

FINAL

Caltrain / HSR

Blended Grade Crossing and Traffic Analysis



Prepared for:
Peninsula Corridor Joint Powers Board (JPB)

Prepared by:
Caltrain Modernization Program Team

June 2013



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Dear Stakeholders,

During the last year, Caltrain staff with consultant support and stakeholder input, has been conducting planning efforts to advance the Caltrain Modernization program and the Caltrain/HSR blended system. This report, the ***Caltrain/HSR Blended Grade Crossing and Traffic Analysis***, is one of the efforts related to planning the Caltrain/HSR blended system.

To fully understand the key model inputs and parameters that were used in this study, it is critical to review the ***Caltrain/HSR Blended Operations Analysis*** prepared in March 2012 (<http://www.caltrain.com/Assets/Caltrain+Modernization+Program/Documents/Final-Caltrain-California+HSR+Blended+Operations+Analysis.pdf>). The 2012 analysis determined that a blended system in the peninsula is operationally viable using a computer simulation model that was specially customized for the Caltrain corridor.

The Caltrain/HSR Blended Grade Crossing and Traffic Analysis was prepared in response to stakeholders' interests in analyzing gate downtime and traffic circulation scenarios not evaluated in the *Caltrain/HSR Blended Operations Analysis*. This analysis has limited application because the results are sensitive to model inputs, including schedule and if and where passing tracks are located.

This analysis does not include any policy or planning recommendations, but serves an educational purpose. As planning for the blended system continues, additional analysis will be needed to confirm the simulations relative to on-the-ground application.

Thank you for participating in the blended system planning process. We appreciate your time and your efforts in shaping this report and partaking in the necessary discussions to shape the future of the peninsula corridor.

A handwritten signature in black ink, appearing to read "M. Lee".

Marian Lee, AICP
Executive Officer, Caltrain Modernization Program

ACKNOWLEDGEMENTS

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Executive Summary

The Caltrain Modernization Program will electrify and upgrade the performance, operating efficiency, capacity, safety, and reliability of Caltrain's commuter rail service. The program includes electrification of the peninsula rail corridor between San Francisco and San Jose, installation of an advanced signal system that includes federally-mandated safety improvements, and the replacement of Caltrain's diesel trains with high-performance electric trains called Electric Multiple Units. The program not only yields benefits to the Caltrain system but also provides the needed system foundation to accommodate the high speed rail system in the future.

The California High Speed Rail Authority's (CHSRA) statewide high speed rail service and Caltrain commuter services will share existing tracks, operating as a "blended system" between San Francisco and San Jose. The blended system will support blended service that will increase train frequency along the corridor impacting gate down time and traffic operations at at-grade railroad traffic crossings.

The study serves an educational purpose. It begins to help us understand the relationship between train traffic, gate down time and local traffic. This is the first of several planning efforts that will be needed to inform the blended system planning process – to ultimately define the blended service schedule, grade crossing improvements and local traffic circulation strategies.

It is critical that the reader review the *Caltrain/ HSR Blended Operations Analysis* (<http://www.caltrain.com/Assets/Caltrain+Modernization+Program/Documents/Final-Caltrain-California+HSR+Blended+Operations+Analysis.pdf>) to fully understand the key inputs to the TrainOps® Model and the planning parameters for defining the future blended system services.

The TrainOps® Model (used for the *Caltrain/ HSR Blended Operations Analysis*) for simulating future gate down times and Synchro Model for simulating local traffic were used for this study. Because the simulated corridor is assumed to be electrified with enhanced performance compared to today's system, some of the results of the simulations may appear counter intuitive. The following are the key findings:

Gate Down Time

Based on evaluation of each of the existing 40 at-grade crossings along the blended system:

- From a systemwide gate down time perspective, the total difference between 5 Caltrain trains/peak hour/direction (operating in our current system) and 6 Caltrain trains/peak hour/direction (operating in an electrified system) is negligible.
- Increasing train service in a modernized corridor does not result increases in gate down times at all of the at-grade crossings. At some of the crossings there are increases, but in others, decreases.
- Number of gate events and gate down time per event effect gate down time. For the Caltrain corridor, increasing the number of trains does not necessarily increase gate events and gate down time per event. With the elimination of "double gate action," improved gate downtime

efficiencies (which can be achieved with the advanced signal system), and overlapping trains at crossings, in several incidences, even with increased train service, there is a reduction in gate down (per hour) at select crossings.

It is very important to note a high level of sensitivity between the assumed schedules and passing track location and simulated gate down time results. The schedule is prototypical and the location of the passing tracks has not yet been determined. The gate downtime results should not be used in absolute terms.

Local Traffic

Five sample intersections were analyzed. They were casually selected from each of the three counties in the blended system. They were also chosen to reflect pre-empted and non pre-empted intersections and passing track and non passing track locations.

The number of gate events and average gate down time per event are the key factors that impact the local traffic simulation results. Results at the 5 sample intersections should not be applied to the rest of the intersections along the corridor. Findings at each of the analyzed intersections are particular to their respective physical and operating environments and are described in detail in this report.

Chapter 1

Introduction

The Caltrain Modernization Program will electrify and upgrade the performance, operating efficiency, capacity, safety, and reliability of Caltrain's commuter rail service. The program includes the electrification of the peninsula rail corridor between San Francisco and San Jose, installation of an advanced signal system that includes federally-mandated safety improvements, and the replacement of Caltrain's diesel trains with high-performance electric trains called Electric Multiple Units (EMUs). The program not only yields benefits to the Caltrain system but also provides the needed system foundation to accommodate high speed rail in the future.

The California High Speed Rail Authority's (CHSRA) statewide high speed rail service and Caltrain commuter services will share existing tracks, operating as a "blended system" between San Francisco and San Jose. The blended system will support blended service that will increase train frequency along the corridor impacting gate down time and traffic operations at at-grade railroad traffic crossings. The purpose of this study is to begin to understand, with a modernized system:

- How the blended service plans potentially impact gate times; and
- How the changes in gate down times potentially impact local traffic at existing at-grade crossings.

This information should be used to inform future decision-making on how grade crossings should be improved to support modernization of the corridor and future blended services. Of high interest to all stakeholders is understanding if and where grade separations are needed to support a blended system. Since this corridor is not contemplating speeds over 125 mph, grade separations¹ are not required. The Peninsula Corridor Joint Powers Board (JPB) with its stakeholders will need to go through a planning process to figure out what makes sense in terms identifying and prioritizing future grade separations.

It must be understood that all of the analysis in this study is based on a future modernized environment and prototypical blended service plans. **It is critical to review the *Caltrain/ HSR Blended Operations Analysis*² to specifically understand what the performance attributes of the modernized environment are and how the potential future blended service plan concepts were developed.**

The service plans being evaluated in this study, developed in the *Caltrain/ HSR Blended Operations Analysis*, include the following:

- Caltrain only, no HSR – 6 Caltrain trains per peak hour per direction ("6/0" scenario);
- Caltrain + HSR – 6 Caltrain plus 2 HSR trains per peak hour per direction ("6/2" scenario); and

¹ There is only one FRA law that requires grade separations. That is if train speeds exceed 125mph.

² Report available on Caltrain website.

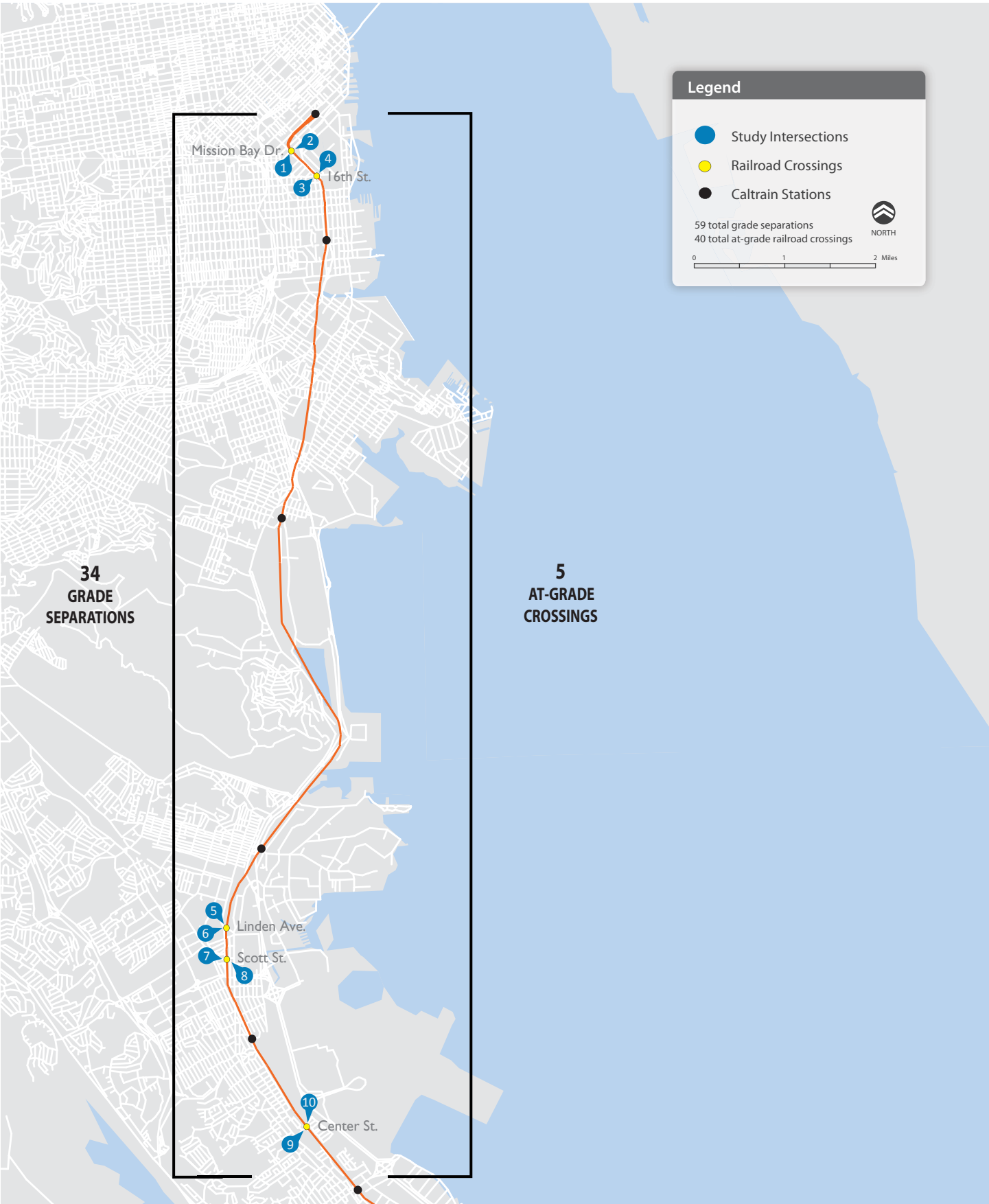
- Caltrain + HSR – 6 Caltrain plus 4 HSR trains per peak hour per direction (“6/4” scenario).

These service plans reflect the potential incremental changes to the service in the corridor. It is important to note that the “6/4” scenario assumes passing tracks in the middle of the corridor. This assumption does not reflect a decision about if and where passing tracks will go. It is an assumption made for the purpose of understanding how the “6/4” scenario with passing tracks impacts gate down time and local traffic compared to the “6/2” and “6/0” scenarios.

