ConnectSF

Shaping our City's Transportation Future

Subway Vision

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SFMTA Municipal Transportation Agency

San Francisco Planning

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1 Introduction

1.1 Purpose of Document

The Subway Vision explores the context and possibilities for a robust subway network in San Francisco. It provides stakeholders with understanding of current and future transportation challenges that can be best addressed through this particular mode of transit. This document will provide policy guidance for the expansion of the subway system, helping readers to understand the conditions that make for successful subway investments and fostering discussion about the benefits and tradeoffs to consider as the City refines the Vision in coming years.

1.2 Policy Justification and Technical Need for Subway Vision

In November 2015, the San Francisco Board of Supervisors passed Ordinance 202-15, which compels the City to develop a Subway Master Plan and calls for the plan to be updated every four years. The Subway Vision is an outgrowth of the City's Transit First Policy, which calls for a safe and efficient transportation system to ensure quality of life and the economic health of San Francisco, and which requires that travel by public transit, bicycle, and on foot must be an attractive alternative to travel by private automobile.

San Francisco has made significant investments in public transportation, with new bus rapid transit routes starting construction, major improvements being installed on other bus routes and light rail lines, Central Subway construction, BART extensions nearing completion, and ongoing work to modernize Caltrain and bring it to downtown San Francisco. However, the city is approaching the end of its pipeline of major public transportation projects and the Subway Vision provides a road map to grow the backbone of the city's transit network.

Subways are major long-term capital investments and their success relies on careful planning and coordination between many partners. This document will help to position San Francisco agencies and stakeholders to advance projects and support advocacy for funding. Major rail expansions in California have historically required extensive planning and design. Planning for the extensions of Bay Area Rapid Transit (BART) in the region began in 2007 with the Metropolitan Transportation Commission's Regional Rail Plan and the extension to San Jose is currently under construction The California High Speed Rail Authority was established in 1996, 12 years before voters approved Proposition 1A, a measure to construct the first segment of the network. Similarly, the Subway Vision is the first step in a lengthy process that will include many iterations of technical work and public engagement. The better understanding achieved now of the priorities and concerns for San Franciscans, the more prepared the city will be for the future.

1.3 How to Use the Plan

The Subway Vision is an early component of Connect SF, San Francisco's coordinated long-range transportation planning effort. Connect SF is a collaboration between agencies around the city and region to provide a blueprint for San Francisco's transportation network in the decades to come. Connect SF will include the following elements:

- An overall Transportation Vision, informed by land use, to guide the future of the city
- An update to the **San Francisco Transportation Plan**, the blueprint for our investments in the city's overall transportation system over the next 40 years

- A **Transit Modal Concept Study**, which will identify key early transit improvements to invest in within San Francisco
- A **Freeway and Street Traffic Management Strategy** to improve how the city's streets and freeways function
- An update to the San Francisco **General Plan's Transportation Element**, which helps determine all transportation-related planning decisions in the city.

This document is the first comprehensive look at the future of the subway system in San Francisco in more than a generation and will surely evolve as the region grows and changes. The document provides the general orientation of potential subway corridors, without specifying detailed locations for subway lines and stations. Those decisions will be made through more extensive planning processes.

Chapter 2 describes the methods driving the analysis behind the Subway Vision. It also describes the travel demand model used to measure the impacts of new subways on travel behavior and other performance metrics.

Chapter 3 reviews prior plans for transit expansion in the city and region and presents a framework for evaluating potential subway corridors and networks. It also includes a description of existing transit service that operates in San Francisco, including issues that limit its speed, reliability, and capacity. The ability of subways to address particular challenges is highlighted. The chapter also presents projected population and employment density for San Francisco, recognizing the importance of matching subways with appropriate land uses. The chapter also describes outreach activities that inform the Subway Vision.

Chapter 4 presents candidate corridors and discusses two approaches for combining corridors into networks. The chapter discusses the performance of potential networks according to key evaluation criteria.

Chapter 5 looks broadly at the potential sources of funding for the Subway Vision, both considering projected local and regional revenues and also identifying needs and opportunities for the state and federal funding that will be necessary to implement subway expansion in San Francisco.

Chapter 6 describes current activities to enhance the transit system and corridors where planning for potential future subways is underway. Upcoming activities under the ConnectSF Program are identified. Finally, additional areas of technical study and policy consideration necessary for efficient and coordinated subway implementation are identified.

2 Methods

This section provides an overview of the methods used in the report. Resulting analysis and findings can be found in subsequent chapters.

2.1 Prior Plans

Staff conducted a review of local and regional plans relevant to subway expansion in San Francisco. Some of these plans focused on specific systemic issues, such as Transbay capacity or opportunities to enhance the performance of the Muni Metro rail system, while other plans focused on particular locations or corridors for transit improvements. Concepts introduced in these plans informed development of potential corridors and networks. Staff also studied major transit expansions in other cities and reviewed literature that discusses the appropriate role of subways in transit systems.

2.2 Analysis

2.2.1 Existing Conditions

Staff assessed existing transit service in San Francisco, including speed, reliability, safety, and capacity, with special attention given to the potential for subway expansion to address existing challenges to the transit system. This analysis identified existing bus and light rail lines with high ridership and where faster and more reliable transit service would have the largest benefit.

2.2.2 Future Conditions

Using inputs from the preferred land use scenario for the 2013 approved Plan Bay Area, the team ran a 2040 future baseline scenario in SF-CHAMP. Outputs from the 2040 baseline run provided an understanding of where future transportation demand is anticipated to occur given projected land use growth. In addition, the demand-based needs assessment work and modeled network concepts build on the baseline results. One analysis performed as part of the needs assessment examined potential travel patterns in a theoretical scenario of a ubiquitous subway network that allowed people to travel to all parts of San Francisco seamlessly on high capacity grade separated rapid transit, shown in **Figure 1**. This tool was used to reveal hidden travel patterns that might be masked by the structure of the existing transit system.

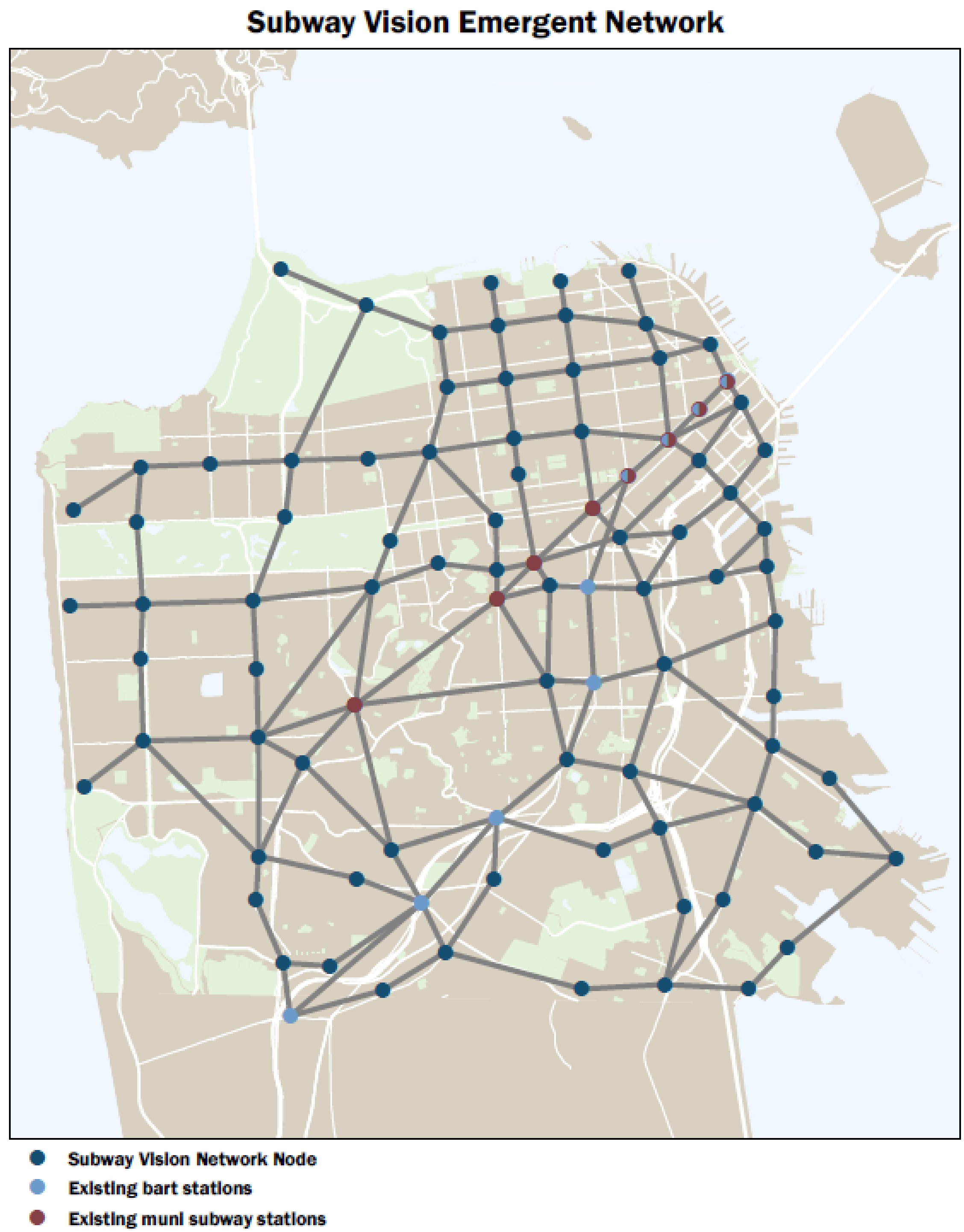

Figure 1: Tested Ubiquitous Subway Network

2.2.3 Subway Network Concepts

Staff used SF-CHAMP to model two conceptual future subway networks. These modeled networks reflected land use patterns from Plan Bay Area 2013 and the completion of major transportation projects currently in the pipeline. The model reported on performance measures for the networks related to the City's congestion, mobility, equity, and climate goals.

2.3 Outreach

As a complement to technical work, staff performed outreach to understand the priorities of people who live and work in San Francisco. Staff deployed an online tool that allowed users to draw desired subway lines and stations and complemented these findings with in-person pop-up events in three neighborhoods to hear from a broader cross-section of San Francisco residents. **Figure 2** shows school children from the Tenderloin providing input on a future subway for San Francisco.

Figure 2: Residents discuss subways with staff in the Tenderloin neighborhood

Staff compiled maps of the subways drawn from the online tool and in-person event and summarized other comments received at the pop-up events.

2.4 Staff Workshops

The core team conducted two workshops, including staff from SFMTA, SFCTA, the Planning Department, and BART. At the first workshop, staff reviewed existing and future conditions and needs and posited potential corridors and networks to be tested. The core team took feedback from the workshop to create the network concepts. After completing technical work on the network concepts, the core team conducted a second workshop with the same staff to review the results and get input on themes and network performance.

