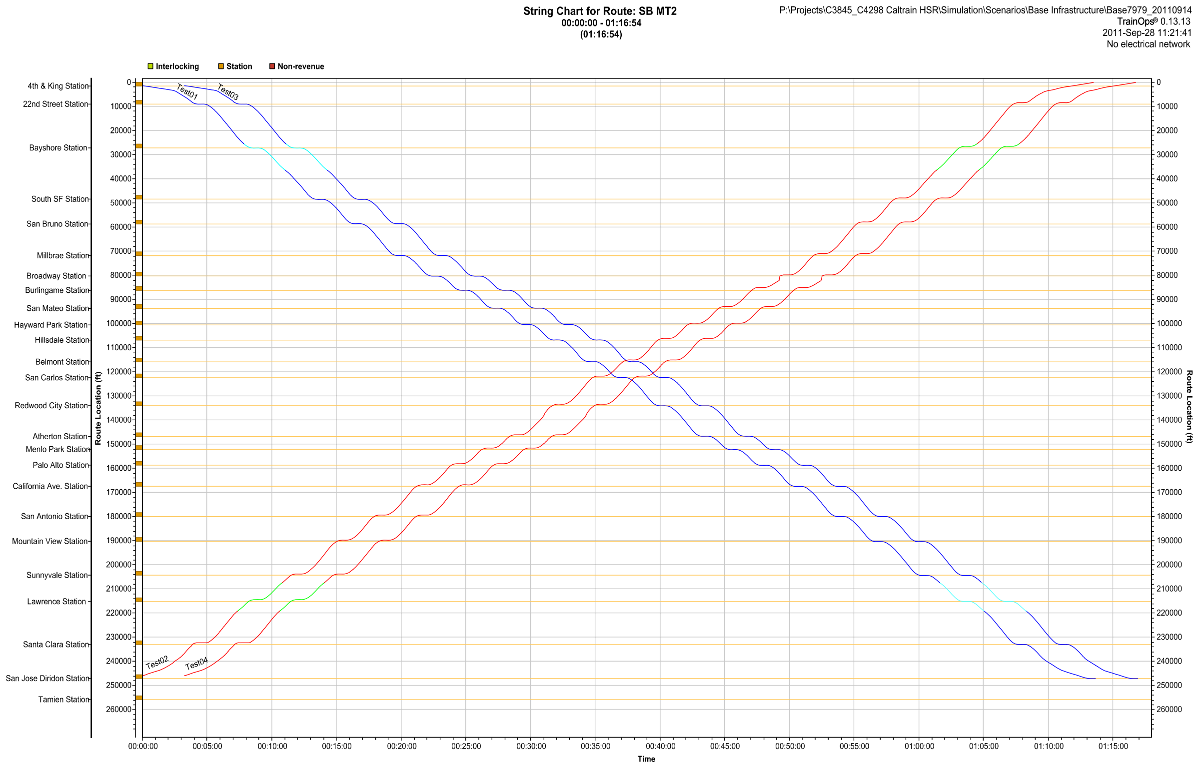


Figure 6. Time-Distance “String” Chart Showing Northbound and Southbound All-Stops Trains Operating on 3:15 Headway



3.3 Rolling Stock

The performance attributes of the future Caltrain and high speed rail vehicles (rolling stock) are detailed below. The specific attributes of each rolling stock type were modeled individually in the simulation, with differences affecting both acceleration and braking rates.

3.3.1 Caltrain

Caltrain is planning to replace its diesel fleet with electric trains called Electric Multiple Units (EMU). EMUs feature individual electric motors on the axles of each car, providing superior acceleration, greater reliability and a smoother ride than the current Caltrain diesel fleet. Commuter railroads in Chicago, New York, New Jersey, Philadelphia and Montreal use EMUs for high capacity, high performance operations. Caltrain is planning to use 8 car trains to augment the seating capacity of an existing 5 car train. The Caltrain EMU performance assumed in the simulation is based on prototypical specifications for existing EMU vehicles. The assumptions include appropriate derating to reflect engineer conservatism:

- Initial acceleration (0 to 19 MPH) is 2.1 MPHPS with declining acceleration rates at higher velocities based on the tractive effort curve shown in Figure 7,
- Brake rate for station stops (with or without near side grade crossing enforcement) is 1.8 MPHPS,

- Brake rate for signal at stop or stop & proceed is 1.2 MPHPS, and
- Brake rate for civil speed enforcement is 1.2 MPHPS.

The full service brake rate of the future Caltrain EMU is 2.5 MPHPS. The lower 1.2 and 1.8 MPHPS deceleration rates used in the simulation reflect the enforcement effects of CBOSS PTC as well as engineer conservatism.

The tractive effort curve graphs the maximum pounds of force produced by the train to accelerate it. The “effort” corresponds to the acceleration capability of the train. Similar to an automobile, the acceleration capability at low speeds is much greater than when operating at high speeds.

Figure 8 displays the acceleration versus velocity curve for the Caltrain EMU, based on performance on level, tangent track. Acceleration at low velocities (up to about 20 MPH) is about 2.1 MPHPS. Table 5 presents the important physical and performance characteristics of the Caltrain Coradia Trainset as simulated in the Blended Operations Analysis.

Figure 7. Alstom Coradia Tractive Effort Curve, Representative of Caltrain EMU Performance

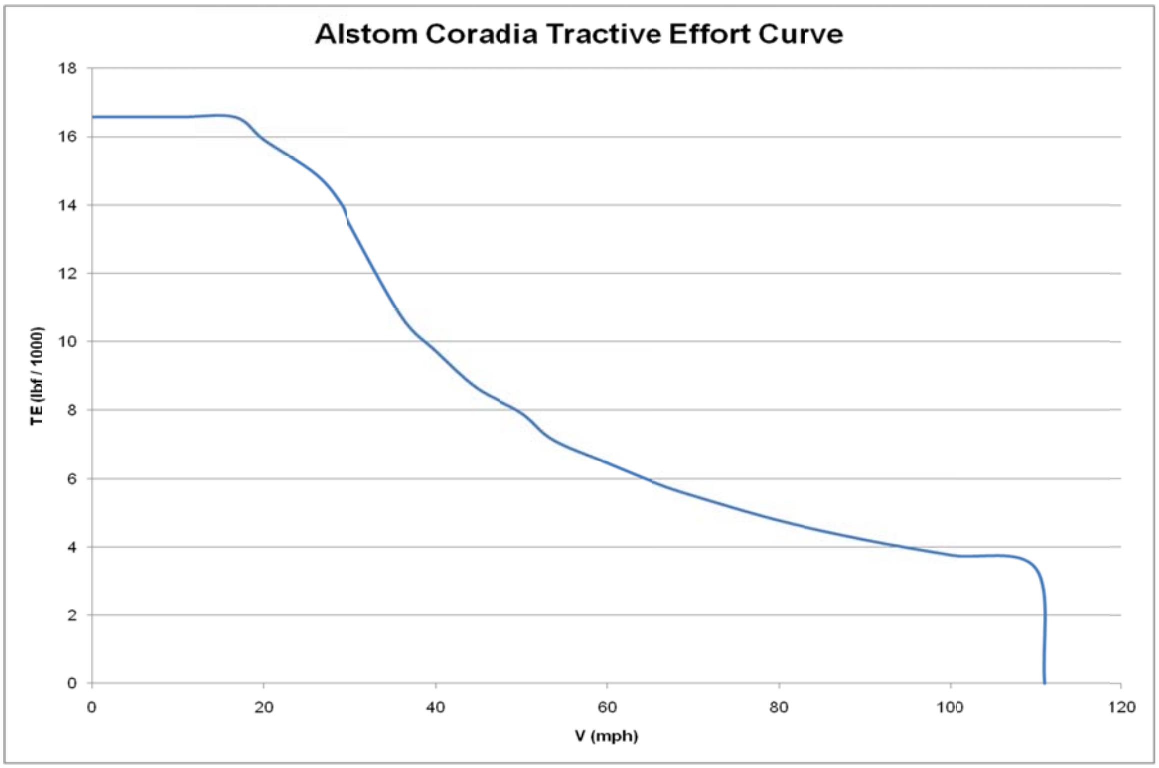
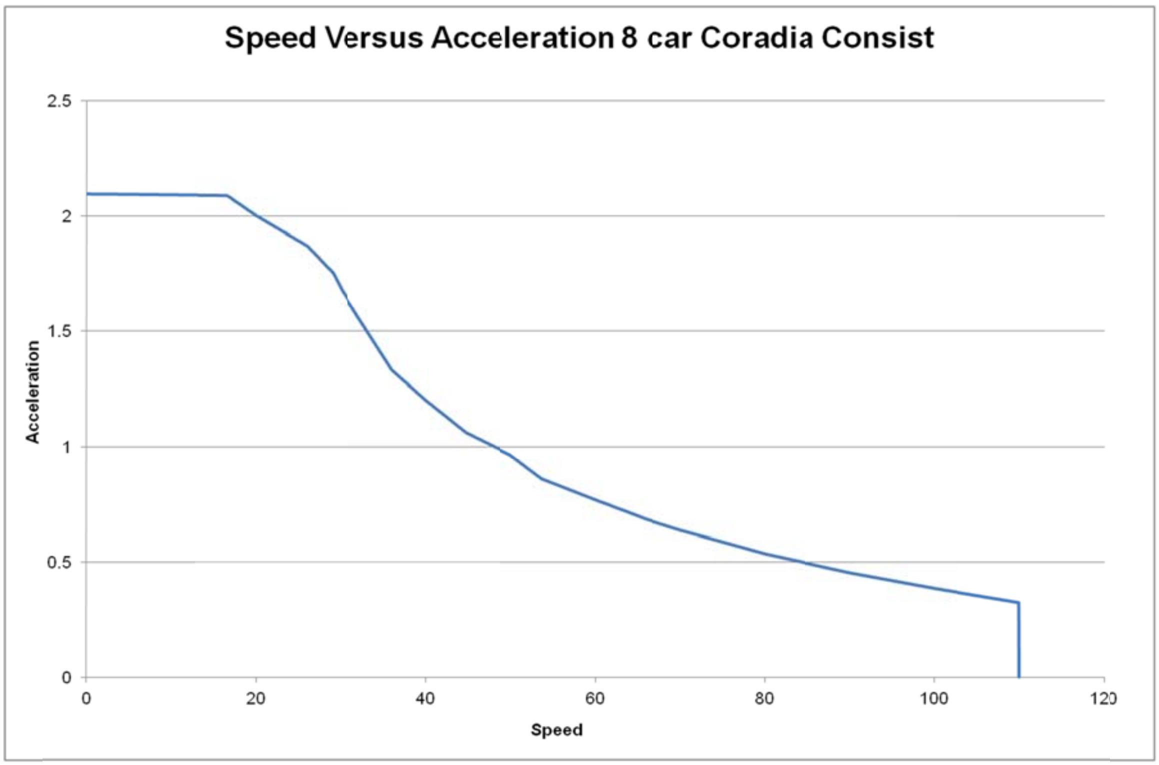


Table 5 – Caltrain Coradia Trainset Physical Characteristics

Description	Value	Unit	Value	Unit	Notes
Frontal Area	13.41	m^2	144.344	ft^2	
Length	213.2	M	699.5	Ft	
Empty Weight	517396	Kg	1140663	Lbs	
Design Deceleration	1.1176	m/s^2	2.50	MPHPS	
Braking Distance	1082.04	M	3550	Ft	3550 ft. from 110-0 mph.
Open Air Resistance	0.4100	$N/(kph^{2)}$	0.2387	lbf/mph^2	AAR Equation.
Maximum Operating Acceleration	0.939	m/s^2	2.1	MPHPS	2.1 MPHPS
Maximum Operating Deceleration	0.894	m/s^2	2.0	MPHPS	2.0 MPHPS

Figure 8. Speed versus Acceleration for Simulated Caltrain EMU



3.3.2 High Speed Rail

The high speed rail trains are based on Siemens "Velaro E" HSR performance data as follows:

- Initial acceleration (0 to 19 MPH) is 1.05 MPHPS with declining acceleration rates at higher velocities, as shown in Figure 9,
- Brake rate for station stops (with or without near side grade crossing enforcement) is 1.5 MPHPS,
- Brake rate for signal at stop or stop & proceed is 1.2 MPHPS, and
- Brake rate for civil speed enforcement is 1.2 MPHPS.

As with the future Caltrain EMU, the full service braking capability of the high speed rail trains is planned to be about 2.5 MPHPS. The lower 1.2 and 1.5 MPHPS deceleration rates used in the simulations reflect the enforcement effects of the CBOSS PTC system, as well as engineer caution.

Table 6 presents the important physical and performance characteristics of the Siemens "Velaro E" High Speed Trainset. The length of a high speed rail trainset used in the simulations is 656 feet (200 meters). The CHSRA has indicated that as ridership demand warrants, the length of the high speed rail trainsets are planned to increase in length up to 1,312 feet (400 meters).

Figure 9. Siemens Velaro E High Speed Trainset Tractive Effort Curve

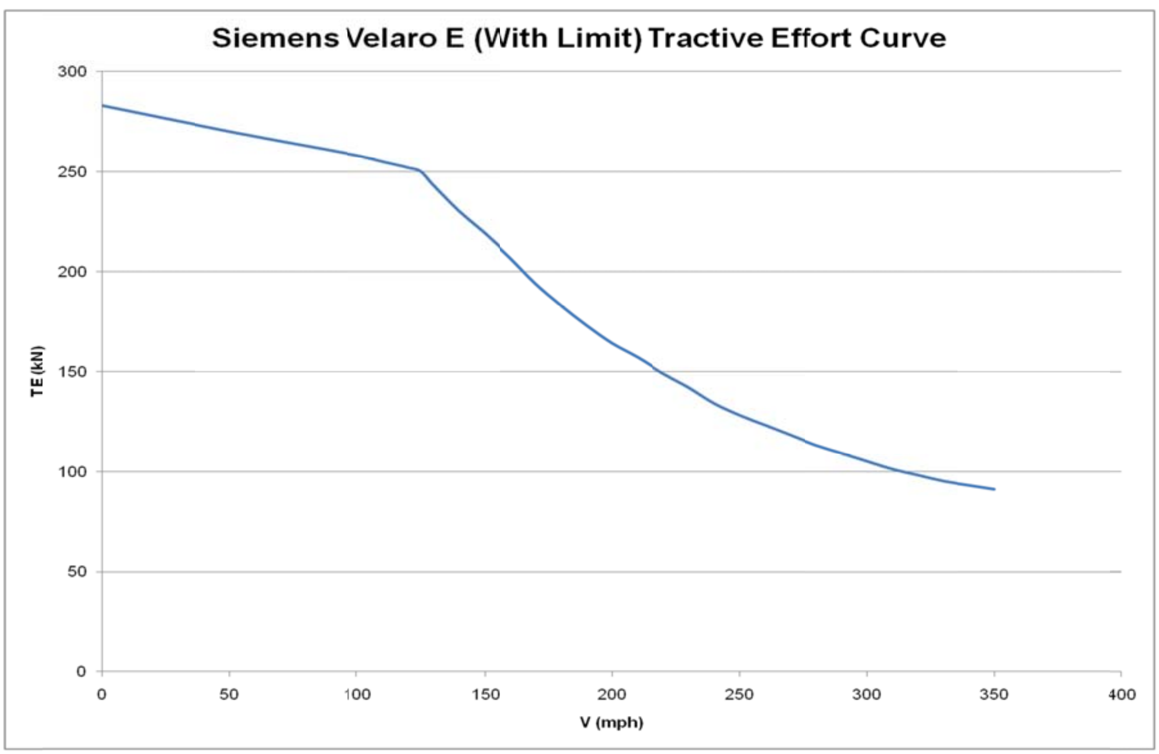
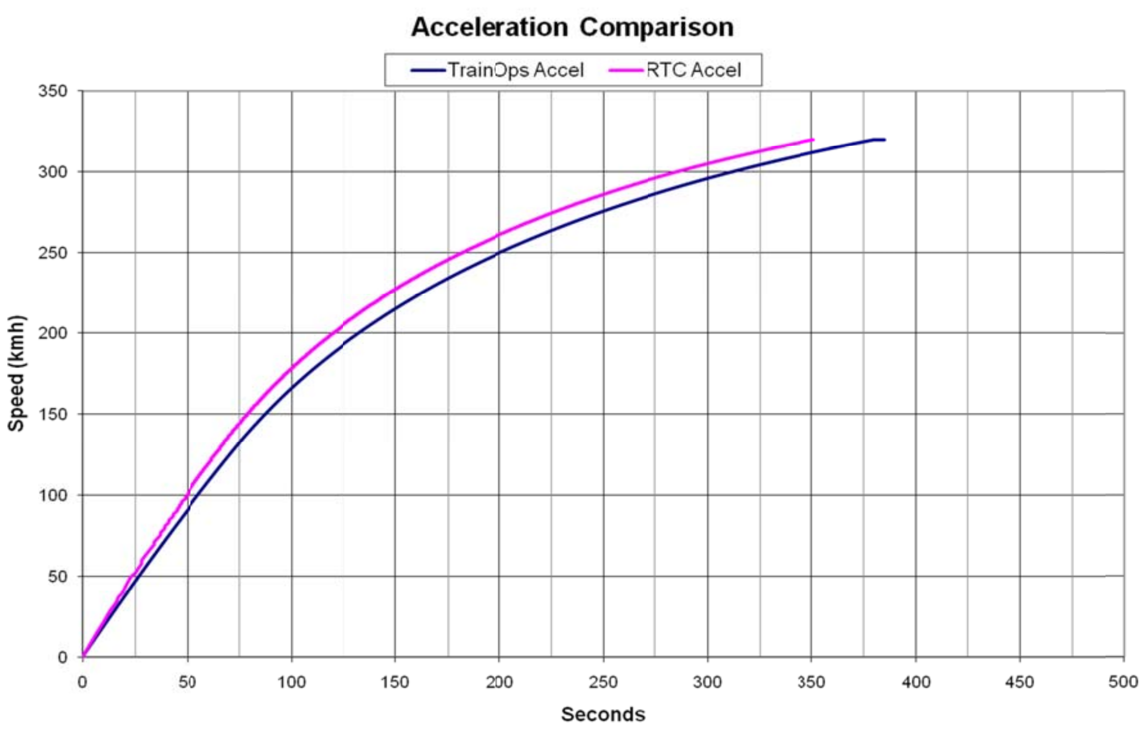


Table 6 – Siemens Velaro E High Speed Trainset Physical Characteristics					
Description	**Value**	**Unit**	**Value**	**Unit**	**Notes**
Frontal Area	11.4755	m^2	123.521	ft^2	
Length	200	M	656.2	Ft	
Empty Weight	439000	Kg	967829	lbs	
Design Deceleration	0.94	m/s^2	2.10	MPHPS	
Braking Distance	3901.34	M	12800	Ft	Spec: 3900 m from 320-0 km/h
Open Air Resistance	0.02895	$N/(m^2kph^{2)}$	0.02895	$lbf/(ft^2mph^2)$	Davis Equation.
Maximum Operating Acceleration	1.1176	m/s^2	2.5	MPHPS	2.5 MPHPS
Maximum Operating Deceleration	0.6706	m/s^2	1.5	MPHPS	1.5 MPHPS

Side-by-side comparison of HSR acceleration using LTK's TrainOps software and the HSR Team's Rail Traffic Controller software was conducted to ensure consistency of results and to confirm that TrainOps is accurately modeling the high performance (low aerodynamic drag) attributes of HSR trainsets. The comparative results of a close correlation between the two independent software applications are demonstrated in Figure 10.

Figure 10. TrainOps and RTC Simulated Accelerations of Siemens Velaro E High Speed Trainset



3.4 Dispatching

3.4.1 Train Priorities

In general, the simulations naturally processed the trains in timetable order, giving priority to trains scheduled earlier versus trains scheduled later at a given interlocking. In rare cases, a Caltrain trip that closely follows high speed rail at Millbrae would request a route at the leaving end of Millbrae Station, effectively trying to overtake high speed rail in this short section of 3rd and 4th main track. Because of the Caltrain Corridor minimum supportable headways and the 30 second route reestablishment time, this dispatching would result in a two to four minute delay to high speed rail which was assumed to be unacceptable. Dispatching logic was added to the simulations to ensure that Caltrain/HSR overtakes did not occur in the short four-track section of the Corridor at Millbrae. Moving HSR ahead of Caltrain at this location avoided delays to HSR with Caltrain also proceeding without delay. Without this logic in place, Caltrain would proceed without delay but HSR would be delayed for 2 to 4 minutes.

3.4.2 *Station "Hold Out Rule"*

At stations specified in the Employee Timetable, Caltrain Operating Rule 6.30 (Rule 6.30) calls for the engineers of two trains approaching a station (with at least one of the trains making a station stop) to coordinate via radio to assure that only one train is in the station at a time. This "hold out" rule is applied at locations where passengers must cross one active track at grade in order to board and alight from trains.

In the model, the following stations, reflective of today's conditions, are assumed to be subject to Rule 6.30 "hold out" operations:

- South San Francisco,
- Broadway,
- Atherton.

