Transportation Solutions Defense and Education Fund

P.O. Box 151439 San Rafael, CA 94915 415-331-1982

February 21, 2012
By E-Mail

John Mason
California High-Speed Rail Authority
770 L Street, Suite 800
Sacramento, CA 95814

Re: Bay Area to Central Valley HST Partially Revised Draft Program EIR Comments

Dear Mr. Mason:

The following comments are offered on behalf of the Transportation Solutions Defense and Education Fund ("TRANSDEF"), the Planning and Conservation League, the Community Coalition on High-Speed Rail and the California Rail Foundation (collectively, "Commenters"). The Partially Revised Draft Program EIR ("PRDPEIR") for the Bay Area to Central Valley High-Speed Train project discloses ten significant and unavoidable impacts (p. 1-5[1]) resulting from the implementation of the Pacheco Pass Alternatives--impacts that had not been identified in the 2008 and 2010 Program EIRs. These impacts would not have been identified absent Commenters' litigation. After a review of these newly identified impacts and new information made available since the certification of the 2010 Revised Final Program EIR ("RFPEIR"), it is clear to Commenters that the California High-Speed Rail Authority is obligated under CEQA to study an Altamont Corridor Rail Project San Francisco/San Jose alternative that has not previously been studied, because it would avoid the major impacts of the other network alternatives. The results of that study will then need to be recirculated in a newly revised draft PEIR.

A. Impact Analyses

Noise and Vibration

The screening distance used in the noise analysis is not the screening distance required by the FTA Guidance manual: "375 feet from **track centerline**." (p. 2-2, emphasis added.) The analysis uses a screening distance "measured from the **centerline of the rail corridor**." (p. 2-4, emphasis added.) The analysis should have used a screening distance of 375 feet from the outer track centerline, not the corridor centerline. A correct application of screening distance would study the impacts on the narrow linear strip

---

[1] All page references are to the PRDPEIR unless otherwise noted.

adjacent to the area studied. The conclusion on page 2-5 that “the limited expansion of the existing Caltrain rail corridor has little to no effect on the number of properties captured in the screening analysis or to the noise and vibration effects to properties just outside the right-of-way” is thus both conclusory and inadequate. It does not establish that the impact metric, population per mile (Table 2-1, p. 2-2), for this narrow strip is consistent with the adjacent area that was studied. The calculated noise and vibration differences of 0.5 dBA and 2.4 Vdb, respectively (p. 2-5), are unsupported without the inclusion of the underlying technical work. The PRDPEIR had no technical appendices.

Monterey Highway

As a result of Commenters’ litigation, a map is offered showing the locations of lane reductions and right-of-way shifting on Monterey Highway. (Figure 2-2.) Its absence in the 2010 Revised Final Program EIR/EIS (RFPEIR) was one of the reasons that document failed as a full disclosure document for the project. This map is still inadequate, however, as it does not depict the location of the UPRR tracks or provide arrows indicating the direction of the shift.

The litigation also resulted in the disclosure of detailed traffic congestion maps (Figures 3-2 through 3-5.) They indicate that narrowing Monterey Highway will make a highly congested region even more congested. However, by limiting the metric to the unnecessarily broad “LOS E or worse,” the maps and analysis fail to address what is perhaps the most important question to the public: will the road network descend into gridlock, experiencing LOS F as a result of the roadway narrowing? The text hints at the answer, but fails to be definitive: “If the peak hour of travel demand is fully occupied, then travelers then shift their time of travel to shoulder hours as a function of time and space.” (p. 3-16.) The public needs to know if this project will create more LOS F, which would increase travel times, and make traveling at peak hour even more onerous.

Peninsula Lane Closures

The analysis of the impact of lane reductions omits the critical information of what capacity would remain after the reductions. (p. 3-6.) It is unclear from the text as to whether the analysis in Tables 3-1a and 3-1b represents the cumulative impact of all the lane reductions, or the impact of each reduction studied separately. It is also unclear from the text whether enough intersections were studied to fully capture the cumulative impacts of traffic diverted onto other local roads. (see footnote 7, p. 3-6.) Commenters’ litigation demonstrated this to have been a problem with the previous analysis of the Monterey Highway lane reductions. Also, it is unclear from the text what the cumulative impact would be on a motorist going through more than one impacted intersection. Detailed mapping of the lane reduction vicinities, intersection labeling, and the study of intersections much further away from the roads in question are all necessary to establish the scale of the areas impacted.

To be consistent with the CEQA Significance Criteria identified on page 3.1-3 of the 2008 FPEIR, the analysis needs to evaluate whether the increase in LOS for some of the intersections (e.g., Page Mill Rd./El Camino Real, p. 3-10) exceeds the LOS standard established by the respective county congestion management agencies. The

FEIR must do this analysis, or identify each intersection projected to have an higher LOS designation as a result of lane closures as a significant impact. Unless this is done, the analysis will be inadequate under CEQA.

The lane closure analysis produced bizarre and counterintuitive results: some lane closures improved traffic by a whole LOS level, and some intersection delays went to zero (e.g., Whipple Ave./Stafford St., p. 3-9.) In the absence of a detailed explanation as to how this is even possible, these data must be considered invalid as substantial evidence.

The proposed mitigations for the lane closure impacts include the generic suggestion of the adjustment of vertical alignments. Because specific relevant information was developed in the project level environmental review, a list of generic mitigations is not adequate. The proposed mitigations need to be screened for feasibility, based on the existing feasibility analyses contained in documents such as the August 2010 Supplemental Alternatives Analysis Report (see e.g., SARA 413 & 417).

Construction Impacts

It appears that the new Section C, focused on Monterey Highway (p. 4-4), was initially written with the intent of supplementing the 2008 FPEIR. A later decision to delete the entire Section C (p. 4-5) failed to fully coordinate the texts. Some of the typical generic impacts (e.g., handling of waste pavement) were left out of the new Section C.

B. New Information and Changed Conditions

Ridership Peer Review Group Reports

Sections 4.3, 4.4, and 4.5 of the July 2011 Independent Peer Review Final Report of the California High-Speed Rail Ridership and Revenue Forecasting Process confirm the criticisms of the ridership model that were raised in Commenters' letters on the RFPEIR. (attachment 1.) The August 2011 Peer Review Final Report (attachment 2) states on page 6 that "We continue to believe that a better solution would have been to fully re-estimate the model in ways described in our first report." On page 7, the report states "That said, we still believe that every effort should be made to eliminate the use of such a large set of constants in future versions of the model. They represent current travel patterns that may not hold true under future conditions." It appears that the Peer Review Group grudgingly accepted the explanations and conclusions offered by Cambridge Systematics, with obvious misgivings. This doesn't change the opinion of the Institute for Transportation Studies that the model's results are unreliable for public investment purposes. (see *infra.*)

Project Section Profile Variations

As demonstrated in the August 2010 Supplemental Alternatives Analysis Report (e.g., SARA 413 & 417), for some subsections of the Peninsula portion of the project, no vertical alternatives other than aerial viaduct appear feasible. If it is known that no other way to build a subsection is possible, the impacts of that vertical alignment need to be studied at the program level. The Authority appears to argue that the SAA report is only preliminary. If so, what additional studies are needed to solidify the analysis and clarify whether other vertical alignments are feasible? Why can't such studies be done now? Deferring such analysis to the project level deprives the program level selection of a preferred alternative of vital impact information. This is why it is untrue that "[t]his type of design detail [horizontal placement and profile variations] is appropriately considered in second-tier, project-level environmental documents because it does **not prevent** adequate identification of the impacts of the programmatic decision at hand." (p. 5-1, emphasis added.) It is equally untrue that "[n]o decision will be made at the program level regarding how to accomplish grade separations or whether to close certain roads." (p. 5-9.) One might argue that an infeasibility determination is not the same as a "decision," but that would be semantics--a distinction without a difference.

Altamont Corridor Rail Project

The conclusion that "the information related to the Altamont Corridor Rail Project does not necessitate further revision of the Program EIR" (p. 5-3) is deeply flawed. In fact, the 2011 Altamont Corridor Rail Project's Preliminary Alternatives Analysis shows that an Altamont Corridor Rail Project route (with appropriate adjustments) would be far more consistent with the project's adopted objectives listed in Table 6-1 (p. 6-5) than the PRDPEIR's Preferred Alternative.

The compilation of public input on the selection of the preferred alternative (starting on p. 6-6) depicts a highly controversial decision--one for which there is no public consensus. A careful analysis of the public input yields four major environmental objections to the various Network Alternatives: 1). impacts on the Don Edwards Wildlife Refuge; 2). impacts on the Grasslands Ecological Area; 3). impacts on Peninsula communities; 4). sprawl inducement.

The 2011 Altamont Corridor Rail Project Preliminary Alternatives Analysis ("PAA") demonstrates that feasible Altamont alternatives exist that avoid each of these impacts, when combined with a blended approach (see discussion, *infra*) that would eliminate the four-track cross-section throughout the Caltrain Corridor. Westbound Altamont trains would reverse direction while loading in the San Jose Terminus, and head to San Francisco on the Caltrain Corridor. (While this extension of service to San Francisco would represent an expansion of the Altamont Corridor Rail Project operational plan, the additional rail infrastructure would be limited to the blended approach) already being considered for the Caltrain Corridor.

The Altamont Corridor Rail Project alternatives that were recommended to be carried forward into the EIR/EIS process met all the following criteria:

- Alternative meets the project goals and objectives and project purpose and need in providing an improved and competitive regional intercity and commuter passenger rail service that maximizes intermodal connections between the Northern San Joaquin Valley and Bay Area and that complements the high speed train system.

- Alternative has no environmental or engineering issues that would make approvals infeasible.
- Alternative is feasible or practical to construct.
- Alternative reduces or avoids adverse environmental impacts. (PAA, p. 2-7)

Ms. Alexis's comment letter (RFPEIR, p. 15-42) points out how the ridership model projects that the Pacheco route gains 13.9 million riders when a San Francisco destination is added to a San Jose-only network alternative. It would then be entirely logical to add that same number of riders to the 94.6 million riders projected for an Altamont route with a San Jose terminus, to create a 108.5 million rider estimate for an Altamont Corridor Rail Project San Francisco/San Jose alternative. This calculation shows an Altamont Corridor Rail Project San Francisco/San Jose alternative exceeding the Preferred Alternative by 14.6 million annual riders, a 15.5% increase in ridership. This analysis remains uncontroverted, as the Authority did not honor Ms. Alexis' request to run the model with this alternative.

This increase in ridership will have a significant positive impact on HST revenues, as the Bay Area's boardings are estimated to make up 35% of the system's 2030 boardings for a San Jose-San Fernando Bay to Basin Scenario. (California High-Speed Rail 2012 Business Plan, Ridership and Revenue Forecasting, draft technical memorandum,Table 5.14.) The outstanding performance of this alternative stands in sharp contrast to one of the PRDPEIR's key conclusions "that both Pacheco Pass and Altamont Pass alternatives have high ridership potential and that ridership and revenue do not differentiate between these alternatives." (p. 6-17.)

By bringing all trains to San Jose, this Altamont Corridor Rail Project San Francisco/San Jose alternative avoids the criticism that "the most promising Altamont Pass alternatives would split HST services (express, suburban express, skip-stop, local, regional) between two branch lines to serve San Jose and either San Francisco or Oakland--reducing total capacity of the system to these markets." (p. 6-21.)

"The preliminary AA report evaluation confirms that a regional and inter-city commuter rail route is feasible for travel through the Altamont Corridor." (*Id.*, p. 5-9.) The Alameda Corridor will be able to support HST equipment:

> In addition, once improved to be fully grade-separated and electrified, with appropriate signaling and train control systems, the Altamont Corridor could support operation of California HST System trains and lightweight multiple-unit passenger equipment compatible with those trains. As such, the Altamont Corridor could allow selected California HST

> System trains to serve regional stops within the Altamont Corridor and to allow regional trains operating within the Altamont Corridor to reach additional destinations within the California HST System (e.g., Sacramento or Merced). (*Id.*, p. 2-3.)

The question then becomes, could the Altamont Corridor Rail Project be analyzed as an HSR network alternative? The PRDPEIR, without foundation, says no. It characterizes the Altamont Corridor Rail Project as "a substantially slower commuter/intercity rail service that does not meet the design requirements for a high-speed train network alternative." (p. 6-18.) Clearly, that condition resulted from the design brief given to the project team. There is no evidence in previous FPEIRs that there are any speed-limiting factors specific to the Altamont Corridor. On the contrary, the Altamont Corridor Rail Project "is being designed to 150 mph (rural) speeds." (*Id.*, p. 3-36.) Although the route will "have an average speed of 70- to 90- mph (including stops)" (*Id.*, p. 2-7), there is not enough information available to the public to be able to estimate the travel time involved in an express HST trip from Los Angeles to San Francisco on any of the alignment alternatives for this route. A study of this alternative is needed to prepare a proper travel time estimate.

The Network Alternatives report (using routes that are allegedly different from the Altamont Corridor Rail Project alignment alternatives) showed an LA-SJ time of 2:19 for an Altamont San Jose Terminus alternative (FPEIR, p. 7-18), which is ten minutes longer than the Pacheco LA-SJ time. (*Id.*, p. 7-48.) If the Altamont Corridor Rail Project were able to attain the express speeds of the Altamont network alternatives, that would result in an LA-SF time of 2:48, ten minutes longer than the Pacheco LA-SF time of 2:38. (*Id.*) There is not enough information available to the public to be able to compare the operational speeds of the network alternatives and the Altamont Corridor Rail Project alignment alternatives. Because of the alternatives' potential to greatly reduce the project's environmental impacts, careful study of the potential to increase operational speeds is needed.

To help meet the Proposition 1A requirement of a 2:40 LA-SF trip time, a wye from either of alternatives EB-4 or EB-6 could be installed near Santa Clara to allow San Francisco express trains to turn north there. (See map, PAA, p. 3-16.) This would save the several minutes the short trip to San Jose would take, along with its respective dwell and turnaround times. If the travel time estimate was still more than 2:40, a speed optimization effort should be made, to see where higher express speeds can be achieved.

The key difference between the Altamont Pass Network Alternatives that were previously studied and the Altamont Corridor Rail Project alignment alternatives is the avoidance of the Don Edwards Wildlife Refuge. In addition, it is Commenters' understanding that the Altamont Corridor Rail Project alternatives were designed to avoid the riparian and property impacts cited in the FPEIR at pp. 7-19 & -20 in the Niles

Canyon/Sunol Valley. Before criticizing these alternatives for impacts they don't have[2], a detailed study of the route design in the Niles Canyon/Sunol Valley area is needed.

With two lawsuits directly challenging the Authority's failure to adequately plan the Pacheco route in light of the UPRR's refusal to share its right-of-way, it is bizarre to read that "In addition, UPRR's position denying use of its rights-of-way for HST tracks presents a greater implementation challenge for the Altamont Pass network alternatives than for the Pacheco Pass Network Alternative serving San Francisco via San Jose." (p. 6-18.) No evidence was offered to substantiate this assertion, nor were any citations to previous EIRs offered. This statement would appear to not apply to the alternatives being studied by the Altamont Corridor Rail Project, as the very first goal of the Project is to "[d]evelop a regional intercity and commuter passenger rail service in the Altamont Corridor linking the northern San Joaquin Valley with the Bay Area that provides dedicated trackage separate from existing lines shared with Class 1 freight operations where feasible." (2011 Altamont Corridor Rail Project Preliminary Alternatives Analysis, p. 2-1.) At a minimum, the Setec Alternative, proposed by Commenters, captured in part by Altamont Corridor Rail Project alternatives EBWS-1, TV-4, and ALT-2, was professionally designed to avoid UPRR rights-of-way.

An Altamont Corridor Rail Project route would also eliminate the ten new significant and unavoidable impacts identified in this PRDPEIR, each which was Pacheco-related. Because such a route, in combination with the blended system approach, would eliminate the most serious environmental impacts of any network alternative studied to date, it must be studied as an alternative, after which a further revised draft must be recirculated, prior to selecting a preferred alternative. That study would, of course, investigate whether an Altamont Corridor Rail Project can meet the HSR design requirements. Because the study will mostly involve compiling and analyzing already existing information, it should not be onerous or time-consuming.

Because the CHSRA's Chair is a former BART director, it might now be feasible for the Authority to negotiate with BART to take over its Dublin line and regauge it for HSR and HSR-compatible regional service. (See Commenters' scoping comments for the Altamont Corridor Rail Project, attachment 3.) That would greatly reduce the environmental and community impacts of building new transportation infrastructure in the Tri-Valley, while better connecting the Valley with San Joaquin County, where many of its employees live. Livermore would receive an excellent rail connection, and avoid the uncertainty of waiting for the funding of an eventual BART extension. If such a route were implemented, the impacts would be strikingly lower, invalidating the assertion that "[t]he Pacheco Pass Network Alternative serving San Francisco via San Jose is least disruptive to communities because it is designed to use existing, publicly owned rail and

---

[2] The RFPEIR criticized Commenters' Setec Alternative as appearing to have the same impacts to high value aquatic resources and threatened and endangered species as the FPEIR's SR-84/South of Livermore alternative (RFPEIR, p. 15-208 - 209), despite the statement within the Setec report that "[t]his new proposed Altamont alternative entirely avoids Niles Canyon and sensitive Sunol Creek areas." (RFPEIR, p. 15-110.)

highway right-of-way as a method of minimizing environmental and community impacts." (p. 6-22.) Such an alignment should be included when studying an Altamont Corridor Rail Project alternative.

The Draft Business Plan Proposes A New Project Alternative

The Draft Business Plan (released November 2011) introduces the key new concepts of a blended system and blended operations: "Blended services linking statewide high-speed rail service with regional and local transit systems will benefit travelers in the near term and provide the platform for continued improvement in rail transportation. Connectivity and mobility will improve significantly across the state by expanding the network of interconnected public transportation systems and can be expedited through early investments in the regional systems." (Draft Business Plan, p. 2-1.) "As further improvements are made, blended operations progress to the point where transfers would not be necessary, and passengers could have a "one-seat ride" on a train that is able to travel over both the high-speed line and upgraded regional rail lines." (*Id.*, p. 2-3.)

The Business Plan is explicit in identifying two pathways to implement the Phase 1 HST project:

> Step 4: San Francisco to Los Angeles/Anaheim (Phase 1)
>
> Completion of the Bay to Basin system leads to Phase 1, the connection between San Francisco and Los Angeles/ Anaheim. This 520-mile connection can be accomplished in two ways:
>
> • Through a coordinated "blended system" that uses upgraded commuter rail systems to connect the metropolitan areas with the inter-regional high-speed system, and
>
> • By expanding fully dedicated high-speed infrastructure to San Francisco and Los Angeles/Anaheim. (*Id.*, p. 2-17.)

Despite the Authority's recognition of the blended system as "an additional phasing option for the urbanized sections that have existing commuter rail corridors" (p. 5-4), the PRDPEIR fails to treat the concept as a Project Alternative. The entire impact analysis is limited to this cursory statement: "...the blended system concept does not appear to distinguish among network alternatives." Failure to treat the blended system under *Laurel Heights II* as significant new information proposing a lower-impact project makes this PRDPEIR inadequate under CEQA. This treatment is inconsistent with the Draft Business Plan, which clearly contemplates a different approach to environmental review than was taken both in the current PRDPEIR and in the previous RFPEIR:

> This infrastructure will require some upgrades to accommodate high-speed operations and added capacity with speeds through urban areas of up to 125 miles per hour. However, such improvements can likely be accomplished while staying substantially within the existing rights-of-way,

> resulting in substantially reduced impacts to the communities along the corridor.
>
> Based on this approach, **initial environmental reviews can focus primarily on the impacts of limited upgrades to the existing facilities, thus avoiding the mitigation requirements associated with an expanded dedicated high-speed system.** Sharing existing commuter rail facilities in urban areas will not only materially reduce the environmental impacts of the planned full system, but will result in substantial cost savings as well. Recognizing that the ultimate goal for the voter-approved program is fully operational high-speed rail service between the two end points included as Phase 1 of the system, **any expansion in the corridor to add additional capacity, accommodate dedicated tracks, significant structure or tunnel work, and additional right-of-way beyond what is defined in the blended system would have to be revisited through future environmental reviews**. Investigations show that the coordinated blended solutions as envisioned can accommodate service levels for many years into the future. (*Id.*, p. 2-18, emphasis added.)

This divergence in approach is captured in the proposal by Senator Simitian, Congresswoman Eshoo and Assemblyman Gordon (the SEG Plan, attachment 4), which should have been evaluated by this PRDPEIR as new information suggesting a lower-impact project alternative, but was not. That plan conveys grave concerns about the long-term impacts on the Peninsula of a certified EIR for the full buildout of the HST system, since such a system cannot be built within a reasonable period of time, and because such a high-capacity system might be unnecessary for the level of ridership expected. The SEG Plan noted the lower impacts of a blended system, and urged that the environmental review of the phased implementation of the full buildout of the system be stopped.

The on-going concern about the reliability of the RFPEIR's ridership numbers, as expressed by the Institute for Transportation Studies (SAR 9003), makes it unclear as to whether a full-build system is even needed in the foreseeable future. "These [very large error] bounds, which were not quantified by CS, may be large enough to include the possibility that the California HSR may achieve healthy profits and the possibility that it may incur significant revenue shortfalls." (SAR 9006.) It is clear that the blended system approach offers a much lower cost (p. 5-4), lower impact (p. 5-9) pathway forward--one that greatly reduces the project's risk. From the standpoint of the public funds at risk, it would be highly irresponsible to not study a blended system alternative.

Commenters assert that the blended system, as described in the SEG Plan, and in accordance with the language of the Draft Business Plan, must be studied as a new alternative in a recirculation of the PRDPEIR. A blended system would mean an earlier project delivery, substantially lower costs and lower environmental impacts. It is conceptually distinct from a phased implementation of the full buildout project, in that urban areas would be excepted from the HST Engineering Criteria (FPEIR, p. 2-8) which require a fully grade-separated access-controlled right-of-way. This would be entirely consistent, however, with the shared-use corridor general criteria (FPEIR, p. 2-9), the project's Purpose (FPEIR, p. 1-4), as well as its Description:

> A fully grade-separated, access-controlled right-of-way would be constructed, except where the system would be able to share tracks at lower speeds with other compatible passenger rail services. Shared-track operations would use existing rail infrastructure in areas where construction of new separate HST facilities would not be feasible. Although shared service would reduce the flexibility and capacity of HST service because of the need to coordinate schedules, it would also result in fewer environmental impacts and a lower construction cost. (FPEIR, p. 2-2.)

Rather than merely delaying the impacts of a phased approach to building a four-track alignment (p. 5-9), a blended approach would eliminate those impacts for the foreseeable future. A 2011 Caltrain study concluded that a blended system is potentially feasible. (attachments 5 & 6.) The implementation of quiet zones should be added to the study of a blended system alternative, resulting in capturing most of the noise reduction benefits of a full-build alternative.

There is no analysis of the impact of blended operations on ridership, despite the obvious impact of transfers on waiting time and impedance. There is no analysis of the impact of either blended operations or phasing on the economic feasibility of the project. An EIR is required to consider and study a reasonable range of feasible alternatives, particularly alternatives that might significantly reduce project impacts. Given the much lower environmental impact of an Altamont Corridor Rail Project alternative, it is imperative that its ridership be assessed to determine if it constitutes an economically feasible alternative that should be considered and studied in depth, as the project cannot access Proposition 1A Bond funds unless it is projected to generate an operating profit.

<u>Deferred Ridership Impact Analysis</u>

The Court has already ruled that deferral of the study of impacts resulting from program-level decisions is not permitted under CEQA. The PRDPEIR impermissibly defers a full analysis of the phased implementation proposed in the Draft Business Plan until the project-level review:

> "The longer duration of construction and also lower ridership forecasts may result in differences in the environmental impacts and benefits as described in the 2008 Final Program

> EIR, the 2010 Revised Final Program EIR, and in this document. This discussion provides a qualitative, general assessment of these differences. The environmental consequences of phased implementation would be explored in more detail as part of second-tier, project level EIRs." (p. 5-4.)

The PRDPEIR's impact analyses have not been redone using the conservative ridership estimates published in the Draft Business Plan. The impact assessments, including the benefit assessments, may thus be quite overstated. While this does not necessarily violate CEQA, it does raise questions as to whether the balance of costs and benefits for a Phased Implementation approach fundamentally alters the desirability of this publicly funded project. This question must be answered at the program level.

Mitigation of Temporary Northern Altamont Terminus Station

The mitigations proposed for newly identified significant impacts on a temporary northern terminus for the Altamont route may be inadequate for a Union City terminus. BART trains have a maximum length, based on the size of station platforms. It is not possible to simply add more train cars, as suggested on p. 5-8. It is also questionable as to whether the BART system is able run more frequent service, given the headway limitations of its existing automation system. Instead of Union City, a Bay to Basin Altamont route would need to go all the way to Santa Clara or San Jose, where it could connect with the more flexible Caltrain system. This would be preferable for the passengers, as the largest number of them are traveling to Silicon Valley, and especially North San Jose. (2011 Altamont Corridor Rail Project Preliminary Alternatives Analysis, p. 2-6).

Preferred Alternative

Especially if an Altamont Corridor Rail Project alternative is to be considered, the justification listed on p. 6-2 for choosing a Pacheco alignment can no longer be considered valid. One of the four stated criteria (Impacts on wetlands, waterbodies, and the environment) would clearly favor an Altamont Corridor Rail Project San Francisco/San Jose alternative, which wouldn't have any major wetlands or waterbody impacts, unlike Pacheco. One of the criteria (Best utilizes the Caltrain Corridor) would equally favor either alternative. One of the criteria (Political support) is not an environmental criterion, and is neither relevant nor appropriate for selecting a preferred alternative based on feasibility and environmental factors. Indeed, the new Chair of the Authority's Board of Directors has publicly admitted[3] that the Authority's earlier choice of the Pacheco alignment based on political criteria was ill-advised. And there is evidence in the record (RFPEIR, p. 15-42) that the final criterion--the best connection between Northern and Southern California--favors an Altamont Corridor Rail Project alternative, as it would likely have 15.5% more annual riders. (see discussion, *supra*.)

---

[3] Statement made by Mr. Dan Richard during a presentation at the January 2012 Planning and Conservation League Annual Symposium.

A more appropriate selection process for a preferred alternative would be to compare how the alternatives meet "[f]urther objectives [are] to provide interfaces between the HST system and major commercial airports, mass transit, and the highway network and to relieve capacity constraints of the existing transportation system in a manner sensitive to and protective of the Bay Area to Central Valley region's and California's unique natural resources." (p. 6-11.) An Altamont Corridor Rail Project San Francisco/San Jose alternative would have the following advantages:

1. It would pass through North San Jose, close enough for a shuttle to SJO.
2. It would pass near SFO, where it might be possible to connect it to the AirTrain.
3. It would offer a less costly and easier future connection to OAK and Oakland.
4. It relieves major interregional capacity constraints on I-80 and I-580.
5. It avoids the environmental impacts identified for other alternatives.
6. It would have significantly higher ridership and revenue.
7. It would serve both statewide and regional travel markets with one rail investment.
8. It could avoid the cost of a BART extension to Livermore.

