BART Sustainable Communities Operations Analysis

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Study Funding Provided By:

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Appendices (separate document)

Executive Summary

Background – The Bay Area Rapid Transit (BART) rail system has provided 40 years of frequent and fast transit service. Over the last 20 years, BART has increased service and reliability, fulfilling its original mandate to help shape growth and development in the Bay Area and reduce the region's dependence on the automobile. The system now carries more than 400,000 passengers daily and delivers about half of the region's total transit passenger miles.

Plan Bay Area – BART expects daily ridership to increase by about 50 percent over the next 12 years, creating enormous opportunities for the system and equally significant challenges. The May 2012 Preferred Plan Bay Area, the region's SB375 guided Sustainable Communities Strategy (SCS), forecasts 250,000 new jobs (40% increase) in BART-adjacent Priority Development Areas (PDAs). Downtown San Francisco and Oakland stations will see ridership increases of between 30% to 34% during the peak hours.

A re-conception of BART's service plan, coupled with significant investment in the BART system are critical aspects of future success and relevance. BART's successful response to its capacity and operational needs and especially its looming capacity limitations require a focus on capacity improvements to meet demand and provide a high level of customer service. The alternative is unacceptable levels of crowding on Transbay service during peak times, degradation in reliability and an inability to realize significant ridership growth. This would diminish BART's current competitive edge over the auto for Transbay trips and could further increase congestion on the freeways, resulting in a loss of both transit and freeway capacity which would detract from development growth in the Bay Area.

Metro Core and Metro Commute Strategy – Plan Bay Area allocates growth to locally-identified areas near transit, and reinforces development within the Bay Area's central cities. In response, BART ridership increases more dramatically in the Bay Area core, leading to changes in BART service patterns. More service will be needed in the core, but current levels service will likely suffice towards the system's fringes. The new service plan has been referred to as the Metro Core-Metro Commute strategy. Metro Core is identified as contiguous areas where transit can be competitive (with driving) for all types of trips throughout the day – the BART service area between Daly City and Richmond, MacArthur and Bay Fair stations. Demand is for frequent, all day transit service. In these areas, BART expects to operate more trains, over longer hours, for more of the day. Metro Commute is identified as areas where transit is primarily competitive for peak period trips into congested job centers. In the Metro Commute areas, passengers still have 15 minute weekday service, but trains may be shorter and have different termini.

This study, the **Sustainable Communities Operations Analysis Study (SCOA)** further develops these service strategies into service plans, and then identifies the improvements needed over the coming years for BART to maintain its current quality of service and meet the projected ridership increases in the Bay Area. These improvements focus on capacity upgrades, efficiency projects, fleet increases and other related capital investments.

Service Plan Alternatives – The SCOA study evaluated different service plan scenarios to identify which service plans would be best suited to meet the growing ridership demands and developed two future service plans that can be introduced over a phased period to meet the growing demand and maintain the good service expected of BART.

The overall service design objective – and the guiding principles for the development of the scenarios and service plans – seeks to provide a high quality transit service by maximizing service (trains per hour), while minimizing the amount of train miles incurred (cars per train). By striking a balance between the two, BART can maintain good levels of service while minimizing operating costs and maintaining its excellent farebox recovery. This strategy is equitable and financially prudent. Users increasingly pay a higher proportion of BART service costs, but individual fares remain modest.

System Investment – As ridership grows, BART needs to make significant investment in its train fleet to ensure that it has available the additional vehicles required to meet demand. This increase in overall train fleet occurs incrementally as ridership grows. In the first stage (Phase 1) the overall train fleet increases to almost 900 cars, allowing BART to run 24 trains per hour Transbay during peak periods with all trains 10 cars long. Significantly, several crossover (turnback) projects reduce the need for additional cars and in essence pay for themselves. These include a new Richmond Crossover and upgrades to the existing 24th Street crossover, Lafayette pocket track and revenue service of the Pleasant Hill crossover. These capital improvement projects would cost around $60 million – and result in about an equal savings in vehicle costs plus operating costs savings

With the increase in fleet size under Phase 1, BART will also need to make further investment for midday storage of trains. Expansion of the existing tail tracks at Dublin / Pleasanton and Millbrae will need to be completed to accommodate this increased fleet. In all cases, the study assumes that BART maintains 85 percent car availability – among the best in the business.

Beyond 24 Transbay trains per hour requires additional, and significant investment including a modernized train control system that could allow up to 30 trains per hour per direction and should provide enough capacity to deliver 30,000 passengers hourly in the peak direction or more than 500,000 riders systemwide. As a result, the new train control system is a prerequisite for Phase 2 service increases.

In the Phase 2 service plan, BART increases Transbay service to 27 trains in the peak hour, peak direction. This, in turn, requires a fleet size of 1,000 vehicles.

In development of the future service plans, service has been tailored to ensure that BART can remain effective and efficient systemwide, but especially in the core. Operating additional long trains to the more remote parts of the system carrying few passengers per car is expensive with little return or benefit to riders. Short turning some service to within the BART Metro Core requires that BART has available the infrastructure required and is located in the correct positions.

A new turn back facility located south of Glen Park station would allow BART to short turn some service during the peak hours when the majority of demand has alighted in the downtown stations. Short turning of trains maximizes the amount of service that can be provided while minimizing the overall size of the train fleet.

Phase 2 also introduces a new BART operating concept – coupling and de-coupling of trains in service at Bay Fair station during evening / weekend service hours. This concept allows BART to run full 10 car trains in the core during evenings and weekends, with the train splitting at Bay Fair with a 5 car train heading to Dublin / Pleasanton and a 5 car train heading to Fremont. This new concept requires upgrades at Bay Fair station and also requires modern information systems to inform passengers. This concept maximizes the available capacity within the core, while minimizing running empty trains to the outer extents of the system with lower demands.

With the significant levels of investment and increase in capacity, BART will be able to maintain its current high farebox recovery ratio and actually increases the farebox recovery under some scenarios, while preserving passenger safety and comfort.

Summary – BART currently operates and manages a vital Bay Area transit system with high performance. The system's on-going State of Good Repair (SOGR) project focuses investment on the critical aspects of the BART system to maintain this service at current levels. However for BART to continue to expand its service to meet the growing demand over the coming years, significant investment in capacity upgrades are required.

The SCOA study provides the analysis to justify a "blueprint" of the most critical, significant and effective BART investments. The entire SCOA strategy seeks to maximize value and minimize cost. These modest investments enable BART to meet growing Bay Area regional transit demand and when coupled with complimentary strategies, such as Demand Management, assure Bay Area residents and taxpayers that their tax dollars and their fares are working hard to keep them getting to work.

1. Introduction

The Bay Area's forecast economic development is expected to result in large BART ridership increases over the next 30 years. Within just the next 12 years, BART expects ridership to increase by about 50 percent. These new customers create enormous opportunities for the system and equally significant challenges.

The May 2012 Preferred Plan Bay Area, the region's SB375 guided Sustainable Communities Strategy (SCS), forecasts 250,000 new jobs (40% increase) in BART-adjacent Priority Development Areas. Downtown San Francisco and Oakland stations will see ridership increases of between 30% to 34% during the peak hours.