The hold out rule applies equally to HSR and Caltrain trips on the Corridor. Where two trains are approaching one of the Rule 6.30 stations at about the same time and one of the trains is not stopping, that train was given priority in the simulation and passed through first. Where both trains are approaching the station and both are stopping, the first train approaching was allowed to enter the station first. The hold out rule does not apply if both approaching trains are passing through the station without stopping.

3.5 Operations

3.5.1 *Caltrain*

The assumed future Caltrain service plan used in the simulation is six trains per peak hour per direction and two trains per hour off-peak hour per direction. Today, Caltrain operates five trains per peak hour per direction.

The future operating concept serves all Caltrain stations. In contrast with the current operating plan, the Caltrain future operating concept tested in simulation includes no programmed overtakes.

This tested service plan represents only one possible plan. Other operating concepts for future operations will be considered and no official decision has been made with respect to future service levels, dispatching strategies (programmed overtakes), stopping patterns or scheduled trip times.

The Caltrain operating concept that was modeled uses peak period skip stop zone express service strategy, with station stop frequency based on ridership from that location. High ridership stations like Redwood City and Palo Alto receive six trains per hour per direction service, with these locations not only accommodating strong boarding ridership but also serving as transfer points for passengers traveling between two lower ridership stations not served by the same train.

The enhanced performance of the planned EMUs, when compared with the current diesel push-pull performance given the proposed service plan, supports San Francisco-San Jose trip times comparable to the current "Baby Bullet" service.

Table 7 shows a representative 60 minute period of the Caltrain future operating concept in the northbound direction while Table 8 shows the same information for southbound operations. The scheduled times in the tables reflect leaving times, except at the last station.

Table 7 – Peak 60 Minutes Northbound Service - AM Simulated Schedule

	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

Table 8 – Peak 60 Minutes Southbound Service – AM Simulated Schedule						
	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

Table 9 displays a representative sample of the Caltrain operating concept for the off peak for northbound service. Trains operate on half-hourly “clockface” or “memory” schedules, with all trains serving all stations. Every other train serves Tamien.

Table 10 displays the same information for off-peak southbound operations. Scheduled times between San Jose Diridon and Tamien stations are shorter during off-peak operations than during peak operations due to the need for less schedule recovery during off-peak periods.

Table 9 – Northbound Service – Midday Simulated Schedule						
	448	**450**	**452**	**454**	**456**	**458**
Tamien Station		11:27a		12:27p		1:27p
San Jose Diridon Station	11:00a	11:30a	12:00p	12:30p	1:00p	1:30p
College Park Station*						
Santa Clara Station	11:05a	11:35a	12:05p	12:35p	1:05p	1:35p
Lawrence Station	11:09a	11:39a	12:09p	12:39p	1:09p	1:39p
Sunnyvale Station	11:12a	11:42a	12:12p	12:42p	1:12p	1:42p
Mountain View Station	11:17a	11:47a	12:17p	12:47p	1:17p	1:47p
San Antonio Station	11:20a	11:50a	12:20p	12:50p	1:20p	1:50p
California Ave. Station	11:23a	11:53a	12:23p	12:53p	1:23p	1:53p
Palo Alto Station	11:27a	11:57a	12:27p	12:57p	1:27p	1:57p
Menlo Park Station	11:29a	11:59a	12:29p	12:59p	1:29p	1:59p
Atherton Station	11:31a	12:01p	12:31p	1:01p	1:31p	2:01p
Redwood City Station	11:35a	12:05p	12:35p	1:05p	1:35p	2:05p
San Carlos Station	11:38a	12:08p	12:38p	1:08p	1:38p	2:08p
Belmont Station	11:40a	12:10p	12:40p	1:10p	1:40p	2:10p
Hillsdale Station	11:43a	12:13p	12:43p	1:13p	1:43p	2:13p
Hayward Park Station	11:45a	12:15p	12:45p	1:15p	1:45p	2:15p
San Mateo Station	11:47a	12:17p	12:47p	1:17p	1:47p	2:17p
Burlingame Station	11:50a	12:20p	12:50p	1:20p	1:50p	2:20p
Broadway Station	11:52a	12:22p	12:52p	1:22p	1:52p	2:22p
Millbrae Station	11:56a	12:26p	12:56p	1:26p	1:56p	2:26p
San Bruno Station	12:00p	12:30p	1:00p	1:30p	2:00p	2:30p
South San Francisco Station	12:04p	12:34p	1:04p	1:34p	2:04p	2:34p
Bayshore Station	12:05p	12:35p	1:05p	1:35p	2:05p	2:35p
22nd Street Station	12:09p	12:39p	1:09p	1:39p	2:09p	2:39p
4th & King Station	12:13p	12:43p	1:13p	1:43p	2:13p	2:43p

*Schedule to be determined

Table 10 – Southbound Service – Midday Simulated Schedule						
	449	**451**	**453**	**455**	**457**	**459**
4th & King Station	11:00a	11:30a	12:00p	12:30p	1:00p	1:30p
22nd Street Station	11:05a	11:35a	12:05p	12:35p	1:05p	1:35p
Bayshore Station	11:09a	11:39a	12:09p	12:39p	1:09p	1:39p
South San Francisco Station	11:14a	11:44a	12:14p	12:44p	1:14p	1:44p
San Bruno Station	11:18a	11:48a	12:18p	12:48p	1:18p	1:48p
Millbrae Station	11:21a	11:51a	12:21p	12:51p	1:21p	1:51p
Broadway Station	11:24a	11:54a	12:24p	12:54p	1:24p	1:54p
Burlingame Station	11:26a	11:56a	12:26p	12:56p	1:26p	1:56p
San Mateo Station	11:29a	11:59a	12:29p	12:59p	1:29p	1:59p
Hayward Park Station	11:31a	12:01p	12:31p	1:01p	1:31p	2:01p
Hillsdale Station	11:34a	12:04p	12:34p	1:04p	1:34p	2:04p
Belmont Station	11:36a	12:06p	12:36p	1:06p	1:36p	2:06p
San Carlos Station	11:38a	12:08p	12:38p	1:08p	1:38p	2:08p
Redwood City Station	11:44a	12:14p	12:44p	1:14p	1:44p	2:14p
Atherton Station	11:47a	12:17p	12:47p	1:17p	1:47p	2:17p
Menlo Park Station	11:49a	12:19p	12:49p	1:19p	1:49p	2:19p
Palo Alto Station	11:52a	12:22p	12:52p	1:22p	1:52p	2:22p
California Ave. Station	11:55a	12:25p	12:55p	1:25p	1:55p	2:25p
San Antonio Station	11:58a	12:28p	12:58p	1:28p	1:58p	2:28p
Mountain View Station	12:02p	12:32p	1:02p	1:32p	2:02p	2:32p
Sunnyvale Station	12:06p	12:36p	1:06p	1:36p	2:06p	2:36p
Lawrence Station	12:09p	12:39p	1:09p	1:39p	2:09p	2:39p
Santa Clara Station	12:14p	12:44p	1:14p	1:44p	2:14p	2:44p
College Park Station*						
San Jose Diridon Station	12:19p	12:49p	1:19p	1:49p	2:19p	2:49p
Tamien Station		12:53p		1:53p		2:53p

*Schedule to be determined

To ensure conservative simulation results, all trains were simulated with a full seated load of 948 passengers (for an 8-car EMU) between all stations.

3.5.2 High Speed Rail

Based on CHSRA input, 4th and King, Millbrae and San Jose Diridon stations were assumed to be the three HSR station stops on the Corridor. Millbrae allows convenient connections to BART and the San Francisco International Airport. A two minute dwell time for HSR trains at Millbrae was assumed.

Short of having a high speed rail schedule, the operating plan assumed uniform scheduled headways, which will support “memory” type schedules. Peak period HSR volumes were subject to significant variation in the simulation scenarios, ranging from one to four HSR trains per hour per direction. An off-peak service level of two HSR trains per hour per direction was assumed.

3.5.3 Other Rail Services

In addition to Caltrain and California HSR, Capitol Corridor and ACE trains were modeled in the extreme southern portion of the Corridor between Santa Clara and San Jose Diridon stations. Additional analysis will be conducted separate from this report to assess future higher service planned by Capitol Corridor and ACE. It will also include assessing the compatibility of existing corridor freight services with the blended operations concept.

3.5.4 Schedule Margin

Schedule margin (sometimes referred to as “pad” or “recovery allowance”) is a standard rail scheduling practice to provide for operating variability, maintenance tolerances, longer dwell times due to inclement weather, wheelchair and bike boardings, temporary speed restrictions and other operating variables. An industry standard six percent schedule margin was applied to all train operations, including both interstation run times and dwells.

This margin was enforced as part of the actual train performance, rather than by enforcing train wait times at stations. In other words, the simulation derated acceleration, maximum speed and deceleration such that the result of each simulated interstation run was six percent longer than the corresponding best possible simulation result without schedule margin.

3.5.5 Simulation Duration

Simulations were processed from 4 AM to 1 PM, effectively testing the morning peak period, transitions to and from the morning peak period and a representative three hour off-peak period.

3.5.6 Dwell Times and Randomization

LTK conducted extensive field observations in May of 2011 to quantify the variability in current Caltrain dwell times and to establish averages at each station served. These are shown in Table 11. The field observations were sorted so that only dwells when the train was behind schedule were used in the statistical analysis in order to ensure that no “hold for time” component of dwell time is represented in the statistics.

Current dwell times are based largely on two passenger streams per Caltrain Gallery Car. Caltrain does operate some Bombardier passenger coaches with two sets of door leaves. However, there were an insufficient number of dwell times for these coaches recorded during the field observations. Therefore, to avoid mixing dwell time observation on the two different existing coach types, only Gallery Car data was used. Future EMUs will support four passenger streams (two double leaf doors at each end of each side of the vehicle), effectively doubling both the passenger boarding and alighting capacity. In order to predict future EMU dwell times, the May 2011 dwell time observations were broken into two parts – “base” dwell time and passenger flow time. The “base” dwell time reflects door open time, door close time, conductor-engineer communication time and train response time to begin moving.

The “base” dwell time was assumed to be 17 seconds based on generally accepted industry standards.

LTK subtracted the “base” dwell time from the May 2011 field observations. Because the passenger flow rate doubles with EMUs, the passenger time of the remaining portion of the dwell observations was cut in half. Finally, the “base” dwell time was added back in to the result used in the simulations. As an example, the Mountain View 2011 field observation average was 64 seconds; the future simulation dwell is 41 seconds. Table 12 shows the simulated dwell time averages, minima and maxima used in the simulations.

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

Dwell times were randomized in the simulation based on the EMU dwell times shown above. As an example, dwell times for individual simulated trains at Palo Alto ranged from 40 seconds to 1:34 in the simulation with an average dwell time of 1:00. The dwell time figures in Table 12 do not reflect additional time associated with the 6 percent schedule margin included in the simulations (refer to Section 3.5.4). The average simulated dwell at Mountain View, for example, was about 43 seconds (the 41 seconds shown in Table 12 plus 6 percent schedule margin).

No other types of simulation input, such as train dispatch times, interlocking route establishment times or vehicle performance, were randomized in the simulations.

3.5.7 Station Stop Types

All trains were dispatched at their scheduled times from their terminal locations in San Francisco and San Jose. “S” (hold for schedule) type stops were used at these locations to ensure schedule adherence. At all other locations, trains were simulated with “D” (depart when ready) stops, given the lack of specific Caltrain and HSR scheduled times at each station for each trip in each scenario.

4 Operations Analysis Results

Summary: This chapter describes the incremental approach that was followed in the development of the blended operations scenarios as well as the simulation results, organized by tested speed scenarios. The three tested speed scenarios were 79/79, 79/110 and 110/110 (Caltrain/HSR). Results are shown by each of the tested blended operations service level and include model outputs: travel time; signal delay; Caltrain service intervals (train headways); and assumed infrastructure.

4.1 Simulation Process

The simulation modeling results reflect the incremental approach in the development of the blended operations scenarios. The first results presented are the “6/0” scenarios (6 Caltrain and 0 HSR trains per peak hour per direction), then layered in additional HSR trains.

HSR frequencies were increased from an initial service level of 1 train per hour per direction (“6/1” scenarios) to up to 4 trains per hour (“6/4” scenarios, bringing total Corridor train volumes to 10 trains per hour per direction).

At the same, varying maximum operating speeds and assumed infrastructure were also tested, with each scenario changing only one variable (train volume, infrastructure or maximum operating speed) at a time so that the impact of the change could be precisely understood.

Where a simulated train volume in a given scenario resulted in unacceptable train congestion and delays for a given infrastructure and a given maximum operating speed, the follow-on simulation scenarios with higher train volumes appropriately included additional infrastructure or changes in maximum operating speeds to eliminate the unacceptable train congestion and delays.

This incremental “three dimensional matrix” of service level, maximum train speed and infrastructure produced a very large number of potential scenarios, which was limited to a number that could be simulated in a reasonable time by using the results of initial scenarios to guide the study team in identifying subsequent scenarios that showed promise blended operations having conceptual feasibility.

Table 13 provides an at-a-glance chart that identifies the tested blended operations simulation scenarios. The infrastructure features are as described in Section 4.2 (79/79 mph scenarios), Section 4.3 (79/110 scenarios) and Section 4.4 (110/110 mph scenarios).

Five potential infrastructure overtake options were conceptually defined as described in Section 3.1.3. These include: North Overtake, Full Midline Overtake, Short Midline Overtake, South Overtake and a 3-track option.

Table 13 and the subsequent sections in this chapter focus on the Full and Short Midline Overtake options. Assessment of the remaining three infrastructure options (North Overtake, South Overtake and the 3-track option) will be completed and the results of those simulations will be presented in a subsequent report.

Table 13 – Summary of Caltrain/California HSR Blended Operation Simulation Scenarios

Caltrain/ HSR Trains per Hour per Direction	Infrastructure
79/79 Scenarios	
6/0	Baseline HSR Infrastructure
6/1	Baseline HSR Infrastructure
6/2	Baseline HSR Infrastructure
6/3	Baseline HSR Infrastructure
6/3	Full Midline 4 Track
6/4	Full Midline 4 Track
6/3	Short Midline 4 Track
6/4	Short Midline 4 Track
79/110 Scenarios	
6/3	Full Midline 4 Track
6/4	Full Midline 4 Track
6/3	Short Midline 4 Track
6/4	Short Midline 4 Track
110/110 Scenarios	
6/0	Baseline HSR Infrastructure
6/2	Baseline HSR Infrastructure
6/3	Baseline HSR Infrastructure
6/3	Full Midline 4 Track
6/4	Full Midline 4 Track
6/3	Short Midline 4 Track
6/4	Short Midline 4 Track

4.2 Analysis by Speed - 79/79 Scenarios

4.2.1 Without Overtake Tracks

The 79/79 simulations with Baseline Infrastructure (existing Caltrain ROW, HSR stations and no 3rd and 4th track for overtakes) were processed with peak period 6/0 (no HSR), 6/1, 6/2 and 6/3 Caltrain/HSR service levels.

To support HSR trains, the six peak hour Caltrain trips in each direction had to be clustered in order to create one or more "slots" for HSR. In the 6/2 scenario, clusters of three Caltrain trips followed by a HSR trip operated. In the 6/3 scenario, clusters of two Caltrain trips followed by a HSR trip operated.

This scheduling strategy can be seen graphically in the time-distance string charts shown in Figure 12 (6/1), Figure 13 (6/2) and Figure 14 (6/3). These three figures should be contrasted with the time-distance string chart shown in Figure 11 which shows the nearly uniform 10-minute Caltrain headways in each direction of the 6/0 scenario. All string charts are included in Appendix A.

Closer headways are required (and are supported by the planned CBOSS PTC system) between Caltrain trips as the number of HSR trains on the corridor increases. HSR trains are unable to operate for the length of the corridor without ending up behind a stopping Caltrain trip. The delays to HSR trains are most severe in the off-peak periods where Caltrain operates all-stop trains.

For the 6/1 and 6/2 Baseline Infrastructure scenarios, the delays do not cause problems for Caltrain service, but do increase the average travel time for HSR service. Increasing the number of HSR trains to three per hour per direction (the 6/3 Baseline Infrastructure scenario) begins to cause cascading delays to Caltrain service during the peak period. Caltrain trips delay HSR trips that, in turn, delay following Caltrain trips. The 6/3 Baseline Infrastructure scenario is operating beyond the practical capacity of the corridor and not a viable option.

4.2.2 With Overtake Tracks

With North Overtake Tracks

The simulation of the North Overtake segment found that the Bayshore to Millbrae four station segment had difficulty supporting the required 7+ minute travel time difference A major contributing factor to the lack of a 7+ minute travel time difference at the North Overtake is the fact that HSR trains will stop at Millbrae Station and will require a longer dwell (estimated to be 2 minutes) than Caltrain due to fewer doors per car and the need to accommodate passengers with luggage.

A significant number of additional Caltrain stops at Bayshore, South San Francisco and San Bruno stations that presently have low ridership would be required in order to accomplish reliable overtakes. The simulation results showed increased trip times for Caltrain passengers and a less effective overtake location for HSR than the Full Midline Overtake due to increasing maximum waiting times for Caltrain trains due to less regular service intervals than the Full Midline Overtake.

Because of these initial results, that may be unacceptable to Caltrain, further study of the North Overtake section and its tangible operating impacts to Caltrain and HSR service was deferred, to be considered at a later phase of this study.

With Full Midline Overtake Tracks

Many of the operating difficulties of the Baseline Infrastructure simulation scenarios are eliminated under the 79/79 scenarios with the Hayward Park to Redwood City Midline Overtake (the Full Midline Overtake). With HSR trains able to overtake Caltrain trips, the required gaps between Caltrain trips for HSR do not need to be as large. HSR trains can effectively make use of twice the Caltrain headway over the length of the corridor (gaining on one Caltrain trip before the Midline Overtake and the previous Caltrain trip after the Midline Overtake).

For example, a Caltrain service gap at Palo Alto of 19 minutes is required in the 79/79 6/2 Baseline Infrastructure scenario, whereas the maximum service gap there in the 79/79 6/2 Midline Overtake scenario is just 11 minutes. Even when HSR service is increased to the 79/79 6/4 service level, the Midline Overtake scenario limits the maximum Palo Alto Caltrain time between trains to 14 minutes.

Almost all of the delay to HSR trains is eliminated in the scenarios with up to three HSR trains per hour. Under the 6/4 scenario with Midline Overtake scenario, the delays are manageable with little negative impact on average travel time.

With Short Midline Overtake Tracks

The 79/79 scenario results using the shorter Hayward Park to Whipple Avenue Midline Overtake show that many of the operational advantages of the full Midline Overtake are achieved, but more significant changes to Caltrain service are necessary for delay-free operation. Since there is less distance in which the HSR overtake of Caltrain can occur, all overtaken trains must stop at a minimum of three of the four stations within the overtake trackage for delay-free operation.

The absence of Redwood City Station – where all Caltrain trips are scheduled to stop in the future operating plan simulated – in the shorter Midline Overtake scenarios makes the operation significantly more challenging. The addition of new scheduled stops for overtaken Caltrain trips has the effect of increasing the average Caltrain travel time in the short Midline Overtake scenarios. See Appendix A, Tables 20 and 21, for the northbound and southbound operating plan changes required in order to obtain reliable operations for the short version of the Midline Overtake during peak periods.

Simulation Results

Table 14 and Table 15 below detail the simulation results for each of the 79/79 scenarios with separate statistics for Caltrain and for HSR. The statistics reflect overall averages for all of the trains operating during the morning peak period. The morning peak period is defined as 6 to 9 a.m.

For Caltrain, all scenarios support an average San Jose to San Francisco simulated trip time of 59 to 61 minutes, with most train trips arriving 2 to 3 minutes ahead of schedule. Signal delay reflects the number of minutes and seconds that the total population of simulated trains (morning peak period and midday) is operating at reduced speed or stopped because of congestion ahead. When divided by the number of peak period Caltrain trips (36), the per-train delays are quite modest. Only the 6/3 Baseline Infrastructure scenario signal delay is of concern, as it reflects some cascading delays of Caltrain delaying HSR and HSR then delaying Caltrain.

Table 14 – Caltrain Simulation Results
Speed: 79/79 (Caltrain/HSR)

Caltrain/HSR Service Level	AM Peak Period Trip Times (H:M:S)	AM Peak Period Signal Delay (H:M:S)	Caltrain Peak Hour Service Intervals (at Palo Alto NB) (Minutes)	Infrastructure Assumed in Simulation
6/0	0:59:53	0:02:12	10/9/11/9/9/12	Baseline HSR Infrastructure
6/1	0:59:56	0:01:44	10/5/7/17/9/12	Baseline HSR Infrastructure
6/2	0:59:56	0:02:49	19/5/7/17/5/7	Baseline HSR Infrastructure
6/3	0:59:58	0:11:03	5/15/6/13/5/16	Baseline HSR Infrastructure
6/3	0:59:58	0:01:00	12/6/12/9/11/10	Full Midline 4 Track
6/4	1:00:13	0:01:36	6/14/10/4/14/12	Full Midline 4 Track
6/3	1:00:13	0:05:12	14/5/14/7/15/5	Short Midline 4 Track
6/4	1:00:41	0:02:45	6/9/15/5/10/15	Short Midline 4 Track

For HSR, San Francisco to San Jose simulated trip times shown in Table 15 range from 45 to 49 minutes with the 6/3 Baseline Infrastructure scenario having an average trip time a minute longer than the next highest average trip time scenario. Again, this points to the significant congestion in that scenario, as evidenced by the more than 90 minutes of total signal delay experienced by the 18 HSR trains operating in that scenario during the peak period.

