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Transmittal

CS Transmittal No. 2217

To: Jeffrey Davis
Federal Transit Administration
201 Mission St. Suite 1650
San Francisco, CA, 94105

Date: April 24, 2013

From: John Funghi
Project No./Contract No.: M544.1
Task No./Title:
Project Phase:
Subject: Central Subway T-Line Phase 1 +2 Service Simulation Report

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☐ *fax – **No:*** ☒ *email – **Address:*** jeffrey.s.davis@dot.gov

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- ☒ *other* See itemized list below
- ☐ *estimate*
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- ☒ *information/use* N/A
- ☐ *action*
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- ☐ *response to comment*
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Reference:

Item No.	*Copies*	*Description*	*Rev. No.*	*Date*
1	1	Central Subway T-Line Phase 1 +2 Service Simulation Report	----	04/24/13

If enclosures are not as noted, kindly notify us at once.

Remarks: Please contact Lewis Ames if you have any questions or require additional information on 415-701-4226 or lewis.ames@sfmta.com.

John Funghi
Program Director

LA:srm

cc: David Kuehn, STV, david.kuehn@stvinc.com
Brad Lebovitz, STV, bradley.lebovitz@stvinc.com
Albert Hoe, CSP, (w/attachments)-via email
Eric Stassevitch, CSP, (w/attachments)-via email
Lewis Ames, SFMTA, (w/attachments)-via email
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Operations Analysis Report

San Francisco Central Subway Project Operations Analysis

FINAL 04/24/2013

Title	Central Subway Project Rail Systems/Operations Capacity Analysis
Entity	USA
Nature of report	Operations Analysis Report
Department	Operations Analysis
Reference	PO 2013.01.036 (SYSTRA C0596800)
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Confidentiality	For San Francisco Central Subway Project Use Only

Approval

Version	Name		Date	Signature
0	**Approved by :**	Ian Martin	March 26, 2013	
1	**Approved by :**	Ian Martin	April 24, 2013	

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Revision History

Revision	Comment	Date
0	Initial Draft	March 26, 2013
1	Final Report	April 24, 2013

Executive Summary

SYSTRA, on behalf of San Francisco Municipal Transportation Agency Central Subway Project, conducted an operations/capacity analysis to test and assess Phases One (Year 2018) and Two (Year 2030) of the Central Subway Project 2018 Service Integration Plan, as detailed in the November 12, 2012 Request for Proposal for Rail Systems / Operations Capacity Analysis.

SYSTRA's analysis focused on determining whether the planned T-Third Phase 1 and Phase 2 headways provide sufficient levels of service, and that the planned service and infrastructure under construction between the Chinatown terminus and the diamond and signal interlocking at 4th and King Streets will perform as expected to fulfill the 2018 Service Plan.

Table 1: Overall On-Time Performance

Southbound	Total No. Trains	Average OTP (-h:mm:ss = late)
2018 (3.75-Minute HW)	201	0:00:58
2030 (2.5-Minute HW)	242	0:00:51

Northbound	Total No. Trains	Average OTP at Destination
2018 (3.75-Minute HW)	203	-00:00:15
2030 (2.5-Minute HW)	244	0:00:37

The simulated train schedules for the E and N lines were unaltered from provided schedule information. SYSTRA developed a conceptual schedule for each simulation year for the T-Third Line, using provided schedule points as an initial guide, and adding consideration of traffic light timings and dwells. The Year 2018 schedule observed the prescribed levels of service, with a highest level of 3.75-minutes. The Year 2030 schedule observed the prescribed levels of service, with a highest level of 2.5 minutes.

The simulations demonstrate that, under the circumstances and assumptions detailed within this report, Muni operations within the study territory can succeed under both the 3.75-minute minimum headway prescribed for Year 2018 and the 2.5-minute headway prescribed for Year 2030. Table 1 illustrates that, on average, both years' levels of service are achievable, given that the absolute value of average on-time-performance is less than half the desired level of service. Some adjustments will need to be made to ensure level of service achievement on a train-by-train basis, as discussed in Section 5 Conclusions and Recommendations.

Additionally, in order to *comfortably* support the Year 2030 minimum headway of 2.5 minutes, Muni may need to consider a longer light cycle at 4th and King or the potential of giving priority to T line trains at this intersection. SYSTRA makes this and other recommendations in the Conclusions and Recommendations.

1 Introduction

SYSTRA, on behalf of San Francisco Municipal Transportation Agency Central Subway Project, conducted an operations/capacity analysis to test and assess Phases One (Year 2018) and Two (Year 2030) of the Central Subway Project 2018 Service Integration Plan, as detailed in the November 12, 2012 Request for Proposal for Rail Systems / Operations Capacity Analysis.

SYSTRA's analysis focused on determining whether the planned T-Third Phase 1 and Phase 2 headways provide sufficient levels of service, and that the planned service and infrastructure under construction between the Chinatown terminus and the diamond and signal interlocking at 4th and King Streets will perform as expected to fulfill the 2018 Service Plan.

This report describes the operations/capacity analysis, from gathering information and preparing the simulation database — including developing conceptual T-Third Line train schedules for the two phases — to performing the simulation and interpreting its results.

This report includes five primary sections; this Introduction and:

- Section Two - Approach and Methodology which describes SYSTRA's process in gathering and vetting the information required to assemble the simulation model.
- Section Three - Model Validation (Calibration) describes the way SYSTRA verified that performance of the updated model in improved RAILSIM software was within acceptable range of the calibrated model in 2010.
- Section Four - Simulation Results reviews the simulation output, and
- Section Five - Conclusions and Recommendations describes SYSTRA findings and suggestions based on simulation results.

The study was performed under contract with the Central Subway PMCM, the Central Subway Partnership (CSP).

1.1 Study Territory

The simulation limits were defined in Section Two of the November 12, 2012 Request for Proposal for Rail Systems / Operations Capacity Analysis. It encompasses:

- Existing N – Line: The simulation territory includes the existing light rail operations between the 2nd & King Street station to the 4th & King Street that is the current T and N – line routes.

- Existing T – Line Third Street: The existing light rail operations between 4th & King Street station south to the T-Third Street station. This route captures the Mission Bay Loop (MBL) turn-back operations. The MBL operation has southbound train turning back via crossing the T-Third northbound access to the loop. The MBL is a single track in street running returning to Third Street via a layover stop on Illinois Street. The modeling from 4th and King Street to 20th Street included the T-Third trains for Sunnydale.

- Future Phase Two between the 4th & King Street intersection and Chinatown station platform.