As the Plan Bay Area/SCS process evolves, the region seeks to allocate growth to locally identified areas near transit, and promises to reinforce development within the Bay Area's central cities. Infrastructure, including water, sewer, power, streets and transit systems will likely all upgrade their core facilities at greater intensity compared to the fringes of the region. BART will be no different.

BART's service planning needs to respond to these challenges to meet demand and provide a continued high level of customer service. If BART fails to change the result could be unacceptable levels of crowding on Transbay service during peak times, degradations in reliability and an inability to realize huge ridership growth. This would diminish BART's current competitive edge over the auto for Transbay trips and could further increase congestion on the freeways, resulting in a loss of both transit and freeway capacity which would detract from development growth in the Bay Area.

A new service planning lexicon classifies both BART transit service and BART investment. **Metro Core** refers to contiguous areas of the system where transit can be competitive for all types of trips throughout the day. Typically, these are areas that are more compact, have higher intensity use, parking fees, lower household auto ownership rates, and walkable environments. In Plan Bay Area, these areas will experience the most growth, development and intensity – the BART service area between Daly City and Richmond, MacArthur and Bay Fair stations. BART expects to operate more trains, over longer hours, for more of the day. In the Metro Core service area, passengers don't need a schedule because trains run frequently and passengers walk and cycle to the station. **Metro Commute** are areas where transit is primarily competitive for peak period trips to congested job centers. Metro Commute areas have high levels of peak period service (compared to many transit systems), but may require a schedule during off-peak periods. There is more automobile access to these stations, and while walking is more difficult, cycling is encouraged. To go along with these categories, BART will also develop improvement plans that recognize these demographic differences.

Capital investment enables this service planning vision. With the investment, BART prospers. Without investment, BART will quickly exceed the capacity of the current system, resulting in unacceptable levels of crowding on the service during peak times and would not be able to realize the huge forecast ridership growth. This would result in riders looking to alternative modes of transportation putting further strain on an already constrained transportation system in the Bay Area. This would diminish BART's current competitive edge over the auto for Transbay trips and could further increase congestion on the freeways, resulting in a loss of both transit and freeway capacity which would detract from development growth in the Bay Area.

To provide enough service and capacity to meet these challenges, BART will need to focus on these essential capital priorities that deliver the visionary service plan:

- Deploy a modern 1,000 car fleet
- Develop larger and more efficient maintenance facilities
- Procure and deploy a modernized train control system that allows more trains to operate on the system during peak periods
- Adjust routes and provide more frequent service within the region's core
- Bring its infrastructure to a state-of-good-repair with an emphasis on power and communications systems renewal
- Rehabilitate stations and deliver strategic trackway improvements that allow for a more efficient use of trains, cars and train operators.

Overview of the BART System

The BART rail system has provided 40 years of frequent and fast transit service. During this time, the system evolved into a convenient and reliable service for its patrons and the backbone of Bay Area regional transit. Compared with the original 1970's core system, BART operates a longer span of service, and carries more riders along an expanded system. During the early 1970's BART carried about 15 million passengers annually.

By 2012, BART served more than 110 million passengers, around 366,000 passengers on an average weekday. Current ridership exceeds 400,000 on most weekdays. Ridership is forecast to continue growing over the coming years to around 168 million passengers in 2025, around 560,000 passengers on an average weekday (see Figure 1).

As ridership grew, the BART system expanded, and additional service was added to the core parts of the system. The original system extended from Daly City to Concord; and from Richmond to Fremont (see Figure 2). During the 1970's and 1980's BART added service to the core part of the system (see Figure 3). In 1996 BART was extended to Pittsburg / Bay Point, and the Dublin / Pleasanton extension opened in 1997. In 2003 BART completed its latest extension with the system expanding to SFO Airport and Millbrae (see Figure 4). BART continues to expand its service and is delivering planned extensions to Warm Springs (2015) and Berryessa (2017), as well as the east Contra Costa County eBART service (2017). A possible Livermore extension and a further extension through downtown San Jose to the City of Santa Clara are also under development.