The blended system study area is shown in **Figure 1-1**. The north, middle and southern portions of the study corridor are shown on individual pages. The figure shows the existing at-grade railroad crossings, adjacent traffic intersections as well as the existing grade separations within the blended system project limits. The existing at-grade crossings in San Bruno that are planned to be grade separated in the near future are not included.

The following chapters provide information on methodology and the analysis. Specifically, Chapter 2 captures the key aspects of the simulation model used for the gate down time analysis and the model used for the local traffic analysis. Chapter 3 presents the simulation results of the changed gate down times, and Chapter 4 presents the simulation results of the changed local traffic associated with the gate down time. The report ends with Chapter 5 capturing the key conclusions of the study.

Also included in the report are six appendices. Appendix A provides definition of key terms used in the study. Appendix B is information on train horn sounding and quiet zone rules. Appendix C includes a summary of the planning process. Appendices D and E outline the traffic methodology and detailed model results. Lastly, Appendix F includes the gate down time simulation sensitivity test results.



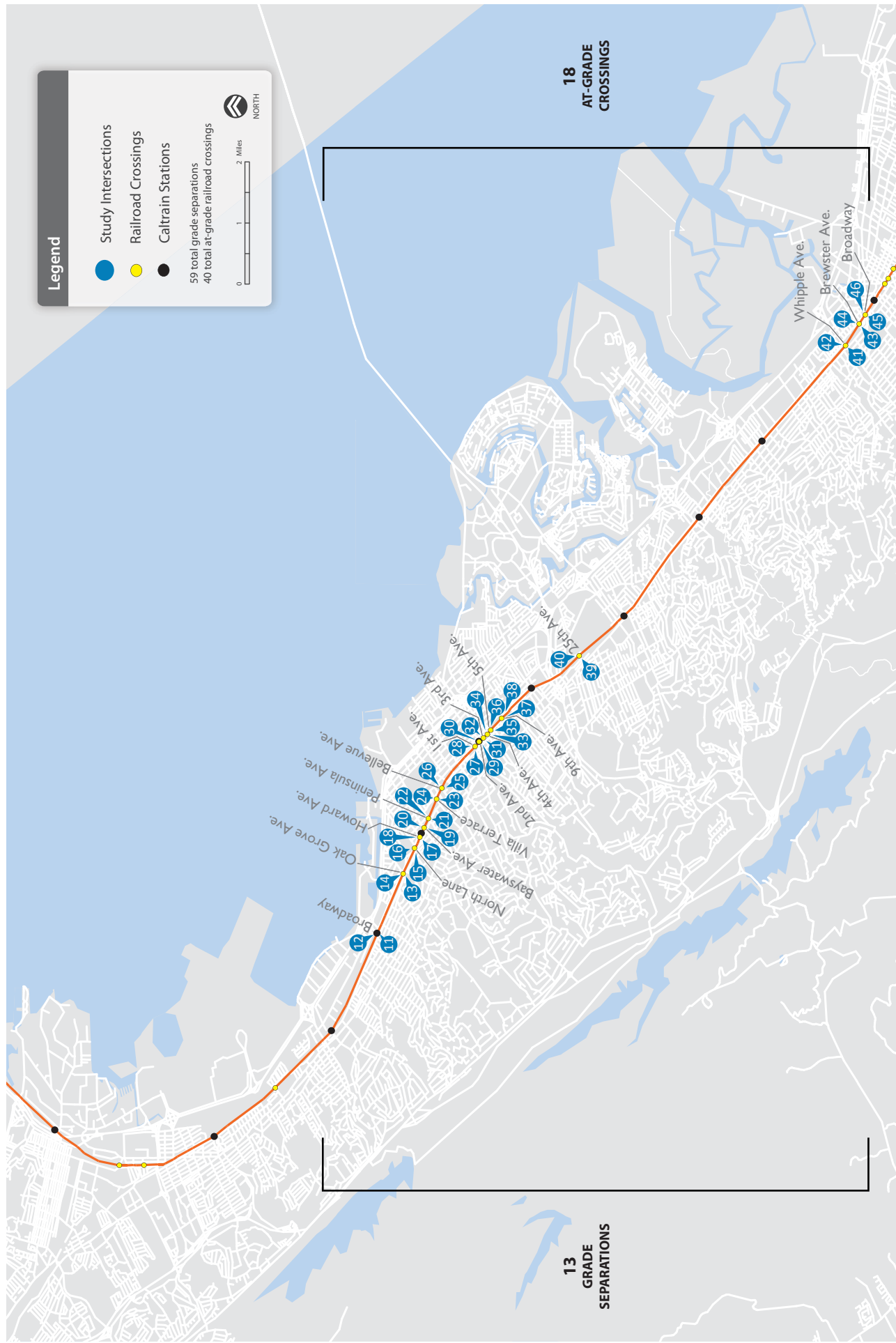


Figure 1-1: Study Area



Figure 1-1: Study Area

Chapter 2

Context: Assumptions and Methodology

This study builds on the analysis completed in the March 2012 *Caltrain/ HSR Blended Operations Analysis*.

It is important for the reader to be familiar with the March 2012 analysis in order to understand and appreciate the findings included in this study.

There are two analysis components to this study: the first is the gate down time simulations, and the second is the traffic analysis. The gate down time simulation uses the same methodology and computer simulation model used for the March 2012 analysis. The traffic analysis was performed using Synchro, a traffic planning tool.

An overview of the analysis methodology is exhibited in **Figure 2-1**.

Figure 2-1 Analysis Process



Detailed discussions of the methodologies adopted to develop simulated gate down times and to evaluate traffic operations within the study area are provided below.

2.1 Gate Down Time Modeling Methodology

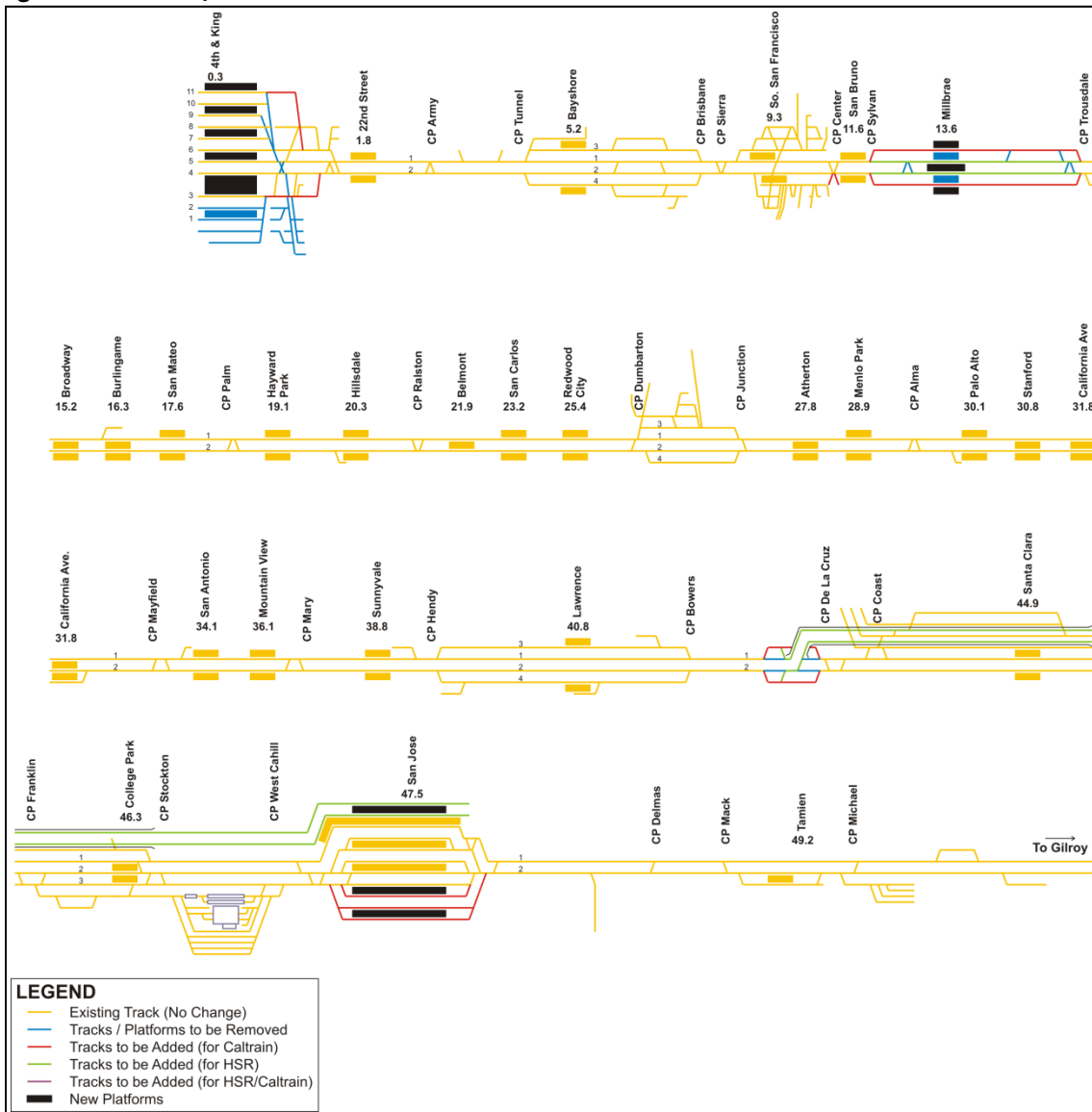
The computer simulation model software used to conduct the gate down time analysis, TrainOps®, is a proprietary software application developed by LTK Engineering Services. The model was customized for application to the Caltrain and HSR operations analysis. The future Caltrain system modeled in the simulation software is different from the one that exists today. Future changes assumed in the model include electrification of the Caltrain system, an advanced signal system known as Communications Based Overlay Signal Systems (CBOSS), and new Caltrain rail cars (“rolling stock”) that have electric propulsion. The LTK modeling assumptions used in the model are summarized in **Table 2-1**. A detailed description of the modeling methodology used in these simulations can be found in the March 2012 Caltrain/ HSR Blended Operations Analysis.

Table 2-1: Caltrain/HSR Blended Operations TrainOps Model Inputs

Model Input Category	Model Input	Assumptions
Infrastructure	Train Propulsion System	Entire Caltrain Corridor electrified, Tamien to San Francisco
	High Speed Rail Stations	Separate HSR Station at San Jose Diridon, new 4-track configuration at Millbrae, new dedicated HSR platforms at 4 th and King
	High Speed Rail Control Points	80 mph connection at CP De La Cruz (Shared Tracks north of connection, dedicated HSR tracks south of connection)
Rolling Stock	Caltrain	EMU, an 8-car consist, Coradia trainset, 700 feet long
	HSR	EMU, Siemens Velaro E High Speed Train, 656 feet long
Train Control	Base	Existing wayside signaling
	Positive Train Control	CBOSS implementation with dynamic profiling to signals at stop, civil speed restrictions, station stops
	CBOSS Response Time – Automatic Signal Territory	6 seconds
	CBOSS Response Time – Control Point Territory – Following Train on Same Route	14 seconds
	CBOSS Response Time – Control Point Territory – Following Train on Different Route	30 seconds
Operations	Caltrain operating philosophy – peak periods	Prototypical skip stop schedule without Caltrain-Caltrain overtakes
	Caltrain operating philosophy – off-peak periods	All stops “memory” type schedule with 2 trains per hour.
	Caltrain period of operation	4 AM to 1 AM
	HSR	All trains stop at San Jose, Millbrae, and San Francisco. Service level varies by scenario
Dispatching	Millbrae 4 Track Segment	No overtakes allowed
	Hold Out Rule	At South San Francisco, Broadway, and Atherton Stations, where passengers must cross one active track at-grade in order to board and alight from trains, only one train in station at a time (unless both are non-stop)

Figure 2-2 shows the baseline infrastructure simulated. It includes existing Caltrain tracks and HSR-related improvements at North Terminal, Millbrae and between CP De La Cruz and South Terminal. The HSR improvements shown are conceptual.