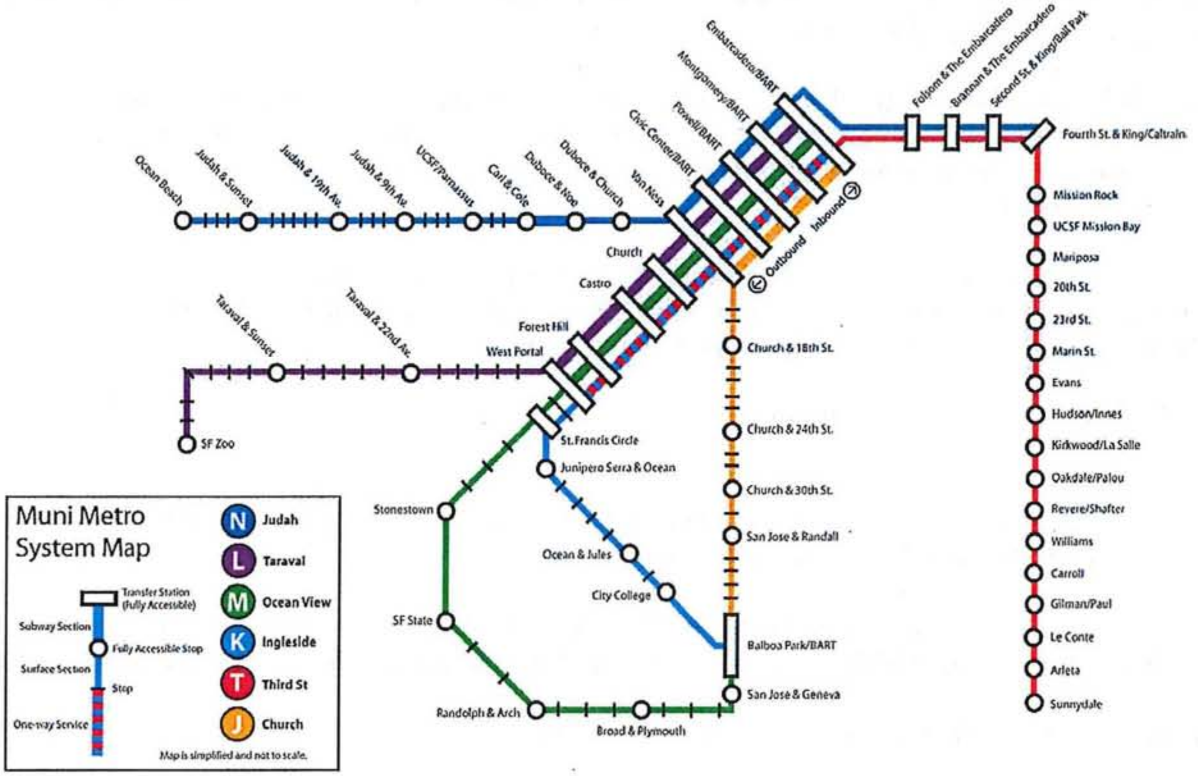


Figure 1: Muni Metro System Map

1.2 Scope of Work

The November 12, 2012 Request for Proposals defined a scope of Work requiring SYSTRA to analyze the proposed Central Subway Project 2018 and 2030 Service Integration Plan in order to confirm that the planned T-Third Phase One (Year 2018) and Phase Two (Year 2030) headways would provide sufficient levels of service.

One goal of the SFMTA was to incorporate the results of SYSTRA's analysis into the updated T-Third Phase One and Two Service Integration plan to be approved by SFMTA Operations.

SYSTRA assessed the performance of the 4th & King Street interlocking to verify the capacity and throughput of three independent light rail routes, namely the T-Third Phase One & Two, the N-Judah and the E-Embarcadero, that cross and connect (T, N, E) at the diamond. The simulation analysis verified the interlocking capacity of the signal programming and timing that control the vehicle movement, speeds and volume.

In preparing the simulation, SYSTRA addressed recommendations from its 2010 simulation analysis as follows:

1- Manage MME pull-outs to avoid peak hour operations at 4th and King Junction: The simulation did not include non-revenue moves for lines other than the T-Line.

2- Double berthing at Berry Street Station: Double berthing was not simulated.

3- Reduce train volumes between 4th/Berry and Chinatown Station: Caltrain Tripper Service was removed from the simulated service plan. The 2018 Service Plan called for 3.75 minute headways on the T line "trunk" and 7.5 minute headways out to 20th Street and beyond. The 2030 Service Plan called for 2.5 minute headways on the T-Third "trunk" and 5 minute headways out to 20th Street and beyond.

4- Higher recovery at the street terminals/adjusted run times: The 2018 and 2030 schedules developed for this study were based on unimpeded station to station run times (including 20 second station dwells). To those run times, eight seconds of run time pad were added for each street intersection between each station pair. An additional nine seconds was added as a station pair dwell pad. Trains at terminals were held for scheduled depart time to ensure proper headway spacing.

5- Improve the 4th and King Street Intersection: T Line trains' schedules take advantage of updated programming for the signals to allow parallel movement through the intersection. No track switch moves were defined or used at 4th and King Intersection.

1.3 Project Schedule

Per its agreement with SFMTA, SYSTRA has delivered this draft Simulation Analysis report. Representatives of the Central Subway Project have been allocated fifteen (15) working days to review the document and submit comments. If no comments are received within the fifteen (15) days, SYSTRA will conclude that the draft document is acceptable. From the fifteen (15) days or receipt of the draft reports comments SYTRA will review and amend, if required, the draft report.

The final report will be delivered, in electronic (pdf) format, to Central Subway Project within fifteen (15) days from the date SYSTRA receives any comments.

1.4 Deliverables

Section Six of the Scope of Work within the November 12, 2012 Request for Proposals defined the project deliverables as

a) Memo of Base Case Validation Results

b) Memo of Preliminary evaluation of the Future Case

c) Final Report

Due to the speed with which the Central Subway Partnership has requested SYSTRA approach this project; all three deliverables are represented in this draft document. SFMTA review should consider this in preparing its review comments which, as noted above, must be received no later than fifteen (15) days from the draft date.

2 Approach and Methodology

2.1 Infrastructure

SYSTRA used the calibrated RAILSIM model from our 2010 SFMTA Muni Central Subway Network Simulation Analysis (under SFMTA contract 2008-02; SYSTRA project C0578200).

The track curve speeds within the model were updated from Chinatown to 4th & King intersection to reflect the track curve speeds indicated on provided drawings, namely: "5/25/2012 Phase 2 – Central Subway Surface, Track and Systems Track Alignment Summary sheets." In addition, the following speeds were coded, per direction from Muni (L. Ames email 2/28/2013):

- CTS Tail track segment speed: Maximum allowable speed though the CTS tail track is 5 mph.
- CTS turnouts and diamond crossover segment speed: Maximum allowable speed though the CTS turnouts and diamond crossover is 20 mph.
- Tangent segment speed: Maximum allowable speed on tangent is 50 mph.
- Portal from tunnel to surface / from surface to tunnel speed: Maximum allowable speed is 30 mph due to OCS wire restrictions.
- Surface segment speed: Maximum allowable speed on the 4th Street surface segment is 25 mph per CPUC GO 143-B Section 9 Table 1 for alignment Classification 9.04 b. (3). Legal speed of parallel traffic is 25 mph.

2.2 Train Control

It was agreed during the course of the study that signal pre-emption would not be used in the analysis, but that traffic signal timing cards would be used.

The intersection of 4th and King Street's was modeled according to the 110 second traffic signal timing card received from SFMTA. The simulation considers only train moves through this intersection and does not consider the impact of train moves on other vehicle or pedestrian traffic or vice versa.

The two cycles of concern to this simulation are the Muni EB/Muni WB and the Muni NB/Muni SB cycles. Although the cycles are listed as four separate cycles on the cards the east bound and west bound cycle times overlap as do the north bound and south bound cycle times. We will therefore consider these as two cycles.

The Muni EB/Muni WB cycle applies to the N and E line trains moving to and from the CALTRAIN platform. The duration of the WT (Steady White "T") cycle is 12 seconds. The duration of the FWT (Flashing White "T") cycle is 6 seconds. The start of this cycle is offset by 11 seconds from the beginning of the full light cycle.

The Muni NB/Muni SB cycle applies to the T line trains headed into and out of Chinatown station. The duration of the WT cycle is 33 seconds. The duration of the FWT cycle is 6 seconds. The start of the WT cycle is offset by 24 seconds from the end of the FWT cycle for the Muni EB/Muni WB cycle.

In both cases trains were allowed to proceed through the 4th and King intersection if they arrived during the WT cycle or the first half (3 seconds) of the FWT cycle.

Due to speed restrictions and station stopping patterns both within and just outside of the 4th and King intersection the running times of the trains through the intersection vary. The time for the various trains to clear the fourth and King intersection is listed in Table 2. This time is measured from the time that the train receives a white 'T' indication on the light until the tail of the train clears the traffic signal on the opposite side of the intersection. During this period of time conflicting moves will not be allowed to occur.