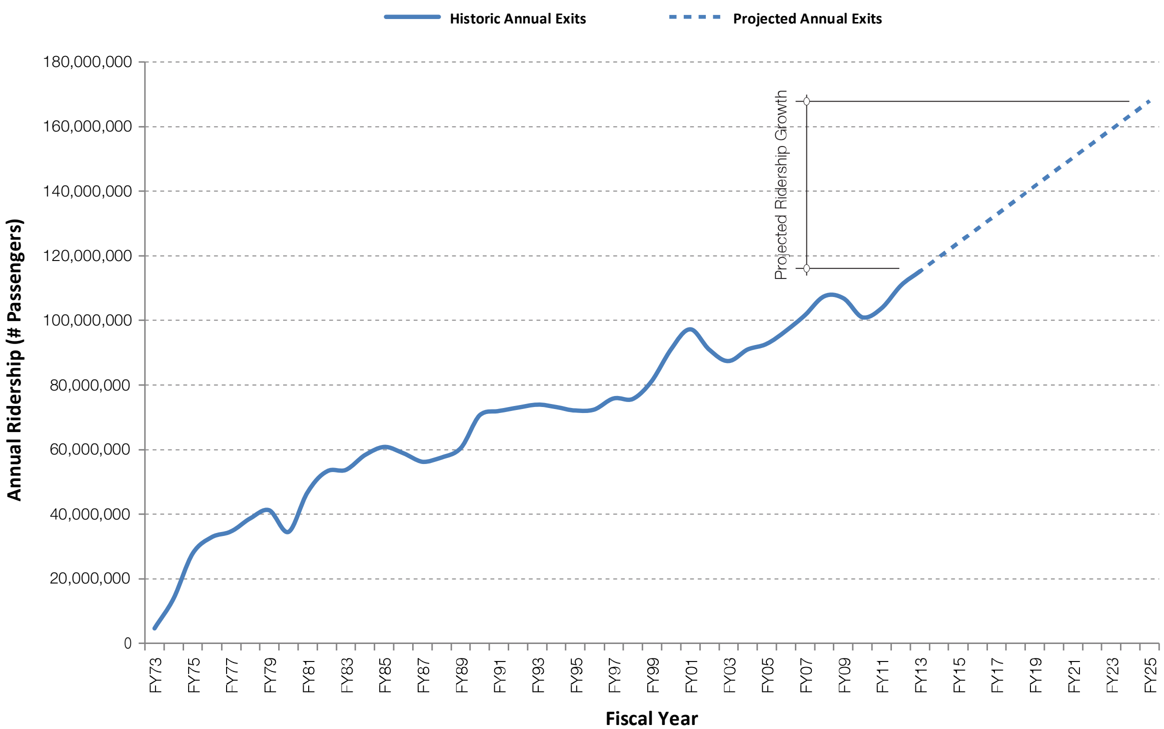


Figure 1: Existing and Projected Annual BART Exits

Introduction

Figure 2: 1974 BART Service

1970's BART Employees

President Richard M Nixon, takes a BART Ride

Pittsburg / Bay Point Station Opens in 1996

Dublin / Pleasanton Extension Opens in 1997

Figure 3: 1994 BART Service

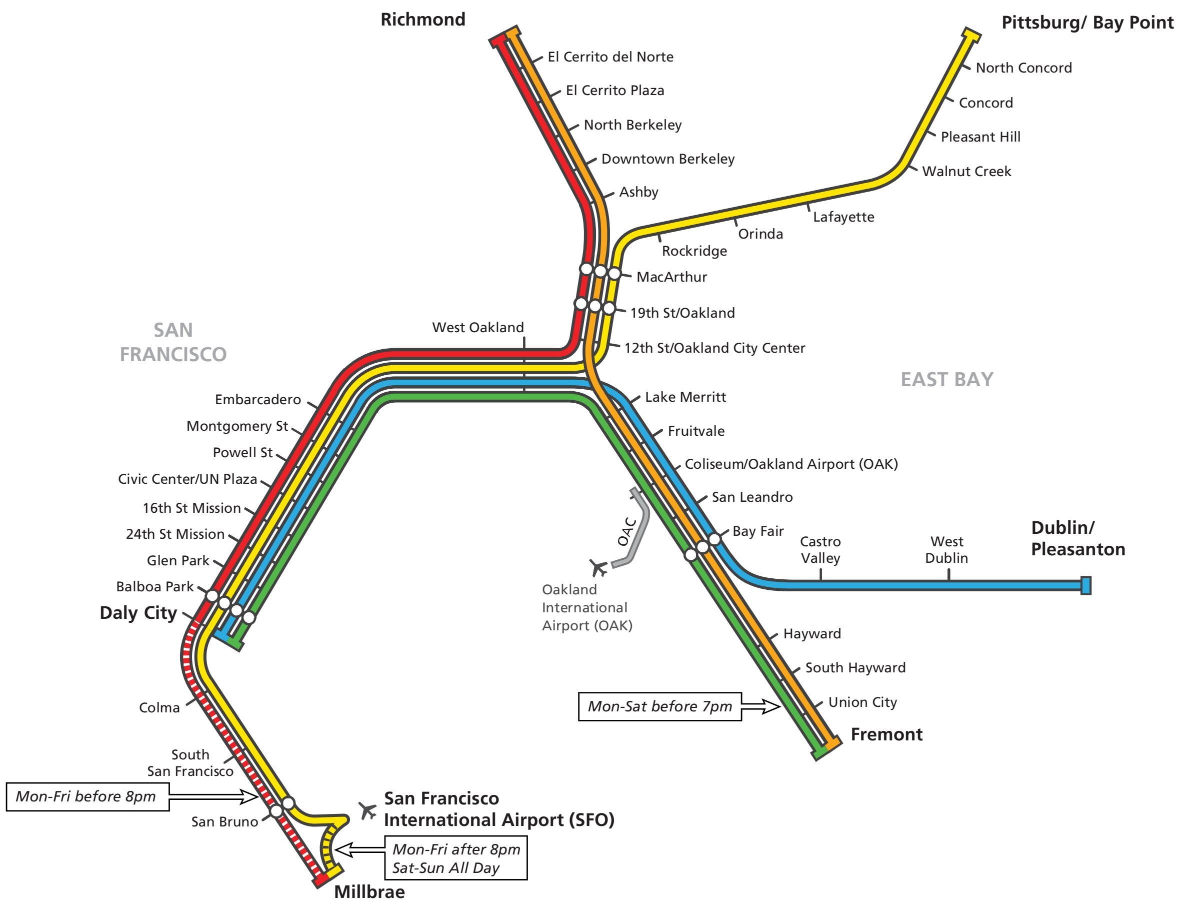


Figure 4: Current (2013) BART Service

There are a few American rail transit systems that serve both regional and urban trip patterns. However, unlike some of the others, BART is unique in regards to the topography and area that it serves. The BART system has 4 branches in the East Bay that merge as they approach San Francisco, providing a trunk service through San Francisco towards the Peninsula, resulting in a complex network that is operationally challenging. As a result, BART can be considered as a Hybrid system offering both a Metro Commute service for commuters during peak periods and Metro Core service during the midday, evenings and weekends for "show and go" riders.

BART continues to evolve and the Bay Area continues to expand. However, regional policy now directs housing and employment growth inward into areas with convenient BART service, but where BART has limitations to providing additional service and capacity. As a key regional asset, BART continues to consider steps to ensure that the agency can still offer reliable and convenient service over the next 40 years. The BART Sustainable Communities Operations Analysis Study (SCOA) identifies what future service might look like over the short to medium future, and identifies improvements and levels of investment required to meet these objectives.

Project Background

Regional Rail Plan

In 2006-7, the Metropolitan Transportation Commission (MTC), along with BART, Caltrain and the High Speed Rail Authority participated in the development of the Regional Rail Plan for the Bay Area. This plan looks forward up to 50 years, although most of the emphasis was on the initial few years and keyed to high speed rail implementation. The Regional Rail Plan allowed for a discussion of BART's future demand and the implications on BART capacity. That, in-turn, lead to a discussion of operational needs, which then lead to a discussion of facility needs. The future year scenarios assumed that BART

> **"will continue to be the core of the regional system, with projected ridership growth from 320,000 today to more than 800,000 by 2050. Thus, the plan recommends a significant emphasis on core capacity upgrades, addressing existing constraints in BART cars and stations to allow for ridership growth."**

While not specifically mentioned in the Regional Rail Plan, the working assumption was that BART would operate 31 trains per hour in the peak direction.

During this process, BART operations staff opined that for maintaining service reliability a turnback west of Civic Center station was an important facility. This allows defective trains to be switched off the main line, and could also allow trains to short-turn, resulting in operating cost and fleet savings. It would also eliminate the turns that currently occur in opposing directions at Montgomery during the first hour of the morning weekday peak. Most importantly, it would allow trains to complete their train cycle quicker and serve more riders during a greater span of the commute period.

MTC Transit Sustainability Project

In 2010, MTC initiated the Transit Sustainability Project (TSP), which was primarily directed to agencies that have experienced high unit operating cost increases (cost per service hour or mile) and low productivity. The overall objectives were to reduce cost, increase effectiveness and place transit where people will use it as the core of the Bay Area gets denser.

BART's cost experience, relative to other agencies, is quite good and unit cost increases have generally tracked with inflation. Another metric compares the amount of service delivered (seat miles) to how much of that service is used (passenger miles). This ratio between passenger miles and seat miles was below BART's benchmark (35%) until Fiscal Year 2011; it now stands at 37.3 % and continues to rise.