Figure 2-2 Caltrain/HSR Baseline Infrastructure



2.1.1 Grade Crossing Warning Systems Functionality

The electrification of the Caltrain corridor will lead to a faster trip times and/or more frequent service with lower energy demands and decreased emissions. Electric vehicles, like the Alstom Coradia consist proposed, will provide faster acceleration, more passenger capacity, and an improved experience for Caltrain passengers.

Installation of the new advanced signal system, CBOSS, will enable grade crossing system gate down time efficiencies. CBOSS will provide an opportunity to improve upon some of the functionality of the current constant warning time (CWT) technology including “gate restarts” (or “double gate action”), which are a frequent occurrence along the corridor today at stations located close to at-grade crossings. Since constant warning time systems depend upon knowing a train’s speed and predicting its arrival at the crossing, “false positives” are a likely result whenever a train is making a station stop that has an at-grade crossing “upstream”, or in front of, the station stop. Once the CWT circuit detects that the train has stopped and a reset time passes, the gates rise to allow for traffic flow across the

railroad tracks. When the train leaves the station, the gates lower again. The intent of this feature today is to allow traffic flow to continue across the track while the train is stopped. However, the gate restart action increases the total gate down time for a crossing and can also disrupt traffic signal phasing for adjacent intersections. In contrast with CBOSS, the existing grade crossing system does not allow for the input of a train's schedule or stopping pattern.

CBOSS, conversely, includes provisions for intelligently managing grade crossings. The CBOSS system is planned to improve gate down efficiencies at vehicular at-grade crossings. This is achieved by coding the train schedule into the advanced signal system. The CBOSS system is being designed to protect crossings near station stops with "station stop targets" (target) set to stop. With these station stop targets in place near the crossings, a train with an imposed target is required to follow a velocity profile to a stop at the target before entering the crossing. For trains approaching a crossing, but making a station stop before the crossing, the target will remain at stop until the train is ready to depart from the station. This means that when a train is making a known station stop, the gates at the station in front of the station will remain in the vertical position until the train is ready to depart the station. A few seconds prior to departing, the train engineer will request clearance past the target, whereupon the gate down action will begin and the stop target will then be lifted. For crossings near station platforms, when a train making a station stop, this feature of CBOSS reduces the gate down time, compared to today.

If a train is scheduled to operate non-stop through an adjacent station, the signal ahead of the train will remain clear in time to prevent train delays. In this case, the wayside crossing equipment and CBOSS interface will automatically provide sufficient approach warning time at the crossing. In this manner, the "inhibit function" of CBOSS provides superior functionality to CWT systems for controlling gate events at stations near grade crossings. One potential drawback to electrification is incompatibility with existing grade crossing CWT technology. Existing CWT technology in the corridor depends upon being able to measure small fluctuations in impedance within the rails in order to detect the speed and position of approaching trains. Under an electrified system, the rail will function as an electric ground, which will cause low voltages and some current to pass through the rail as trains pass. While these voltages are not extreme, they will interfere with the existing constant warning time technology. For the purpose of this study, it is assumed that a replacement train velocity measurement technology can be developed concurrently with Peninsula Corridor Electrification Project such that CWT benefits are retained under corridor electrification.

The benefits of the improved CBOSS functionality, as well as retention of existing CWT benefits, are reflected in the TrainOps simulations of future gate down times with the blended system corridor.

2.2 Traffic Analysis Methodology

Traffic operations at study highway-railroad crossings and intersections were evaluated using the methodology outlined in **Appendix E-1**.

The operating characteristic of an intersection is described by the concept of Level of Service (LOS). LOS is a qualitative description of the performance of an intersection based on the average delay per vehicle. Traffic analyses were conducted for peak traffic periods (AM peak period from 7 to 9 AM and PM peak period from 4 to 6 PM).

To understand the interrelated traffic conditions for streets crossing the railroad tracks, the most critically sensitive intersection was selected on both the east and the west sides of the railroad

crossing. Often these were the nearest signalized intersection, but for locations without a nearby signalized intersection, the nearest capacity critical unsignalized intersection was selected. Signalized intersections are important in that they affect the traffic arrival patterns at the crossings and also they can impede the uninterrupted flow of traffic leaving the crossing. The study intersection selections were reviewed with local traffic engineers.

Traffic analysis was performed using Synchro (version 7) traffic analysis package. Synchro is a macroscopic traffic analysis tool that is primarily used for evaluating arterial corridors. For this analysis, the Highway Capacity Manual (HCM) 2000 methodology was used to determine intersection operations. According to this methodology, intersection levels of service range from LOS A, which indicates free flow or excellent conditions with short delays, to LOS F, which indicates congested or overloaded conditions with extremely long delays. LOS definitions for signalized and unsignalized intersections per HCM methodology are included in **Appendix D**.

Synchro software is primarily used to analyze traffic operations, but not railroad operations. As such, the traffic analysis model developed using Synchro was adjusted as follows to evaluate railroad operations:

- Railway tracks were represented as a two-way roadway with one lane in each direction, a railroad crossing as an intersection controlled by a traffic signal, and trains as large trucks traveling along the two-way roadway.
- The traffic signal at a railroad crossing was coded to operate in conjunction with the traffic signal at the neighboring pre-empted intersection. In other words, both traffic signals were coded to operate as a single traffic controller. This function would enable coordinated traffic movement at the neighboring pre-empted intersection with the arrival and departure of trains. In the absence of a neighboring pre-empted intersection, traffic signal at a railroad crossing was coded to operate independently.
- To code an operational railroad crossing in Synchro, the number of gate events and the average duration of a gate event were inputted.

For each peak period of traffic analysis, a simulated peak hour of gate down time was identified. This peak hour represents the hour within the peak period of traffic analysis that has the highest cumulative gate down time. For each individual crossing the maximum 60-minute gate down time was selected between the peak traffic periods from 7 AM to 9 AM and 4 PM to 6 PM. This approach was chosen to select the worst peak hour for each individual crossing, as the highest gate down time for a 60-minute period will be different for each crossing. For each crossing, the number of gate events and the average duration of a gate event corresponding to the AM and PM peak hours were identified. The gate down times at the study crossings during the AM and PM peak hours are shown in Chapter 3.

Intersection volumes under 2035 conditions were developed from the following sources:

- Santa Clara Valley Transportation Authority (SCVTA) Countywide Transportation Model forecasts;
- San Francisco County Transportation Authority's Chain Activity Modeling Process (SF-CHAMP) Model forecasts; and

- Other sources provided by the cities (e.g., Redwood City Downtown Precise Plan Draft Environmental Impact Report, August 2010).

2.2.1 Advance Signal Pre-emption Locations

Advance pre-emption, a feature which provides additional time to close the gate at a crossing prior to a train arrival to enhance safety and traffic clearance across the tracks, is currently provided only at six of the study crossings. In addition to these six locations, advance pre-emption is planned at five crossings located in Redwood City, Palo Alto, and Mountain View as part of the Advance Signal Pre-emption Improvement Project, undertaken by the JPB with coordination and participation with the local jurisdictions. It is anticipated that the advance pre-emption feature at these five new locations will be operational by late 2013 or early 2014, and therefore these signal changes are assumed in the 2035 model/analysis. The details of the existing and planned advance pre-emption locations are provided in **Table 2-2**.

Table 2-2 Advance Pre-emption Details

City	Crossing	Advance Pre-emption Time (seconds)
Existing Locations		
San Francisco	Mission Bay Drive	14
San Francisco	16 th Street	14
South San Francisco	Linden Avenue	22
San Bruno	San Bruno Avenue*	6
Burlingame	Broadway	8
San Mateo	25 th Avenue	14
Planned Locations		
Redwood City	Brewster Avenue	14
Palo Alto	Churchill Avenue	4
Palo Alto	Meadow Drive	8
Mountain View	Rengstorff Avenue	6
Mountain View	Castro Street	10

*Not modeled because it is currently being grade separated

Chapter 3

Simulated Gate Down Time

This chapter provides information on simulated gate down times associated with the prototypical schedules developed for the *Caltrain/ HSR Blended System Operations Analysis* as follows:

- “6/0” - six Caltrain trains and zero high speed rail trains per peak hour per direction;
- “6/2” - six Caltrain trains and two high speed rail trains per peak hour per direction (without passing tracks); and
- “6/4” - six Caltrain trains and four high speed rail trains per peak hour per direction (with passing tracks assumed to be located from Hayward Park to Redwood City³).

Many have assumed that an increase in train traffic would result in a proportional increase in gate down time. However, the relationship between train service level changes and gate down time is not directly linear. Multiple factors, including train frequency, train length, train performance, station stopping patterns, system performance, grade crossing warning technology, crossing proximity to a station and location of passing tracks, affect gate down time. Some of the factors offset each other resulting in a range of results with some crossings experiencing increased down time and others, decreased down time.

In the model, the relationship of gate time to changes in train frequency is driven by both the number of gate events and the gate down time per event. These, in turn, are influenced by:

- Elimination of “double gate action”
- Improved gate downtime efficiencies
- Overlapping trains at crossings

Elimination of “double gate action” is one of the performance attributes of the peninsula corridor’s new advanced signal system, CBOSS. CBOSS will eliminate the “double gate action” that currently occurs at crossings adjacent to station platform resulting in reduce gate down time for select train events. Today, when the train stops at a station short of an adjacent at-grade crossing, the gates come down as the train approaches the station. While the train is stopped at the station, the gates go back up. Then when the train leaves the station, the gates come back down until the train passes the at-grade crossing which then allows the gates to go back up. With CBOSS, when the train stops at the station adjacent to an at-grade crossing, the gates will not come down; the gates will stay up until the train is ready to leave the station and traverse the at-grade crossing. The crossings that benefit from the removal of the double gate action today are called out in the following tables.

Gate down time efficiencies is another performance attribute of CBOSS. Today, at some crossings, trains will slow down beyond the expected speed when crossing an at-grade crossing resulting in

³ The Long-Middle 4 Track Overtake out of five overtake options was chosen for this simulation because at the start of this study, that option was the most defined with relatively good operational performance.

longer gate down times. With CBOSS, train speeds can be more efficiently managed, eliminating slow downs beyond the expected speed. This anticipated effect of the CBOSS system has been incorporated into the model.