PRDPEIR Section 6.2 fails to mention that each of the clarified and revised impacts has been identified not only as significant but also as unavoidable. The absence of any discussion of this very important change since the 2010 RFPEIR nullifies the statement that "These clarified and additional impacts along the Monterey Highway and in certain portions of the San Francisco Peninsula have been carefully considered in reevaluating the preferred alternative recommendation." (p. 6-3.) The selection of the Preferred Alternative must be conducted in the explicit context of the newly identified unavoidable impacts.

<u>Conclusion</u>

The PRDPEIR improperly fails to take into account significant new information that shows that there exists a previously-unstudied feasible alternative, using the Altamont Rail Corridor alignment, that would significantly reduce the impacts associated with the previously-chosen Pacheco Pass alignment. Under *Laurel Heights II*, CHSRA must study the Altamont Corridor Rail Project San Francisco/San Jose alternative and recirculate. CEQA requires the lead agency to select the project alternative with the fewest environmental impacts.

Commenters would like to see a successful HSR system in operation. They are convinced that the blended approach, coupled with an Altamont Corridor Rail Project San Francisco/San Jose alternative, would result in higher ridership, higher community support, lower cost, and faster delivery than the PRDPEIR's Preferred Alternative. They appreciate this opportunity to comment on this important document.

Sincerely,

David Schonbrunn, President
Transportation Solutions Defense and Education Fund

Bruce Reznik, Executive Director
Planning and Conservation League

James R. Janz, President
Community Coalition on High-Speed Rail

Richard Tolmach, President
California Rail Foundation

cc: Stuart Flashman, Esq.

Attachments
Peer Review Group July Report
Peer Review Group August Report
Commenters' Scoping Comments
SEG Plan
Caltrain Capacity Analysis Update
Caltrain Draft Blended Operations Analysis

Attachment 1

FINAL REPORT

Independent Peer Review of the California High-Speed Rail Ridership and Revenue Forecasting Process

---

Findings and Recommendations from the January-March, 2011 Review Period

July 22, 2011

The California High Speed Rail Authority (HSRA) convened an independent peer review of the ridership and revenue forecasting process and outcomes. Reporting to the Executive Director, the Panel is charged with providing a comprehensive in-depth review of the models used to estimate ridership and revenue and the forecasts derived from them. The Panel held its first meeting at the Authority offices in Sacramento on Monday and Tuesday, January 10-11, 2011. This report summarizes the key issues, findings, and recommendations of the Panel.

The Panel consists of five members:

- Frank Koppelman, PhD, Professor Emeritus of Civil Engineering, Northwestern University (chair)
- Kay W. Axhausen, Dr.Ing., Professor, Institute for Transport Planning and Systems, ETH Zurich (Swiss Federal Institute of Technology Zurich)
- Billy Charlton, San Francisco County Transportation Authority
- Eric Miller, PhD, Professor, Department of Civil Engineering and Director, Cities Centre, University of Toronto
- Kenneth A. Small, PhD., Professor Emeritus, Department of Economics, University of California-Irvine

Rick Donnelly, PhD, AICP of Parsons Brinckerhoff served as facilitator and recorder of the meeting. In this capacity he serves at the convenience of the chair rather than as member of the project management consultant team.

The Panel has based their comments and recommendations upon a review of a large number of reports and information generated by Cambridge Systematics, Inc. (CS), the developers of the model, as well as resulting forecasts developed for the Authority. These reports are identified in the Appendix to this report. Several panelists also reviewed the recent critique of the model and forecasts by the Institute of Transportation Studies (Brownstone et al. 2010) and subsequent correspondence about it. That critique provided additional insight into the forecasts and the controversies surrounding them, but did not frame the Panel's deliberations.

The views expressed in this report are consensus findings reached through a high degree of agreement and common thinking among the panelists.

Overall the Panel was impressed with many aspects of the work on ridership and revenue forecasting completed to date on the project. The approach undertaken by CS was ambitious, it represented a significant improvement in practice in several respects (for example, through the development and linkage of a complex set of advanced models), and it demonstrated commendable openness. However, there are important technical deficiencies in the model and the documentation thereof. The purpose of this report is to provide a critical review of the models and associated forecasts, focusing on those aspects that are questionable or deserving of more work.

1 Charge to the Panel

Roelof van Ark, Executive Director of the Authority, opened the meeting by welcoming the Panel, introducing them to the project, and outlining his charge to its members. A relative newcomer to the project, his near-term priority is to strengthen the organization with top-notch, committed professionals. He is also committed to increased accountability and transparency in their work, including all aspects of the ridership and revenue forecasting. His goal is to address differences in a professional manner, using open and honest dialogue. This is one of four independent review panels serving the Authority. Like the others, this Panel will report directly to the Executive Director.

The Panel's work to date has looked at the system as a whole. Ultimately the Panel's reviews are expected to assist the Authority's need for technical support in completing an update to the business plan, and investment and risk analyses. It is the Panel's understanding that the model was not designed to support the analysis of the Minimal Operable Section (MOS) and associated detailed analyses. Mr. van Ark noted the controversy to date with the forecasts and underlying models, which in part motivated the formation of this Panel. However, the purpose of this Panel is not to further debate those controversies. Rather, the Authority is highly interested in the advice of this Panel about where to go next in their forecasting efforts, based upon the progress and capabilities to date. In addition to conducting more detailed analyses, the Authority requires the capability to assess public-private financing schemes and station area developments. It also desires to not waste taxpayer money on unnecessary and unproductive modeling and data collection.

2 Understanding of the current forecasting process

CS was hired by the Metropolitan Transportation Commission (MTC) in 2004 to develop a statewide multi-modal travel demand model to help evaluate alignments for segments of the high-speed rail (HSR) network. The model relied on trip tables and adapted mode choice models of existing travel demand models to forecast intra-regional travel in the two largest metropolitan areas to be served by HSR – namely, San Francisco (the MTC model) and Los Angeles (the SCAG model). In addition, a population-based estimate of intra-regional travel was used for forecasting HSR trips within San Diego. The intra-regional mode choice models are traditional nested logit models, with the top-level choice being that between motorized and non-motorized modes. HSR was added to the transit nest in each instance.

For inter-regional travel, a four step sequential model was developed that included trip frequency, destination choice, mode choice, and assignment components. The inter-regional mode choice model included a primary mode choice (car, rail, HSR, or air) and then a choice of access/egress modes. Trips by mode from the intra-regional and inter-regional models, along with intra-regional auto trips estimated from the Caltrans Statewide model, were aggregated prior to the assignment step.

The data used to estimate the inter-regional models was compiled from several sources. The main source was a stated preference survey that was conducted at airports, rail stations and by telephone from August to November of 2005. On-board surveys were conducted on the Altamont Commuter Express and the Metrolink trains in October and November of 2005. Telephone surveys of Amtrak passengers from the Capitol Corridor, the Pacific Sunliner, and the San Joaquin services were conducted during the same time frame. Air passenger surveys were done at six California airports (Sacramento, San Jose, San Francisco, Fresno, Oakland and San Diego) between August and November 2005. Unfortunately, surveying was not allowed at airports in the Los Angeles area. An effort was made to represent travel in and out of the LA area by over-sampling flights to these airports from surveyed airports. Finally, a random-digit-dialing telephone survey was conducted to capture auto trips in the San Diego, Los Angeles, Bakersfield, Tulare County, Fresno, Merced, San Francisco Bay Area, Modesto/Stockton, and Sacramento regions in August 2005. Overall, surveys from 3,172 respondents were collected during the study (1,234 air, 249 rail on-board, 181 rail telephone, and 1,508 auto).

The other primary data source for model development was the Caltrans Household Survey, conducted in 2000-2001. This was an activity-based survey that collected information from 17,040 households in all 58 counties in California. In addition, several surveys were used for model calibration (i.e., adjustment of various alternative-specific coefficients) to match known aggregate properties of travel patterns. For validation, checks of model predictions against additional known aggregate properties of travel patterns were evaluated. The main data sources for calibration and validation of the inter-regional models were the 1995 American Travel Survey, 2000 Census Transportation Planning Package, USDOT 10% air passenger ticket sample data for 2000, rail passenger data from California rail operators, Caltrans Household Survey, and traffic counts obtained from the Caltrans traffic count database. The intra-regional models were not calibrated and validated by CSI because they were assumed to have been calibrated and validated by the local agencies. The 2000 highway assignment validation results were summarized by facility type, area type, region and gateway. All highway summaries were reported to be within three percent of observed data.

The inter-regional model was finalized in February 2007. In 2008, the SCAG intra-regional models were refined, and in 2010 some changes were made to fix anomalies in the MTC models. During the same time, detailed travel forecasts under a no-build scenario (i.e., without HSR) were developed for 2030 using the model, and 2035 forecasts were developed by factoring up the 2030 results.

In addition, the model was used to analyze four main sets of scenarios including an HSR system as currently planned by the HSRA, either for Phase I or for the full system:

- Baseline assumptions plus various air and HSR fare structures and auto-operating costs; these resulted in figures used in the 2008 business plan;
- One of the fare structures analyzed in the initial set of scenarios (set 1 above) plus an 8% assumed increase in air and auto costs and a revised service plan;
- Assumptions of the second set of scenarios, but with an increase in the assumed parking costs at HSR stations;
- Assumptions of the third set of scenarios, but using the revised rather than original SCAG and MTC intra-regional models. This fourth set of assumptions was used in the EIR/EIS overall forecast of riders and revenue.

Overall the model responded reasonably, with ridership and revenue being affected by changes in fare price, parking costs and levels of service. All of the original model development and some of its early application were performed under the MTC contract, which was completed in September 2008. A small amount of model application work for the HSRA, contracted by the Parsons Transportation Group, was also completed in parallel with the MTC contract. CSI has served the HSRA since September 2008 through the program management contract held by PB Americas, Inc. During this time some model refinement was carried out, as well as further development and interpretation of forecasts.

3 Incomplete documentation

The Panel found several instances of incomplete or outdated information in the documentation, or could not locate such if it did exist. Two major areas were identified as key omissions that should be addressed quickly. It is expected that these information are readily available to the model developers, or can be quickly summarized from their work completed to date.

3.1 Inputs to model application

The assumptions about, data development, and summaries of several key inputs to the model should be documented. We could find little or no discussion of these inputs and their underlying assumptions:

- Fare levels or structure
- Levels of highway and airport congestion
- Levels of service (train frequency)
- Levels of ridership and service on competing intercity bus services
- Fuel prices (sensitivity tests on auto operating cost assumptions are advised)
- Induced effects
- Competitive responses from other modes (sensitivity tests of both reduced fares and varied levels of service). These include especially the airline industry, but also "curbside" express intercity bus services that have grown rapidly in the last decade in the Eastern and Midwestern United States.
- Socioeconomic and land use forecast inputs

The level of service topic is particularly important to tie to operating and business assumptions made by the Authority, and should be attributed as such. For example, the frequencies in San Francisco (8 million residents) in full build-out of 12 trains per hour are comparable to Tokyo, with 30 million residents). The Panel questioned whether such assumptions are realistic, and what the effect of lower levels of service (decreased frequency) on ridership would be. These issues should be clearly addressed in the documentation.

3.2 Validation and documentation

There appeared to be considerable confusion between estimation, calibration, and validation in the documentation. While this is not unique to these reports, we feel that the following definitions are widely accepted and should be used in both the revision of current documentation and in all future work:

- *Model estimation* is the inference of model form and parameters from survey data and the related statistical testing of those parameters as well as of alternative model formulations (i.e. specifications).
- *Model calibration* is the adjustment of the completed model system, mainly through changes in alternative-specific constants, so that its predictions match specific targets generated from observed data (including the data used in estimation).
- *Model validation* is the testing, and perhaps further adjustment, of the model system using data other than (and usually newer than) the data from which it was estimated.

There is no evidence that model validation defined in this manner was carried out. Rather, elements of the model were estimated using travel survey data collected in 2005. The resulting model was calibrated to observed data from the year 2000. Moreover, the targets used in calibration appear to reflect essentially the same information as that used in estimation.

A more thorough descriptive analysis and interpretation of the data used to build the model would have been helpful for our analyses. Some of the analyses needed before the Panel can complete our review of the current model include:

For the calibration year only

- Maps, graphs, and tabular summaries of statistical measures of the deviation between assignment results and observed modal flows (road, air, rail)
- Tabular summaries of comparison of assigned versus observed screen line volumes

For both calibration and forecast years

- Overall mode shares by origin-destination distance
- Mode shares by income
- Tables and maps of long distance trips per day by person type (income, region of residence, etc.) and trip purpose
- Summary of income elasticities by mode

For forecast years only

- Mode shares by network distance from HSR stations (distinguished among HSR stations with different access modes)
- Tables of own- and cross-elasticities by mode for the time and cost variables across the state, by origin-destination distance or inter-regional pairs, by income group and distance band from the HSR stations
- A brief assessment of access and egress mode shares (and parking demand in particular) detailed appropriately by HSR station
- Analysis of the effects on forecasts of expert judgments that were made to override estimated model coefficients

As a further check on model validity, it would be useful to compare key results with what has been observed in other systems, as discussed earlier. Such external comparisons have the advantage of implicitly incorporating various practical considerations that cannot easily be included in a mathematical model. These include operational problems, cutbacks due to inadequate funding, unanticipated responses of competitive suppliers, and feedback effects from a project on local employment. Flyvbjerg et al. (2007) suggest a somewhat formal process for such comparisons called reference class forecasting that is commended for consideration. A similar but less formal approach would be to identify a few relevant case studies for comparison. In either case, when results differ, much can be learned from examining the reasons. The hope here is to avoid the types of systematic over-estimates of demand that Flyvbjerg et al. identified in other large rail projects around the world.

Yet another check would be to compare the assumed characteristics of air service with what has developed in other places when HSR service is introduced. The model assumes a rather passive response by air carriers, but the history of U.S. air deregulation suggests that air carriers in fact react strongly to changes in their competitive environment. Evidence from other places where HSR has been introduced, as well as from the extensive theoretical and empirical literature on the airline industry, will help assess the likelihood of drastic changes in air carrier pricing and service. Such changes might include price wars on the one hand or complete abandonment of the market by airlines on the other. Either outcome could have drastic impacts on HSR ridership and revenue. The research literature has begun to develop models specifically designed to analyze how the airline industry would respond to the introduction of HSR services (e.g., Adler et al. 2010).

4 Short term issues

The Panel has significant concerns about the model formulation, primarily with respect to specification that should have been addressed during previous work. Pending improvements to the model, we recommend that any use of the model include some steps to make the demand forecasts more conservative, especially in forecasts for financial (investment and risk) analysis.

4.1 Representation of distance in destination and mode choice models

The current model classifies travel further than 100 miles as long distance trips. This demarcation seems reasonable, especially given that a similar definition was used in the 1995 American Traveler Survey, which was an important source of such information at the time this model was developed. The choice of an ultimately arbitrary division of the travel market into two distance segments, however well justified, might lead to discontinuities between them. The CSI models report should show explicitly that this is not a problem. Otherwise, CSI should consider joint models in which distance is entered in a non-linear manner (e.g., a Box-Cox transformation) and as part of suitable interaction terms. Such non-linear formulations are moderately more difficult to estimate, but can be estimated using several off-the-shelf software packages and common languages including Biogeme, ALOGIT, and Gauss.

A second issue of concern to the Panel is the non-monotonic nature of the cubic functions of distance specified for some trip purposes. We recommend that a Box-Cox transform be adopted to ensure that the distance function is monotonic. This would reduce the number of estimated parameters by one, and it appears it would make only a small difference in goodness of fit based upon our inspection of the estimated curves.

4.2 Observed heterogeneity

Observed heterogeneity in the mode choice models was apparently not investigated with respect to trip-makers' preferences for specific modes or differential sensitivity to different level of service measures. These and other interaction terms that might normally be expected in such models are missing in this one. Interactions between socioeconomic variables (income, etc.) and time/cost variables should be included in the model. The effect of such variables is to account for heterogeneity in traveler response (i.e., for variation across the population of travelers in how various service characteristics are evaluated). Such heterogeneity has been found in virtually every study that has looked for it, and in some cases detailed results turn out quite different when it is included. The Panel found no evidence that these results are biased in aggregate or that any differences are in a particular direction as a consequence, but believes it is a relatively simple improvement that will make the model more reliable. This is also a near-term high priority item.

4.3 Inadequate exploration of level of service variables

The Panel found no evidence that alternative representations of level of service variables were investigated, which is important to obtaining a good behavioral representation and sensitivity to changes in service. Examples of such alternative specifications include:

- Replacing the simple headway variable by its inverse (frequency of service) or some other non-linear transformation;
- Dividing the cost variable by some function of income, in order to represent the well-established tendency of higher income travelers to exhibit less sensitivity to cost; and
- Dividing out-of-vehicle time by some function of overall travel distance, in order to represent the reduced importance of out-of-vehicle time with increasing trip length.

It is essential that the model be appropriately sensitive, as one of the chief causes of over-optimistic demand forecasts in other studies has been that financial constraints may lead to less frequent service or lower speeds than planned. At a minimum, this sensitivity analysis should include documenting the effect of varying levels of service on the resulting forecasts.

4.4 Inadequate justification of constraint on out-of-vehicle travel time

The Panel felt that the constraint imposed on out-of-vehicle travel time in the main mode choice model was unjustified. The rationale for asserting a substantially different value was understood to revolve around the difficulties of calibrating the final model, and the fact that the asserted value (1.0) is roughly consistent with assumptions that (a) out-of-vehicle time equals one-half the headway and (b) out-of-vehicle time is valued twice as much as in-vehicle time. The Panel feels that these two assumptions are valid only for urban trips with small headways, and thus do not justify changing an empirically estimated value – especially because the estimated value is consistent with other results for intercity markets where behavior is much different from an urban market. Specifically, Adler et al. (2005) found that headway for an intercity trip is valued at 0.2 to 0.25 as much as in-vehicle travel time; this result is further supported by unpublished values found by PB in their statewide modeling work. Furthermore, the Panel suspects that difficulties in calibration might have been influenced by under-specification of the choice models as discussed in section 2.3 above.

We want to highlight that the headway variable captures the impact of the schedule delay (the difference, early or late, between desired and scheduled departure time, and not of any initial waiting time at first boarding. The initial waiting time has been shown to be the choice of the traveler reflecting their risk preference with respect to access time, time needed at the station or the stop. If needed, the model should include a variable to capture the waiting times at any transfer, as these are outside of the control of the traveler.

4.5 Excessive use of alternative-specific constants

The destination and mode choice models at both the intra-regional and inter-regional levels have a surprisingly large number of constants. While difficult to independently assess, it would appear that these constants exerted a significant influence on the forecasts, which the Panel feels is an undesirable property of the model. We believe this may be a symptom of an under-specified or mis-specified model as discussed in the above sections (i.e., a model with an inadequate set of observable variables explaining behavior or with an important parameter constrained inappropriately). It is hoped that addressing the issues identified in previous sections will reduce the need for such constants.

5 Long term issues

Several important issues were identified that should be considered to enhance the improved model to provide the best possible estimates of HSR ridership. While not practical to address all of these issues immediately, the Panel believes that their consideration will measurably enhance the utility and credibility of the model and forecasts obtained using it. As per Section 4, pending improvements to the model, we recommend that any use of the model include some steps to make the demand forecasts more conservative, especially in forecasts for financial (investment and risk) analysis.

5.1 Model validation

Apparent omissions in model validation concerned the Panel. It was strongly felt that a number of checks on the reasonability and validity of the model should have been carried out and documented, to include:

- Comparisons to other observations and forecasts in California developed from data sets that are different from those used in this model (e.g., California statewide model, 2001 NHTS);
- Comparisons of forecasted ridership to actual ridership on HSR systems in other parts of the world;[1]
- Sensitivity testing of the importance of assumed HSR levels of service and of alternate assumptions about highway and airport congestion;
- Sensitivity testing of the effects of alternate levels of socioeconomic variables used in forecasting, using independent estimates of growth from sources such as Global Insight,

[1] It is recognized that such comparisons are difficult because no comparable service exists within the USA, and several important traveler and social differences exists between North Americas, Europeans, and Asians. However, it is felt that these differences should at least be tabulated and discussed.

the Federal Reserve Bank of San Francisco, Bureau of Business and Economic Research, and published U.S. Department of Commerce and Census trends;
- Sensitivity testing of assumptions about parking availability at planned HSR stations.

Some of these comparisons may of necessity be more qualitative than the more familiar statistical tests of model performance, but they are essential when modeling non-existent major new transportation modes or services like HSR.

5.2 Stated preference (SP) bias

Another major concern to the Panel is the potential influence of bias introduced by the use of stated preference (SP) survey data in model development. Respondents have been observed in many SP surveys to exhibit various systematic biases concerning their responses to hypothetical options. These biases depend greatly on the details of the survey, as well as the local environment of the respondents themselves. The research community has developed many guidelines to minimize such bias, and this needs to be fully discussed in the validation of the model. It is especially important in this case, because HSR mode share in the "main mode" choice model is determined solely by the SP responses. Thus, if respondents systematically overstate or understate their willingness to ride HSR (perhaps because they support it or oppose it as a concept) the resulting bias will be carried over directly into the HSR ridership forecasts.

We can suggest two ways to address SP bias:

- Examine other studies in the United States where there is more opportunity for internal validation though a combination of SP and revealed preference (RP) survey questions. Where HSR exists, it would be possible to question respondents about both their actual (RP) mode choices and their responses to hypothetical changes in the system (SP). Techniques are available to compare the two in order to illuminate systematic differences. This methodology is well developed in the research literature. Even where true HSR does not exist, a "near HSR" service – such as Amtrak's Acela service in the Northeast Corridor – would generate useful comparison data. The Panel recommends a search for existing combined RP/SP data sets. If found, an assessment of SP survey bias and a comparison of survey questions and methods with those used by CSI should be undertaken to learn as much as possible about whether such bias might affect the SP data used in the California HSR ridership forecasts. Even studies from abroad can be used for this purpose, despite their limitations for direct comparison of model results due to differences in urban development patterns, urban transit systems, and socio-demographics.
- It is possible to consider HSR as a drastic improvement to existing conventional rail service. California has two of the most well used conventional rail corridors in the United States (Los Angeles-San Diego and San Francisco-Sacramento). It is possible to perform a combined RP/SP survey in these corridors, where respondents are asked both about their use of existing conventional rail and about their hypothetical use of improved service, including both minor and major increases in speed. This will permit a direct investigation of SP bias in California data. Such an investigation is highly recommended as part of any enhancement of this model, as further elaborated in section 6 below.

6 Econometric issues

The survey designed and conducted for CSI included the use of Choice Based Sampling. That is, the sample was biased both for administrative purposes and to ensure that a minimum number of respondents were found to choose each of the major modes (both existing and proposed). The use of a choice based sample is known to bias estimation results unless the estimation procedure is modified to take account of this sampling. The method used by CSI, which was believed to be correct at the time of model estimation, has since been shown to be incorrect and a new procedure has been developed which is correct (Bierlaire et al. 2007). Future estimation work should take advantage of this new knowledge.

7 Data requirements for model enhancement

CSI has presented the Authority with a proposed work plan to continue the evolution of the forecasting process and the underlying models. The Panel focused primarily on the current models and forecasts in this first meeting, which precluded a careful and thorough review of this proposal. However, it was clear even from a cursory review that further data collection will be required for the evolution of the models, even if they are not made available for the re-estimation of the models implied above.

Two tasks – 16 and 17, presumably additions to previous work – are identified in the proposal. Task 16 includes plans for data collection to assist with updating the models, both to refine the existing model as well as support re-estimation of the enhanced model. The Panel supports this proposal. In fact, it is recommended that the data collected be expanded beyond that described in the proposal.

Several panelists advanced the notion that a combined RP/SP survey would be useful, especially if well designed to illuminate the SP response bias in the California context. It obviously cannot be measured for the HSR mode, as it does not presently exist, but would allow its measurement for other modes. Targeted sampling in heavily used conventional rail corridors in the state (i.e., San Diego-Los Angeles, San Francisco-Sacramento) is recommended as a means of conducting SP experiments in an environment as close to HSR as possible. This would allow the direct comparison of SP to RP coefficients, a key to quantifying the effect of respondent bias. Several successful protocols are available to help with design, such as the PAPI or CATI-KITE surveys (Frei et al. 2010).

In order to be useful for model estimation, and especially within the context of the recommendations contained herein, the RP data should include information about several aspects of the long distance trip, to include:

- Primary mode of transport
- Modes of access and egress
- Station choice
- Destination and group (party) size
- Trip frequency and primary purpose

The use of an eight-week retrospective survey of long distance travel is highly recommended. Such an approach will yield a substantially larger amount of data on such trips than the traditional 24 or 48-hour diaries typically used in household travel surveys.

The Panel has learned that plans for the design of a new statewide travel survey are underway, and perhaps complete. It is highly recommended that the Authority quickly determine the status of such efforts and opportunities for collaboration. The ability to share costs, eliminate duplication of effort, and ensure consistency with other California models should not be lost.

8 Conclusions

The current model system represents an ambitious step towards defining the best practice in North America, replacing ad hoc and closed proprietary models used in many previous HSR feasibility studies. In many ways the model is generally well founded and implemented. However, in order to have full confidence in it the issues identified in Section 4 must be addressed quickly. Moreover, the incomplete, unclear, or out-of-date elements of the documentation discussed in Section 3 must be completed as part of the short-term actions. Once these issues are addressed the Panel will be in a position to make a more definitive determination about the model and forecasts derived from it.

References

Adler, N., Pels, E. & Nash, C. (2010), "High-speed rail and air transport competition: Game engineering as tool for cost-benefit analysis", *Transportation Research Part B*, 44(7): 812-833.

Adler, T., Falzarano, S. & Spitz, G. (2005), "Modeling service trade-offs in air itinerary choices", *Transportation Research Record*, 1915, 20-26.

Bierlaire, M., Bolduc, D. & McFadden, D. (2008), "The estimation of generalized extreme value models from choice-based samples", *Transportation Research Part B*, 42(4), 381-394.

Brownstone, D., Hansen, M. & Madanat, S. (2010), "Review of Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study", Research Report UCB-ITS-RR-2010-1, Institute of Transportation Studies, University of California-Berkeley.

Flyvbjerg, B., Holm, M.K.S. & Buhl, S.L. (2006), "Inaccuracies in travel forecasts", *Transport Reviews*, 26(1), 1-24.

Frei, A., Kuhnimhof, T. & Axhausen, K.W. (2010), "Long distance travel in Europe today: experiences with a new survey," unpublished presentation at the 89th Annual Meeting of the Transportation Research Board, Washington, D.C., January.

Appendix: Materials Consulted

Cambridge Systematics prepared all documents listed unless otherwise indicated.