One way to increase that ratio further, is to use short-turns. BART currently utilizes short turns during the peak periods. In the AM BART short turns service at Montgomery station back towards Pittsburg / Bay Point, and during the PM short turns service at 24th Street back towards Pittsburg / Bay Point. A new turnback was identified in the TSP as important and possibly cost effective. The TSP proposed short-turns at both Civic Center (in concert with BART staff's previous thoughts) and also at Bay Fair (for the Richmond-Fremont Line midday). In the MTC study, turning the Dublin / Pleasanton-Daly City Line at Civic Center at all times and the Richmond-Fremont at Bay Fair midday resulted in an estimated $20 million annual savings in operating and maintenance expenses, and a savings of about 30 peak hour cars.

Plan Bay Area

The Plan Bay Area process is the Bay Area's state-mandated Sustainable Communities Strategy. In May 2012, the Joint Policy Committee adopted the Plan Bay Area Preferred Land Use Scenario. This scenario resulted from a process where several scenarios were considered; however all the scenarios assumed total nine county population of about 9.2 million residents (a 30 percent increase) and about 4.5 million jobs (a 33 percent increase) by 2040. Within the BART service area of San Francisco, Alameda, Contra Costa and San Mateo County, Plan Bay Area forecasts employment increases as shown in Table 1.

Table 1: Plan Bay Area Employment Increases

County	Projected Increase Range
San Francisco	34%
Alameda	36%
Contra Costa	35%
San Mateo	29%

Source: May 2012 Preferred Plan Bay Area

Introduction

BART System Capacity

Overview of System Capacity

BART capacity can be divided into three distinct categories, each with their own constraints and demand criteria. The three categories are:

- Line Capacity;
- Station Capacity; and
- Access Capacity.

The BART Metro Vision study being completed in parallel with the SCOA study looks to address the long range improvements of BART capacity increases and looks at the opportunities of a second Transbay Tube in addition to infill stations and system expansions. The State of Good Repair study is also underway, which looks to focus investment within the system that is required for BART to maintain its current service and operations. These studies are complimentary to the SCOA study.

When considering BART capacity, Line, Station and Access Capacity all need to be considered in relation to each other. Providing balanced capacity among the three components ensures that the system can be expanded without shifting capacity constraints from one component to another.

Line Capacity

Line Capacity relates to the maximum number of passengers that can be accommodated through key segments of the system. Key characteristics of line capacity relate to the maximum number of trains and passengers that can be accommodated at the system maximum load section (MLS). Today, the main line capacity constraint is through the Transbay Tube and can accommodate about 22,500 passengers per hour (on 23 trains per hour, within fleet availability of about 212 cars operating in the peak hour, peak direction). The focus of this study is on line capacity and opportunities to increase line capacity.

Line capacity is dependent on both right-of-way and available equipment. The right-of-way components provide the communications and power to safely operate increasing levels of train service. On its most intense segment – the Transbay Tube – BART has enough power and communications bandwidth to operate 24 trains per hour. In other parts of the system, power or communications may limit service to below Transbay Tube thresholds. Adding one additional train during the peak hour in the Transbay Tube can increase line capacity by up to 1,070 passengers, assuming equipment is available.

Increasing the number of cars for each train set would add about 107 passengers per additional car to the line capacity, without requiring any significant changes in service plans. BART's current 23 train peak hour schedule is about 20 cars less than a full complement of 10-car trains – or the capacity of about 2,100 passengers. However increasing the number of train cars requires either increasing the overall fleet, using equipment more efficiently through faster (express) services, or decreasing vehicle allocation (and hence capacity) on other segments /lines.

Maintaining the system's right-of-way and equipment in a state-of-good-repair is vital to maintaining the system's design capacity. As these systems degrade, fewer trains will be able to operate reliably and fewer cars will be available for peak hour service. BART currently deploys almost 86% of its fleet every weekday – among the highest rate in the United States. Good maintenance practices and adequate funding allows for fewer cars to be purchased.

Changes in line capacity need to also consider the impact on station capacity (while the focus of the study is on line capacity, station capacity issues will be recognized as appropriate). By increasing the overall length of train consists, more passengers can be carried, increasing the boarding / alighting loads per train. These increased loads can put additional demand on station platforms, vertical circulation and add fare / faregate equipment, requiring potential station capacity increases. However, increasing the number of trains per hour can provide a benefit to station capacity by reducing the overall build-up of passengers on platforms, resulting in lower platform demands. In addition smaller boarding / alighting loads put less demand on vertical circulation and faregates. Increasing train frequency can provide additional station capacity without requiring any station improvements, *assuming that trains are not operating at maximum capacity throughout the peak hour.*

Station Capacity

Station Capacity relates to the maximum number of passengers that can use a station. Station capacity is broken down further into platform capacity (maximum number of passengers that can be accommodated on the platform within certain design thresholds), vertical circulation capacity (maximum passenger throughput for stairs, escalators and elevators), and faregate capacity (maximum passenger throughput at the faregates). All three station capacity components relate to each other and changes in capacity need to carefully consider impacts on the other two components. For example, increasing vertical circulation capacity will impact platform capacity in two ways. First, the additional stair / escalator footprint will reduce the overall available space on the platform. Second, additional vertical circulation will allow passengers to get to the platforms more quickly, increasing the peak demand on the platform, by reducing the metering effect of lower vertical circulation capacity.

Balancing line and station capacity is an important principle. It makes little sense to increase line capacity beyond what can be reasonably processed in stations, and the expense incurred in larger stations is of little value if line capacity is limited below the station capacity. In addition, station capacity improvements that only serve peak period needs require careful study and a thoughtful evaluation process as cost may be high relative to trips served.

The Core Stations Modifications Study completed in 2011 reviewed all existing BART stations to identify any station capacity improvements that would be required with projected ridership with the extension of BART to San Jose. The study looked at what platform and vertical circulation improvements would be required to meet future demands. Some of the major station improvements are included in this report although no new station capacity analysis has been completed.

Access Capacity

Station access capacity plays another key role in the demands on the BART system (as with station capacity, this study does not focus on access capacity but does recognize its ability to constrain the system). Access to the station considers how passengers get to / from stations in addition to considering demographics around stations. Access to / from stations by car, walking, bicycle and transit all play a key role in the demands of station and line capacity. Those stations with limited parking, for example, may result in passengers arriving at stations earlier in the AM peak to guarantee a parking space, and at a time when line demand is lower than its peak. BART is moving towards market-based parking pricing, with the BART Board's action on East Bay parking and access in March 2013.

In addition, as the region moves towards more development near transit, there is evidence (Lund, Cervero, Willson, 2004) that residential TOD generates strong transit mode share, but is not as peaked as typical park-n-and-ride. Supplementing the land use discussion, other research argues that transit proximity to jobs creates even more transit use than residential proximity (Barnes, 2005) – and this could then result in higher peaks depending on job start times. Access mode will also play a role in station capacity; those stations that are served by a single low frequency transit route could result in large platoons of passengers arriving within a short space of time increasing the demand on faregates, vertical circulation and platforms.

Introduction

BART Sustainable Communities Operational Analysis (SCOA)

The Sustainable Communities Operational Analysis is an evaluation of transit planning though embodied in both the Regional Rail Plan and the MTC TSP process. In addition, SCOA parallels the Plan Bay Area process – MTC and ABAG's process to deliver the region's first Sustainable Communities Strategy. Plan Bay Area is scheduled to be adopted by MTC and ABAG in June 2013.