Overlapping trains at crossings (which can be described as “2-for-1” events) occur when two trains on separate tracks pass through the at-grade crossing at the same time. Such an event triggers one gate event versus two. In the tested scenario with passing tracks, there is a four-track section where “3-for-1” and “4-for 1” events can be realized. Furthermore, with additional tracks at-grade, as in the case of the Long-Middle passing track section, the probability of multiple trains passing through crossing at the same time increases. All of these factors have an effect of partially offsetting the gate down time increases such that down time is not always proportional to the change in train service level.

The following describes the simulations results of the “6/0”, “6/2”, and “6/4” scenarios. The “6/0” results are reflected in **Tables 3-1 and 3-2**. The tables reflect AM and PM peak hours. The morning and evening peak hour schedules and gate down times are different. The “6/2” results are reflected in **Tables 3-3 and 3-4**. The “6/4” results are reflected in **Tables 3-5 and 3-6**. These tables document the number of minutes that gates are down today (out of 60 peak minutes) and the approximate change in down time predicted by the simulation of the future scenarios. The gate down time results in Tables 3-1 through 3-6 show the worst case peak hour gate down time for each crossing for the tested prototypical schedules.

The “6/0” gate down times at majority of the at-grade crossings; compared to today’s times, decrease by up to 6.5 minutes over a 60-minute period. This is the result of eliminating double gate action, gate downtime efficiencies and “2-for-1” at-grade crossing events. The other crossings experience increases in gate down times up to 4.5 minutes over a 60-minute period. These crossings include those near stations that do not benefit from removal of the double gate actions, gate downtime efficiencies or the “2-for1” at-grade crossing events. They include the Broadway and Atherton stations where service is being restored and four crossings in Palo Alto which are not adjacent to stations.

In the “6/2” scenario, train traffic grows by 60 percent. However, nine to ten at-grade crossings experience reduced gate down times by up to 4 minutes over a 60-minute period. As would be expected, most crossings did experience increases in gate down time by up to 7 minutes over a 60-minute period. These increases show that gate down time reductions due to elimination of double gate action, gate downtime efficiencies and “2-for-1” events at at-grade crossings are minimized as the train service levels increase.

In the “6/4” scenario, with doubling in train traffic, three to five crossings on the corridor experience declines in gate down time. More crossings experience increases in gate down time since the benefits from eliminating double gate action and “2-for-1” events at-grade crossings and gate downtime efficiencies are further minimized with even higher train service levels. A particularity worth noting relates to the crossings that benefit from the passing track location. These are crossings where gate down times are lowered in the 6/4 scenario, when compared to today’s gate down times. This reflects the benefits of “3-for-1” and “4-for-1” events.

All of the results are schedule-dependent. These results should be used to understand what factors will influence future gate down time. The results should not be used in absolute terms since they are based on prototypical schedules developed for the *Caltrain/ HSR Blended System Operations Analysis* and were used for this study. See **Appendix F** to understand the level of sensitivity between schedules and gate down times.

Table 3-1 Gate Down Time Summary of Changes – Existing versus 6/0 Scenario (AM Peak Hour)

City	Model Results Approximate Minutes/Peak AM Hour					Worst Case Peak Hour
	Today	Future Change	Total	Decrease	Increase	
San Francisco	14.5	0.0	14.5		Mission Bay Boulevard	7:47 – 8:47
	12.0	0.5	12.5		16 th Street	7:17 – 8:17
South San Francisco	8.5	1.5	10.0		Linden Avenue	7:08 – 8:08
San Bruno	9.0	0.0	9.0	Scott Street		7:07 – 8:07
Millbrae	11.5	-3.0	8.5	Center Street		7:28 – 8:28
Burlingame	7.5	1.5	9.0		Broadway (w/service)*	7:30 – 8:30
	11.0	-1.0	10.0	Oak Grove Avenue		7:22 – 8:22
	11.0	-1.5	9.5	North Lane*		7:29 – 8:29
	12.5	-2.0	10.5	Howard Avenue*		7:29 – 8:29
	11.5	-1.5	10.0	Bayswater Avenue*		7:00 – 8:00
Burlingame, San Mateo	9.5	0.5	10.0		Peninsula Avenue	7:00 – 8:00
San Mateo	8.5	0.0	8.5	Villa Terrace		7:08 – 8:08
	10.5	-1.0	9.5	Bellevue Avenue		7:20 – 8:20
	14.5	-5.5	9.0	First Avenue*		7:42 – 8:42
	13.5	-4.0	9.5	Second Avenue*		7:42 – 8:42
	15.0	-6.5	8.5	Third Avenue*		7:42 – 8:42
	12.0	-3.5	8.5	Fourth Avenue		7:42 – 8:42
	10.0	-1.5	8.5	Fifth Avenue		7:42 – 8:42
	10.0	-2.0	8.0	Ninth Avenue		7:00 – 8:00
	10.0	-1.0	9.0	25 th Avenue		7:16 – 8:16
Redwood City	12.0	-3.0	9.0	Whipple Avenue		7:46 – 8:46
	14.0	-5.5	8.5	Brewster Avenue*		7:09 – 8:09
	17.0	-6.0	11.0	Broadway*		7:09 – 8:09
	10.5	-0.5	10.5	Maple Street		7:07 – 8:07
	13.0	-2.5	10.5	Main Street		7:07 – 8:07
	11.0	-2.0	9.0	Chestnut Street		7:07 – 8:07
Atherton	7.5	1.5	9.0		Fair Oaks Lane*	7:53 – 8:53
	10.0	-1.5	8.5	Watkins Avenue*		7:56 – 8:56
Menlo Park	10.0	-1.0	9.0	Encinal Avenue		7:05 – 8:05
	9.5	-0.5	9.0	Glenwood Avenue		7:05 – 8:05
	14.0	-4.5	9.5	Oak Grove Avenue*		7:00 – 8:00
	12.0	-1.0	11.0	Ravenswood Avenue*		7:03 – 8:03
Palo Alto	9.0	1.0	10.0		Alma Street	7:27 – 8:27
	7.0	1.0	8.0		Churchill Avenue	7:00 – 8:00
	7.0	1.5	8.5		East Meadow Drive	7:03 – 8:03
	7.5	1.5	9.0		Charleston Avenue	7:03 – 8:03
Mountain View	7.5	1.0	8.5		Rengstorff Avenue	7:05 – 8:05
	13.0	-3.0	10.0	Castro Street*		7:36 – 8:36
Sunnyvale	7.5	1.0	8.5		Mary Avenue	7:39 – 8:39
	10.5	-1.5	9.0	Sunnyvale Avenue*		7:02 – 8:02

Notes:

Represents decrease in gate down times compared to existing conditions

Represents increase in gate down times compared to existing conditions

* Railroad crossing is close to station and benefits from the elimination of the “double gate action” due to CBOSS enhanced capabilities

Table 3-2 Gate Down Time Summary of Changes – Existing versus 6/0 Scenario (PM Peak Hour)

City	Model Results		Approximate Minutes/Peak PM Hour		Worst Case Peak Hour
	Today	Future Change	Total		
San Francisco	11.5	3.0	14.5		Mission Bay Boulevard 16:46 – 17:46
	8.5	4.5	13.0		16 th Street 16:45 – 17:45
South San Francisco	8.0	1.5	9.5		Linden Avenue 16:56 – 17:56
San Bruno	7.0	1.5	8.5		Scott Street 16:56 – 17:56
Millbrae	10.5	-2.5	8.0	Center Street	16:36 – 17:36
Burlingame	6.5	1.5	8.0		Broadway (w/service)* 16:59 – 17:59
	8.5	1.0	9.5		Oak Grove Avenue 16:19 – 17:19
	10.5	-1.5	9.0	North Lane*	16:19 – 17:19
	12.0	-2.0	10.0	Howard Avenue*	16:47 – 17:47
	10.5	-1.0	9.5	Bayswater Avenue*	16:47 – 17:47
Burlingame, San Mateo	10.0	-0.5	9.5	Peninsula Avenue	16:47 – 17:47
San Mateo	7.5	1.0	8.5		Villa Terrace 16:58 – 17:58
	9.5	0.0	9.5	Bellevue Avenue	16:58 – 17:58
	12.5	-3.5	9.0	First Avenue*	16:44 – 17:44
	11.5	-2.0	9.5	Second Avenue*	16:56 – 17:56
	12.0	-3.5	8.5	Third Avenue*	16:56 – 17:56
	9.5	-1.0	8.5	Fourth Avenue	16:42 – 17:42
	8.5	0.5	9.0		Fifth Avenue 16:44 – 17:44
	7.5	1.0	8.5		Ninth Avenue 16:44 – 17:44
	9.5	-1.5	8.0	25 th Avenue	16:57 – 17:57
Redwood City	10.0	-0.5	9.5	Whipple Avenue	16:52 – 17:52
	13.0	-5.0	8.0	Brewster Avenue*	16:52 – 17:52
	15.5	-5.0	10.5	Broadway*	16:59 – 17:59
	9.5	1.0	10.5		Maple Street 16:54 – 17:54
	10.0	0.5	10.5		Main Street 16:54 – 17:54
	8.5	-0.5	8.0	Chestnut Street	16:58 – 17:58
Atherton	6.5	2.5	9.0		Fair Oaks Lane* 16:56 – 17:56
	7.5	0.5	8.0		Watkins Avenue* 16:56 – 17:56
Menlo Park	8.0	0.5	8.5		Encinal Avenue 16:56 – 17:56
	10.5	-1.0	9.5	Glenwood Avenue	16:56 – 17:56
	11.5	-1.5	10.0	Oak Grove Avenue*	16:56 – 17:56
	10.0	1.0	11.0		Ravenswood Avenue* 16:58 – 17:58
Palo Alto	7.5	2.5	10.0		Alma Street 16:54 – 17:54
	6.5	0.0	6.5	Churchill Avenue	16:32 – 17:32
	6.5	2.0	8.5		East Meadow Drive 16:36 – 17:36
	6.5	2.0	8.5		Charleston Avenue 16:49 – 17:49
Mountain View	6.5	1.5	8.0		Rengstorff Avenue 16:54 – 17:54
	13.0	-3.5	9.5	Castro Street*	16:55 – 17:55
Sunnyvale	7.0	1.5	8.5		Mary Avenue 16:58 – 17:58
	11.5	-3.0	8.5	Sunnyvale Avenue*	17:00 – 18:00

Notes:

Represents decrease in gate down times compared to existing conditions

Represents increase in gate down times compared to existing conditions

* Railroad crossing is close to station and benefits from the elimination of the “double gate action” due to CBOSS enhanced capabilities

Table 3-3 Gate Down Time Summary of Changes – Existing versus 6/2 Scenario (AM Peak Hour)