2005-07 model development and results

- 2010 Project Level EIR/EIS Technical Appendix (prepared by Parsons Brinckerhoff) Ridership and Revenue (Draft), December 2010
- Report to the Legislature (Business Plan) (prepared by the California High-Speed Rail

- Authority)
  Source Document 5: Ridership and Revenue Forecasts (by PB), November 7, 2008
- Bay Area/California High-Speed Rail Ridership and Forecasting Study
  - Findings from Third Peer Review Panel Meeting, September 2007
  - Ridership and Revenue Forecasts, August 2007
  - Statewide Model Networks, August 2007
  - Final Report, July 2010
  - Statewide Model Validation, July 2007
  - Interregional Model System Development, August 2006
  - Level-of-Service Assumptions and Forecast Alternatives, August 2006
  - Findings from Second Peer Review Panel Meeting, July 2006
  - Socioeconomic Data, Transportation Supply & Base Year Travel Patterns Data,
  - December 2005
  - Findings from First Peer Review Panel Meeting, July 2005
  - Model Design, Data Collection and Performance Measures, May 2005
- High Speed Rail Study Survey Documentation, December 2005 (Corey, Canapary & Galanis Research)

2008-10 Technical Reports and Forecasts

- Ridership and Revenue Results
  - Revised Service Plan May 2009, August 14, 2009
  - Hanford/Visalia, March 16, 2010
  - Alternative Alignment Between Gilroy and Merced, March 8, 2010
  - Split SF Terminal Operations Scenario and New Caltrain Operating Plan, August 17,
  - 2010
  - Inland Empire Alignment and Station Alternatives, August 17, 2010
  - Alternative Station Configurations in San Diego County, August 17, 2010
  - Alternative Station Locations in the San Fernando Valley, August 17, 2010
  - Anaheim 3 Trains Per Hour Scenario, August 17, 2010
  - San Gabriel Valley Alignment and Station Location Alternatives, August 17, 2010
  - Increased Parking Cost Scenario and Revised 2035 Factoring Process, January 14,
  - 2010
  - Increased Parking Cost Scenario, March 9, 2010
- Ridership and Revenue Forecasting for the Finance Plan, October 2008
- Refinement and Recalibration of the MTC Intraregional Model, March 2010

Attachment 2

FINAL REPORT

Independent Peer Review of the California High-Speed Rail Ridership and Revenue Forecasting Process

Findings and Recommendations from April-July 2011 Review Period

August 1, 2011

1 Introduction

The peer review panel held its second formal meeting on May 2-3 at the offices of the San Francisco County Transportation Authority. All members were present except for the recorder, who attended via videoconferencing:

- Frank S. Koppelman, PhD, Professor Emeritus of Civil Engineering, Northwestern University (chair)
- Kay W. Axhausen, Dr.Ing., Professor, Institute for Transport Planning and Systems, ETH Zurich (Swiss Federal Institute of Technology Zurich)
- Billy Charlton, San Francisco County Transportation Authority
- Eric Miller, PhD, Professor, Department of Civil Engineering and Director, Cities Centre, University of Toronto
- Kenneth A. Small, PhD, Professor Emeritus, Department of Economics, University of California-Irvine

Rick Donnelly, PhD, AICP of Parsons Brinckerhoff served as facilitator and recorder for the panel. In this capacity he serves at the convenience of the chair rather than as a representative of the project management team.

The panel invited several others to attend some portions of the meeting. They included Nick Brand from Parsons Brinckerhoff (representing the project management team) and Jeff Buxbaum, David Kurth, and Kimon Proussaloglou from Cambridge Systematics (CS). During the meeting the following broad topics were discussed:

- Briefing on ridership forecasting milestones in the near future (all in attendance)
- Discussion of the proposed Cambridge Systematics work plan for model enhancements (all in attendance)
- Review of CS responses to issues of concern identified in previous peer review panel findings (closed meeting among panelists)
- Discussion of panel assessment of CS responses (all in attendance)
- Identification of topics for further discussion and wrap-up (all in attendance)

Several topics discussed in the meeting were left unresolved, pending further investigation by the CS team. In such instances one or more panelists identified issues or questions during the meeting that could not be answered without further research or model summaries. The panel subsequently met with the CS staff identified above in videoconferences on May 27th and June 14th, 2011 to receive and discuss their responses. This report documents the findings over the panel from all three meetings, as well as teleconferences and email exchanges during that time.

2 Review of Supplemental Documentation

We identified two areas of concern about documentation in Section 3 of our first report. In some instances documentation was incomplete or missing. In other cases key information needed to interpret previous model validation work was not found. CS resolved both issues over the past three months. In addition, CS has re-validated the current model using more recent socioeconomic, travel survey, and traffic count data. The review of this newer data has largely alleviated our concerns with previous gaps of documentation on this subject.

2.1 Documentation Addenda

Following our initial meeting in January, we identified a number of missing, incomplete, or confusing aspects in the documentation. There was no evidence that these issues pointed to problems with the model, but rather that a thorough review of the model could not be completed without this additional information. CS developed a 43-page memo (Cambridge Systematics 2011) summarizing their responses to the information we requested, shown in Table 1. While their responses were limited to information about inter-regional travel[1], we felt that this was highly responsive to their needs, and permitted us to make well-informed impressions of the current model.

Table 1: Incomplete documentation identified in first peer review panel report

Further information about inputs to model application were sought in the following areas:

- Fare levels and structures
- Levels of highway and airport congestion
- Levels of service (train frequency)
- Levels of ridership and service on competing intercity bus services
- Fuel prices
- Induced effects
- Competitive responses from other modes
- Socioeconomic and land use forecast inputs

Further documentation of the model validation results were sought, to include:

For the calibration year only

- Maps, graphs, and tabular summaries of statistical measures of the deviation between assignment results and observed modal flows (road, air, rail)
- Tabular summaries of comparisons of assigned versus screenline volumes

For both calibration and forecast years

- Overall mode shares by origin-destination distance
- Mode shares by income
- Tables and maps of long distance trips per day by person type and trip purpose
- Summary of income elasticities by mode

For forecast years only

- Mode shares by network distance from HSR stations
- Tables of own- and cross-elasticities by model for the time and cost variables across the state, by OD distance or intra-regional pairs, by income group and distance band from HSR stations
- A brief assessment of access and egress mode shares by HSR station
- Analysis of the effects of forecasts of expert judgments that were made to override estimated model coefficients

[1] As part of their model design CS defined regions of the state that are aggregations of counties. Inter-regional trips are those with trip ends in different regions, irrespective of the distance traveled, while intra-regional trips have both trip ends within the same region. A map of the regions can be found in Cambridge Systematics (2006).

We reviewed this memo and its predecessors in great detail, and several hours were spent discussing the information presented. We were very pleased with content, quality, and quantity of the information. Only a few items left us with lingering concerns. We continue to struggle with the arbitrary distinction between intra-regional and inter-regional trips, although we understand the practical rationale for it. We would like a more clearly defined demarcation of geographic travel segments in future work, if the distinction is maintained at all.

We have been concerned about the possibility of discontinuity in mode choice at the 100-mile demarcation between local (less than 100 miles) and long-distance (greater than or equal to 100 mile) travel markets. CS presented evidence that indeed such a discontinuity does occur, but the effect was shown to be small. If the long versus short distance segmentation is retained in the model structure, clear and conclusive evidence should be produced to demonstrate that any remaining discontinuity is small enough to have little to no impact on model forecasts. CS is currently undertaking an exploration of the effect of combining the long and short distance models into a single model that takes account of distance in the model specification. The initial results of such work will be presented to the panel at the planned August 10th and 11th meeting.

We also noted that the reported elasticities for total auto trips with respect to auto travel times have unexpected signs in Table 12 of the CS memo (Cambridge Systematics 2011, but also that they were very small in magnitude and not statistically significant. The panel believes that this anomaly is of negligible importance and is adequately explained by location-specific differences in trip generation effects (as suggested in the CS memo), and is therefore satisfied that no further action is needed with respect to this particular finding.

We are satisfied with the documentation presented in Cambridge Systematics (2011), and conclude that it demonstrates that the model produces results that are reasonable and within expected ranges for the current environmental planning and Business Plan applications of the model.

The longer-term issues mentioned in Section 5 of our report from January, 2011 remain unaddressed. We continue to view these as critical to a full assessment of the credibility of model forecasts for future applications. These were examined in the panel's August meeting and our conclusions will be reported shortly.

2.2 Expanded Validation Efforts

This section considers the work being done by CS to validate and, if necessary, adjust the model to reflect changes in socioeconomic conditions and travel patterns since the years 2000 and 2005, which were the sources of the data used in model development. CS has developed a proposed work plan for enhancement of the current model to address expected future needs of the Agency and our recommendations. We reviewed their fourth draft of the proposal, dated April 20, 2011, in preparation for the May 2-3 meeting. We discussed the proposal at length, and compared it to both the short and long-term recommendations they made after their January, 2011 meeting.

Jeff Buxbaum of CS summarized the anticipated uses of the current model. Owing to the business plan deadline the CS team plans several short-term actions:

- Collection of data for re-validating the model to observed 2008-09 flows. This was scheduled for completion in May and June.

- Changes to the model based on the re-validation work, schedule for completion in June, resulting in an interim model to be used until the next generation model is complete.
- Continued to work on ridership and revenue forecasting with the existing model to evaluate different configurations of initial operating segments (IOS), Phase 1, and the full system, scheduled for completion in July.

In parallel to these efforts, CS staff is also planning to carry out enhancements that will be incorporated into the interim model after the business plan forecasts are complete. These enhancements are discussed in Section 4. We discussed the relationship between the current, interim, and possibly a model to be developed in the future, both during the May 2nd meeting and in subsequent internal discussions. We emphasized that any model development work beyond that needed for the IOS and 2011 business plan should be directed towards addressing the long-term issues previously identified in addition to meeting the schedules and capabilities required by the Authority. How exactly that can be done was discussed at length, as summarized in the remainder of this section.

Two important inputs identified for the re-validation work were analyses of the 10 percent sample of air passenger tickets and an Internet panel survey of long distance journeys. The former is being processed by Geoffrey Gosling as part of his work, while the latter will be performed by Harris Interactive to specifications developed by the CS team.

CS plans to use the Harris Interactive data to learn more about long distance journeys in relation to traveler and household attributes (e.g., income, household size, number of workers, auto availability). Harris has a pre-selected and verified a panel of respondents, from which they can deliver responses for a wide variety of desired sample frames. We discussed the representativeness of a pre-selected panel for intercity travel market analysis. While a specially-drawn random sample might in principle offer advantages, time and budget constraints precluded this possibility and the use of the Harris poll clearly represents the most cost-effective way to quickly obtain data needed for short-term improvements to the model.

Two other sources of data – retrospective travel surveys and an upcoming California Department of Transportation (Caltrans) statewide travel survey – represent other possible sources of information to support model development. Again, undertaking a retrospective survey simply is not feasible within the scope of the current work, while the Authority does not appear to be able to influence the design, sampling frame, or other details of the Caltrans survey. While the Harris poll data will provide very useful immediate input to the model upgrade, comparison to the results of the Caltrans statewide travel survey, as soon as it becomes available, will provide additional useful information for the modeling work as well as an additional check on the Harris poll results.

Other potential sources of travel behavior data discussed included the 2009 National Household Travel Survey (NHTS) and Amtrak passenger surveys. The number of intercity trips in the NHTS is very small, greatly reducing its utility for use in this work. California was not one of the states that purchased additional sampling to increase the number of observations using rural and intercity travel. Amtrak historically has not shared data, but CS agreed to renew attempts to identify and obtain relevant data from them. The panel felt that this information would be particularly

useful for the analysis of IOS alternatives in the Central Valley, where Amtrak will be a larger competitor to HSR than air service.
The CS team is also planning to adopt the networks and zone system being used by the statewide travel model under development by the University of California at Davis (UCD). The zone systems of that and the current model are slightly different, but this is not expected to create significant difficulties.

Furthermore, 2030 socioeconomic forecasts are not yet available for the UCD zone system. Jeff Buxbaum reported that new economic data from economy.com will be purchased as a placeholder until an independent economist can be contracted to provide an alternative to the forecasts presently used. We endorses this approach, believing that the testing of alternative economic futures will enhance the credibility of the model with policy-makers and potential investors and enable them to better gauge the risk associated with such assumptions in the forecasts.

3 Short-Term Issues Resolved

We found that significant progress has been made in the resolution of many short-term issues identified in Section 4 of our January 2011 report.

3.1 Representation of Distance Effects in the Model

In Section 4.1 of our first report, we expressed concern about the representation of distance in the destination and mode choice models. In response to our comments, CS conducted tests demonstrating that the discontinuity between the short and long-distance models at 100 miles is present but not quantitatively significant. The evidence from their testing suggests that the number of trips affected is very small, leading us to conclude that further work on this issue – which would likely take the form of joint models of short and long-distance travel – can be deferred and dealt with as part of developing an updated version of the model.

3.2 Observed Heterogeneity

In Section 4.2 of our first report, we outlined concerns that observed heterogeneity was not adequately treated in the current model. At the time, we found no evidence that the forecast results were biased in aggregate, but that an improvement in this area (i.e., characterizing some parameters as functions of distance or household characteristics) was a candidate for quick resolution. CS conducted exploratory estimations of alternative mode choice models that explored the influence of income and its interaction with other variables. This led us to conclude that the effects were significant, which is in line with typical findings from both urban and statewide models, and should be included in an enhanced model structure when possible. However, we found no evidence that the current treatment of income biases model results toward more or less optimistic forecasts.

3.3 Examination of Level-of-Service Variables

In Section 4.3 of our first report we criticized the lack of sensitivity testing of key service variables. CS conducted a large number of sensitivity tests over the past few months that are documented in Cambridge Systematics (2011). We are satisfied that the model is appropriately sensitive across the range of values tested, leading us to conclude that this issue has largely been resolved, apart from station access.

3.4 Constraint on HSR Vehicle Headways

In Section 4.4 we expressed concern with the original model's constraining of the coefficient on headway to equal that of travel time, for the HSR mode. This was in response to several problems, as described in the original CS final report (Cambridge Systematics 2006) and the Authority's response on this issue (CHSRA 2010). We continue to believe that a better solution would have been to fully re-estimate the model in ways described in our first report. However, the schedule for producing the 2011 business plan and other deadlines beyond the control of the Authority precluded delaying the project for the four to six months that such work would have required. We also recognize that a viable model sometimes needs professional judgment to overrule statistically estimated parameters, and any of us might also have made such a decision in similar circumstances.

We have examined in detail the question of how the model performs with respect to headway. It is important to note that the portion of waiting time that is independent of headway (e.g. walking time from a station entrance to a platform) is presumed to be included in the mode-specific constants of the model. Thus, the constrained coefficient truly reflects only the effect of headway in mode choice, and cannot be expected to equal the ratio of out-of-vehicle to in-vehicle travel times.

CS calculated the elasticity of total HSR ridership with respect to HSR headway at approximately -0.30 (see last two rows of Table 14 in Cambridge Systematics (2011). This elasticity is about the same size that the panel would expect, based on experience with urban transit and accounting for the expectation that headway is likely to be less important in intercity than in urban transit. It also compares well to elasticities found in a national survey in Switzerland, covering trips 10-300 km in length, whose values are shown in Table 2. Furthermore, the panel feels that if the original model had kept the estimated coefficient (which was approximately one-

Table 2: Swiss elasticities for long distance travel (Source: Vrtic & Axhausen 2003)

Demand elasticities shown for distances greater than 10 kilometers
(SP parameters at the mean values of the underlying RP trips)

Parameter(s)	Mode	All	Commute	Business	Shopping	Leisure/ Vacation
Travel time car	Car	-0.425	-0.665	-0.68	-0.545	-0.53
	Train/transit	0.671	0.776	1.531	1.008	0.937
Cost car	Car	-0.121	-0.312	-0.076	-0.156	-0.174
	Train/transit	0.191	0.365	0.171	0.288	0.308
In-vehicle-time train/transit	Car	0.365	0.48	0.615	0.46	0.456
	Train/transit	-0.575	-0.56	-1.386	-0.85	-0.805
Fare train/transit	Car	0.157	0.435	0.092	0.223	0.217
	Train/transit	-0.247	-0.508	-0.206	-0.512	-0.373
Access/egress train/transit	Car	0.172	0.272	0.111	0.279	0.127
	Train/transit	-0.272	-0.318	-0.249	-0.515	-0.224
Headway	Car	0.144	0.32	0.154	0.121	0.116
	Train/transit	-0.277	-0.374	-0.346	-0.224	-0.205
Number of travelers	Car	0.115	0.133	0.151	0.101	0.134
	Train/transit	-0.181	-0.156	-0.339	-0.186	-0.237

fifth as large as the value they constrained it to), the resulting elasticity would have been too low to be plausible. Therefore, we conclude that in the end, this problem with the model did not misrepresent traveler behavior in important ways.

3.5 Excessive Use of Constants

In Section 4.5 of our first report we criticized the excessive use of alternative-specific constants. The fear was that this would cause the model to be unrealistically unresponsive to changes, or to display paradoxical responses to changes in conditions. The extensive documentation provided to us by CS, in response to our first report, does not reveal such unrealism or paradoxical behavior. Therefore, this originally perceived problem with the model does not seem to be adversely affecting its behavior. In particular, we now think that the magnitude of alternative specific constants is neither an indication of poor model fit nor of inadequate representation of the impact of operational or travelers variables on behavior. That said, we still believe that every effort should be made to eliminate the use of such a large set of constants in future versions of the model. They represent current travel patterns that may not hold true under future conditions.

4 Initial Investigations into Mode Choice Model Improvements

In parallel with addressing the short-term issues described above, CS invested considerable effort exploring alternative mode choice model formulations, both to inform future model development work and to investigate the robustness of their current model to changes in specification. The bulk of this work has focused upon the re-estimation of the line haul mode choice models. We anticipate that this work will be incorporated into a new version of the modeling system that will be available for use sometime in 2012.

4.1 Long Distance Mode Choice Model for Business Trips

The panel previously expressed reservations about the omission of income from the current line haul mode choice model. Several model formulations designed to incorporate this effect and others were presented, all with encouraging estimation results. The panel offered several observations and interpretations of the findings, all of which were agreed with by CS:

- The model was tested using both three and seven groupings of income. The panel agreed that three income levels, as suggested by CS, appeared to perform as well as seven, and this smaller number of categories is easier to forecast and implement. These income categories, plus one for missing income information, substantially improve the model and give sensible results when interacted with the cost variable. We maintain our longer-term recommendation that estimation of imputed income be undertaken to (1) obtain continuous values of household income to replace the current categorical variables, and (2) provide income estimates for households for which no income response was given.
- With respect to mode-specific dummy variables for income categories, it appears that interacting cost and performance variables with all income categories would be over-fitting. We recommend retaining only the high-income category for this purpose. We continue to recommend that over the longer term, a variable defined as cost adjusted by a function of income be explored when additional choice data (revealed or stated preference) becomes available.
- Reliability was found to be statistically insignificant for business trips. This was not entirely unexpected, as some panel members suspect that the effects of reliability are

embedded in the constants due to an inability of SP data questions to fully capture reliability as viewed by the user. New data collection should consider representing reliability in terms of the distribution of possible travel times, so that a variable could be constructed representing the time difference between the median and 80th (or 90th) percentile of the time distribution. Small, Brownstone, and colleagues, who have devoted substantial efforts to studying the usefulness of alternative measures of reliability, has adopted this formulation. It was also felt that reliability might become a more significant determinant of behavior as highway congestion increases. In principle, reliability is a relevant policy variable for designing a rail system because it can help guide operational decision-making. In practice, however, reliability cannot be forecasted accurately enough at this time for it to be a useful part of the demand model for its short- and medium-term uses. Rather, it would be desirable to include this variable as an enhancement of models to be estimated for longer-term future uses.

- Including non-linear distance interaction effects led to a significant improvement in model fit without major changes in time, cost, or other coefficients. We agree with the CS proposal to include it as in Interim Models 2A and 2B in Table 4 of Cambridge Systematics (2011). Additional refinements for the longer term that are worth exploring are: (1) replacing the distance interaction with use of non-linear transforms of the base variables (e.g., powers of line haul travel time); and (2) differentiating non-linear distance interaction effects or non-linear transforms of base variables by time of day.

Overall we were satisfied with the estimation results, and strongly endorse their inclusion in the next version of the modeling system.

4.2 Long Distance Mode Choice Model for Non-Business Trips

CS has tested several alternative formulations of the model of non-business and non-commuting trips over the past several months. The most promising ones were shared with us during the May 2-3 meeting in San Francisco and in subsequent videoconferences. In this model, unlike the model of business trips, the inclusion of income led to unsatisfactory results, leading us to recommend removing income from this portion of the model until further investigation with new data can take place.

Paradoxically, reliability proved to be a reasonably strong factor in this model, whereas it was not for the business long distance travel. Because of that paradox, we recommended that reliability be excluded from this model, as well as the model for business trips, for the reasons outlined in Section 4.1.

The specification and interpretation of the headway coefficient were discussed at length, as in the case of the model of business trips. As before, one cannot choose between competing specifications solely based on estimation results. We were concerned that the SP experiment described to survey respondents included frequencies between one and two trains per hour, but that the application range is much larger. As a result, any tapering effect at higher frequencies, which is likely a priori and might be important to forecasts, would not be detected within the bounds of the SP survey. In this case, the difference between using frequency versus logarithm of frequency as a variable would be important. Insofar as it is feasible and fits well, we recommends that the same specification be used in both the business and non-business long distance models.

We make the same recommendations with respect to the distance coefficient in this model as it does for the model of long-distance business trips. Overall, we are satisfied with the estimation results, view the resulting model as superior to the current formulation, and recommend that this enhanced model be implemented as quickly as possible. Future analyses should examine a non-linear transformation of several variables in place of interactions with distance.

4.3 Models of Short-Distance and of Pooled Short and Long-Distance Trips

The CS team briefly presented three short distance models. They covered business, commuting, and non-business travel. In addition, the team presented a combined model of mode choice that includes both short and long-distance trips. These models each had some advantages and disadvantages, leading us to recommend further model development. It noted that when the in-vehicle time, cost, and service frequency variables were differentiated between commuting versus business travel, the resulting coefficients were significantly different, suggesting the need for separating these two purposes.

4.4 Restructuring the Segmentation of Trips by Purpose Rather than Distance

CS estimated models that differentiated between commuting and business travel. Several interesting results were obtained, including a reduction in the magnitudes of the in-vehicle time coefficients relative to the current model, smaller egress logsum coefficients, and reasonable implied values of time by income segment. However, the nesting coefficients were slightly higher than 1.0 (although perhaps not significantly so), and model fit was better for business-only travel versus pooled commuting and business purposes. When the in-vehicle time, cost, and service frequency variables were differentiated between commuting versus business travel, the resulting coefficients were significantly different, suggesting the need for separating these two purposes.

5 Conclusions

The work completed by CS since the first meeting of the panel has greatly improved our confidence in the existing model. We were encouraged by the depth and extent to which CS addressed the short-term issues we identified in January. Further, we support the work that CS has undertaken to date for model improvement. This conclusion is based upon the work they have done to address those issues identified by ourselves and critics as potentially critical shortcomings of the model. In addition, our examination of additional data and analyses provided to us by CS, has led us to determine that these issues are not critical to current applications of the model.

We also find that the strategy being used by CS to go forward, namely building a substantially improved model for future work, is paying off very well. Key to this strategy are improvements to the mode choice model, which have in part now been completed as described in Section 4 of this report, and we believe this component of the model will provide a sound basis for the further demands on the model called for by future forecasting needs.

References

California High-Speed Rail Authority [CHSRA] (2010), "California High-Speed Rail Authority response to the UC Berkeley ITS Review."

Cambridge Systematics, Inc. (2006), “Interregional model system development - final report.”
Cambridge Systematics, Inc. (2011), “Information requested in ‘Section 3.2 Validation and Documentation’ of the Independent Peer Review of the California High-Speed Rail Ridership and Revenue Forecasting Process, 2005-10, Draft Report for Internal Review.”
Vrtic, M. and Axhausen, K.W. (2003), Verifizierung von Prognosemethoden im Personenverkehr: Ergebnisse einer Vorher-/Nachher Untersuchung auf der Grundlage eines netzbasierten Verkehrsmodells, Endbericht an die SBB - Division Personenverkehr und Bundesamt für Raumentwicklung – Technischer Bericht, IVT, ETH Zürich, Zürich.

The CHSRA and Cambridge Systematics references are available online at http://www.cahighspeedrail.ca.gov/Ridership_and_Revenue_Forecasting_Study.aspx

Attachment 3

Law Offices of
Stuart M. Flashman
5626 Ocean View Drive
Oakland, CA 94618-1533
(510) 652-5373 (voice & FAX)
e-mail: stuflash@aol.com

December 4, 2009

Mr. Dan Leavitt, Deputy Director
California High-Speed Rail
Authority,
925 L Street, Suite 1425
Sacramento, CA 95814

ATTN: Altamont Corridor Rail
Project EIR/EIS

RE: Notice of Preparation for Environmental Impact Report/ Environmental Impact Statement (EIR/EIS) for Altamont Corridor Rail Project from Stockton to San Jose, California.

Dear Mr. Leavitt:

Thank you for the opportunity to provide scoping comments for the EIR/EIS for the above-referenced project. These comments are provided on behalf of my clients: the Planning and Conservation League, the California Rail Foundation, and the Transportation Solutions Defense and Education Fund.

My clients appreciate the Authority's moving forward on preparing an EIR/EIS for this very important project. However, my clients are concerned that it does not appear that the proposed project is currently funded. A basic question, therefore, is the feasibility of this project in the absence of funding. From that standpoint, my clients believe that it is important that the alternatives section of the EIR/EIS consider alternative projects that might have greater feasibility, i.e., a better prospect of funding. In particular, especially given that the Authority is being required to revise its Programmatic EIR/EIS for the Bay Area to Central Valley High-Speed Rail Project and revisit its decisions on that project, my clients believe the EIR/EIS needs to include consideration of an alternative where the Altamont Rail Corridor alignment serves as the route for that project. Such an alternative would provide funding for the Altamont Rail Corridor. In addition, the combined project would add the benefit of the resulting ACE service between the Northern San Joaquin Valley and San Jose to the benefits of the previously approved Bay Area to Central Valley High-Speed Rail Project, without increasing project costs.

In addition, this alternative would allow High-Speed Rail service to be extended from San Jose to Sacramento in an earlier time frame, at a lower cost and with a much higher ridership than would otherwise be possible.

The I-580 Alternative

This Alternative seeks to achieve the fastest possible travel times through the Tri-Valley at the lowest cost and with the least disturbance of residents. To avoid the substantial expense of tunneling and/or bridging through the Niles Canyon area, an existing rail right-of-way would be converted from the BART gauge to standard gauge. This alternative would take advantage of the proposed BART Livermore Extension, now in its DEIR comment process, by replacing the proposed BART service with ACE service and adding a new Isabel/I-580 station. The alternative would thus provide for a Livermore Extension.[1] High-Speed and ACE trains would emerge into the Tri-Valley from the tunnel through the Altamont Pass and travel entirely within the I-580 right-of-way, thus minimizing travel time, construction cost and community impacts. The Dublin and Isabel stations would be built with proper height platforms, and equipped, if possible, with a center run-through track for express service. This Alternative would be far more cost-effective than separately building both a BART Livermore Extension and an Altamont Corridor Rail Project. Using standard gauge, HSR-compatible tracks would also add the flexibility of being able to connect a wide variety of destinations with direct local and express service.