Table 2 Train clearing times for the 4th and King intersection

Train Route	Clearing Time
E/N Line West Bound	43 Seconds
E/N Line East Bound	28 Seconds
T Line North Bound	38 Seconds
T Line South Bound	35 Seconds

Trains entering the intersection near the end of the light cycle will transit through the intersection during potentially conflicting light cycles. SYSTRA made no attempt to assess the impact of this on vehicle or pedestrian traffic. There is the possibility of this timing interfering with trains on conflicting moves through the intersection which is considered in the simulation. These train moves, along with the light cycle times, are depicted in Figure 2. Figure 2 lists the potential impact of these 'late' train moves through the intersection on the crossing trains within the intersection. Note that the east bound E and N line trains will always interfere with the T line light cycle since the 43 second clearing time is greater than the time provided between the start of the two cycles.

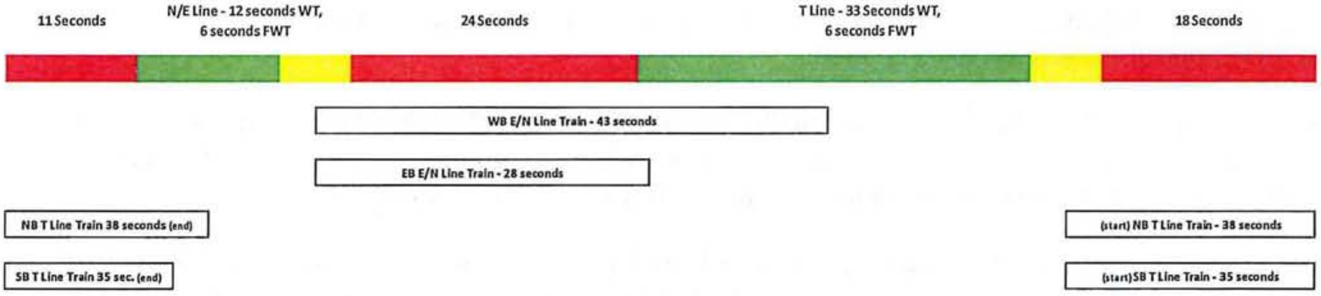


Figure 2 Clearing times of worst case trains at the 4th and King intersection

Table 3: Potential Conflicts for the 4th & King Intersection

Train Route	Maximum time into the opposing train light cycle
E/N Line East Bound	16 Seconds
E/N Line West Bound	1 Seconds
T Line North Bound	6 Seconds
T Line South Bound	3 Seconds

2.2.1 Street Running

A major part of the T-Third line simulated in this task was made up of street running operations which are subject to operator variability, traffic light delays weather conditions and other human interactions (pedestrian crossing, etc.) Part of the T-Third line also operates in a shared right-of-way. All of this contributes to a large degree of variability in run times.

In order to accurately reflect these variations in run times a combination of modeling techniques was used including randomizing starting times for trains and traffic light stop times and using actual light cycle times for specific traffic lights.

The source of most of the information for traffic light stop and dwell times is documented in the 'SF Muni Central Subway Simulation Report' dated April 5, 2010. Up to date traffic light timing cards were also provided for specific intersections as described in the following sections.

2.2.1.1 Trains entering the simulation at 23rd Street

In this effort we are only simulating trains between 23rd street and Chinatown station. Trains from Sunnydale enter the simulation at 23rd street with their first stop being 20th street station. Running time observations from the SYSTRA 2010 simulation were analyzed to determine the variability in run times between Sunnydale and 23rd street.

The T-Third between Sunnydale and 23rd street contains sections of shared right-of-way and a freight train crossing. The rare occurrence of a freight train crossing the line or a traffic incident in a section of shared right-of-way can cause extreme delays. Observed running times that were outside of 1.75 standard deviations from the mean were considered to be outliers and were discarded.

The remaining observations showed running time variability with a standard deviation greater than 10 minutes. For the planned 3.75 minute headway a run time variability approaching 7 minutes will cause conflicts and delays at the Mission Bay Loop where trains turning at the loop need to be interspersed with trains arriving from Sunnydale. Larger variability will cause trains to be out of order (i.e. two trains from Mission Bay Loop following behind each other). For the 2.5 minute headway the variability must be less than 5 minutes to avoid the above stated problems.

In order to avoid these conflicts this run time variability needs to be reduced. As previously mentioned there are conditions on the T-Third line between Sunnydale and 23rd street that will always present the possibility of a severely delayed train but the variability in normal operations can be reduced by some combination of the following methods:

- Providing more prioritization opportunities for trains at street crossings or
- Provide more schedule pad and have early trains hold for schedule at selected stops along their route

For the purpose of the randomized simulations it was assumed that the variability of trains at 23rd street would be no more than 5 minutes. The put-in times of trains entering the simulation at 23rd street was randomized with these constraints using a normalized distribution.

2.2.1.2 4th and King Intersection

The 4th and King intersection is a primary focus of this simulation. Trains at this intersection were lined up according to the timing card received from SFMTA for a proposed 110 second light cycle. Trains that arrive during the 'WT' phase of the 4th and King light or during the first half (3 seconds) of the FWT cycle were allowed to go through the intersection after stopping and requesting their route. Trains that arrived outside of these times were forced to wait until the start of the next 'WT' phase.

The headways of the T-Third line trains at this intersection were examined according to these rules to determine whether this cycle time was sufficient.

The crossing E and N trains were lined up in the same way. Using the light cycle timing described above these trains do not interfere with the T-Third trains. In the case of prioritizing trains these trains would be vying for priority along with the T-Third trains.

2.2.1.3 Other intersections

All other intersections within the study area were simulated using a random chance of the train being stopped at that intersection and a random dwell time according to information previously provided by SFMTA and documented in 'Table 1: Average Signal Delay – SFMTA Assumptions for 2030 RAILSIM Model' in the 'SF Muni Central Subway Simulation Report' dated April 5, 2010.

2.2.1.4 Central Subway Portal

SFMTA informed us that the transition time to and from cab signaling is between three and five seconds. The stopping time of the trains at the portal was randomized using a normal distribution to be within this range.

2.3 Rolling Stock

Muni operates two-car, Breda LRV train compositions. The fleet includes 151 Breda LRVs, numbered 1400-1550.

No modifications were required to the rolling stock, which had been modeled and calibrated under a previous study. Their calibration was documented in SYSTRA's report entitled: Core Area Calibration Report, dated 18th November 2009, issued to SFMTA.

2.4 Operations

2.4.1 Operating Hours

SYSTRA simulated the operations between 6:00 AM and 10:00 PM (Morning Peak through Evening time periods), as described in the Service Integration Plan for Operations, Fleet and Financial Planning document supplied by SFMTA. These hours are defined in Table 4 and Table 5

Table 4: Operating Hours & Headway 2018

Operating Period	From	To	Headway (minutes) T-Third Bayshore - Stockton	Headway (minutes) Ts – Line 19th / 3rd – Stockton	Maximum Frequency
Morning (AM) Peak	6 AM	10 AM	7.5	7.5	3.75
Midday	10 AM	4 PM	10	10	5
Afternoon (PM) Peak	4 PM	8 PM	7.5	7.5	3.75
Evening	8 PM	10 PM	12	-	12

Table 5: Operating Hours & Headway 2030

Operating Period	From	To	Headway (minutes) T-Third Bayshore - Stockton	Headway (minutes) Ts – Line 19th / 3rd – Stockton	Maximum Frequency
Morning (AM) Peak	6 AM	10 AM	5	5	2.5
Midday	10 AM	4 PM	10	10	5
Afternoon (PM) Peak	4 PM	8 PM	5	5	2.5
Evening	8 PM	10 PM	12	-	12

2.4.2 Operating Headways

The simulations modeled San Francisco Muni high frequency headway over the 4th & King Street intersection, as described in the Service Integration Plan for Operations, Fleet and Financial Planning document supplied by SFMTA, and summarized in Table 4 served as the initial set of simulations. A second set of simulations tested the ability of the study territory to support the more aggressive headways illustrated in Table 5.