City	Model Results Approximate Minutes/Peak AM Hour					Worst Case Peak Hour
	Today	Future Change	Total	Decrease	Increase	
San Francisco	14.5	3.5	17.5		Mission Bay Boulevard	7:13 – 8:13
	12.0	3.0	15.0		16 th Street	7:56 – 8:56
South San Francisco	8.5	3.5	12.0		Linden Avenue	7:28 – 8:28
San Bruno	9.0	2.0	11.0		Scott Street	7:28 – 8:28
Millbrae	11.5	-1.0	10.0	Center Street		7:06 – 8:06
Burlingame	7.5	4.0	11.5		Broadway*	7:27 – 8:27
	11.0	2.5	13.5		Oak Grove Avenue	7:22 – 8:22
	11.0	1.0	12.0		North Lane*	7:26 – 8:26
	12.5	1.0	13.5		Howard Avenue*	7:46 – 8:46
	11.5	1.0	12.5		Bayswater Avenue*	7:46 – 8:46
Burlingame, San Mateo	9.5	2.5	13.0		Peninsula Avenue	7:20 – 8:20
San Mateo	8.5	2.5	11.0		Villa Terrace	7:20 – 8:20
	10.5	2.0	12.5		Bellevue Avenue	7:20 – 8:20
	14.5	-1.5	13.0	First Avenue*		7:18 – 8:18
	13.5	-2.0	11.5	Second Avenue*		7:18 – 8:18
	15.0	-4.0	11.0	Third Avenue*		7:18 – 8:18
	12.0	-0.5	11.5	Fourth Avenue		7:18 – 8:18
	10.0	1.5	11.5		Fifth Avenue	7:18 – 8:18
	10.0	1.0	11.0		Ninth Avenue	7:17 – 8:17
	10.0	1.5	11.5		25 th Avenue	7:16 – 8:16
Redwood City	12.0	0.5	12.5		Whipple Avenue	7:09 – 8:09
	14.0	-3.5	10.5	Brewster Avenue*		7:09 – 8:09
	17.0	-2.5	14.5	Broadway*		7:09 – 8:09
	10.5	2.0	12.5		Maple Street	7:07 – 8:07
	13.0	0.5	13.5		Main Street	7:07 – 8:07
	11.0	0.0	11.0	Chestnut Street		7:07 – 8:07
Atherton	7.5	3.5	11.0		Fair Oaks Lane*	7:24 – 8:24
	10.0	1.0	11.0		Watkins Avenue*	7:58 – 8:58
Menlo Park	10.0	0.5	10.5		Encinal Avenue	7:28 – 8:28
	9.5	1.5	11.0		Glenwood Avenue	7:05 – 8:05
	14.0	-1.5	12.5	Oak Grove Avenue*		7:04 – 8:04
	12.0	1.5	13.5		Ravenswood Avenue*	7:03 – 8:03
Palo Alto	9.0	4.0	13.0		Alma Street	7:27 – 8:27
	7.0	3.5	10.5		Churchill Avenue	7:33 – 8:33
	7.0	4.0	11.0		East Meadow Drive	7:35 – 8:35
	7.5	4.0	11.5		Charleston Avenue	7:35 – 8:35
Mountain View	7.5	3.5	11.0		Rengstorff Avenue	7:04 – 8:04
	13.0	-0.5	12.5	Castro Street*		7:39 – 8:39
Sunnyvale	7.5	4.5	12.0		Mary Avenue	7:42 – 8:42
	10.5	1.5	12.0		Sunnyvale Avenue*	7:41 – 8:41

Notes:

 Represents decrease in gate down times compared to existing conditions

 Represents increase in gate down times compared to existing conditions

* Railroad crossing is close to station and benefits from the elimination of the “double gate action” due to CBOSS enhanced capabilities

Table 3-4 Gate Down Time Summary of Changes – Existing versus 6/2 Scenario (PM Peak Hour)

City	Model Results Approximate Minutes/Peak PM Hour				Worst Case Peak Hour
	Today	Future Change	Total		
San Francisco	11.5	6.0	17.5		Mission Bay Boulevard 16:51 – 17:51
	8.5	7.0	15.5		16 th Street 16:53 – 17:53
South San Francisco	8.0	4.0	12.0		Linden Avenue 16:37 – 17:37
San Bruno	7.0	3.5	10.5		Scott Street 16:36 – 17:36
Millbrae	10.5	-0.5	10.0	Center Street	16:33 – 17:33
Burlingame	6.5	5.0	11.5		Broadway* 16:58 – 17:58
	8.5	4.0	12.5		Oak Grove Avenue 16:29 – 17:29
	10.5	0.5	11.0		North Lane* 16:56 – 17:56
	12.0	0.0	12.0	Howard Avenue*	16:55 – 17:55
	10.5	1.5	12.0		Bayswater Avenue* 16:55 – 17:55
Burlingame, San Mateo	10.0	2.0	12.0		Peninsula Avenue 16:55 – 17:55
San Mateo	7.5	3.5	11.0		Villa Terrace 16:55 – 17:55
	9.5	3.0	12.5		Bellevue Avenue 16:43 – 17:43
	12.5	-0.5	12.0	First Avenue*	16:53 – 17:53
	11.5	0.0	11.5	Second Avenue*	17:00 – 18:00
	12.0	-1.5	10.5	Third Avenue*	17:00 – 18:00
	9.5	1.5	11.0		Fourth Avenue 16:44 – 17:44
	8.5	2.5	11.0		Fifth Avenue 16:52 – 17:52
	7.5	4.0	11.5		Ninth Avenue 16:52 – 17:52
	9.5	1.5	11.0		25 th Avenue 16:23 – 17:23
Redwood City	10.0	2.0	12.0		Whipple Avenue 16:54 – 17:54
	13.0	-3.0	10.0	Brewster Avenue*	16:54 – 17:54
	15.5	-2.0	13.5	Broadway*	16:55 – 17:55
	9.5	3.0	12.5		Maple Street 16:56 – 17:56
	10.0	2.0	12.0		Main Street 16:57 – 17:57
	8.5	1.5	10.0		Chestnut Street 16:57 – 17:57
Atherton	6.5	5.5	12.0		Fair Oaks Lane* 16:58 – 17:58
	7.5	3.5	11.0		Watkins Avenue* 16:58 – 17:58
Menlo Park	8.0	3.0	11.0		Encinal Avenue 16:58 – 17:58
	10.5	1.0	11.5		Glenwood Avenue 16:59 – 17:59
	11.5	2.0	13.5		Oak Grove Avenue* 16:59 – 17:59
	10.0	4.0	14.0		Ravenswood Avenue* 17:00 – 18:00
Palo Alto	7.5	3.5	11.0		Alma Street 16:46 – 17:46
	6.5	4.5	11.0		Churchill Avenue 16:43 – 17:43
	6.5	3.5	10.0		East Meadow Drive 17:00 – 18:00
	6.5	4.0	10.5		Charleston Avenue 17:00 – 18:00
Mountain View	6.5	4.5	11.0		Rengstorff Avenue 16:31 – 17:31
	13.0	-2.0	11.0	Castro Street*	16:37 – 17:37
Sunnyvale	7.0	4.0	11.0		Mary Avenue 16:53 – 17:53
	11.5	-1.0	10.5	Sunnyvale Avenue*	16:38 – 17:38

Notes:

- Represents decrease in gate down times compared to existing conditions
- Represents increase in gate down times compared to existing conditions

* Railroad crossing is close to station and benefits from the elimination of the “double gate action” due to CBOSS enhanced capabilities

Table 3-5 Gate Down Time Summary of Changes – Existing versus 6/4 Scenario (AM Peak Hour)

City	Model Results Approximate Minutes/Peak AM Hour					Worst Case Peak Hour
	Today	Future Change	Total	Decrease	Increase	
San Francisco	14.5	7.5	22.0		Mission Bay Boulevard	8:00 – 9:00
	12.0	8.0	20.0		16 th Street	7:17 – 8:17
South San Francisco	8.5	6.5	15.0		Linden Avenue	7:38 – 8:38
San Bruno	9.0	5.0	14.0		Scott Street	7:07 – 8:07
Millbrae	11.5	2.5	14.0		Center Street	7:28 – 8:28
Burlingame	7.5	5.5	13.0		Broadway*	7:13 – 8:13
	11.0	4.5	15.5		Oak Grove Avenue	7:12 – 8:12
	11.0	3.0	14.0		North Lane*	7:18 – 8:18
	12.5	3.0	15.5		Howard Avenue*	7:49 – 8:49
	11.5	3.5	15.0		Bayswater Avenue*	7:00 – 8:00
Burlingame, San Mateo	9.5	5.5	15.0		Peninsula Avenue	7:00 – 8:00
San Mateo	8.5	5.5	14.0		Villa Terrace	7:16 – 8:16
	10.5	5.5	16.0		Bellevue Avenue	7:16 – 8:16
	14.5	0.0	14.5	First Avenue*		7:14 – 8:14
	13.5	-0.5	13.0	Second Avenue*		7:14 – 8:14
	15.0	-2.5	12.5	Third Avenue*		7:14 – 8:14
	12.0	1.0	13.0		Fourth Avenue	7:14 – 8:14
	10.0	3.0	13.0		Fifth Avenue	7:14 – 8:14
	10.0	2.5	12.5		Ninth Avenue	7:14 – 8:14
	10.0	2.0	12.0		25 th Avenue	7:12 – 8:12
Redwood City	12.0	2.0	14.0		Whipple Avenue	7:05 – 8:05
	14.0	-2.0	12.0	Brewster Avenue*		7:05 – 8:05
	17.0	-1.5	15.5	Broadway*		7:05 – 8:05
	10.5	3.5	14.0		Maple Street	7:33 – 8:33
	13.0	1.5	14.5		Main Street	7:03 – 8:03
	11.0	1.5	12.5		Chestnut Street	7:03 – 8:03
Atherton	7.5	6.0	13.5		Fair Oaks Lane*	7:35 – 8:35
	10.0	3.5	13.5		Watkins Avenue*	7:35 – 8:35
Menlo Park	10.0	3.5	13.5		Encinal Avenue	7:01 – 8:01
	9.5	5.0	14.5		Glenwood Avenue	7:26 – 8:26
	14.0	2.0	16.0		Oak Grove Avenue*	7:26 – 8:26
	12.0	5.0	17.0		Ravenswood Avenue*	7:37 – 8:37
Palo Alto	9.0	6.5	15.5		Alma Street	7:38 – 8:38
	7.0	6.5	13.5		Churchill Avenue	7:31 – 8:31
	7.0	6.0	13.0		East Meadow Drive	7:42 – 8:42
	7.5	5.5	13.0		Charleston Avenue	7:35 – 8:35
Mountain View	7.5	5.5	13.0		Rengstorff Avenue	7:45 – 8:45
	13.0	1.5	14.5		Castro Street*	7:37 – 8:37
Sunnyvale	7.5	7.0	14.5		Mary Avenue	7:41 – 8:41
	10.5	4.0	14.5		Sunnyvale Avenue*	7:42 – 8:42

Notes:

Represents decrease in gate down times compared to existing conditions

Represents increase in gate down times compared to existing conditions

* Railroad crossing is close to station and benefits from the elimination of the “double gate action” due to CBOSS enhanced capabilities

Table 3-6 Gate Down Time Summary of Changes – Existing versus 6/4 Scenario (PM Peak Hour)