3 Existing and Future Conditions, Subway Characteristics, and Outreach

This chapter summarizes existing and future transit and transportation network conditions relevant for subway operations in San Francisco. The findings identify factors that constrain transit operations within the city and how subways may help to address them. The chapter also studies land use characteristics and existing travel patterns to inform where subway investment might be most appropriate in San Francisco. The chapter also identifies overall themes from online and in-person outreach.

3.1 Prior Plan Review

Previous and ongoing plans are relevant to the expansion of subways in San Francisco. Some planning documents provide support for subway expansion, while others make specific recommendations that will inform the corridors studied in subsequent chapters. **Table 1** considers plans that are both local and regional in nature.

Table 1: Plan and Policy Review

Plan	Lead Agency		Year	Key Findings
Local				
A Vision for Rapid Transit in San Francisco	SFMTA		2002	Recommendations include subway on Geary, undergrounding M Line, spot improvements to N-Judah, rail on Fillmore-16th corridor
Geary BRT EIR/EIS Alternative Screening Report	SFCTA		2009	Includes light rail and subway among alternatives screened for Geary BRT. Not recommended for further analysis in existing effort due to costs and timing.
San Francisco Transportation Plan 2040	SFCTA		2013	Identifies transit investment as one key strategy for continuing to accommodate housing and job growth.
M-Line/19th Avenue Transit Study	SFCTA		2014	Considers options including partial subway and bridges for grade separation, and full subway from West Portal to ParkMerced.
SFMTA Transit Effectiveness Project	SFMTA		2014	Provides recommendations to enhance key transit routes in San Francisco with a combination of short-term operating and long-term capital improvements.
SFMTA Rail Capacity Strategy	SFMTA		2016	Identifies strategies for enhancing the San Francisco rail network, both from the perspective of providing service to neighborhoods with high demand and from the perspective of operational improvements.
Waterfront Transportation Assessment	SFMTA/SFCTA		2015	Describes several transportation challenges and possible solutions to accommodate anticipated growth along the San Francisco Waterfront. Identifies Central Subway extension to Fisherman's Wharf.
Railyard Alternatives and I-280 Boulevard Feasibility Study	SF Planning		Ongoing	Describes potential strategies for alleviating Mission Bay congestion and extending Caltrain to the Transbay Terminal, including the exploration of removing I-280 north of Mariposa.
Regional				
Bay Crossing Study 1	MTC		1991	Suggests several possibilities for 2nd Transbay Tube.
Bay Crossing Study 2	MTC		2002	Recommends new BART and/or conventional rail tunnel from Oakland to 2nd Street
Bay Crossing Study 3	MTC		2012	Develops a new set of conceptual alternatives to address transbay travel demand.
Transbay Transit Centers Operations Analysis EIS	TJPA		2004	Describes regional trans goals, objectives, and performance metrics. Suggests spot improvements for BART both inside and out of San Francisco and identifying operational strategies to increase capacity.
Transbay Terminal/Caltrain Downtown Extension (FEIR)	TJPA/FTA/San Francisco		2004	Identifies several alternatives for extending Caltrain from its current terminus at 4th and King to downtown San Francisco in a subway alignment.
Regional Rail Plan	MTC		2007	Promotes long-range vision for a robust, interconnected regional rail network. Recommends second transbay crossing and several upgrades for BART and Caltrain to improve service within and outside of San Francisco.
BART Ocean Beach Conceptual Alignment Study	BART		2014	Identifies several alternatives that would connect the Richmond district to downtown San Francisco and the BART system. Suggests three possible alignments, mostly using Geary.
Caltrain Modernization Study	Caltrain		2014	Identifies several operational improvements to increase capacity and service for Caltrain.
BART Vision Plan	BART		Ongoing	Broadly-scoped study to identify and prioritize major investments to meet regional transportation needs, such as extending service into the Richmond District and providing a second transbay tube.

Common themes in the prior plan review include additional Transbay service, the conversion of the M-Ocean to a full subway and extending it to Daly City, a subway to serve the Geary corridor, and the extension of Caltrain and high-speed rail to downtown San Francisco.

3.2 Current System Operations

This section draws largely on work from the Rail Capacity Strategy and Short Range Transit Plan to describe current transit operations in San Francisco and the challenges faced by each mode. This section highlights those challenges that Subway expansion may be uniquely suited to address.

3.2.1 Existing Rail

Two transit operators provide subway service in San Francisco. Bay Area Rapid Transit (BART) operates four lines in a single subway between Embarcadero and Balboa Park, connecting San Francisco to the East Bay and San Mateo County. Approximately 430,000 trips occur on the BART system every day and two out of three of these trips either start or end at one of the four stations in downtown San Francisco.[1]

The San Francisco Municipal Transportation Agency operates light rail service in a subway under Market Street and Twin Peaks known as Muni Metro. Muni Metro was opened in 1980 and serves nine stations. In total, Muni Metro and surface portions of the light rail network carry over 150,000 passengers per day. As depicted in **Figure 3**, the Muni Metro System operates at capacity during weekday morning and evening peak periods, but has some unused capacity during the day.

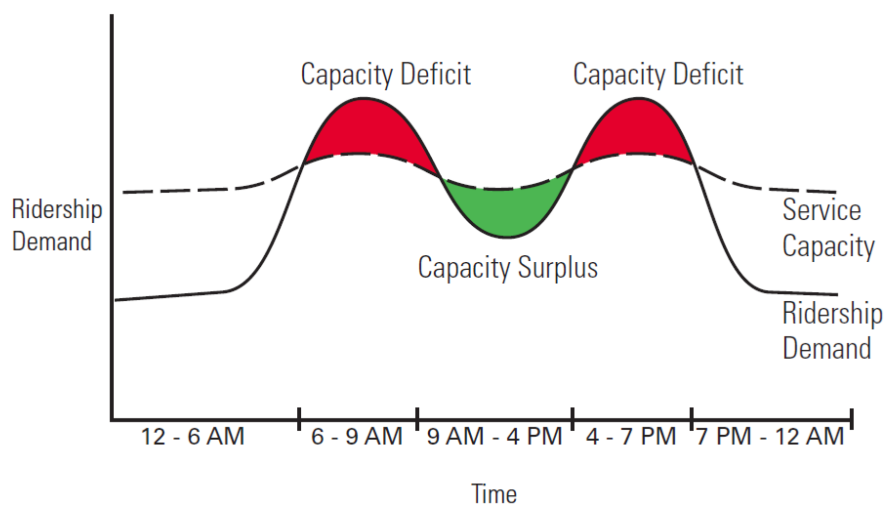

Figure 3: Muni Metro capacity throughout the day

Each light rail line that operates in Muni Metro also operates on surface streets. Portions of these lines operate in dedicated right-of-way, such as the M-Ocean on 19th Avenue and the J-Church on San Jose Avenue. Other portions of these lines operate in mixed traffic, such as the L-Taraval.

Caltrain connects San Francisco to San Jose on grade-separated tracks. There are three stations in San Francisco: Bayshore Station, 22nd Street Station, and the terminus station at 4th and King. Caltrain serves

[1] http://www.bart.gov/about/reports/ridership

approximately 58,000 passengers on an average weekday, including 15,500 riders at stations located in San Francisco. Its fullest trains are those that travel into San Francisco during the morning peak hour and depart San Francisco in the evening peak hour.[2]

3.2.2 Other Transit

Many of the highest ridership transit lines in San Francisco are bus lines. SFMTA bus service consists of a mixture of rapid, local, community, and express routes, operating in a variety of vehicles including 30-, 40-, and 60-foot motor coaches and 40- and 60-foot electric trolley coaches. The 14 and 14-Rapid buses on Mission Street collectively carry approximately 45,000 daily passengers, providing more finely-grained service and additional capacity along the BART corridor through the city. Where these routes overlap with the 49 along Mission Street is the busiest bus corridor in the region. The 38 and 38-Rapid buses on Geary Boulevard carry approximately 51,000 daily passengers, providing frequent transit service to population centers without rail.

Other notable bus transit operators providing service in San Francisco include AC Transit, which provides service between San Francisco and the East Bay, Golden Gate Transit, which connects San Francisco with the North Bay, and SamTrans, which provides service between San Francisco and communities on the Peninsula.

3.3 Existing and Future Demand

Subways are a tremendous capital investment, and only significant travel demand justifies them. The identification of potential subway corridors should consider both ridership on existing transit facilities and trips taken on all modes that might be taken on transit if subway service were provided.

3.3.1 Population and Employment Density

Population and employment density are the two highest predictors of transit ridership and cost effectiveness, particularly within a quarter mile catchment area of a station. Cervero and Guerra (2011) found that light rail systems need approximately 30 residents or employees per acre and heavy rail systems need around 45 people per gross acre to rate among the top quartile of cost effectiveness for rail investments in the United States. [3] **Figure 4** shows projected residential and employment density for San Francisco in 2040.

[2] http://www.caltrain.com/Assets/_Marketing/pdf/2015+Annual+Passenger+Counts.pdf
[3] Transit Capacity and Quality of Service Manual, 3rd Edition