Table 15 – HSR Simulation Results Speed: 79/79 (Caltrain/HSR)			
Caltrain/HSR Service Level	**AM Peak Period Trip Times (H:M:S)**	**AM Peak Period Signal Delay (H:M:S)**	**Infrastructure Assumed in Simulation**
6/1	0:47:56	0:20:33	Baseline HSR Infrastructure
6/2	0:46:37	0:20:59	Baseline HSR Infrastructure
6/3	0:48:56	1:34:10	Baseline HSR Infrastructure
6/3	0:45:14	0:17:01	Full Midline 4 Track
6/4	0:45:51	0:29:14	Full Midline 4 Track
6/3	0:44:50	0:02:13	Short Midline 4 Track
6/4	0:45:20	0:16:48	Short Midline 4 Track

4.3 Analysis by Speed - 79/110 Scenarios

The 79/110 scenarios are identical to the 79/79 scenarios except that HSR trains are permitted to operate at up to 110 MPH (where supported by track geometry) in the overtake segments and up to 79 MPH outside of the overtake segments. By definition, 79/110 scenarios exist only with overtake infrastructure.

In the 79/110 overtake simulations, the results were much the same as the 79/79 simulation scenarios with the largest difference being the enhanced reliability of the overtake and a correspondingly lower number of stops required for overtaken trains.

The ability of HSR trains to operate at up to 110 MPH in the overtake areas produced more reliable overtakes than under the comparable 79/79 scenario. The faster average HSR travel time over the corridor required a small number of stops to be exchanged between trips approaching the terminals, moving stops from a Caltrain trip being followed by an HSR trip to a train that had been overtaken.

Table 16 presents the Caltrain simulation statistics for the 79/110 scenarios. Caltrain trip times are virtually identical to the 79/79 scenarios as there is no change in those trains' maximum authorized speeds. Signal delay for all scenarios is virtually zero on a per-train basis. The longest intervals between trains, as measured at Palo Alto northbound (NB), are 14 minutes (in the 6/4 full Midline Overtake and the 6/3 Short Midline Overtake), which is only a small increase over the 12 minute interval experienced in the 6/0 Baseline Infrastructure scenario.

Table 16 – Caltrain Simulation Results **Speed: 79/110 (Caltrain/HSR - Only on Overtake Track)**				
Caltrain/HSR Service Level	**AM Peak Period Trip Times (H:M:S)**	**AM Peak Period Signal Delay (H:M:S)**	**Caltrain Peak Hour Service Intervals (at Palo Alto NB) (Minutes)**	**Infrastructure Assumed in Simulation**
6/3	0:59:57	0:03:47	12/7/13/7/11/10	Full Midline 4 Track
6/4	0:59:52	0:06:07	5/12/12/5/12/14	Full Midline 4 Track
6/3	0:59:50	0:03:30	13/5/14/7/12/9	Short Midline 4 Track
6/4	1:00:11	0:00:00	7/11/12/6/11/13	Short Midline 4 Track

For HSR, the 110 MPH maximum operating speed (within the overtake trackage limits only) provides a modest travel time benefit. Whereas the 79/79 average simulated trip times range from 45 to 49 minutes, Table 17 indicates that the 79/110 average simulated trip times are all about 43 minutes for HSR trains (all HSR trip times include a two-minute stop at Millbrae and six percent schedule margin for the entire run). When measured on a per-train basis, no HSR train experiences more than one minute of signal delay on its San Francisco to San Jose trip.

Table 17 – HSR Simulation Results **Speed: 79/110 (Caltrain/HSR - Only on Overtake Track)**			
Caltrain/HSR Service Level	**AM Peak Period Trip Times (H:M:S)**	**AM Peak Period Signal Delay (H:M:S)**	**Infrastructure Assumed in Simulation**
6/3	0:43:12	0:15:41	Full Midline 4 Track
6/4	0:43:14	0:18:39	Full Midline 4 Track
6/3	0:43:26	0:01:15	Short Midline 4 Track
6/4	0:43:51	0:18:02	Short Midline 4 Track

4.4 Analysis by Speed - 110/110 Scenarios

4.4.1 Without Overtake Tracks

For the 110/110 Baseline Infrastructure simulation with 6/0 service level (no HSR), the Caltrain 79/79 6/0 operating plan required significant changes to eliminate following move delays (a Caltrain trip delaying a following trip). Due to Caltrain's skip stop zone express schedule tested in the simulations, a train skipping a stop would often close in upon the preceding train on an alternate pattern. By adjusting the schedule patterns to keep the Caltrain trip times approximately equal, it was possible to eliminate all of this delay in the 110/110 6/0 scenario.

It should be noted that the higher speeds in the 110 mph simulation mean that a greater safe braking distance is required by the CBOSS PTC system than is the case under 79 MPH operation.

The operating challenges with creating a delay-free Caltrain schedule under 6/0 carry over to the Baseline Infrastructure simulations with 6/2 and 6/3 levels of HSR service. With a much shorter trip time under a 110 MPH maximum speed, HSR trains close in on Caltrain trips faster than under the comparable 79/79 scenarios.

This has the effect of significantly increasing the total delay for HSR. The 6/2 Baseline Infrastructure HSR signal delay is more than 60 minutes of total delay for the entire group of simulated trains over the morning peak period (versus 21 minutes for the comparable scenario under 79/79).

4.4.2 With Full Midline Overtake Tracks

For the 110/110 Hayward Park to Redwood City Midline overtake simulations, the overtake itself was possible without delay. However, many schedule modifications to Caltrain trips were necessary to prevent delays before and after the overtake because of the pronounced travel time difference between HSR and Caltrain trips.

While no additional stops were necessary, schedule patterns were necessarily adjusted to keep overtaken trains running faster prior to the overtake and slower after the overtake. Similarly, trains that were not overtaken were made to run slower prior to the overtake and faster thereafter, strategies to keep from delaying HSR trains. See Appendix A, Table 22 and Table 23, for the northbound and southbound operating plan changes that were required in order to obtain reliable operations for the 110/110 scenario during the peak periods.

4.4.3 With Short Midline Overtake Tracks

In the 110/110 Hayward Park to Whipple Avenue Midline Overtake simulation, the reduced overtake length required additional deviations from the original Caltrain schedule pattern in the southern half of the schedule. The increased two-track shared use corridor distance from Whipple Avenue to San Jose Diridon station, makes it very difficult for a 110 mph train to leave San Jose without encountering delay prior to reaching the overtake, and for a southbound HSR train to keep from being delayed by the Caltrain train it follows after the overtake. Since all Caltrain trips stop at Redwood City, which is not part of the overtake, a northbound HSR train needs either a longer scheduled headway leaving San Jose or, if that is not possible, for the overtaken train to make fewer stops prior to the overtake.

4.4.4 Simulation Results

Table 18 and Table 19 below detail the simulation results for each of the 110/110 scenarios with separate statistics for Caltrain and for HSR. The statistics reflect overall averages for all of the trains operating during the morning peak period.

The Caltrain terminal-to-terminal trip times range from 56 to 57 minutes, a reduction of 3 to 4 minutes from the 79/79 simulation scenarios.

Table 18 – Caltrain Simulation Results Speed: 110/110 (Caltrain/HSR)				
Caltrain/HSR Service Level	**AM Peak Period Trip Times (H:M:S)**	**AM Peak Period Signal Delay (H:M:S)**	**Caltrain Peak Hour Service Intervals (at Palo Alto NB) (Minutes)**	**Infrastructure Assumed in Simulation**
6/0	0:56:42	0:01:31	9/8/13/9/9/12	Baseline HSR Infrastructure
6/2	0:56:42	0:02:12	18/5/6/18/5/8	Baseline HSR Infrastructure
6/3	0:57:01	0:31:19	15/6/14/5/13/7	Baseline HSR Infrastructure
6/3	0:56:40	0:00:09	14/5/13/6/14/8	Full Midline 4 Track
6/4	0:56:27	0:02:36	5/11/14/4/12/14	Full Midline 4 Track
6/3	0:56:35	0:06:57	15/5/14/5/14/7	Short Midline 4 Track
6/4	0:56:31	0:01:01	5/11/14/4/11/15	Short Midline 4 Track

Table 19 – HSR Simulation Results Speed: 110/110 (Caltrain/HSR)			
Caltrain/HSR Service Level	**AM Peak Period Trip Times (H:M:S)**	**AM Peak Period Signal Delay (H:M:S)**	**Infrastructure Assumed in Simulation**
6/2	0:41:30	1:04:03	Baseline HSR Infrastructure
6/3	0:43:35	2:15:12	Baseline HSR Infrastructure
6/3	0:37:24	0:10:17	Full Midline 4 Track
6/4	0:38:35	0:44:24	Full Midline 4 Track
6/3	0:38:02	0:19:50	Short Midline 4 Track
6/4	0:39:20	0:52:15	Short Midline 4 Track

The HSR San Francisco to San Jose trip times (with appropriate schedule margin and a two-minute stop at Millbrae included) are about 37 to 39 minutes in the 110/110 scenarios. This can be compared to the 45-48 minute range for the 79/79 scenarios, and to about 43 minutes in the 79/110 scenarios.

5 Conclusion

Based on the results of the TrainOps simulation model customized for application to the Caltrain and high speed rail operations analysis, a blended operation where Caltrain and high speed rail trains share tracks is conceptually feasible.

This report only addresses the finding that blended operations on the Caltrain Corridor are conceptually feasible. The report is not intended to define what the blended system is. It provides a “proof of concept” for a blended system in the Caltrain Corridor. Subsequent work to be completed includes: engineering, identifying maintenance needs, cost estimating, ridership forecasts and environmental clearance.

Assuming electrification with the CBOSS PTC system and EMU electric rail vehicles – a system with superior performance attributes from that of today’s diesel-powered system – the Corridor can support up to 10 trains per peak hour per direction. This is double the train traffic that is being operated today.

The blended system with Caltrain scheduling strategies and no passing tracks can reliably support up to 6 Caltrain trains and 2 high speed rail trains per peak hour per direction. With additional overtake tracks, the blended system can support up to 6 Caltrain trains and 4 high speed rail trains per peak hour per peak direction.

If train speeds can be increased up to 110 mph, travel times can be reduced. High speed rail trains experience greater travel time savings. Caltrain trips, making more station stops than high speed rail (and therefore having fewer opportunities to attain maximum speed between station stops), would experience less travel time savings.

Building on this “proof of concept”, there is more analysis to be done. Additional analysis will include completion of the overtake track options at various locations along the corridor and an assessment of alternative service plan/operations variables. These efforts will be conducted over the next several months and be used to further inform the definition of the blended system.

6 Appendix A – Caltrain Tested Schedule Modifications

Table 20 presents the northbound operating plan changes required in order to obtain reliable operations for the short version of the Midline Overtake during peak periods under the 6/4 79/79 scenario. In general, station stops were added to Caltrain trips, increasing overall trip time, in order to achieve the necessary minimum 7 minute travel time difference between HSR and Caltrain trips being overtaken. During the peak hour, a total of 5 additional Caltrain station stops – distributed across the 6 trains per hour in the simulation and not otherwise included in the future operating plan assumed for simulation -- is needed in the northbound direction to achieve reliable overtakes.

Table 20 – Revisions to AM Peak Hour Stopping Patterns of Tested Schedule to Accommodate 79/79 Hayward Park to Whipple Avenue (MP 24.3) Midline – Northbound

Caltrain trains:	416	418	420	422	424	426
Overtaken by HSR trains:		*HSR16*	*HSR18*		*HSR20*	*HSR22*
Tamien Station		•			•	
San Jose Diridon Station	•	•	•	•	•	•
College Park Station*						
Santa Clara Station	•			•		
Lawrence Station		•			•	
Sunnyvale Station	•	•	•	•	•	•
Mountain View Station	•	•	•	•	•	•
San Antonio Station			•			•
California Ave. Station	•			•		
Palo Alto Station	•	•	•	•	•	•
Menlo Park Station	O	X	•	O	X	•
Atherton Station	X		O			
Redwood City Station	•	•	•	•	•	•
San Carlos Station		O	•		O	•
Belmont Station		•	O		•	O
Hillsdale Station	•	•	•	•	•	•
Hayward Park Station			•			O
San Mateo Station	•	•	O	X	•	
Burlingame Station		•			•	
Broadway Station				•		
Millbrae Station	•	•	•	•	•	•
San Bruno Station			•			•
South San Francisco Station	X	O		X	O	
Bayshore Station						•
22nd Street Station			•			
4th & King Station	•	•	•	•	•	•

X	**Station stop removed from originally-developed Caltrain operating plan to accommodate HSR.**
•	**Station stop in originally-developed Caltrain operating plan that remains in 79/79 Hayward Park to Whipple Avenue Midline HSR scenarios.**
O	**Station stop not in originally-developed Caltrain operating plan that was added to accommodate HSR.**

***Schedule to be determined**

Table 21 presents the same information for the southbound direction for the 6/4 79/79 scenario with the Short Midline Overtake.

Table 21 – Revisions to AM Peak Hour Stopping Patterns of Tested Schedule to Accommodate 79/79 Hayward Park to Whipple Avenue (MP 24.3) Midline – Southbound

Caltrain trains:	417	419	421	423	425	427
Overtaken by HSR trains:	*HSR15*	*HSR17*		*HSR19*		*HSR21*
4th & King Station	•	•	•	•	•	•
22nd Street Station	•	•	•	•	•	•
Bayshore Station		•				
South San Francisco Station				•		
San Bruno Station		•			•	
Millbrae Station	•	•	•	•	•	•
Broadway Station						X
Burlingame Station		•			•	
San Mateo Station	O	•	X	O	X	•
Hayward Park Station		•		O		
Hillsdale Station	•	•		•	•	
Belmont Station	O		•			•
San Carlos Station	•	•		•	X	O
Redwood City Station		•	•		•	•
Atherton Station					•	
Menlo Park Station	•		•	•		•
Palo Alto Station	•	•	•	•	•	•
California Ave. Station			•			•
San Antonio Station	•			•		
Mountain View Station	•	•	•	•	•	•
Sunnyvale Station			•			•
Lawrence Station	•			•		
Santa Clara Station	•			X	O	
College Park Station*						
San Jose Diridon Station	•	•	•	•	•	•
Tamien Station	•		•		•	

X	**Station stop removed from originally-developed Caltrain operating plan to accommodate HSR.**
•	**Station stop in originally-developed Caltrain operating plan that remains in 79/79 Hayward Park to Whipple Avenue Midline HSR scenarios.**
O	**Station stop not in originally-developed Caltrain operating plan that was added to accommodate HSR.**

***Schedule to be determined**

Table 22 shows how the initially tested Caltrain zone express skip stop operating plan was altered during the peak 60 minutes to accommodate the 110/110 scenario HSR operations with a minimum of following move delay to HSR in the northbound direction. Table 23 shows the same information for the southbound direction.

Table 22 – Revisions to AM Peak Hour Stopping Patterns of Tested Schedule to Accommodate 110/110 Hayward Park to Redwood City Midline – Northbound						
Caltrain train:	**416**	**418**	**420**	**422**	**424**	**426**
Overtaken by HSR train:		***HSR16***	***HSR18***		***HSR20***	***HSR22***
Tamien Station		•			•	
San Jose Diridon Station	•	•	•	•	•	•
College Park Station*						
Santa Clara Station	•			•		
Lawrence Station		•			•	
Sunnyvale Station	•	•	•	•	•	•
Mountain View Station	•	•	•	•	•	•
San Antonio Station			•			•
California Ave. Station	•			•		
Palo Alto Station	•	•	•	•	•	•
Menlo Park Station		•	•		•	•
Atherton Station	•					
Redwood City Station	•	•	•	•	•	•
San Carlos Station			•			•
Belmont Station		•			•	
Hillsdale Station	•	•	•	•	•	•
Hayward Park Station			•			
San Mateo Station	X	•	O	X	•	O
Burlingame Station		•			•	
Broadway Station				X	O	
Millbrae Station	•	•	•	•	•	•
San Bruno Station			•			•
South San Francisco Station	X	O		X	O	
Bayshore Station						•
22nd Street Station			•			
4th & King Station	•	•	•	•	•	•

X	**Station stop removed from originally-developed Caltrain operating plan to accommodate 110/110 HSR.**
•	**Station stop in originally-developed Caltrain operating plan that remains in 110/110 HSR scenarios**
O	**Station stop not in originally-developed Caltrain operating plan that was added to accommodate 110/110 HSR.**

***Schedule to be determined**

Table 23 – Revisions to AM Peak Hour Stopping Patterns of Tested Schedule to Accommodate 110/110 Hayward Park to Redwood City Midline – Southbound

Caltrain train:	**417**	**419**	**421**	**423**	**425**	**427**
Overtaken by HSR train:		*HSR15*	*HSR17*		*HSR19*	*HSR21*
4th & King Station	•	•	•	•	•	•
22nd Street Station	•	•	•	•	•	•
Bayshore Station		•				
South San Francisco Station				•		
San Bruno Station		•			•	
Millbrae Station	•	•	•	•	•	•
Broadway Station						•
Burlingame Station		•			•	
San Mateo Station		•	•		•	•
Hayward Park Station		•				
Hillsdale Station	•	•		•	•	
Belmont Station			•			•
San Carlos Station	•	•		•	•	
Redwood City Station		•	•		•	•
Atherton Station					•	
Menlo Park Station	•		•	•		•
Palo Alto Station	•	•	•	•	•	•
California Ave. Station			•			•
San Antonio Station	•			•		
Mountain View Station	•	•	•	•	•	•
Sunnyvale Station			•			•
Lawrence Station	X	O		X	O	
Santa Clara Station	•			•		
College Park Station						
San Jose Diridon Station	•	•	•	•	•	•
Tamien Station	•		•		•	

X	**Station stop removed from originally-developed Caltrain operating plan to accommodate 110/110 HSR.**
•	**Station stop in originally-developed Caltrain operating plan that remains in 110/110 HSR scenarios**
O	**Station stop not in originally-developed Caltrain operating plan that was added to accommodate 110/110 HSR.**

***Schedule to be determined**

7 Appendix B – Time-Distance String Charts

Time-Distance String Chart Color Legend

- Northbound Caltrain Main Track
- Southbound Caltrain Main Track
- Northbound HSR Main Track Including Overtake Track
- Southbound HSR Main Track Including Overtake Track
- Existing Northbound Caltrain "Siding" Track at Lawrence and Bayshore
- Existing Southbound Caltrain "Siding" Track at Lawrence and Bayshore