			Model Results Approximate Minutes/Peak PM Hour			
City	Today	Future Change	Total	Decrease	Increase	Worst Case Peak Hour
San Francisco	11.5	10.0	21.5		Mission Bay Boulevard	16:51 – 17:51
	8.5	9.5	18.0		16 th Street	16:42 – 17:42
South San Francisco	8.0	7.0	15.0		Linden Avenue	16:40 – 17:40
San Bruno	7.0	6.0	13.0		Scott Street	16:40 – 17:40
Millbrae	10.5	2.0	12.5		Center Street	16:36 – 17:36
Burlingame	6.5	6.0	12.5		Broadway*	16:52 – 17:52
	8.5	6.5	15.0		Oak Grove Avenue	16:59 – 17:59
	10.5	3.5	14.0		North Lane*	16:32 – 17:32
	12.0	3.5	15.5		Howard Avenue*	17:00 – 18:00
	10.5	4.0	14.5		Bayswater Avenue*	17:00 – 18:00
Burlingame, San Mateo	10.0	4.0	14.0		Peninsula Avenue	17:00 – 18:00
San Mateo	7.5	6.0	13.5		Villa Terrace	17:00 – 18:00
	9.5	5.5	15.0		Bellevue Avenue	16:30 – 17:30
	12.5	1.5	14.0		First Avenue*	17:00 – 18:00
	11.5	1.5	13.0		Second Avenue*	17:00 – 18:00
	12.0	0.0	12.0	Third Avenue*		17:00 – 18:00
	9.5	3.0	12.5		Fourth Avenue	17:00 – 18:00
	8.5	4.0	12.5		Fifth Avenue	17:00 – 18:00
	7.5	5.5	13.0		Ninth Avenue	16:29 – 17:29
	9.5	2.5	12.0		25 th Avenue	16:55 – 17:55
Redwood City	10.0	2.0	12.0		Whipple Avenue	16:48 – 17:48
	13.0	-3.0	10.0	Brewster Avenue*		16:47 – 17:47
	15.5	-2.5	13.0	Broadway*		16:32 – 17:32
	9.5	3.5	13.0		Maple Street	16:35 – 17:35
	10.0	3.0	13.0		Main Street	16:45 – 17:45
	8.5	3.0	11.5		Chestnut Street	16:49 – 17:49
Atherton	6.5	6.5	13.0		Fair Oaks Lane*	16:50 – 17:50
	7.5	5.0	12.5		Watkins Avenue*	16:50 – 17:50
Menlo Park	8.0	5.5	13.5		Encinal Avenue	16:51 – 17:51
	10.5	3.5	14.0		Glenwood Avenue	16:51 – 17:51
	11.5	4.0	15.5		Oak Grove Avenue*	16:51 – 17:51
	10.0	7.0	17.0		Ravenswood Avenue*	16:52 – 17:52
Palo Alto	7.5	8.5	16.0		Alma Street	16:53 – 17:53
	6.5	6.0	12.5		Churchill Avenue	16:41 – 17:41
	6.5	5.0	11.5		East Meadow Drive	16:48 – 17:48
	6.5	6.0	12.5		Charleston Avenue	16:58 – 17:58
Mountain View	6.5	7.0	13.5		Rengstorff Avenue	16:59 – 17:59
	13.0	0.5	13.5		Castro Street*	17:00 – 18:00
Sunnyvale	7.0	7.0	14.0		Mary Avenue	16:56 – 17:56
	11.5	2.5	14.0		Sunnyvale Avenue*	16:58 – 17:58

Notes:

Represents decrease in gate down times compared to existing conditions

Represents increase in gate down times compared to existing conditions

* Railroad crossing is close to station and benefits from the elimination of the “double gate action” due to CBOSS enhanced capabilities

Chapter 4

Sample Simulated Traffic

In order to understand the traffic impact associated with simulated future gate down times, this component of the study was scoped to analyze the future vehicle delays and traffic levels of service at all of the at-grade crossing intersections along the total length of the blended system corridor for each of the “6/0”, “6/2”, and “6/4” service plan scenarios as described in the previous chapter. However, the scope was altered because the gate downtime inputs are speculative (as discussed in the previous chapter) and the traditional traffic analysis tool (Synchro) has limitations for this particular use.

Synchro is a planning tool. It was modified to simulate railroad crossings and train traffic based on average headways. Schedule of trains cannot be coded in Synchro. Thus the model was tweaked to maintain a minimum or average headway between trains.

The tool provided acceptable results for non-pre-empted intersections but because the model only evaluates one intersection, it does not reflect what might occur at neighboring intersections (i.e. queuing impact). A non-pre-empted intersection operates independent of any activated railroad grade crossing.

Additionally, the tool has limitations with simulating the pre-empted intersections because the related traffic signal phasing cannot be coded. When a train arrives at a crossing, termination of an active phase at the adjoining pre-empted intersection cannot be coded in Synchro. A pre-empted intersection has an interconnected vehicular traffic signal controller that uses communication from the railroad grade crossing circuitry to reduce/eliminate concurrent signals allowing vehicles to proceed to an activated grade crossing.

Model limitations combined with the speculative assumptions in the simulated future gate down times (i.e., prototypical schedules and assumed passing track location) discussed in the previous chapter brought to question the usefulness of evaluating all of the intersections. Focused on trying to begin understanding the level of sensitivity between future gate down times and local traffic levels of service, this component of the study was re-scoped to evaluating just a sample set of intersections.

4.1 Sample Intersections

The following five intersections were selected for evaluation:

- 16th Street/7th Street/Mississippi Street (located in San Francisco)
- 25th Avenue/El Camino Real (located in San Mateo)
- 25th Avenue/Delaware Street (located in San Mateo)
- Broadway/El Camino Real (located in Redwood City)
- Churchill Avenue/Alma Street (located in Palo Alto)

16th Street/7th Street/Mississippi Street, 25th Avenue/Delaware Street, and Churchill Avenue/Alma Street are pre-empted intersections. The remaining two are non-pre-empted intersections.

This sample set was selected based on the following railroad crossing and intersection characteristics in order to get a wide range of intersection typologies:

- Geographic location;
- Type of traffic control at the intersection;
- Availability of pre-emption at the intersection;
- Availability of advance pre-emption at the neighboring railroad crossing;
- Availability of passing tracks at the neighboring railroad crossing;
- Number of travel lanes across the railroad crossing; and
- Presence of a central business district in the vicinity of the intersection.

4.2 Simulation Results

For each peak period of traffic analysis, a simulated peak hour of gate down time was identified. This peak hour represents the hour within the peak period of traffic analysis that has the highest cumulative gate down time. **This approach was chosen to understand the worst case scenario, within the study assumptions** (i.e. using prototypical schedules).

The inputs into the traffic model are intersection geometry, signal phasing/timing, traffic volumes and gate down time. The gate down time results in Chapter 3 show the total number of minutes per crossing for each of the crossings' worst case peak hour. However the gate down time input into the traffic model is a more detailed breakdown of the gate down time that includes the number of gate events and the average gate down time per event.

Another traffic model input is if the traffic signal is pre-empted or not. A pre-empted traffic signal receives communication from the railroad grade crossing warning system that "clears off" traffic movements traveling across the railroad tracks but permits other traffic movements that do not cross the railroad tracks. When a traffic signal is pre-empted the signal phasing is interrupted to give priority to the train passing through the crossing. Typically pre-empted intersections are close to the railroad crossing. If a traffic signal is not pre-empted the railroad gates do not communicate with the traffic signal. The sample intersections are labeled as pre-empted (P) or non pre-empted (NP) in the table below.

Table 4-1 shows the simulation results of the 2035 No-Build Conditions (scenario without any changes to Caltrain service) compared to existing conditions. The 2035 No-Build scenario assumes no change in train service levels compared to today, which means that the projected increase in delay and level of service are the result of forecasted housing and job growth derived from the Association of Bay Area Governments (ABAG) regional growth forecasts.

Table 4-1 Existing vs. 2035 No-Build (LOS and Delay Values)

Intersection	City	Average Delay (sec per vehicle) / LOS*			
		Existing		2035 No-Build	
		AM Peak	PM Peak	AM Peak	PM Peak
16 th Street/7 th Street/Mississippi Street (P)	San Francisco	41.7 / D	35.2 / D	224.4 / F	283.6 / F
25 th Avenue/El Camino Real (N)	San Mateo	18.8 / B	23.3 / C	171.1 / F	74.7 / E
25 th Avenue/Delaware Street (P)	San Mateo	10.2 / B	10.3 / B	12.4 / B	13.1 / B
Broadway/El Camino Real (NP)	Redwood City	22.8 / C	26.1 / C	47.9 / D	61.5 / E
Churchill Avenue/Alma Street (P)	Palo Alto	49.9 / D	71.1 / E	103.2 / F	132.5 / F

*Per HCM 2000, more than 80 seconds of delay/vehicle is classified as excessive delays. See Appendix D for additional information.

(P) = Pre-empted intersection

(NP) = Not pre-empted intersection

Under 2035 No-Build Conditions, the 25th Avenue/Delaware Street intersection during both the AM and PM peak hours, and the Broadway/El Camino Real intersection during the AM peak hour would continue to operate at an acceptable LOS (LOS D or better). The remaining intersections would operate at an unacceptable LOS (LOS E or F). The 16th Street/7th Street/Mississippi Street intersection during both the AM and PM peak hours, the 25th Avenue/El Camino Real intersection during the AM peak hour, and the Churchill Avenue/Alma Street intersection during both the AM and PM peak hours would worsen to LOS F. Whereas, the 25th Avenue/El Camino Real and Broadway/El Camino Real intersections would worsen to LOS E during the PM peak hours.

Table 4-2 shows the Synchro simulation results for the existing conditions, the “2035 No-Build” and the three of “2035 Build” scenarios for the “6/0”, “6/2” and “6/4” service plans. The three columns on the right side of Table 4-2 show the incremental change in delay for each service level. The intersection characteristics and factors that influence the simulation results are described in the following pages for each of the intersections.

Table 4-2 Existing vs. 2035 No-Build vs. Build (LOS and Delay Values)

		Average Delay (sec per vehicle) / LOS		Change in Average Delay 2035 Service Change			
	Intersection	City	Existing	2035 No-Build	"6/0"	"6/2"	"6/4"
AM Peak Hour							
	16 th Street/7 th Street/Mississippi Street (P)	San Francisco	41.7 / D	224.4 / F	2.7	4.2	Model not Reacting
	25 th Avenue/El Camino Real (NP)	San Mateo	18.8 / B	171.1 / F	0.0	0.0	0.0
	25 th Avenue/Delaware Street (P)	San Mateo	10.2 / B	12.4 / B	0.1	0.6	Change Not Significant
	Broadway/El Camino Real (NP)	Redwood City	22.8 / C	47.9 / D	0.0	0.0	0.0
	Churchill Avenue/Alma Street (P)	Palo Alto	49.9 / D	103.2 / F	4.2	1.2	8.4
PM Peak Hour							
	16 th Street/7 th Street/Mississippi Street (P)	San Francisco	35.2 / D	283.6 / F	-27.2	-18.4	2.9
	25 th Avenue/El Camino Real (NP)	San Mateo	23.3 / C	74.7 / E	0.0	0.0	0.0
	25 th Avenue/Delaware Street (P)	San Mateo	10.3 / B	13.1 / B	1.9	0.6	Change Not Significant
	Broadway/El Camino Real (NP)	Redwood City	26.1 / C	61.5 / E	0.0	0.0	0.0
	Churchill Avenue/Alma Street (P)	Palo Alto	71.1 / E	132.5 / F	0.0	1.6	4.5

(P) = Pre-empted intersection

(NP) = Not pre-empted intersection

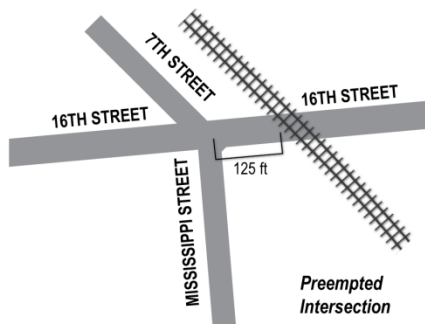
16th Street/7th Street/Mississippi Street, San Francisco

The **16th Street/7th Street/Mississippi Street** intersection is located immediately west of the 16th Street railroad crossing in San Francisco in between the 4th and King and 22nd Street Caltrain Stations. This is a pre-empted intersection (the railroad crossing communicates with the traffic signal). Figure 4-1 includes a diagram of the intersection and presents key simulation inputs and visual representation of the results in Table 4-2.