The BART Sustainable Communities Operational Analysis (SCOA) focuses on BART transit operations to align this aspect of BART's business with Plan Bay Area. The District is also advancing a BART Metro Vision effort, which will consider infill stations and possible extensions, in comparison with other strategic investments.

The overall purpose of the SCOA is to position the BART system to:

- Provide transit services that sustainably delivers access for the region's future land use,
- Capture more reverse commute trips and a greater share of off peak travel, and
- Identify the necessary service and operational improvements – and the associated capital program – critical to implementation.

BART SCOA will use information developed in both Plan Bay Area and BART Vision studies to consider how the system can and will function as service increases, and what investments are desirable to retain frequent and reliable service.

The consultants have developed seven objectives for evaluating the SCOA concepts and service plans. These include:

1. Safety – Service and facility changes will allow for safe delivery of passenger service.
2. Reliability – All service and facility changes will be designed and delivered to ensure the BART system delivers scheduled service reasonably consistent with the published schedule.
3. Market Driven – Service and facilities improvements will acknowledge forecast regional trip markets and transit competitive markets.
4. Forward Thinking – Services and especially facilities will be designed to allow for future extensions and improvements of service as may be warranted.
5. Effectiveness – Service and facilities improvements will be designed to increase BART's effectiveness measures.
6. Efficiency – Service and facilities improvements will allow BART to deliver more service to more passengers at less net cost per passenger.
7. Equity – Ensure that service changes do not adversely impact minority and low-income in accordance with FTA Title VI guidelines.

The SCOA study developed five service plans (informed by best practices from other agencies) to test against the base-case alternative. The first three service plans evaluated different operating strategies, with the findings from these used to develop the final two service plan. These final two service plans are identified as Phase 1 (service plan to operate up to year 2025) and Phase 2 (service plan from 2025 to 2050) with significant capital investment.

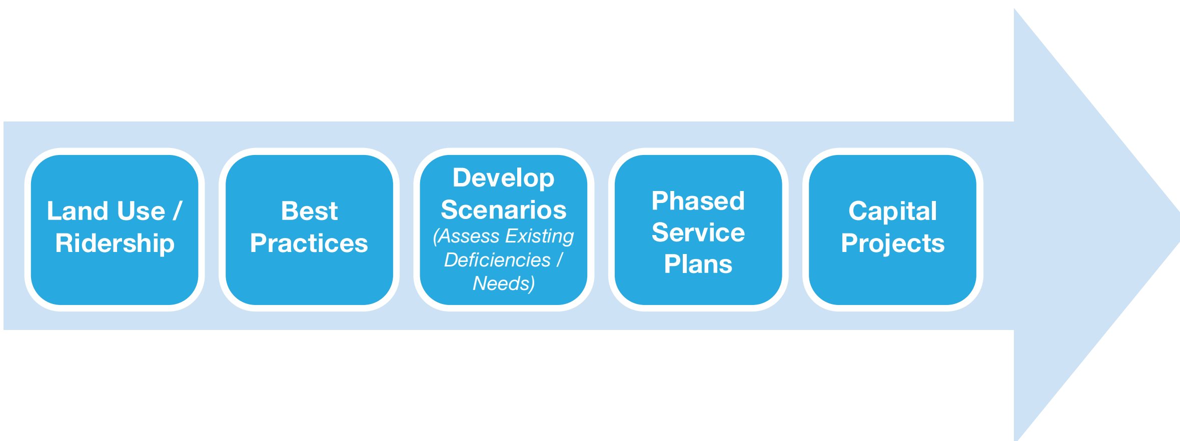


Figure 5: BART SCOA Study Process

The immediate design year is 2025 and uses Plan Bay Area forecast projections for ridership. The base-case options and two of the three scenarios tested limit service to 24 trains Transbay in the peak direction; it is possible that 24 trains will be inadequate to accommodate peak hour Transbay demand, and a third scenario will assume up to 30 trains during the peak commute period. These options will allow the consultants, working closely with BART Operations Planning staff, to consider express service, additional short-turns, coupling and other service changes, before developing the final service plans.

The Plan Bay Area horizon year is 2040. BART provided ridership information based upon the BART Ridership Model indicating that 2040 ridership would be approximately 684,000 riders. The future Phase 2 service plans indicate that ridership levels up to 750,000 riders could be accommodated.

Introduction

Key Performance Indicators

To evaluate and compare the different service plans developed, a series of Key Performance Indicators (KPI) were developed to allow comparisons between different scenarios. In total, 15 KPIs were used in evaluation of the different service plans. Results for all 15 KPI's are included in Appendix D. The main report focuses on 6 main KPI's. The following provides a summary of the KPI's.

Capacity Utilization is passenger miles divided by seat miles. It is a straight forward measure of how efficiently resources are being consumed within the system. BART's current capacity utilization is around 37% and BART has an internal performance measure 35%. The service plans will look to maximize passenger miles while limiting seat miles to maximize capacity utilization. For the purposes of this report, capacity utilization is based upon the annual passenger and seat miles. More detailed analysis of peak period / midday and evening / weekends helps to refine service during those times. However it is important to note that a 1:1 passenger mile-seat mile ratio would maximize revenue return, but could result in crowded trains and unhappy passengers.

O&M Cost (Operating and Maintenance Costs) are used to provide a cost comparison between the different service plans and are developed through BARTs O&M Cost model and are calculated based upon the overall peak fleet size, car miles, car hours and train hours.

Farebox Recovery Ratio is a common industry standard for evaluating the cost effectiveness of a transit system and is calculated by dividing fare revenue by operating and maintenance costs. Farebox Recovery Ratio is an indication of how effective a transit provider is covering their costs through fare revenue.

Peak Fleet Requirement is a measure that will be used to help in evaluating the effectiveness of the short turning of train service and appropriate locations to turn service. The quicker a vehicle can complete its route and return back into service the lower the number of vehicles required to provide the level of service.

Transbay Peak Passengers per Car (Peak Direction) is one metric that will be used to help determine if sufficient capacity is provided to meet the demand. BART's internal goal is to ensure that crowding levels during peak times do not exceed 107 passengers per car, averaged across all cars and all service lines. During the midday and evenings / weekends, the goal should be to ensure that rail cars have an average of more than 60 passengers per car to help maximize the capacity utilization.

Transbay Peak Capacity (Passengers per hour, peak direction) is a metric for comparing how much capacity is provided at one of the most capacity constrained portions of the BART system and relates to the maximum number of passengers that can be accommodated through the Transbay Tube, based on a cap of 107 passengers per car.

The following KPIs were used to help inform the evaluation of the service plans and the results of these KPIs are contained in Appendix D for each of the service plans tested.

Passengers per Revenue Vehicle Mile is a service effectiveness measure commonly used to evaluate the total number of passengers for each revenue vehicle mile (by rail car).

O&M Cost per Boarding is a cost effectiveness measure and is based upon the total O&M cost and total number of boardings (passengers).