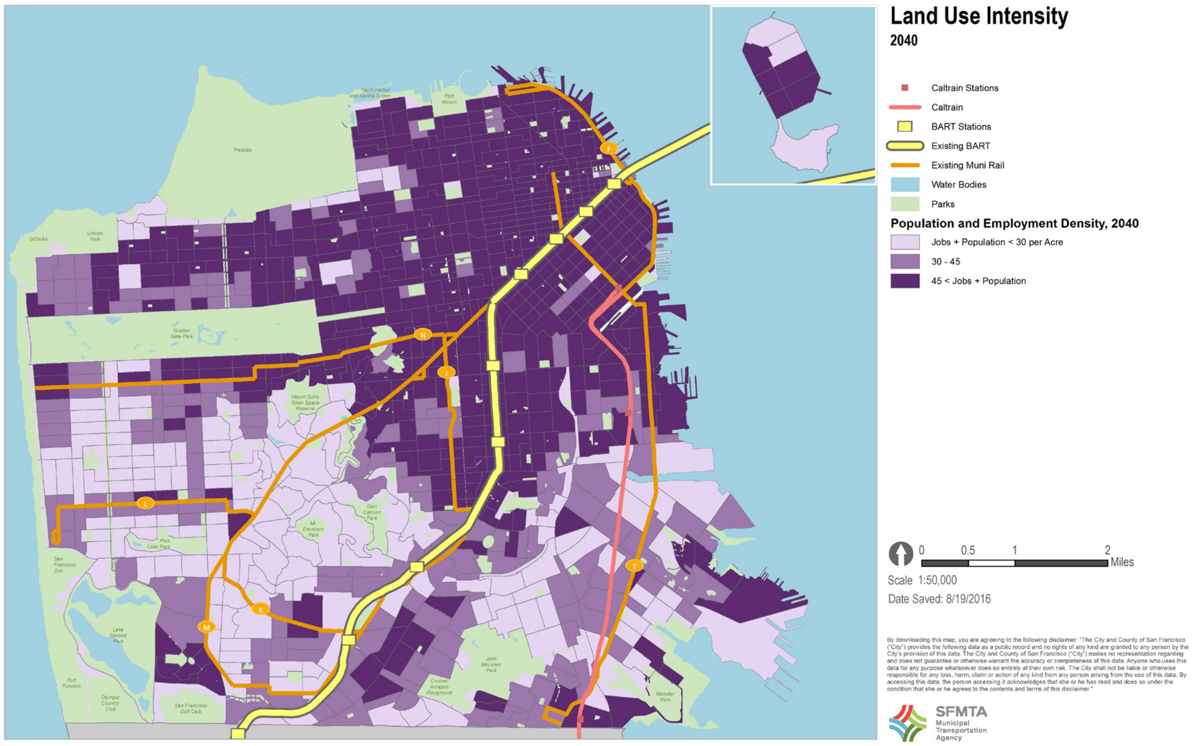

Figure 4: 2040 Population and Employment Density

Travel patterns in San Francisco reflect that of most North American cities with trips to and from the downtown core being most common. Trips between downtown and centrally located neighborhoods both south and north of Market Street for the most trips within San Francisco. However, travel patterns other than downtown-oriented trips are also significant. In particular, several neighborhoods are connected to the central part of the city, which extends roughly from the edge of Golden Gate Park to Van Ness Avenue, between 21st Street and Geary Boulevard. **Figure 5** illustrates daily bi-directional trips between 12 zones in San Francisco.

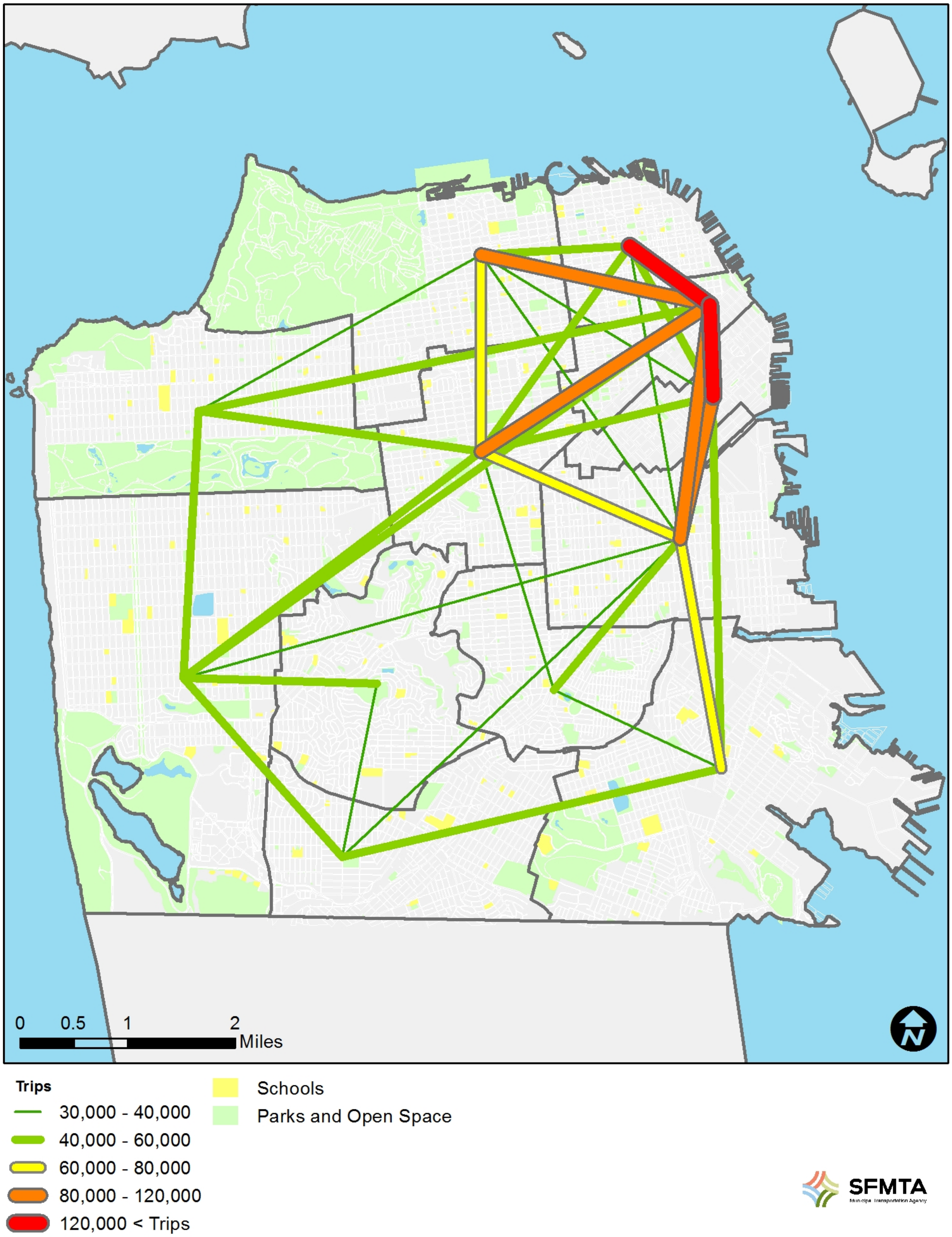

Figure 5: General travel patterns in San Francisco

3.3.2 Existing Transit Corridors

Many of San Francisco's key transit corridors encompass multiple routes. Two bus routes on Geary Boulevard, the 38 and 38R, each carry approximately 26,000 daily passengers, but the 1-California operates approximately a quarter mile to the north and also carries 26,000 daily passengers, and the 31, 31AX, and 31BX combine for approximately 12,000 daily passengers, and operate approximately a quarter mile to the south. Similarly, the 14, 14R, 49, and BART all operate along Mission Street. Because the catchment area for a subway station is generally larger than that for a bus stop[4], the transit ridership for multiple parallel bus lines may be indicative of the potential ridership for a single subway line.

Figure 6 shows several busy transit corridors in San Francisco that are served by multiple bus, light rail, and subway lines. The highest ridership corridor in San Francisco encompasses the core of the light rail lines in San Francisco, connecting travelers between Embarcadero and West Portal Station. The Muni light rail system along this corridor serves 176,000 daily passengers. Bus lines crossing the northern part of the city serve 112,000 daily passengers, higher than any other corridor that does not currently have subways.

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[4] Transit Capacity and Quality of Service Manual, 3rd Edition, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp100/part%203.pdf

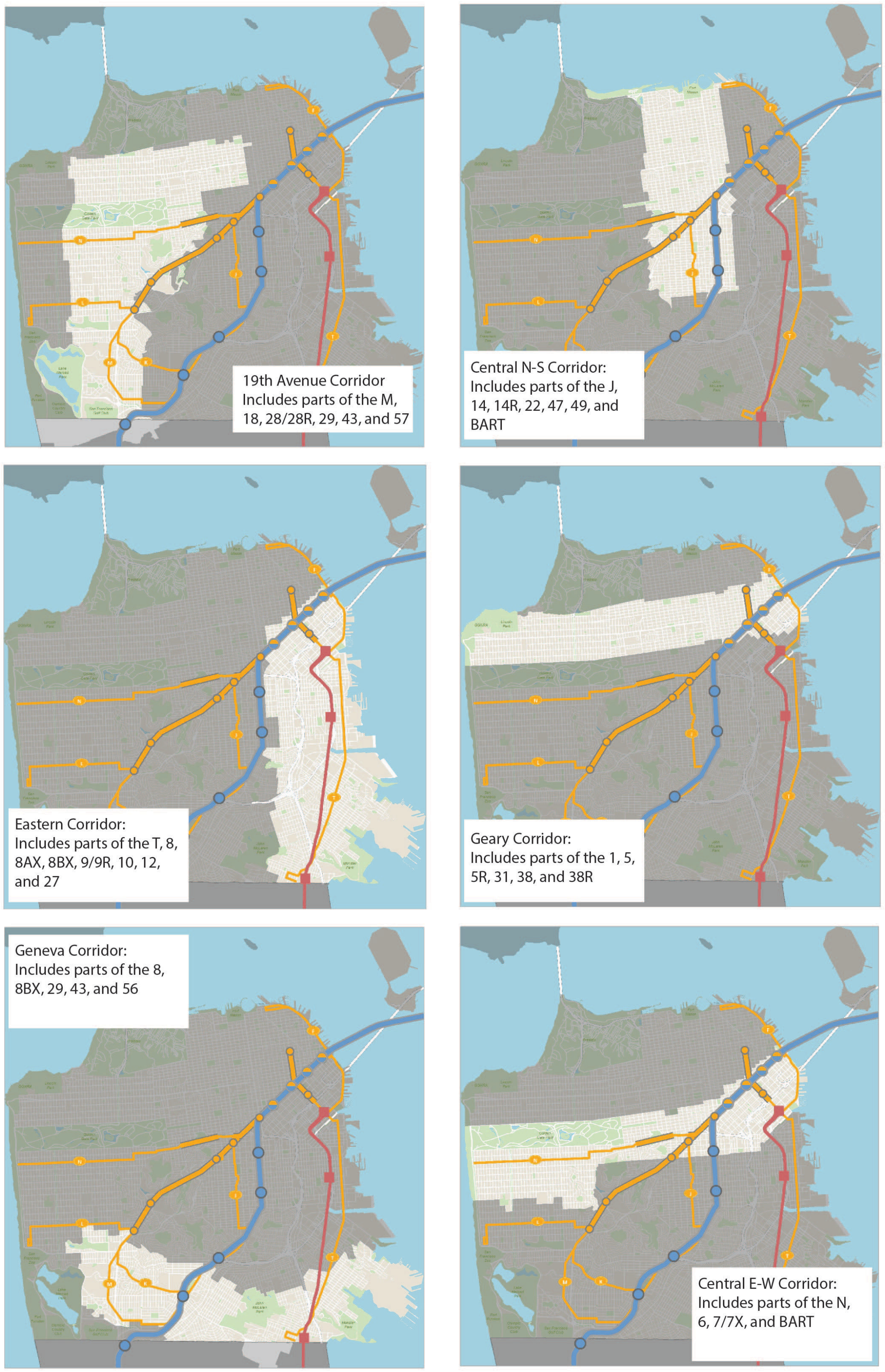

Figure 6: Key Transit Corridors in San Francisco

3.4 Public Outreach

The project team also engaged the public both online and in person to determine where people feel that subways are most needed. A web mapping application allowed users to draw subway lines and stations and submit them to the project team. Staff recorded over 2600 unique submissions, highlighting the need for a subway along the Geary corridor, some sort of Central Subway extension, a 19th Avenue subway, and north-south connections spanning from Van Ness Avenue to Divisadero Street. Additional Transbay connections were also frequently suggested. **Figure 7** illustrates the responses, highlighting these most popular corridors.