The I-580 rail right-of-way would then connect to the Capitol Corridor to San Jose. (See attached map, where the short purple line indicates a cut-and-cover tunnel under a high school's athletic fields.) If a wye were installed at that point, ACE and HSR service to Oakland could be provided as well. An intermodal station would be built either where the I-580 rail line crosses the BART Fremont line, or at Shinn Street, allowing transfers to the existing BART system. Especially if purchase of this portion of the Capitol Corridor became possible, it would enable greatly improved service not only to downtown San Jose, but also to North San Jose and Santa Clara, with associated greater ridership and larger travel market.

The Transbay Alternative

While not part of the proposed alignment for the Altamont Corridor Rail Project, my clients also ask that the Authority study an alternative route that would enable both ACE and High-Speed Rail trains on the Altamont Corridor to access the Caltrain Corridor to San Francisco. To connect the Altamont Corridor to San Francisco, the I-580 rail corridor could be extended along I-238 into San Leandro. It would then use a cover-and-cut tunnel under Lewelling Blvd., until turning to parallel the Bay shoreline. From there it would travel south,

---

[1] While the alternative designates the rail gauge and cities served, it is agnostic on the political question of which agency--BART, ACE or the CAHSRA--would operate the service.

roughly parallel to the shoreline, until turning onto a new two-track high rail bridge, parallel and next to the San Mateo Bridge. (See attached map.) Once across the Bay, the tracks would connect into the Caltrain Corridor via an AirTrain station near the Airport. This alternative, by avoiding residential areas along the Peninsula, would also avoid the significant community impacts identified in previously-studied Bay Area to Central Valley Alternatives.

By connecting to the Caltrain Corridor much further north than other proposed alternatives, this Transbay Alternative would also eliminate much of the conflict with UP freight traffic on that Corridor, making the remaining conflicts more manageable. Building this rail bridge would have the added benefit of providing additional Transbay capacity for future growth of BART ridership. Providing a separate connection to San Francisco for Tri-Valley and Central Valley travelers would remove a substantial passenger load from the Transbay Tube, thereby freeing up capacity for expected growth of demand for BART service in the Inner East Bay.

The Local Service Alternative

If funding can be found for proposed Smart Growth efforts in Livermore, a low-cost Local Service Alternative could also be included. This alternative would divert from the I-580 rail right-of-way to join either the current ACE alignment or the former SPRR right-of-way as close to the tunnel as possible. A single-track line dedicated to HSR-compatible trainsets, with passing sidings as needed, would serve stations at Vasco Road and Downtown Livermore. With funding for this Local Service Alternative, there would be no need to build a station at Isabel, thus enabling higher operating speeds on the main line, with only one HSR stop in the Tri-Valley. This line would have adequate capacity for the service levels expected for this area, while reducing construction costs and the need to acquire additional right-of-way. This alternative would provide a low-cost, low-impact connection from the Downtown Livermore station to the I-580 rail right-of-way. It is not clear that any of the current BART Livermore Extension alternatives meet these criteria.

Oakland Alternative

Another alternative that should be considered, in that same context, is a corridor that would provide direct service to Oakland as well as to San Jose. In addition to the service to Oakland *per se*, this option could also provide greatly improved service to San Francisco as well.

Cumulative Impacts

The EIR/EIS should also more generally include a discussion of cumulative impacts including both the Altamont Corridor Project’s impacts and those of the two high-speed rail projects being conducted by the authority (the Los Angeles to Fresno segment and the Fresno to San Francisco segment). Of course, an alternative that integrates the Altamont Corridor Project into the Bay Area to Central Valley High-Speed Rail Project would automatically include such cumulative impacts in its analysis.

The EIR/EIS should also take into account the potential problems that would be created for the Bay Area to Central Valley High-Speed Rail Project if the Authority is unable to reach agreement with the Union Pacific Railroad (UP), pursuant to that company's MOU with the Peninsula Joint Powers Authority, over the High-Speed Rail Authority's use of the Caltrain right-of-way for intercity passenger rail service. At the moment, it appears that such an agreement is unlikely. Consequently, the EIR/EIS needs to discuss the impact on Bay Area transit service, including the Altamont Rail Corridor Project, and on regional GHG emissions if the High-Speed Rail line is unable to use the Caltrain right-of-way between San Francisco and San Jose.

Finally, if the Authority is unable to reach agreement with UP over use of the Caltrain right-of-way, the EIR/EIS should include discussion of alternative approaches to extending service from the Altamont Corridor Project into San Francisco. These should include, in addition to extending corridor service into downtown Oakland and connecting to BART at that point, extending service into another part of Oakland (e.g., the Oakland Coliseum area) and connecting to BART at that point, or options for a new Bay Crossing, perhaps combining both local and regional rail service, similar to that suggested above, that could provide direct access to San Francisco without the need to use the Caltrain right-of-way.

Thank you for allowing these comments on the proposed scope of the Altamont Rail Corridor Project EIR/EIS. Please keep me, and my clients, informed of future developments on this project.

Most sincerely,

Stuart M. Flashman

Stuart M. Flashman


San Leandro Routing Idea
Current Dublin BART Line
Fremont BART Line
BART-HSR Station
Capitol Corridor connection Southward
238 beyond BART
Hayward Air Terminal
Small Shopping Center w/Safeway
Llewelling Blvd. 100 ft right-of-way
92
San Mateo Bridge
Existing BART Dublin Line
238 Median and Elevated Structure
Cover and Cut Shallow Tunnel (2 miles total)

Attachment 4

Statement on California High-Speed Rail by:
Congresswoman Anna G. Eshoo
Senator S. Joseph Simitian
Assemblyman Richard S. Gordon

April 18, 2011

Since the passage of Proposition 1A in 2008, each of us has expressed our support for "high-speed rail done right," by which we mean a genuinely statewide system that makes prudent use of limited public funds and which is responsive to legitimate concerns about the impact of high-speed rail on our cities, towns, neighborhoods and homes.

To date, however, the California High Speed Rail Authority has failed to develop and describe such a system for the Peninsula and South Bay. For that reason, we have taken it upon ourselves today to set forth some basic parameters for what "high-speed rail done right" looks like in our region.

We start with the premise that for the Authority to succeed in its statewide mission it must be sensitive and responsive to local concerns about local impacts. Moreover, it is undeniable that funding will be severely limited at both the state and national levels for the foreseeable future.

Much of the projected cost for the San Jose to San Francisco leg of the project is driven by the fact that the Authority has, to date, proposed what is essentially a second rail system for the Peninsula and South Bay, unnecessarily duplicating existing usable infrastructure. Even if such a duplicative system could be constructed without adverse impact along the CalTrain corridor, and we do not believe it can, the cost of such duplication simply cannot be justified.

If we can barely find the funds to do high speed rail right, we most certainly cannot find the funds to do high speed rail wrong.

Accordingly, we call upon the High-Speed Rail Authority and our local CalTrain Joint Powers Board to develop plans for a blended system that integrates high-speed rail with a 21st Century CalTrain.

To that end:

- We explicitly reject the notion of high-speed rail running from San Jose to San Francisco on an elevated structure or "viaduct"; and we call on the High-Speed Rail Authority to eliminate further consideration of an aerial option;

- We fully expect that high-speed rail running from San Jose to San Francisco can and should remain within the existing CalTrain right of way; and,

- Third and finally, consistent with a project of this more limited scope, the Authority should abandon its preparation of an EIR (Environmental Impact Report) for a phased project of larger dimensions over a 25 year timeframe. Continuing to plan for a project of this scope in the face of limited funding and growing community resistance is a fool's errand; and is particularly ill-advised when predicated on ridership projections that are less than credible.

Within the existing right-of-way, at or below grade, a single blended system could allow high-speed rail arriving in San Jose to continue north in a seamless fashion as part of a 21st Century CalTrain (using some combination of electrification, positive train control, new rolling stock and/or other appropriate upgrades) while maintaining the currently projected speeds and travel time for high-speed rail.

The net result of such a system would be a substantially upgraded commuter service for Peninsula and South Bay residents capable of accommodating high-speed rail from San Jose to San Francisco.

All of this is possible, but only if the High-Speed Rail Authority takes this opportunity to rethink its direction.

Over the course of the past 18 months the Authority has come under considerable criticism from the California Legislative Analyst's Office, the Bureau of State Audits, the California Office of the Inspector General, the Authority's own Peer Review Group and the Institute of Transportation Studies at the University of California at Berkeley. The Authority would do well to take these critiques to heart, and to make them the basis for a renewed and improved effort.

Frankly, a great many of our constituents are convinced that the High-Speed Rail Authority has already wandered so far afield that it is too late for a successful course correction. We hope the Authority can prove otherwise.

An essential first step is a rethinking of the Authority's plans for the Peninsula and South Bay. A commitment to a project which eschews an aerial viaduct, stays within the existing right-of-way, sets aside any notion of a phased project expansion at a later date, and incorporates the necessary upgrades for CalTrain - which would produce a truly blended system along the CalTrain corridor - is the essential next step.

Attachment 5

Caltrain Capacity Analysis Update

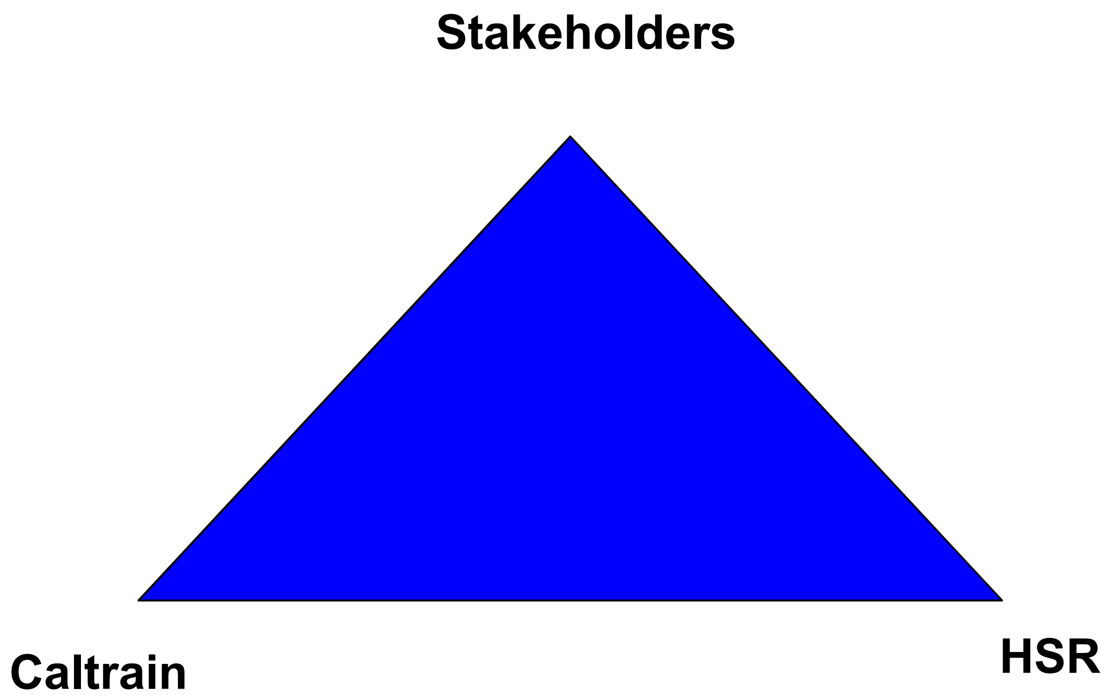
August / September 2011 Stakeholder Meetings

Presentation Topics

- Modernization Program
- Capacity Analysis Update
  - Context
  - Preliminary Findings
- Next Steps
- Discussion

Caltrain Modernization Program

Partnership



Caltrain Program Focus Areas

- Projects
  - Caltrain Electrification
  - Advanced Signal Upgrade

- Coordinated Planning
  - HSR
  - Stakeholders

Capacity Analysis Update

HSR Context

- HSR Priority Segments
  - Merced to Fresno; Fresno to Bakersfield
  - Spring 2012 Environmental Clearance
- HSR Business Plan
  - Initial Operating Segment being defined
  - Extend North? South?
- SF to SJ Segment
  - Design and EIR/EIS work on hold

Peninsula Vision

- Elected officials call for “blended system”
- What is it?
  - System from SJ to Transbay Terminal
  - Support both Caltrain and HSR
  - Utilize existing right of way and tracks
  - Minimize impacts to communities
  - Lower project cost

Caltrain Capacity Analysis

- Is the “blended system” concept feasible?
- Multiple considerations
  - **Operational**
  - Infrastructure
  - Cost (Capital & Operating)
  - Ridership
  - Prop 1A requirements
  - CEQA/NEPA requirements

Scope of Work

- LTK Engineering Services
- Build simulation model
  - Main Line
  - Terminals
- 1st set of model runs / analysis
- **Preliminary Findings (Summer)**
- 2nd set of model runs / analysis
- Draft Analysis

Simulation Model - System and Train

System	Electric Advanced Signal System
Trains	Caltrain EMU trains High-speed rail trains

Simulation Model –Tracks

Base	Mainline (4th & King to Diridon) Current Capital Projects – San Bruno – South Terminal
Additions	HSR Stations – 4th and King – Millbrae – Diridon

Simulation Model – Passing Tracks

Tested	North (4 track section) *(Bayshore to Millbrae)* → **Middle (4 track section)** ***(Hayward Park to Redwood City)*** *(Hayward Park to San Carlos)*
Not Yet Tested	South (4 track section) Long (3 track section)

Preliminary Findings

- Blended system concept has merit
- Potential up to 10 trains / hour / direction

Passing Tracks Middle (4 track section)	No	Yes
Caltrain	6	6
HSR	2	4

Tested Service Characteristics

	Caltrain	HSR
Travel Speeds *(up to)*	79mph*	79mph 110mph
Headways *(peak hour)*	6 trains (5 - 20 min.)	Without passing tracks 1 train (60 min.) 2 trains (30 min.)
	6 trains (5 - 15 min.)	With passing tracks 3 trains (20 min.) 4 trains (15 min.)
Station Stops *(one-way)*	13 -14	3

**Note: Caltrain to be tested at up to 110mph*

Next Steps

Outreach

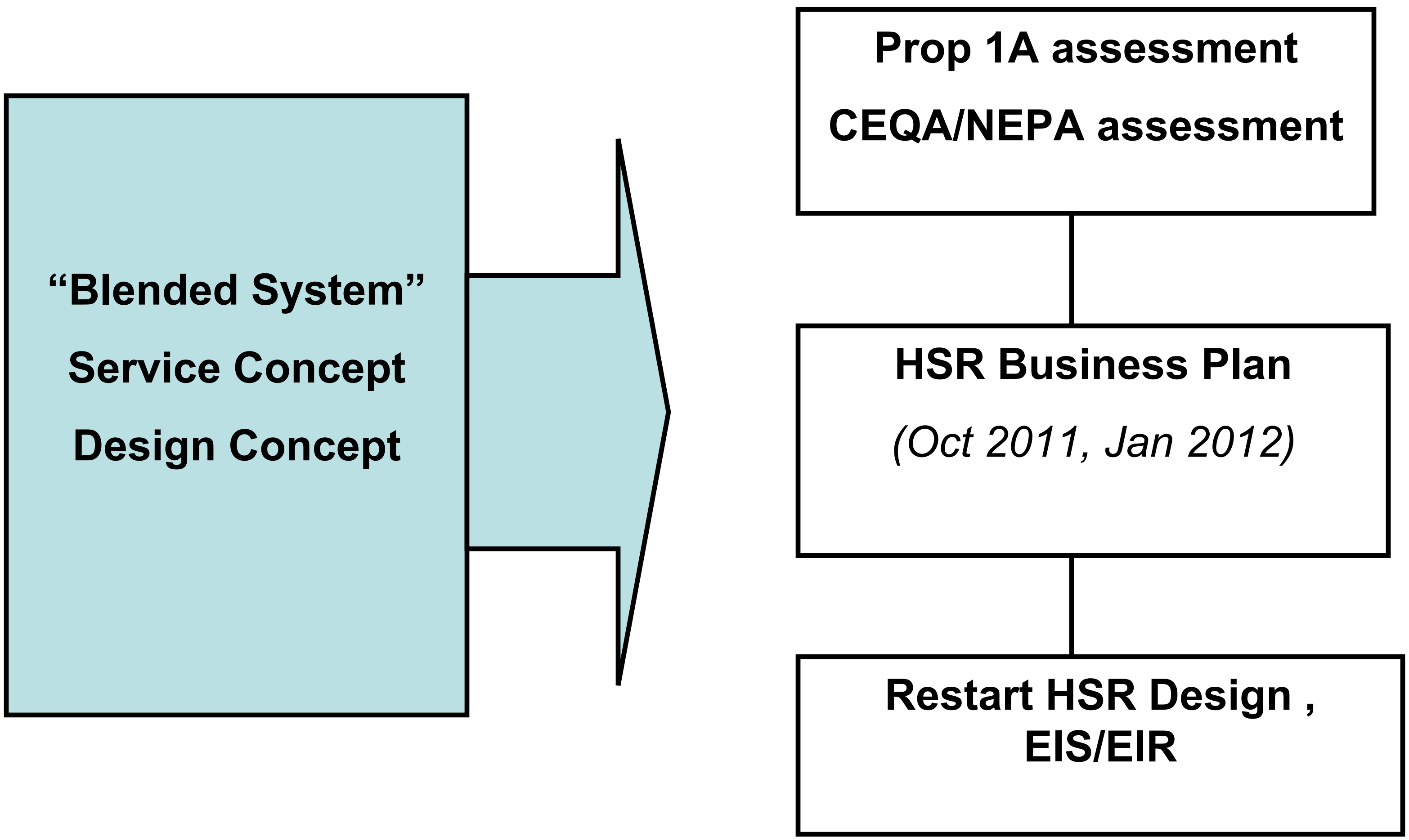
- Scheduled Public Venues
  - San Mateo Rail Corridor Working Group (August 17th)
  - Friends of Caltrain (August 19th)
  - Peninsula Cities Consortium (September 2nd)

- Other
  - Transportation Agencies
  - Cities / Counties
  - Bay Area Council
  - San Francisco Planning + Urban Research Association
  - Peninsula Freight Rail User's Group

Concept Development

- Additional rail service simulations / analysis
- Design
  - Passing tracks (4 track section) location
  - Grade crossings upgrades/separations/closures
  - System upgrades
- Project cost estimate

HSR Coordination



Discussion

Contact Information:

Caltrain Modernization Program

Marian Lee *leem@samtrans.com*
Seamus Murphy *murphys@samtrans.com*

www.caltrain.com

Attachment 6

November 2011

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.

Michael J. Scanlon

Draft

Caltrain/California HSR Blended Operations Analysis

Prepared for:
Peninsula Corridor Joint Powers Board (PCJPB)

Prepared by:
LTK Engineering Services

November 2011

Table of Contents

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.

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

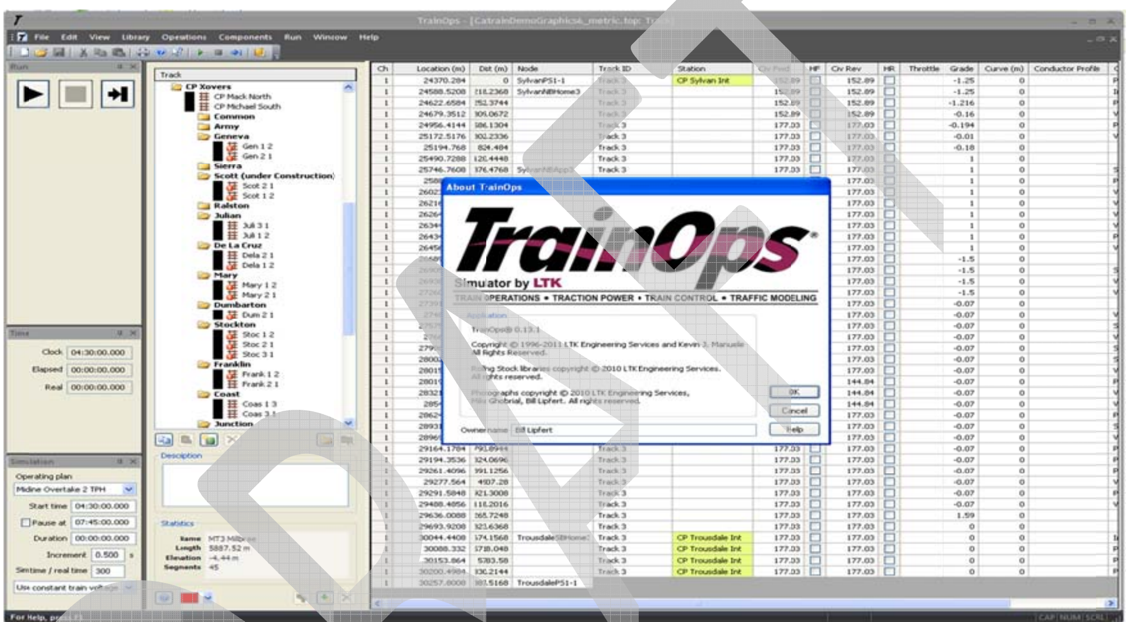
TrainOps was first developed in 1996 by LTK Engineering Services and has been continually enhanced and upgraded in the last 15 years. These enhancements include the addition of new features and ability to model new technologies, as well as adding support for the latest Windows operating systems.

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

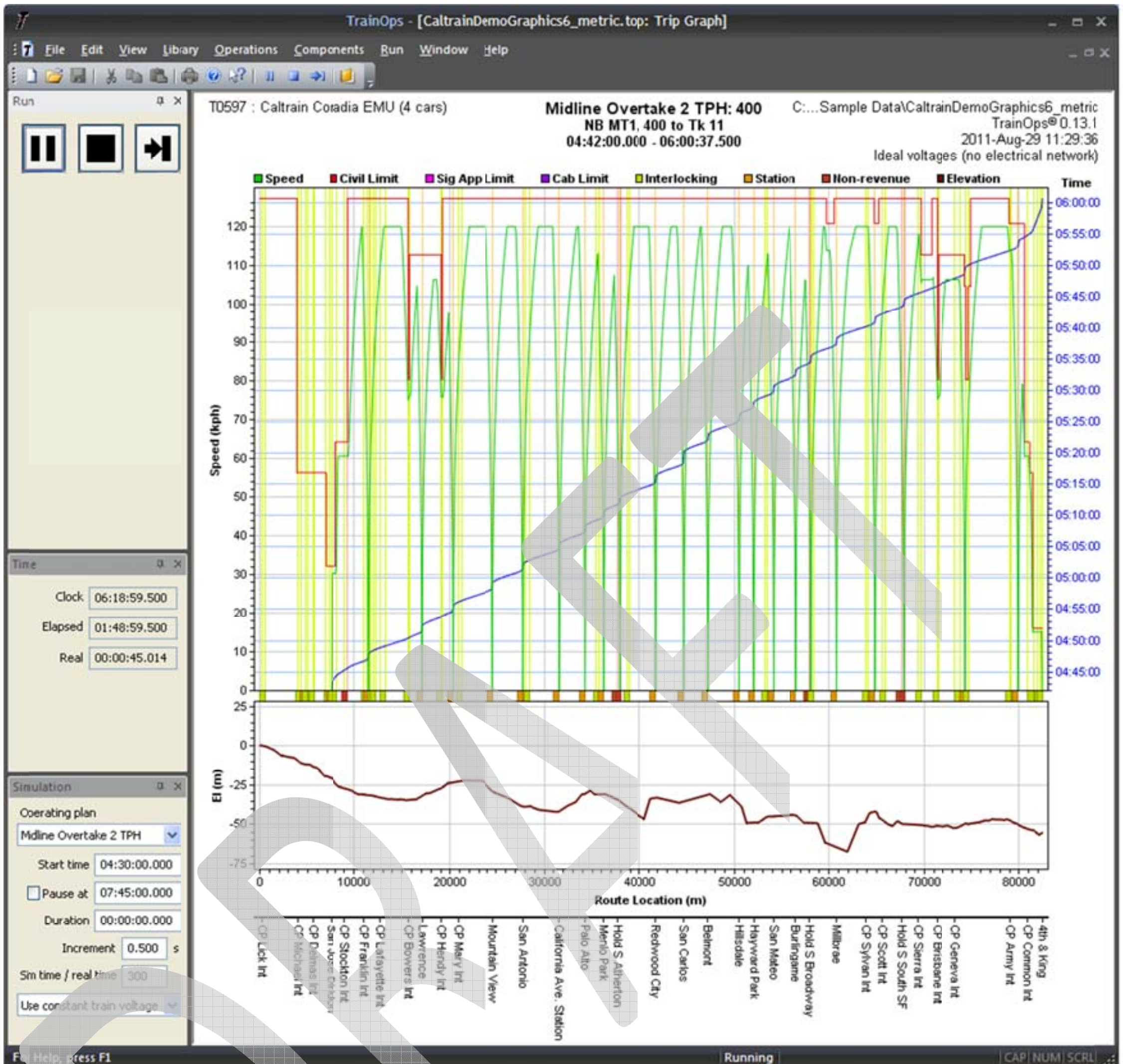


Although TrainOps is not licensed to rail operators or other consulting engineering firms, the software has a long history of successful calibration and application. This history includes application at the following rail systems:

- 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. As part of the TrainOps QA/QC testing, LTK tested the 30 second value and also “extreme” values (0 seconds and 300 seconds) 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

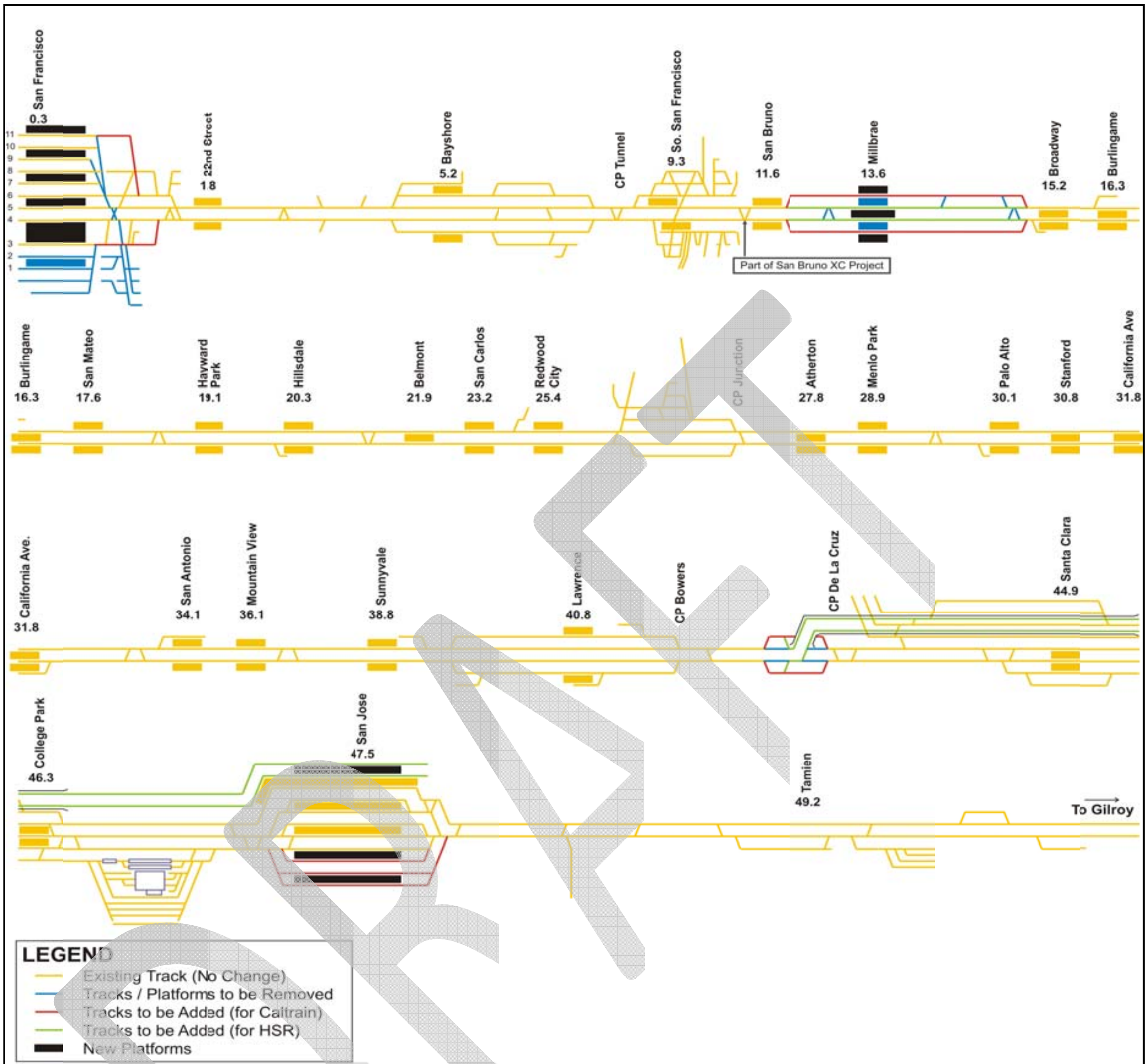
3.1.1 Existing and Under Construction Tracks

The simulation model reflects existing Caltrain tracks and interlockings from 4th and King (North Terminal) to San Jose Diridon (South Terminal) 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) 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 4th & King 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 stations developed by HSR to date were incorporated into the simulation database, as described below.

