BRIEFING BOOK

CORE CAPACITY TRANSIT STUDY

SAN FRANCISCO BAY AREA

JULY 2016

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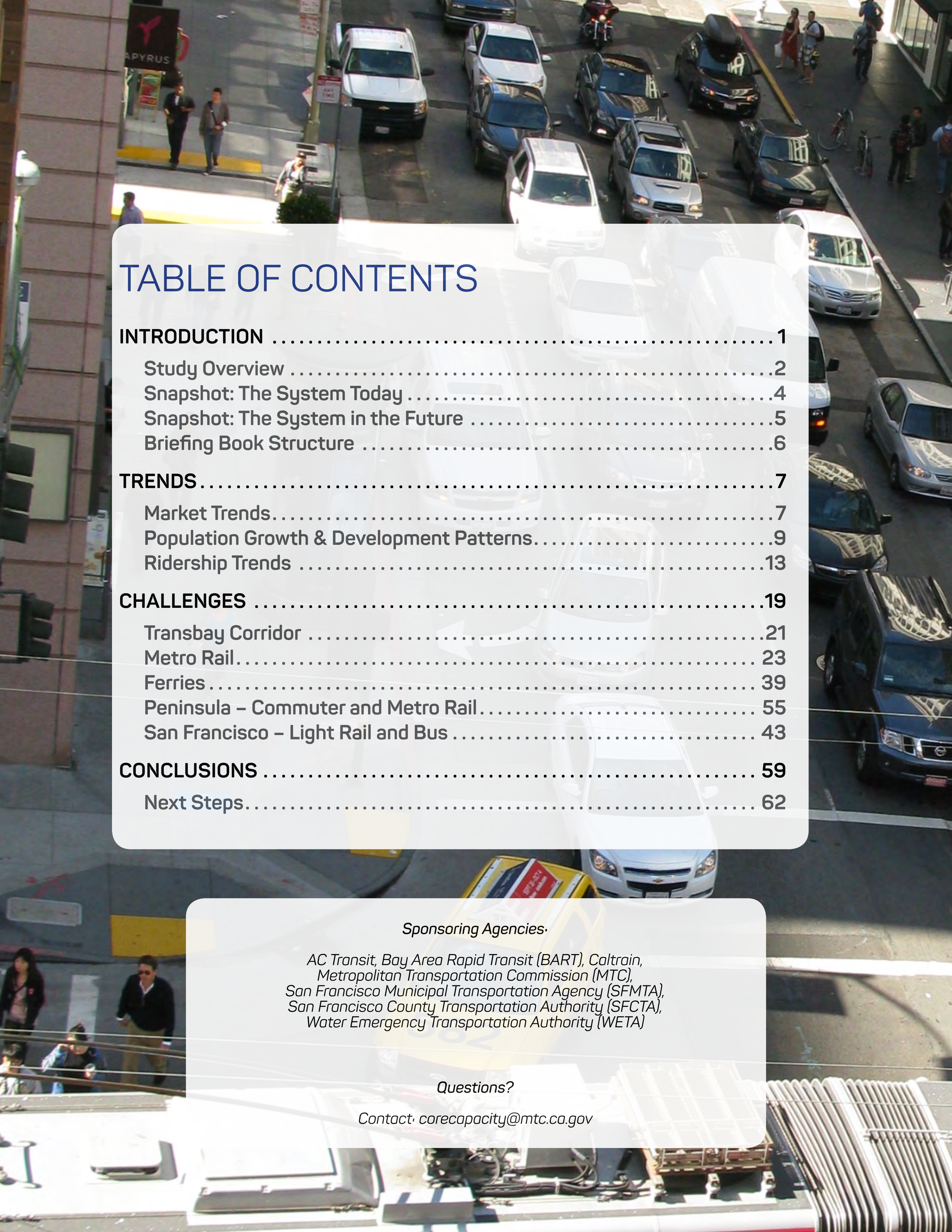

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Sponsoring Agencies:

AC Transit, Bay Area Rapid Transit (BART), Caltrain,
Metropolitan Transportation Commission (MTC),
San Francisco Municipal Transportation Agency (SFMTA),
San Francisco County Transportation Authority (SFCTA),
Water Emergency Transportation Authority (WETA)

Questions?

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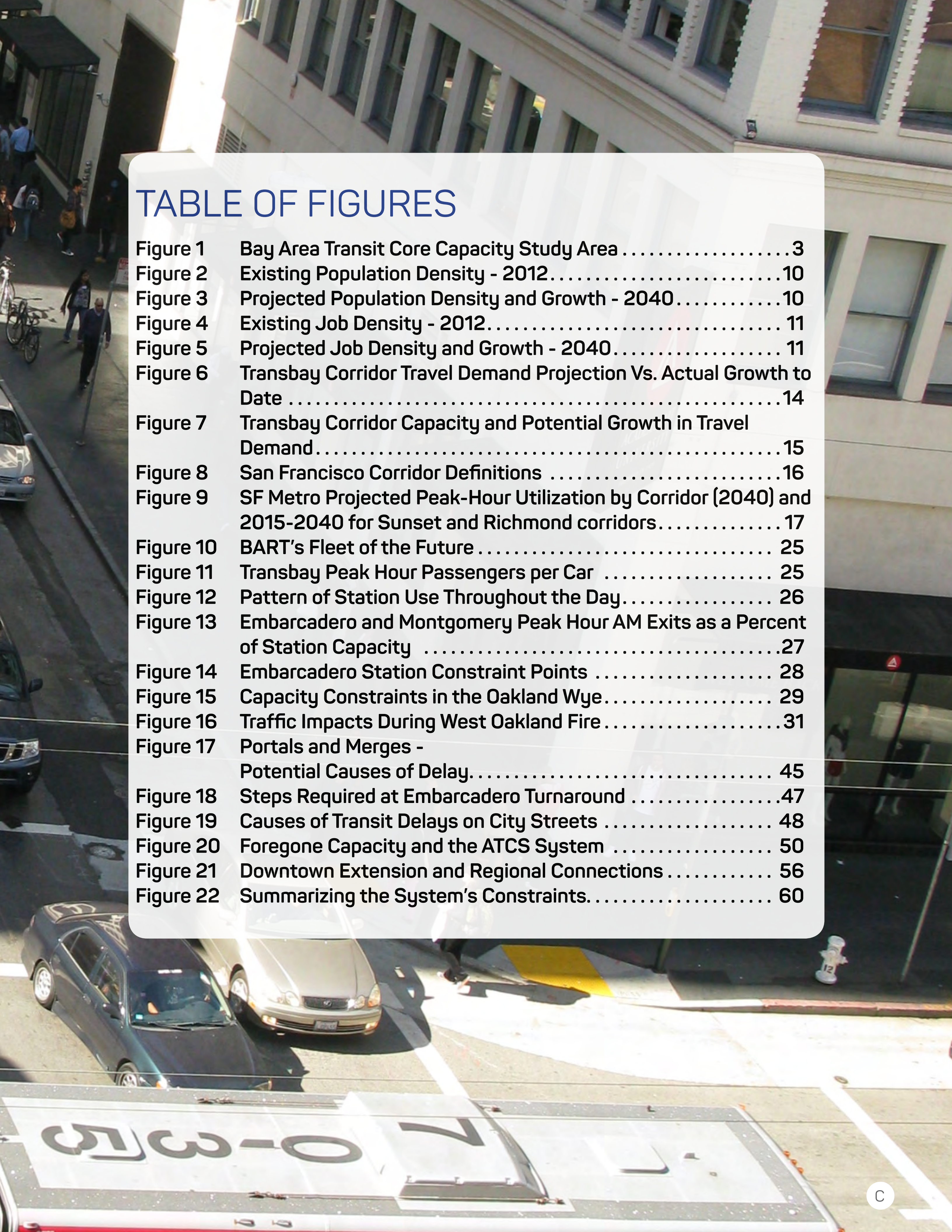

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INTRODUCTION

Bay Area residents depend more and more each day on the region's transit systems. Five main agencies move hundreds of thousands of people into and out of San Francisco's Core every day, helping them access the dense job centers of the Financial District and South of Market (SoMa) neighborhoods, as well as the emerging job centers in Mid-Market and Mission Bay. Facing increasingly crowded conditions in recent years as the region and transit ridership have grown rapidly, our transit system is challenged to deliver quality service to riders both now and in the future.

The Bay Area Rapid Transit District (BART), the San Francisco Municipal Transportation Agency (SFMTA), AC Transit, Caltrain, and the Water Emergency Transportation Authority (WETA) are all committed to identifying investments and improvements to increase transit capacity to and from the San Francisco Core. While all of these operators are independently considering various improvements and investments to their respective systems, no study to date has brought the major transit operators together to address this regional issue in a comprehensive, coordinated manner.

The Bay Area Core Capacity Transit Study (CCTS) is a collaborative effort by those five transit operators, the San Francisco County Transportation Authority (SFCTA), and the Metropolitan Transportation Commission (MTC). The project aims to estimate potential future demand for travel to and from the San Francisco Core and come up with a plan for meeting demand in ways that support sustainable economic growth and improve the quality of life for the region's residents, visitors, and workers.

This Briefing Book lays out the facts about land use patterns, ridership trends, and the constraints imposed by existing transit infrastructure serving the San Francisco Core. The book aims to get everyone with an interest in the Bay Area's economic vitality — and the transit system that enables it — on the same page about key issues the system faces. Working collaboratively, we can have a constructive conversation about potential solutions over the coming months.

INTRODUCTION

STUDY OVERVIEW

The CCTS is a multi-agency study to identify and prioritize the major investments needed to serve the growing demand for quality transit service into the San Francisco Core. Figure 1 shows the study area, which includes the two primary transit corridors that feed the Core: the Transbay Corridor and the San Francisco Metro Corridor.

The study will look at short-, medium-, and long-term investments that can help steadily upgrade the system and keep pace with anticipated population growth over the next quarter century.

Specifically,

- **Short-term projects** are improvements to existing infrastructure that can be implemented over the next **three to five years**.
- **Medium-term projects** are larger improvements that require additional study and will likely take **five to 15 years** to implement.
- **Long-term projects** are significant transit investments to serve levels of ridership anticipated **20 to 25 years from today and beyond**.

A KEY INPUT TO THE 2017 PLAN BAY AREA UPDATE

The Core Capacity Transit Study is a parallel effort to Plan Bay Area 2040, a regional long-range planning effort sponsored by the Metropolitan Transportation Commission and the Association of Bay Area Governments (ABAG). Plan Bay Area 2040 will update the region's overall land use goals and transportation funding priorities for the next 25 years. As an important step toward funding and implementation, the projects developed through the CCTS will be considered for funding and prioritization for the nine-county region.

STUDY PARTNERS

The CCTS was established through a charter and funding commitments by seven Bay Area agencies and is also supported by a U.S. Department of Transportation TIGER grant. The seven partner agencies include:

- Lead agency: Metropolitan Transportation Commission (MTC)
- Transit operators: San Francisco Municipal Transportation Agency (SFMTA), Bay Area Rapid Transit (BART), Alameda-Contra Costa Transit (AC Transit), the Water Emergency Transportation Authority (WETA), and Caltrain
- Funding and planning partner: San Francisco County Transportation Authority (SFCTA)

Figure 1 Bay Area Transit Core Capacity Study Area

SNAPSHOT: THE SYSTEM TODAY

The San Francisco Core—the Financial District, SoMa, Mission Bay, and the areas around them—is the Bay Area's largest and densest single job center. Rapid housing and employment growth in eastern SoMa, Mission Bay, and Mid-Market, as well as increases in the number of workers in existing office towers in the historically dense Financial District, has increased the urgency to improve mobility. While much of this growth was planned, it has occurred much faster than anticipated. The rapid new development has been the result of changing market conditions and preferences, including a rapidly growing economy and reductions in average office space per employee. A generational shift in where young professionals prefer to live, documented in several surveys, likely also plays an important role.

This combination of forces has raised demand for transit during peak hours much more quickly than expected. At the same time, aging infrastructure has caused increased maintenance issues, exacerbating crowding on days when vehicles must be taken out of service or infrastructure like tracks and wiring need emergency repairs. Certain aspects of the design of the rail networks that serve the Core limit the system's potential capacity, cause recurring reliability issues, and limit their ability to be resilient in the face of major maintenance problems or natural disasters. Buses are limited by the need to contend with traffic on city streets and the Bay Bridge. Additionally, at current service levels, ferry capacity only accomodates a small share of transbay travelers.

SNAPSHOT: THE SYSTEM IN THE FUTURE

Addressing the transit system's capacity limitations will become more critical as the Core continues to densify. Failing to do so could limit the area's potential to accomodate growth, which would in turn slow the regional economy or push growth to low-density areas on the urban fringe. The region anticipates that two million more people will call the Bay Area home by 2040, and many of them are expected to find housing along the region's transit networks, commuting to jobs in the Core. The region's land use vision channels thousands of new housing units and millions of square feet of new office space into neighborhoods like the Financial District, South of Market, Civic Center, Market-Octavia, Showplace Square, and Mission Bay. Much of the balance of Bay Area job and housing growth is projected to occur in transit-accessible mixed-use areas the region has prioritized for infill development. Many of these areas are centered on BART or Caltrain stations, and many of the new residents and workers in them will turn to transit as their first option.

In an effort to meet this challenge, the region's transit systems have already begun planning investments that will help them bring more riders into the Core:

- **A new train control system** will allow BART to run more trains per hour through the Transbay Tube. In addition, the agency is in the process of replacing its fleet of rail cars with an expanded fleet of larger cars that can hold more passengers. The larger fleet will allow it to run more maximum-length (10-car) trains.
- **Muni is building a new subway alignment through downtown, expanding its fleet,** and making changes that will help to speed up buses and trains on crowded city streets. In addition, Muni operations staff has been studying and piloting various ways to increase capacity in the Muni Metro tunnel.
- Once complete, the new Transbay Transit Center will **provide space for a larger fleet of transbay buses**, and direct access ramps to and from the freeway will speed those buses on their way. AC Transit is also exploring the potential of double-decker buses, which would nearly double bus capacity without taking up any additional room on the bridge.
- **Caltrain is working to convert from diesel to cleaner, faster electric trains**, and the agency plans to extend service further into the Core once the downtown rail extension to the Transbay Transit Center has been completed.
- **WETA is planning increased service** across the Bay, expanded docking facilities at existing terminals, and new terminals that will provide direct service to new areas in the East Bay.

Of course, the region has not yet identified funding for many of these critical improvements. Even if it does, ridership forecasts suggest that demand could still far exceed capacity in some key corridors. In the transbay corridor, the Bay Bridge is already at capacity for vehicles, leaving an already crowded transit system to absorb a large share of the projected travel growth through the corridor. Transit demand is also projected to grow significantly in the Sunset corridor, pushing the limits of Muni Metro's current capacity.

If planned capacity improvements are not implemented, the transit system will likely experience further increases in crowding. Once the region's roadway and transit networks reach their limits, the system will constrain economic development in the Core and in the region as a whole.

BRIEFING BOOK STRUCTURE

The Briefing Book starts with a chapter on **Trends**, which details the land use patterns and market preferences that have driven significant ridership growth in recent years and that are projected to further increase demand in the future. Next, it looks at the specific constraints that limit each agency's ability to increase capacity to meet growing demand in a **Challenges** chapter.

This book will grow over the course of the study, with a **Solutions** chapter to be added as the project team identifies potential recommendations, advances engineering studies, and facilitates a process of aligning the visions of study partners, other stakeholders, and the general public.

TRENDS

CHALLENGES

SOLUTIONS

TRENDS

Land use plans, market preferences, and ridership trends are the backdrop to the crowding each of the transit agencies serving the Core face today. Some of these dynamics were planned, while others were unforeseen by earlier generations of planners and policy-makers.

"Population in San Francisco & Alameda County is projected to increase by almost 700,000 by 2040."

MARKET TRENDS

A variety of emerging market trends support the region's expressed desire to locate a large share of job and housing growth in the Bay Area's central cities or along key transit corridors. In recent years, demand for jobs and housing near transit stations has increased, and trends indicate that it will continue to grow in the coming years.

Demand for transit-accessible office space is likely to continue increasing. Based on a survey of real estate professionals across the country, the 2015 edition of the Pricewaterhouse Coopers/Urban Land Institute "Emerging Trends in Real Estate" predicts that office development around high-capacity transit stations is likely to continue to be strong, while traditional suburban office park development will continue to weaken.[1] This national trend may be particularly pronounced in the Bay Area, where a large share of the workforce is employed in knowledge-based industries that have a higher propensity than other sectors to locate in transit-oriented areas.[2] Bay Area offices are already more transit-oriented than those in other parts of the country – as of 2009, 35% of the region's employment was located within one half mile of fixed-guideway transit, the second highest share nationally.[3]

Offices in a variety of professional sectors also seem to be adding more workers per square foot, which means growth in travel demand related to new office space could add to already intense transit demand generated by existing office towers. The trend is not universal across all sectors. Some sectors with a major presence in the San Francisco Core, such as the legal sector, still program 250 to 350 square feet per employee, which is in-line with averages over the last several decades. However, the biggest driver of job growth in San Francisco and across the region as a whole, the technology sector, has been a leader in shrinking the per-employee space average, with some technology companies reportedly programming as little as 100 to 120 square feet per employee in new projects.[4] Increased density in occupied office space may be partially offset by another important trend: To hedge against skyrocketing rents, companies have started leasing more office space than

1 Urban Land Institute and Pricewaterhouse Coopers (2015). "Emerging Trends in Real Estate, United States and Canada 2015."
2 Center for Transit-Oriented Development (CTOD) (2011). "Transit and Regional Economic Development."
3 Federal Transit Administration (2014). "Trends in Transit-Oriented Development, 2000-2010."
4 Strategic Economics (2013a)

they need in the short term to ensure that they can grow when the time is right. Still, experts expect that per-worker space will continue to decline over time.