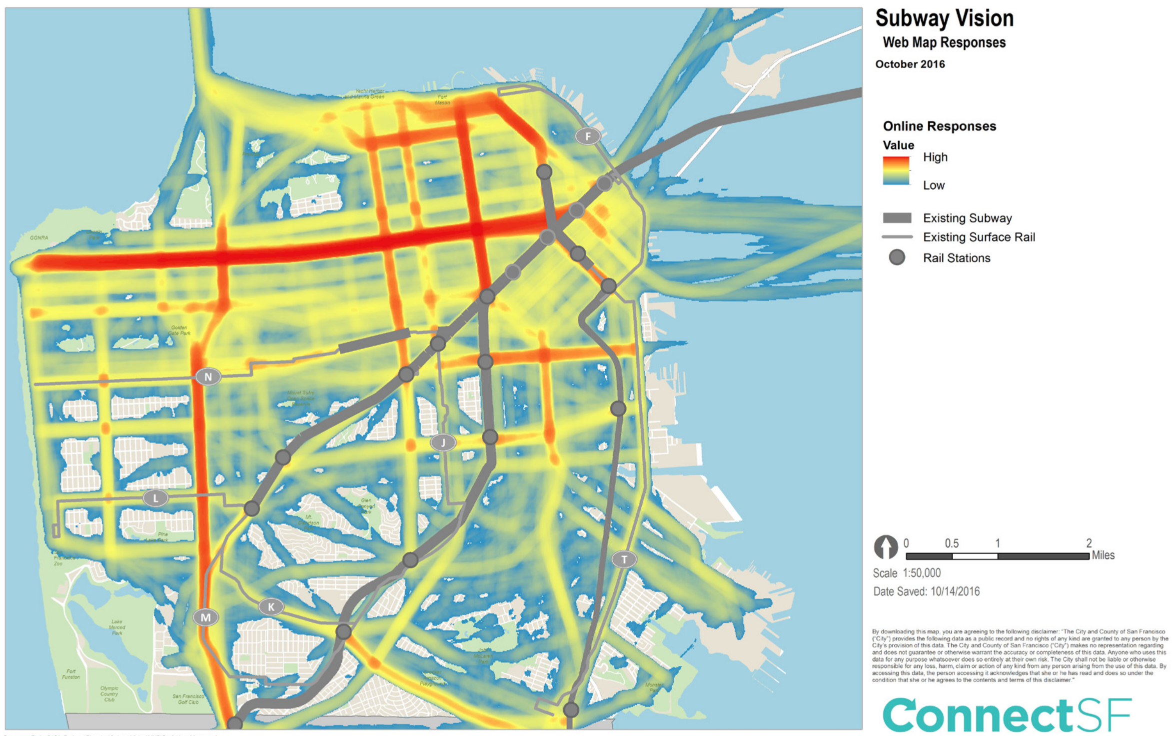

Figure 7: Online Response Heat Map

Online engagement does not reach everyone, and the web mapping application was supplemented by in-person events in three locations in San Francisco: the Bayview, Excelsior, and Tenderloin neighborhoods. Staff answered questions about the Subway Vision and related planning efforts and provided paper maps for participants to suggest subway lines (**Figure 7**). These pop-up events featured in-person translation services, and many participants had not heard of the Subway Vision planning effort previously. The in-person events garnered an additional 153 responses, illustrated in **Figure 9**.

Figure 8: Bayview Residents Draw a Subway Vision for San Francisco

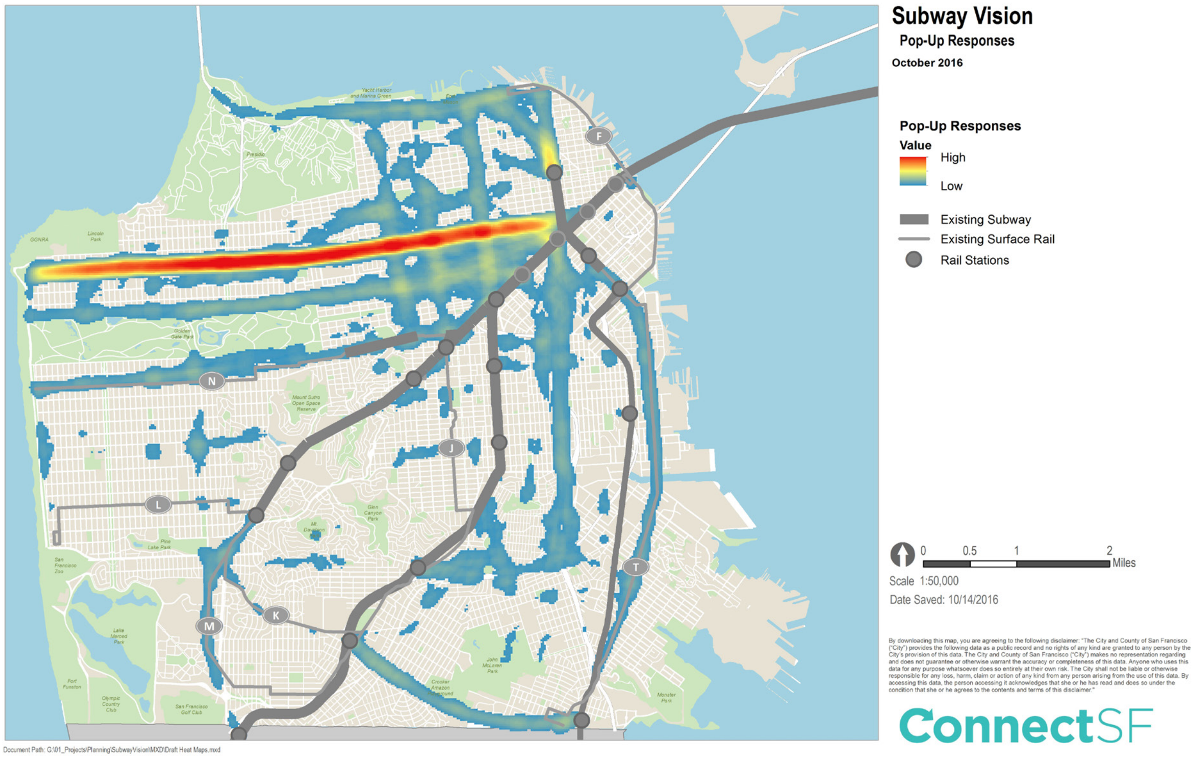

Figure 9: Pop-Up Responses

The pop-up responses were generally consistent with the online responses, indicating support for a new Subway along Geary or Fulton, an extension of the Central Subway, Geneva, Potrero, and Judah.

3.5 Characteristics of Subways

3.5.1 Operating speed

Subways generally run at higher operating speeds than surface transit systems. Stations are further apart, allowing for acceleration to higher speeds, are unaffected by traffic signals or other surface traffic controls, and have dedicated right-of-way that remove conflicts with other modes. **Figure 10** shows how grade separation improves the average transit vehicle speed independent of vehicle technology.

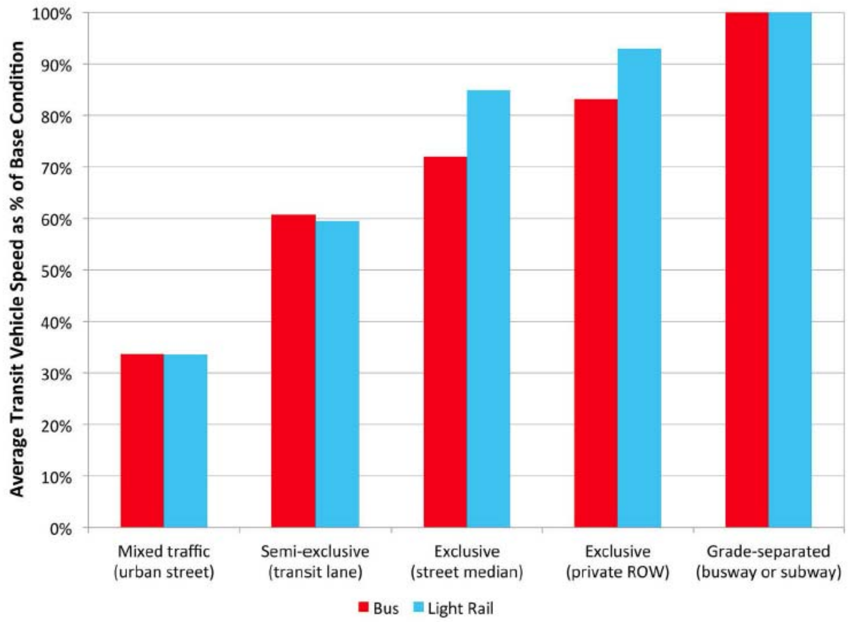

Figure 10: Grade Separation and Transit Speed[5]

Subway investment has the potential to significantly increase the speed of public transportation in San Francisco. Average operating speed can be evaluated as the average revenue miles per revenue service hour. For Muni buses in San Francisco, that is 6.5 miles per hour. Light rail performs slightly better but much of the light rail network in San Francisco is not grade-separated, so much of the travel time benefit of subways is not realized. New York's subway system operates at an average speed of 17 MPH, which suggests that significant improvements can be made with investments in new subways. **Table 2** compares the Muni average operating speed to New York City Subway and Chicago's "L".

Table 2: Average operating speeds for public transportation

Mode	Average Operating Speed (MPH)
Muni Bus	6.5
Muni Light Rail[6]	8.2
Muni Subway	15.7*
New York City Metro Subway	17
Chicago 'L'	18.5

** Scheduled speed*

To illustrate the difference in travel time, 14R Mission Rapid bus operates on a similar route as BART between Daly City and the Embarcadero in San Francisco. As a rapid route, the 14R makes fewer stops than most buses and, due to recent improvements, runs in a dedicated lane through the most congested portion of its route. However, as shown in **Figure 11** below, despite these advantages, the 14R is scheduled for 55 minutes of travel time from the Daly City BART station to Mission Street at Main Street during the morning peak period, while BART takes just 17 minutes to travel from the Daly City BART

[5] Transit Capacity and Quality of Service Manual, 3rd Edition
[6] San Francisco Office of the Controller, 2014: *City Services Benchmarking: Public Transportation*

station to Embarcadero Station, roughly the same distance. This shorter travel time does come at the expense of access, as BART serves nine stations along this corridor, while the 14R services 22 stops, thereby requiring BART passengers to walk longer distances to access the stations.