7.1 Morning Peak Period

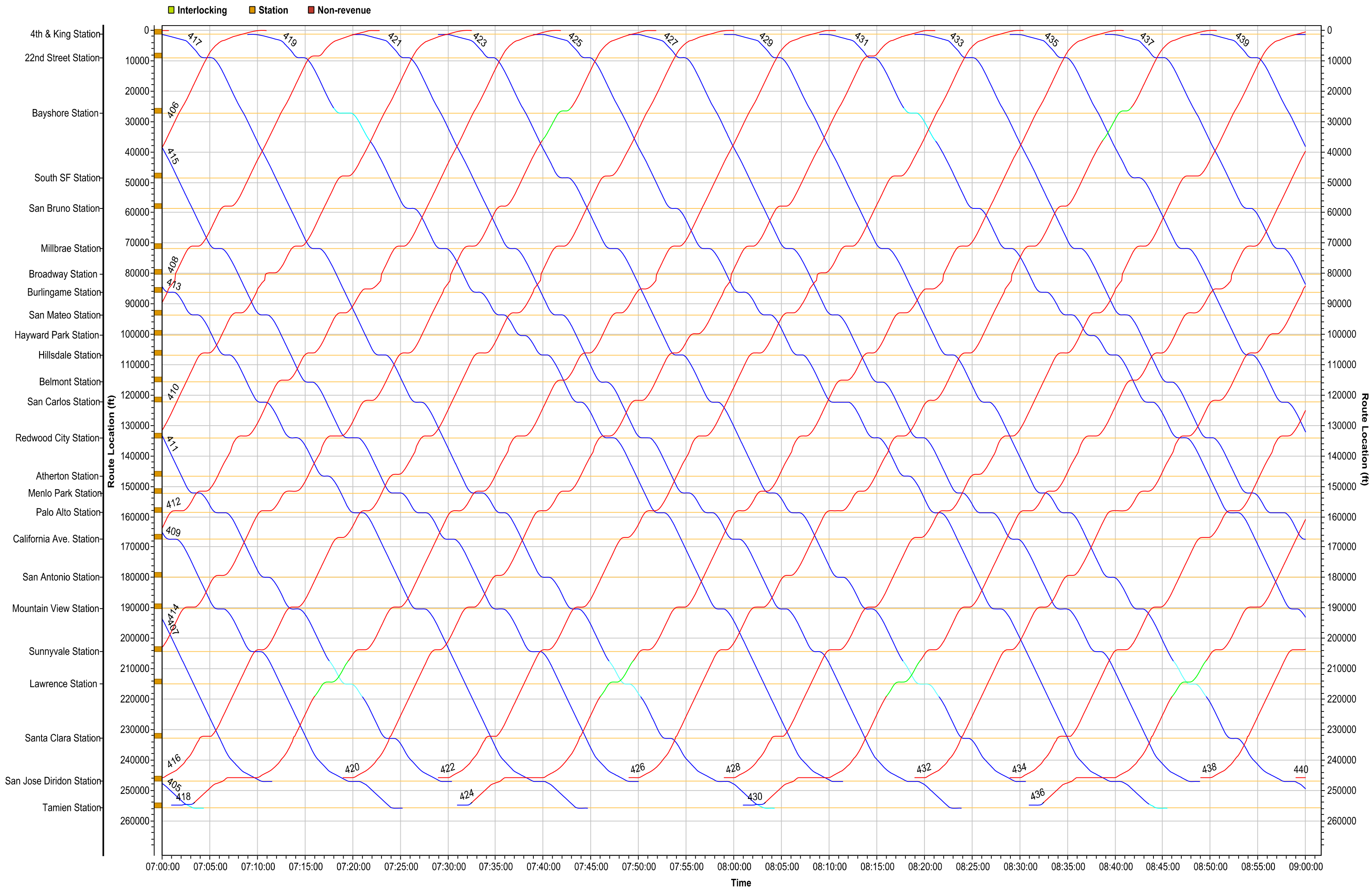


Figure 11. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 0 HSR TPH

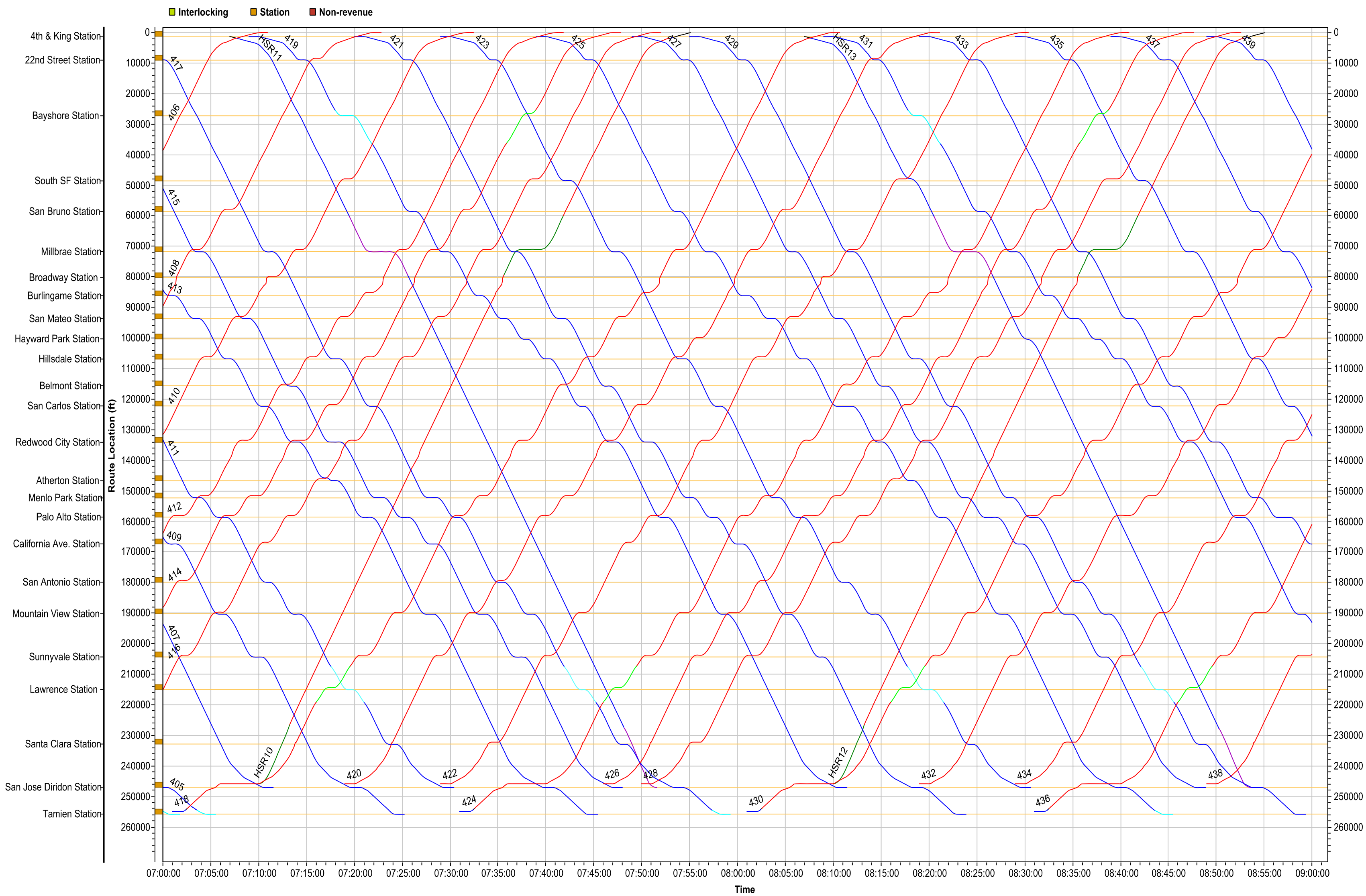


Figure 12. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 1 HSR TPH

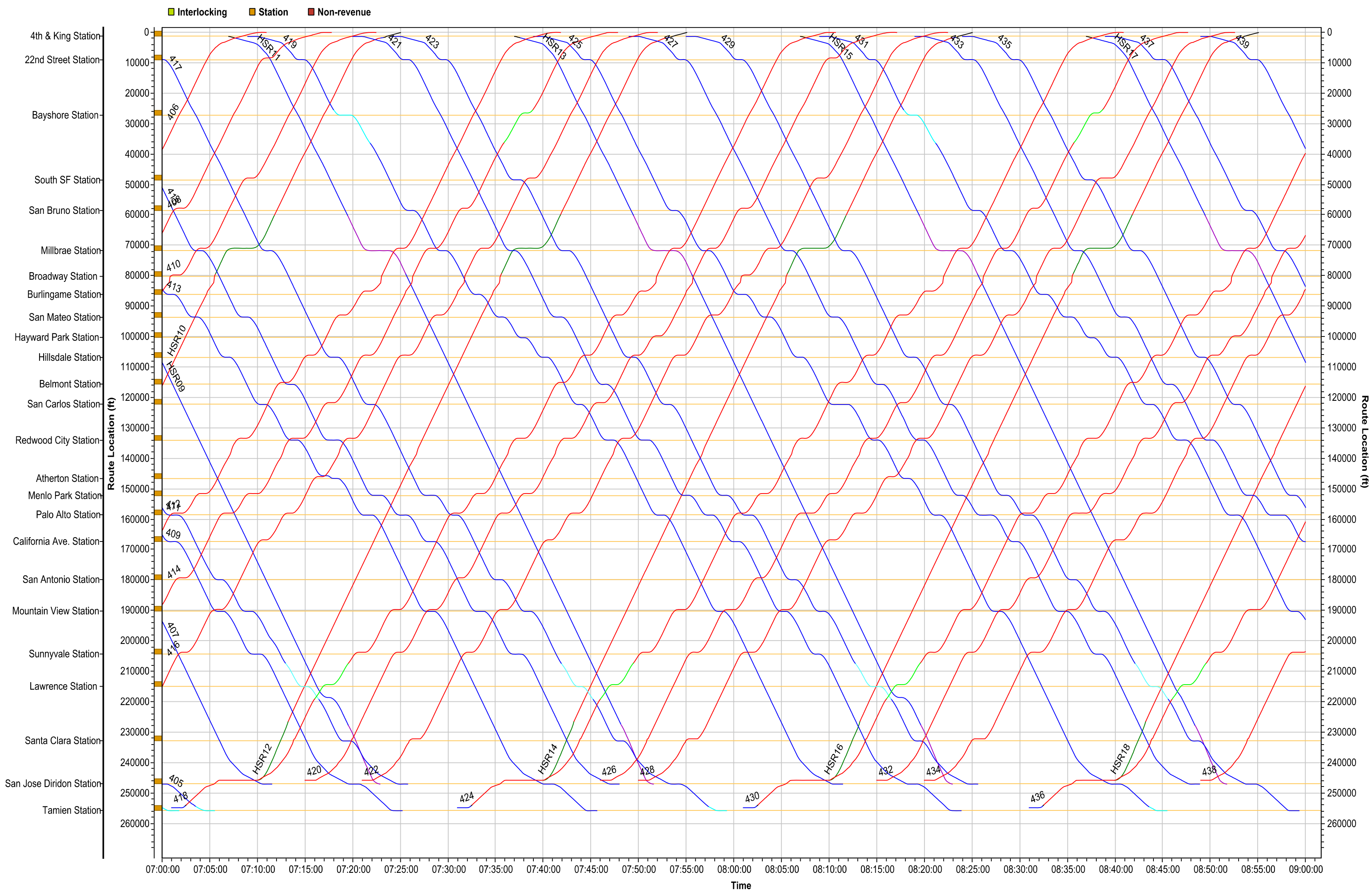


Figure 13. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 2 HSR TPH

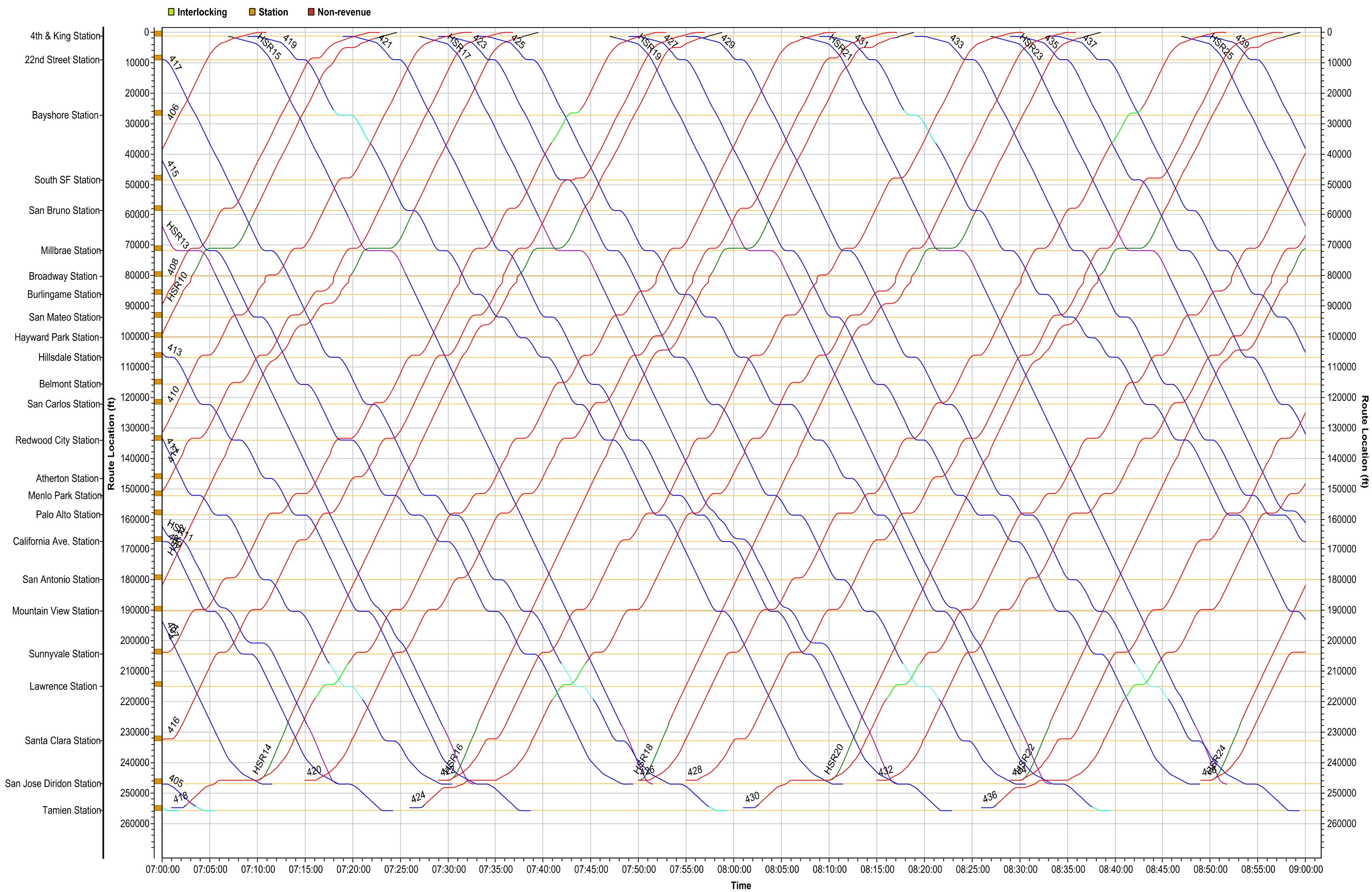


Figure 14. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 3 HSR TPH

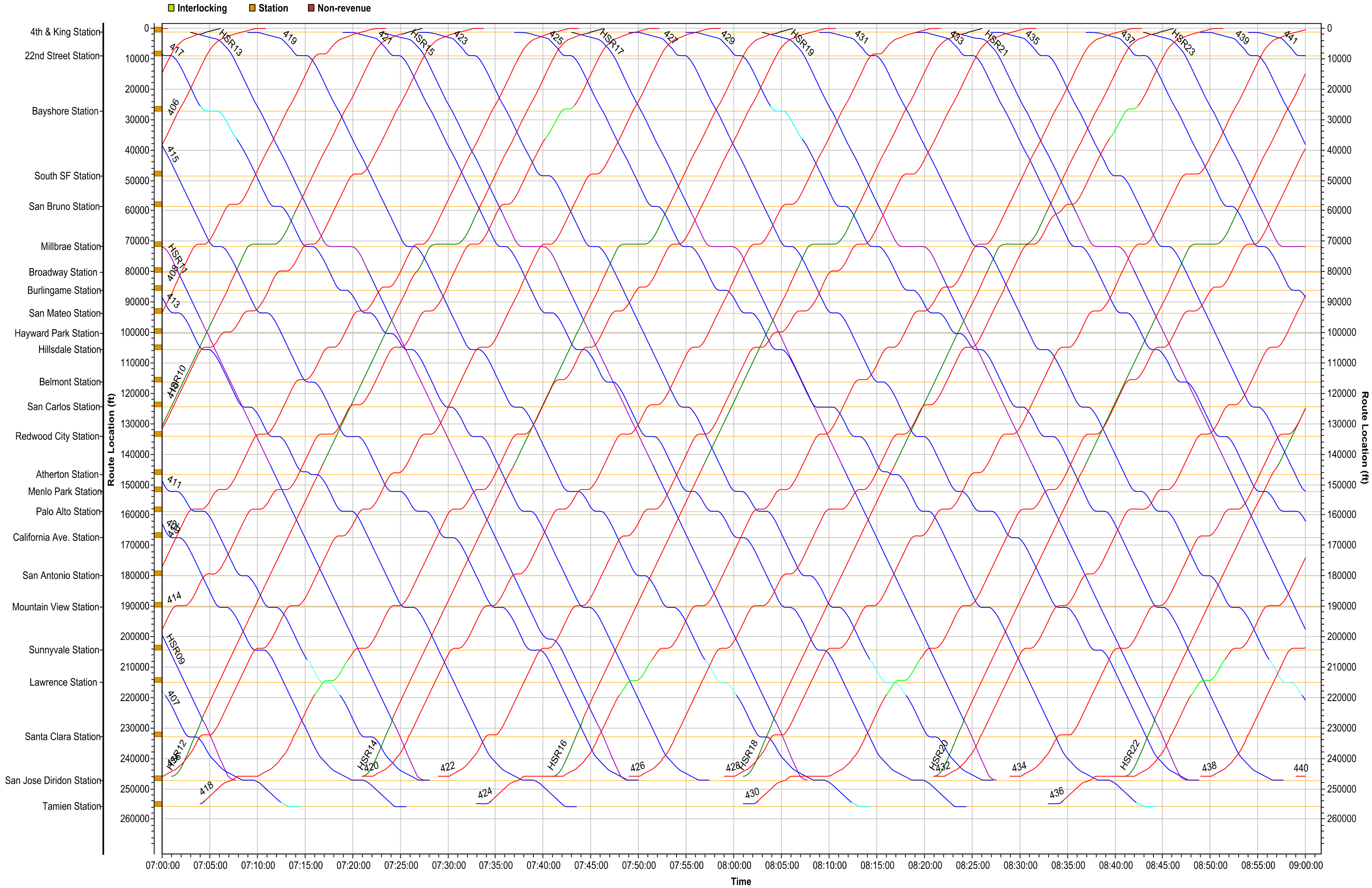


Figure 15 Time-Distance "String" Chart – 7 to 9 AM - 79/79 Full Midline Overtake 3 HSR TPH

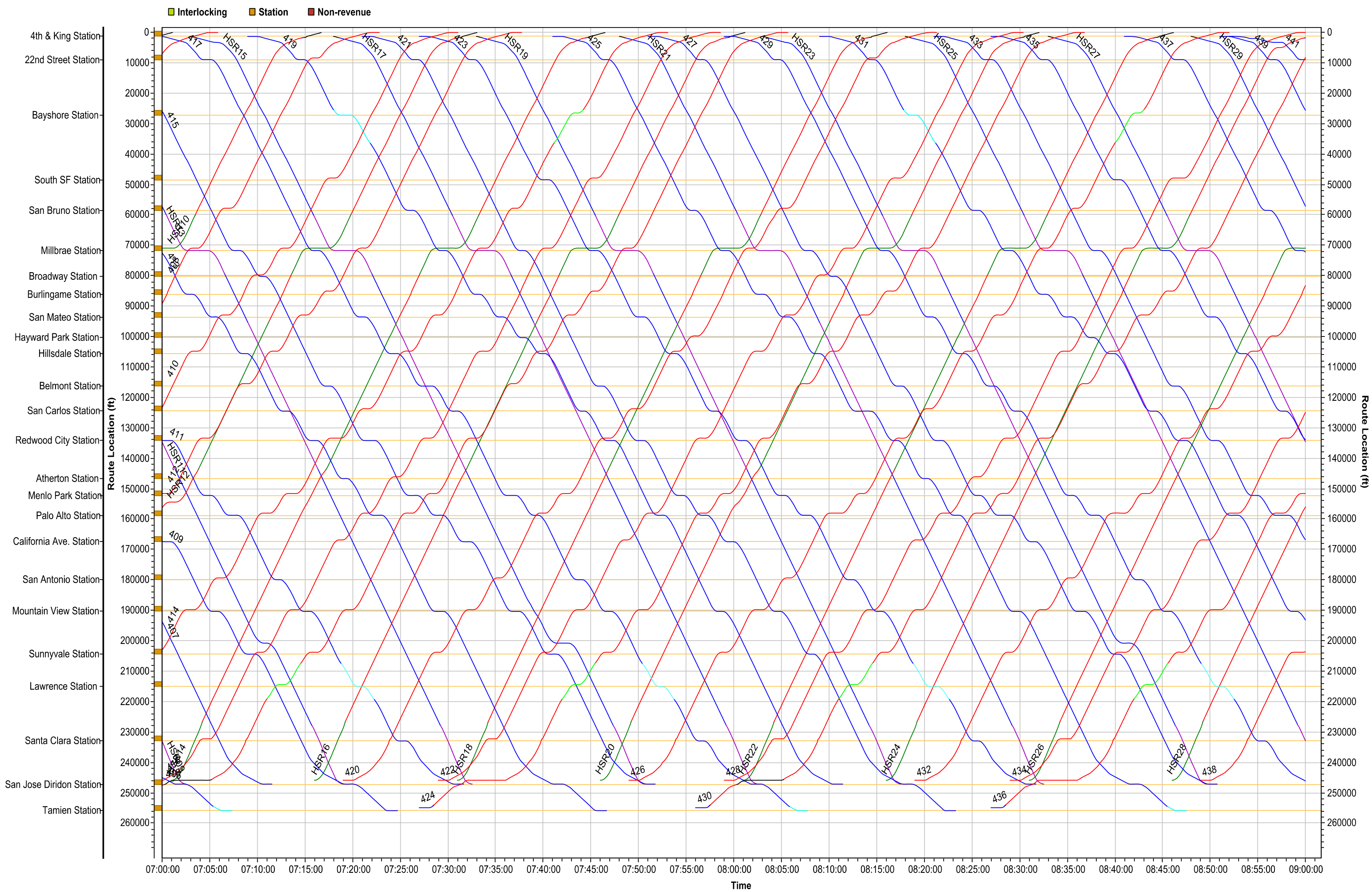


Figure 16. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Full Midline Overtake 4 HSR TPH