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.

4th and King Station

At the 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.

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 9.1-mile long 4-track segment of tracks from milepost 18.1 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 6.1-mile long 4-track segment of tracks from milepost 18.1 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.

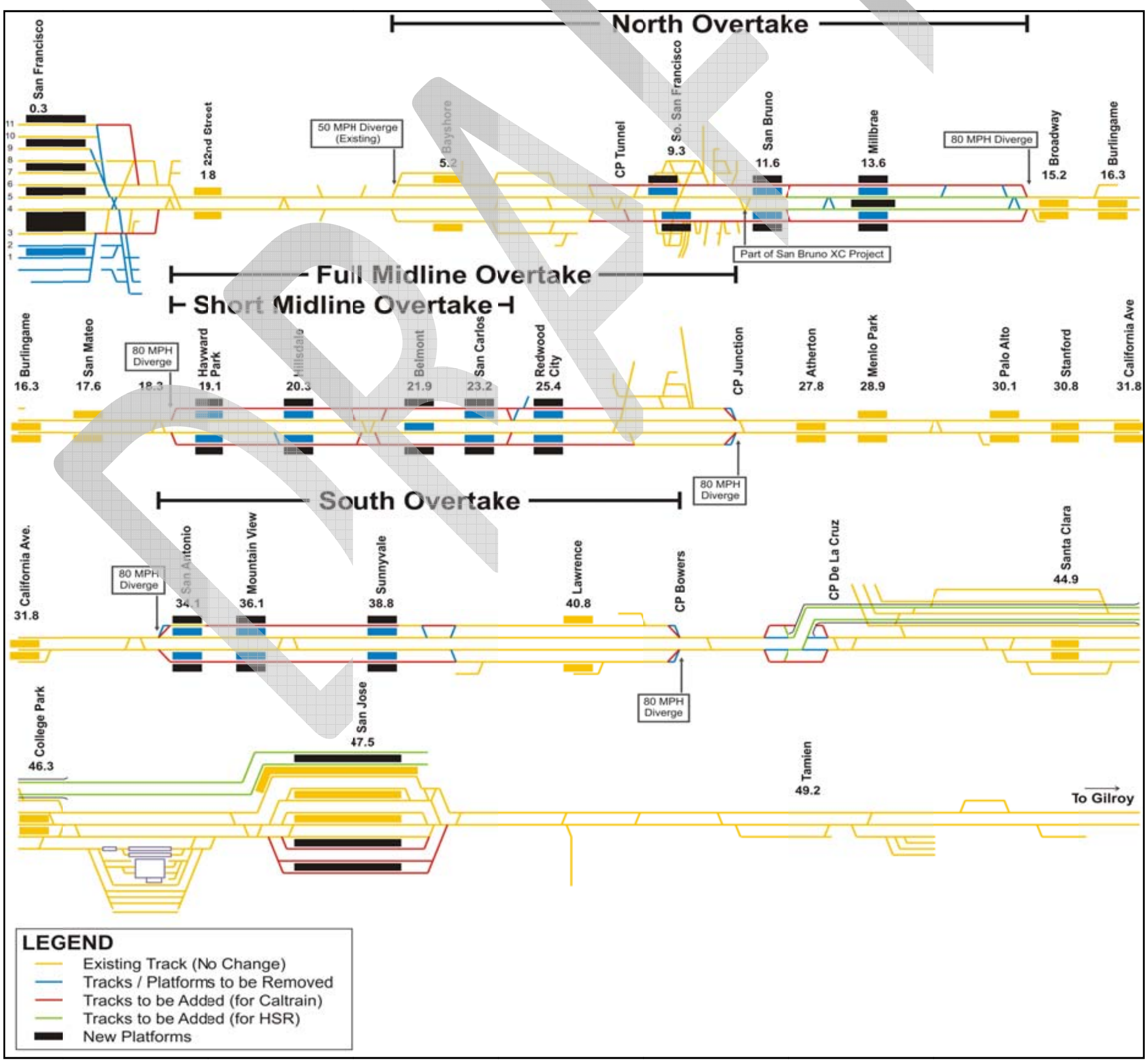
In addition to the 4-track options, a 3-track option is also being considered. Four tracks allow two dedicated tracks for high speed rail for a limited segment of the corridor – one track per direction. Three tracks allow one dedicated track for high speed rail for a limited segment of the corridor – 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 4th & King in San Francisco, at Millbrae, 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.

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 SF 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 SF 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 SF 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 SF 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

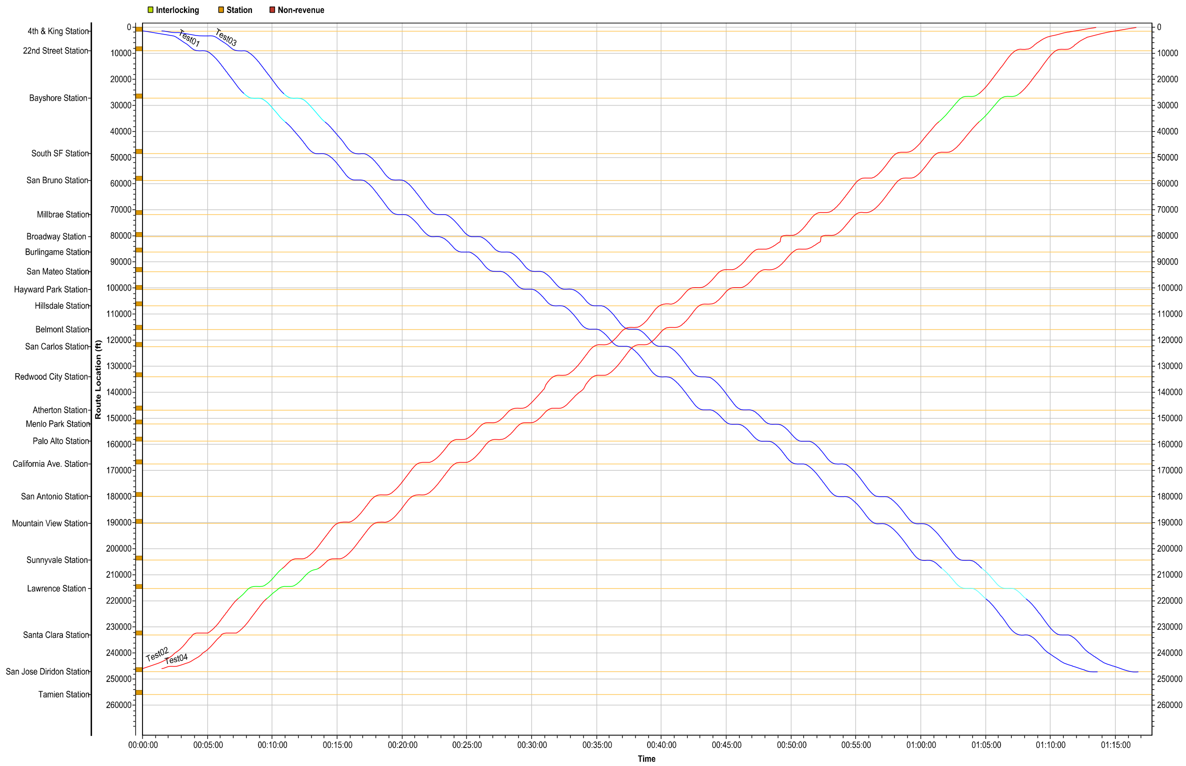
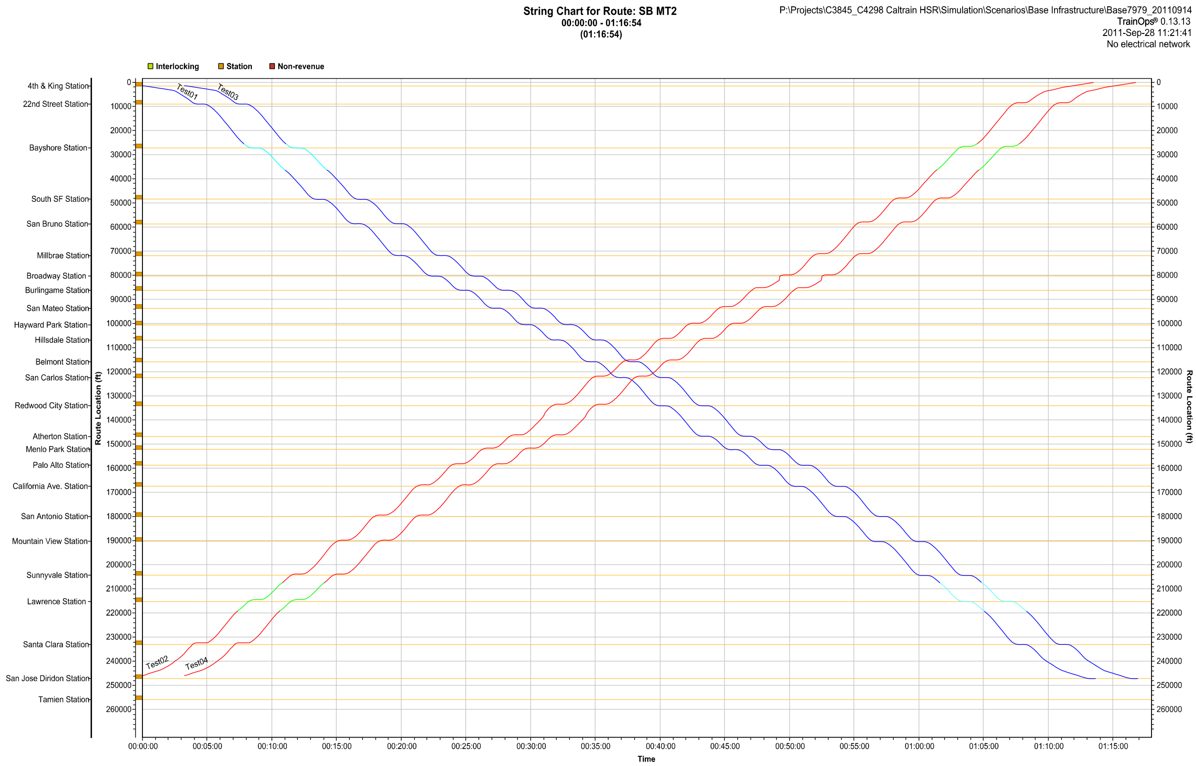


Figure 6. Time-Distance "String" Chart Showing Northbound and Southbound All-Stops Trains Operating on 3:15 Headway



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. EMU performance is based on preliminary specification documents and appropriate derating to reflect engineer conservatism:

- Initial acceleration (0 to 19 MPH) is 1.87 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.

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

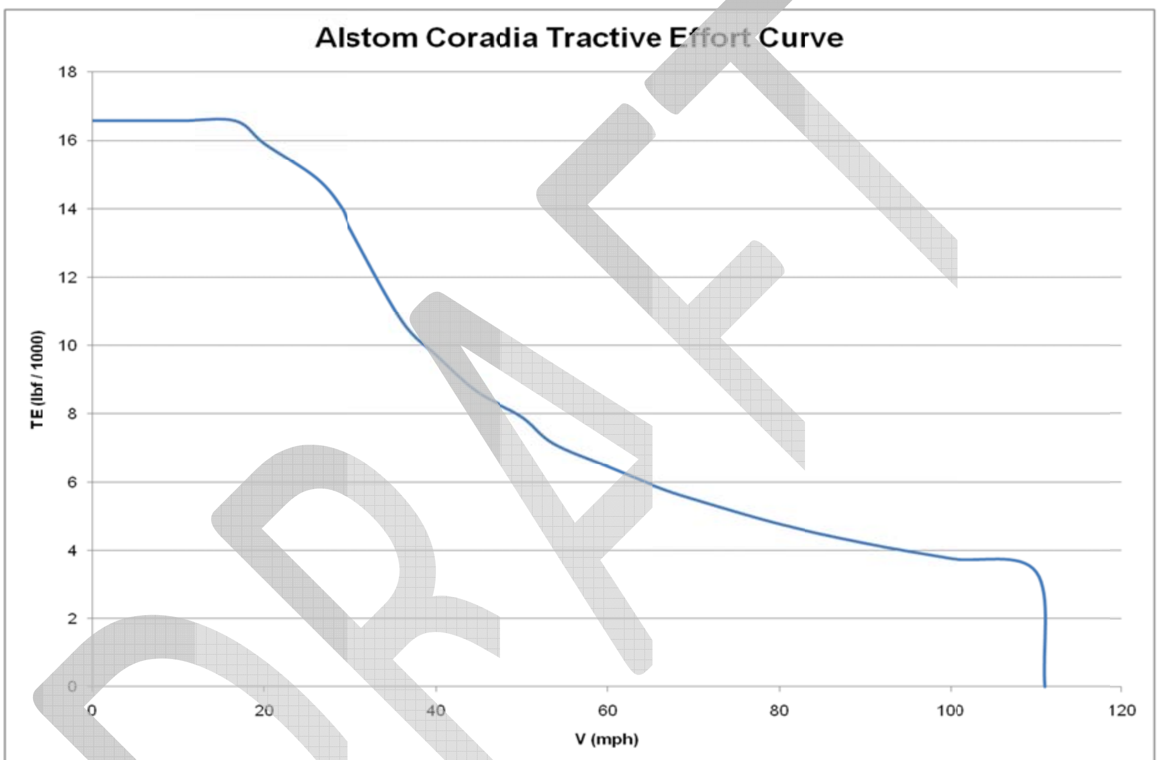
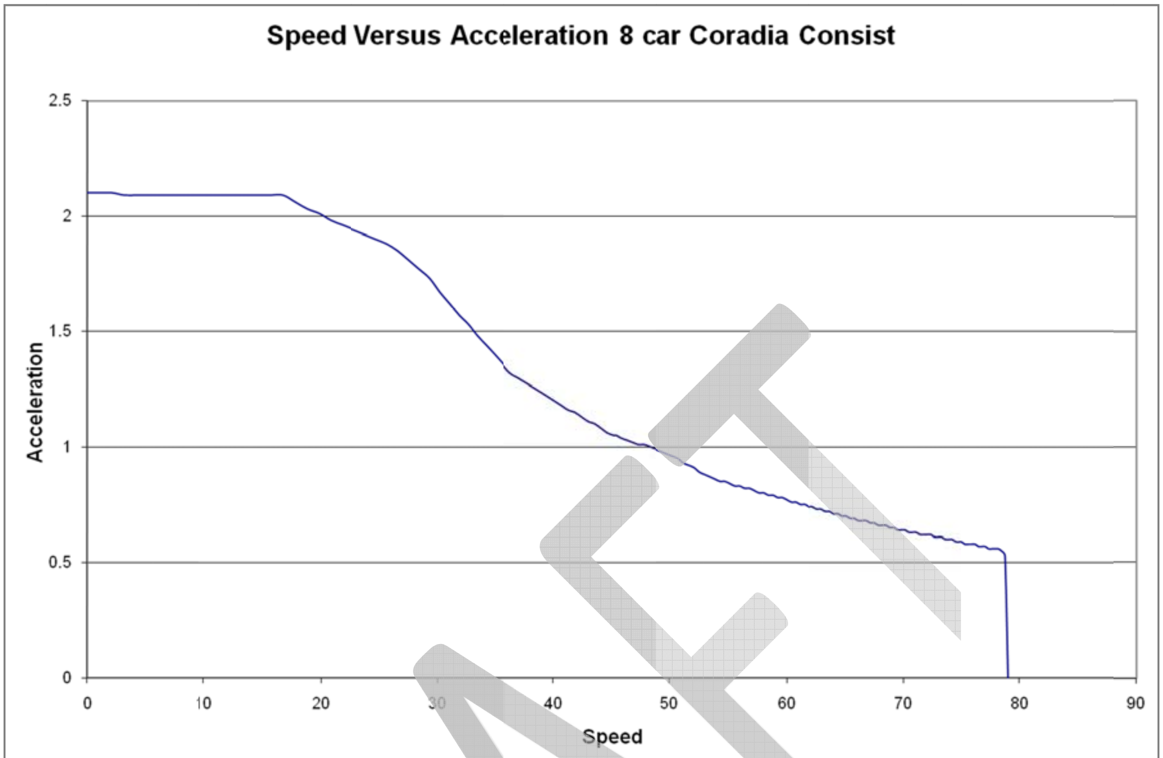


Table 5 – Caltrain Coradia Trainset Physical Characteristics

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

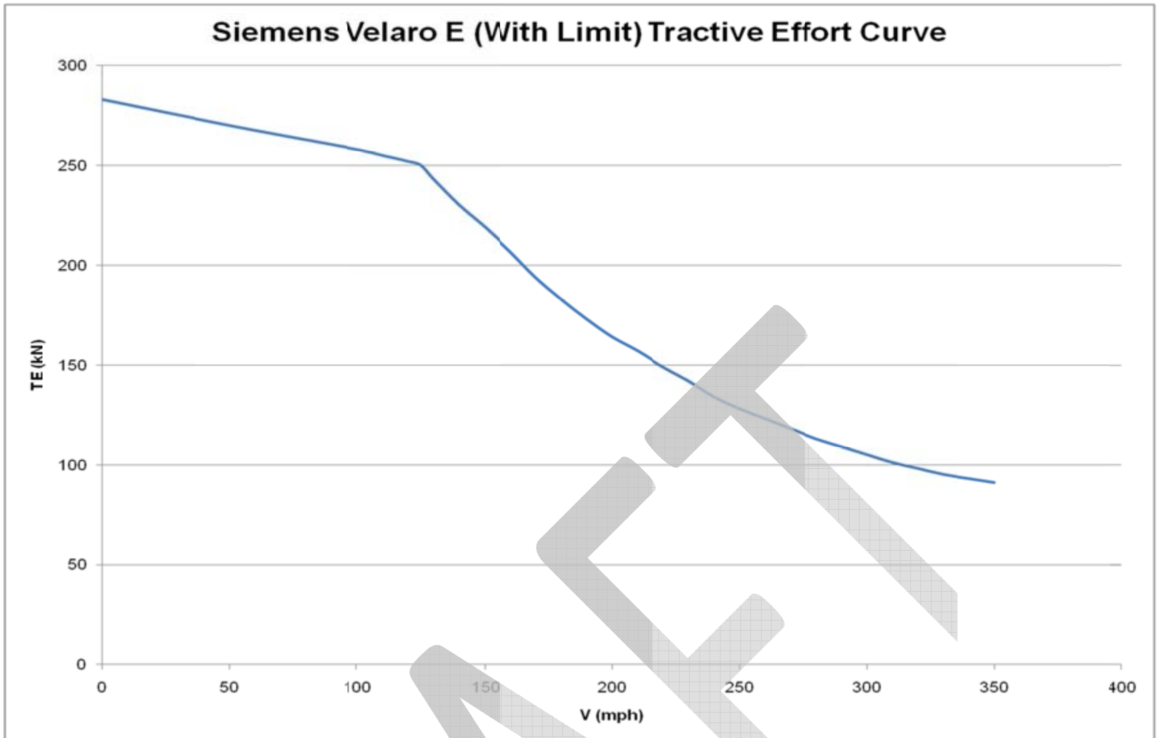
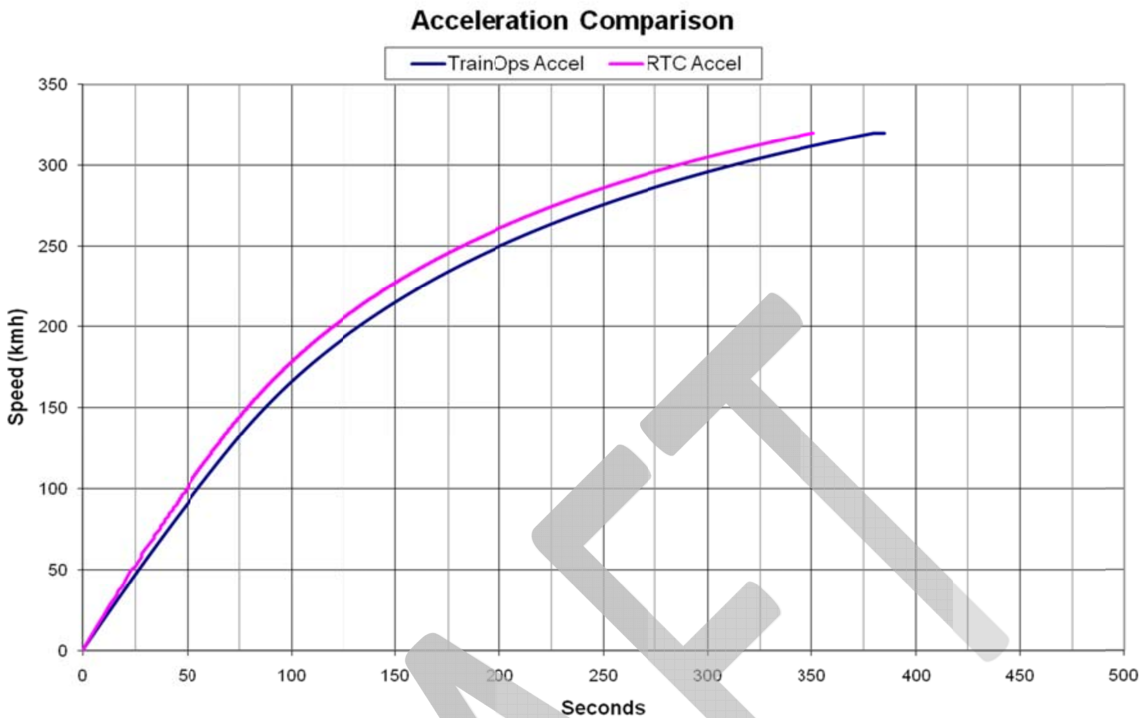


Table 6 – Siemens Velaro E High Speed Trainset Physical Characteristics

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. These simulations were revised to reflect strict processing in timetable order, with no overtakes permitted in either direction at Millbrae.

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 SF 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 SF 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	10:53a		11:53a		12:53p	

*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 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 SF 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 SF 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, 4^{th} and King, Millbrae and 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. 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 SF	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 (Includes 6% Schedule Margin)

	Average	Min	Max
22nd Street	0:00:36	0:00:36	0:01:01
Bayshore	0:00:47	0:00:33	0:01:19
Belmont	0:00:48	0:00:36	0:01:19
Burlingame	0:00:42	0:00:36	0:00:51
California Ave.	0:00:45	0:00:32	0:00:57
Hayward Park	0:00:39	0:00:34	0:00:46
Hillsdale	0:00:44	0:00:36	0:00:54
Lawrence	0:00:42	0:00:34	0:01:03
Menlo Park	0:00:47	0:00:36	0:01:10
Millbrae	0:00:46	0:00:40	0:00:52
Mountain View	0:00:52	0:00:43	0:01:15
Palo Alto	0:01:00	0:00:40	0:01:34
Redwood City	0:00:54	0:00:40	0:01:16
San Antonio	0:00:41	0:00:34	0:00:55
San Bruno	0:00:42	0:00:35	0:00:48
San Carlos	0:00:48	0:00:34	0:01:47
San Mateo	0:00:46	0:00:39	0:00:52
Santa Clara	0:00:45	0:00:34	0:01:17
South SF	0:00:46	0:00:35	0:01:19
Sunnyvale	0:00:50	0:00:36	0:01:17
Overall Average	0:00:46	0:00:36	0:01:08

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.

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.

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.