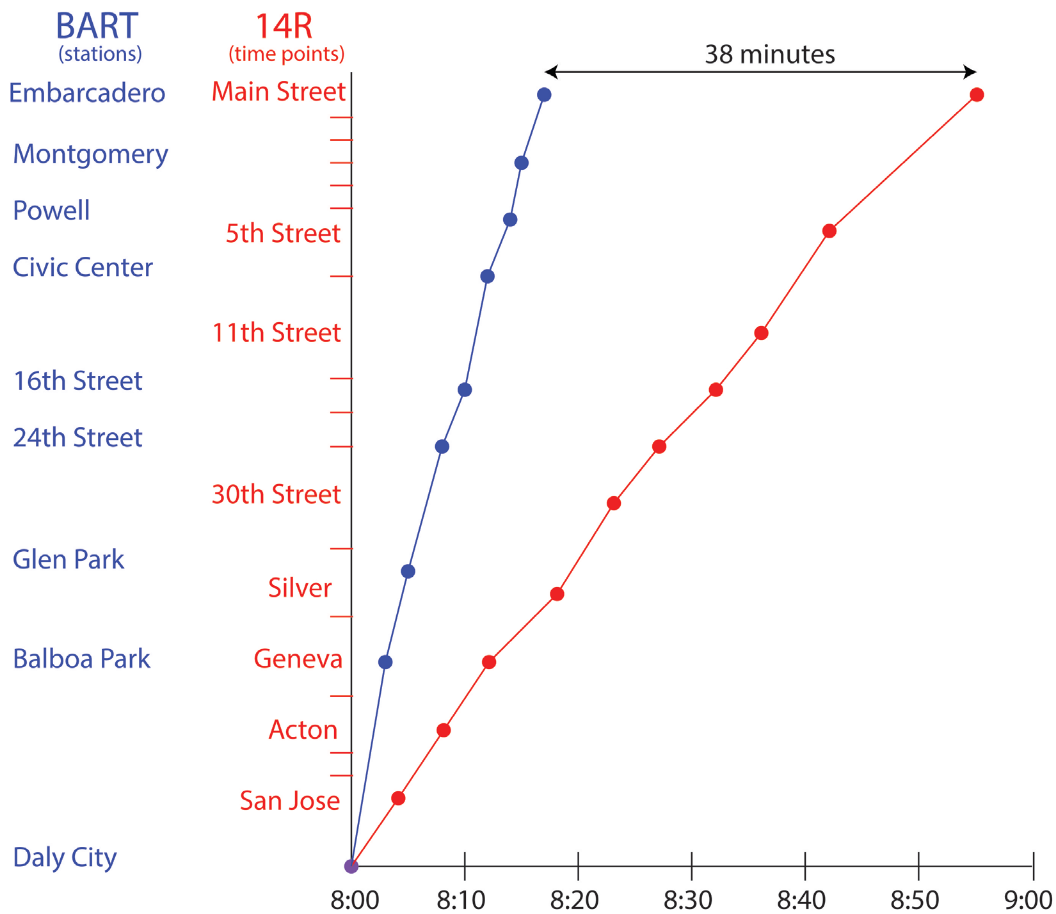

Figure 11: Travel Time from Daly City to Embarcadero

3.5.2 Reliability and Schedule Adherence

For many public transit passengers, arriving at their destinations at or before a predetermined time is of critical importance. Such a trip could be for work, a doctor's appointment, or any other purpose. While scheduled travel time may provide an estimate of typical time required to reach a destination, to be reasonably certain of timely arrival at their destinations, passengers often include some extra cushion in travel time based on past experiences riding a specific route or transit system. This is true of other modes as well, and transit is very competitive with driving along corridors where the reliability of public transportation and driving are similar, such as the Bay Bridge Corridor.

Transit planners generally use the 85th percentile travel time from one point to another (meaning 85 percent of the trips have an equal or shorter travel time) to approximate this travel time cushion that passengers may apply, knowing that individual preferences will vary.

Figure 12 shows locations from which the 85th percentile of travel time to Embarcadero station is 30 minutes or less. This is a limited network compared to the locations from which the 50th percentile, or average, travel time is 30 minutes or less, indicated on the map by the timer icons further from downtown. All SFMTA transit lines include large surface sections that increase the variability between the 50th and 85th percentile travel times.

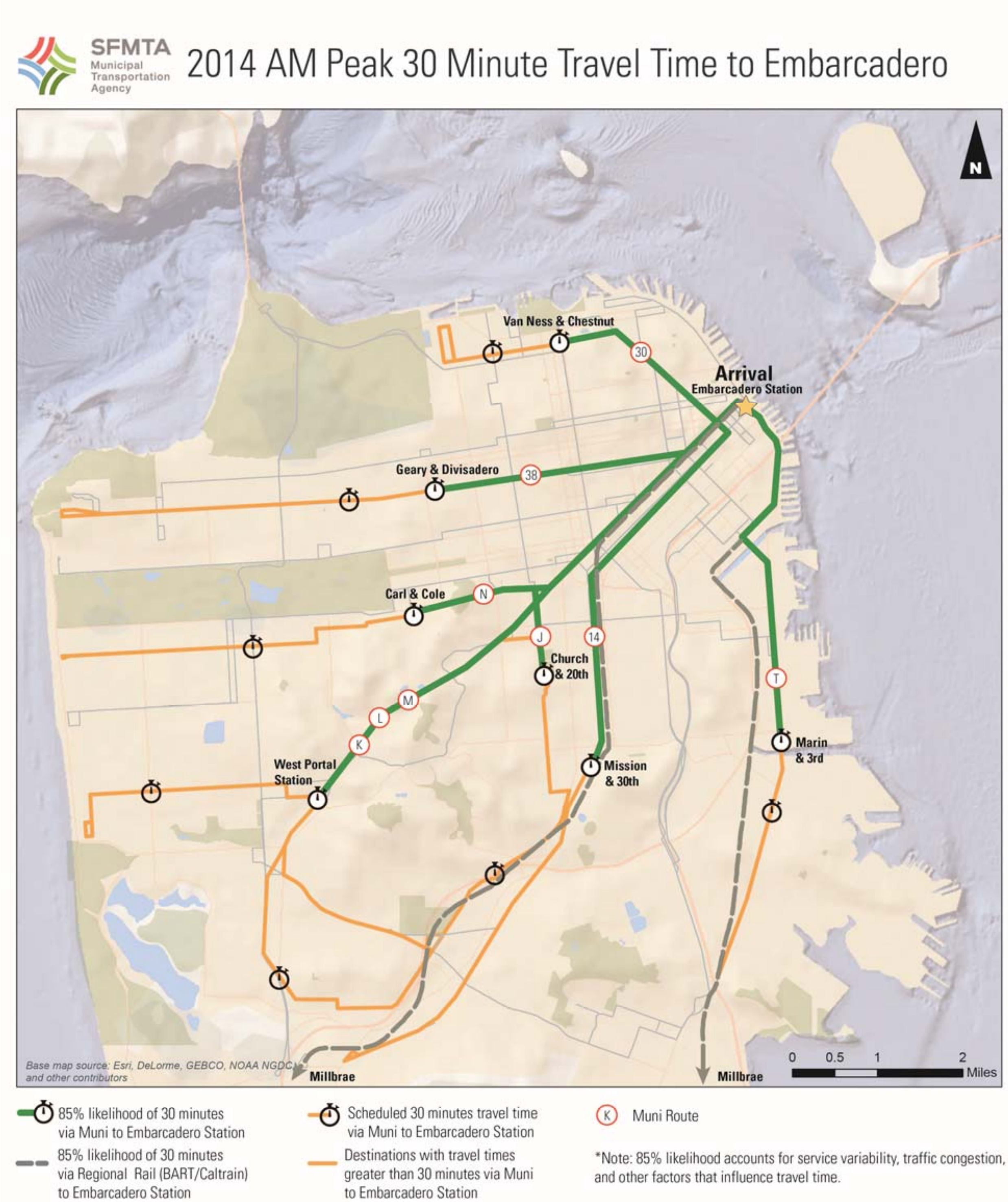

Figure 12: 30 minute Travel Time from Embarcadero. 50th and 85th Percentile

3.5.3 Safety

Subways virtually eliminate conflicts with motor vehicles, bicyclists, pedestrians, and other modes of travel. As shown in **Table 3**, on a per-mile basis, light rail vehicles average fewer collisions than buses or cable cars, and this includes light rail vehicles operating in mixed traffic. Portals and other interfaces between types of grade separation are known conflict points for transit vehicles. For example, the M line crosses northbound 19th Avenue twice between Eucalyptus Drive and Winston Drive.

Table 3: Collisions involving transit vehicles

Mode	Collisions per 100,000 miles (July 2015 –May 2016)
Cable Car	15.8
Motor Coach	6.5
Trolley Coach	9.7
Light Rail – Surface & Subway	2.6
Light Rail – Subway only	0.0

Source: SFMTA Transtat Database

Subway expansion may also have additional safety benefits. In San Francisco, pedestrians, bicycles, transit vehicles, and motor vehicles all compete for limited street space. While enhancing safety is a priority for the City, there is a limited array of tools available for reducing the speed of motor vehicle traffic that do not also impact the efficiency of surface-running transit operations. Locating key transit corridors in subways can create space on the roadway for improved pedestrian or bicycle facilities.

3.5.4 Capacity

Crowded transit vehicles are less comfortable for passengers, slow transit operations when boarding and alighting take more time, and inhibit passengers wishing to use their travel time productively. Subway expansion provides an opportunity to increase the capacity and reduce crowding on local and regional transit systems.

The ability to expand the capacity of public transportation systems operating on surface streets is limited. Transit agencies can use larger vehicles or run more frequent service, but these strategies can only expand capacity to a certain degree. When the number of buses begins to approach even half the capacity of a corridor, their speeds begin to drop.[7] This suggests that while improvements can certainly be made to surface transportation, there is a point beyond which investing in a higher capacity mode may be justified.

San Francisco's Travel Demand Model, SF-CHAMP, projects crowding on transit routes for 2020 and 2040. Each transit vehicle has a maximum person carrying capacity. When the average number of persons a vehicle exceeds 80 percent of the maximum person capacity, that route is considered "crowded". Transit routes projected to operate beyond 100 percent capacity are considered "Over Capacity."

Figure 13 shows crowding projected on transit routes for the 2040 afternoon peak period. While demand for regional transit service between San Francisco and the East Bay and Marin County already exceeds capacity, most key corridors are projected to operate over capacity. Many transit lines operate along Market Street; the most crowded lines include light rail operating in the Market Street Subway, the F Historic Streetcar, and bus routes running on the surface of Market Street.