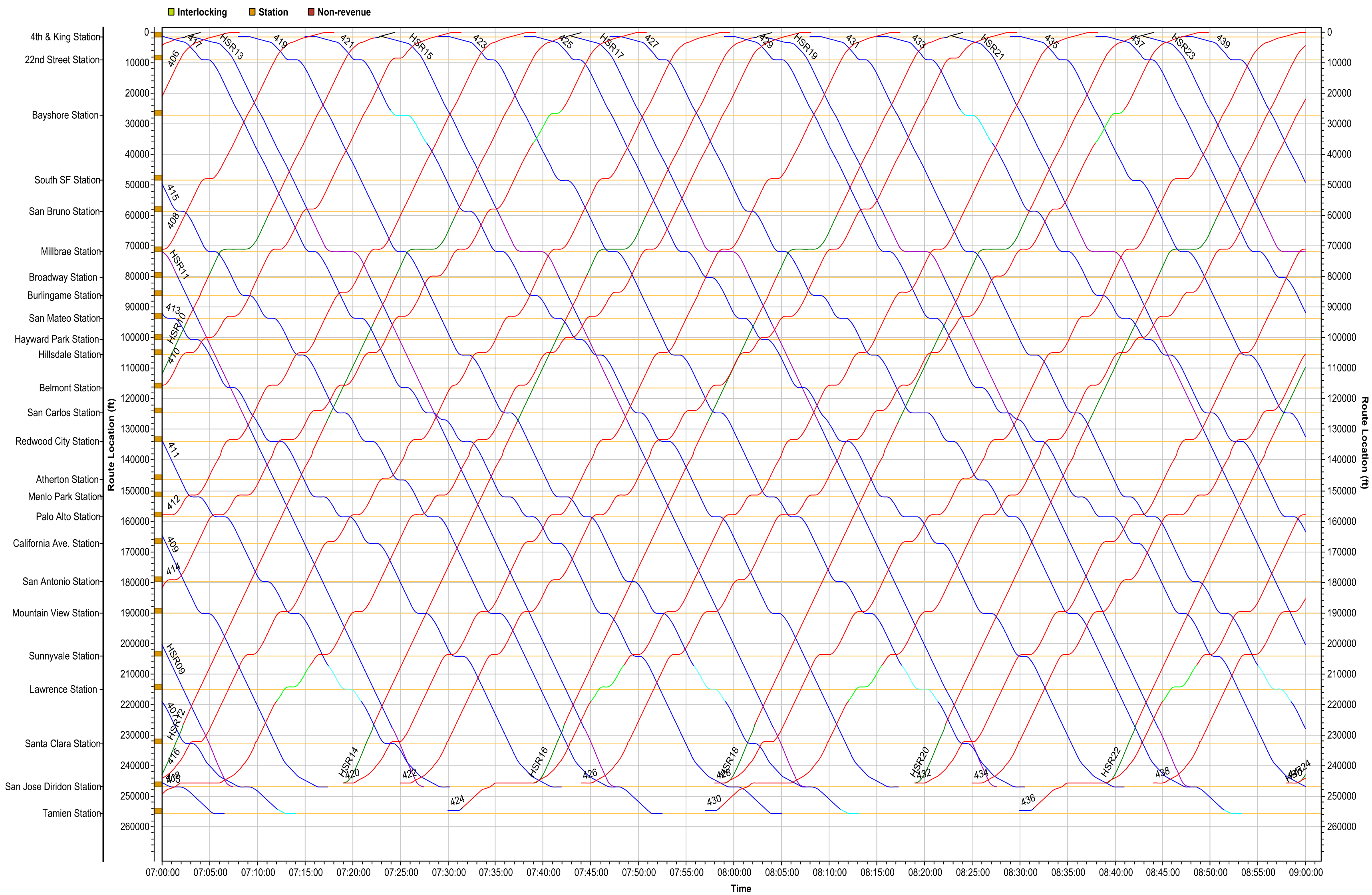


Figure 17. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Short Midline Overtake 3 HSR TPH

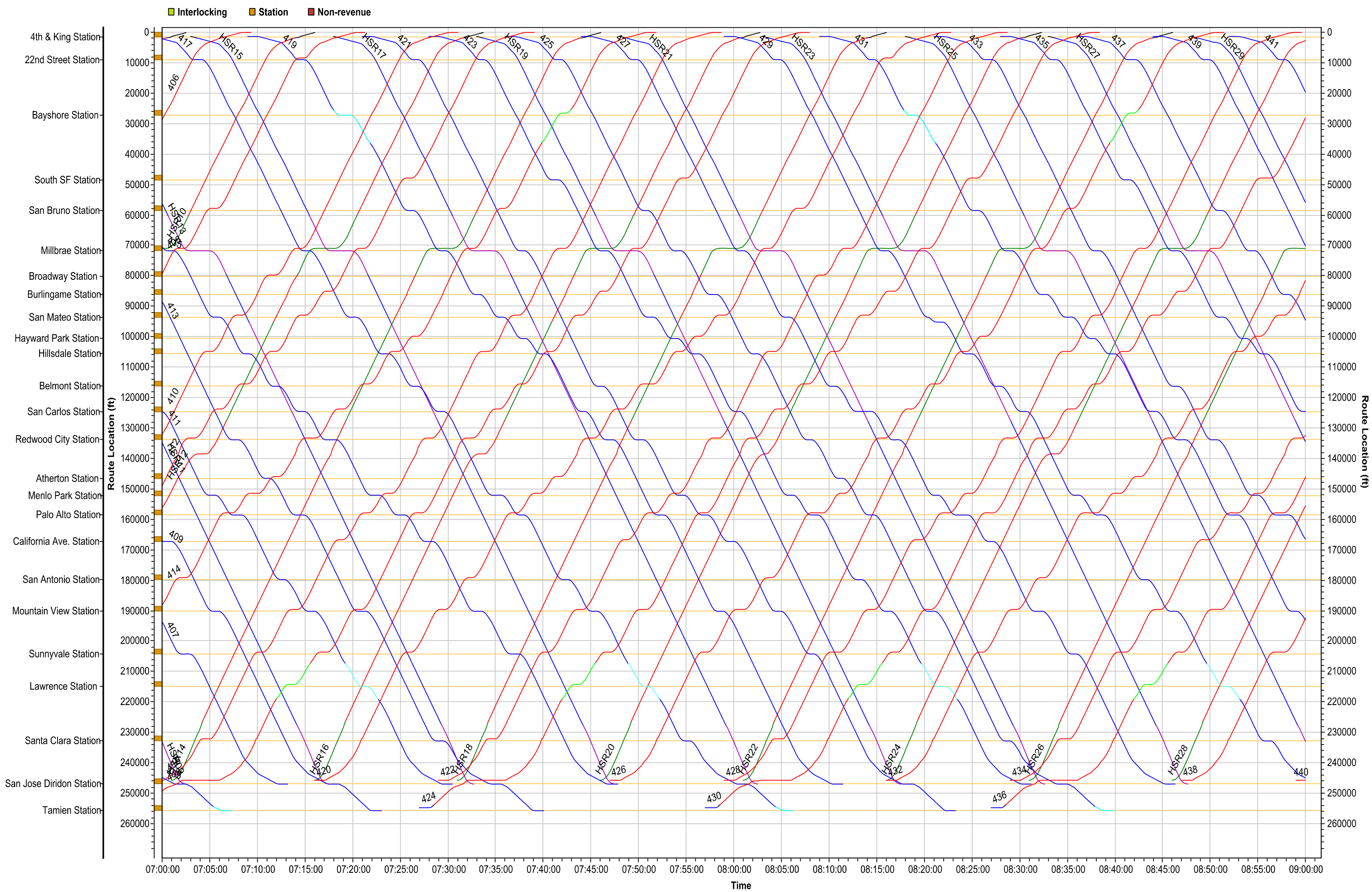


Figure 18. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Short Midline Overtake 4 HSR TPH

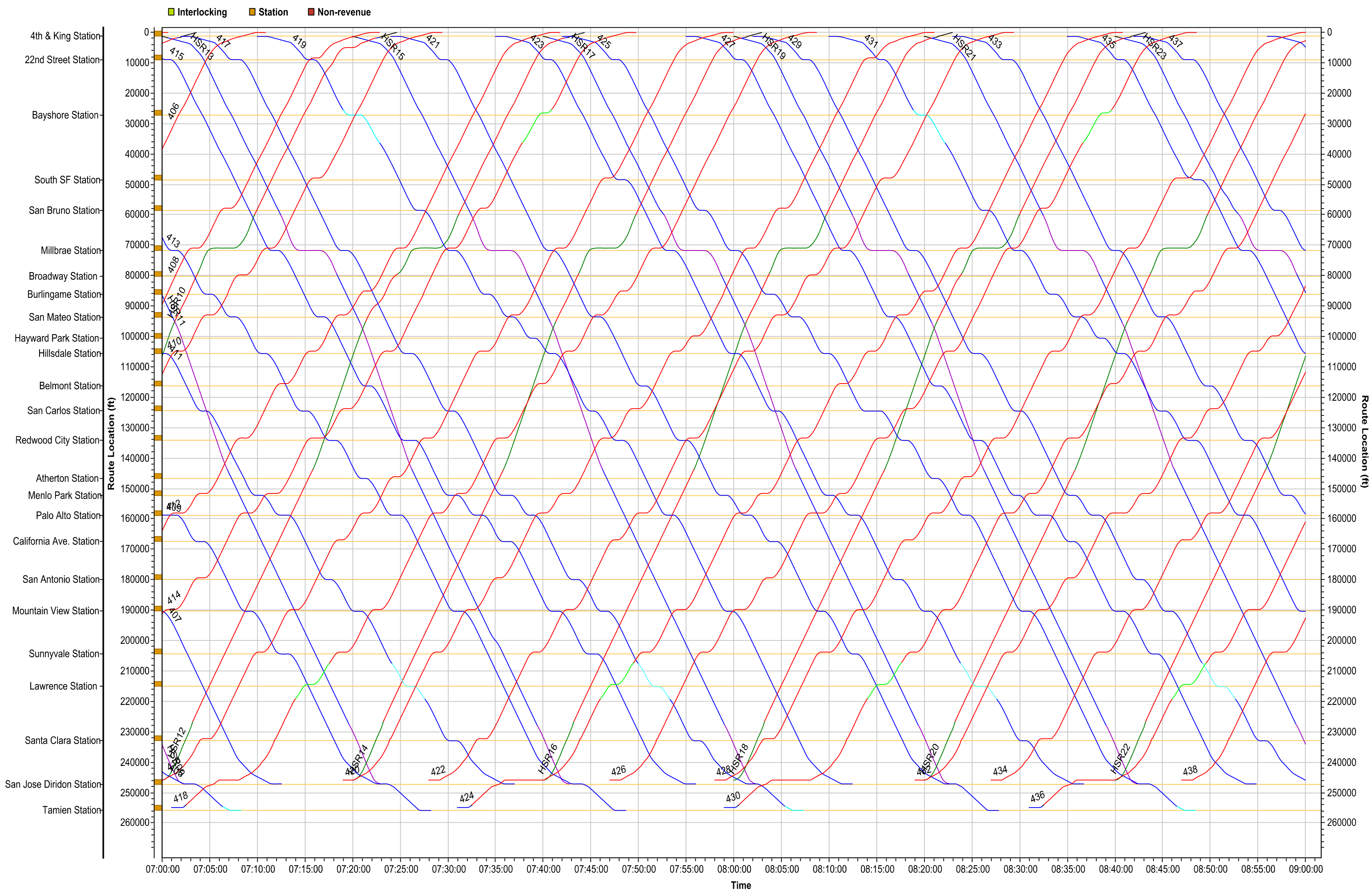


Figure 19. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Full Midline Overtake 3 HSR TPH

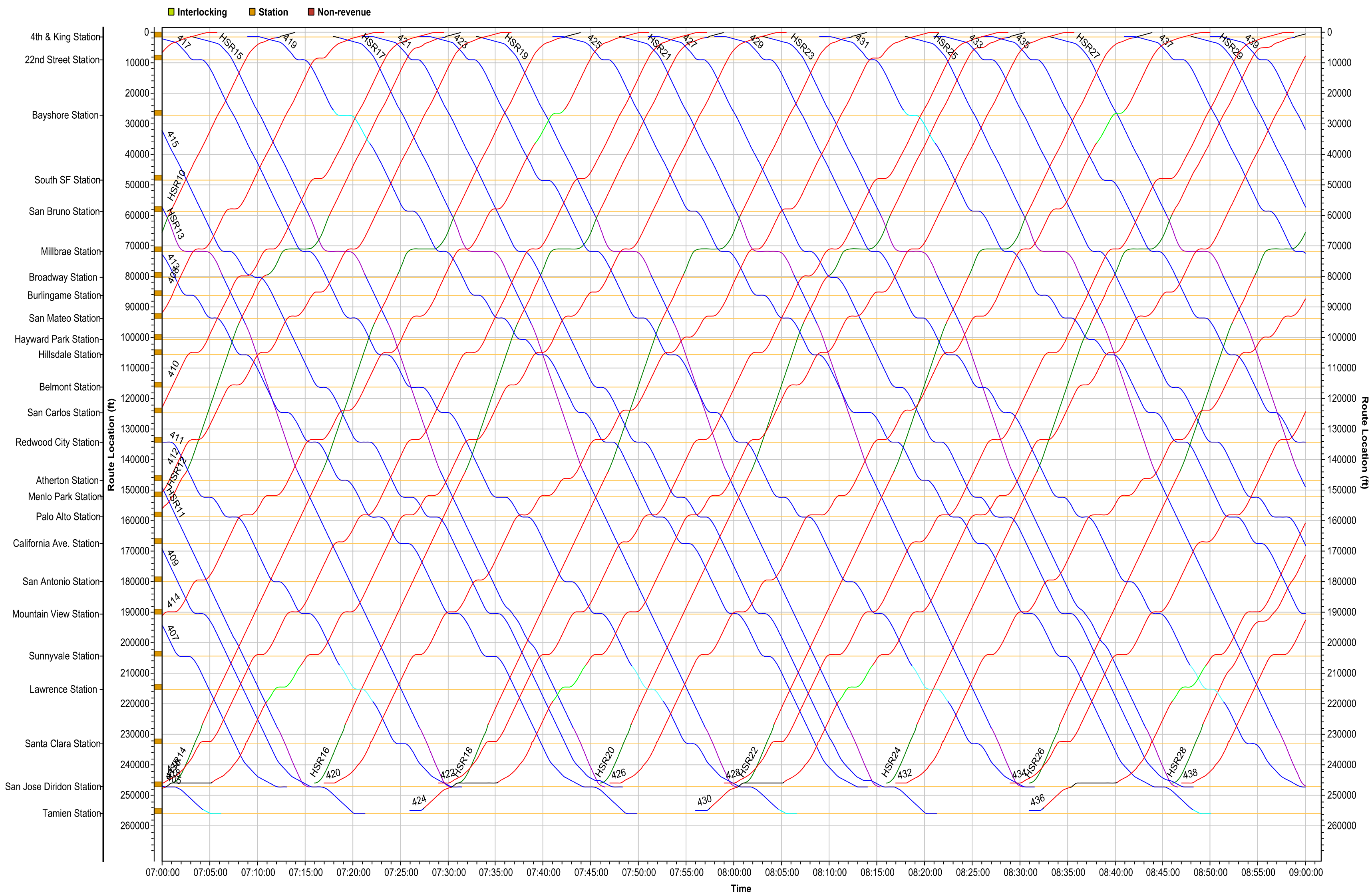


Figure 20. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Full Midline Overtake 4 HSR TPH

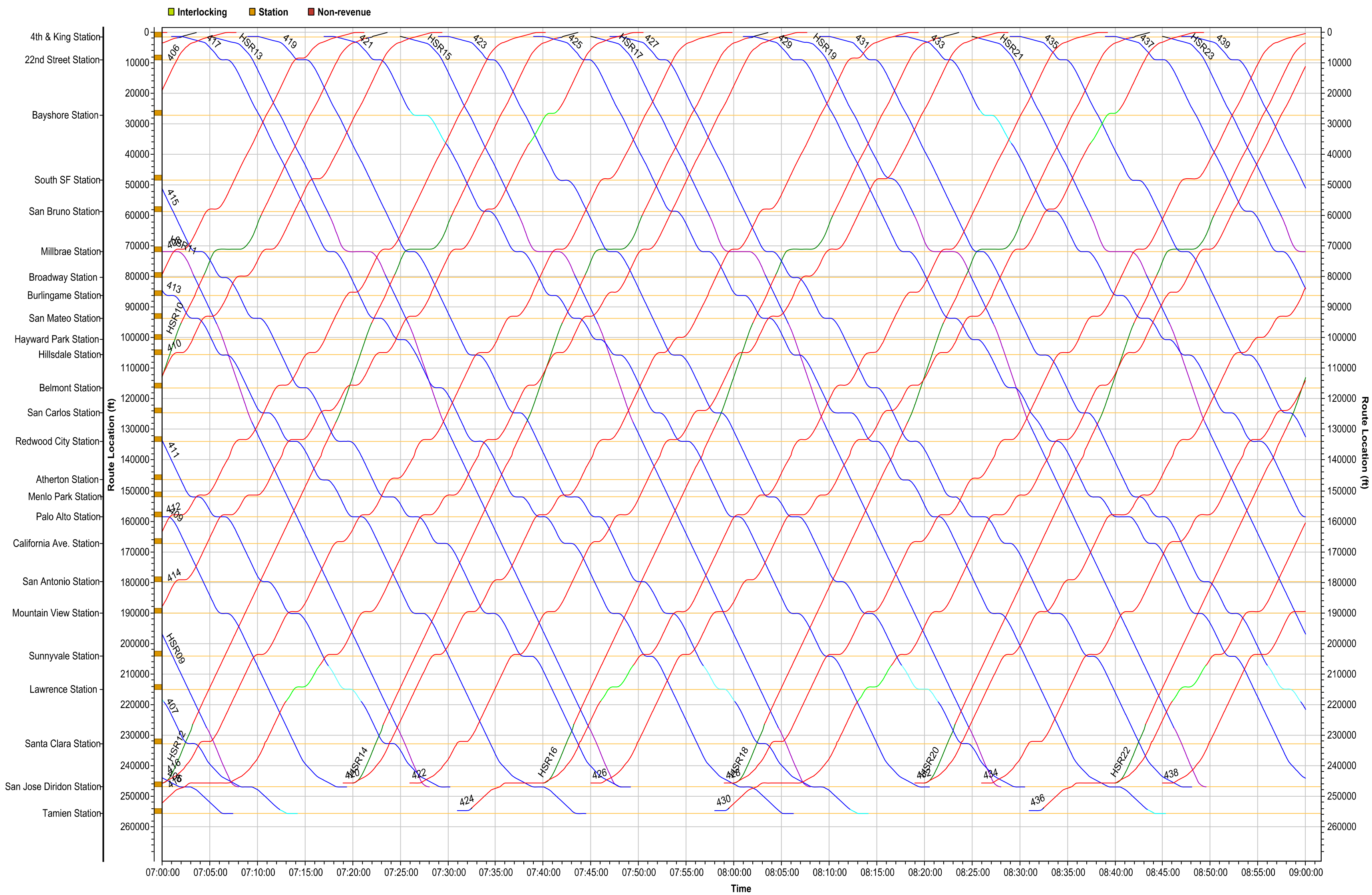


Figure 21. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Short Midline Overtake 3 HSR TPH