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	Trip Times (H:M:S)	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	Trip Times (H:M:S)	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	Trip Times (H:M:S)	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	Trip Times (H:M:S)	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, 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	Trip Times (H:M:S)	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	Trip Times (H:M:S)	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 SF 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 SF 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 SF 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 SF 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

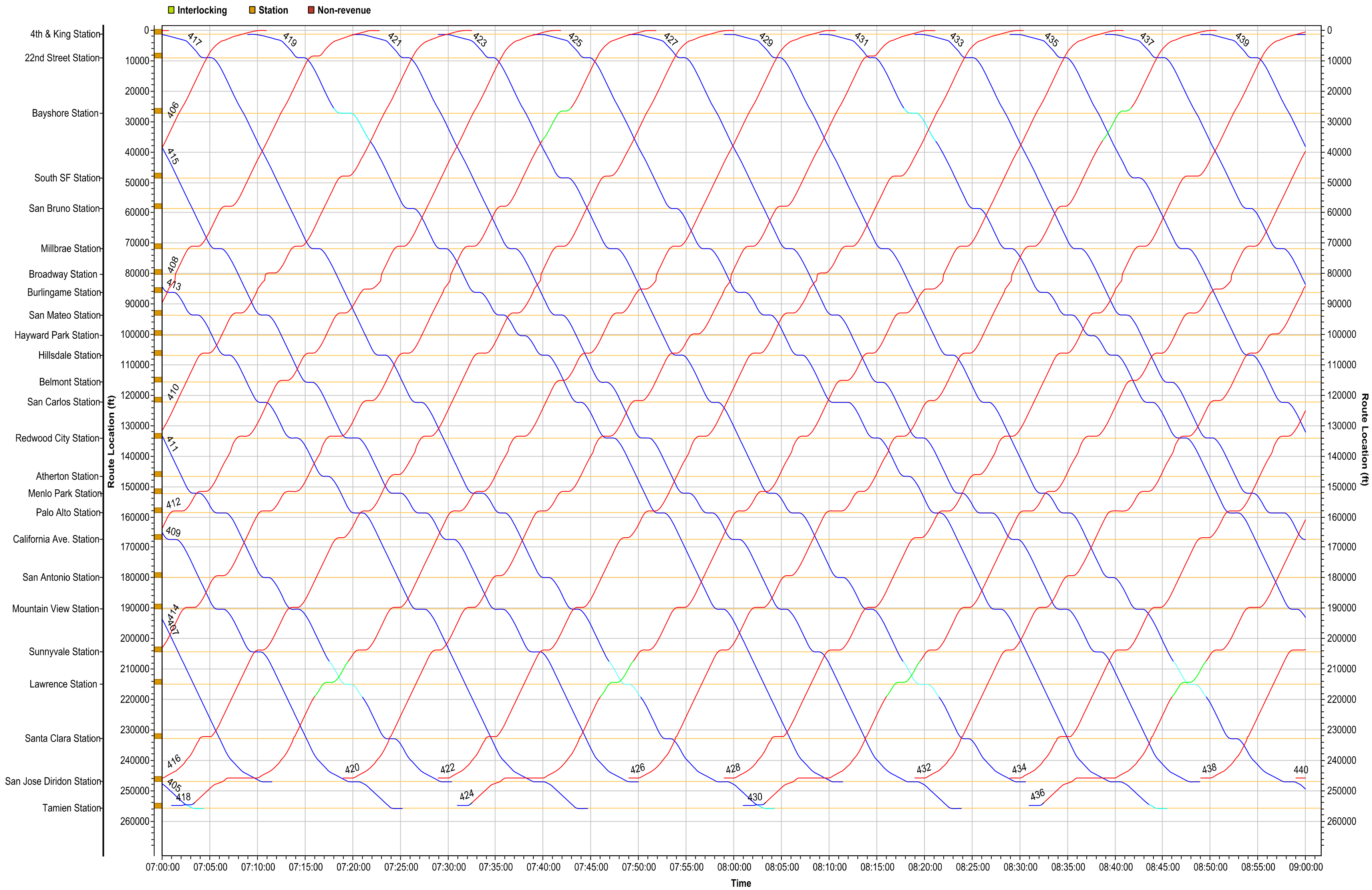


Figure 11. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 0 HSR TPH

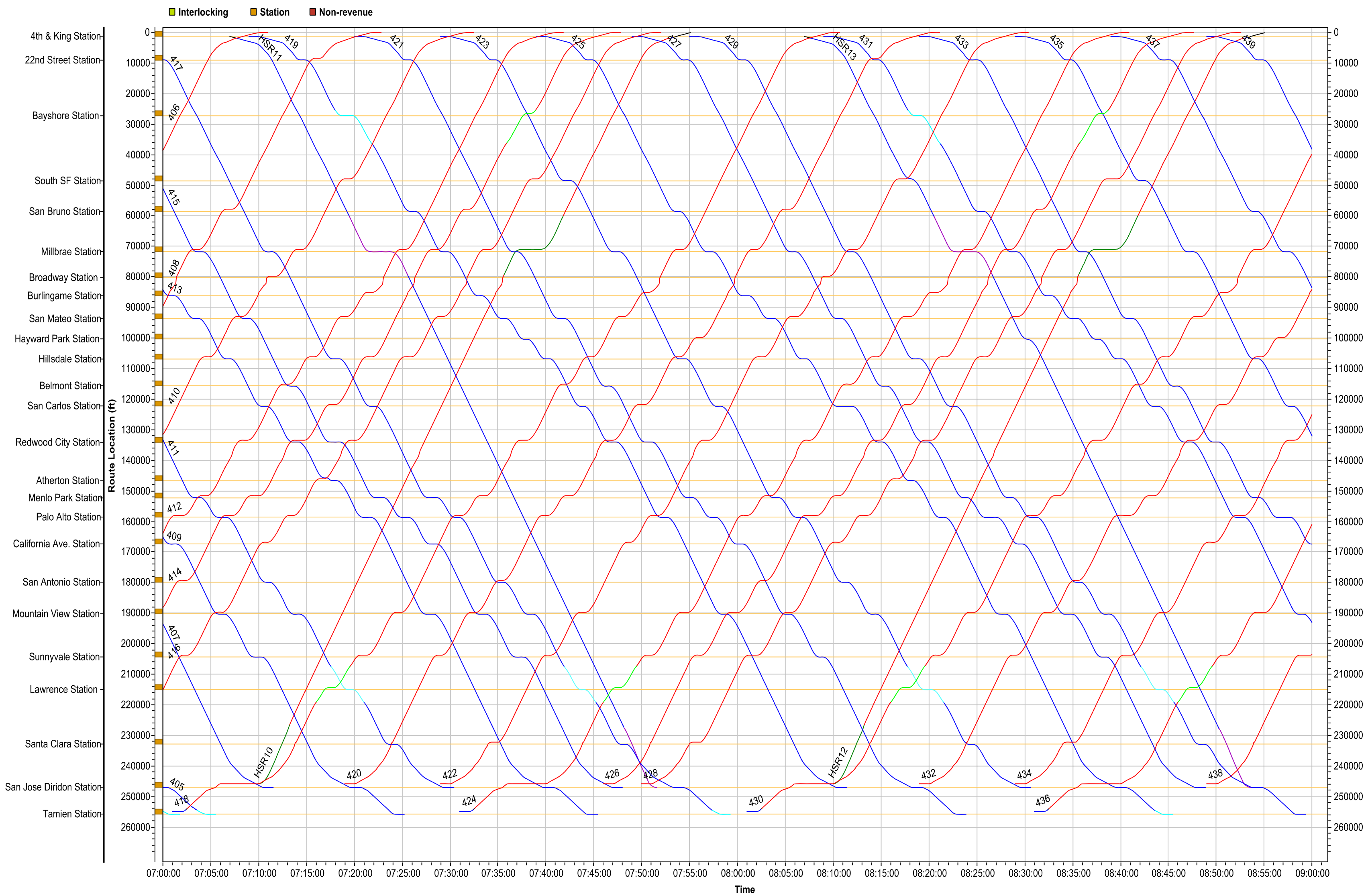


Figure 12. Time-Distance “String” Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 1 HSR TPH

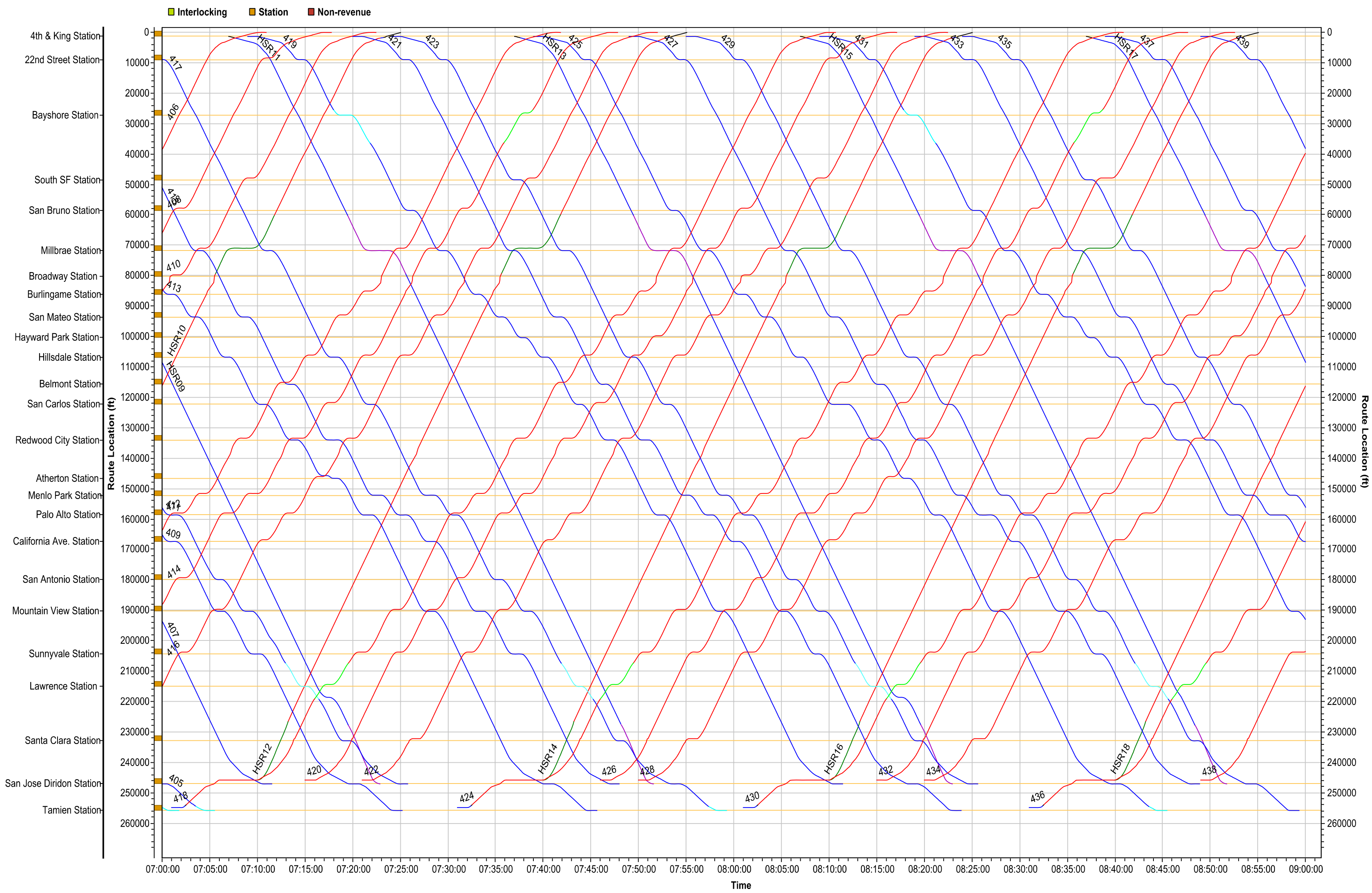


Figure 13. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 2 HSR TPH

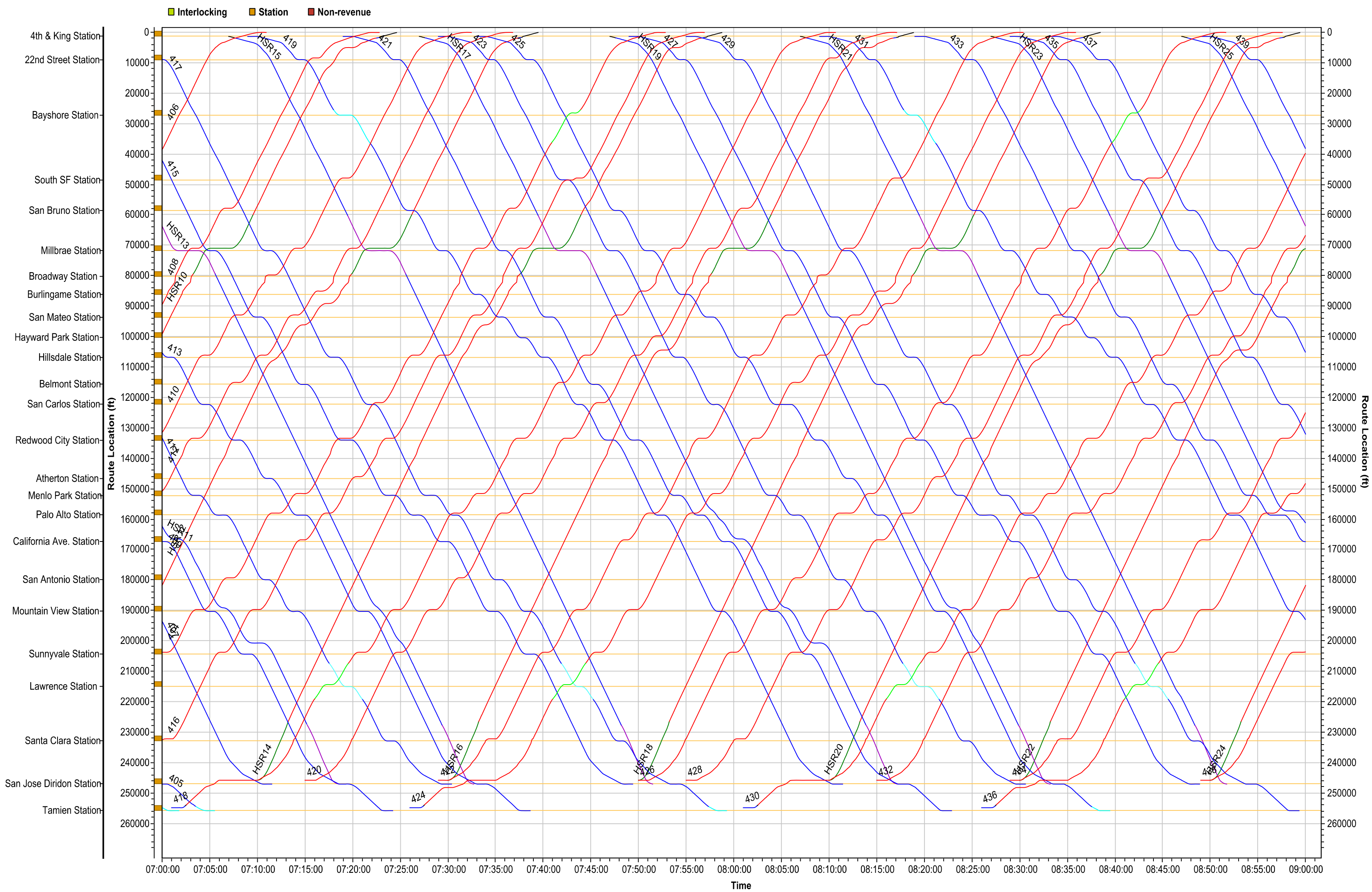


Figure 14. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Baseline Infrastructure 3 HSR TPH

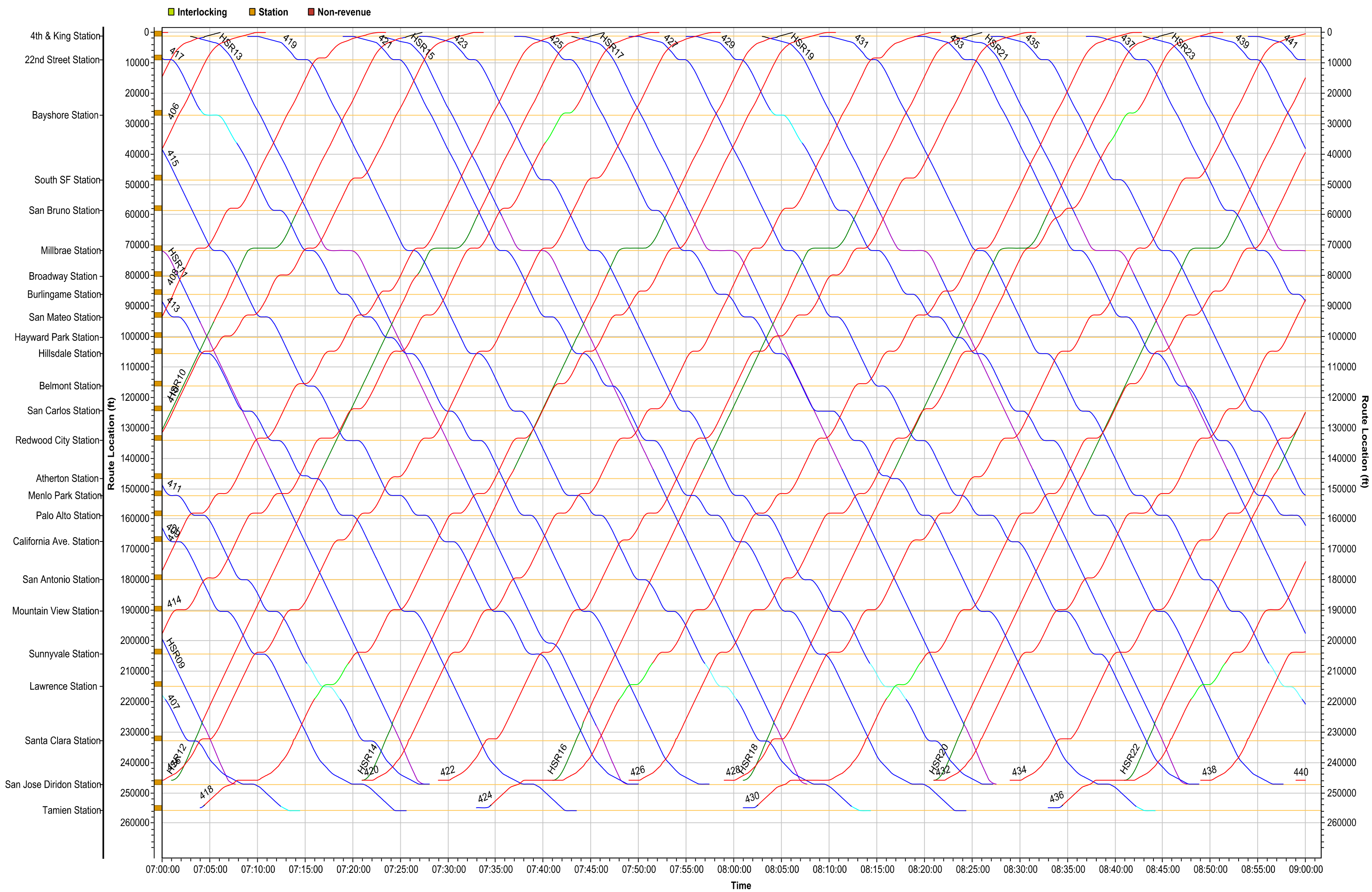


Figure 15 Time-Distance "String" Chart – 7 to 9 AM - 79/79 Full Midline Overtake 3 HSR TPH

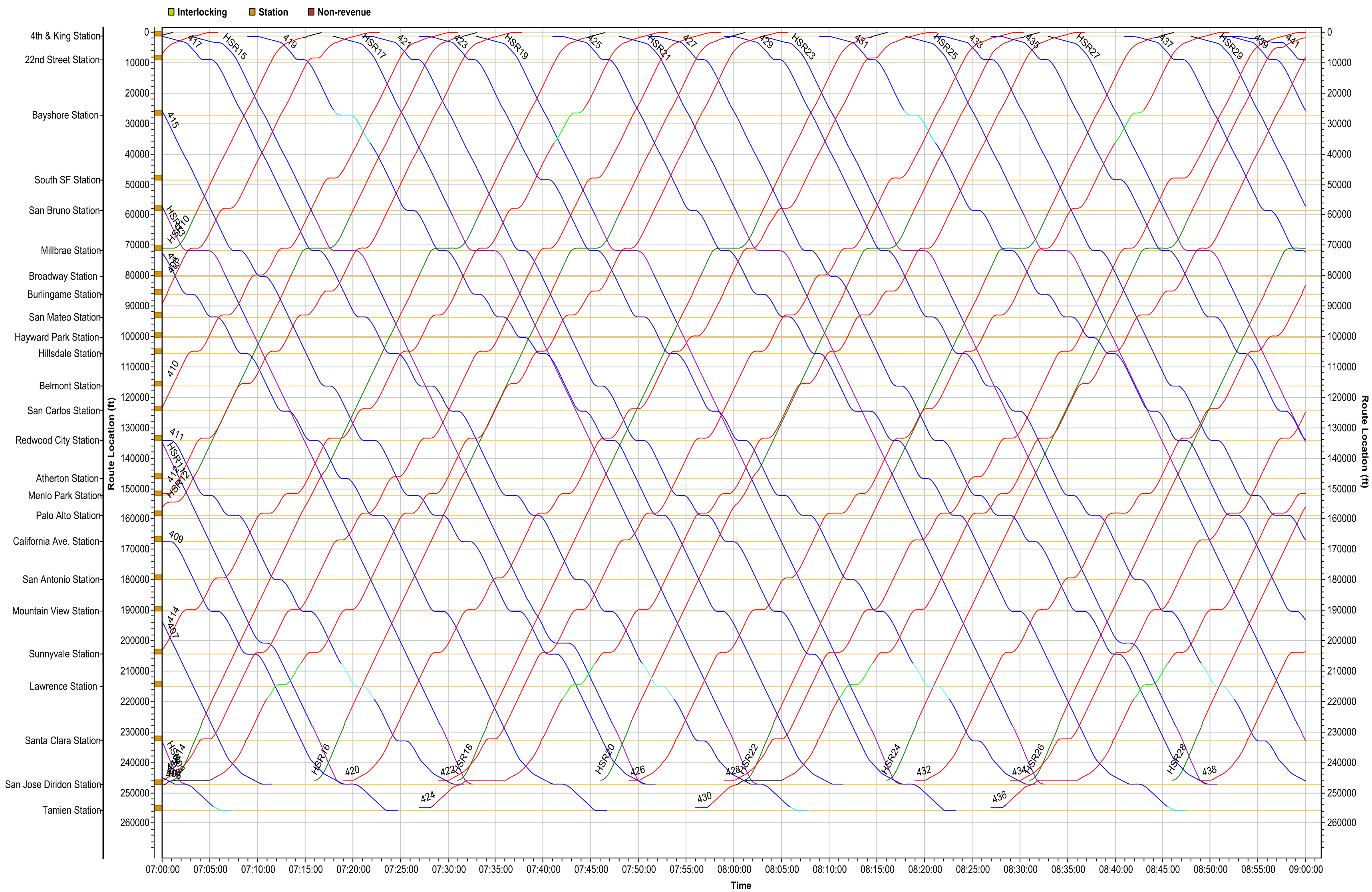


Figure 16. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Full Midline Overtake 4 HSR TPH

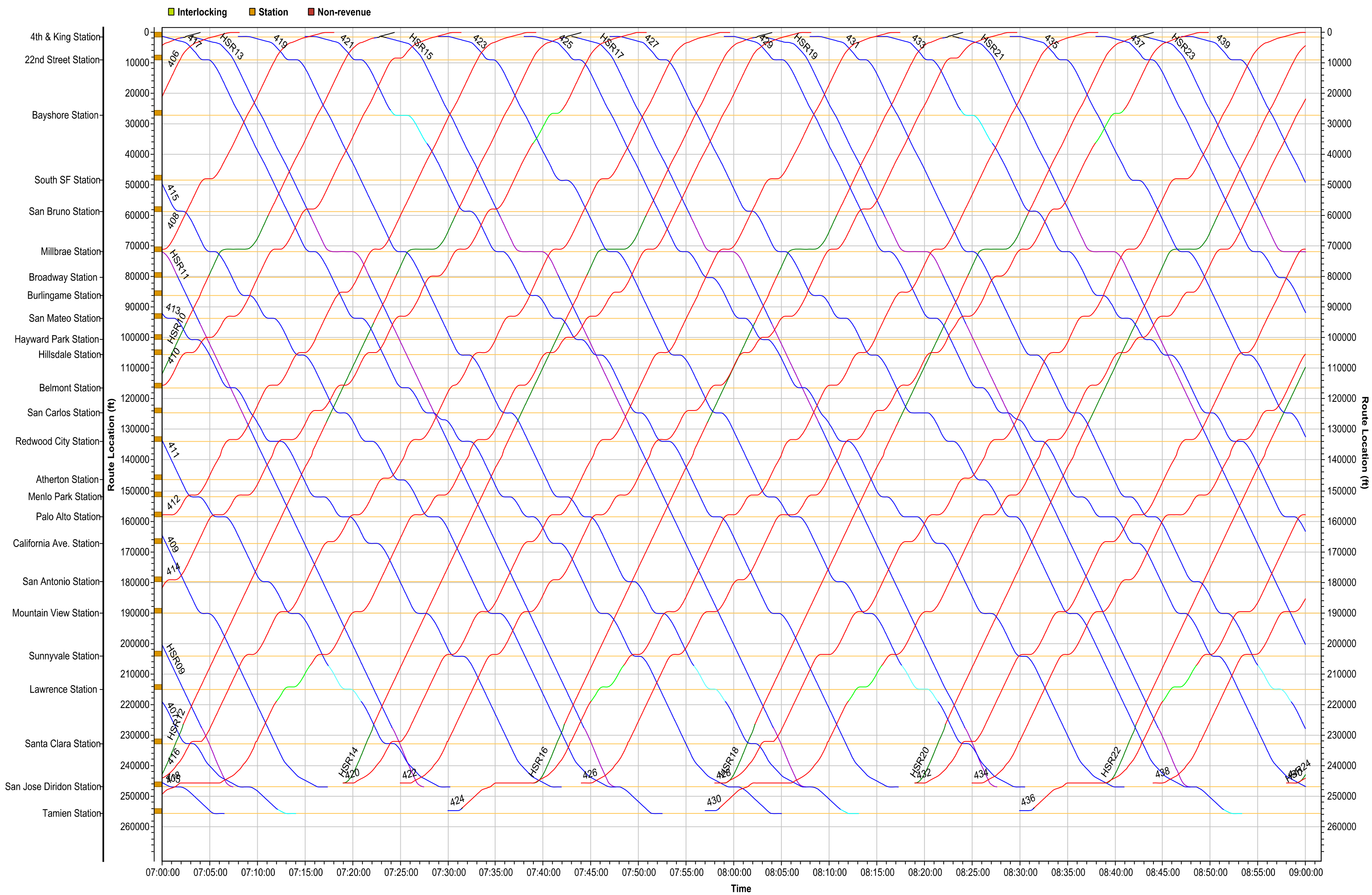


Figure 17. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Short Midline Overtake 3 HSR TPH