O&M Cost per Seat Mile is a cost effectiveness measure comparing the total cost on a per seat mile basis.

Fare Revenue per Seat Mile is a cost effectiveness measure used to evaluate the average fare revenue generated per seat mile operated.

Peak Car Usage (Operating and Ready Reserve) similar to the peak fleet requirement, this measure evaluates the number of vehicles that are required be available for service. BART aims to maintain a peak fleet availability of 85% of the overall fleet.

Maximum Load Section Capacity Utilization provides a comparison of the crowding levels on trains at different screenlines around the BART system.

In addition to the KPI's reported above the following summary information is provided as part of the evaluation criteria:

- Annual Car Miles
- Annual Train Hours
- Annual Car Hours

The SCOA process recognizes that KPIs are tools for informed decision-making, and not rules that must be adhered to. As a result, there may be tension between KPIs. As an example, the KPIs can illustrate tradeoffs between attractive and marketable service and efficient service: while adding additional Transbay Service helps to reduce crowding levels through the Transbay Tube, this has an associated capital cost increase in addition to added car miles and car/train hours.

2. Existing Infrastructure and Demand Conditions and Constraints

The system's current operating practices were identified and documented to understand current system infrastructure and service constraints, with respect to patronage, cost, operational bottlenecks, condition of physical infrastructure and ability to meet current demand. From this perspective, future operational strategies can be tailored to best meet the needs of the future system. The following sections outline some of the key constraints BART staff identified within the current system.

Operational Bottlenecks/Station Dwell Times

As passenger demand increases, time taken for passengers to board and alight a train can also increase, resulting in overall increased trip times. Improvements in vehicle design with the addition of more doors should reduce dwell times. The two busiest stations within the BART system are Embarcadero and Montgomery stations, with nearly 40,000 daily exits at each station. Figure 6 provides a snapshot of typical station entries and exits during the day for key BART stations. About 20% of all station exiting activity occurs at just these two stations. BART currently schedules 25 second dwell time for each train at these two stations.

From a review comparing door opening times and closing times, the dwell times for trains in the peak direction during peak times was calculated. Table 2 presents a summary of dwell activity at Embarcadero and Montgomery on the peak direction track during peak times (also see Figure 7).

With the observed dwell times, there is padding in the train schedules (Performance Level 2.2 is BART's padding in train schedules) so that dwells longer than the scheduled dwell times do not delay service. Current demand at the busiest stations can be met with the current two-door per car fleet, however, as passenger demand increases faster dwell times afforded by three-door cars will provide additional schedule and operational reliability. BART currently has relatively low dwell times within the stations compared to other similar transit systems and BART will need to maintain these with the increased ridership and new car fleet. New train door technologies and associated door cycle times are areas of concern for the new car fleet since BART's current doors close in about one second which is among the best of its international peers.

Table 2: Embarcadero and Montgomery Summary of Dwell Times at the Stations

	Embarcadero	**Montgomery**
Westbound Platform (AM Peak)		
Less than 25 second dwell	3% of trains	24% of trains
Dwell for less than 40 seconds	59% of trains	88% of trains
90th Percentile dwell time	52 seconds	41 seconds
Eastbound Platform (PM Peak)		
Less than 25 second dwell	4% of trains	10% of trains
Dwell for less than 40 seconds	62% of trains	79% of trains
90th Percentile dwell time	52 seconds	46 seconds