[7] Transit Capacity and Quality of Service Manual, 3rd Edition

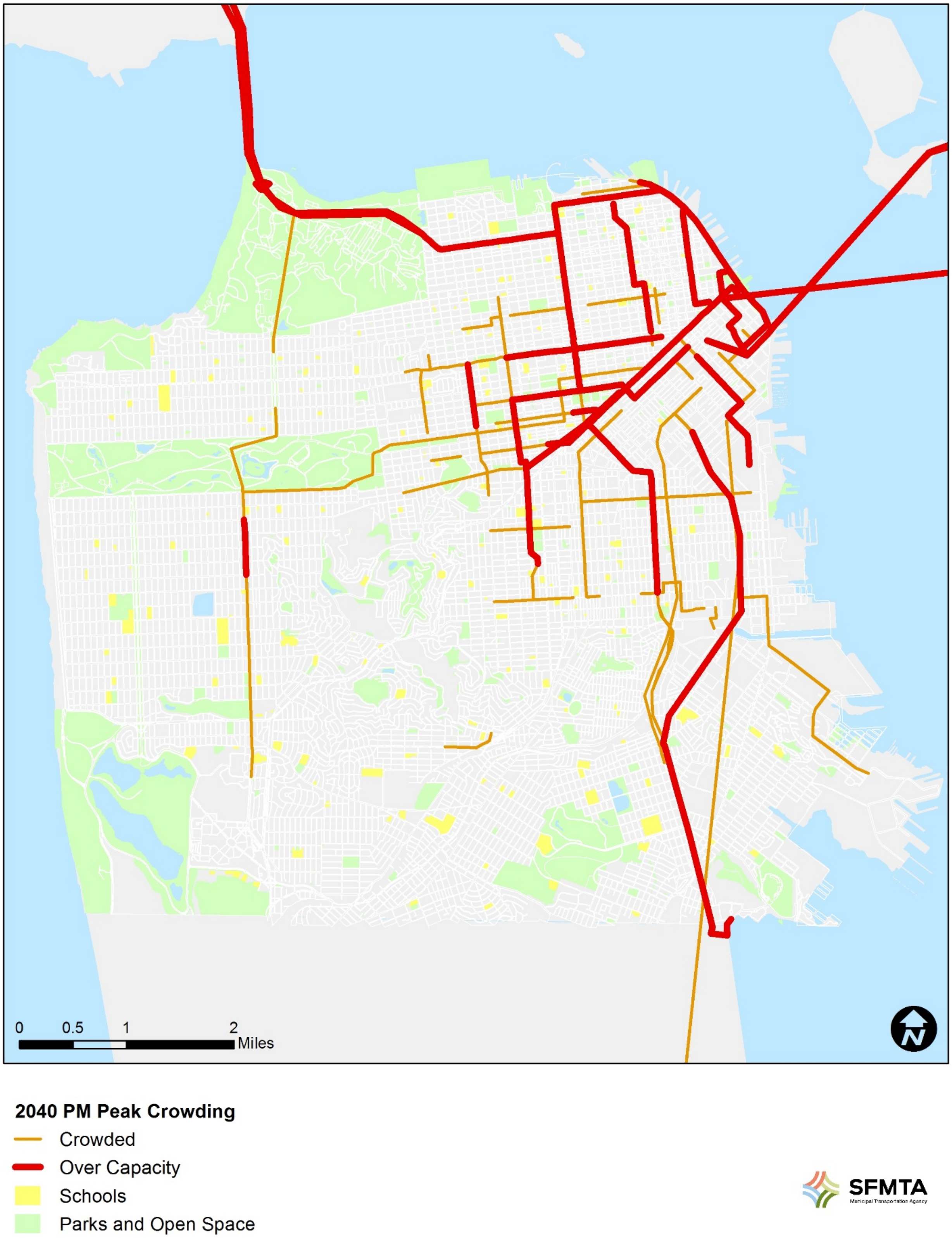

Figure 13: 2040 PM Peak Crowding

Subways vs. Surface Rail Mode Capacities

Subways have higher capacity than either buses or surface rail. This is particularly true where subways operate completely within a closed system. San Francisco's light rail network operates both on street and underground, and capacity limitations in the on-street sections preclude full use of the system's underground capacity.

In on-street operations, train lengths are limited by a number of infrastructure factors including platform lengths, block lengths, and terminal storage capacity. This results in one- or two-car train operations on the five light rail lines, with three-car train operations for shuttle or other special service. In the Muni Metro subway, a majority of the platforms are capable of serving four car trains.

The unreliability of surface operations also reduces the capacity of trains in the subway. Delay due to traffic can cause vehicles to bunch, which continues to affect vehicles even while grade-separated.

As shown in **Figure 14**, Muni Metro's current capacity lands near the middle of the predicted person capacity of an on-street light rail line. BART's current capacity is near the middle of predicted person capacity of Heavy Rail with Fixed Block Signals.

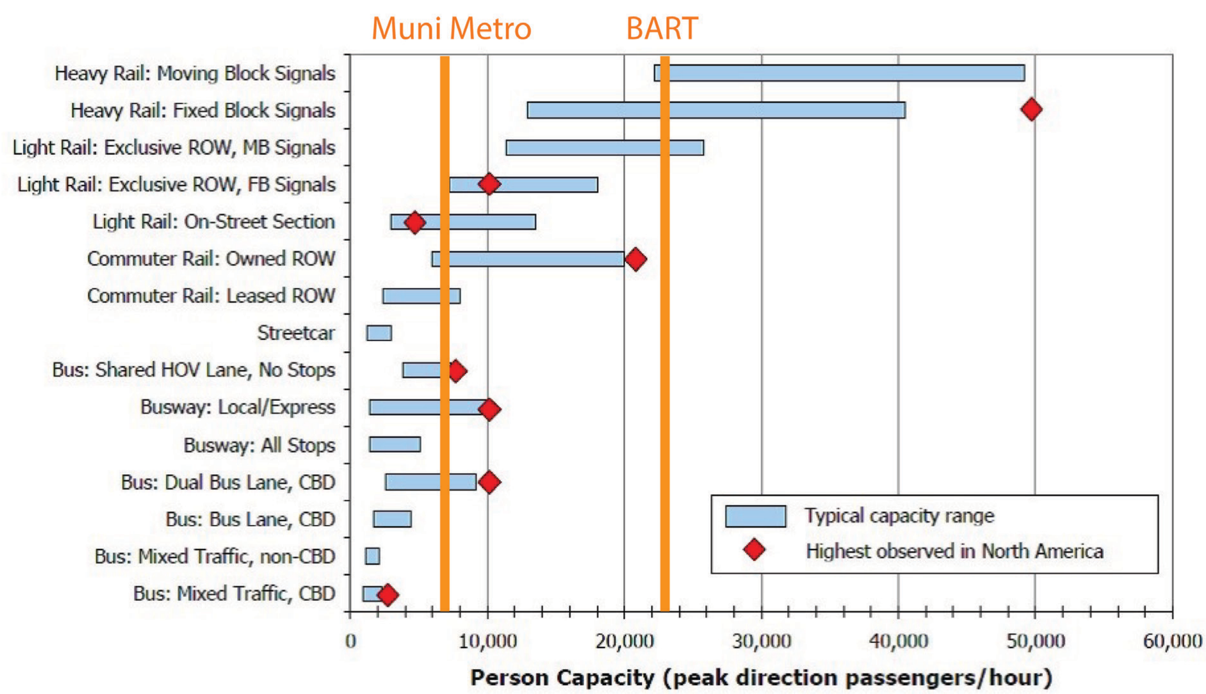

Figure 14: Peak hour person capacity by mode

3.5.5 Flexibility and Resiliency

All of the light rail lines operated by Muni feed into the Muni Metro subway from Embarcadero to Van Ness Station. Between Van Ness and West Portal stations three light rail lines operate in the Muni Metro subway. With all five lines operating in a single subway, delays or disruptions don't affect just a single line, or even just the subway, but the entire Muni rail system. Similarly, all BART lines use a single tunnel from West Oakland to Balboa Park. Any source of delay, whether due to medical emergencies, police activities, or equipment failure, impacts the entire system throughout San Francisco and beyond.

Additional subway lines would increase resiliency in the event of breakdowns. Possible alignments may provide additional options for routing both passengers and trains from one part of the city to another.

3.5.6 Integration with Existing Subway System

Among the challenges for existing transit systems is the lack of flexibility of current systems. Delays in surface sections of partial subways can impact underground parts of the system. This section describes characteristics of potential subway alignments that affect their potential to positively or negatively impact existing transit systems.

Characteristics of strong system integration include:

- Realistic entry and exit points into the existing BART and Muni systems
- Reducing the number of trains using the most congested parts of the BART and Muni systems
- Improving access to and from maintenance facilities
- Providing redundant routes that could be used in the event of a system breakdown
- Conversion of partial subway lines, which have less capacity and are susceptible to surface delays, into full subways

Routes with weaker system integration might have the following characteristics:

- Extensions for subway lines that are running near capacity
- Increasing the passenger traffic at system maximum load points

Subway proposals should consider these operating characteristics throughout the planning and design process.

4 Candidate Projects and Analysis

This chapter discusses potential subway corridors and networks that emerged from prior plan review, outreach, and technical analysis.

4.1 Corridor Development

The prior plan review, corridor demand analysis, and public outreach was provided for the first of two Subway Vision staff workshops. From the wide variety of materials, many corridors emerged that might warrant consideration for future subways.

Staff focused on surface rail lines, the existing highest-ridership transit corridors, and other areas with significant trip patterns as the most promising subway candidates. **Figure 15** illustrates the range of possible corridors identified for further analysis. Despite the specific suggestions from public outreach and past plans, this planning effort does not specify particular streets for subway lines, but wider corridors that encompass a range of possible alignments.