On the other end of employees' commutes, the appetite for transit-oriented housing also points toward increased demand for high-capacity transit. San Francisco's housing market is a leading national example of the strength of demand for central-city housing, but the Urban Land Institute's 2015 "Emerging Trends in Real Estate" for the United States and Canada predicts that suburbs located near central cities and on high-capacity transit systems are likely to be strong growth markets in the coming years, while demand in auto-oriented suburbs and exurbs will weaken. These trends might be somewhat muted in the Bay Area given the expense of housing in transit-oriented locations across the region — affordability may still drive a notable number of households to the region's edges.

The larger trends seem to be driven in part by the attitudes of two key age cohorts: so-called "millennials," young adults born between 1980 and 2000, and baby boomers, born between the end of World War II (1945) and the mid-1960s and reaching retirement age today. Surveys have shown that both groups are interested in being less dependent on automobiles to get around than past generations of equivalent ages.

Large majorities of millennials have expressed a desire to live in places where cars are not required.[5] Other surveys have found that people in this age group are traveling differently than those in other cohorts, making fewer vehicular trips and using transit more often.[6] Smaller but still strong shares of seniors have expressed a similar desire to live in walkable, transit-oriented places, and one survey of Americans older than 50 found that a bus stop is the most desired amenity to have close to home.[7]

Ridership trends support the idea that shifts in attitude have increased interest in living transit-

5 Global Strategy Group (2014). "Rockefeller Millennials Survey." AND Urban Land Institute (2015). "America in 2015: A ULI Survey of Views on Housing, Transportation, and Community."

6 Federal Highway Administration (2011). "Summary of Travel Trends: 2009 National Household Travel Survey." Page 26.

7 AARP Public Policy Institute (2014). "What is Livable? Community Preferences of Older Adults."

oriented lifestyles. In 2014, transit ridership nationwide rose to its highest level in more than 50 years,[8] and ridership trends among Bay Area operators provide strong local evidence.

Of course, a portion of new residents in central cities are likely to commute to jobs in the suburbs that are located on or near transit corridors, traveling in the opposite direction of traditional peak commuter flows into the city.

8 American Public Transportation Association (2014). "Public Transportation Use is Growing – Here Are the Facts."

There is strong evidence of this occurring in the Bay Area today, with thousands of San Francisco residents commuting daily to jobs in Santa Clara County. It can be highly efficient for transit agencies like BART and Caltrain to serve these riders, as they take up what would otherwise be empty seats. As a later section notes, while ridership is projected to approach capacity in the peak direction in several corridors in the future, so-called reverse commutes are projected to account for some of the growth in overall transit demand.

POPULATION GROWTH & DEVELOPMENT PATTERNS

Today, the San Francisco Core and downtown Oakland are vital employment centers, and they are forecast to become larger and more dense in the coming years. Coupled with major projected growth in housing near transit, development activity over the coming 25 years could create significant new travel demand in corridors that are nearing capacity today.

Plan Bay Area projections have San Francisco growing by more than 200,000 people (35%) by 2040, and Alameda County is projected to grow by nearly 500,000 people (32%) in the same time frame.[9] Both areas are already growing rapidly. Since 2010, 35% of the region's overall population growth has been in Alameda County or San Francisco,[10] and the number of jobs in San Francisco grew by 25% between 2010 and 2014.[11]

San Francisco is forecast to incorporate 17% of the region's new jobs.[12] A market assessment conducted for this study found that the Financial District could add 50,000 to 70,000 jobs to its current total of more than 200,000 if the trend toward decreased office space per employee continues.[13] The surrounding neighborhoods of SoMa, Civic Center/Mid-Market, and Mission Bay/Showplace Square could also grow significantly (albeit in a less concentrated fashion than the Financial District). Collectively, these neighborhoods could attract between 63,000 and 85,000 new jobs, which would represent between roughly 40% and 55% growth, respectively.

9 Metropolitan Transportation Commission (MTC) and the Association of Bay Area Governments (ABAG) (2013a). "Plan Bay Area." *Page 40.*

10 ABAG (2015). "San Francisco Bay Area State of the Region 2015: Economy, Population, Housing." Page 40.

11 U.S. Census Bureau. Quarterly Workforce Indicators, 2010-2014.

12 MTC and ABAG (2013a). Page 57.

13 Strategic Economics. "Revised San Francisco Market Assessment." Memorandum, December 3, 2015.

TRENDS

Figure 2 Existing Population Density - 2012

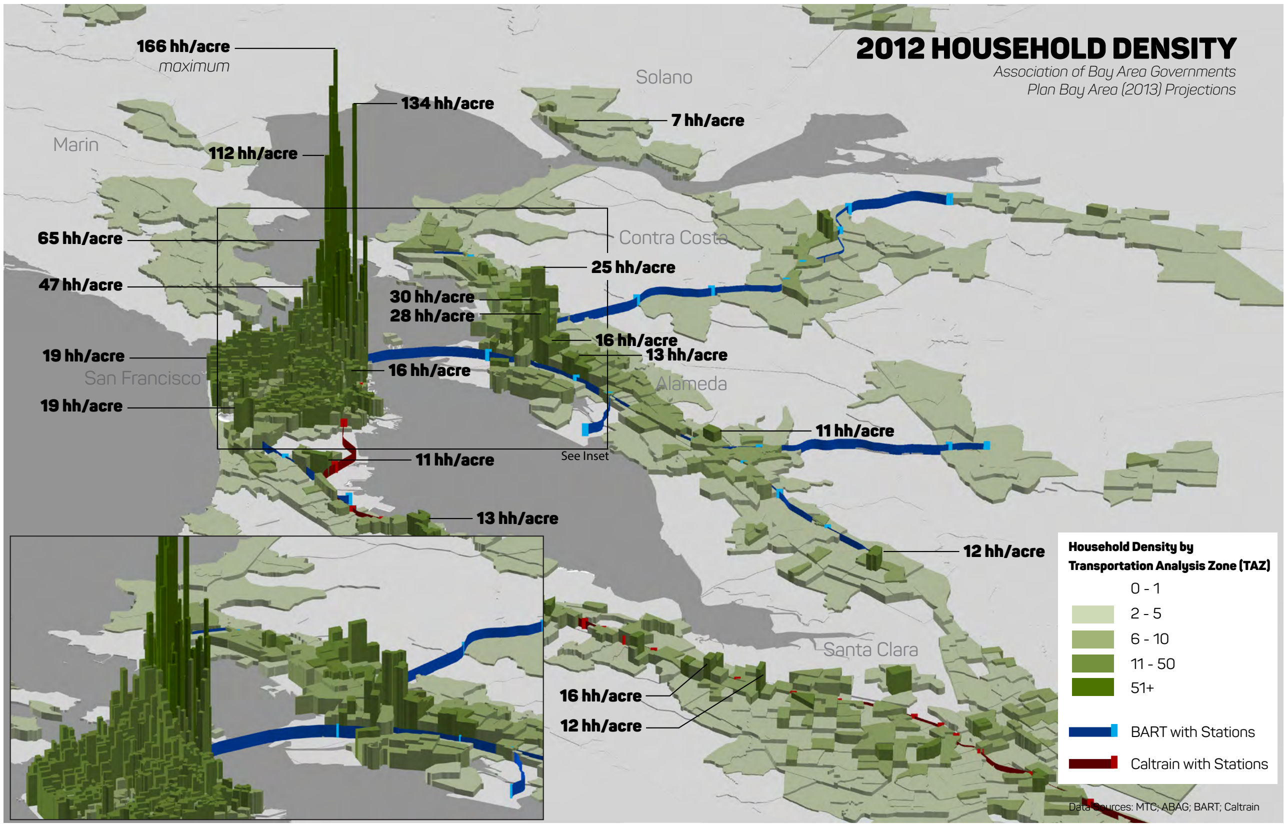


Figure 3 Projected Population Density and Growth - 2040

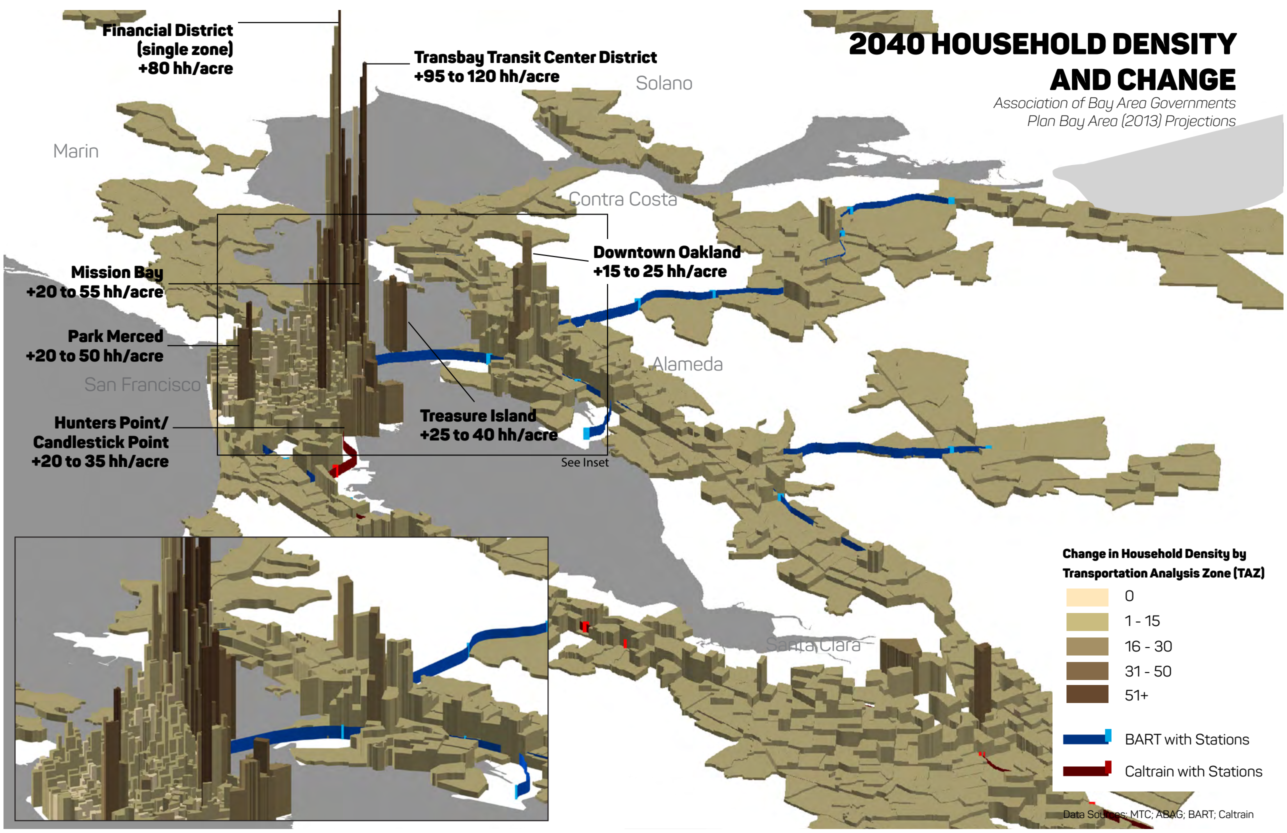


Figure 4 Existing Job Density - 2012

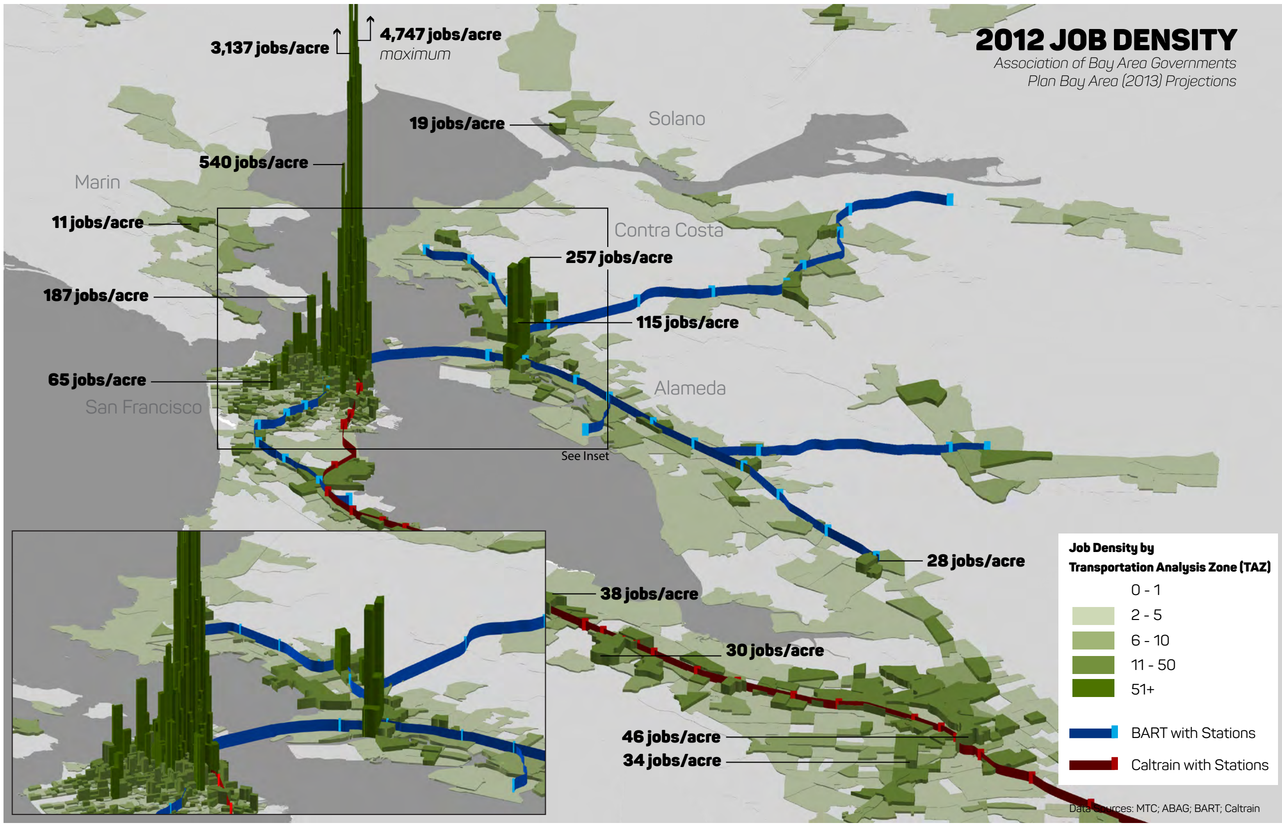
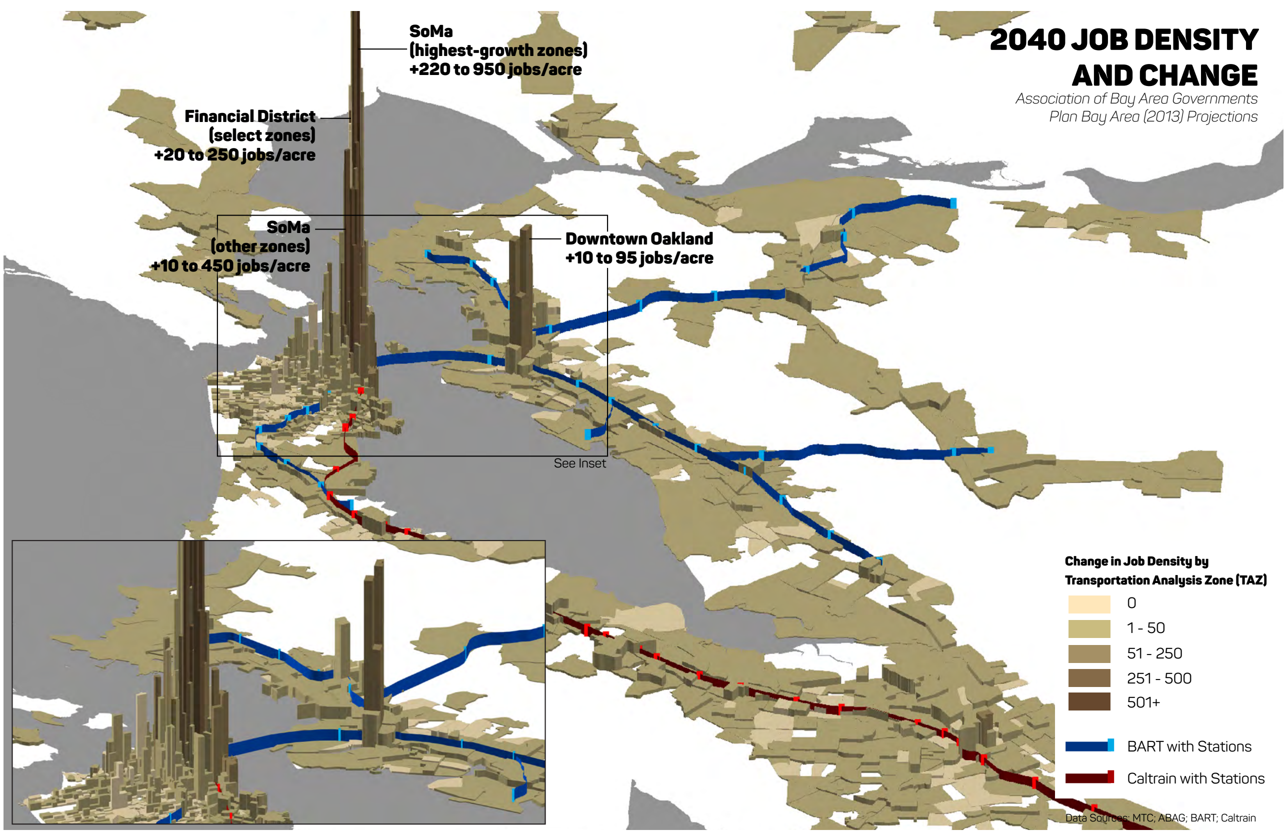


Figure 5 Projected Job Density and Growth - 2040



Other San Francisco developments that are slated to spur the area's growth include the planned Treasure Island development, which will bring 8,000 residential units, 140,000 square feet of commercial space, and 100,000 square feet of office space to the center of the Bay.[14] Land use plans for the areas around the currently under-construction Central Subway, which will link SoMa, Mission Bay, and the developed areas of Union Square and the Financial District, are anticipated to add thousands of jobs and housing units, per the Central SoMa Plan.