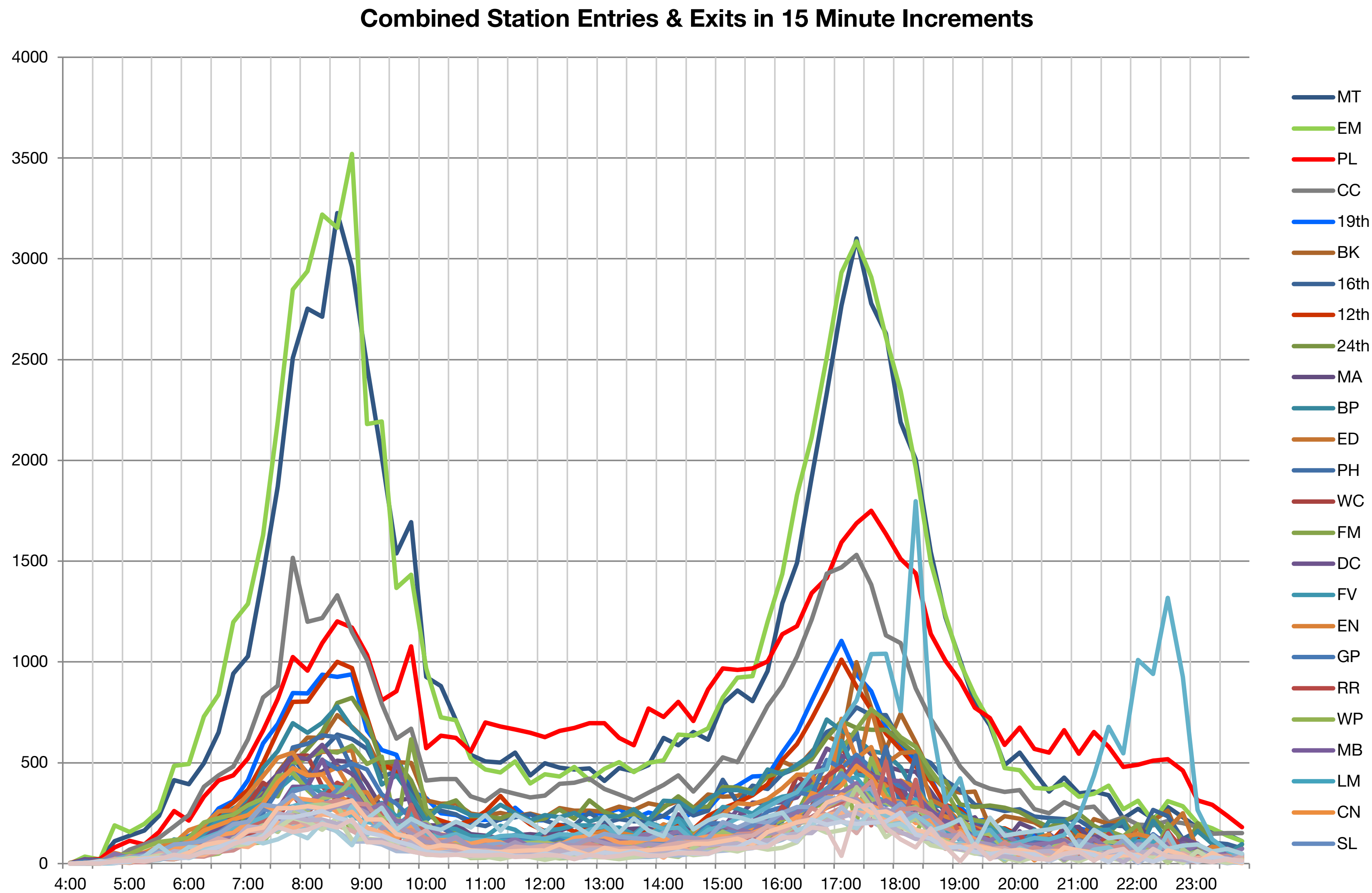


Figure 6: Typical Entry and Exit Activity at Key BART Stations

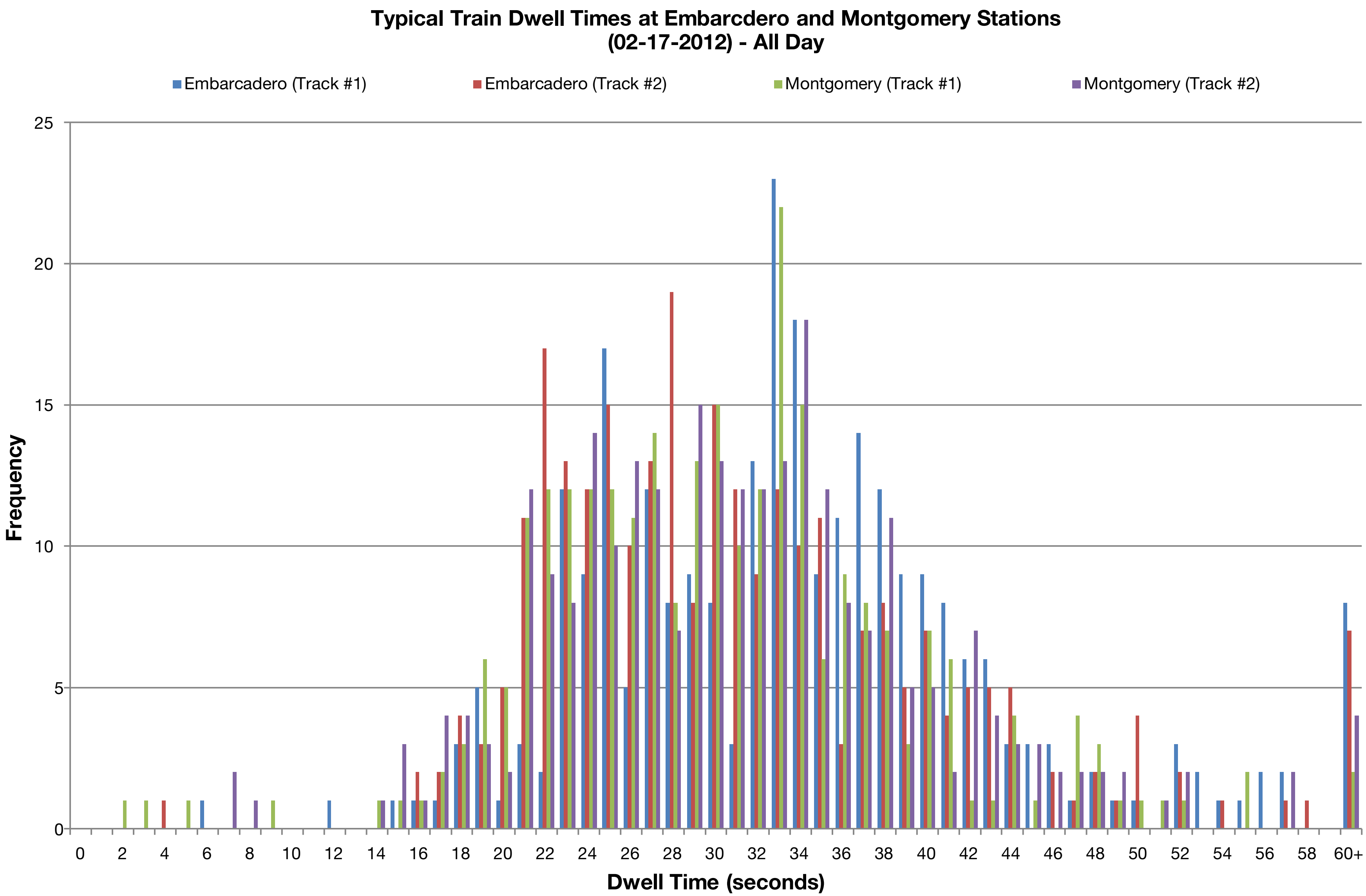


Figure 7: Typical Train Dwell Times at Embarcadero and Montgomery

Existing Infrastructure and Demand Conditions and Constraints

Station to Station Running Times

Station to station running times can identify areas within the system that may be susceptible to delay resulting from either speed / operating restrictions or from infrastructure issues. One of the key locations within the BART system is the Oakland Wye. The Oakland Wye is a multi-level interchange between West Oakland, 12th Street and Lake Merritt stations. BART provided information on the running times between these stations to identify any possible issues with regards route selection, route clearing and secondary delays.

The information indicates that actual performance through the Wye is largely consistent with scheduled speeds. As a result, while the Wye does not cause significant delay to operations, it does result in slower overall speeds that could result in longer cycle times. Scheduled run times through this area do include a 10% padding to account for fluctuations in the running times through the Oakland Wye.

Running times at other key locations within the BART system are consistent with the scheduled run times; more information can be found in Appendix A2 (a separate document).

A previous BART signal system headway and capacity constraint study (Systra, 2012) identified the Oakland Wye is critically important to BART's current operations and future growth in train service. The underlying signalling is in general well designed, although does have some issues that need to be addressed. The Sequential Occupancy Release System (SORS) overlay, however, was found to have severe and excessive impacts, and in many locations is unnecessarily restrictive. The study found that *"SORS could be made to be much less restrictive, and need not be as restrictive as the underlying signal system"*.

In addition, there are many other constrains on other Wye legs that were identified as unnecessarily restrictive. In particular the C2 Southbound Track between MacArthur and the Oakland Wye has some significant headway capacity constraints. The Systra Report summary can be found in Appendix A4.

Figure 8 presents the configuration of the Oakland Wye with the current operating speeds and speed restrictions. BART has corrected the design problems with the Oakland Wye which originally lead to the speed restrictions; however the speed restrictions remain in-place as a cautionary measure. It may be possible for 18mph speed restrictions to be lifted in the future back to the original 27mph speed codes and BART should investigate further restoring the restricted speeds. Further information on the running times, speeds and operating issues at the Oakland Wye can be found in Appendix A1.