2.4.3 Schedules

SYSTRA developed Year 2018 and Year 2030 schedules for this analysis by collecting available schedule information as follows:

- E Line schedules were provided by SFMTA and were previously in use for the America's Cup race that was held in San Francisco during August 2012.
- N Line schedules were taken from the 511 web site.
- Schedule information for the T Line was adapted from the current data available on the 511 web site.

Train ID's were constructed based on route, direction, and order of dispatch from put-in. For example, Train TSB0016 is a T-Train and it is Southbound. The 0016 identifies the train as the 16th train in the simulated sequence departing from Chinatown.

With this information, the "sketch" operating plan was ready for preliminary simulation to test station-to-station run times for completion of the T Line schedule. The schedules of the E and N lines were applied to the simulation without alteration. The preliminary simulation was performed with no randomization and no consideration of traffic signals/intersections. Its only purpose was to establish the station-to-station run times on which the final T Line schedule would be based.

To the run times from the preliminary simulation, eight seconds of pad were added for every street intersection between each station pair (for example, where three street intersections exist between two stations, 24 seconds of pad was applied). An additional nine seconds pad was added to each station pair. Trains at terminals were held for scheduled depart time to ensure proper headway spacing. These adjustments were in keeping with SYSTRA's recommendations from the 2010 study.

Finally, an additional 12 seconds of pad were added between Chinatown and Union Square Market to allow for crossover moves at Chinatown.

The calculations and the final station-to-station run times that were used in developing the T-Third schedule are shown in Table 6:

Table 6: Establishing Station-to-Station Run Times for T-Third Schedule

(All times in mm:ss)

From	To	# of Intersections between stations	Unconstrained Simulated Travel Time	Padding based on 8 sec per intersection	Sub-Total	Station pair dwell pad	Total
			Mission Bay Loop to Chinatown				
MISSION BAY LOOP	MARIPOSA	2	02:41	00:16	02:57	00:09	03:06
MARIPOSA	UCSF MISSION BAY	2	01:21	00:16	01:37	00:09	01:46
UCSF MISSION BAY	Mission Rock Sta	3	01:21	00:24	01:45	00:09	01:54
Mission Rock Sta	Fourth + Berry	3	02:12	00:24	02:36	00:09	02:45
Fourth + Berry	4th + King	0	00:26	00:00	00:26	00:09	00:35
4th + King	4TH + BRANNAN	2	01:28	00:16	01:44	00:09	01:53
4TH + BRANNAN	Central Subway Portal	1	00:34	00:08	00:42	00:09	00:51
Central Subway Portal	MOSCONE	0	00:54	00:00	00:54	00:09	01:03
MOSCONE	UNION SQUARE MARKET	0	01:16	00:00	01:16	00:09	01:25
UNION SQUARE MARKET	CHINATOWN Sta	0	01:28	00:00	01:28	00:09	01:37
			Chinatown to Mission Bay Loop				
CHINATOWN Sta	UNION SQUARE MARKET	0	01:22	00:12**	01:34	00:09	01:43
UNION SQUARE MARKET	MOSCONE	0	01:15	00:00	01:15	00:09	01:24
MOSCONE	Central Subway Portal	0	00:37	00:00	00:37	00:09	00:46
Central Subway Portal	4TH + BRANNAN	1	00:51	00:08	00:59	00:09	01:08
4TH + BRANNAN	4th + King	2	00:57	00:16	01:13	00:09	01:22
4th + King	Fourth + Berry	0	00:59	00:00	00:59	00:09	01:08
Fourth + Berry	Mission Rock Sta	4	02:10	00:32	02:42	00:09	02:51

Table 6: Establishing Station-to-Station Run Times for T-Third Schedule

(All times in mm:ss)

From	To	# of Intersections between stations	Unconstrained Simulated Travel Time	Padding based on 8 sec per intersection	Sub-Total	Station pair dwell pad	Total
Mission Rock Sta	UCSF MISSION BAY	3	01:10	00:24	01:34	0:09	01:43
UCSF MISSION BAY	MARIPOSA	2	01:16	00:16	01:32	00:09	01:41
MARIPOSA	MISSION BAY LOOP	0	01:35	00:00	01:35	00:09	01:44
23rd Street to Mariposa							
23RD STREET	20TH STREET	2	01:26	00:16	01:42	00:09	01:51
20TH STREET	MARIPOSA	3	01:35	00:24	01:59	00:09	02:08
Mariposa to 23rd Street							
MARIPOSA	20TH STREET	3	01:22	00:24	01:46	00:09	01:55
20TH STREET	23RD STREET	2	01:21	00:16	01:37	00:09	01:46
2nd and King to King and 6th							
2nd + King	4th + King	3	01:36	00:24	02:00	00:09	02:09
4th + King	King + Fourth	0	01:13	00:00	01:13	00:09	01:22
King + Fourth	King + 6th	1	02:11	00:08	02:19	00:09	02:28
King and 6th to 2nd and King							
King + 6th	King + Fourth	1	02:07	00:08	02:15	00:09	02:24
King + Fourth	4th + King	0	00:29	00:00	00:29	00:09	00:38
4th + King	2nd + King	3	02:22	00:24	02:46	00:09	02:55

**Added 12 seconds of pad for crossover move.

It must be noted that SYSTRA only considered loading of the system for the T-Line trains. All T-Line trains entering the simulation were started at 20th Street with the assumption that they originated at the MME. When these trains left the simulation, they exited through 20th Street. The N and E Line trains entered and left the simulation via 2nd and King, and 4th and King. Congestion at 4th and King remains an issue.

2.4.4 Passenger Counts

Passenger counts were taken from Service Plan R1 2011-03-16.pdf, Section 4.1 2018 Capacity Analysis, Figure 14: 2018 Capacity for Long and Short Line, as detailed in Table 19. This document lists the LRV Capacity @ 85% avg. load at 101. Since two-car trains were simulated, the number was doubled to 202, and kept constant for all trains.

In the 2010 study, a passenger count of 310 was applied, and was used for all trains.

2.5 Simulation Scenarios

Each of the two operating years (2018 and 2030) was simulated as randomized simulation. Random variability was applied to:

- Whether a train was stopped by a traffic signal
- Traffic Signal Stop dwell times

- Station Stop Dwell Times
- Train Put-In Times at 23rd Street

2.6 Other Data and Assumptions

Throughout all scenarios SYSTRA did not consider the number of train-sets available for operation or that Muni had sufficient Train Operators to meet the required headway. Fully detailed equipment cycling was not required by the scope of work and was not performed.

2.6.1 Chinatown Station

Information was not available as to what SFMTA plans to do with this station during non-service hours. There were questions such as would Chinatown Station be closed or would security be provided in case trains were stored either in the station or on the tail tracks that could not readily be answered.

After considering various options for Chinatown Station, it was finally decided that no trains would be stored at Chinatown, and that all trains would originate at the Muni Metro East Rail Maintenance Facility.

2.6.2 Mission Bay Loop

In the process of creating the equipment turns at the Mission Bay Loop it became apparent that turning trains "one for one" would not work given the headway changes. SYSTRA determined that it was necessary to remove some trains from the simulation at Mariposa Station and route them to the Muni Metro East Rail Maintenance Facility. Those trains were returned as non-revenue trains during the afternoon hours when headways increased, entering service at the Mariposa Station. Removal of trains occurred again during the late-evening hours, again due to the increased headways.

Further, SYSTRA assumed that Mission Bay Loop was not used as a station platform and that more than one train was allowed to occupy the loop at any one time (in a joint layover). SYSTRA therefore allowed a maximum of two train-sets to occupy the loop at any one time. This was useful during transitions from one level of service to another (from peak to off-peak service, when trains can bunch together).