Trends in employment and housing growth on the eastern end of the Bay Bridge are another important part of the picture. Downtown Oakland has experienced strong growth and rising rents in recent years, with residents and companies drawn by the area's strong transit infrastructure, central location, and affordability relative to the San Francisco Core. Whether the recent trends will sustain themselves through the next economic downturn is uncertain, but an analysis completed for this study found that the area has potential to add 12,000 to 24,000 jobs through 2040, as well as 6,500 to 13,000 housing units.

14 Treasure Island Development Authority (2015). "Development Project."

While these growth projections are lower than what is forecast for the San Francisco Core, any increases in residential population or employment could have an impact on the same transit lines that are crucial to the San Francisco Core. Some of the new demand would fill available seats in the Transbay corridor (about 10% of Downtown Oakland workers commute from San Francisco today), but a larger share of commuters would likely come from other parts of Oakland or other places along key routes that might already be stretched by transbay commuters.

Regional planning agencies hope to focus growth outside the Core in Priority Development Areas (PDAs), which are intended to accommodate new housing and office space through infill and transit-oriented development. The location of regional PDAs aligns closely with existing BART and Caltrain stations and planned transit improvements, directly focusing employment and housing growth along key public transportation corridors that connect to the Core. All but one of the top 10 non-San Francisco or Oakland PDAs for housing and job growth is near a BART or Caltrain station. A large share of new employees and residents of PDAs will likely rely on transit.

RIDERSHIP TRENDS

As housing and employment in the Core areas of San Francisco have grown in recent years, demand for transportation to and from the Core has grown as well. In the transbay corridor, the bulk of this growth has occurred on transit, likely in part because of the broad land use and demographic trends outlined in the previous section, but also because the Bay Bridge has already reached maximum vehicle capacity.

As a whole, transit serving the Core has seen growth in ridership over the last 10 years that has exceeded even the most aggressive forecasts.

- **BART:** Average weekday BART ridership grew 36% between 2005 and 2015 (from approximately 310,700 passengers to 423,100). Daily exits at the stations in the Core areas of San Francisco (including Embarcadero, Montgomery, Powell, and Civic Center stations), grew 40% over the same time period. Today, two out of every three BART trips begin or end at one of those Core San Francisco stations. Peak-hour demand from transbay travel on BART now exceeds available capacity: Peak direction transbay trains during the peak period often carry more than 115 passengers per car, exceeding BART's standard maximum of 107 passengers per car.
- **SFMTA (Muni):** SFMTA's Muni is the region's most-used transit system, carrying an average of approximately 720,400 passengers per weekday in the 2013-14 fiscal year.[15] Over the last decade, ridership has grown by roughly 5.6%.[16] More recent data for the Muni Metro light rail lines, which operate in a tunnel under Market Street and on surface streets outside the Core, show that morning peak-hour ridership has grown by roughly one-third in the last five years, from approximately 6,400 in 2010 to 8,550 in 2015. Several Muni Metro lines are already at capacity traveling into the Core at peak times.
- **AC Transit:** Morning San Francisco-bound ridership on AC Transit's transbay routes grew nearly 40% between 2010 and 2015, from an average of approximately 2,000 morning peak-hour passengers to more than 2,700. On average, peak-direction transbay ridership is at 93% of seated capacity.
- **Caltrain:** Caltrain's daily ridership has soared in the last 10 years, more than doubling, from roughly 26,500 in 2005 to more than 58,000 in 2015. The San Francisco Caltrain station at 4th and King is by far the busiest station in the system, accounting for nearly one quarter of Caltrain's total boardings. The 10 highest-demand trains operated by Caltrain in each direction now have ridership exceeding 100% of seated capacity, with the very busiest trains exceeding 120% of seated capacity.
- **WETA:** The region's ferry service is operated by the Water Emergency Transportation Authority (WETA). Ridership on WETA routes grew from roughly 3,500 average weekday passengers in the 2009-10 fiscal year to more than 6,200 in 2013-14.[17] WETA's Oakland/Alameda service and its Vallejo service are roughly equally popular today, with the former serving approximately 2,400 average weekday passengers and the latter serving roughly 2,500.

Regional land use and employment forecasts strongly suggest that growth in transit ridership is likely to continue in the coming years. However, the disparity between official projections and the breakneck pace of ridership growth over the last few years has illustrated just how difficult it is to predict future ridership levels. In the transbay corridor, the region has already realized levels of travel demand that Plan Bay Area predicted for 2040, as Figure 6 shows.

Given the inherent difficulty in accurately predicting the future, the CCTS study team is looking at a range of growth projections in each

15 Metropolitan Transportation Commission (2015). "Statistical Summary of Bay Area Transit Operators: Fiscal Years 2009-10 Through 2013-14." July 2015.

16 Compares 2013-2014 ridership with 2004 Ridership as reported to the National Transit Database. http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2004/agency_profiles/9015.pdf

17 MTC (2015).

of the study corridors. In the transbay corridor, the scenarios include the following:

- **Low-Growth Scenario:** Ridership in the corridor would grow at the same rate as Plan Bay Area originally projected, 0.6% per year through 2040. In the transbay corridor, this amounts to roughly 13% growth through 2040. This scenario represents the potential that the growth rates seen over the last several years have been an aberration, and that land development will return to a much more modest pace after the next market downturn.
- **Core Capacity Transit Study Market Assessment Growth Projection:** This scenario assumes that demand will grow by roughly 1.35% per year, based on job growth rates estimated for the Core as part of the San Francisco Market Assessment completed for this study. The assessment estimated that the Core could house between 100,000 and 140,000 additional jobs by 2040, and this scenario assumes that the share of employees wishing to travel in the peak hour remains constant.
- **High-Growth Scenario:** Under this scenario, ridership would grow by an average of 2.35% per year, the rate assumed for Transportation 2035, the MTC regional plan that preceded Plan Bay Area. The 2035 plan was developed during the period of growth before the 2008 economic downturn, and thus represents a far more optimistic projection than Plan Bay Area, which was developed as the region was just climbing out of the downturn.

Figure 7 shows trend lines for these three scenarios in the transbay corridor, breaking demand out by mode and comparing total demand to the sum of potential levels of capacity on all modes in the corridor. As the figure shows, projected growth in all scenarios uses up most or all available capacity by 2040, and this assumes a number of projects that are not currently fully-funded are constructed.

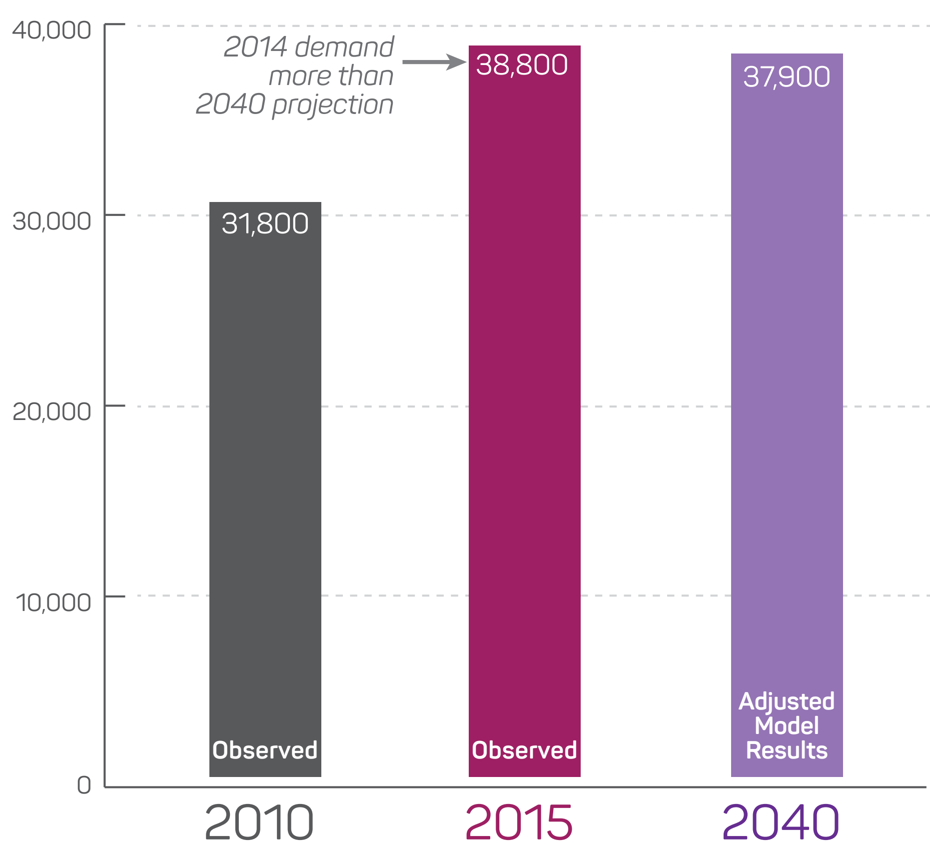


Figure 6 Transbay Corridor Travel Demand Projection Vs. Actual Growth to Date

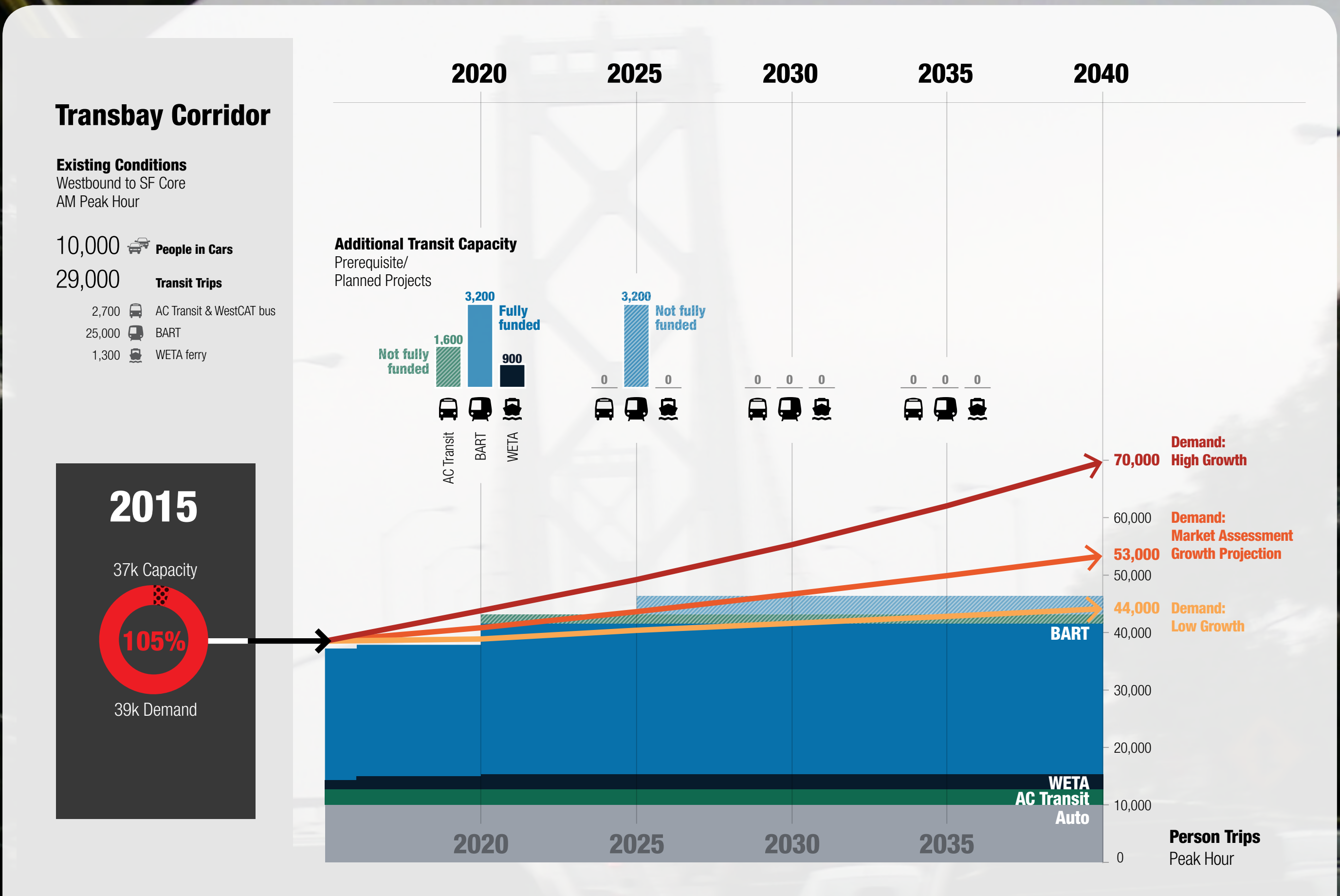


Figure 7 Transbay Corridor Capacity and Potential Growth in Travel Demand

Image: Flickr user Gohsuke Takama

TRENDS

In the San Francisco Metro corridor, the study is looking at transit capacity and demand into the Core in five corridors fanning out across the city from northwest to southeast, as shown in Figure 8.

The study is looking at growth scenarios that would result in an additional 17,000 to 20,000 additional morning-peak-hour riders spread across the five corridors by 2040.

Figure 9 shows forecast demand relative to capacity for the five Metro corridors. Some key findings by corridor are:

- The Sunset and Richmond corridors are forecast to be overcapacity in the future and the Northern Neighborhoods corridor is forecast to be nearing capacity. Planners suspect that in all three of these corridors, there is latent demand for transit, which means investments that improve travel time and reliability or add capacity are likely to attract substantial additional ridership
- The Northern Neighborhoods and Richmond corridors are currently served exclusively by bus lines. In San Francisco, buses generally deliver far less capacity on a line-by-line basis than light rail, even when buses can use transit-only lanes, transit signal priority, and other bus rapid transit treatments.
- In the Mission corridor, BART and Muni buses are projected to provide plenty of planned capacity to handle projected demand
- In the Bayshore corridor, the T-Third is projected to provide ample capacity once the increased service associated with the Central Subway comes online. Though Caltrain also provides significant capacity in the corridor, the line's limited number of stops in San Francisco mean that travelers within the City rely on Muni for trips in this corridor.