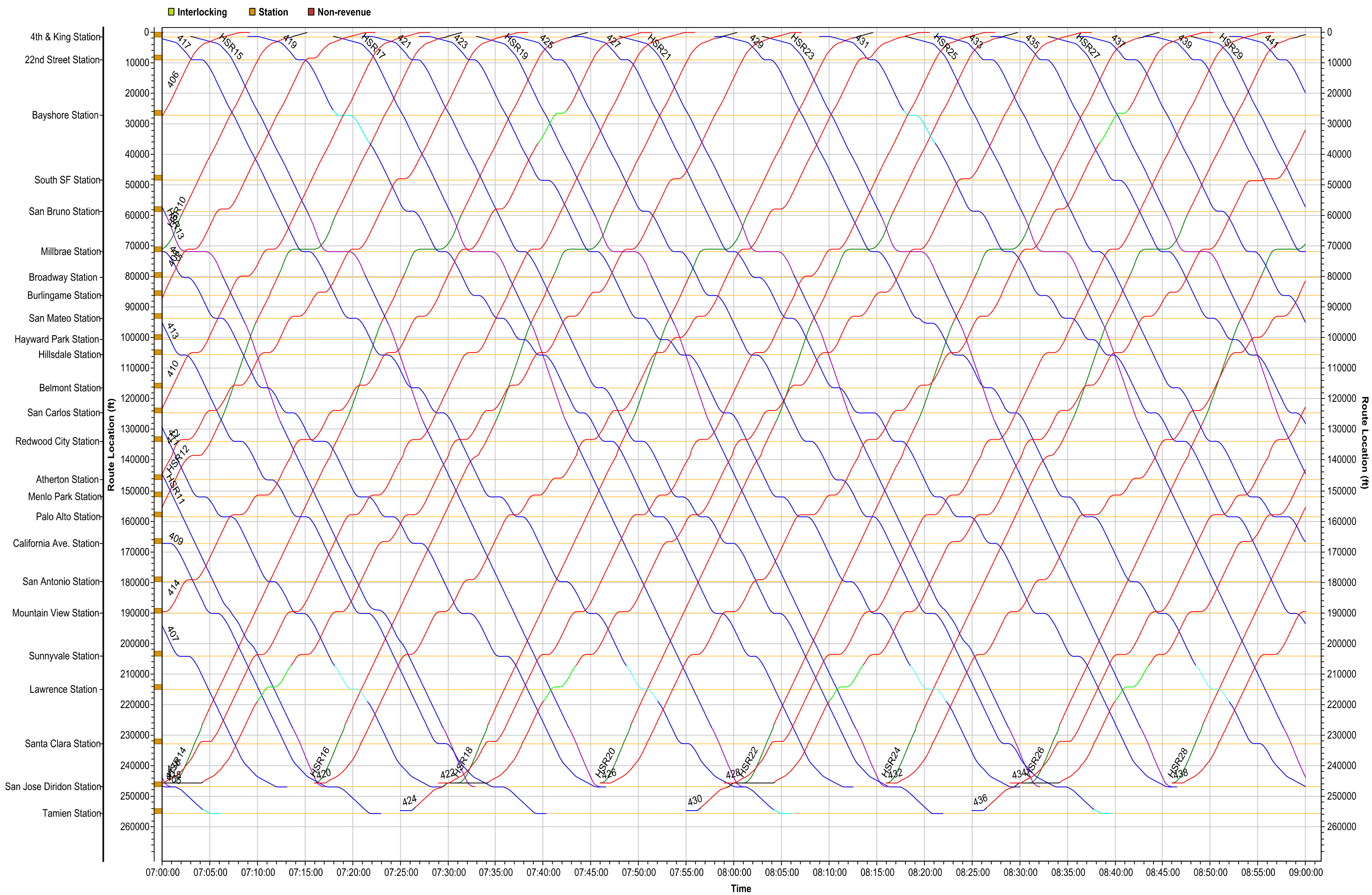


Figure 22. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Short Midline Overtake 4 HSR TPH

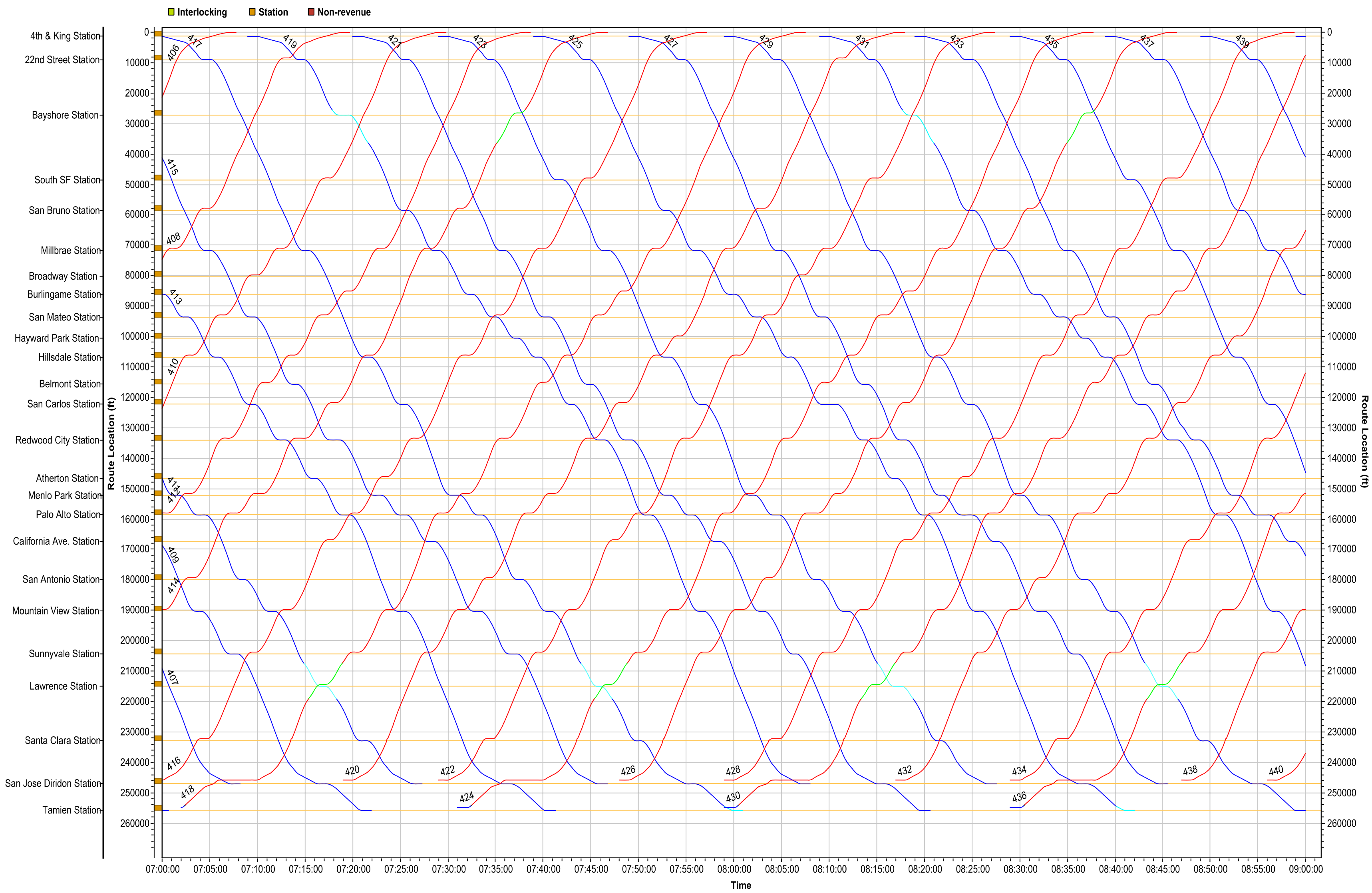


Figure 23. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Baseline Infrastructure 0 HSR TPH

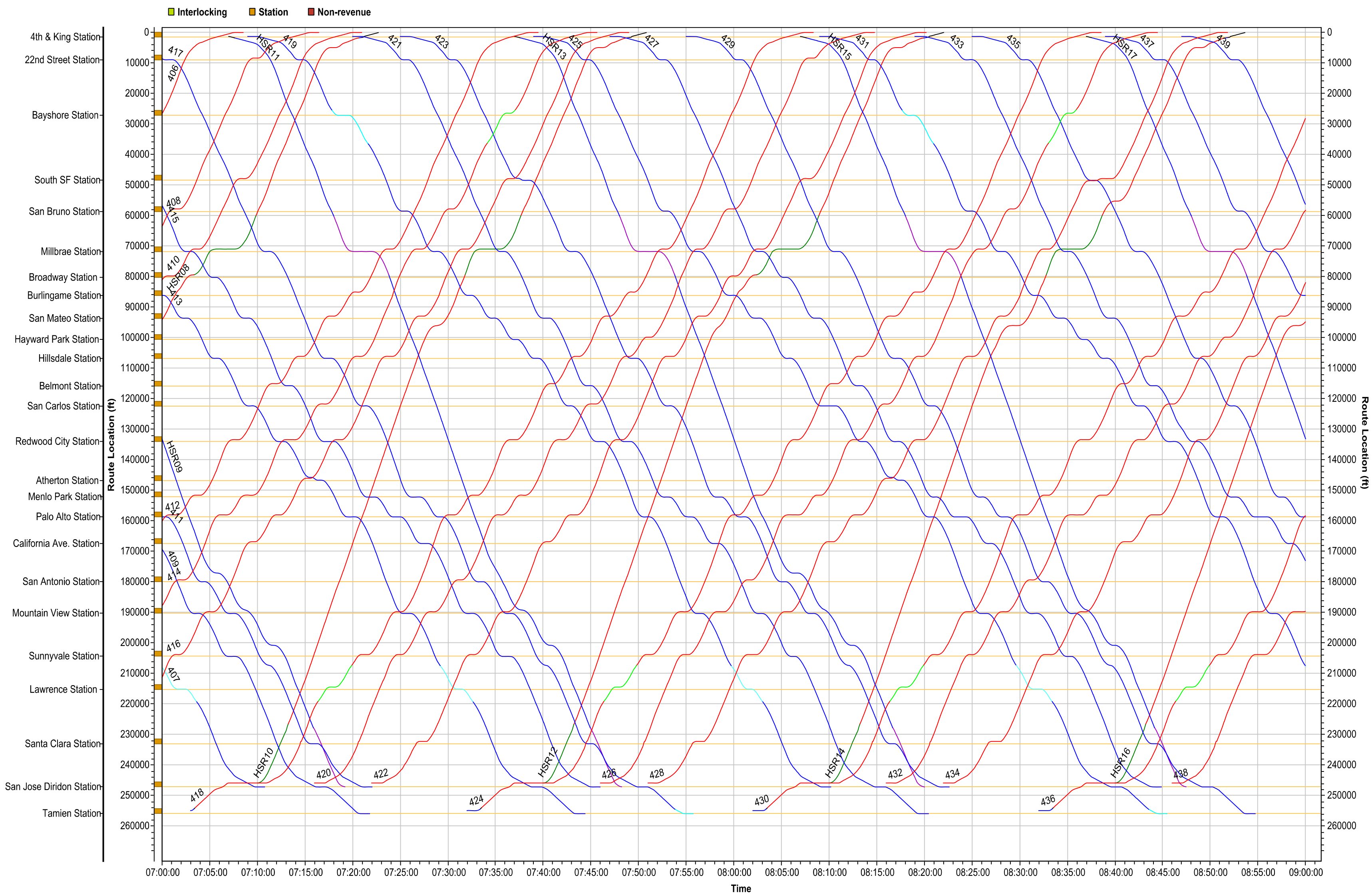


Figure 24. Time-Distance “String” Chart – 7 to 9 AM - 110/110 Baseline Infrastructure 2 HSR TPH

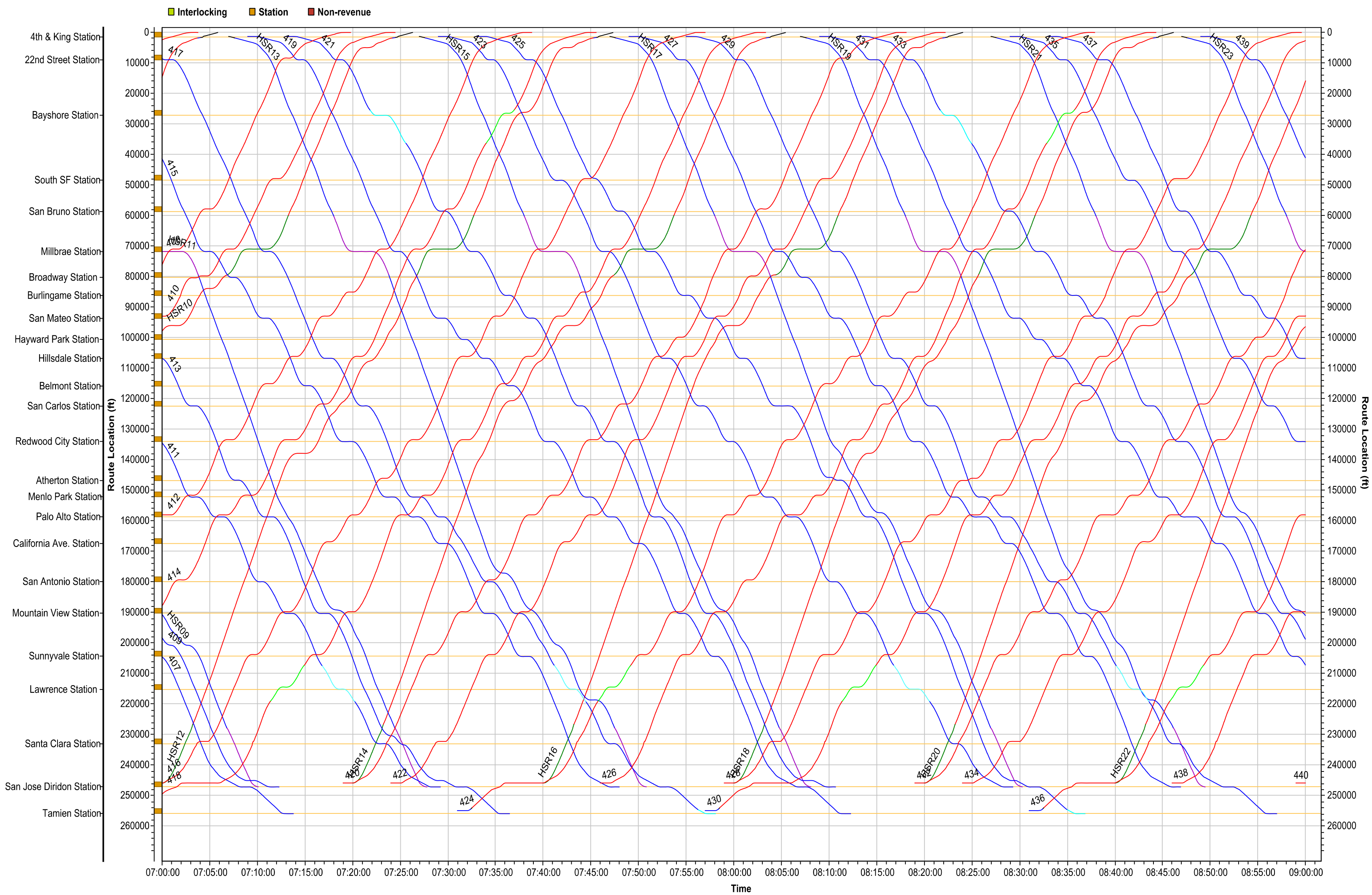


Figure 25. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Baseline Infrastructure 3 HSR TPH

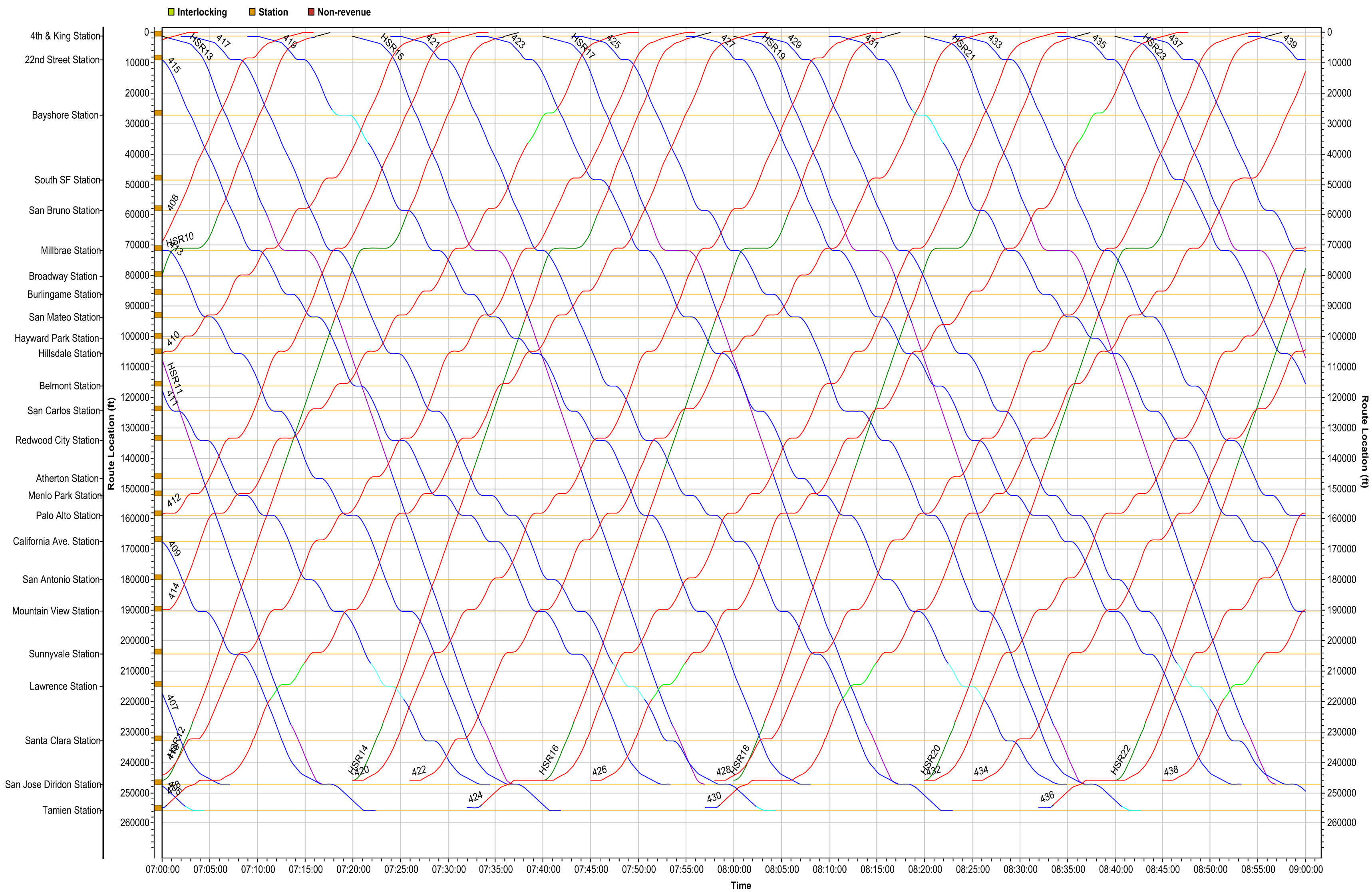


Figure 26. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Full Midline Overtake 3 HSR TPH

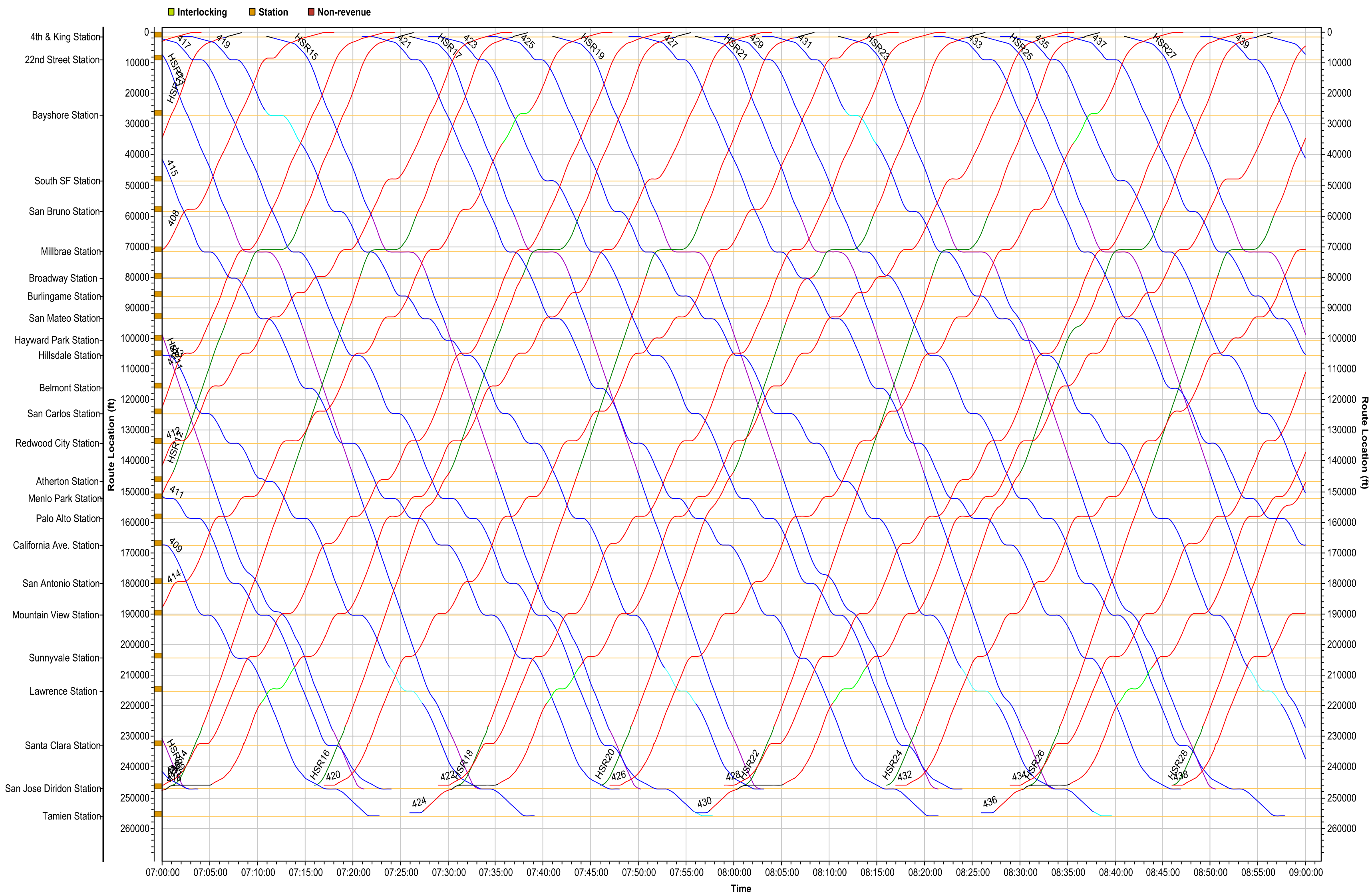


Figure 27. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Full Midline Overtake 4 HSR TPH