Figure 4-1: 16th Street/7th Street/Mississippi Street Intersection

Simulation Inputs

Intersection



Key Data

	AM Peak	PM Peak
Current Peak Hour Events:	12 events	7 events
Current Avg Gate Downtime:	58 sec / event	75 sec / event
Current Vehicle Delay:	41.7 seconds	35.2 seconds
Current Level of Service:	D	D

2035 Simulation Results: AM Peak

	2035 No-Build	2035 "6/0"	2035 "6/2"	2035 "6/4"
Simulated Peak Hour Events:	12 events / hr*	13 events / hr	15 events / hr	20 events / hr
Simulated Avg Gate Downtime:	58 sec / event*	59 sec / event	59 sec / event	59 sec / event
Simulated Vehicle Delay:				Model not Reactive
Total seconds of vehicle delay Incremental change in delay	224.4 seconds -	227.1 seconds +2.7 seconds	231.3 seconds +4.2 seconds	
Simulated LOS:	F	F	F	
	*No change from present			

2035 Simulation Results: PM Peak

	2035 No-Build	2035 "6/0"	2035 "6/2"	2035 "6/4"
Simulated Peak Hour Events:	7 events / hr*	12 events / hr	15 events / hr	17 events / hr
Simulated Avg Gate Downtime:	75 sec / event*	63 sec / event	61 sec / event	62 sec / event
Simulated Vehicle Delay:				
Total seconds of vehicle delay Incremental change in delay	283.6 seconds -	256.4 seconds -27.2 seconds	238.0 seconds -18.4 seconds	240.9 seconds +2.9 seconds
Simulated LOS:	F	F	F	F
	*No change from present			

The following describes the results and key points contained in Figure 4-1:

Existing Conditions

- Under current conditions, the intersection is nearing saturation and operates at level of service D in both the AM and PM peak hours simulated.

Simulation – AM Peak

- **2035 No Project:** Under the no project scenario, the gate down time is the same as today (number of train events and average gate down time per event) as this scenario assumes no change to Caltrain service. However, the simulation projects a significant increase in congestion and associated vehicle delay at the intersection due to projected overall growth in vehicle traffic as defined in the 2009 ABAG land use and population projections. Under this scenario the intersection operates at LOS F.
- **2035 6/0:** Both the number of gate events and the average gate down time per event increase over the no project scenario, resulting in an increase in average delay of 2.7 seconds per vehicle. The intersection LOS in this scenario remains at LOS F.
- **2035 6/2:** Both the number of gate events and the average gate down time per event increase further increase over the 6/0 scenario, resulting in an additional delay of 4.2 seconds per vehicle compared to 6/0. The intersection LOS in this scenario remains at LOS F.
- **2035 6/4:** Even though the number of gate events have increased over the 6/2 scenario, the intersection operations has far exceeded its capacity and the model is not responding to the change in gate events.

Simulation – PM Peak

- **2035 No Project:** The same rationale described for the AM peak hour applies for the PM peak hour.
- **2035 6/0:** The LOS results of the 6/0 scenario may seem counter intuitive because the average delay is decreasing compared to the no project scenario. Even though the number of train events is increasing, the factor that is driving the decreased delay is the decrease in the average gate downtime per event. This change is a result of the tested prototypical schedule and means that the trains passing through the crossing are more closely overlapping than today.
- **2035 6/2:** The same gate down time effect is happening for 6/2 as described for 6/0. Even though the number of gate downtime events is increasing, the average gate down time per event is less in 6/2 than it is in 6/0, which is driving the decrease in delay of 18.4 seconds per vehicle change from the 6/0 scenario.
- **2035 6/4:** Under this scenario, the average delay per vehicle increases by 2.9 seconds per vehicle, because both the number of gate events and the average gate down time per event is slightly increasing over the 6/2 scenario.

25th Avenue / El Camino Real, San Mateo

The **25th Avenue / El Camino Real** intersection is located west of the 25th Avenue railroad crossing in San Mateo in between the Hayward Park and Hillsdale Caltrain Stations. This is a non pre-empted intersection (the railroad crossing does not communicate with the traffic signal).

Existing Conditions

- Under current conditions, the intersection operates at LOS B in both the AM and PM peak hours simulated.

Simulation – AM and PM Peak

- **2035 No Project:** Under the no project scenario, the gate down time is the same as today (number of train events and average gate down time per event) as this scenario assumes no change to Caltrain service. However, the simulation projects a significant increase in congestion and associated vehicle delay at the intersection due to projected overall growth in vehicle traffic as defined in the 2009 ABAG land use and population projections. Under this scenario the intersection operates at LOS E and LOS F in the AM and PM peak hours, respectively.
- **2035 6/0, 6/2 and 6/4:** Because this intersection is not pre-empted (the railroad crossing does not communicate with the traffic signal) the change in average gate down time and number of train events does not influence the average delay for the 6/0, 6/2 and 6/4 scenarios compared to the no project scenario. This is reflected in Table 4-2 as no change to the average delay compared to the no project scenario for both the AM and PM peak hours and continues to operate at LOS B.

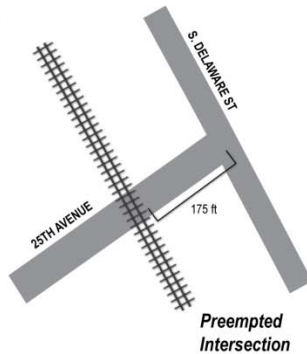
25th Avenue / Delaware Street, San Mateo

The **25th Avenue / Delaware Street** intersection is located east of the 25th Avenue railroad crossing in San Mateo in between the Hayward Park and Hillsdale Caltrain Stations. This is a pre-empted intersection (the railroad crossing communicates with the traffic signal). This 25th Avenue crossing is located within the full-long passing track option, which was assumed for this study. Figure 4-2 includes a diagram of the intersection and presents key simulation inputs and visual representation of the results in Table 4-2.

Figure 4-2: 25th Avenue / Delaware Street Intersection

Simulation Inputs

Intersection



Key Data

	AM Peak	PM Peak
Current Peak Hour Events:	10 events	10 events
Current Avg Gate Downtime:	63 sec / event	57 sec / event
Current Vehicle Delay:	10.2 seconds	10.3 seconds
Current Level of Service:	B	B

2035 Simulation Results: AM Peak

	2035 No-Build	2035 "6/0"	2035 "6/2"	2035 "6/4"
Simulated Peak Hour Events:	10 events / hr*	13 events / hr	17 events / hr	18 events / hr
Simulated Avg Gate Downtime:	63 sec / event*	41 sec / event	41 sec / event	41 sec / event
Simulated Vehicle Delay:				No Change to Vehicle Delay
Total seconds of vehicle delay Incremental change in delay	12.4 seconds -	12.5 seconds +0.1 seconds	13.1 seconds +0.6 seconds	
Simulated LOS:	B	B	B	
*No change from present				

2035 Simulation Results: PM Peak

	2035 No-Build	2035 "6/0"	2035 "6/2"	2035 "6/4"
Simulated Peak Hour Events:	10 events / hr*	11 events / hr	16 events / hr	15 events / hr
Simulated Avg Gate Downtime:	57 sec / event*	44 sec / event	41 sec / event	48 sec / event
Simulated Vehicle Delay:				No Change to Vehicle Delay
Total seconds of vehicle delay Incremental change in delay	13.1 seconds -	15.0 seconds +1.9 seconds	15.6 seconds +0.6 seconds	
Simulated LOS:	B	B	B	
*No change from present				

The following describes the results and key points contained in Figure 4-2:

Existing Conditions

- Under current conditions, the intersection is nearing saturation and operates at level of service B in both the AM and PM peak hours simulated.

Simulation – AM Peak

- **2035 No Project:** Under the no project scenario, the gate down time is the same as today (number of train events and average gate down time per event) as this scenario assumes no change to Caltrain service. The simulation does not project a significant increase in congestion in the no project scenario because the vehicle traffic for this intersection was not as significant as seen in the other sample intersections. Under this scenario the intersection continues to operate at LOS B in the AM and PM peak hours.
- **2035 6/0, 6/2:** The average gate down time per event remains the same for the 6/0 and 6/2 with incremental increases in gate events compared to the no project scenario resulting in increases in average delay of 0.1 and 0.6 seconds per vehicle, respectively. The intersection LOS in these scenarios remains at LOS B.
- **2035 6/4:** The interplay of the average gate down time and the number of train events is such that there is no net change in the average delay under this scenario. Because the 25th Avenue crossing is located within the assume Long-middle passing track option, which allows for 2+ trains to pass through the crossing at the same time. With the prototypical tested schedule, the four overtake tracks had the effect of only slightly increasing the number of gate events over the 6/2 scenario. The intersection LOS in this scenario remains at LOS B.

Simulation – PM Peak

- **2035 No Project:** The same rationale described for the AM peak hour applies for the PM peak hour.
- **2035 6/0:** The interplay of the increased number of gate events increases and the decrease in average gate down time per event over the no project scenario resulted in an increase in average delay of 1.9 seconds per vehicle. The intersection LOS in this scenario remains at LOS B.
- **2035 6/2:** The interplay of the increased number of gate events and the decrease in average gate down time per event compared to the 6/0 scenario resulted in an additional delay of 0.6 seconds per vehicle compared to 6/0. The intersection LOS in this scenario remains at LOS B.
- **2035 6/4:** The same rationale described for the AM peak hour applies for the PM peak hour.

Broadway / El Camino Real, Redwood City

The **Broadway / El Camino Real** intersection is located west of the Broadway railroad crossing in Redwood City in between the San Carlos and Redwood City Caltrain Stations. This is a non pre-empted intersection (the railroad crossing does not communicate with the traffic signal).

Existing Conditions

- Under current conditions, the intersection operates at LOS C in both the AM and PM peak hours simulated.