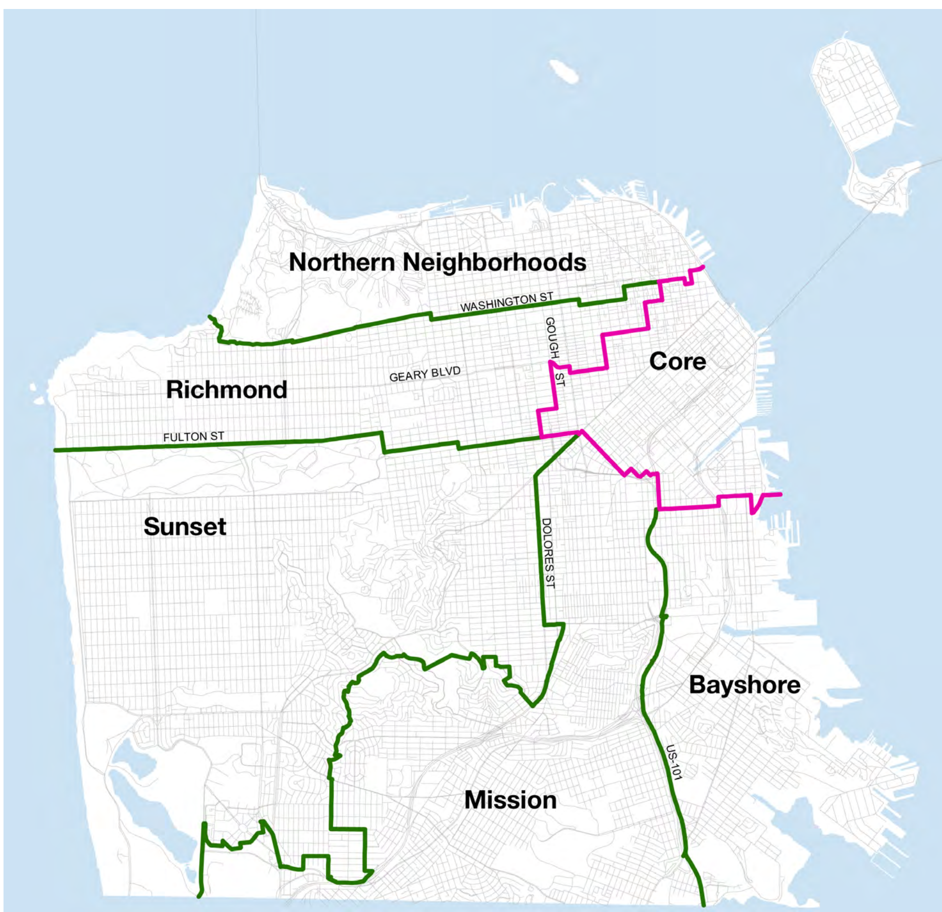


Figure 8 San Francisco Corridor Definitions

Corridor	Projected Percent of Capacity Filled (2040)
Northern Neighborhoods	90%
Richmond	112%
Sunset	131%
Mission	65%
Bayshore	58%

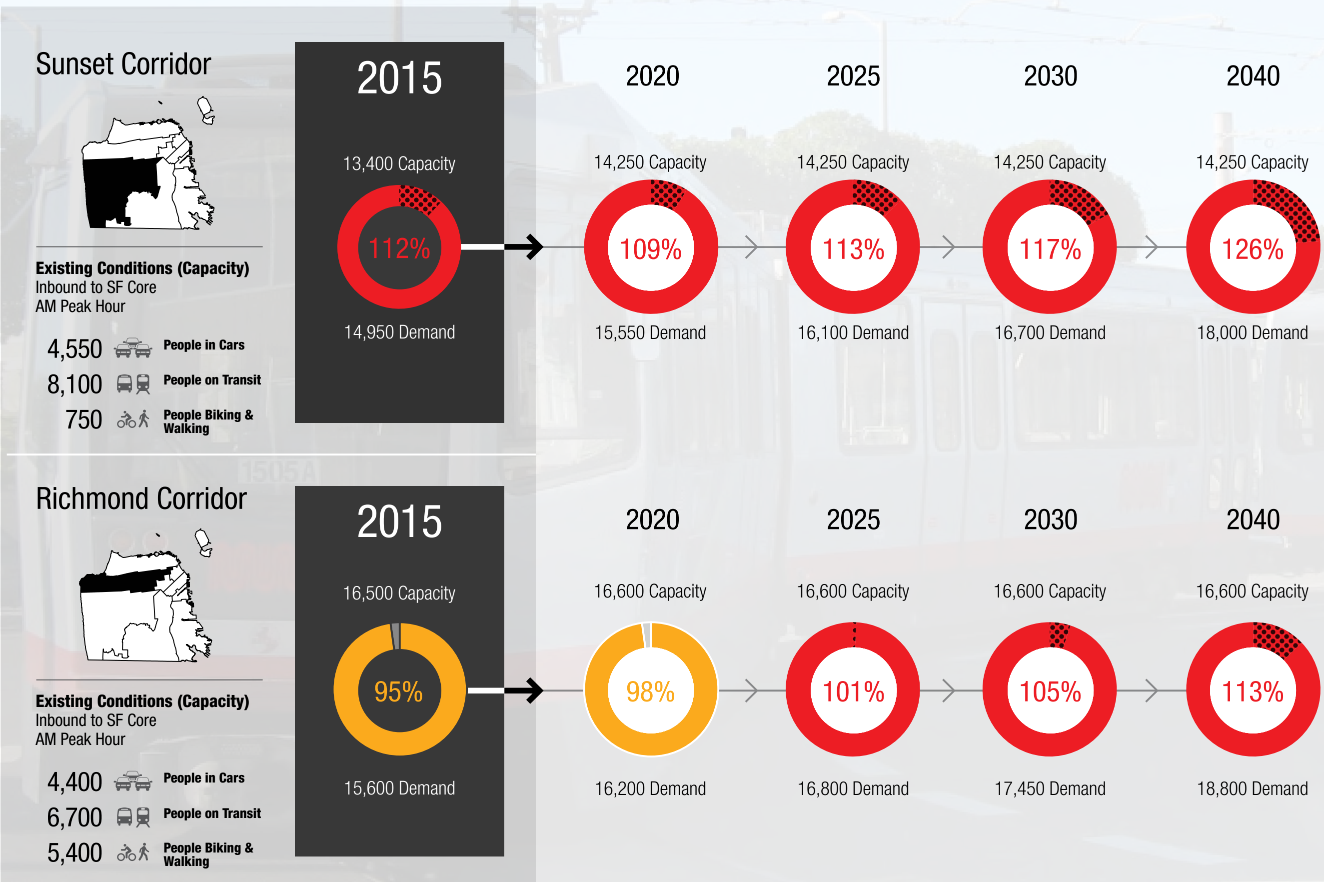


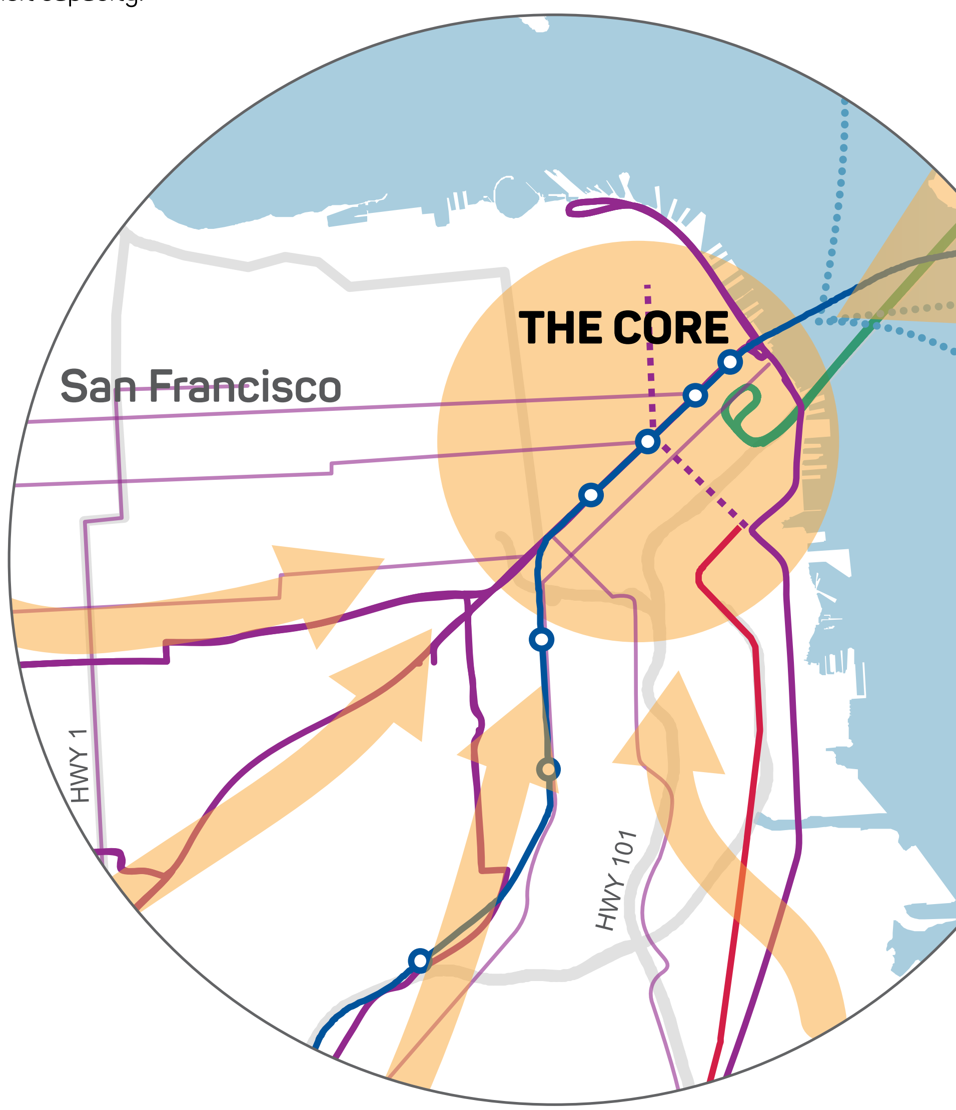
Figure 9 SF Metro Projected Peak-Hour Utilization by Corridor (2040) and 2015-2040 for Sunset and Richmond corridors

Image: Flickr user lpcmldst0128

CHALLENGES

The infrastructure and systems that carry commuters into the Core today were designed and built for the travel patterns of another era. As transit ridership has grown over the last decade, the constraints facing these systems have become clearer. The agencies that operate service in key corridors have identified infrastructure investments that would address some of these challenges, but they have yet to secure funding for many of these important projects. Even if they do, growth at recent rates would push ridership well past augmented capacity levels. The system's structural constraints could put a damper on the region's efforts to be a more livable, equitable, economically vibrant, and environmentally sensitive place.

This chapter reviews the interrelated capacity constraints each transit network faces. It will take a concerted effort by all transit operators to address the shortfall between projected future transit demand and planned transit capacity.



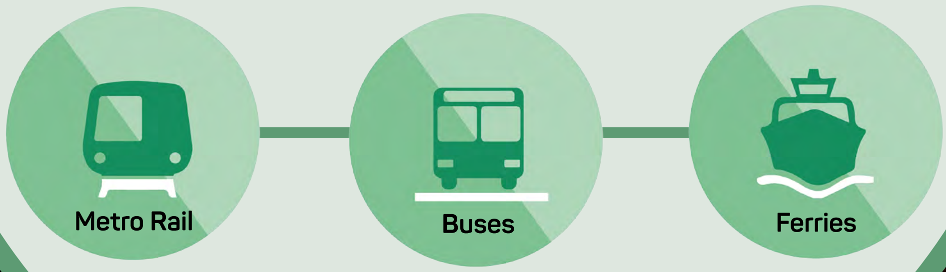
"Strategies for addressing these problems will require the combined efforts of multiple agencies."

Image: Flickr user Mike Behnken

TRANSBAY CORRIDOR

BART, AC Transit, and the WETA all provide transit capacity in the transbay corridor. While BART does and will continue to provide a large share of the capacity, AC Transit and WETA carry thousands of passengers per day across the Bay and serve as important alternatives to BART when the rail system is not operating at full capacity.

In the interest of thinking about the corridor as an integrated system, this section refers to each service by the type of technology it employs: “metro rail” for BART, “buses” for AC Transit, and “ferries” for WETA.




BART

CHALLENGES

"Two-thirds of all BART trips either begin or end on Market Street in San Francisco."

Metro Rail

METRO RAIL

Increased ridership is already placing extraordinary demands on rail service in the transbay corridor. Over the last decade, daily ridership on the whole BART system has increased 36%, outpacing official forecasts. This ridership is focused on the San Francisco Core: Two-thirds of all BART trips either begin or end on Market Street in San Francisco, and a large portion of BART riders travel westbound from the East Bay into San Francisco during the morning peak commute period, and eastbound in the evening peak commute period. Trains in the transbay corridor today exceed BART's standards for crowding during peak periods, and Embarcadero and Montgomery stations are approaching their effective capacity to process passengers.

BART projects that daily ridership will increase by 25% to nearly 500,000 by 2025 and by 50% to 600,000 by 2040. To accommodate forecast growth, BART has planned major investments, including an expanded fleet of cars, a modern train control system, an expanded maintenance facility, and upgrades to its power systems. The agency has not yet identified funding for all of these important projects, but if these upgrades are implemented, the agency will be able to run 28 10-car trains per hour per direction through the Transbay Tube (30 per hour during special events). These enhancements allow BART to transport approximately 30,000 peak-direction passengers each hour, a one-third increase over today's 23,500. This change would also improve service frequencies for BART riders.[17]

Even if BART identifies funding for these planned upgrades, BART will still lack operational flexibility in the transbay corridor once they are complete. Due to the system's original design, with branches converging for travel

17 BART Operations Planning Staff

across the Bay and through the San Francisco Core, the system will still be vulnerable to major delays when there are problems at a critical merge point just south of Downtown Oakland (called the "Oakland Wye") or in the two-track core of the system. Major challenges and opportunities are summarized in more detail in the sections that follow.

CARS

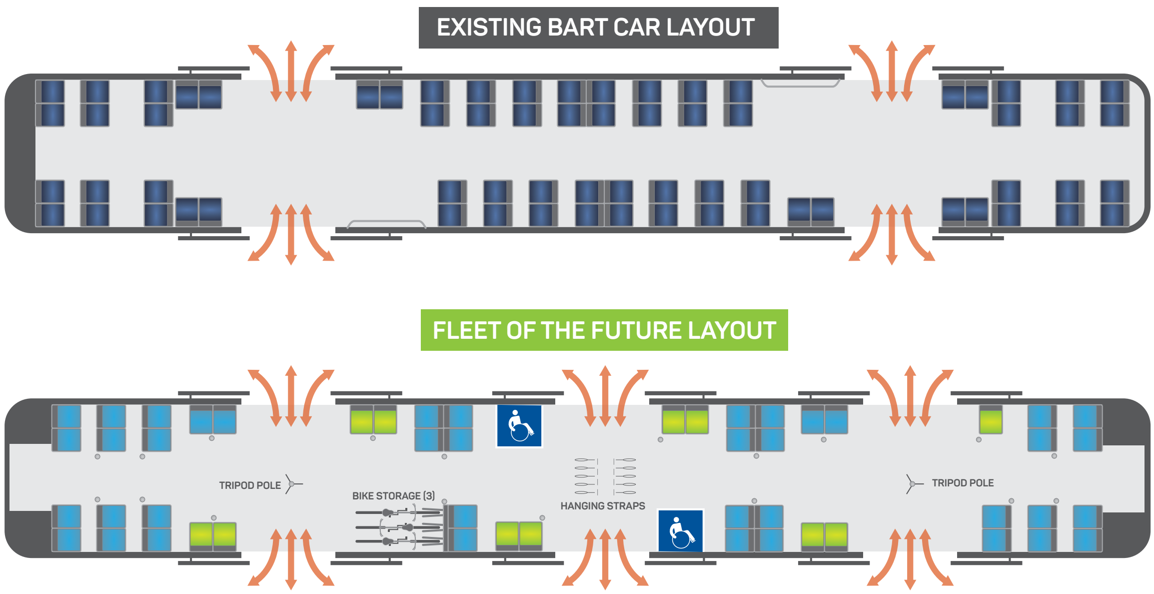
The rail system's aging vehicle fleet is one of the principal factors limiting transbay capacity. There are three major issues with the capacity of the cars:

1. **There are not enough cars in the existing fleet to serve the projected demand.** Though BART would like to run all 10-car trains through the Transbay Tube during peak commute periods, the system is limited to shorter trains on many runs due to a lack of cars.
2. **The layout of existing cars is not optimized to carry the maximum number of passengers**. The number and placement of seats within the cars limits the number of standing passengers that can be accommodated.
3. **Each existing car has just two doors**, and crowding around the doors slows boarding and alighting, increasing dwell times at individual stations, and limiting the speed at which trains can move through the Market Street portion of the system, reducing line capacity.

BART's standard for its current fleet is to accommodate 107 passengers per car. However, passenger loads today routinely exceed 115 passengers per car (5.5 square feet per standee) during the peak hour, and regularly go as high as 140 (3.75 square feet per standee) during the highest-demand parts of the peak commute period.[18] Crowding also varies by car, with central cars experiencing far more crowding than end cars.