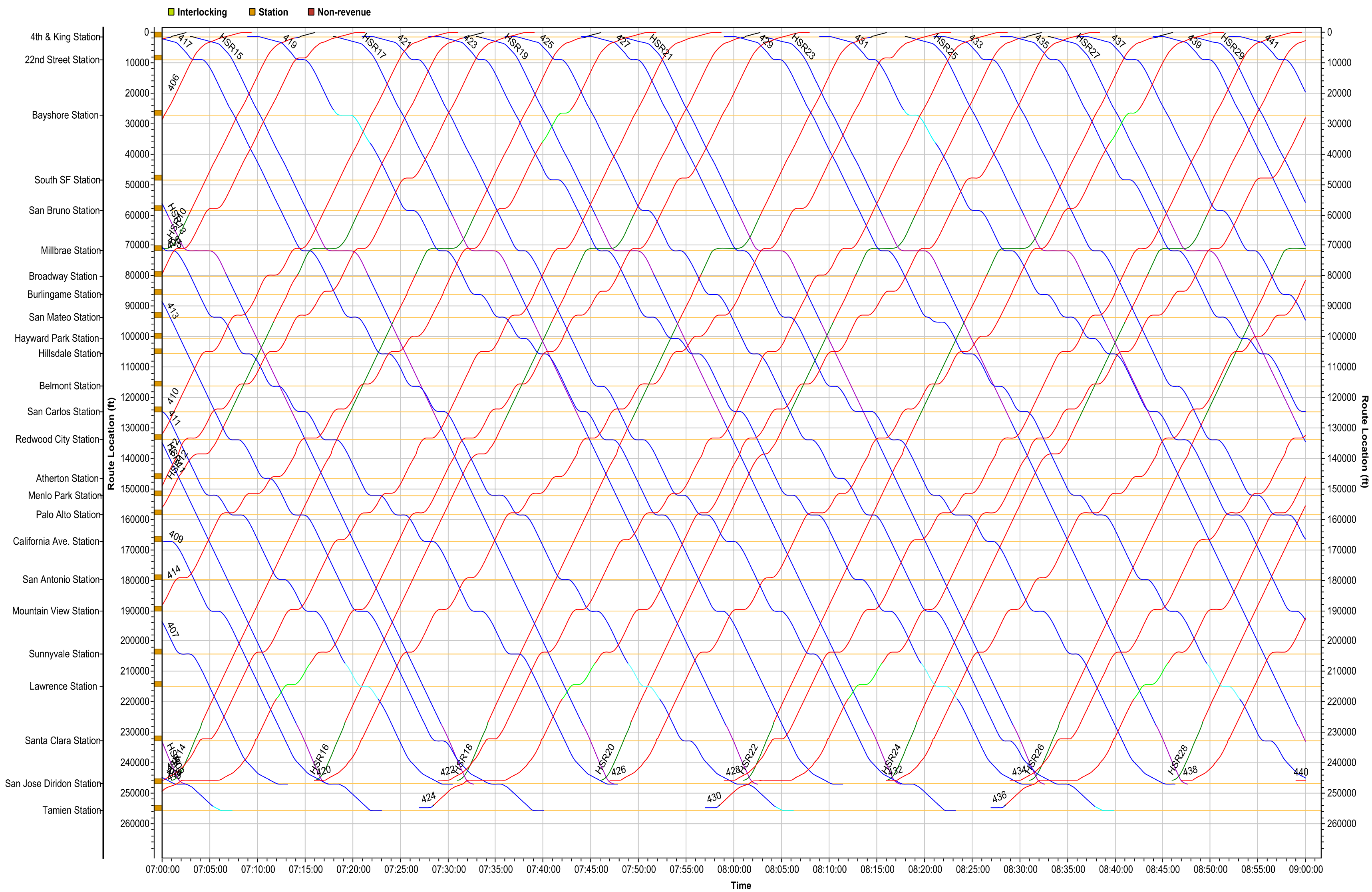


Figure 18. Time-Distance "String" Chart – 7 to 9 AM - 79/79 Short Midline Overtake 4 HSR TPH

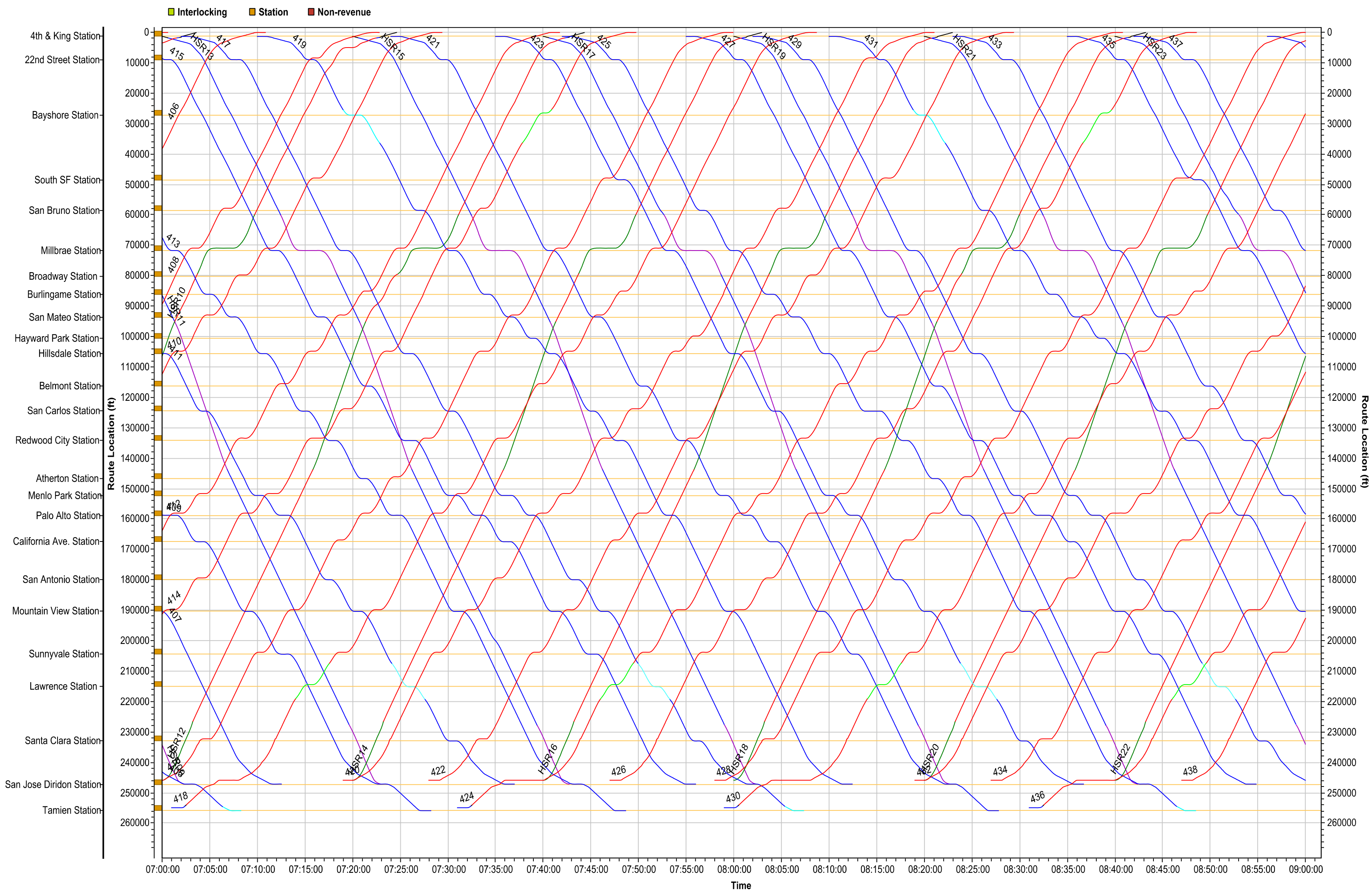


Figure 19. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Full Midline Overtake 3 HSR TPH

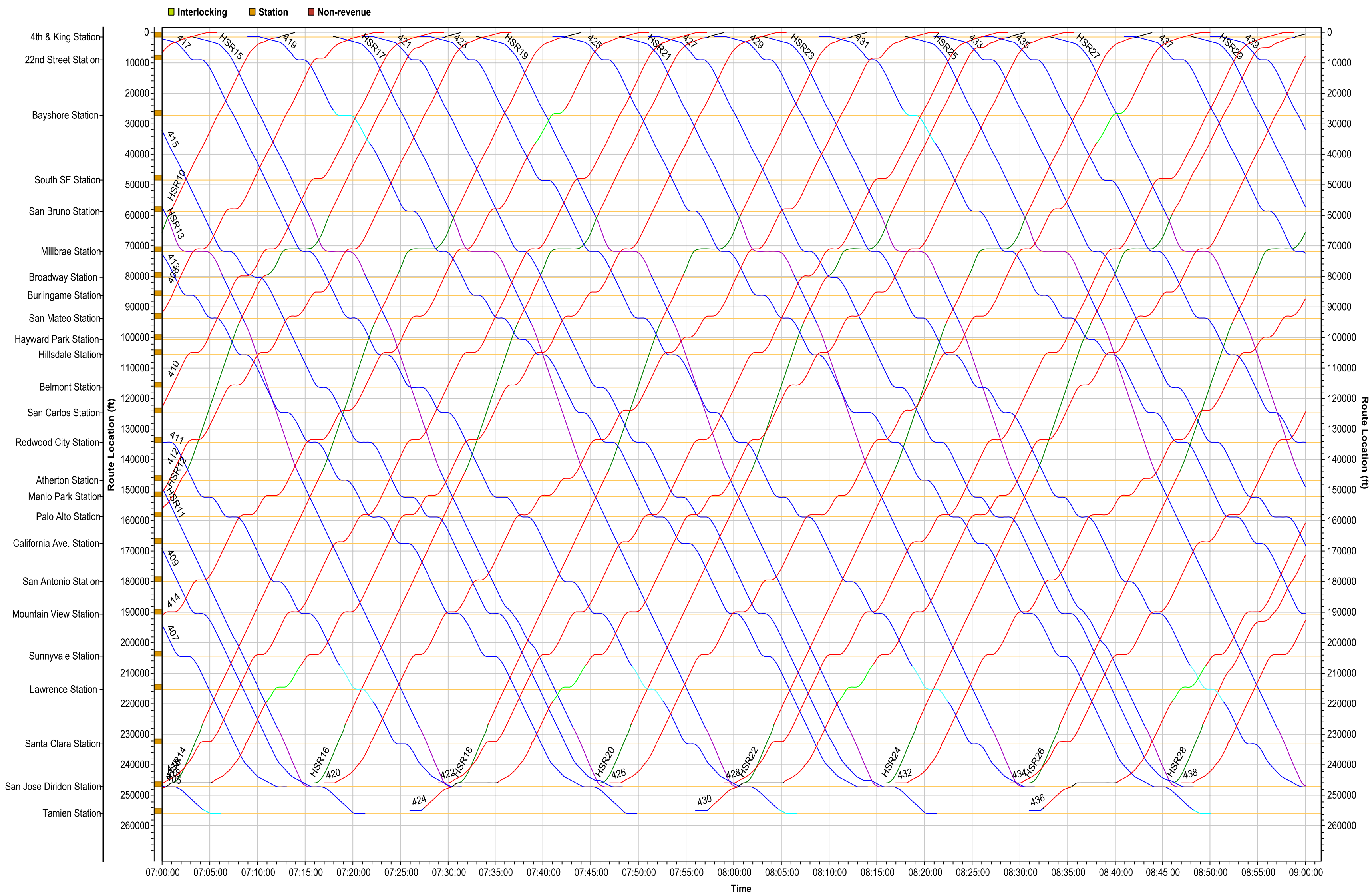


Figure 20. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Full Midline Overtake 4 HSR TPH

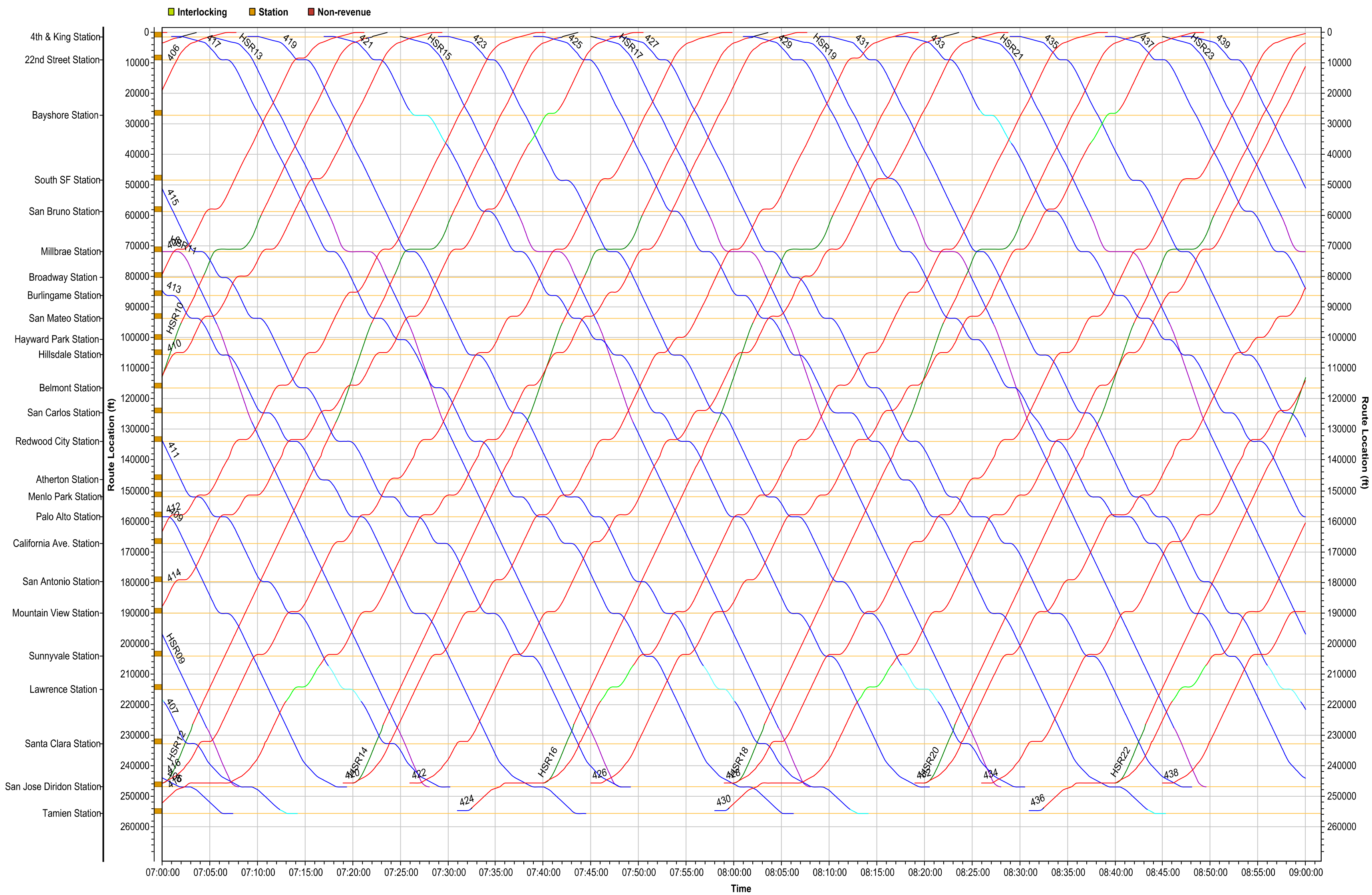


Figure 21. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Short Midline Overtake 3 HSR TPH

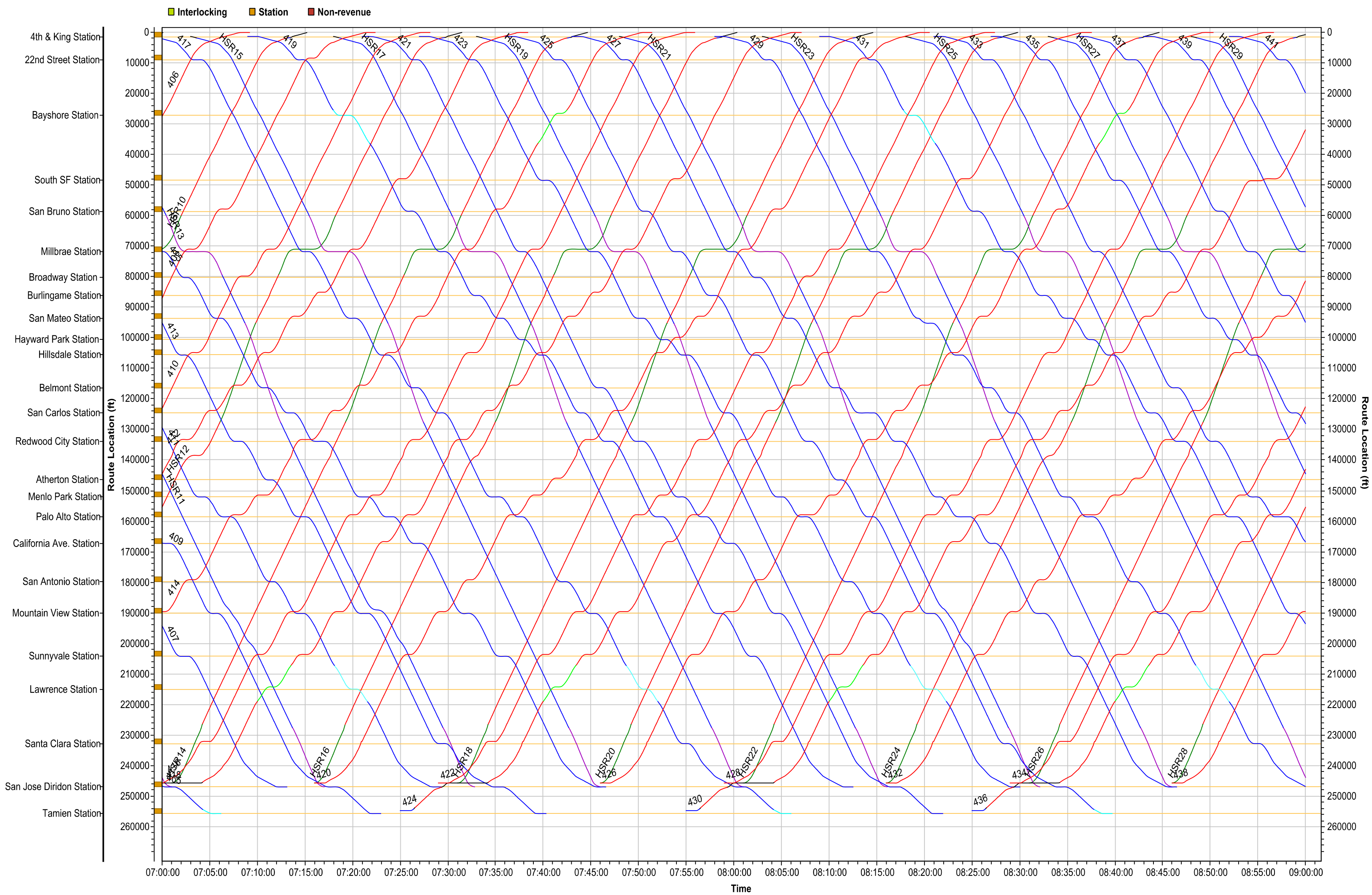


Figure 22. Time-Distance "String" Chart – 7 to 9 AM - 79/110 Short Midline Overtake 4 HSR TPH

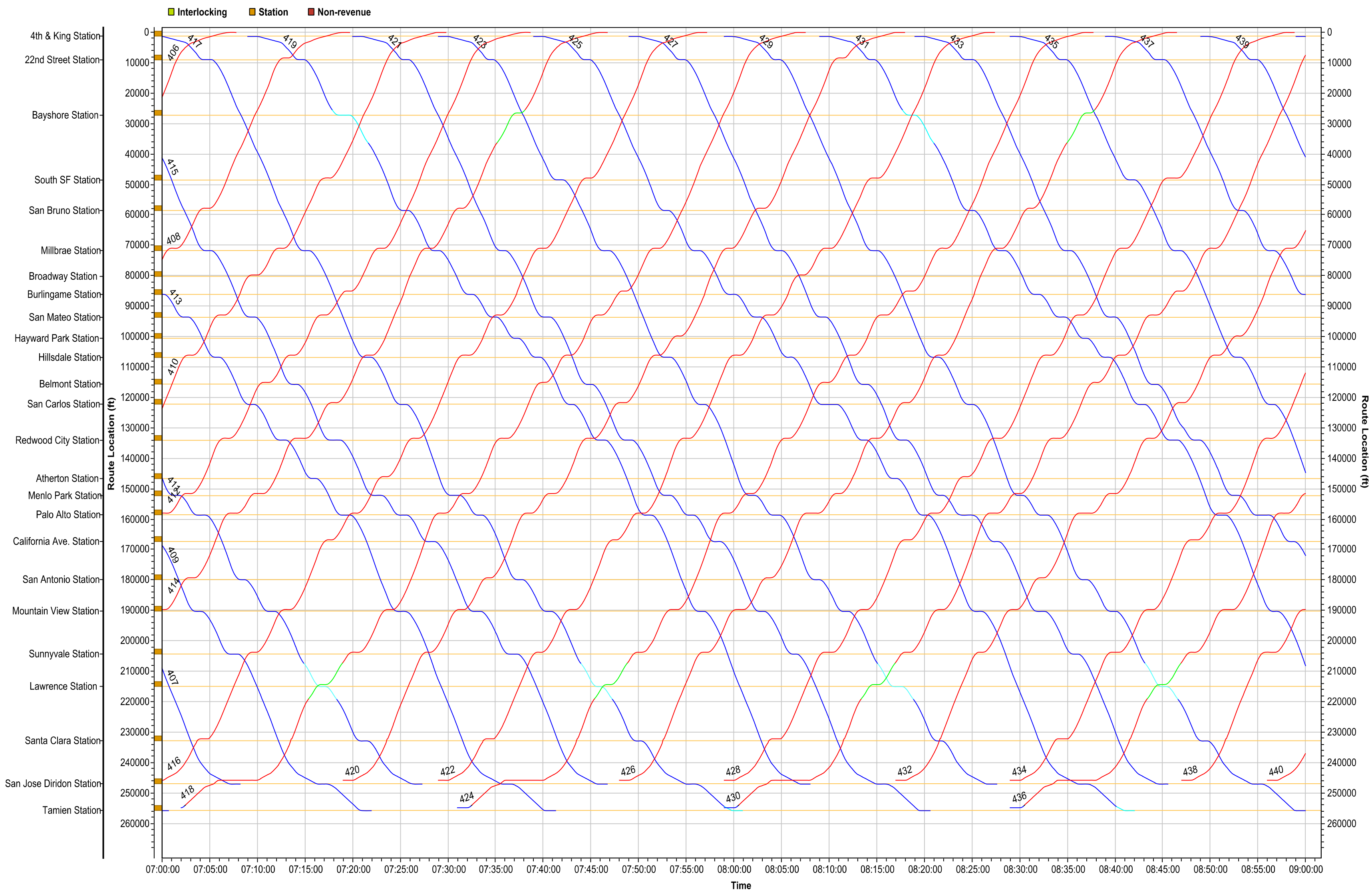


Figure 23. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Baseline Infrastructure 0 HSR TPH

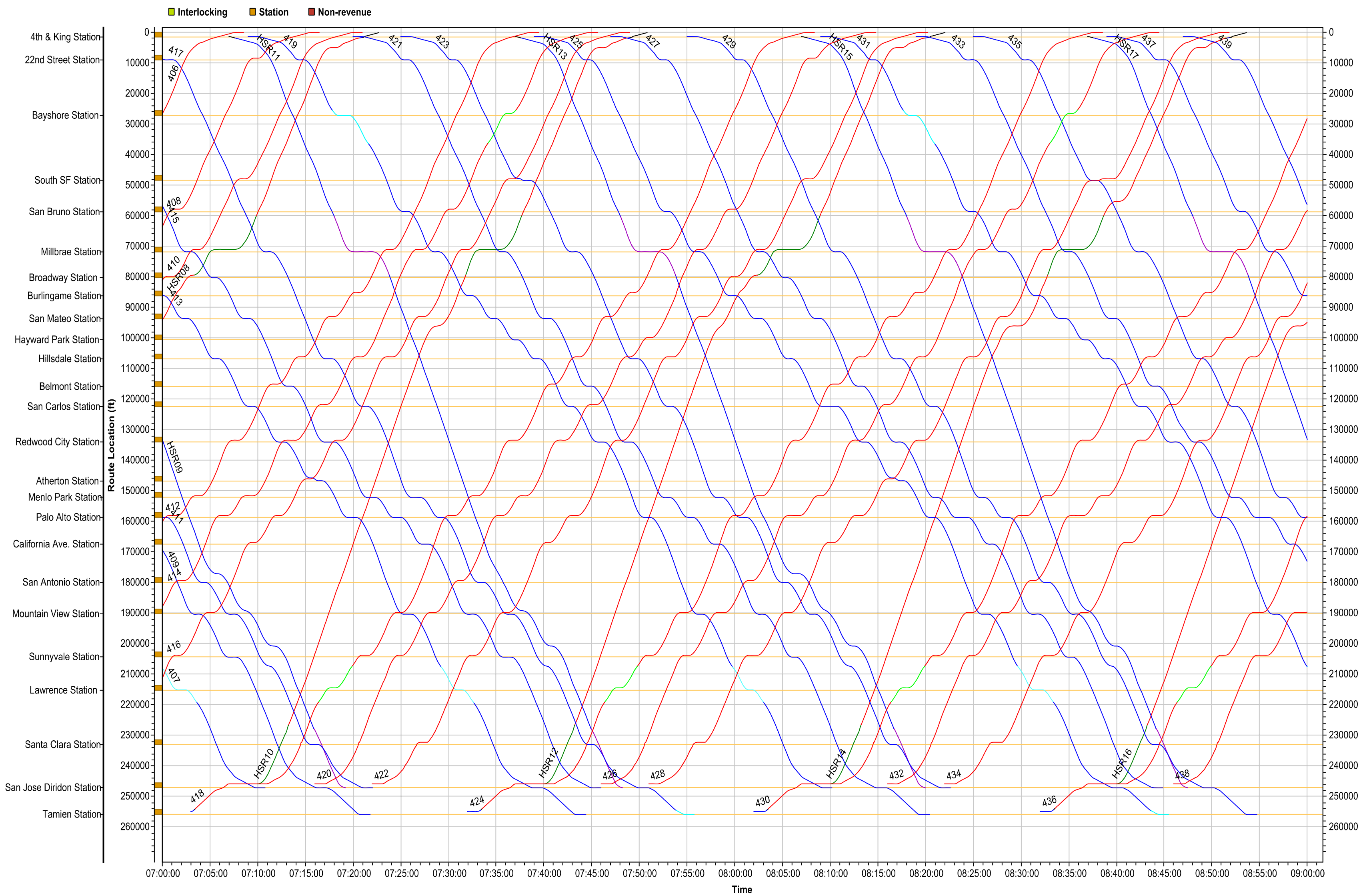


Figure 24. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Baseline Infrastructure 2 HSR TPH