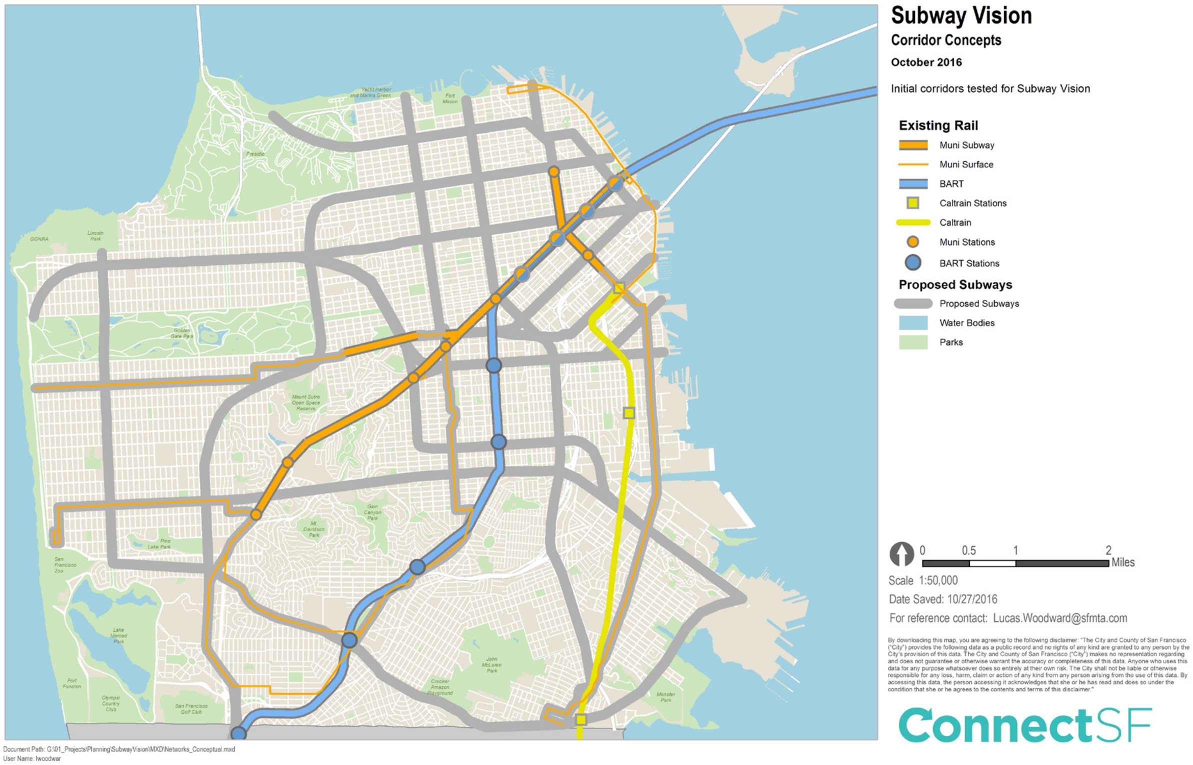

Figure 15: Initial Corridor Concepts

4.2 Network Development

Staff compiled corridors into two alternative subway networks in a second multi-agency workshop. These networks were devised to test different approaches to expanding the subway system in San Francisco. While both network approaches yield approximately 30 new miles of subway investment, Network A focuses on expansion that serves the most popular existing trip patterns in the city, centered on the northeast quadrant of the city and providing additional capacity parallel to the Market Street subway. Network B focuses on expanding the reach of the subway system, providing subway service along corridors that currently have fewer options for high-capacity transit.

Figure 16 illustrates the differences between the service areas of each network, by census tract. Gray areas are served by existing subways. Yellow indicates areas newly served under both network approaches. Green indicates additional areas served only with Network A, and pink indicates additional areas served only with Network B.

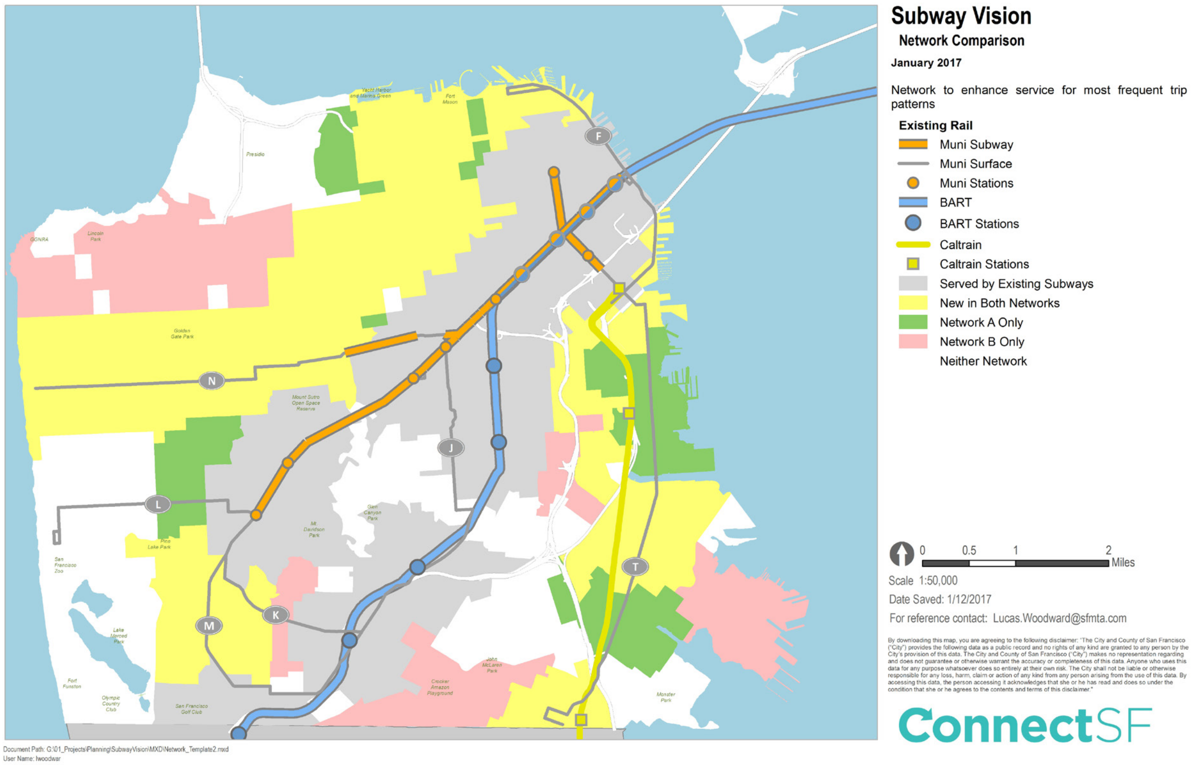

Figure 16: Subway Network Comparison

The purpose of two distinct network approaches was not to make them as different as possible, but sufficiently varied to illustrate the tradeoffs of each approach. Several principles are common to both networks to ensure a fair comparison. **Table 4** lists the principles for developing subway networks.

Table 4: Subway Network Development Principles

Both Networks	Network A	Network B
• Proposals should incorporate corridors with appropriate population and jobs density, potential travel time savings, travel time variability, and crowding. • Partial subways are discouraged because they preclude taking full advantage of subway capacity. • Subways should have realistic entry points into the existing BART/Muni networks as well as terminal stations/end points • Avoid duplicative corridors unless redundancy is a key system benefit	• Serve the highest-demand corridors and trips patterns so that the highest number of trips possible are taken by subway. • Prioritize corridors that generated most trips in Emergent Network exercise • Network design that supports all trip purposes and patterns in areas of appropriate land use	• Expand the reach of the subway system so that more of San Francisco's land area and population are accessible • Subways with catchment area overlaps discouraged • Extra consideration for corridors with no existing rail • Despite goal of coverage, avoid corridors with lowest population and jobs density

The subways that San Francisco will ultimately build will likely not all come from one network or another. The Subway Vision is intended to illuminate the decision-making process, discuss key tradeoffs among potential subway alignments, and highlight projects with the highest potential.

4.3 Evaluation Framework

Subway Vision staff developed an evaluation framework to determine project concepts that may be appropriate for subway transit and determining how those concepts would perform in a network.

In choosing project concepts to include in potential subway networks, staff considered a number of existing and future conditions:

- Population and Employment Density: where population and employment centers are predicted to be located in 2040
- Operational Resiliency and Redundancy: whether concept may improve the ability for subway service to recover from service interruptions.
- Capacity and Crowding: if concept would provide additional service at points in the transit system that are at capacity today or will be in 2040.
- Speed: comparing current travel times on existing transit to a potential subway

Once project concepts were combined into networks, staff also sought to analyze a number of considerations at the network-level. The intent of these considerations was to see how a comprehensive subway network could improve upon the transportation system experience and performance compared to what is already planned. These include:

- Capacity and Crowding: Time that passengers would spend in crowded conditions.
- Projected Ridership (in relation to capital costs and hours of transit service)
- Sea-Level Rise: parts of network that are in vulnerable zones
- Network connectivity: how many more trips are projected to start and end via subway system
- Speed: transit travel time to key destinations compared to driving
- Environment: vehicle miles traveled (VMT) and associated greenhouse gas (GHG) emissions
- Equity
    - Travel times for low-income people compared to all San Franciscans
    - Travel time to key destinations for low-income people
- Transportation costs
- Mode split of trips starting and ending in San Francisco

This chapter presents results from the initial analysis of potential subway corridors and networks. These results include both off-model analysis based on land use and operating characteristics of existing transit systems and on modeled projections of travel patterns.

4.4 Land Use

As discussed in Chapter 3, the built environment surrounding subway stations has a major impact on the ridership and cost-effectiveness of a subway system. This section describes the land use characteristics of possible subway networks for both 2010 and projected land uses in 2040. **Table 5** presents the results for Network A and Network B.

While both networks significantly expand subways in San Francisco, Network B placed more emphasis on extending the reach of the subway system throughout San Francisco. To measure access to the subway system, the approximate land area, population, and employment within ½ mile of hypothetical subway stations. These numbers cannot be exact, as the precise alignments of subway networks need further study, but they provide an order-of-magnitude comparison to existing conditions.

Table 5: Access to the Subway System

	Population	2040 Population	Jobs	2040 Jobs	Area
Existing Stations	352,000	460,000	333,000	474,000	8,400
New Areas in Network A	278,000	342,000	152,000	228,000	10,900
Total Area in Network A	630,000	802,000	485,000	702,000	19,400
New Areas in Network B	334,000	403,000	145,000	197,000	12,300
Total Area in Network B	686,000	863,000	477,000	671,000	20,800
San Francisco	**803,000**	**1,036,000**	**526,000**	**767,000**	**30,000**

As shown in **Table 5** both networks more than double the areas within a half mile from a subway station in San Francisco. Network A emphasizes employment centers, with 92 percent of 2040's projected jobs located within a half mile of a subway station, compared with 88 percent for Network B. Network B emphasizes access to residential areas, with 83 percent of residents living within a half mile of a subway station, compared with 77 percent for Network A.

4.5 Key Model Results

Model results indicate significant benefits of implementation of both network concepts versus the 2040 baseline. Indicators tied to the evaluation framework include:

- **Travel time savings.** Both networks would save transit riders nearly 25,000 hours of travel time per day, with individual route travel times improving by 50%-70%. These benefits accrue to neighborhoods across San Francisco as shown in **Figure 17**.
- **Reliability.** Both network concepts would allow for some lines to operate exclusively in a grade separated environment, enhancing reliability to a level similar to BART versus lines that must operate portions of their routes on the surface.
- **Ridership.** Systemwide ridership would increase by more than 15% under either concept.
- **Environmental.** Both network concepts would have a modest (1%-2%) reduction on citywide VMT, with a similar reduction in driving delay and congestion. The relative small amount of change is an indication of latent demand for driving on San Francisco's congested networks.
- **Access.** The network concepts would allow more than 80% of San Francisco residents to walk to a subway station (versus 45% in the baseline) and more than 90% of jobs would be within walking distance of a subway station (versus 60% in the baseline)
- **Equity.** Under either network concept, low income travelers would have their travel time reduced a similar amount to the population overall.