18 BART Operations Planning staff (2015)

Figure 1 Figure 10 BART's Fleet of the Future



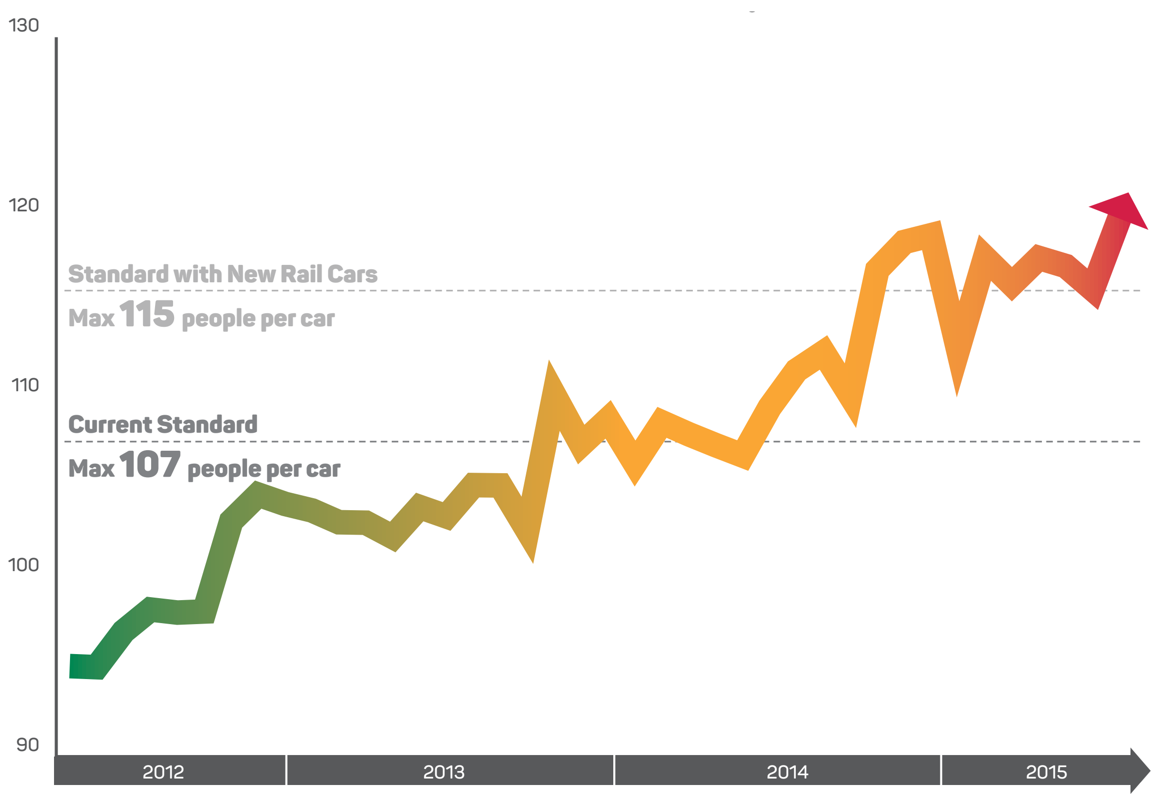


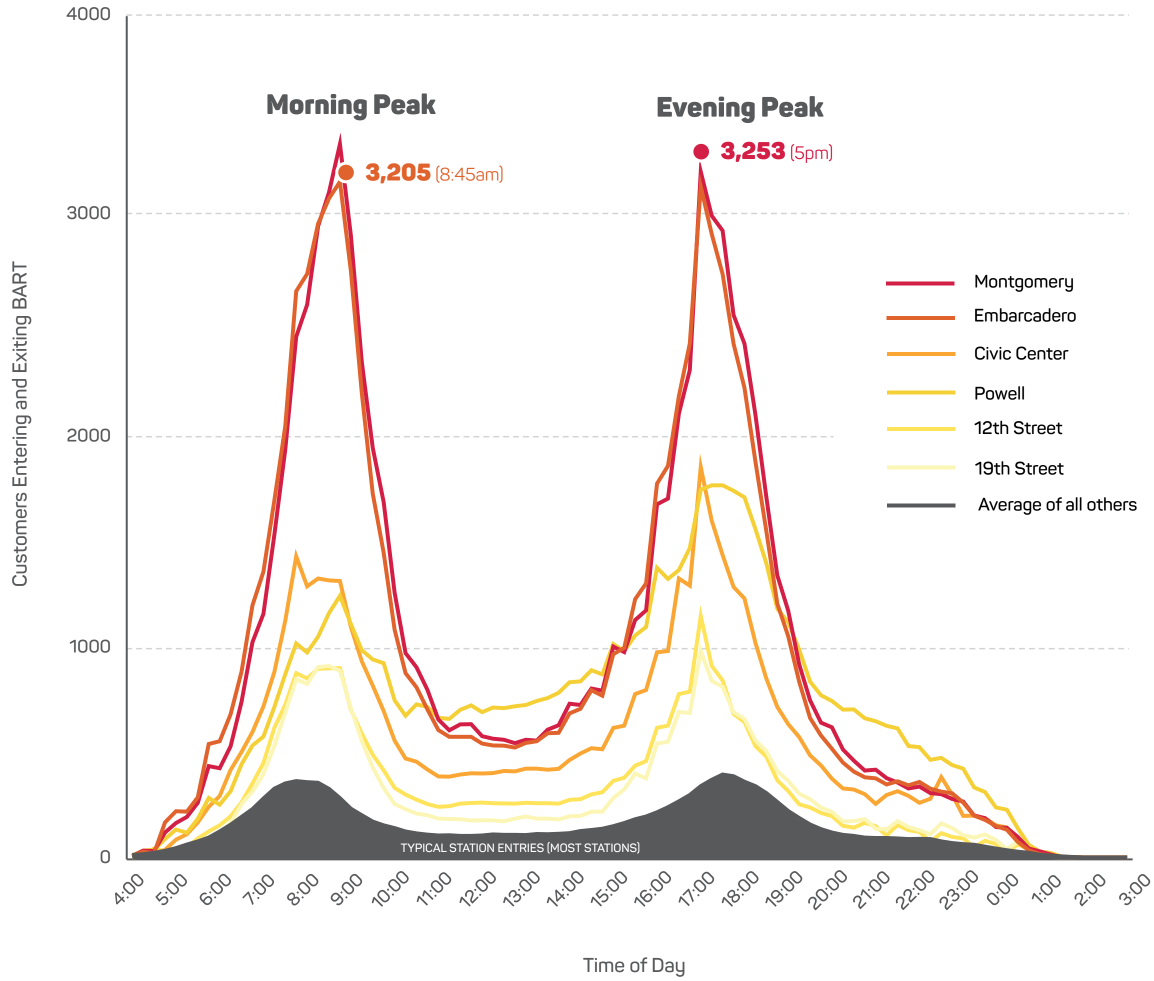
Figure 1 Figure 11 Transbay Peak Hour Passengers per Car
(AM/PM Peak Hour Average)

STATIONS

Rail system demand is concentrated in the Core: two-thirds of all BART trips either begin or end on Market Street in downtown San Francisco. Within the Core, demand centers on Montgomery and Embarcadero Stations. As shown in Figure 12, ridership at these two stations peaks sharply during the busiest part of the morning and evening peak periods, reaching levels far higher than any other station.

During these peak periods, station crowding is already a concern, particularly when service delays occur. If a train is delayed during the

Figure 1 Figure 12 Pattern of Station Use Throughout the Day
(entries and exits by time and station, per 15-minute period)



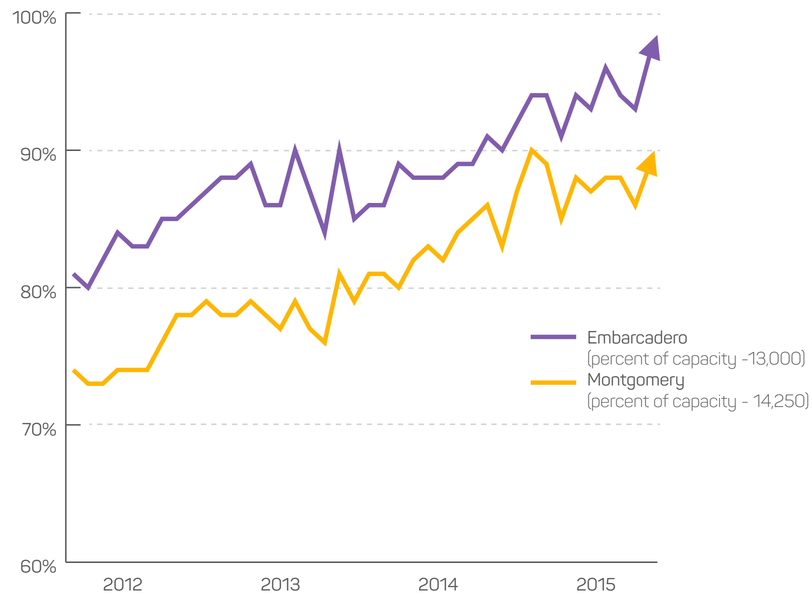


Figure 1 Figure 13 Embarcadero and Montgomery Peak Hour AM Exits as a Percent of Station Capacity

(Average Weekday, Excluding Friday)

Metro Rail

CHALLENGES

peak commute period, a larger-than-normal number of passengers are left waiting on the platform. In the worst cases, crowds of waiting passengers can slow passengers trying to exit trains, and crowded cars delay passengers trying to board trains, further increasing delays. A single delayed train can cause ripple effects throughout the system, as that train will be late to all future stops, and trains behind it can stack up. Queuing can also be an issue, albeit with fewer ripple effects on train service, on the concourses, and at fare gates.

BART stations must be capable of safely and effectively processing passengers during normal operations and also during train delays. As ridership at these stations continues to increase, the ability to process passengers will require modifications to the stations to allow larger numbers of passengers to move from the platforms to the street level.

BART has completed an extensive study of how the Embarcadero and Montgomery stations could be retrofitted to accommodate anticipated peak-hour crowds at the two stations.

However, the design of the underground stations make platform expansion complex and extremely expensive, and no major changes to Montgomery or Embarcadero stations are planned at this time. In the future, it may be possible to add a small amount of station capacity by reconfiguring existing stairwells, adding additional stairways, or installing platform screen doors.[19]

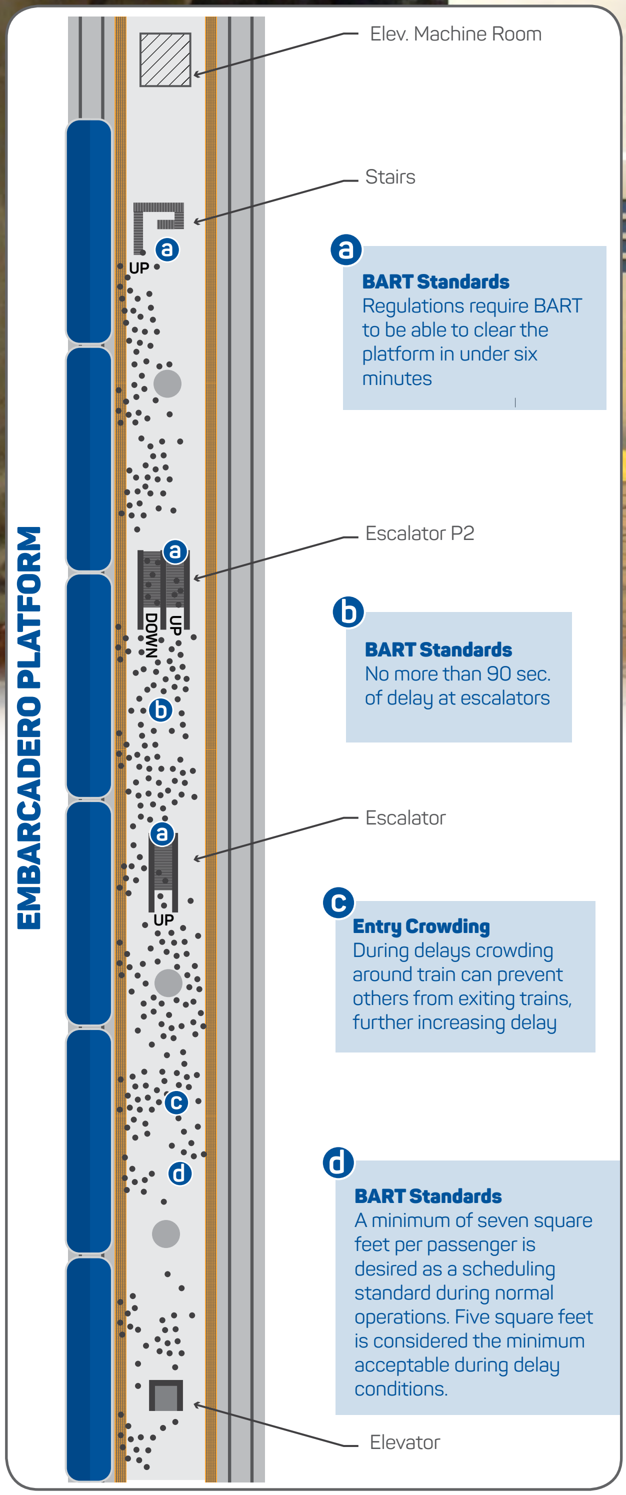


Figure 1 Figure 14 Embarcadero Station

19 BART/SVRT Core Stations Modifications Study(2010)

SYSTEM DESIGN

All metro rail service between the East Bay and the San Francisco Core uses the Transbay Tube under the San Francisco Bay. There are three major capacity limitations inherent in this design:

1 OAKLAND WYE MERGE POINT

When traveling westbound, all metro rail lines converge at a point just east of West Oakland Station, at a complex multi-level merge point known as the Oakland Wye. This is an extremely vulnerable point in the network, as any delay to one train at or near the Wye impacts several other trains, sending ripples of delay though the entire metro rail system.

The Oakland Wye interlocking (the system that ensures safe train movements through track junctions) contains speed restrictions that slow operations and make it difficult for trains to merge precisely into their tightly scheduled "slots" in the Transbay Tube. These restrictions were programmed into BART's original train-control system to ensure that trains operate safely through the Wye's relatively tight curves. Modifications to the train-control system may enable trains to pass through the curves at slightly higher speeds.

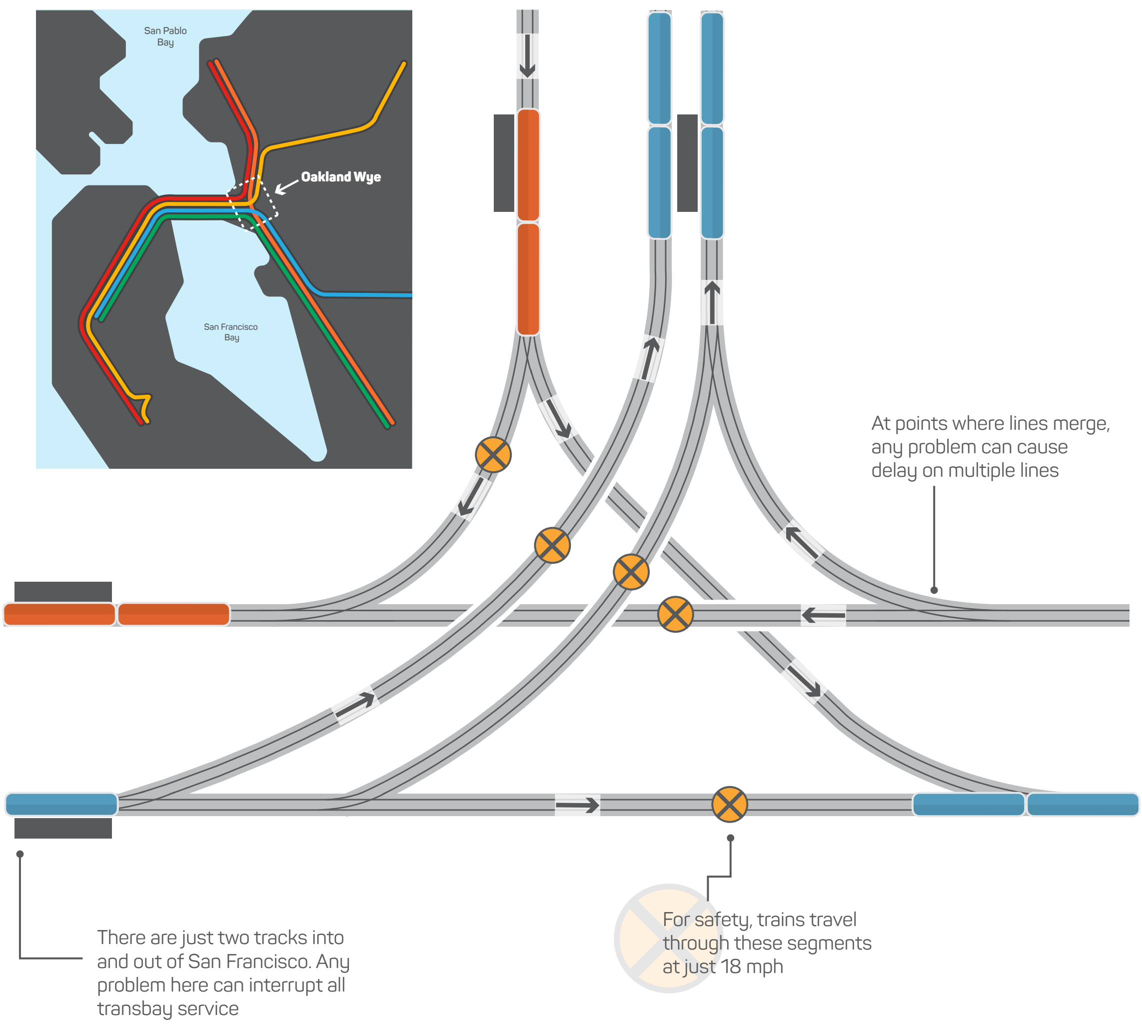


Figure 1 Figure 15 Capacity Constraints in the

2 TRAIN CONTROL AND TRACTION POWER

To prevent collisions, trains must maintain a minimum following distance when running through the Transbay Tube. To accomplish this goal, the existing train control signal system divides the metro rail system into fixed "blocks," allowing just one train at a time (plus a small buffer behind each train) to operate inside each block at any given time. This system can safely manage approximately one train every 2.5 minutes, allowing a maximum of 24 peak-hour trains in each direction.

Limits on the existing traction power system also restrict the number of trains that can operate through the Transbay Tube and elsewhere in the system.