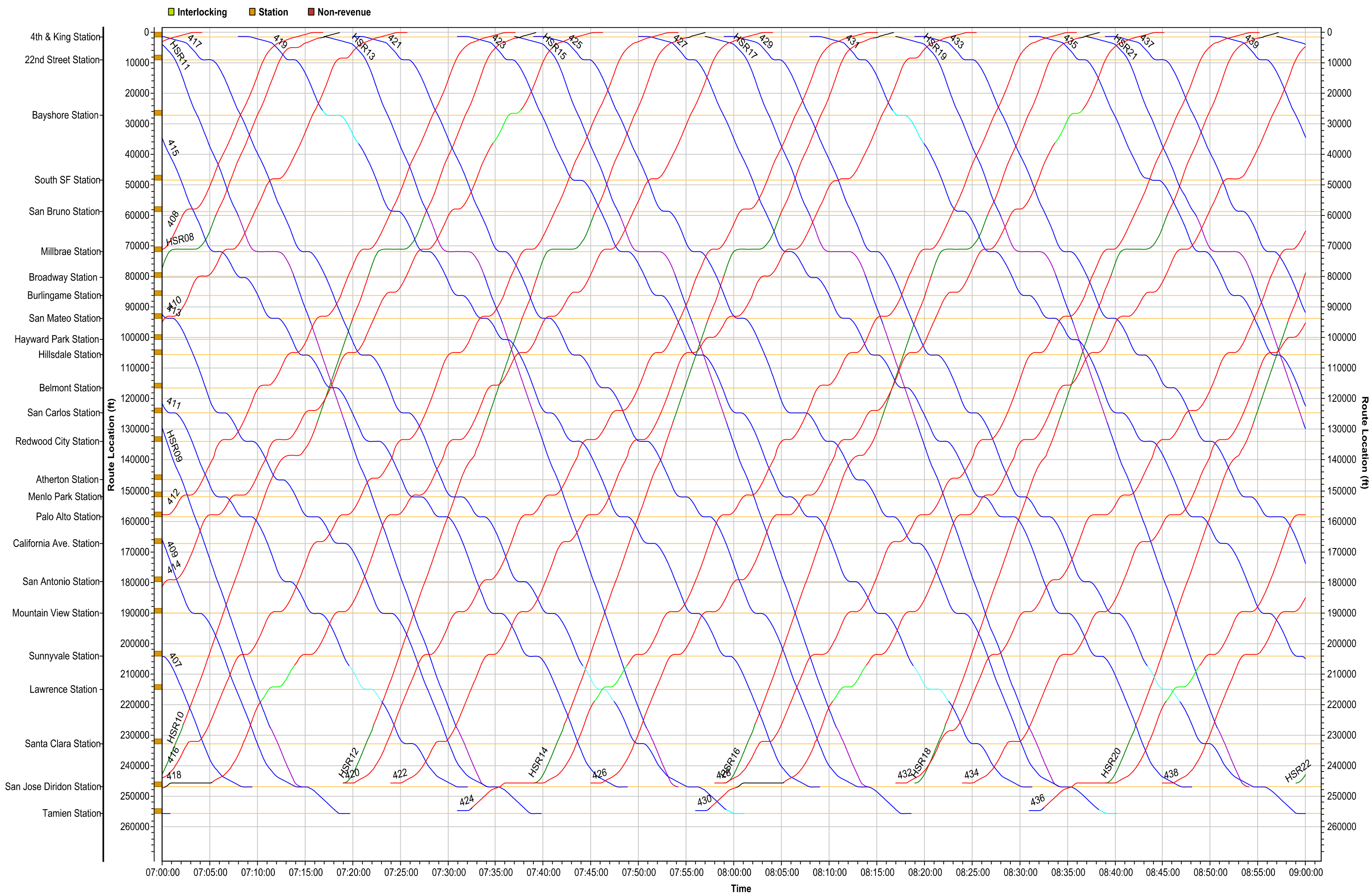


Figure 28. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Short Midline Overtake 3 HSR TPH

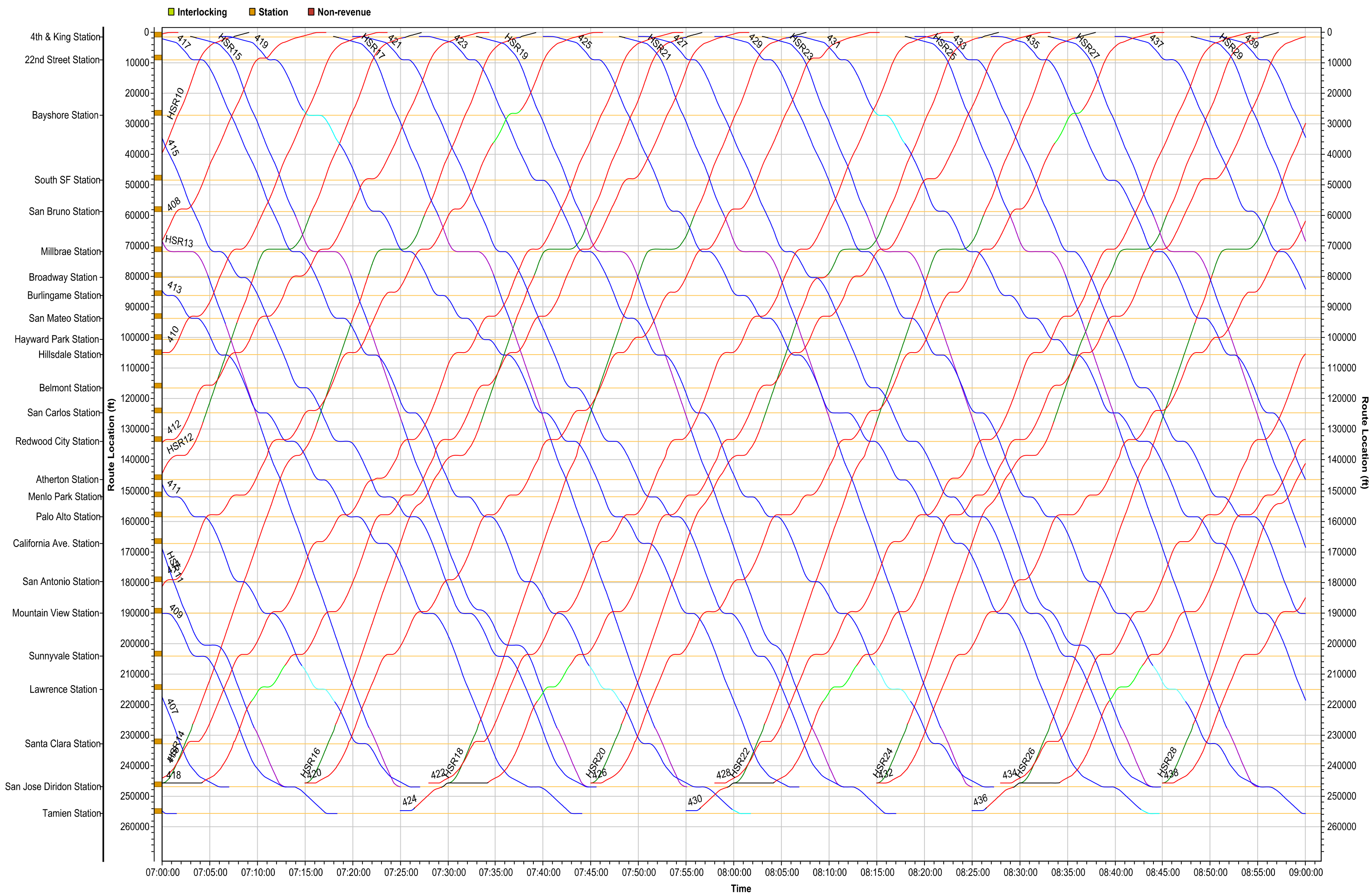


Figure 29. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Short Midline Overtake 4 HSR TPH

7.2 Midday

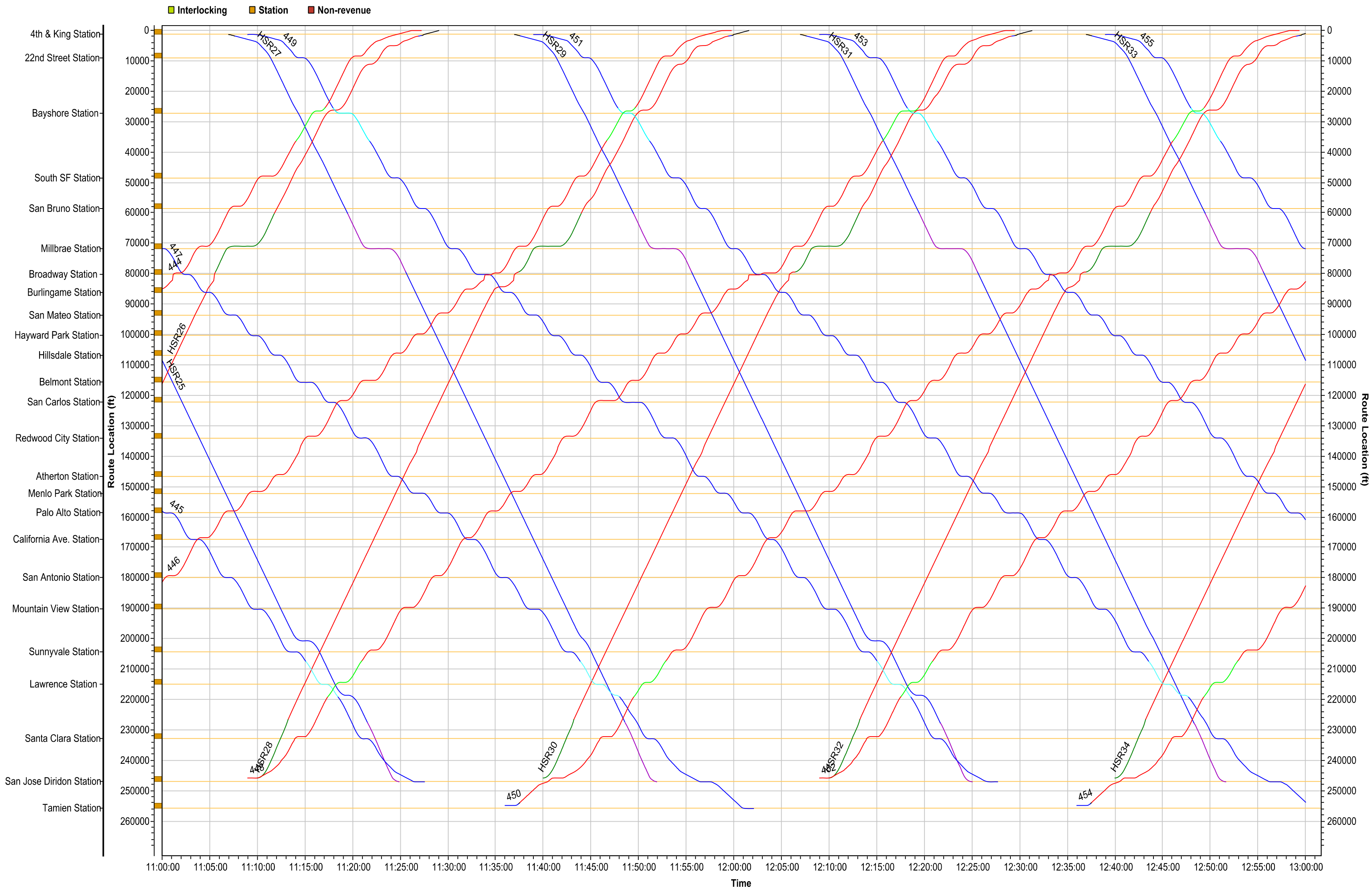


Figure 30. Time-Distance “String” Chart – 11 AM to 1 PM - 79/79 Baseline Infrastructure 2 HSR TPH

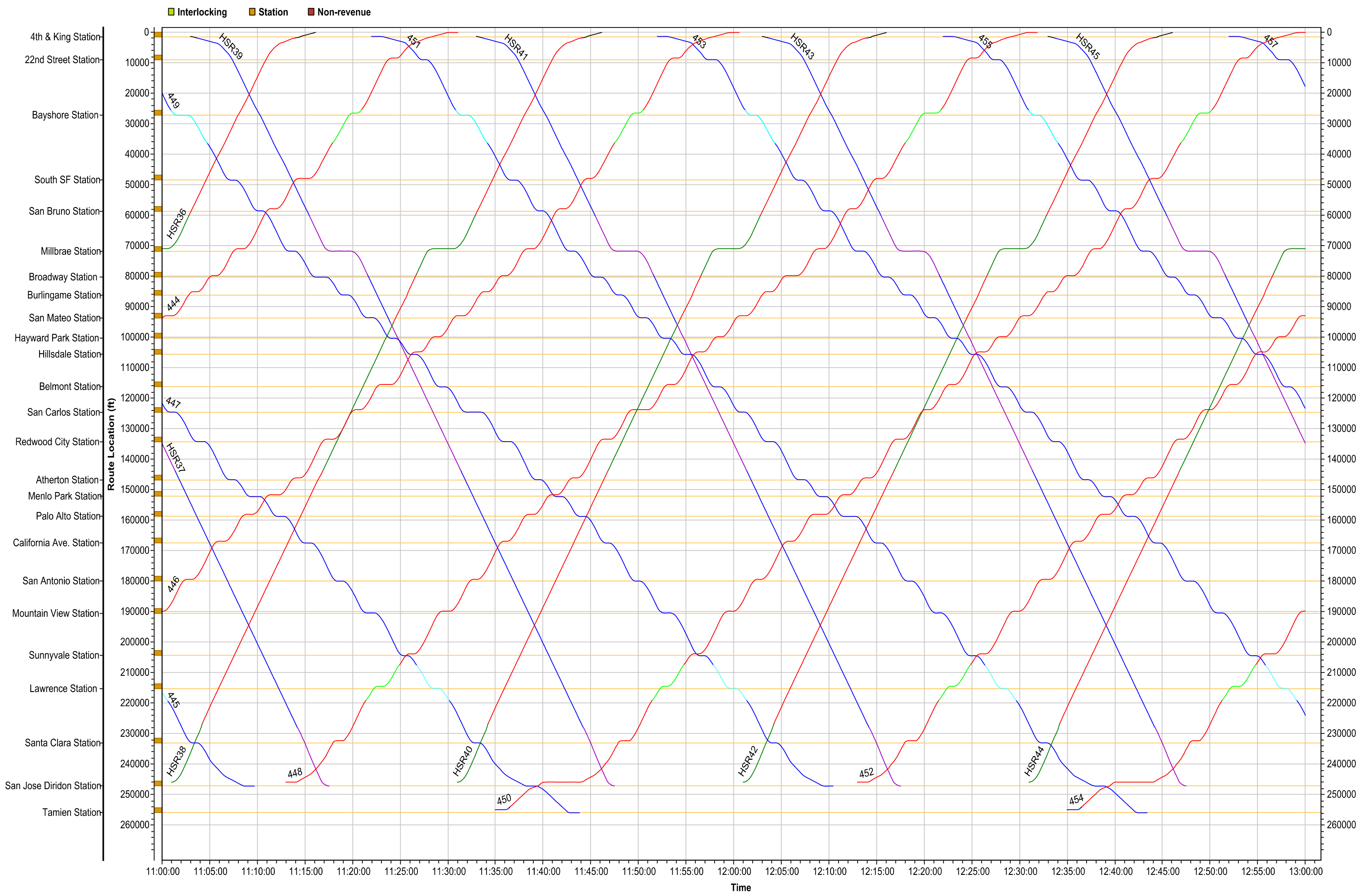


Figure 31. Time-Distance "String" Chart – 11 AM to 1 PM - 79/79 Midline Overtake 4 HSR TPH (2 HSR TPH Schedule in Off-Peak Periods)

8 Appendix C – Glossary

Advance Approach: ***Aspect*** giving a train on the Caltrain Corridor authority to proceed, subject to being able stop at the second wayside signal. Part of existing four ***Aspect*** Caltrain wayside system.

Approach: ***Aspect*** giving a train on the Caltrain Corridor authority to proceed, subject to being able to stop at the next wayside signal. Part of existing four ***Aspect*** Caltrain wayside system.

AREMA formula: Standard formula of the American Railway Engineering and Maintenance-of-Way Association (AREMA)for calculating the safe operating speed for a curve.

Aspect: The particular combination of lights, positions and flashing status of a wayside and/or cab signal that provides the train engineer with information on routing and occupancy status ahead.

At-grade crossing: Highway or street that requires automobile, bicycle and pedestrian traffic to cross the tracks at the same level.

Automatic signal: Wayside signal located between ***Interlockings***.

Automatic territory: Track located outside of ***interlockings***.

Automatic train control: System of wayside and on-board devices that monitors the engineer's compliance with signal indications and, if the engineer fails to comply within a specified time period, automatically applies the brakes to reduce the train's speed or stop it.

Bidirectional-ridership: Ridership that does not follow an AM/PM period specific pattern, as opposed to suburb-to-city unidirectional ridership.

Brake rate: Rate at which a train decelerates on level track.

Cab signaling: Signal indication or speed target displayed to the engineer within the vehicle.

Cant-deficiency: Lateral acceleration to the outside of a curve, expressed by the amount of superelevation that would be necessary to reach a balanced condition (no lateral acceleration). See also **Unbalance.**

CBOSS: Communications Based Overlay System. Caltrain implementation of PTC functionality with additional features for operational improvements.

Central control communication time: Time for the central control (dispatch center) instructions to reach an interlocking.

Clear: ***Aspect*** giving train authority to proceed at maximum speed. Part of existing four ***Aspect*** Caltrain wayside system.

Clockface schedule: A ***timetable*** schedule where trains arrive at an even interval that repeats hourly.

Conflicting route: A train immediately following another train through an ***interlocking*** on a different route that shares some track segments with the first train.

Consist: Collection of rolling stock cars that form a trainset.

Control line: Electrical connection between multiple signals that, when spanning from most favorable ***Aspect*** to most restrictive ***Aspect***, defines the distance that a train can follow another train without needing to make a brake application.

Control Point (CP): A location on the Caltrain Corridor with wayside signals that can be controlled by a Train Dispatcher, allowing trains to be held at that point as required. Almost all Control Points on the Caltrain Corridor are associated with interlockings, a collection of signals and track switches where trains can be routed from track to track as needed to maintain fluid railroad operations.

Dwell time: Time from when a train stops a station until it begins moving again.

EMU: Electrical Multiple Unit. Electrified train type where all cars provide ***tractive effort***.

Fleeted route: A train following another train through an ***interlocking*** on the same route without the dispatcher needing to reset the route for the following train.

Full seated load: Maximum seated capacity for a train.

Golden run: Ideal simulation run with best possible vehicle performance, no underspeed and without randomization.

Headway: Time (either scheduled or actual) between successive trains on the corridor.

Holdout rule: Operating rule on the Caltrain Corridor that requires trains to wait for other trains to pass or finish unloading passengers at stations where pedestrians must cross the track.

Interlocking territory: Track located within track junctions where powered switches are present.

Interlocking: Control point protected by signals where movable bridges, rail crossings or turnouts exist.

Layover: Time spent between runs at a terminal or yard.

Loss-of-shunt time: Time for the electrical circuit within an ***interlocking*** to be grounded and then reset.

Maintenance tolerance: Additional conservatism added to safe operating speed to limit occurrences of temporary speed restrictions due to rail wear and loss of ***super-elevation*** over time.

Maximum operating speed: Maximum permissible speed on a given segment of track.

Minimum train separation: Closest distance at which one train can follow another without being delayed.

Passenger alighting time: Total time for passengers to exit the train. It is a component of ***dwell time***.

Passenger boarding time: Total time for passengers to enter the train. It is a component of ***dwell time***.

Peak period: Heaviest ridership periods which, for the Caltrain Corridor, are defined as 6-10 AM in the morning and 3-7 PM in the evening.

PTC: Positive Train Control, an impending FRA requirement for railroads carrying passengers and/or certain types of hazardous materials to enforce safe train separation, civil speed restrictions, temporary speed restrictions and roadway worker safety zones.

Recovery allowance: Time added to a schedule to plan for unexpected delays. See also ***schedule margin***.

Right-of-way: Property encompassing a rail corridor controlled by the railroad.