A.

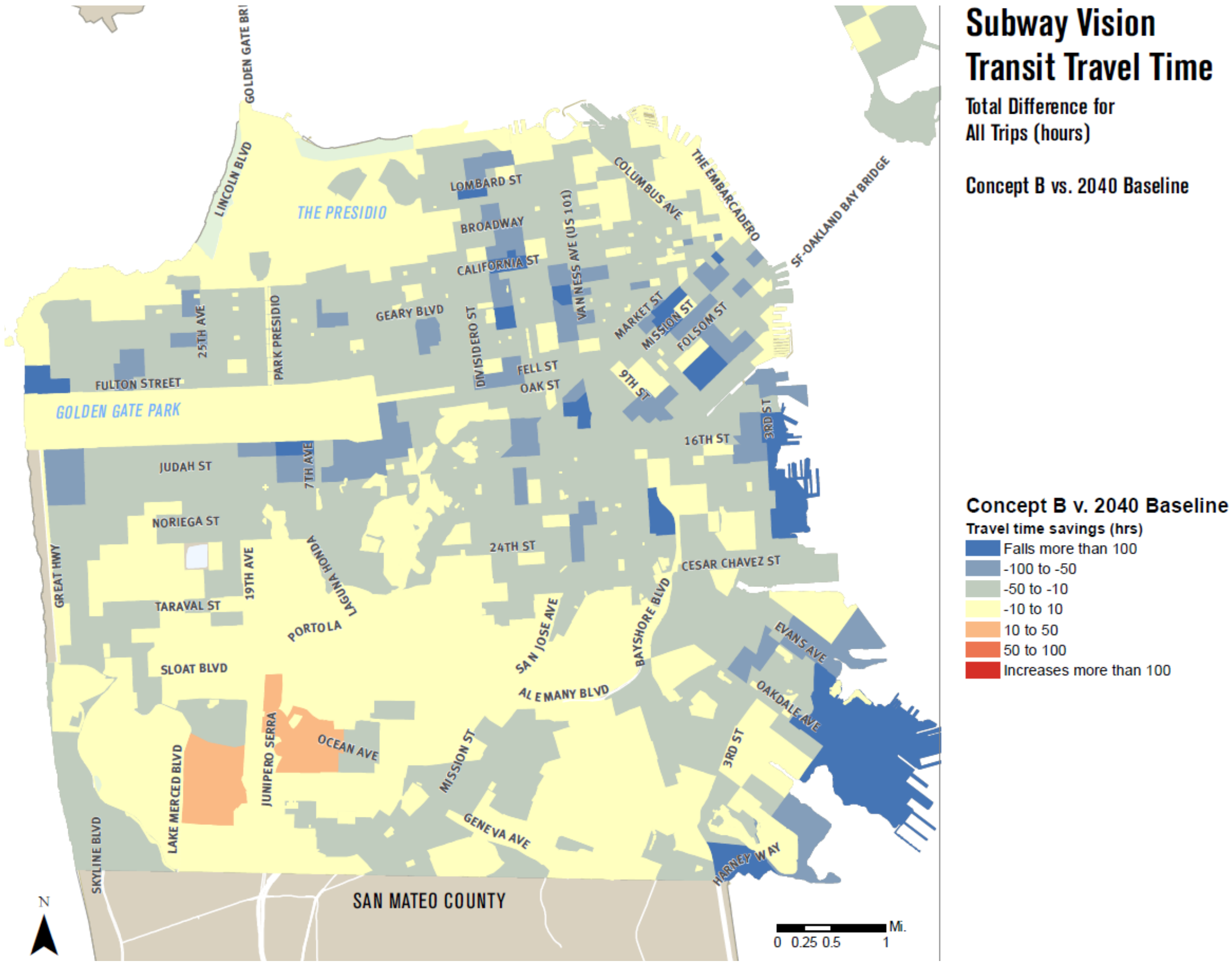

Figure 17: Travel Time Savings with Network B

5 Funding

The Subway Vision has identified $25-$50 billion in costs for approximately 30 miles of new subway construction in San Francisco. Unfortunately, it will be a challenge to get there with the funding currently available to grow our transit system. With existing sources, we anticipate only $4.5 billion in discretionary revenue could possibly be available through 2040 for subway expansion projects. And that amount would only be available if the city places subway expansion ahead of all other transportation improvements that are eligible to receive these funds, such as other transit expansion projects (e.g. Geary Bus Rapid Transit, Better Market Street, MuniForward), bicycle and pedestrian infrastructure, transit state of good repair, new transit vehicles, transit service improvements, local streets and roads maintenance, lifeline transportation, and transportation demand management.

This report sets a compelling vision for what San Francisco's subway system could become. However, even if San Francisco and regional voters approve multiple new revenue measures for transportation (including a new 1-cent sales tax, a vehicle license fee, new regional bridge tolls, and a regional gas tax), we currently estimate that these would only raise an additional $11 billion through 2040, and that would have to be divided among all transportation needs in San Francisco, not just rail expansion.

In short, fully funding the Subway Vision poses a significant challenge. To raise more local funding we would have to identify and approve an even more ambitious set of local and regional revenues for transportation. New local funding can help leverage additional state and federal transportation dollars, but those sources are historically unreliable and even if they were secured still wouldn't be enough to close the gap. While we work to secure additional transportation revenues, we must work together to establish our priorities for the funds we already have, both within the Subway Vision and for overall citywide transportation investment.

6 Next Steps

6.1 Ongoing Efforts

There are a number of projects and studies currently underway that will move the city towards the implementation of the Subway Vision and achieve some of the benefits of subways discussed in this document.

- The T-Third Concept Study will initiate in early 2017 to analyze at a high level the potential feasibility, benefits, and issues of extending the T-Third LRT line from the Chinatown station through North Beach and Russian Hill.
- The Muni Subway Expansion project is currently underway to consider options for improving the M-line south of West Portal. Working with developers, the SFMTA is considering an alternative that would place the entire M-Line underground, improving safety and efficiency and providing opportunities to enhance the 19th Avenue streetscape.
- The Bay Area Core Capacity Transit Study, a collaborative effort led by the Metropolitan Transportation Commission (MTC), is identifying and prioritizing investments that will improve travel on public transportation to and from the San Francisco core.
- With the passage of Measure RR in the Bay Area, BART will make significant investments in system modernization. Improvements to train control and power infrastructure will improve the safety of the system and increase capacity during peak hours. The program also includes funding set aside for the study of future projects to relieve crowding and congestion and improve system flexibility.
- Non-rail improvements across the Muni system are underway through the Muni Forward program. Additionally, the city is pursuing BRT projects on the Van Ness, Geary, and Geneva-Harney corridors.

6.2 Implementing the Subway Vision

While this document lays the foundation for future subway expansion planning, there are numerous other steps to implementation.

6.2.1 Land Use

The efficiency and cost-effectiveness of future subways will depend on appropriate land uses. Currently, most areas of San Francisco with the highest concentration of jobs and housing, including downtown, SoMa, and the Mission district, already have access to the subway system or will have access upon completion of the Central Subway. Other parts of the city may be logical candidates for subway expansion. The City should ensure that these potential areas have the appropriate type and scale of development for subway service. This includes considering how trip making activity and potential destinations may introduce additional crowding on the existing subway system, or increase demand where the system has available capacity.

As potential subway corridors and station locations become more clearly defined, the city should look for opportunities to acquire the land necessary for stations, station entrances, rail yards and other facilities that might be needed as part of subway expansion in the city. Further, the city should work closely with developers to leverage funding from development impact fees into transformative improvements that improve mobility for both existing and future residents and employees. For example, the proposed M-Line Subway emerged from precisely this type of partnership. Similarly the Geneva-Harney Bus Rapid Transit (BRT) project was pursued in partnership with forthcoming development in the Candlestick-Hunters Point area.

6.2.2 Fleet, Facilities, and Stations

Even the addition of one subway line would be a significant increase in the track mileage of rail systems in the city. In order to ensure that a new subway would deliver the potential benefits described in this document, the investment in tunnels and tracking would need to be accompanied by a larger, modernized fleet of rail cars and expanded maintenance facilities to keep them running reliably. These facilities could be within or outside of San Francisco, particularly for regional rail operators. But as potential subway corridors are further refined, a parallel effort will be needed to address future fleet and facility needs.

Because any future subway expansion would need realistic entry points into existing subway stations, later iterations of the Subway Vision should consider investments needed in existing stations. For example, some potential corridors envision existing stations becoming transfer points. Likewise, stations that might see additional demand or transfer activity with subway expansion may need retrofitting such as moving stairways to ensure that platform capacity does not constrain the capacity of the subway system.

6.2.3 Feasibility studies and environmental review

The initial technical work and community engagement included in this Subway Vision are only the first steps for any new subway. The strongest corridor candidates will need more focused outreach and technical study. Studies will include ridership forecasts and detailed cost estimates. The Subway Vision's comprehensive approach will help to guide the analysis for future subway corridors by ensuring that studies for any particular subway corridor or other major transit investment reflect the possibility of other promising projects being implemented.

The environmental impacts of any major transit expansion must be adequately studied and disclosed to the public. Substantial time must be set aside for environmental review for any future project.

6.2.4 Enhanced Project Delivery and Staff Capacity

Subway expansion will need to be the top priority of many full-time planners, project managers, engineers, and environmental specialists. The city must ensure that staffing and contracting needs are met and that work programs are focused on the specific steps necessary to implement the Subway Vision. Best practices in subway project delivery, not just in North America but Europe and Asia, will need to be put into practice and continually improved upon.

6.3 Long-Range Efforts

Constructing more subways in San Francisco is a long-term effort. It will require intensive analysis, outreach to stakeholders, political commitment, and tireless pursuit of new funding sources. But every significant transit expansion in the Bay Area needed a starting point, and this document lays the foundation for these activities.

The vehicle for major transportation decision-making for the next 50 years will be Connect SF, a comprehensive look toward the future of San Francisco. The schedule for Connect SF is shown in **Table 6**.

Table 6: Connect SF Schedule

Phase	**Timeline**	**Description**
Transportation Vision	2016-2017	Broadly envisions the transportation future of San Francisco and identifies specific goals and performance measures.
Modal Studies	2017-2018	Plans for modes of transportation within the city, including transit, freeways, and arterials.
SFTP 2050	Mid-2018	Identifies policy recommendations, investment scenarios, and transportation project priorities for a 2050 time horizon.
Transportation Element Update	2019	All of the city's actions and investments must be consistent with this required element of the city's General Plan.
Plan Bay Area Call For Projects	2019	Submitting transportation priorities to Regional Transportation Plan