2.6.3 N and E Trains

In order to simulate the congestion that might occur at the 4th and King intersection, the current N and E (from the America's Cup race) train schedules were added to the operating plan. The randomized dwell times and traffic light delays developed for the N trains during a previous task were used. Put-in times were not randomized.

The simulation results for the N and E trains will not be compiled or analyzed as part of this study, as these trains were only included in the simulation in order to simulate the conflicts that would occur with T-Third operations.

2.6.4 Fire Code Ventilation Zones

The simulation did not include consideration of fire codes that may prevent multiple trains from occupying a section of tunnel simultaneously.

SYSTRA has since learned that there such a restriction exists within the governing fire code that permits only one train between station pairs at a time. SYSTRA's understanding is that the planned vent zones surrounding Chinatown Station are designed such that a train entering Chinatown can approach the crossover in front of the station while another train simultaneously departs Chinatown station from the same track through the crossover.

Assuming this is the case, SYSTRA does not have any reason to believe that the constraints imposed by the fire code would have a significant enough impact on headways to prevent the planned 2.5-minute headway from being achieved. The 2030 simulation and, to a lesser extent, the 2018 simulation do exhibit train bunching in the tunnel prior to Chinatown station. Implementation of the fire code constraints would spread these trains out through the tunnel. There is a risk that this bunching of trains observed at Chinatown could then occur at the portal entrance to the tunnel as trains await the opportunity to enter. SYSTRA cannot say definitively at this time whether this is likely to occur.

3 Model Validation (Calibration)

Because SYSTRA started with a pre-existing and already calibrated RAILSIM model for this study, full calibration was not necessary. However, database updates and the fact that RAILSIM Network Simulator has evolved significantly since the 2010 simulation study dictated that some validation be performed.

Today's RAILSIM includes many software improvements. These affect simulations in that the software is handling resistance differently. Current RAILSIM now includes rotational mass in its computations, which results in lower grade, curve and rolling resistance.

The frequency of train stopping in the Muni model, due to grade/street crossings, indicated a greater chance of this software difference having a noticeable impact.

SYSTRA replicated certain train runs from the 2010 study, and simulated them in the current (2013) RAILSIM software. The simulation times were very similar to the 2010 simulation results and were within 10% of the 2010 observed run time average, indicating that the current model can be considered calibrated within a reasonable tolerance. The results of the validation are provided in Table 7.

Table 7: Model Behavior in Previous and Current Simulations vs. 2010 Observed Run Times

	2010 Observed Run Time Average	2010 Calibration			2013 Validation		
		Run Time	Diff.	% Diff.	Run Time	Diff.	% Diff.
From 23rd St. To 20th St.	01:04	01:07	-00:03	-4%	01:07	-00:03	-4%
From 20th St. To Mariposa	01:10	01:10	-00:00	0%	01:14	-00:04	-6%
From Mariposa To UCSF Mission Bay	00:56	01:01	-00:05	-8%	01:01	-00:05	-8%
From UCSF Mission Bay To Mission Rock	00:55	01:01	-00:06	-10%	01:01	-00:06	-10%
From Mission Rock To 4th + Berry	02:01	01:53	00:08	6%	01:53	00:07	6%

4 Simulation Results

The simulations were based on the timetables developed to support the 2018 and 2030 service plans, as described in the Service Plan R1 2011-03 16 provided by SFMTA and referenced in Table 19.

Table 8: Overall On-Time Performance

Southbound	Total No. Trains	Average OTP (-h:mm:ss = late)
2018 (3.75-Minute HW)	201	0:00:58
2030 (2.5-Minute HW)	242	0:00:51
Northbound	**Total No. Trains**	**Average OTP at Destination**
2018 (3.75-Minute HW)	203	-00:00:15
2030 (2.5-Minute HW)	244	0:00:37

Table 9: On-Time Performance of T-Third Trains at Key Locations

Southbound	Chinatown to MBL (Trains)	On-Time Performance		Chinatown to 23rd St (Trains)	On-Time Performance	
		Earliest	Latest		Earliest	Latest
2018 (3.75-Minute HW)	91	0:02:45	0:01:04	110	0:04:14	0:00:10
2030 (2.5-Minute HW)	112	0:02:38	0:05:02	130	0:04:18	0:00:08
Northbound	**23rd St to Chinatown (No. Trains)**	**On-Time Performance**		**MBL to Chinatown (No. Trains)**	**On-Time Performance**	
		Earliest	**Latest**		**Earliest**	**Latest**
2018 (3.75-Minute HW)	115	0:04:14	0:03:17	88	00:02:47	0:02:17
2030 (2.5-Minute HW)	139	0:04:43	0:04:17	105	0:03:29	0:00:46

Times provided in h:mm:ss

4.1 Year 2018 Simulation

As shown in Table 9, the earliest Southbound arrival at Mission Bay Loop was 00:02:50 with the latest arrival being -00:01:58. For services arriving at 23rd Street the earliest arrival was 00:04:15 with the latest arrival being -00:00:41.

The average Southbound on-time performance of T-Third trains was 00:01:43.

Northbound services departing Mission Bay Loop and arriving in Chinatown has the earliest arrival being 00:02:49 with the latest arrival being -00:02:15. Northbound services departing 23rd Street and arriving in Chinatown had an earliest arrival of 00:04:15 with the latest arrival being -00:02:15. The average on-time performance arriving in Chinatown was 00:00:57.

The average Northbound on-time performance of T-Third trains was.

Table 10: T-Third Throughput: Year 2018 Simulation

AM Southbound	Chinatown		4th & King		Mission Bay Loop		23rd St.	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
6:00 - 6:59:59 AM	8	8	10	10	0	0	7	7
7:00 - 7:59:59 AM	16	16	16	16	6	6	9	9
8:00 - 8:59:59 AM	16	16	15	15	8	8	8	8
9:00 - 9:59:59 AM	12	12	12	12	6	6	6	6
10:00 - 10:59:59 AM	12	12	12	12	6	6	6	6
Total	64	64	65	65	26	26	36	36
AM Northbound	**23rd St.**		**Mission Bay Loop**		**4th & King**		**Chinatown**	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
6:00 - 6:59:59 AM	12	12	0	0	10	10	9	9
7:00 - 7:59:59 AM	10	10	6	6	16	16	16	16
8:00 - 8:59:59 AM	8	8	7	7	15	15	16	16
9:00 - 9:59:59 AM	6	6	6	6	12	12	12	12
10:00 - 10:59:59 AM	6	6	6	6	12	12	12	12
Total	42	42	25	25	65	65	65	65
PM Southbound	**Chinatown**		**4th & King**		**Mission Bay Loop**		**23rd St.**	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
3:00 - 3:59:59 PM	13	13	12	12	6	6	6	6
4:00 - 4:59:59 PM	16	16	16	16	8	8	8	8
5:00 - 5:59:59 PM	16	16	16	16	7	7	8	8
6:00 - 6:59:59 PM	10	10	11	11	4	4	6	6
7:00 - 7:59:59 PM	10	10	10	10	5	5	5	5
Total	65	65	65	65	30	30	33	33
PM Northbound	**23rd St.**		**Mission Bay Loop**		**4th & King**		**Chinatown**	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
3:00 - 3:59:59 PM	7	7	6	6	13	13	12	12
4:00 - 4:59:59 PM	8	8	8	8	16	16	16	16
5:00 - 5:59:59 PM	7	7	7	7	16	16	16	16
6:00 - 6:59:59 PM	5	5	5	5	10	10	10	10
7:00 - 7:59:59 PM	5	5	5	5	10	10	10	10
Total	32	32	31	31	65	65	64	64

*16 Trains Per Hour satisfies the 3.75-minute target headway.