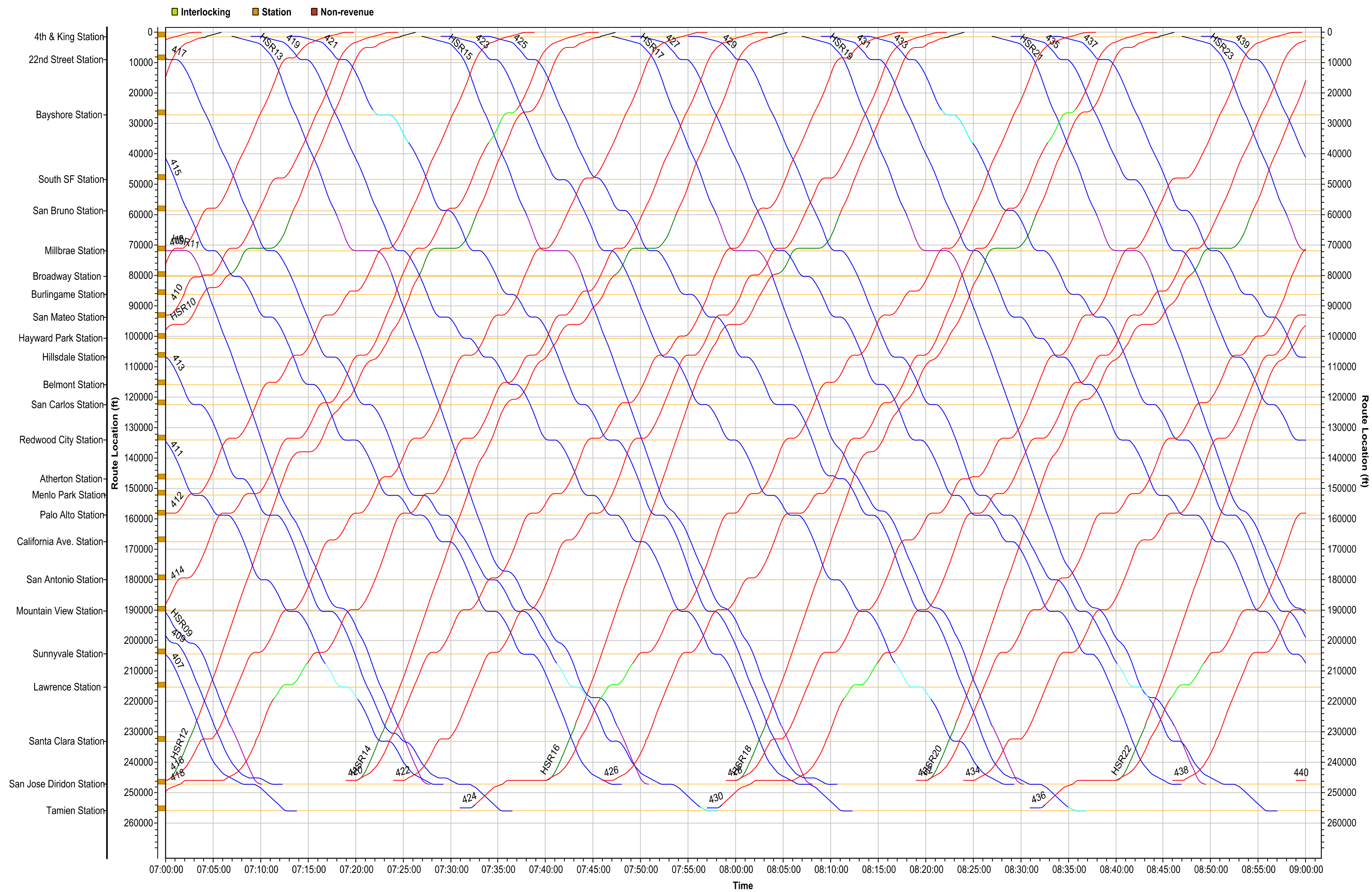


Figure 25. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Baseline Infrastructure 3 HSR TPH

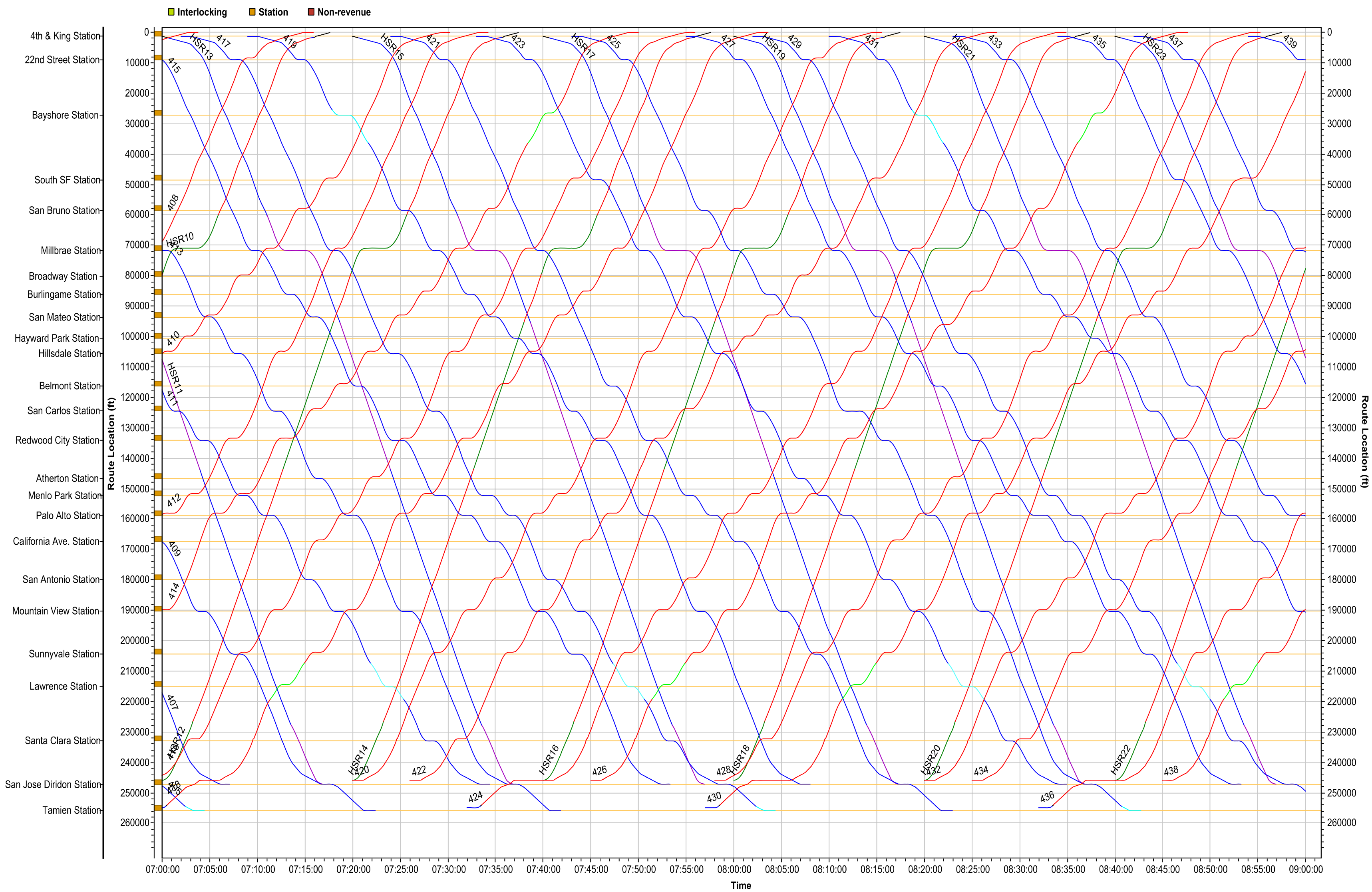


Figure 26. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Full Midline Overtake 3 HSR TPH

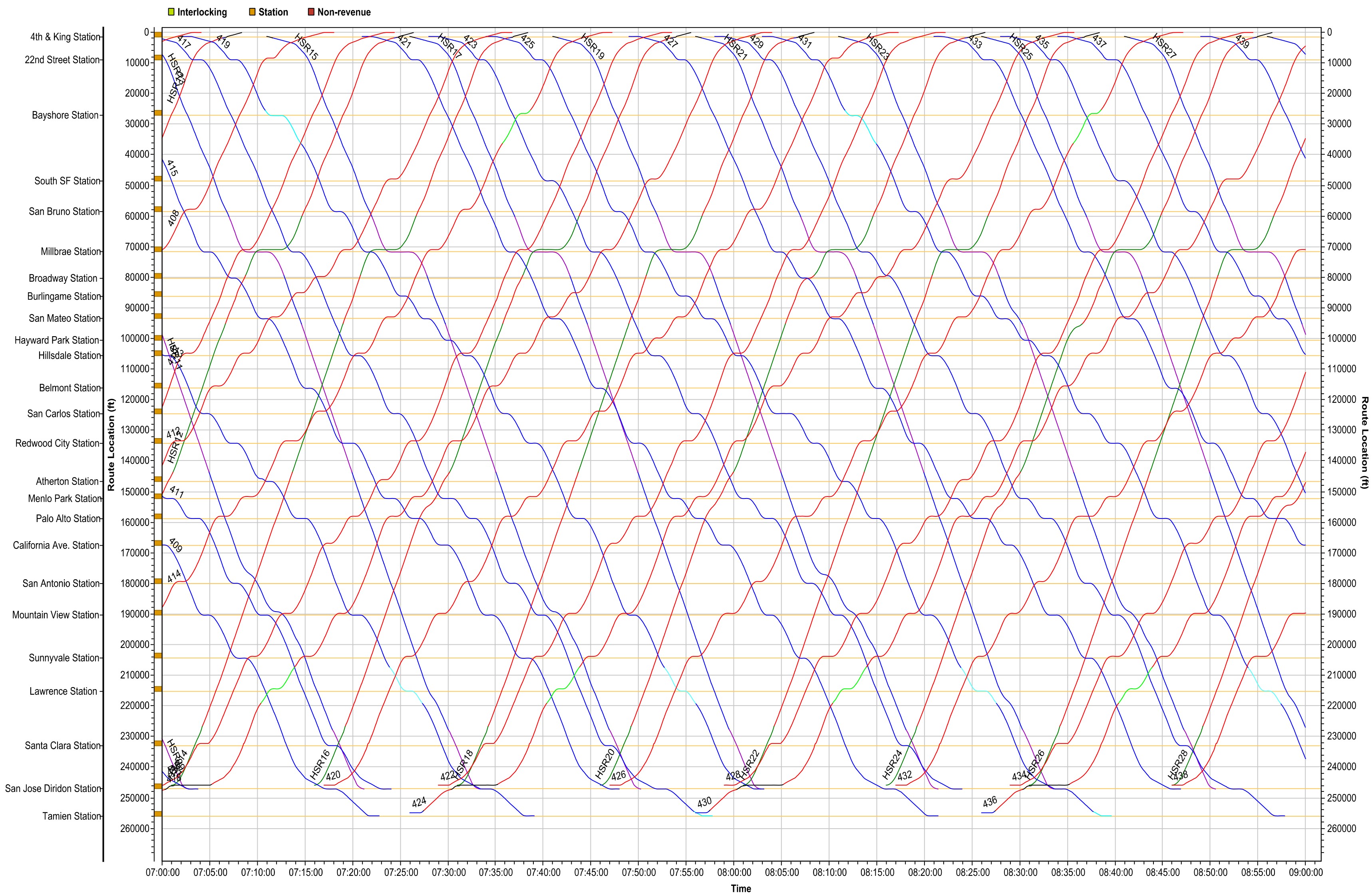


Figure 27. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Full Midline Overtake 4 HSR TPH

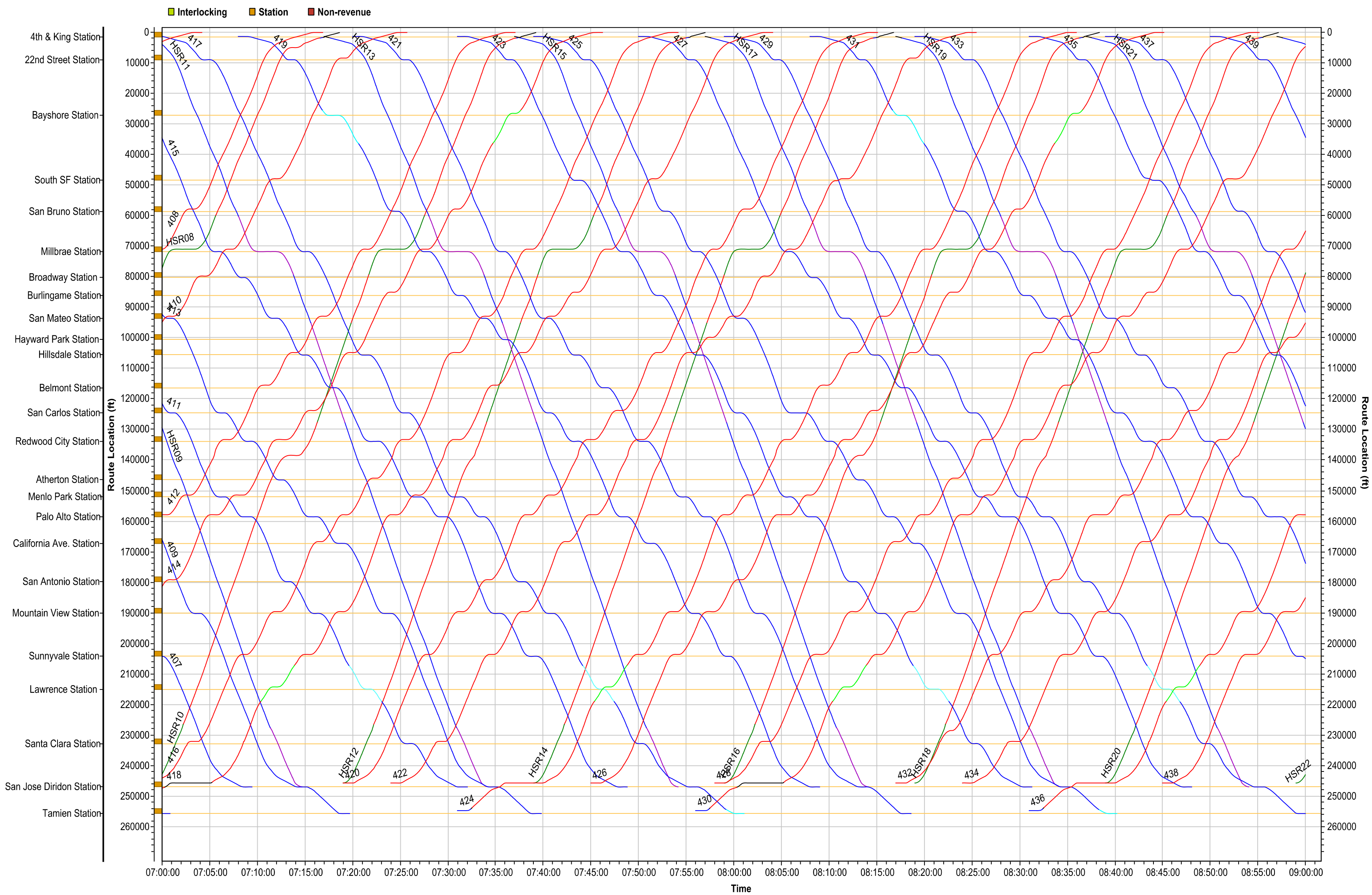


Figure 28. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Short Midline Overtake 3 HSR TPH

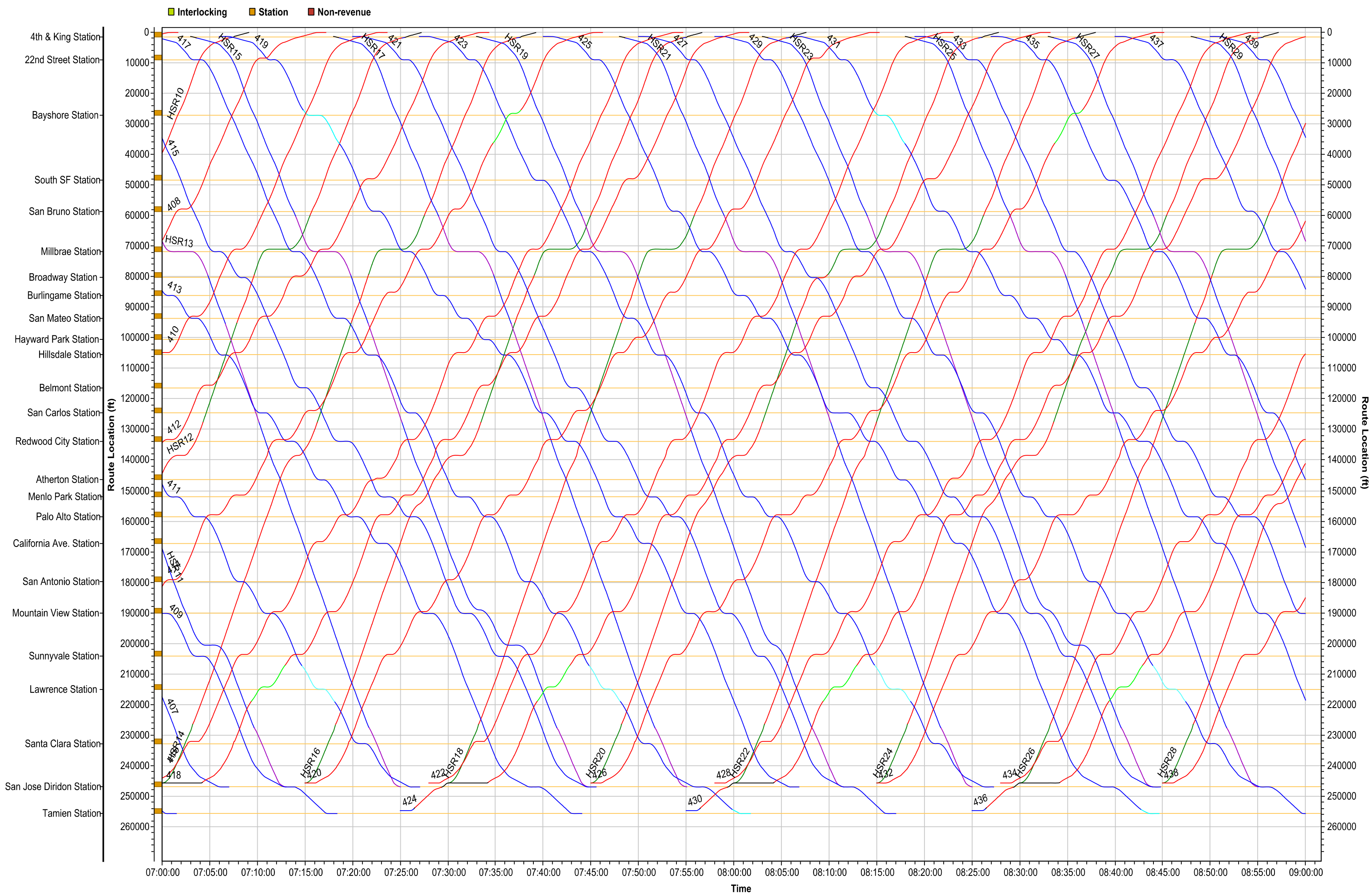


Figure 29. Time-Distance "String" Chart – 7 to 9 AM - 110/110 Short Midline Overtake 4 HSR TPH

7.2 Midday

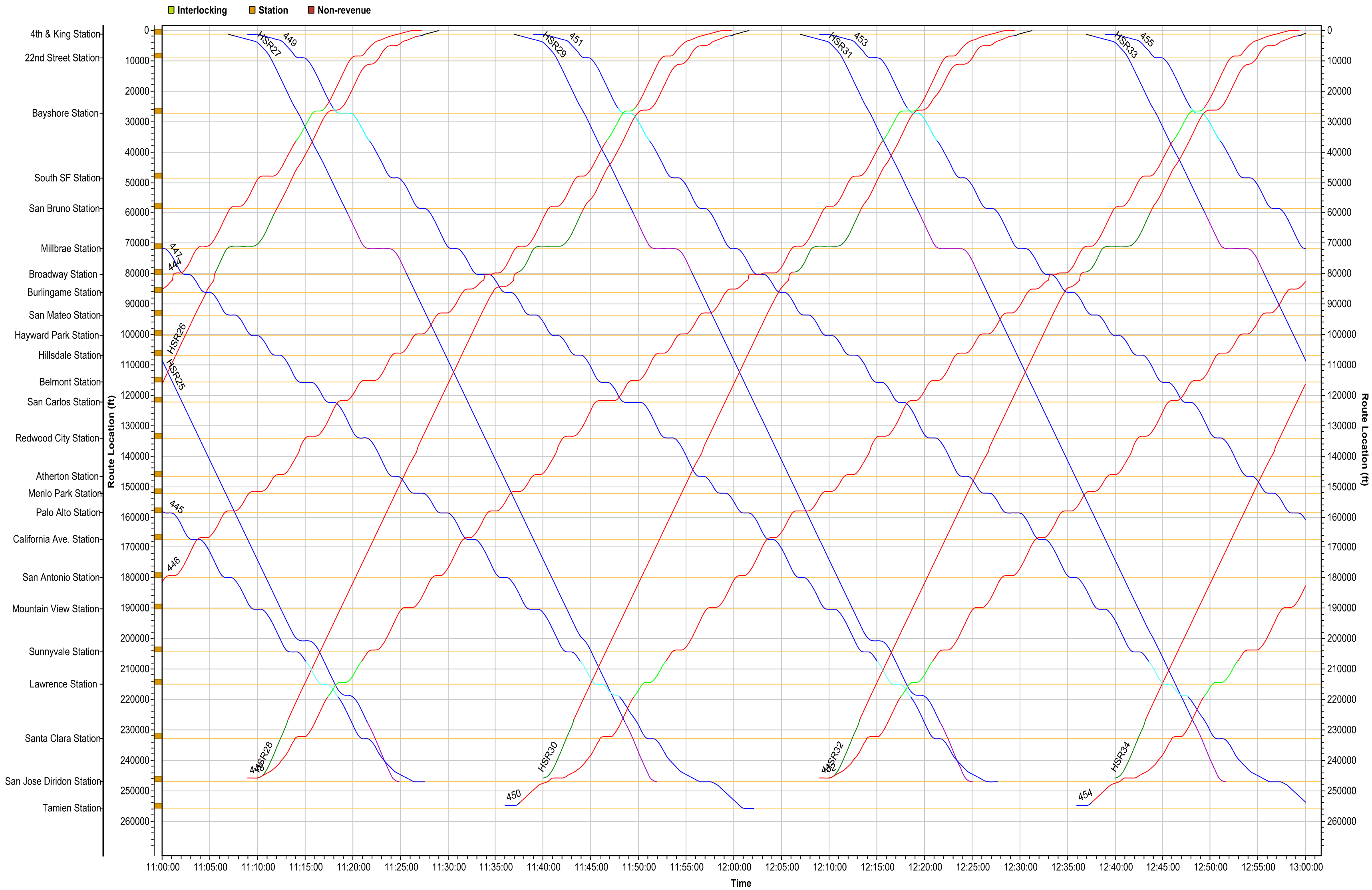


Figure 30. Time-Distance "String" Chart – 11 AM to 1 PM - 79/79 Baseline Infrastructure 2 HSR TPH

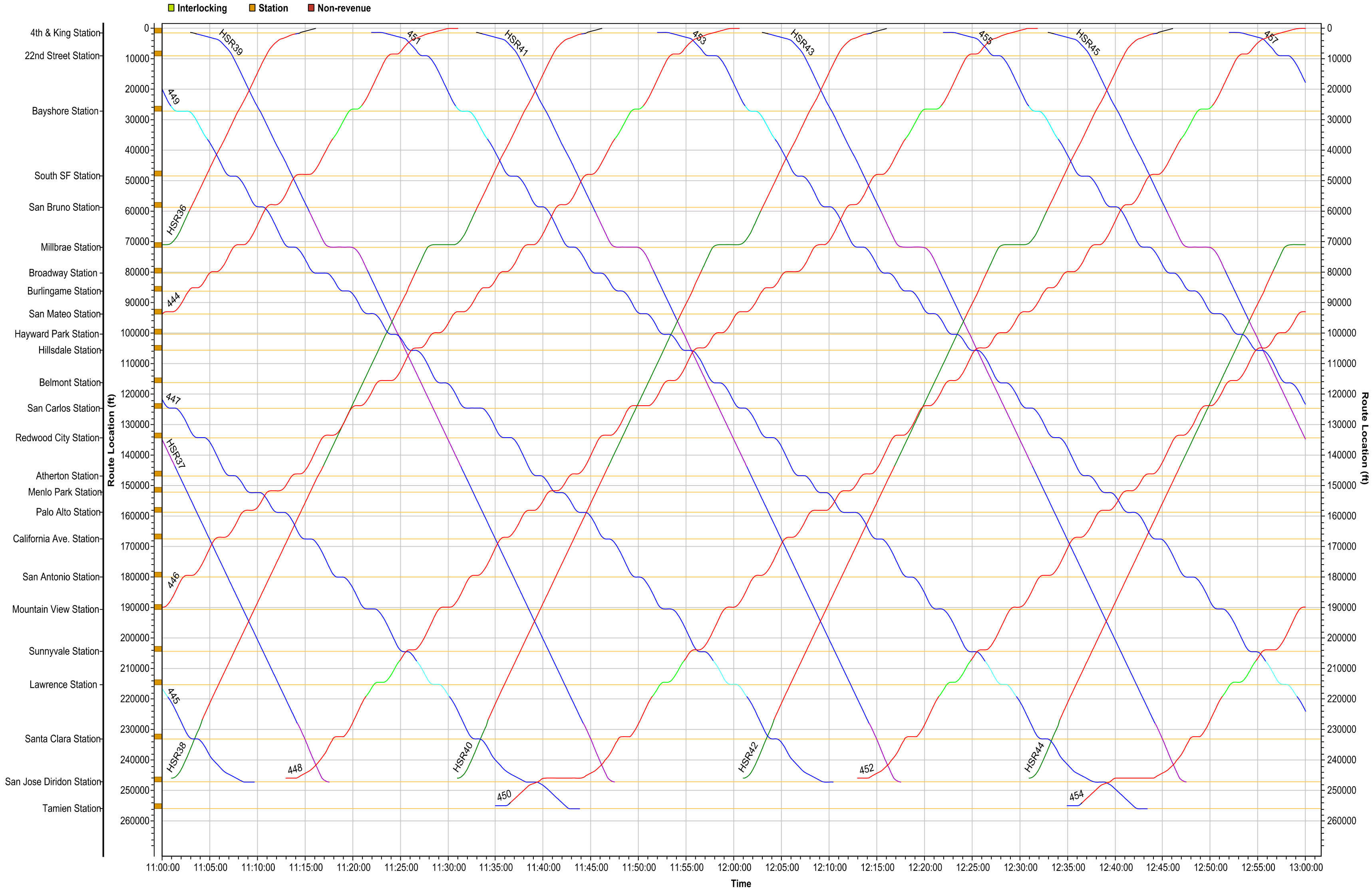


Figure 31. Time-Distance “String” Chart – 11 AM to 1 PM - 79/79 Midline Overtake 4 HSR TPH (2 HSR TPH Schedule in Off-Peak Periods)

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.

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.