3 SYSTEM REDUNDANCY

The Transbay Tube, which has just one track in each direction, is the only rail corridor between San Francisco and the East Bay. The lack of redundancy presents a number of challenges for the regional transportation system.

The transit system is vulnerable to catastrophic delay in the case of mechanical failure or another problem in or near the Transbay Tube. A disabled train or a track maintenance issue can shut down service in one direction or require a single-track operation, creating delays that cascade through the metro rail system. Transbay bus service and ferries can only replace a small share of this capacity in an emergency. As shown in Figure 16, a major incident such as the 2012 building fire near West Oakland Station can affect not only metro rail service but also traffic throughout the region.[20] In addition, no alternate transit corridor is available when planned Tube maintenance is required. During summer 2015, scheduled track maintenance in the Tube required shutting down all transbay rail service for two weekends.

20 MTC 511 traffic data, June 8, 2012

Metro Rail

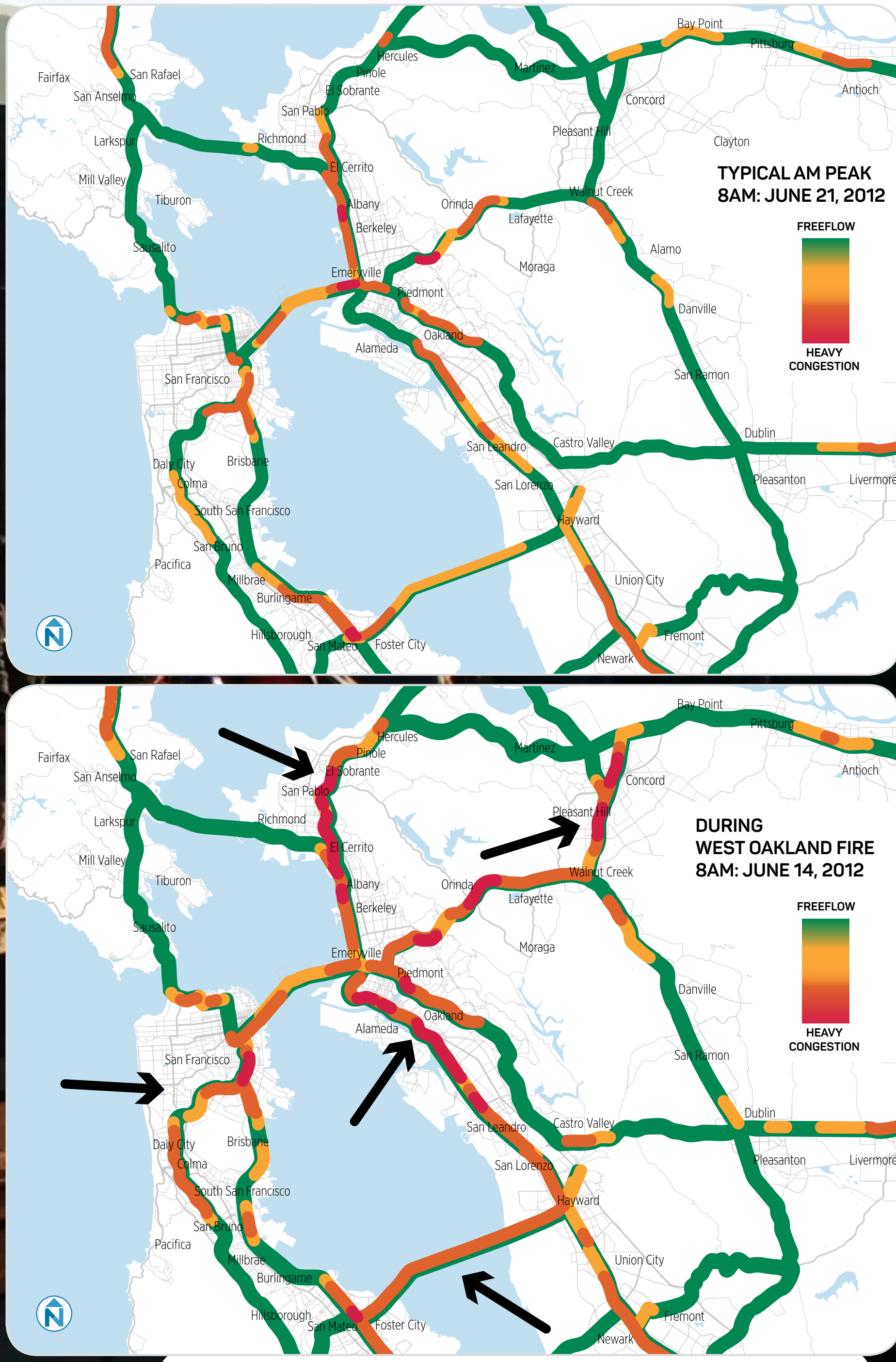


Figure 1 Figure 16 Traffic Impacts During West

Metro Rail

Image: Flickr user Eric Fischer

Metro Rail

PLANNED IMPROVEMENTS

BART has completed a variety of studies on the challenges facing the system, and it has created plans to address a number of the rail-car, station-access, and system design issues outlined in this chapter.

Rail Cars

BART is taking steps to address the issues with its rail cars. Through its Fleet of the Future program, BART has identified the need to replace the existing fleet of 669 cars and expand it to 1,081 cars. The first 850 new cars are funded, and will be phased into operation beginning between 2017 and 2021. BART also has plans to reconfigure and expand its Hayward Maintenance Complex so that it has enough capacity to serve the larger fleet.

The new cars will have reconfigured seating and more space around the doors to more easily accommodate passenger circulation in crowded conditions and accommodate more standing passengers. The cars will also feature three doors per side, allowing for faster boarding.

Despite these planned investments, major limitations remain. Full funding for the remaining 231 cars has not yet been identified. Similarly, funding for the expansion of the Hayward Maintenance Complex has not yet been identified. The fleet cannot increase without an expansion in maintenance capacity.

Train Control and Traction Power

BART now has a project underway to modernize its train-control system. Instead of "fixed blocks," the new signal system will use "moving blocks" that optimize throughput (trains per hour) even where speeds are slow. Moving blocks continuously adjust the distance between trains, while allowing trains to get as close as safety will allow. This means that trains run closer together in slower areas, such as near stations, and farther apart in faster areas, such as between stations. The new system will be able to provide more reliable service while allowing up to 30 trains per hour through the Transbay Tube. Full funding for the new train control system has not yet been fully identified.

BART has already begun implementing upgrades to its traction power system. For example, a new transmission cable is being constructed between West Oakland and Embarcadero as part of the Earthquake Safety Project. However, the agency has not yet identified full funding to make all needed power-system upgrades.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AC TRANSIT

Buses

CHALLENGES

BUSES

AC Transit currently operates 30 routes across the Bay Bridge, providing capacity for just fewer than 3,000 riders from the East Bay into San Francisco during the morning peak hour. Transbay bus services have seen increased demand as metro rail and ferry services have neared capacity during peak periods. In addition to augmenting transbay capacity, buses increase the transit system coverage, serving parts of the Bay that do not have easy access to a rail station. Transbay bus service can be a major contributor to accommodating future demand in the transbay corridor, especially in the next 10 to 15 years.

This section provides more detail on the challenges constraining transbay bus capacity today, and the opportunities to carry more passengers on this mode in the future.

TERMINAL CAPACITY

A major limit on transbay bus service today is San Francisco terminal capacity (room at the end of the line to let passengers off, then wait a few minutes for passengers traveling in the other direction to board). The existing Temporary Transbay Terminal has 17 bays (bus parking slots) for passenger loading and unloading. The capacity of the terminal limits how much bus service can be provided across the Bay Bridge.

However, with the opening of the Transbay Transit Center in 2017, terminal capacity in San Francisco will increase significantly. The Transit Center will provide a total of 50 bus bays, of which 30 will be dedicated to transbay bus service. That will be more than enough room to accommodate the number of peak-hour buses AC Transit is currently planning to run to the new terminal. Those buses would have space for as many as 7,300 peak-hour riders in the peak direction,[21] and the new terminal will have enough room to accommodate service levels that would bring nearly 2.5 times that many riders. Regardless, the new terminal will enable bus service to be a major contributor to serving future demand in the transbay corridor, if buses can provide competitive travel times and reliability.

If AC Transit is able to purchase the number of buses necessary to provide capacity at this scale, space for bus storage and maintenance on the East Bay side of the system will become a much more urgent priority. Current facilities will hit capacity limits with a relatively marginal growth in the size of the fleet.

BAY BRIDGE APPROACHES

Today, transbay buses face traffic delay on both the east and west sides of the Bay Bridge.

On the east side of the bridge, transbay buses face delay when approaching the Bay Bridge toll plaza. I-80, I-880, and I-580 all converge at this point, creating a complicated set of intersecting highway lanes that buses must safely navigate and merge through to gain access to the bridge. Though high-occupancy vehicle (HOV) lanes help some buses move faster than general traffic on freeway approaches equipped with the lanes, they end at the toll plaza, requiring buses to merge with general traffic for the journey across the bridge. When traffic is particularly heavy, queues can back up past the start of HOV lanes, delaying bus access. If more drivers try to use the Bay Bridge in the future, what manifests itself today as occasional heavy queues could become the daily norm,

21 Arup (2015). "Transbay Corridor Current and Planned Transit Capacity and Demand." Memorandum, July 30, 2015.

and transbay bus speed and reliability would degrade considerably. No current plans are in place to remedy these challenges.

Transbay buses also face delay on the west side of the bridge, where they encounter significant peak period delay on San Francisco city streets traveling both to and from the bridge. With the opening of the Transbay Transit Center in 2017, new access ramps will allow transbay buses to move directly from the Bay Bridge to the terminal. The expected travel time savings could make bus service more competitive for riders and allow for more frequent service.

BAY BRIDGE SPAN CONGESTION

Once on the bridge, buses share lanes with truck and automobile traffic, and are subject to the impacts and delays of operating in mixed traffic across such a congested corridor.

Caltrans manages westbound Bay Bridge traffic using metering lights just west of the bridge toll plaza. This system is designed to limit throughput to the free-flow capacity of the span, moving any backup to the toll plaza approach. Buses use HOV lanes that bypass these bridge approach queues, and therefore should not face traffic delay at the bridge when the system works as designed. However, in practice, metering lights are not always perfectly timed for present conditions, and traffic delay does occur on the span, limiting bus speeds.

The Bay Bridge's stated operating speed limit is 50 miles per hour, but morning and evening peak congestion can reduce speeds consider-

> "Congestion slows crossing speeds and reduces reliability."

Buses

CHALLENGES

ably, to below 30 miles per hour.[22] Transbay buses are caught in the same congestion, which slows crossing speeds and reduces reliability when travel speeds are reduced.

22 Alameda County Transportation Commission. "2014 LOS Monitoring Study."

BUS CONFIGURATION

The total number and capacity of the buses that are currently used in the corridor is another potential constraint on system capacity as transbay demand grows.

Older 57-seat MCI coaches on certain routes were recently replaced with new 36-seat Gillig coaches, though the agency does not have any additional smaller buses on order. The smaller vehicles were selected because they have a newer, more efficient design that is more comfortable for passengers and more ADA accessible.[23] The remaining MCI coaches will be replaced with higher capacity models. AC Transit is also in the process of growing its fleet of buses overall using funds from Alameda CTC.

The agency is also currently testing the potential of double-decker buses for a variety of routes, including those that are most crowded running across the Bay. These buses can carry as many as 80 passengers each, and could add significant capacity on transbay routes.

> "AC Transit may quickly run into space limitations on its new, smaller vehicles."

23 AC Transit (2015). "Transbay Service FAQs," www.actransit.org.


RESTRICTED AREA
ENCINAL

FERRIES

Ferries currently make connections between four ferry terminals on each side of the San Francisco Bay, with service reaching Oakland, Alameda, and Vallejo in the East Bay.[24] The San Francisco Ferry Terminal is the main hub on the west side of the Bay, providing direct service to the San Francisco Core. The Water Emergency Transportation Authority (WETA) operates the East Bay routes and is a passenger-only ferry service.

Ferries have become increasingly popular in the past few years, with ridership between the East Bay and Peninsula terminals growing from around 1.5 million passengers in 2012 to more than 2.1 million in 2015.[25] Daily boardings on individual routes have also grown markedly in recent years, reaching peak ridership levels in the middle of the summer. The Alameda/Oakland route's summer ridership has grown from just over 2,000 passengers per day in 2012 to approximately 3,750 in the summer of 2015. In the same period, Vallejo ridership has more than tripled to nearly 3,300; Harbor Bay ridership has grown from less than 1,000 to more than 1,200. WETA survey data show that 41% of ferry passengers would drive alone if they could not take the ferry, and an additional 50% would take BART.[26]

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24 North Bay ferry service is outside the scope of this study.
25 San Francisco Bay Area Water Emergency Transportation Authority 2016 Short Range Transit Plan
26 Connolly, Kevin (2015). "Water Emergency Transportation Authority." Presentation to the SPUR Transportation Policy Board, August 2015.

Ferries

CHALLENGES

SCALE OF SERVICE

As of 2015, East Bay WETA ferry routes provided space for just over 1,300 commuters in the peak direction during the morning peak hour. That amounts to approximately 4% of the total capacity in the transbay corridor. Peak-hour ridership is estimated at just under 1,300 riders, or approximately 3% of total estimated ridership in the corridor.

WETA plans to vastly expand capacity in the future, adding several new routes, replacing the current fleet with larger vessels, and increasing frequencies on existing routes. Expansion routes would connect Richmond, Berkeley, and Treasure Island terminals to downtown San Francisco and an additional terminal at Mission Bay within the next 10 years. Berkeley and Richmond routes are envisioned as commute-only services, which would operate in the peak direction during peak periods. Treasure Island service would run every 50 minutes or more frequently.

WETA currently owns 12 vessels and contracts with a third party for two additional vessels. The agency plans to replace its current fleet with larger vessels in the near future.[27]

Overall, WETA service levels would increase from five peak-hour trips in 2015 to 15 peak-direction vessels by 2040.[28] This would mean a nearly three-fold increase in peak-hour ferry capacity, making room for more than 4,000 peak-hour passengers in each direction, or more than 11% of total capacity in the corridor.

27 Connolly, Kevin (2015).
28 Arup (2015).

CONNECTIVITY

Ferries offer commuters a high-quality commuting experience, with majestic views and on-board refreshments, among other amenities. As a result, they are able to attract choice riders (those with the option to drive). However, constraints on land-side connectivity mean that ferries are only convenient to a small share of the total commute market, which may limit the ability of this mode to attract a significantly larger share of the transbay commute market as demand grows.

Ferry terminals are located on the waterfront, alongside which the Bay Area's land use patterns limit the number of places with both available space for a terminal and sufficient density to support frequent ferry service. However, that is slated to change, with major development planned for waterfront areas like Mission Bay, Hunters Point, Candlestick Point, and Treasure Island in San Francisco and Brooklyn Basin, Alameda Point, Alameda Estuary, and Richmond in the East Bay. As density grows along the waterfront, ferry service could become an increasingly important commute option for these areas, which are not directly served by BART or other high-capacity transit modes. Additionally, as bicycle infrastructure becomes more abundant throughout the Bay Area, bicycle commuters could take increasing advantage of transbay ferry service, which can accommodate 30 to 60 bicycles per vessel.[29]

Commuters that do not live close to a ferry terminal or commute by bicycle face a longer and often more complicated connection on

29 San Francisco Bay Area Water Emergency Transportation Authority 2016 Short Range Transit Plan

"WETA currently lacks extra vessels to support potential new ferry service routes."

either side of the journey. To be effective, ferry terminals need strong connecting transit service or large amounts of parking on one end. Bayland environmental constraints limit opportunities for parking expansion.

ROLE OF FERRY SERVICE

Despite their limitations, ferries play an important role in transbay mobility. Whether passengers prefer the ferry for its spaciousness, bicycle parking, breathtaking views of the surrounding landscape, direct access to waterfront locations, or reliability in the case of a Bay Bridge or transbay tube breakdown, ferries provide an essential and increasingly important service for transbay commuters. The increasing importance of ferry service is due to the nature of water transportation. Because there is very little commuter traffic in the Bay and because ferries are not confined to a single right-of-way, expanding service will not lead to increased transbay congestion as it would for other modes. Ferries also fulfill an important emergency response role in the corridor. WETA was, in part, founded for this purpose, and the agency estimates that with its current fleet, it could evacuate more than 100,000 people within 48 hours.

Image: Flickr user Austin Cross

Light Rail

Buses

SAN FRANCISCO – LIGHT RAIL AND BUS

San Francisco's light rail and bus systems together carry more than 40% of the Bay Area's daily transit riders, including hundreds of thousands of people traveling into the San Francisco Core. A variety of interconnected issues limit the system's capacity, leading to overloaded trains and buses into the Core during commute hours.

These networks' capacity constraints fall in three main areas.

- **System design issues:** Aspects of the system's configuration lead to delays. These complicating design features include the way trains must transition between surface streets and underground tunnels, the limited number of parallel tracks for parking or passing other trains, and the way trains must turn around on the eastern end of the Muni Metro subway.
- **Surface reliability:** Buses and trains running in mixed traffic on San Francisco streets are delayed by the same congestion as cars and other vehicles.
- **Fleet management and safety:** Several issues prevent the use of trains longer than two cars. These include an insufficient number of cars in the fleet, short distances between intersections on City streets, and other issues.