Rolling stock: Individual car, locomotive or self-propelled multiple unit vehicle of a trainset.

Route reestablishment time: Time required for a train to be granted permission via signal indication to enter an ***interlocking***.

ROW: See right-of-way

Schedule margin: Additional time added to a train schedule to account for unpredictable delays and less than ideal train and engineer performance.

Signal block: Section of track between two signals.

Signal delay: Time that a train is braking or stopped for a signal because it is displaying an ***Aspect*** more restrictive than the best ***Aspect*** that can be displayed at that location for a given train route.

Skip-stop: Scheduling technique of alternating station stops to increase average travel speeds and to reduce trip times.

Super-elevation: Difference in elevation between inside and outside rails in a curve.

Switch movement time: Time it takes for a switch to mechanically change positions and for switch detectors to verify that the switch has moved to the requested new position.

Timetable: Schedule provided to passengers and/or operating personnel.

Track alignment: Horizontal curve values and vertical grade values along the corridor.

Tractive effort: Force that a train's motors generate for forward movement.

Unbalance: Lateral acceleration to the outside of a curve, expressed by the amount of superelevation that would be necessary to reach a balanced condition (no lateral acceleration). See also: ***Cant-deficiency***.

Wayside signaling: Signals alongside the track that convey to the train engineer occupancy and/or routing status ahead.

9 Appendix D – Stakeholder Outreach

Efforts to conduct the Caltrain/California HSR Blended Operations Analysis began in June 2011.

Preliminary results were defined in August 2011. Between August to November 2011, JPB staff conducted outreach meetings to share preliminary findings. Outreach was focused on sharing information with city/county and transportation agency staff. Presentations were made at requested city council and transportation agency board meetings and additional stakeholder venues, including the San Mateo County Rail Corridor Partnership, Peninsula Cities Consortium, Friends of Caltrain, San Mateo County Economic Development Association, Peninsula Freight Rail Users Group, chambers of commerce, Silicon Valley Leadership Group, Bay Area Council and San Francisco Planning and Urban Research Association.

The draft report was prepared and released for public comment November 2011. Comments received on the draft report and staff responses are noted in attached Table 1. Appropriate modifications to the draft report were made and are reflected in this final report.

TABLE 1: DRAFT Caltrain / California HSR Blended Operations Analysis Report (Report) Comments and Response to Comments February 2012		
From	**Comments**	**Caltrain Responses**
Comments from Cities		
Redwood City	Does the new rolling stock come before the CBOSS PTC Project?	The analysis assumes that both the new electric rolling stock for Caltrain and the CBOSS PTC Project are in place to support blended operations. In terms of actual implementation, CBOSS PTC project is scheduled for completion in 2015. Electrified revenue service will occur after 2015. The date is TBD and dependent on identification of funding.
	Provide travel time results while holding the infrastructure constant for each of the tested speed scenarios.	Two infrastructure options were tested- one without passing tracks and the other with passing tracks. For both infrastructure options, train speeds up to 79mph and 110mph were tested. The travel time results are noted in Tables 14 - 19 of the report.
	In the description of sensitivity testing (in Section 2.2), it isn't clear what the input values represent.	The input values represent software's response to different delay times in establishing a new route through an interlocking (control point) in the event that the interlocking had just been occupied by a train on a conflicting route. This information has been added to the report.
	Please provide more explanation of what the tractive effort curve is.	Tractive effort curve graphs the maximum pounds of force produced by the train to accelerate it. The "effort" corresponds to the acceleration capability of the train. This information has been added to the report.
	In the dwell time study, why were all calculations completed for Gallery vehicles instead of including Bombardier vehicles?	Because there were an insufficient number of dwell times for the Bombardier coaches recorded during the field observations. Therefore, to avoid mixing dwell time observation on the two different existing coach types, only Gallery Car data was used. This information has been added to the report.
	Provide vehicle performance characteristics of existing Caltrain's Bombardier and Gallery cars for reference.	Caltrain's existing vehicle performance characteristics is included in **Attachment B.** This information was not included in the report because all Caltrain trains are assumed to be EMU trains in this analysis.
San Carlos	Glad no decision on overtake sections have been made. In favor of "pure 2 track option".	Noted.
	Review May 2010 HSR AA comment letter when the Middle Overtake options are contemplated.	The comment letter has been reviewed and noted. The comments will be helpful when we reach the **"Infrastructure"** box in the planning process. **See Planning Process Chart Attachment A.**
	How will the overtake options blend vertically with existing tracks?	The simulation model is neutral to vertical profile assumptions. Vertical profiles will be identified when we reach the "Infrastructure" box in the planning process. **See Planning Process Chart Attachment A**.
Mountain View	Evaluate local traffic impacts associated with increased train service levels.	Local traffic impacts associated with increased train service levels is being studied currently (***Grade Crossing and Traffic Analysis Study***). This study is anticipated to be completed by September 2012. **See Planning Process Chart Attachment A.**
	Consider removing the Southern Overtake option from additional consideration.	In response to stakeholder request, we have committed to studying all passing track options. Discussion about eliminating overtake options would be timely after conclusion of the ***Service Plan / Operations Considerations Study*** which will complete examination of all passing track options. The study is to be completed Summer 2012. **See Planning Process Chart Attachment A.**
	Clarify difference between three and four-track configurations. Is there a possibility of having a three-track configuration in Mountain View?	The 4-track option allows for two dedicated tracks for high speed rail trains to bypass Caltrain trains along a limited segment of the corridor - one track for each direction. The 3-track option allows for one dedicated track for high speed rail trains to bypass Caltrain trains along a limited segment of the corridor - one track for both directions.
	With the possibility of higher train speeds along the Corridor, Caltrain should fully analyze the need for grade separations, platform or other station-related improvements to ensure appropriate level of safety.	The need for grade separations is being studied currently (***Grade Crossing and Traffic Analysis Study***). Design will be developed when we reach the "**Infrastructure**" box in the planning process. **See Planning Process Chart Attachment A.**

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Comments from Cities		
Belmont	Do not support the Full Midline or Short Midline Overtake Track Options.	Noted. In response to stakeholder request, we have committed to studying all passing track options. Discussion about eliminating overtake options would be timely after conclusion of the ***Service Plan / Operations Considerations Study*** which will complete examination of all passing track options. The study is to be completed Summer 2012. **See Planning Process Chart Attachment A.**
Comments from Transportation Agency / Corporation		
CHSRA	Analysis of grade crossings, bridges, tunnels, track structure and alignment is needed before endorsing speeds up to 110 mph.	Infrastructure need will be identified when we reach the "**Infrastructure**" box in the planning process. **See Planning Process Chart Attachment A.**
Union Pacific Railroad (UPRR)	Request that UPRR be provided opportunity to participate in future studies involving the blended system. Future studies should include potential impact and possible mitigation to protect freight operations and freight rail customer access.	Assessment of freight traffic on the blended system is being addressed in the ***Service Plan / Operations Considerations Study***. The study is scheduled to be completed summer 2012. We are in contact with UP and will be following up to define the next steps for coordination. **See Planning Process Chart Attachment A.**
Comments from Advocacy Groups		
Peninsula Freight Rail Users Group (PFRUG)	Any reduction in freight access in unacceptable to PFRUG.	Noted.
	Consider freight service "status quo" and not the minimum allowable by existing agreements. Include freight rail service into the "capacity analysis".	Assessment of freight traffic on the blended system is being addressed in the ***Service Plan / Operations Considerations Study***. The study is scheduled to be completed Summer 2012. We are in contact PFRUG and will be following up to define the next steps for coordination. **See Planning Process Chart Attachment A.**
	Add to report "Peak Commute Hour Capacity Analysis". Peak-hour capacity conclusions cannot apply to off-peak hours.	We agree. The report accurately captures that the analysis was completed only for the peak period.
	New tracks must be designed to allow access to current freight access points. Consider how the overhead catenary system may affect capacity.	Infrastructure need will be identified when we reach the "**Infrastructure**" box in the planning process. **See Planning Process Chart Attachment A.**
	Consult Union Pacific before finalizing the report.	We are in contact with UP and will be following up to define the next steps for coordination.

TABLE 1: DRAFT Caltrain / California HSR Blended Operations Analysis Report (Report) Comments and Response to Comments February 2012		
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Comments from Individuals		
Mark Olbert	Why is Caltrain's current service level contemplated?	What is being contemplated in the blended system is more than today's service level. Today, Caltrain provides 5 trains in the peak hour per direction. The blended system analysis contemplates 6 trains per peak hour per direction.
	How much of the scheduling delay in the analysis results is related to suboptimal infrastructure?	Most of the scheduling delay is related to congestion in the 4th and King terminal, not suboptimal (track) infrastructure along the mainline.
	HSR delays in report (5 - 10 minutes from San Francisco to Los Angeles) do not seem significant enough to warrant passing tracks	Noted. The industry standard for intercity passenger rail operations between city pairs (San Francisco -Los Angeles) up to 450 miles apart is for lateness to not exceed 20 minutes over this distance. The Caltrain Corridor makes up about one-eighth of this distance so a maximum of three minutes of lateness within the Caltrain Corridor was considered the maximum tolerable lateness. Three minutes of HSR delay was assumed to be the threshold for including HSR passing tracks.
	Assume no overtake tracks and figure out "best" Caltrain and HSR service plan.	This scenario was studied and is included in the analysis. Without passing tracks, the corridor can support 6 Caltrain trains and 2 HSR trains per peak hour per direction.
	Consider a balance of Caltrain & HSR service for increasing use of mass transit. Would argue that only increasing Caltrain service/ridership is not the whole picture.	Additional service plans will be considered when we reach the "**Service Plan Options**" box in the planning process. **See Planning Process Chart Attachment A.**
	Adding Caltrain stops to allow for HSR to pass doesn't seem all bad - does add travel time, but also increases access.	Noted.
Clem Tiller	Model "Altamont HSR" (HSR coming in at Redwood City Junction).	Caltrain's current work is on the blended system based on CHSRA's decision to utilize the Caltrain corridor to access downtown SF. There is no Caltrain analysis on a different high-speed rail alignment at this time.
	Model additional Caltrain stopping patterns. Include analysis of programmed Caltrain overtakes (in the 6 Caltrain / 4 HSR scenario).	In the ***Service Plan / Operations Considerations Study***, the baby bullet stopping pattern will be studied. The study is scheduled to be completed Summer 2012. Additionally, other service plan options will be considered when we reach the "**Service Plan Options**" box in the planning process. **See Planning Process Chart Attachment A.**
	Create methodology to quantify quality of service (i.e. ride time, wait time, potential ridership).	An evaluation approach for quantifying the quality of service will be addressed when we get to the "**Service Plan Options**" box in the planning process. **See Planning Process Chart Attachment A**.

TABLE 1: DRAFT Caltrain / California HSR Blended Operations Analysis Report (Report) Comments and Response to Comments February 2012		
From	**Comments**	**Caltrain Responses**
Comments from Individuals		
Michael Drury	Avoid making recommendations that are contingent solely on HSR funding.	Noted.
	Develop a Service Implementation Plan that would outline the rollout of service improvements.	The development of a service implementation plan would begin after reaching the "**Blended System Alternatives**" box in the planning process. **See Planning Process Chart Attachment A.**
	Study grade separations for cost effectiveness and community impacts.	Grade separations cost effectiveness and community impacts assessment will begin to be addressed when we get to the "**Infrastructure Need**" box in the planning process. **See Planning Process Chart Attachment A.**
	Consider crossing closures in grade crossing analysis.	Crossing closures is one of several solutions that is being considered in the ***Grade Crossing and Traffic Analysis Study*** . This study is anticipated to be completed by September 2012. **See Planning Process Chart Attachment A.**
	Improve travel time between San Francisco and San Jose, don't just keep as status quo. Model Baby Bullet service.	Baby bullet service is being analyzed in the ***Service Plan / Operations Considerations Study*** , the baby bullet stopping pattern will be studied. The study is scheduled to be completed Summer 2012. **See Planning Process Chart Attachment A.**
	Consider a "clock face" schedule.	Additional service plans will be considered when we reach the "Service Plan Options" box in the planning process. **See Planning Process Chart Attachment A.**
	Consider eliminating skip-stop train patterns.	Additional service plan options will be considered when we reach the "**Service Plan Options**" box in the planning process. **See Planning Process Chart Attachment A.**
Vaughn Wolffe	Model the Dumbarton Rail Corridor Project Alternative that merges onto the Caltrain corridor and travels to San Francisco and to San Jose.	The Dumbarton Rail Project is being tested as part of the ***Service Plan / Operations Considerations Study*** . The study is scheduled to be completed Summer 2012. **See Planning Process Chart Attachment A.**
	What train length was assumed for Caltrain within the simulation model?	An eight-car EMU consist which is 680 feet in length.
	What modifications would have to be made to accommodate 10 car trains?	As part of the **Service Plan / Operations Considerations Study**, we will be studying the feasibility and impacts of running longer trains. The study is scheduled to be completed Summer 2012. **See Planning Process Chart Attachment A.**
	What are ROW impacts for the blended system?	ROW impacts will be addressed when we get to the "**Infrastructure Needs**" box in the planning process. **See Planning Process Chart Attachment A.**

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Comments from Individuals		
Roland Lebrun	Caltrain too slow (not capable of 150 mph) - this would inhibit a "double blended" implementation between Gilroy and San Jose.	The Caltrain and HSR Blended System would terminate at the Diridon Station. Blended System operations is not contemplated between San Jose and Gilroy.
	Ignore CBOSS PTC and recalibrate the simulation model with ETCS parameters. Under ETCS control, the need for additional platform faces should be questioned.	The simulation reflects the specified design characteristics of the Positive Train Control system that Caltrain will be installing in compliance with federal regulations. The Federal Railroad Administration has not approved the ECTS/ERTMS system for the United States and as such, the need for additional platform faces under a ETCS/ERTMS system is unknown at this time.
	Thank you for confirming that 110/110 mph is the only viable scenario.	It should be clarified that 110/110 mph is one of the viable scenarios. The 110/110 does provide the best travel times. However, all 3 speed scenarios tested (79/79 mph, 79/110 mph and 110/110 mph) were operational viable.
	Diridon Station area modifications in model (eliminate 80 mph merge, modify acceleration, deceleration assumptions). Millbrae Station area modifications in model (eliminate passing tracks and HSR turnouts, assume 2-track configuration, relocate HSR turnouts to San Bruno Grade Separation Project, look at 100 mph HSR turnouts). DTX project (change design, have 3 tracks for Caltrain & 15 min "turn around" time).	Infrastructure design solutions will be addressed when we get to the "**Infrastructure Needs**" box in the planning process. Further refinements to optimize performance will also be addressed when we get to the "Blended System Alternatives" box in the planning process. **See Planning Process Chart Attachment A.**
	Not necessarily true that we need 5 stations to accommodate successful overtake.	Noted. The report has been expanded with more explanation about how making three out of five station stops allows for both delay free overtakes and consistency with the tested skip-stop operating plan.
	Make EMU "preliminary specification documents" available to public. All EMU sets should be identical, capable of 60 second coupling/decoupling.	EMU prototypical specification were assumed for the analysis. "Preliminary specification documents" have not yet been developed. Section 3.3 of the report has been modified accordingly.
	No need to "enforce strict processing in timetable order".	The report has been modified to clarify dispatching logic assumptions. Dispatching logic was added to the simulations to prevent delays to HSR and Caltrain.
	Ignore ACE and Capitol Corridor impact on HSR.	ACE and CC have requested evaluation of how the blended system impacts their current and future operations. This will be evaluated in the ***Service Plan / Operations Considerations Study*** . The study is scheduled to be completed Summer 2012. **See Planning Process Chart Attachment A.**
	Figure 8 shows initial tractive effort 2.1 - max speed of 79 mph. Why not 110 mph?	Figure 8 should have shown a maximum speed of 110 mph. This is corrected in the final report.

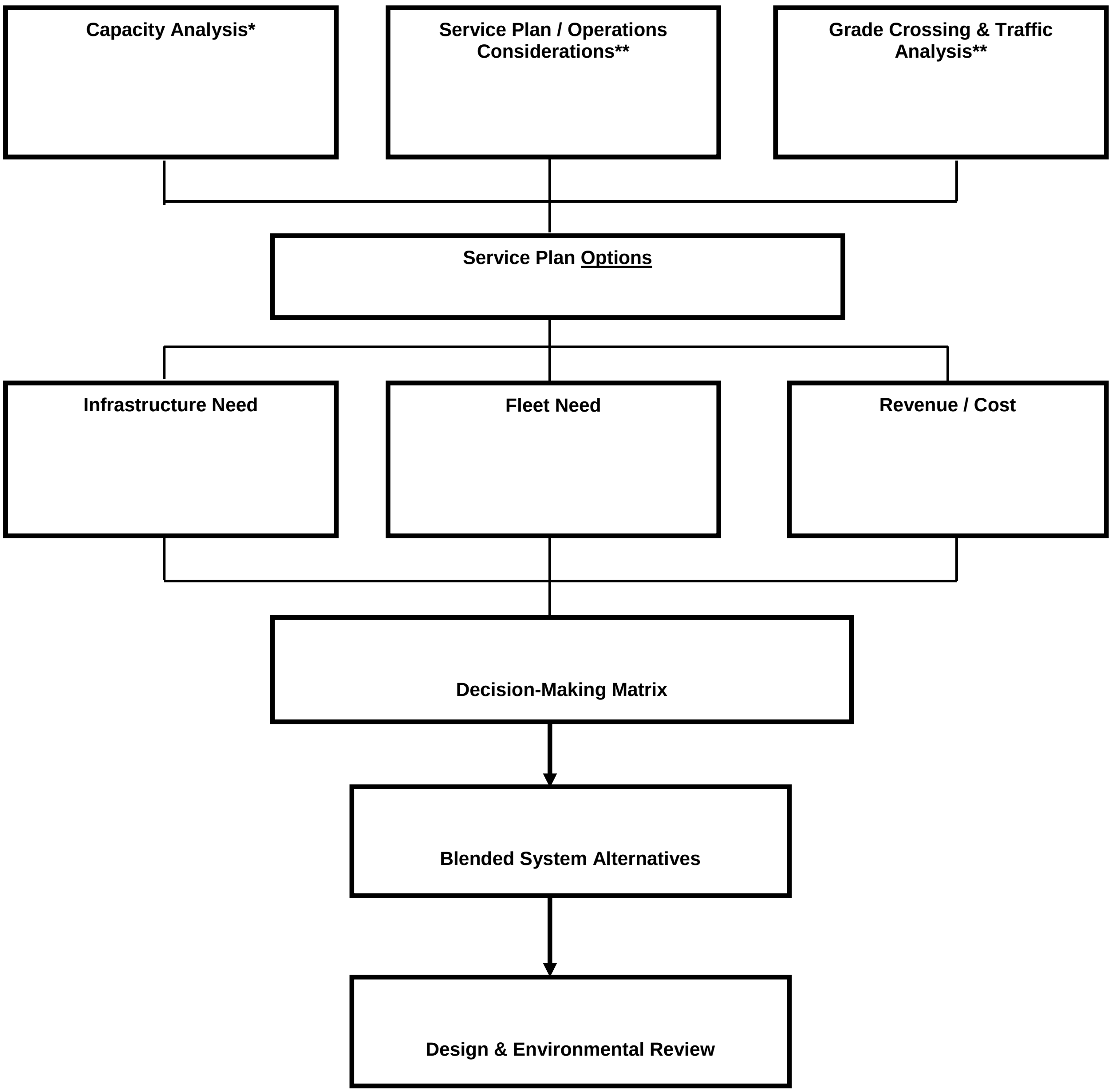
Attachment A: Caltrain / High –Speed Rail Blended System Planning Process

Capacity Analysis to Project Alternatives

The following is a visual depiction of a planning process that will assist in defining a vision for modernizing the Caltrain system. The total planning effort is anticipated to span up to 2 years.

The process is focused on, first, gathering sufficient data to define the service plan options for the rail corridor, and then the tradeoffs associated with providing expanded services. The information would be used to facilitate policy discussions to inform what project alternatives would be studied environmentally before landing on a locally preferred alternative for design and construction.

Caltrain is in the process of collecting data related to the "Service Plan/ Operations Considerations" study (**) and "Grade Crossing and Traffic Analysis" study (**). The efforts identified in the remaining boxes are planned to be completed by summer of 2013.



Attachment B: Existing Caltrain Vehicle Performance

Caltrain / California HSR Blended Operation Response to Comments

The existing Caltrain vehicle performance characteristics are as follows:

Current Caltrain Passenger Vehicles Approximate Physical Characteristics					
Vehicle Type	Frontal Area (square feet)	Length (ft)	Empty Weight (lbs)	Maximum Operating Acceleration Rate* (MPHPS)	Maximum Operating Deceleration (MPHPS)
Gallery Car	157.14	85	126,700	N/A, not powered	1.8
Bombardier Bi-level	155.8	85	124,000	N/A, not powered	2
MP36 Locomotives	N/A			0.65	1.6
F40 Locomotives				less than 0.65	1.6

Notes:
MPHPS = Miles per hour per second
Acceleration rate from 0 to 60 mph
Decelerations rate from 60 mph