4.2 Year 2030 Simulation

For Southbound services trains departing Chinatown to Mission Bay Loop had the earliest arrival being 00:02:38 with the latest arrival being -00:05:02. Services to 23rd Street had the earliest arrival being 00:04:18 and the latest arrival being -00:00:08.

The average Southbound on-time performance of T-Third trains was just under a minute early, at 0:00:51.

Northbound services arriving in Chinatown from 23rd Street had the earliest arrival being 00:04:43 with the latest arrival being -00:04:17. The earliest Northbound service from Mission Bay Loop arriving in Chinatown was 00:03:29 and the latest just under a minute late at -00:00:46.

The average Northbound on-time performance of T-Third trains was about two-thirds of a minute early, at 000:00:37.

Table 11: T-Third Throughput: Year 2030 Simulation

AM Southbound	Chinatown		4th & King		Mission Bay Loop		23rd St.	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
6:00 - 6:59:59 AM	12	12	11	11	1	1	9	8
7:00 - 7:59:59 AM	24	24	24	24	11	11	10	11
8:00 - 8:59:59 AM	23	23	24	24	9	9	12	11
9:00 - 9:59:59 AM	12	12	12	12	6	6	8	8
10:00 - 10:59:59 AM	12	12	12	12	6	6	6	6
Total	83	83	83	83	33	33	45	44

AM Northbound	23rd St.		Mission Bay Loop		4th & King		Chinatown	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
6:00 - 6:59:59 AM	16	16	0	0	14	14	12	12
7:00 - 7:59:59 AM	12	12	12	12	24	24	24	24
8:00 - 8:59:59 AM	10	10	9	9	21	20	22	23
9:00 - 9:59:59 AM	6	6	6	6	12	13	12	12
10:00 - 10:59:59 AM	6	6	6	6	12	12	12	12
Total	50	50	33	33	83	83	82	83

PM Southbound	Chinatown		4th & King		Mission Bay Loop		23rd St.	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
3:00 - 3:59:59 PM	13	13	12	12	6	5	6	6
4:00 - 4:59:59 PM	24	24	24	24	11	11	10	11
5:00 - 5:59:59 PM	24	24	23	23	10	10	12	12
6:00 - 6:59:59 PM	12	12	14	14	7	6	8	7
7:00 - 7:59:59 PM	12	12	12	12	6	6	6	6
Total	85	85	85	85	40	38	42	42

PM Northbound	23rd St.		Mission Bay Loop		4th & King		Chinatown	
Time at Location	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.	Sch.	Sim.
3:00 - 3:59:59 PM	8	9	6	6	15	15	14	13
4:00 - 4:59:59 PM	12	12	11	11	24	24	24	24
5:00 - 5:59:59 PM	10	10	10	10	22	22	23	24
6:00 - 6:59:59 PM	6	6	6	6	12	12	12	12
7:00 - 7:59:59 PM	6	6	6	6	12	12	12	12
Total	42	43	39	39	85	85	85	85

Highlighted cells indicate instances where trains in the simulation arrived either just before the start of or just after the end of the associated time period, while their scheduled time fell within the time period.

*24 Trains Per Hour satisfied the target headway.

5 Conclusions and Recommendations

The simulations demonstrate that, under the given circumstances and with the given assumptions, Muni operations within the study territory can succeed under the 3.75-minute minimum headway proposed for Year 2018. In order to comfortably support the Year 2030 minimum headway of 2.5 minutes, Muni may need to consider a longer light cycle at 4th and King or the potential of giving priority to T line trains at this intersection.

As the headways become tighter there will be an increased risk of trains queuing outside of stations due to variations in run times and dwells. Although this did not appear to be a major concern in the 2018 operations, the 2.5 minute headway in the 2030 operating plan makes this a likely event. In particular, southbound T line trains approaching the 4th and Berry station will foul the 4th and King intersection and block all traffic if they are allowed to proceed into the intersection while the train ahead is either dwelling at the platform or held for the traffic light crossing Berry Street. It is recommended that southbound T Line trains be prevented from entering the 4th and King intersection until the train ahead has been cleared through the 4th and Berry intersection.

Under the 2030 operating plan it must be expected that T line trains will be crossing through the 4th and King intersection north and/or south bound on nearly every light cycle. It is recommended that SFMTA and Muni further study the potential impacts of this on traffic patterns given the relatively long clearing times for these trains through this intersection. It is further recommended that SFMTA and Muni investigate the possibility of increasing allowable speeds in and around the 4th and King intersection to improve the clearing times of trains through this intersection.

The Year 2018 and the Year 2030 simulations required that more than one train occupy the Mission Bay Loop at certain times during the peak periods. Trains not required during off-peak service were routed to the Muni Metro East (MME) sidings at the end of peak periods.

SYSTRA recommends that the facility for the joint layover at Mission Bay Loop should be utilized in order to ease periods when trains are transitioning from one level of service to another (such as the transition from peak to off-peak service levels, when trains can bunch together). As previously described Mission Bay Loop is approximately 700 feet, with each train-set being 150 feet. The loop has sufficient space to allow more than one train-set to occupy the track. It is recommended that up to two train-sets be permitted to occupy the loop at any one time during these transitions.

While not used in any of our scenario simulations it is recommended that SFMTA and Muni consider how the start and end of service at Chinatown will be provided. It is recommended that consideration is given to storage train-sets at Chinatown overnight and these train-sets be available for the morning service. However, it is possible that train-sets could be scheduled to Chinatown prior to the peak operating hours and at the end of the day. No consideration within in this report or simulations was given to track outages for maintenance purposes.

Under both the Year 2018 and the Year 2030 simulations the variation in running times between Sunnydale and Mission Bay Loop were restricted to 5-minutes in order to avoid interference at Mission Bay Loop. It is recommended that Muni further study the variation in run times between Sunnydale and Mission Bay Loop and verify that the mean runtime variation can be brought down to this level by the start of the 2018 operations.

In all simulations SYSTRA did not consider any Muni Train Operators being available. However, there are a number of equipment dependencies at Chinatown and Mission Bay Loop that require consideration, as the time required by the train schedule for the next train trip is considered sufficient to the requirements of the fleet but may be insufficient for the Train Operator. Further examination of the management of the Train Operators should be considered.

As a general recommendation it would be good operating practice to have Train Operators available for 'jumping ahead' at Chinatown and to a lesser extent at Mission Bay Loop. This would involve the arriving Train Operator taking *not* the next, but the second departure from the origin. This is especially important for trains arriving slightly late, causing scheduled departures to be too close to arrival times.

The assignment of additional Train Operators is highly recommended during peak hours at Chinatown and Mission Bay Loop to assure that trains depart per their scheduled time. Under the 2018 Plan, with trains arriving and departing every 3.75 minutes, even though a Train Operator would only have to walk the length of the train (150 feet), allowance must be made for late arrivals, crew comfort relief, etc. When the 2030 Plan is implemented, assignment of additional Train Operators is considered a requirement, not an option.

It is also recommended that a study on the fleet availability and the programming of the fleet dependencies be considered, with a focus on Chinatown and Mission Bay Loop. As the schedules require a tight turn at both locations, it is recommended that consideration be given to the availability of additional train-sets as backup for late running or equipment failures.

Finally, SYSTRA reiterates its recommendation regarding the Management of Pull-Outs from the 2010 Central Subway Simulation Report (Section 7.5.1).

SYSTRA's recommendations are summarized in Table 12 for 2018, and Table 13 for 2030.

Finally, the status of SYSTRA's recommendations from the previous study (conducted in 2010) is presented in Table 14.

Table 12: Recommendations for 2018 Service Integration
Shaded/Bold items will have greatest benefit.