SFMTA is already tackling some of these issues through Muni Forward, recent vehicle purchases, and regular efforts to incrementally improve operations.

SYSTEM DESIGN

The design of the Muni Metro system traces back to two very different eras of rail investment in San Francisco. Track was laid on the surface portions of the lines in the late 1800s and early 1900s, when streetcars were among the most advanced urban mobility technologies available. This period was before the proliferation of automobiles. As such, there was less competition for street space and, in turn, fewer potential sources of delay for trains. San Francisco's network was built in part to provide access to newly developing communities on the City's west side, and stops were made frequent to provide many of the new residents front-door access to their homes.

The portion of the Muni Metro Tunnel between Embarcadero station and just west of Castro station was built in the 1970s. By this time, cars were the dominant mode of transportation. With people living further and further away from traditional downtowns, planners felt they needed to prioritize making transit as fast and efficient as possible to ensure it would be a viable alternative to the private automobile. The Muni Metro Tunnel was constructed as part of the build-out of the BART system, and it made light rail travel along Market Street much quicker and more reliable by pulling trains off the surface and into their own right-of-way, where they could operate unencumbered by other vehicles and traffic lights.

The challenges facing the Muni Metro system today are an outgrowth of the very different realities and motivations of rail planners in these two eras. Today, there are many more competing demands on the City's streets than there were 100 years ago. Unpredictable delays, slower speeds, and inconsistent travel times throughout the surface portions of the light rail system attest to this evolution, and these factors make it exceedingly difficult to take full advantage of the modern segment of the network, through the San Francisco Core. Distances between stops that are far shorter than those typically associated with high quality rail transit further undermine the service.

The most modern parts of the system are also limited in a critical way. Designed with only two sets of tracks, the tunnel lacks space for trains to pass other trains or for operators to get disabled trains out of the way of those still carrying passengers. This exacerbates delays that might otherwise be quite minor.

Other aspects of the light rail system's design limit the number of trains that can be run through the system in a given hour, and other design issues create a similar problem for buses.

Portals

The light rail system's train control system automates the operation of trains underground and optimizes spacing between trains to prevent collisions. Given the complex nature of operations above ground, train crews must be in control when trains are at street level in order to respond to the unpredictable actions of private vehicles, cyclists, and pedestrians.

Trains enter the subway at West Portal, Duboce Portal (near Duboce and Market streets), and just southeast of Embarcadero station. At each of these points, trains typically stop briefly to transition into or out of automated operation. The transition time can notably increase operating times, particularly in the inbound direction. From time to time, trains are unable to communicate with the tunnel's automatic train control system. When this happens, the train that failed to connect to the system enters the subway under manual control and must run much more slowly than it would if managed automatically. This in turn slows every train behind it.

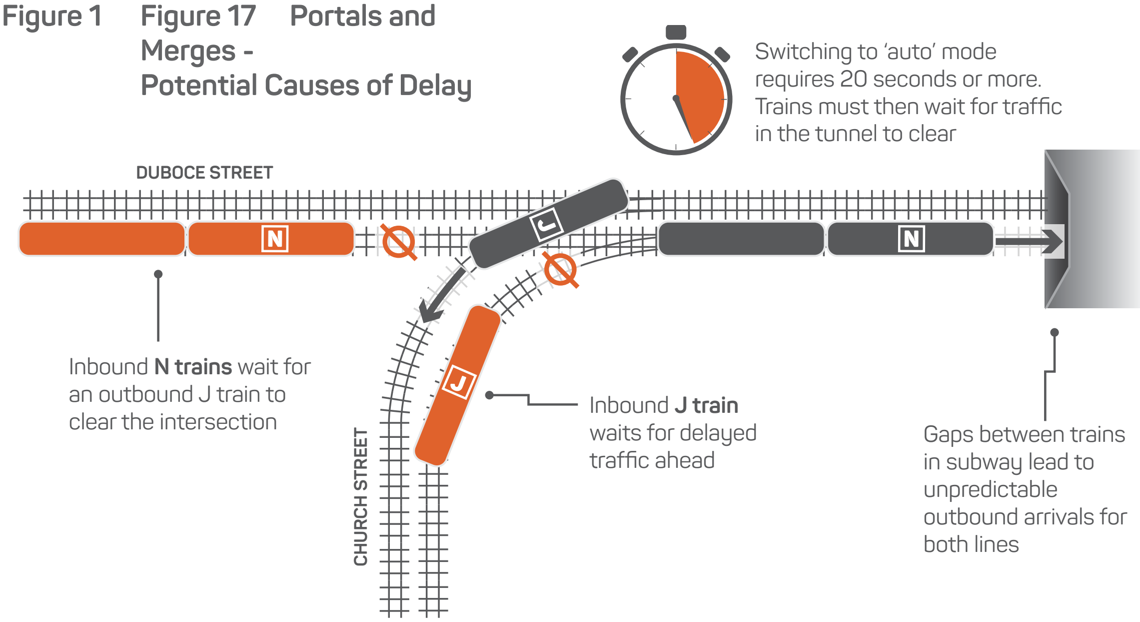
West Portal station is a particularly complex transition point. Three lines converge at the intersection of Ulloa Street and West Portal Avenue, which is controlled only by stop signs and experiences high pedestrian volumes and erratic driver behavior. Factors that can delay trains include unpredictable movements by all users of the intersection, unpredictable train arrival times, the need to switch into and out of automatic operation when entering or exiting the subway, and the need to stop twice before fully leaving the station in the outbound direction (once to open and close train doors, and once to wait for the intersection to clear and a directional switch in the intersection to align). Because so many lines travel through the portal, any delays have ripple effects throughout the system.

Merges

San Francisco's light rail lines converge at six different points in the system, several near the portals. In the eastbound direction, merge points include St. Francis Circle (K and M), West Portal (K/M and L), Church and Duboce streets (J and N), Van Ness station (K/L/M and J/N). In the westbound direction, merge points include 4th and King streets (N and KT) and Embarcadero station (N/KT and J/L/M).

As noted previously, the train control system maintains a buffer between trains to ensure that they have enough time and distance to stop safely if they need to do so unexpectedly. Though system operators set the schedule to minimize simultaneous arrivals, the variability in above-ground operating conditions makes it difficult to avoid them in practice. When two trains arrive at a point where lines converge at

Figure 1 Figure 17 Portals and Merges - Potential Causes of Delay



the same time, one of the two trains must wait to allow the appropriate buffer in the subway, exacerbating any delays that caused trains to go off schedule in the first place. Likewise, when gaps between trains are longer than planned because of surface delays, the gaps that start above ground persist in the subway. This reduces the number of trains that can run through the subway in a given hour and, in turn, directly reduces overall passenger capacity.

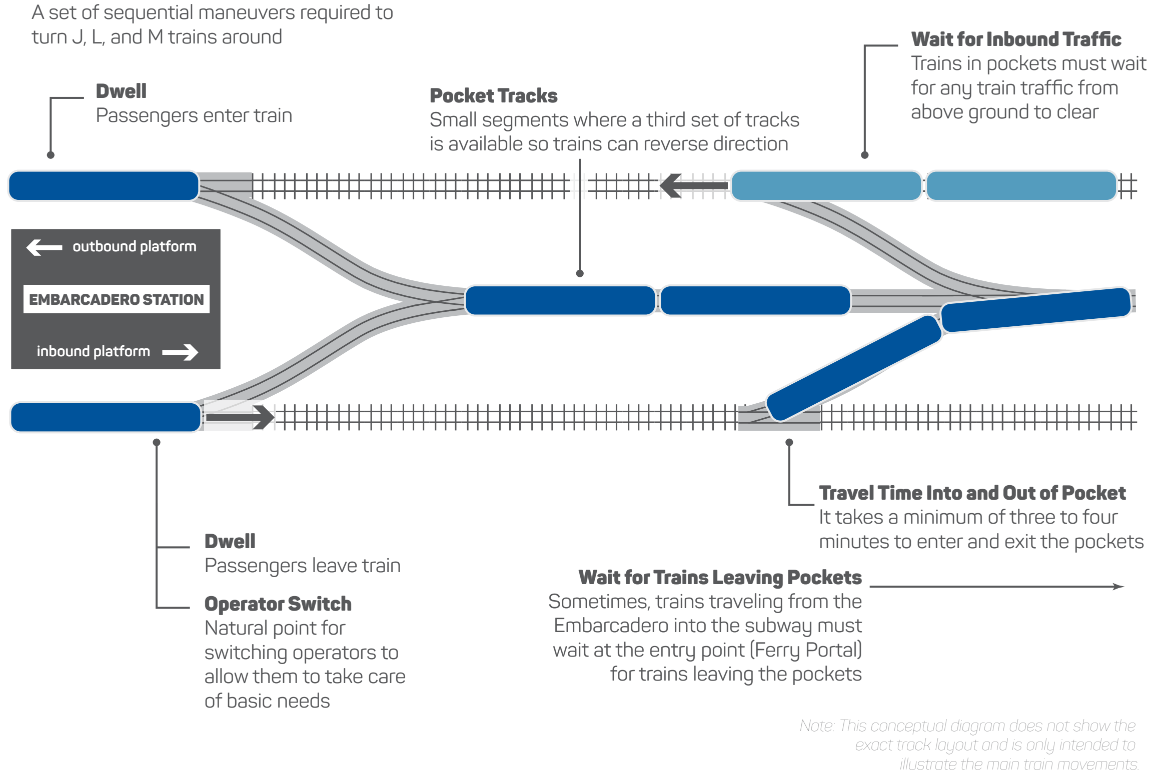
Embarcadero Turnback

Three light rail lines terminate at Embarcadero station: the J, L, and M. Trains that terminate at Embarcadero station must turn using short track segments that fork off the main tracks, called turnback pockets. To do so, trains must complete a sequence of steps, each requiring anywhere from 30 seconds to several minutes, using the pocket tracks beyond the station (illustrated in Figure 18). There are two pocket tracks in this location, one long enough for two-car trains and the other long enough for four-car trains (though SFMTA currently does not run any trains that long). As the figure shows, the two turnback pockets are located just east of the station, between the two sets of mainline tracks, with one turnback located nearer to the station than the other.

It takes trains approximately five minutes to complete the maneuvers required to turn around. Given that there are two pockets, a total of 24 trains could theoretically make the turn in a peak hour, though only 22 are scheduled to do so. Any delays in other parts of the system reduce the chances that trains will arrive at the turnaround at optimal times. When trains arrive at Embarcadero station in bunches or when there are long gaps between trains, some must wait for others to complete the turnaround before they can begin the turnaround themselves. This also adds

Figure 1 Figure 18 Steps Required at Embarcadero

A set of sequential maneuvers required to turn J, L, and M trains around



delays for trains coming into the subway from the Embarcadero.

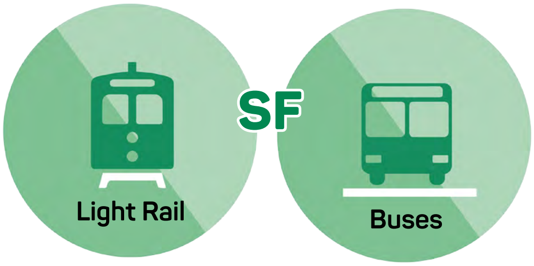
Once the Central Subway opens, SFMTA will need to find a place to turn around K-Ingleside trains as well (the K and T currently interline, with T-Third trains turning into K-Ingleside trains when traveling westbound in the subway, and vice versa in the opposite direction). Given that the J, L, and M currently take up almost all scheduled capacity in the Embarcadero turnback, turning K trains could require route changes, schedule adjustments, or a new set of pocket tracks. SFMTA has explored creating a set of pocket tracks along the Embarcadero, near Harrison Street.

There are only a few places in the rest of the system in which trains can turn around or pull off the two sets of main tracks. This means that when trains must be removed from service because of maintenance issues, it is difficult to get them out of the way of other train traffic, which can in turn create severe delays. Additional strategically placed pocket tracks could also make it easier to offer more regular shuttle service in the subway, where ridership is greatest.

Market Street

San Francisco's local bus system centers on Market Street, where lines coming from all over the city converge for the final portions of routes to the Ferry Building or Transbay Terminal. The street often sees five or more buses per minute in peak periods. The density of buses means that operations on Market Street can be notably slower than in other parts of the system. Buses are often delayed behind platoons of bicycles, and high volumes of pedestrians and vehicles crossing Market Street at intersections demand significant green time in each cycle of signal phases, which means less green time for vehicles traveling along Market Street. One advantage buses on the surface of Market Street have over trains underground is the ability to steer clear of delayed buses or other vehicles. As noted earlier, trains cannot pass those that are delayed because the subway has only two sets of tracks.

The Better Market Street project is a multi-agency effort to decide how to most efficiently redistribute Market Street's right of way, in close consultation with community stakeholders. The effort has considered a variety of ways



of prioritizing transit traffic along the street, which carries numerous bus lines and SFMTA's historic streetcar. The short segment of Market Street on which the 38-Geary line runs is a particularly important segment, given the large number of buses per hour scheduled along the corridor. The project is currently going through environmental review, and changes to the corridor will likely be implemented shortly after that process is complete.

SURFACE RELIABILITY AND STREET DESIGN

When they are not traveling in one of San Francisco's limited number of transit-only lanes, buses and light rail trains are delayed by congestion, just like any other vehicle on the city's crowded streets. Such delays affect trains more than they affect cars because it takes much longer for trains to safely and comfortably accelerate and decelerate, and trains cannot navigate around blockages like double parked vehicles. Delays affect passengers both onboard and downstream as they cascade along an entire route and, often, lead to slower and more crowded conditions. Lengthy delays can also cause a delayed vehicle to run late on all of its scheduled trips later in the day.

Delays on city streets are caused by a few main issues, shown in Figure 19.

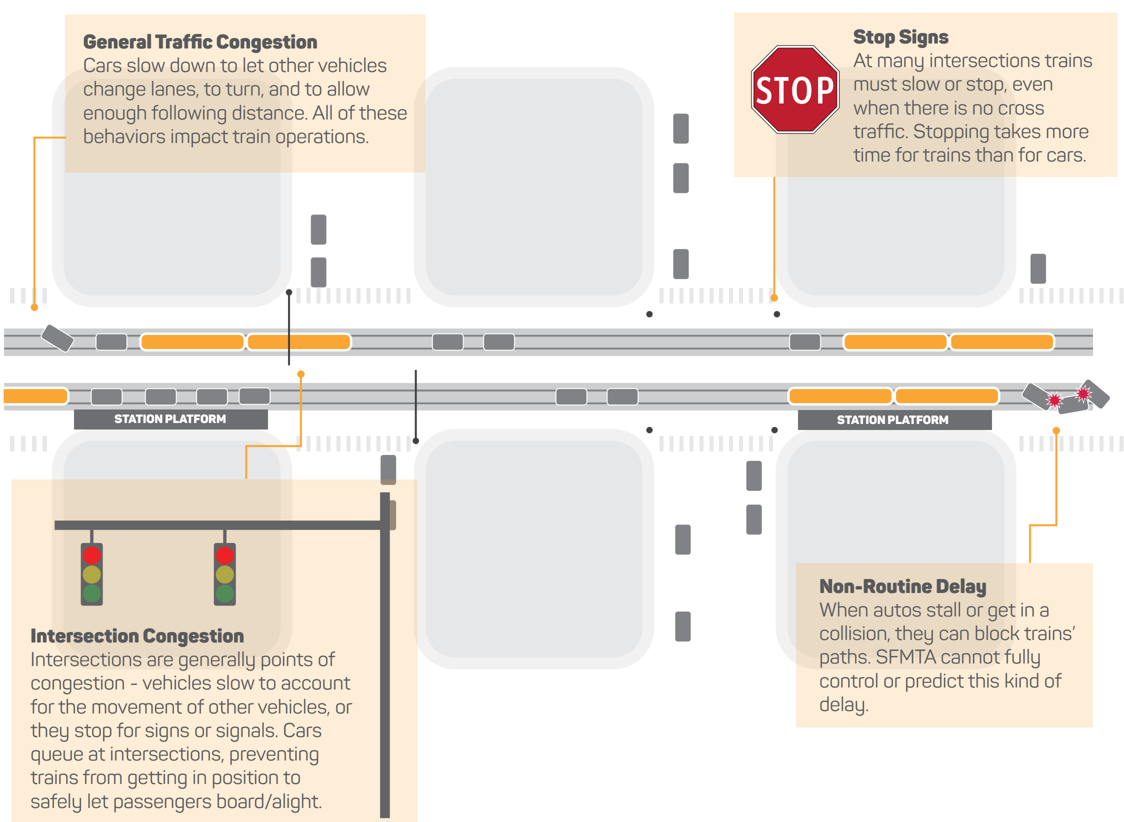


Figure 1 Figure 19 Causes of Transit Delays on

- **Traffic:** Buses and trains are subject to the congestion that affects all traffic on city streets when they run in lanes with cars, trucks, and other vehicles. There is a wide array of issues that can cause delays, including: other vehicles changing lanes, doubled-parked cars, lost or distracted drivers, intersection queues, and blockages caused by collisions. Regardless of the reason, cars blocking tracks are major sources of train delays.
- **Congestion at Intersections:** Intersections are a focal point of traffic delays due to the often complex interaction of vehicles, cyclists, and pedestrians as they change speeds and make turns.
- **Loading and Unloading Passengers:** SFMTA's system-wide All-Door Boarding policy allows Muni riders with valid proof of payment to enter vehicles through any door, instead of requiring all passengers to queue and enter vehicles through the first door to pay fares or show operators proof of payment. The use of all doors has improved efficiency and reduced average "dwell time," or time spent at stations waiting for passengers to load and unload. Loading and unloading time for typical crowds is factored into bus and train schedules, but when transit vehicles are delayed due to traffic congestion, crwoded conditions, the boarding and de-boarding of customers who require additional time, and other factors, they end up arriving at stops at irregular intervals which can create "bunching." This can, in turn, result in larger-than-normal crowds during longer-than-normal intervals between vehicles, lengthening boarding times further and contributing to even more bunching.
- **Stop Spacing:** Along all of the surface portions of Muni Metro routes, some stops are as close together as one or two blocks. Given the time it takes trains to accelerate and decelerate, frequent stops can increase travel times notably over what they would be if stops were as far apart as they are in many light rail systems — one-quarter to one-half mile apart. Frequent stops can also make passengers feel like travel times are longer than they actually are. People tend to perceive time spent regularly slowing down and speeding up as longer than equivalent time spent more consistently in motion.
- **Other Street Design Issues:** Stop signs and narrow lanes in certain areas further limit trains' average speeds on the surface.