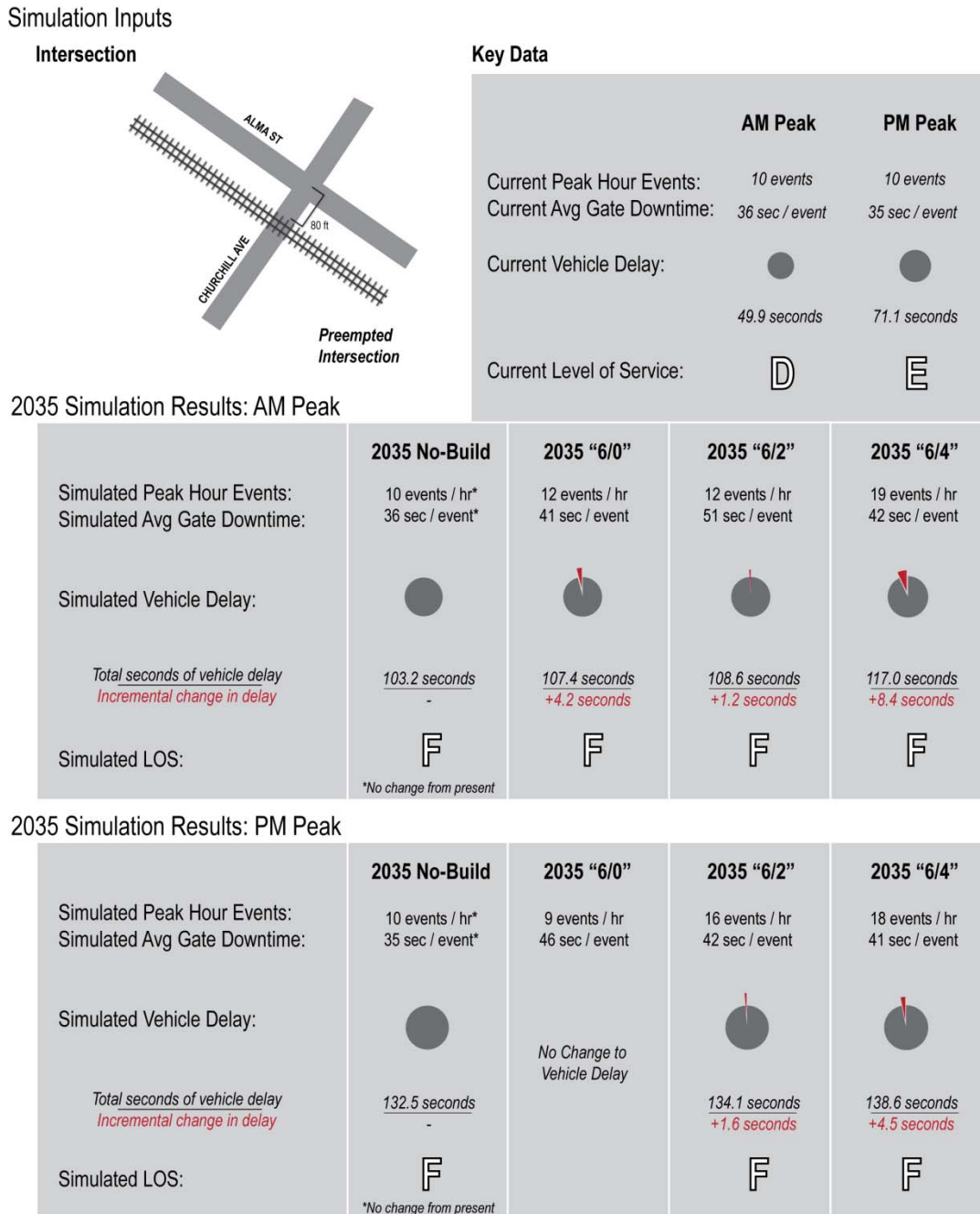
Simulation – AM and PM Peak

- **2035 No Project:** Under the no project scenario, the gate down time is the same as today (number of train events and average gate down time per event) as this scenario assumes no change to Caltrain service. However, the simulation projects an increase in congestion and associated vehicle delay at the intersection due to projected overall growth in vehicle traffic as defined in the 2009 ABAG land use and population projections. Under this scenario the intersection operates at LOS D and LOS E in the AM and PM peak hours, respectively.
- **2035 6/0, 6/2 and 6/4:** Because this intersection is not pre-empted (the railroad crossing does not communicate with the traffic signal) the change in average gate down time and number of train events does not influence the average delay for the 6/0, 6/2 and 6/4 scenarios. This is reflected in Table 4-2 as no change to the average delay compared to the no project scenario and the intersection continues to operate at LOS D and LOS E in the AM and PM peak hours, respectively.

Churchill Avenue / Alma Street, Palo Alto

The **Churchill Avenue / Alma Street** intersection is located west of the Churchill Avenue railroad crossing in Palo Alto in between the Palo Alto and California Avenue Caltrain Stations. This is a pre-empted intersection (the railroad crossing communicates with the traffic signal). Figure 4-3 includes a diagram of the intersection and presents key simulation inputs and visual representation of the results in Table 4.2.

Figure 4-3: Churchill Avenue / Alma Street Intersection



The following describes the results and key points contained in Figure 4-3:

Existing Conditions

- Under current conditions, the intersection is operating at level of service D and E in the AM and PM peak hours simulated, respectively.

Simulation – AM Peak

- **2035 No Project:** Under the no project scenario, the gate down time is the same as today (number of train events and average gate down time per event) as this scenario assumes no change to Caltrain service. However, the simulation projects a significant increase in congestion and associated vehicle delay at the intersection due to projected overall growth in vehicle traffic as defined in the 2009 ABAG land use and population projections. Under this scenario the intersection operates at LOS F in both the AM and PM peak hours.
- **2035 6/0:** Both the number of gate events and the average gate down time per event increase over the no project scenario, resulting in an increase in average delay of 4.2 seconds per vehicle. The intersection LOS in this scenario remains at LOS F.
- **2035 6/2:** The number of gate events remains the same as in the 6/0 scenario while the average gate down time per event increase resulting in an additional delay of 1.2 seconds per vehicle compared to 6/0. The intersection LOS in this scenario remains at LOS F.
- **2035 6/4:** Even though the average gate down time per event is decreasing compared to 6/2 the increase in gate events is driving the increase in average delay, resulting in additional delay of 8.4 seconds per vehicle. The intersection LOS in this scenario remains at LOS F.

Simulation – PM Peak

- **2035 No Project:** The same rationale described for the AM peak hour applies for the PM peak hour.
- **2035 6/0:** The interplay of the average gate down time and the number of train events is such that there is no net change in the average delay under this scenario. The intersection LOS in this scenario remains at LOS F.
- **2035 6/2:** While the average gate down time per event decreased the driving factor for increased delay compared to 6/0 was the number of gate events, resulting in an increased average delay of 1.6 seconds. The intersection LOS in this scenario remains at LOS F.
- **2035 6/4:** While the average gate down time per event decreased the driving factor for increased delay compared to 6/2 was the number of gate events, resulting in an increased average delay of 4.5 seconds per vehicle. The intersection LOS in this scenario remains at LOS F.

4.3 Added Sensitivity Analysis

As the study was progressing, city/county staff expressed interest in understanding the sensitivity of how a future grade separation might impact local traffic at an existing at-grade crossing. To address this question, scope was added to this study to conduct a grade separation analysis at 25th Avenue in San Mateo and at Broadway in Redwood City. These crossings were selected because these crossings are the only study intersection within the limits of the Full-Middle passing track option, which was assumed for this study.

The following three intersections located in the vicinity of the two crossings were analyzed:

- 25th Avenue/El Camino Real
- 25th Avenue/Delaware Street
- Broadway/El Camino Real

The analysis for both the at-grade crossing and grade-separated crossing scenarios are based on the same geometric configurations of the study intersections and neighboring intersection operations. This would not necessarily be the case if a grade separation were to be constructed at an existing at-grade crossing. For the grade separation crossing simulation, the signal phasing was optimized in the model, because future signal phasing plans do not exist.

Similar to intersection LOS analysis under 2035 conditions, intersection LOS values were reported using the HCM Methodology. A summary of differences in intersection delays under 2035 Grade-Separated Crossing scenario, compared to 2035 At-Grade Crossing scenario, is provided in **Table 4-3**.

Table 4-3 2035 Grade-Separated Crossing vs. At-Grade Crossing Scenarios

	Intersection	City	Average Delay (sec per vehicle) / LOS		Difference in Average Delay between 2035 At-Grade and Grade-Separated Crossings	
			2035 At-Grade Crossing		AM Peak	PM Peak
			AM Peak	PM Peak		
HCM Methodology						
	25 th Avenue/El Camino Real (NP)	San Mateo	171.1 / F	74.7 / E	0.0	0.0
	25 th Avenue/Delaware Street (P)	San Mateo	12.4 / B	13.1 / B	-5.1	-5.0
	Broadway/El Camino Real (P)	Redwood City	47.9 / D	61.5 / E	-1.4	-0.1

(P) = Pre-empted intersection

(NP) = Not pre-empted intersection

Specific to the study's simulation methodology, the results of the grade separation analysis show:

- If the traffic intersection is not pre-empted (the railroad crossing does not communicate with the traffic signal), meaning that the traffic signal operates independently from the at-grade crossing, a grade separation will have little effect on the traffic flow, as seen is in the 25th Avenue/El Camino Real results.
- Conversely, in the case of pre-empted (the railroad crossing communicates with the traffic signal) traffic intersections, a grade separation will improve traffic circulation and reduce the average delay at the intersection. This is shown in the case of the 25th Avenue/Delaware Street

and Broadway/El Camino Real intersections. A pre-empted intersection is linked to the railroad crossing. Thus when a train approaches the crossing, the traffic signal phasing is interrupted to allow the train to go through the crossing. In the case of a pre-empted intersection, grade separating the railroad crossing will eliminate the signal phasing interruption, and the traffic intersection can operate uninterrupted.

Chapter 5

Conclusions

The blended system has been defined conceptually. The specifics are to be determined.

One of the specific areas requiring definition is how the at-grade crossings along the blended system will be improved. These improvements may range from traffic signal improvements to at-grade crossing improvements to road closures to grade separations. Because the blended system will not operate at speeds greater than 110 mph, full grade separation is not required. Short this requirement, a process and criteria will need to be established to define an at-grade crossing improvement program beyond Caltrain's existing program which is updated and assessed regularly.

This study begins to lend objectivity to evaluating future traffic conditions associated with the blended system.

The results of this study reveal that there is not a direct linear relationship between train service level changes and gate down time. Though it may seem intuitive that an increase in train traffic would result in a proportional increase in gate down time, the findings of this study show some departure from a purely linear relationship. In some cases, even with more trains, the gate down time is reduced. These outcomes result from having an advanced signal system and overlapping trains at crossings.

The sample crossing traffic analysis indicates that local traffic is influenced by both number of gate events and downtime per gate event. Based on evaluation of the sample crossings, additional general key findings cannot be made. The simulation results for each crossing are particular to that crossing's own specific physical and operating environment.

These findings, while not definitive, will help to inform discussions about the blended system. They can be used to influence the development of blended service plans, a blended system at-grade crossing improvement program and local traffic circulation strategies.

Additional analysis is necessary. However, before doing so, speculation should be minimized. A better understanding of the schedule and decision on passing tracks should be advanced before further traffic analysis is conducted. This study helped highlight the sensitivities of the analysis inputs. Once key blended system inputs are better defined, the future blended system traffic analysis will serve as one criterion to help consider what the blended system looks like and which alternatives should be evaluated in through a separate environmental evaluation and clearance process. Future local traffic analysis will be included in the following:

- Peninsula Corridor Electrification EIR
- Continued blended system planning
- Blended System EIR/EIS

The Peninsula Corridor Electrification EIR is scheduled to be completed in fall 2014. Timing of the other efforts is to be determined.