Category	# Issue	Recommendation	Key Capacity Assumption
Use of Operators	5.1 Headway Support / Crewing	Consider use of 'Jump Ahead' platform operators at Chinatown, especially during peak hours. Similar to Embarcadero in some cases.	Simulation assumed adequate crewing.
Fleet	5.2 Equipment cycling and fleet	Have backup trainsets at Chinatown in the event of exceptional delays from Third Street	Simulation did not consider failures. Simulation assumed adequate equipment present.
Operations	**5.3 Mission Bay Loop Use**	Allow 2 trainsets to occupy Mission Bay Loop during transitions, particularly peak to off-peak. Mission Bay Loop is approximately 700 linear track feet, with each train-set being 150 feet. The loop has sufficient space to allow more than one train-set to occupy the track.	The simulations required double occupancy during transitions. The simulation also routed trains not needed for off-peak service to MME sidings at the end of peak periods.
	5.4 Chinatown Tail Tracks Storage	Consider storing trainsets at Chinatown overnight.	Simulation assumed no storage.
	5.5 Third Street LR Service Level Maintenance of Frequency	Reduce mean runtime variation to maximum of 5 minutes between Sunnydale and Mission Bay Loop.	Simulation restricted variation to within 5 minutes.
	5.6 Management of Pull-Outs	Follow recommendation as described in 2010 Study Report (Section 7.5.1).	4th and King traffic needs to be alleviated – adjusting the pull-outs will help this.

Table 13: Recommendations for 2030 Service Integration (with at least 5.3 and 5.5 from Phase I)

Category	# Issue	Recommendation	Key Capacity Assumption
For 2030 Service Integration (with at least 5.3 and 5.5 from Phase I)			
	5.7 Peak Period Pull Out	Prevent southbound T Third trains from entering the 4th and King intersection until the train ahead clears 4th and Berry.	Simulation indicated possibility of trains 'fouling' intersections outside stations.
	5.8 Speeds	Increase allowable speeds in and around the 4th and King intersection.	T line trains will be crossing 4th and King intersection on nearly every light cycle and are likely to interfere with other traffic.
Signals	5.9 4th and King Southbound Signal AM Peak	Lengthen light cycle at 4th and King. Give priority to T line trains during peak period.	Simulation used signal timing from provided 110 timing card. Simulation did not use priority
	5.10 Traffic Signals	Study potential impacts of longer light cycles	T line trains crossing 4th and King intersection on nearly every light cycle.

Table 14: Status of Recommendations From Previous Study

#	2010 Recommendation	2013 Simulations	Current Status
1	Manage MME pull-outs to avoid peak hour operations at 4th and King Junction	The 2013 simulation did not include non-revenue moves for lines other than the T-Line.	Remains valid to support line management to achieve frequency and line capacity through operating practices.
2	Double berthing at Berry Street Station:	Double berthing was not simulated.	Not carried forward. It is not expected to be used as an operating practice in the startup planning and 2019 Service Plan.
3	Reduce train volumes between 4th/Berry and Chinatown Station:	Caltrain Tripper Service was removed from the simulated service plan. The 2018 Service Plan called for 3.75 minute headways on the T line "trunk" and 7.5 minute headways out to 20th Street and beyond. The 2030 Service Plan called for 2.5 minute headways on the T-Third "trunk" and 5 minute headways out to 20th Street and beyond.	Now included in the 2019 Service Plan.
4	Higher recovery at the street terminals/adjusted run times.	The 2018 and 2030 schedules developed for this study were based on unimpeded station to station run times (including 20 second station dwells). To those run times, eight seconds of run time pad were added for each street intersection between each station pair. An additional nine seconds was added as a station pair dwell pad. Trains at terminals were held for scheduled depart time to ensure proper headway spacing.	Carried forward and included in 2013 simulation.
5	Improve the 4th and King Street Intersection	T Line trains' schedules take advantage of updated programming for the signals to allow parallel movement through the intersection. No track switch moves were defined or used at 4th and King Intersection.	Carried forward and included in 2013 simulation.

Appendix A Source Data

San Francisco Central Subway Project supplied SYSTRA with the documents as identified in the following tables: -

A.1 Project Definition

Table 15: Source Documents – Project Definition

Document Title	Reference Number	Date Received
CS Operation Analysis – Rail Simulation		12/18/2012
SYSTRA SFMuni Central Subway Simulation Report	20100105	12/18/2012
Design Criteria : Section 1 - Introduction		01/16/2013
Executive Summary relating to Purchase Order	2013.01.36	01/24/2013
T-Third Rail Simulation Data Assumption 2010 vs 2013 Summary Table	Rev 0a	02/01/2013 20/14/2013
SFMTA Central Subway Overview Presentation – 2013		02/01/2013

A.2 Infrastructure

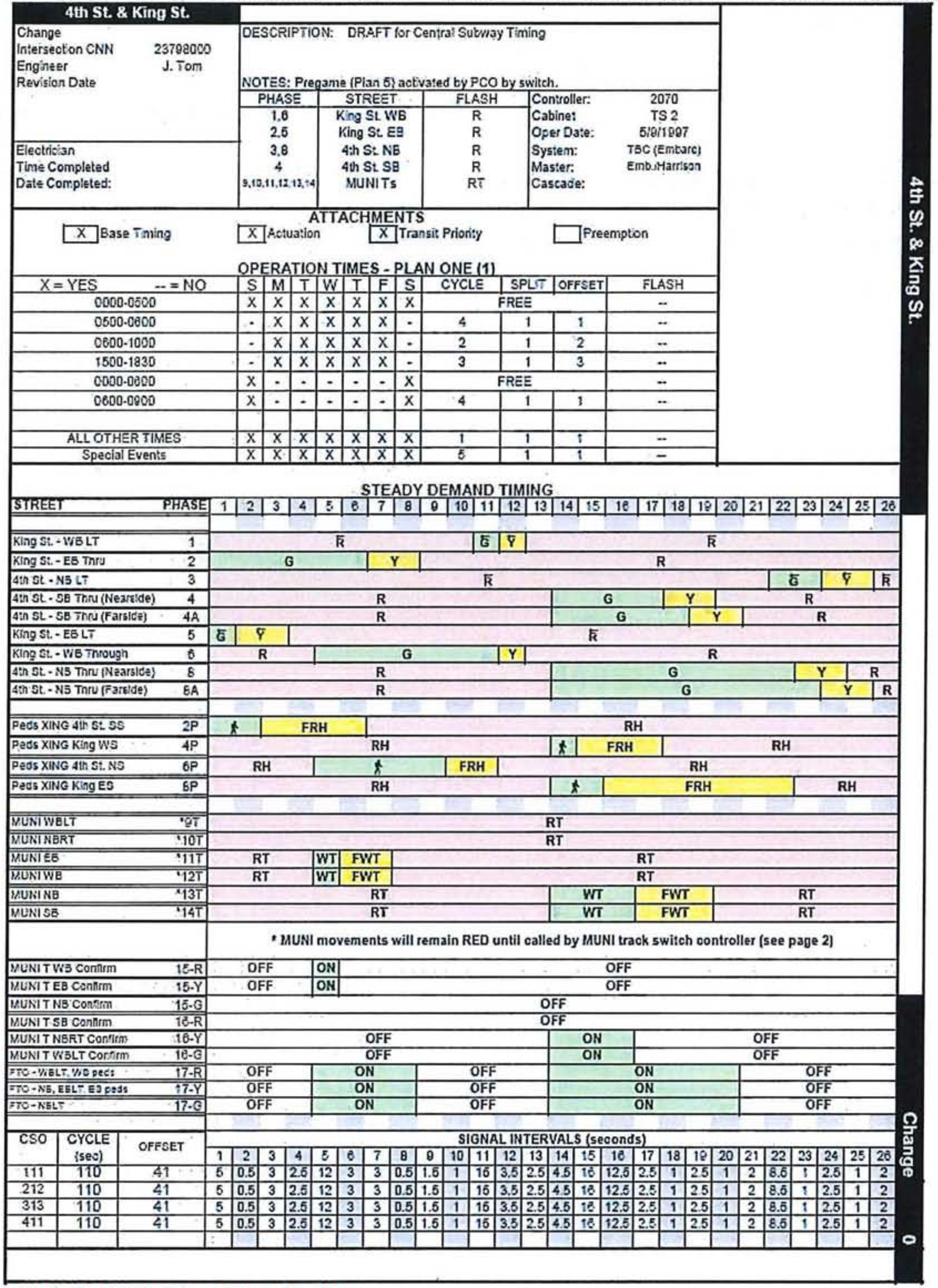
Table 16: Source Documents – Infrastructure