BUSES AND TRAIN CARS AVAILABLE

Buses and train cars are expensive, and it often takes years between the time new vehicles are ordered and their delivery. Muni ridership has grown far more quickly than forecast (see Chapter 2), leaving the SFMTA with too few vehicles to serve all potential transit riders in the short term. The agency has accelerated the purchase of additional vehicles to more quickly accommodate newly forecast ridership levels.

The City's current fleet of light rail vehicles is more prone to maintenance issues than those of other systems. Reliability has improved recently as a result of maintenance campaigns focused on the issues that most contribute to delay (i.e. problems with train doors), but the maintenance issues have, at times, further constrained the number of passengers the system can serve.

SAFETY SYSTEMS IN THE MUNI METRO TUNNEL

As noted earlier in this chapter, train control systems typically enforce a minimum following distance between trains to allow for an emergency stop without the risk of a collision from behind. The light rail signal system is one of the earliest installations in the United States of communications-based train control, which, as noted in the East Bay Metro Rail section, dynamically keeps a safe amount of buffer space between trains.

As noted earlier, the Muni Metro Tunnel's train control system allows train movements to be managed automatically, which allows trains to be spaced more closely than they would under manual operation. This increases the number of trains per hour that the subway can accommodate; a traditional system can carry about 30 trains per hour per direction, but SFMTA currently schedules as many as 36 trains per hour at peak times.

Absent the capacity limitations of the portals, merges, and turnbacks, as well as the lack of predictability of surface operations addressed earlier in the chapter, the system could safely accommodate more trains per hour. However, those issues often reduce service below even scheduled levels.

Each train, no matter how long it is, requires the same amount of time to maneuver through the portals, turnbacks, and other elements of the system that limit the total number of trains the system can handle in a given hour. In other words, a one-car train, carrying a maximum of approximately 120 passengers, takes up space that could otherwise be filled by a four-car

Spacing for Safety

The Muni Metro Tunnel keeps trains at a safe distance from each other. Late trains and maintenance issues, among other problems, can prevent the tunnel from functioning optimally.

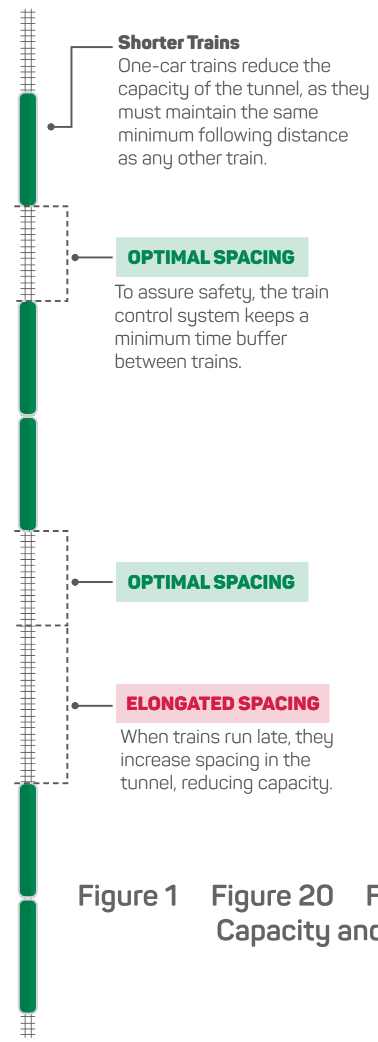


Figure 1 Figure 20 Foregone Capacity and the ATCS

train carrying four times as many passengers. Limitations on train lengths, whether due to constraints like short block lengths on above-ground portions of the system or because of fleet limitations, prevent the tunnel's full potential capacity from being used at the system's highest ridership points. In other words, running only shorter trains cuts the subway's capacity by at least half at the points where more capacity is most needed.

PLANNED IMPROVEMENTS

The SFMTA has plans for or is already implementing a number of changes that will begin addressing the issues noted above, though funding shortfalls remain.

Light-Rail Vehicle Replacement and Expansion

SFMTA's light-rail vehicle replacement planning and design effort has been underway for several years, and the first new vehicles will enter service in early 2017. Many aspects of the new trains will increase capacity both directly and indirectly.

Capacity will directly increase with growth in the size of the fleet, from approximately 150 vehicles today to as many as 260 in the future (SFMTA has ordered a total of 215 trains so far, but the agency can purchase 45 more in the future once it identifies funding for the additional vehicles). The larger fleet will enable SFMTA to run longer trains and consider different service patterns.

The design of the new vehicles should improve reliability substantially. As discussed in prior sections, the impact of a broken train or one that is having trouble connecting to the subway's train control system can cause delays that persist for an entire commute period, creating overcrowded conditions. Noteworthy aspects of the new design for reliability include:

- The new vehicles are being manufactured nearby in Sacramento, giving SFMTA better access to parts needed for routine maintenance. The current vehicles, manufactured in Italy, had custom and hard-to-order parts, which has forced trains to be out of service for longer than might otherwise be necessary for routine repairs.
- The trains themselves have been simplified to reduce maintenance issues. For example, there will be dramatically fewer moving pieces involved in opening and shutting the doors than there are in today's trains. As a result, SFMTA expects that the new vehicles' average distance between major

Light Rail

SF

Buses

maintenance issues will be quintupled, from 5,000 miles to 25,000 miles.

Trolley Bus and Motor Coach Replacement and Expansion

SFMTA is in the midst replacing its entire fleet of buses and, ultimately, expanding the fleet significantly. New buses have been phased in over the last several years, and all of the old vehicles will be replaced by 2019. In addition to providing greater reliability and a smoother and more comfortable ride, the new buses have floors closer to street level, which allow for faster boarding and alighting.

Reconfiguring and Expanding Maintenance Facilities

To accommodate all of the new train cars, SFMTA will need to establish additional maintenance and storage facilities. Updates are also needed are needed at existing maintenance yards (Muni Metro East and the Green Yard at Balboa Park Station). The agency will need to identify additional maintenance and storage space for both buses and trains over the long term.

Technological Investments

The agency is making a set of investments in new technologies that should collectively minimize surface delays and allow for better management of the system's daily operations. These include:

- Implementation of a new radio system on all trains that will allow staff in a centralized and state-of-the-art Transportation Management Center to adjust service in real time.
- Implementation of 40 miles of transit priority streets with "red carpet" transit priority lanes and transit signal priority, which can help reduce the amount of time buses and trains are stuck at red lights.

Infrastructure Investments

Finally, SFMTA is also investing in infrastructure that will improve capacity. Improvements that the agency hopes to implement soon include:

- Adjustments the layout of the intersection of West Portal and Ulloa (right outside West Portal Station) to simplify the ways different travelers cross the intersection and reduce the number of movements that can delay train travel through the intersection.
- A new pocket track along the Embarcadero east of Harrison Street that will create a new location to turn back trains near the eastern end of the Muni Metro Tunnel.
- A new surface train control system along the Embarcadero and King Street to reduce the number of times trains need to slow down or stop in that portion of the system.

Several longer term capital investments are also under consideration and will be evaluated as a part of the Core Capacity Transit Study and through ConnectSF, San Francisco's update to its long-range transportation plan that will identify the next generation of major transit improvements. These include:

- The Muni Subway Expansion Project, which would upgrade the M-Ocean View to a full subway line, providing a backbone of fast, reliable, high-capacity transit that runs across the whole city. This investment put the surface portion of the M from West Portal to Parkmerced underground and build four-car station platforms, enabling the use of four-car trains all the way through the Market Street subway, per the subway's original design.
- A light rail corridor on Geneva Avenue that would connect the two railyards (Muni Metro East and Balboa Park Green Yard) to provide more flexibility and efficiency.
- New rail service on Geary Boulevard, including subway service in the eastern part of this high-ridership and overcapacity corridor.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Commuter Rail

Metro Rail

- Extension of the Central Subway from its planned terminus in Chinatown north to Fisherman's Wharf.

PENINSULA - COMMUTER AND METRO RAIL

Commuter and metro rail systems provide complementary service along the San Francisco Peninsula. The commuter rail line, operated by Caltrain, roughly parallels the US -101 corridor, while the metro rail line (BART) travels further west near the I-280 corridor before diverging to serve San Bruno, San Francisco International Airport, and Millbrae.

While metro rail has spare capacity in the corridor, the commuter rail system is facing serious crowding issues today. Major upgrades to the commuter rail corridor are planned, including the Caltrain Modernization program, which includes upgrading train control and signal systems, electrifying the railroad, and expanding the fleet with

PENINSULA
Commuter Rail

Figure 1 Figure 21 Downtown Extension and Regional

new Electric Multiple Unit (EMU) vehicles. In the longer term, Caltrain plans to further expand its fleet, serve the new Transbay Transit Center via the downtown extension project, and operate in a shared corridor with California High Speed Rail (HSR) as part of a blended system.

COMMUTER RAIL

Peninsula commuter rail service runs from Gilroy and San Jose to San Francisco, terminating at the 4th and King Street Station. Rail service has operated in the corridor since the 1800s. The rail line transitioned to commuter rail service with the growth of the Peninsula suburbs in the early 20th Century and came under public control in the 1980s. The service has experienced huge growth in ridership since "baby bullet" express service began in 2004, and ridership has more than doubled since 2006.[30] Key challenges include system capacity and connectivity to complementary transit services.

30 Caltrain (2015a). "2015 Annual Passenger Counts." Presentation to Board of Directors, March 7, 2015.

SYSTEM CAPACITY

Many peak-period trains now regularly carry passenger loads well above seated capacity. Caltrain has projected that average weekday ridership will grow by more than a third by 2021, to 83,000,[31] suggesting that crowding may grow more acute as economic growth continues on both ends of the Peninsula. To address

31 Caltrain (2015b). "Short Range Transit Plan Framework." Presentation to Board of Directors, June 4, 2015.

crowding issues, Caltrain recently added 16 used rail cars to its fleet, which will allow the agency to lengthen trains.

The Caltrain Modernization Program (CalMod) includes a new train control system, the electrification of the rail corridor between San Francisco and San Jose, and the expansion of the fleet with new, Electric Multiple Unit trains. Together, these ongoing and planned investments will help address long-term capacity needs. The train control and signal system portions of the project are complete and are undergoing testing. The electrification of the railroad completed environmental review in 2015 and is scheduled to be fully implemented by 2020.

The overall CalMod program will cost $1.7 billion, with local, regional, and federal sources of funding, as well as a substantial contribution from California High Speed Rail. Electrification will allow trains to accelerate and decelerate more quickly, allowing Caltrain to run more trains per hour in peak periods. Once California High Speed Rail is fully implemented, Caltrain's regional service will be supplemented with fast intercity service to two stations on the Peninsula, San Jose, and south to Southern California.

SYSTEM CONNECTIVITY

Today, commuter rail service terminates at 4th and King Street station, which is located at the edge of the San Francisco Core, one mile from metro rail stations on Market Street and 1.2 miles from the Temporary Transbay Terminal at Folsom and Beale Streets. The N-Judah and T-Third currently bridge the last mile to Market Street and the Financial District via the Embarcadero, and the Central Subway will make the connection on the T-Third more direct via Fourth Street. To improve transit system connectivity even further and to transport Caltrain riders from the Peninsula into the heart of the San Francisco Core, the region has committed to the Downtown Rail Extension (DTX) project, which will extend commuter rail to the new Transbay Transit Center.

In the future, Caltrain and High Speed Rail will operate as a blended system sharing the Peninsula Corridor. The region has deemed DTX a top priority, but full funding has not yet been secured.

METRO RAIL

Metro rail service (operated by BART) runs south from San Francisco along the I-280 corridor, terminating at San Francisco International Airport, and a station in Millbrae that allows direct connections to Peninsula commuter rail service (operated by Caltrain).

SYSTEM CAPACITY

Current passenger demand in this corridor does not exceed capacity, and forecasts do not suggest capacity constraints in the foreseeable future. As a result, Peninsula metro rail service may offer an opportunity to provide transit access to more potential riders into the San Francisco Core.

Access facilities may be the major limitation on the metro rail corridor's share of the overall Peninsula commute market. With the exception of Millbrae station (which has less frequent peak-hour service than other stations in the corridor), parking facilities in this corridor fill to capacity during the AM peak period. In order to increase the metro rail system's share of the commute market, it may be necessary to improve access opportunities at Peninsula stations by all modes of transportation.

In order to better serve demand in the core system, BART has begun to explore potential operational changes that may affect service frequencies on the Peninsula. BART's Sustainable Communities Operational Analysis, completed in 2013, raises the possibility of improving the current "turnback" to allow BART to turn trains around at 24th Street/Mission station, and constructing a new turnback near Glen Park. The turnbacks will allow BART greater flexibility in maintaining reliability and turning trains around when needed.

CONCLUSIONS

Bay Area transit commuters can today feel the effects of transit networks running up against constraints imposed by the design of the region's transit infrastructure. The systems that provide access to the San Francisco Core were designed in an era in which the high passenger volumes of today – driven by job and housing growth – could scarcely have been imagined. As a result, congested trains, buses, and ferries are now the norm during peak commuting periods, with delays becoming more and more frequent.

The five transit agencies that are cosponsoring the Core Capacity Transit Study — AC Transit, BART, Caltrain, SFMTA, and WETA — each have plans to increase capacity and improve reliability in the coming years, though the region still needs to identify funding to implement many of these plans. These projects include new train control systems and maintenance facilities, station and terminal capacity increases, and operational improvements that could temporarily ease some of the crowded conditions passengers experience on a daily basis. It is important that the region focus on securing the funding necessary to make these upgrades.

While it is impossible to predict exactly how quickly the region's population will grow over the long term, some critical transit lines serving the Core are highly likely to once again approach capacity constraints in the next 25 years, even if all of the already-identified projects are implemented. If population and employment growth continues on or near the trajectory seen over the last few years, additional infrastructure improvements will be much more urgently needed.

Regardless of the pace of growth, there are a number of key operational improvements that could ensure the system functions much more efficiently. Several of the key networks serving the San Francisco Core were conceived in the 1950s and mostly built by the 1970s. The Transbay Tube, Oakland Wye, and Market Street Subway will remain constraint points in the system, with limited redundancy in the event of failure or need for major repairs. Addressing some or all of these issues could markedly improve transit travel time, reliability, and comfort, as well as generating new capacity.

The Core Capacity Transit Study is considering a variety of potential approaches to addressing the issues raised throughout this briefing book. Future versions of the document will detail the solutions the study and its sponsor agencies are considering.

Figure 22 Summarizing the System's Constraints

80
Berkeley
BART
Limited MetroRail cars
TRANSBAY METRORAIL
Major delays systemwide with maintenance issues/breakdowns in the Transbay Tube
TRANSBAY BUS
Congestion with private vehicles at Bay Bridge ramps
CORRIDOR
TRANSBAY METRORAIL
Speed restrictions and congestion in the Oakland Wye
HWY 580
TRANSBAY FERRY
Vessel availability and size constraints
Alameda
Oakland
TRANSBAY FERRY
Landside access limitations
MetroRail
Commuter Rail
Light Rail
Transbay Bus
Ferry
Merge issues
Mainline issues
N

NEXT STEPS

This Briefing Book has laid out the trends and structural challenges facing each of the main transit networks that connect to the San Francisco Core. It provides policy makers and agency staff with a common set of facts they can draw on as they work to identify and prioritize critical investments. It is a living document that will evolve with the study, with a new chapter detailing potential solutions to be added as the study team narrows in on a set of promising projects.

TRENDS CHALLENGES SOLUTIONS

Sponsoring Agencies:

AC Transit, Bay Area Rapid Transit (BART), Caltrain, Metropolitan Transportation Commission (MTC), San Francisco Municipal Transportation Agency (SFMTA), San Francisco County Transportation Authority (SFCTA), Water Emergency Transportation Authority (WETA)

Questions?
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CORE CAPACITY TRANSIT STUDY