Document Title	Reference Number	Date Received
Issue For Bid – Train Signals 4th Street	CN1300-SG001-SG022	01/14/2013
Traffic Signals for 4th Street	CN1300-ET-112	01/14/2013
Design Criteria : Section 7 – Track Geometry and Clearance		01/16/2013
Design Criteria : Section 8 – Track Work and Track Work Details		01/16/2013
Design Criteria : Section 10 - Traffic Control Implemented in the Construction of the Project		01/16/2013
Photograph of King Street Yard South of 4th Street		01/28/2013
LRV Operators Training Manual (Revision 3) – Detailed T-Line Alignment	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) – Section 4.7 Muni Metro Extension	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) - Section 4.8 3rd Street & MME	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) - King and 4th Interlocking Operations	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) – Signal &Switch Operations King Street & 4th Street, including timing at interlocking	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) - Maximum Authorized Speed	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) - 4th & King Street Interlocking Guidelines	TN.MO.MN.011	01/29/2013
LRV Operators Training Manual (Revision 3) - Southbound to Northbound Switchback Loop at 18th & 19th Streets	TN.MO.MN.011	01/29/2013
CS Systems and Track Drawings as Issued		02/26/2013

A.3 Train Control

Table 17: Source Documents – Train Control

Document Title	Reference Number	Date Received
Design Criteria : Section 18 – Train Control and Signaling System including Operations through Interlockings		01/16/2013
Five Surface Alignment Intersections Signal Timing Cards (sample on next page)		02/26/2013



4th St. & King St.

Change
Intersection CNN 23798000
Engineer J. Tom
Revision Date

Electrician
Time Completed
Date Completed:

DESCRIPTION: DRAFT for Central Subway Timing

NOTES: Pregame (Plan 5) activated by PCO by switch.

PHASE	STREET	FLASH
1,6	King St. WB	R
2,5	King St. EB	R
3,8	4th St. NB	R
4	4th St. SB	R
9,10,11,12,13,14	MUNI Ts	RT

Controller: 2070
Cabinet TS 2
Oper Date: 5/9/1997
System: TBC (Embarc)
Master: Emb./Harrison
Cascade:

ATTACHMENTS

☒ Base Timing ☒ Actuation ☒ Transit Priority ☐ Preemption

OPERATION TIMES - PLAN ONE (1)

X = YES -- = NO	S	M	T	W	T	F	S	CYCLE	SPLIT	OFFSET	FLASH
0000-0500	X	X	X	X	X	X	X	FREE			--
0500-0600	-	X	X	X	X	X	-	4	1	1	--
0600-1000	-	X	X	X	X	X	-	2	1	2	--
1500-1830	-	X	X	X	X	X	-	3	1	3	--
0000-0600	X	-	-	-	-	-	X	FREE			--
0600-0900	X	-	-	-	-	-	X	4	1	1	--
ALL OTHER TIMES	X	X	X	X	X	X	X	1	1	1	--
Special Events	X	X	X	X	X	X	X	5	1	1	--

STEADY DEMAND TIMING

STREET	PHASE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
King St. - WB LT	1	R̄										Ḡ	Ȳ	R̄													
King St. - EB Thru	2	G						Y		R																	
4th St. - NB LT	3	R̄																					Ḡ		Ȳ		R̄
4th St. - SB Thru (Nearside)	4	R													G				Y		R						
4th St. - SB Thru (Farside)	4A	R													G					Y		R					
King St. - EB LT	5	Ḡ	Ȳ		R̄																						
King St. - WB Through	6	R				G							Y	R													
4th St. - NB Thru (Nearside)	8	R													G									Y		R	
4th St. - NB Thru (Farside)	8A	R													G										Y		R
Peds XING 4th St. SS	2P	🚶		FRH				RH																			
Peds XING King WS	4P	RH													🚶	FRH			RH								
Peds XING 4th St. NS	6P	RH				🚶					FRH		RH														
Peds XING King ES	8P	RH													🚶		FRH							RH			
MUNI WBLT	*9T	RT																									
MUNI NBRT	*10T	RT																									
MUNI EB	*11T	RT				WT	FWT		RT																		
MUNI WB	*12T	RT				WT	FWT		RT																		
MUNI NB	*13T	RT													WT			FWT			RT						
MUNI SB	*14T	RT													WT			FWT			RT						

* MUNI movements will remain RED until called by MUNI track switch controller (see page 2)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
MUNI T WB Confirm	15-R	OFF				ON	OFF																				
MUNI T EB Confirm	15-Y	OFF				ON	OFF																				
MUNI T NB Confirm	15-G	OFF																									
MUNI T SB Confirm	16-R	OFF																									
MUNI T NBRT Confirm	16-Y	OFF													ON			OFF									
MUNI T WBLT Confirm	16-G	OFF													ON			OFF									
FTO - WBLT, WB peds	17-R	OFF				ON				OFF					ON							OFF					
FTO - NB, EBLT, EB peds	17-Y	OFF				ON				OFF					ON							OFF					
FTO - NBLT	17-G	OFF				ON				OFF					ON							OFF					

SIGNAL INTERVALS (seconds)

CSO	CYCLE (sec)	OFFSET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
111	110	41	5	0.5	3	2.5	12	3	3	0.5	1.5	1	16	3.5	2.5	4.5	16	12.5	2.5	1	2.5	1	2	8.5	1	2.5	1	2
212	110	41	5	0.5	3	2.5	12	3	3	0.5	1.5	1	16	3.5	2.5	4.5	16	12.5	2.5	1	2.5	1	2	8.5	1	2.5	1	2
313	110	41	5	0.5	3	2.5	12	3	3	0.5	1.5	1	16	3.5	2.5	4.5	16	12.5	2.5	1	2.5	1	2	8.5	1	2.5	1	2
411	110	41	5	0.5	3	2.5	12	3	3	0.5	1.5	1	16	3.5	2.5	4.5	16	12.5	2.5	1	2.5	1	2	8.5	1	2.5	1	2

4th St. & King St.

Change 0

Figure 3. Sample Timing Card: 4th and King, CH 110

A.4 Rolling Stock

Table 18: Source Documents – Rolling Stock

Document Title	Reference Number	Date Received
Design Criteria : Section 6 – Physical Characteristics, Performance of Lrn2 Vehicles		01/16/2013
LRV Operators Training Manual (Revision 3)	TN.MO.MN.011	01/29/2013
Muni Rail Core Area Calibration Report	SFMTA-2008-02 (SYSTRA - C0578200)	11/18/2009

A.5 Operations

Table 19: Source Documents – Operations

Document Title	Reference Number	Date Received
Service Plan R1 2011 -03 16 (Third Street Light Rail Phases 1 & 2 2018 -2030 Service Integration Plan)		12/18/2012
Design Criteria : Section 4 – Operating and Maintenance Requirements		01/16/2013
CS NextBus T-Third Travel Times with Service Plan Analysis (2011-03-11)		02/01/2013
E-Line Off-Peak Schedule based on America's Cup Initial Service		02/01/2013

Appendix B Train Schedules

The following pages contain the Southbound and Northbound train schedules that were used for the simulations. As discussed within the body of this report, the E and N schedules were used as provided, and the T schedule was developed as described in Section 2.4.3.

B.1 2018 – 3.75-minute Headway

B.1.1 T-Third Southbound