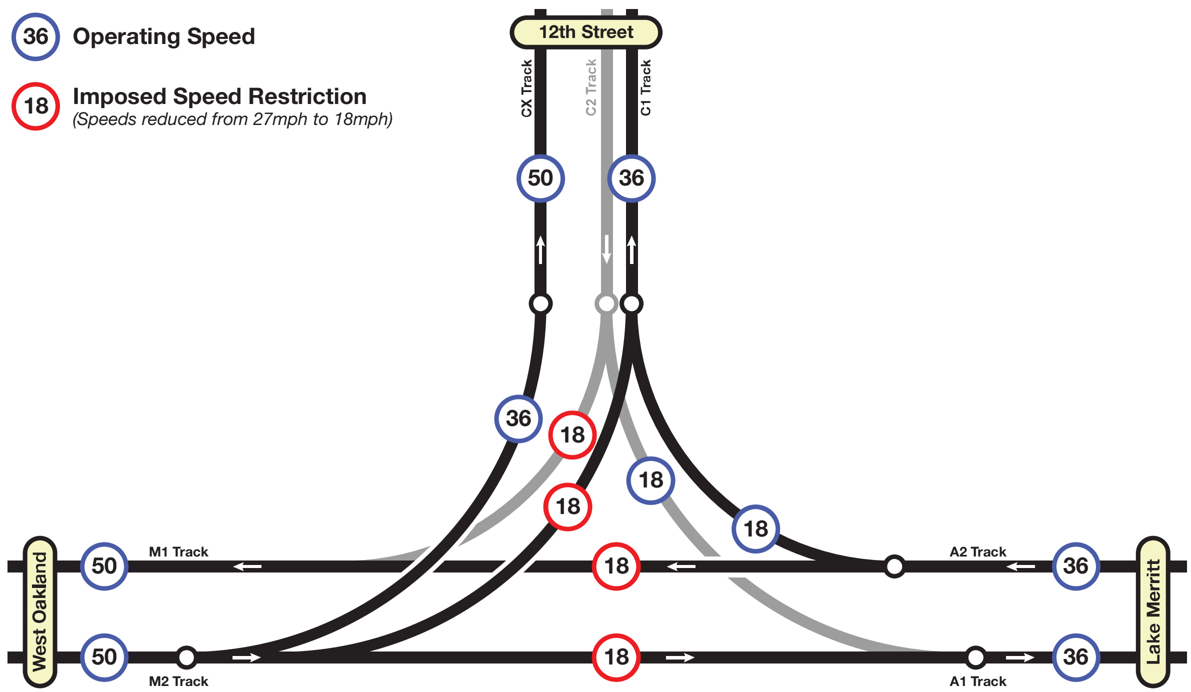


Figure 8: Current BART Operating Speeds at Oakland Wye

Other key junction hotspots within the BART system include the junctions near MacArthur, San Bruno and Bay Fair stations. Train reliability is impacted near Daly City station due to its transition into different train control systems. As BART extensions were built, different generations of train control systems were used by manufacturers such as GRS (Alstom), Westinghouse and Bombardier. At Bay Fair, reliability issues exist with the current train control system between the new and old track systems and the underlying train control system needs to be considered with any increase in train capacity with future scenario plans. The primary issues at MacArthur station is the convergence from 4 to 3 tracks and legacy equipment south of the station. At these hotspot areas, train control can require manual operations and this reduces reliability over the automatic control system. Figure 9 shows a summary of the major train control reliability hotspots with the current BART system.

A key component of train control system reliability is the State of Good Repair (SOGR) of adjacent traction power system and track structures. Specifically, the integrity of the negative traction power return cable plant, insulated rail bonds and resilience of the rail/tie interface at interlockings plays a significant role in the reliability of the train control system. Therefore a future strategy will likely require the integration of the train control, track and traction power infrastructures into one systematic and coordinated modernization campaign. Otherwise some of the key train control reliability hotspots will not be remedied.

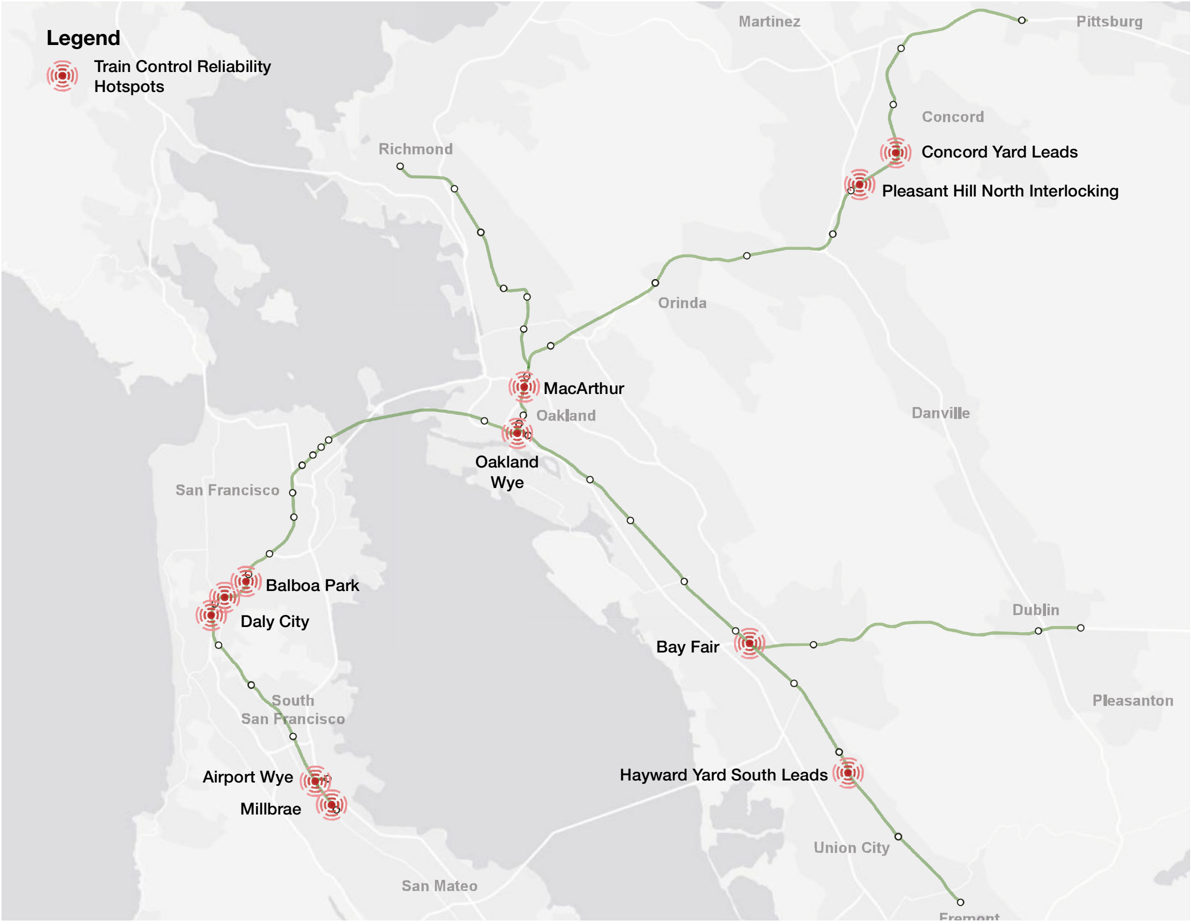


Figure 9: Current Train Control Reliability Hotspots

Transbay Tube

The Transbay Tube is one of the most critical sections within the BART system with upwards of 23 trains per hour using the tube in the peak direction during peak times. California Public Utilities Commission (CPUC, which regulates transit safety in California) requirements also restrict the maximum number of trains that can be in the Transbay Tube at any one time. During normal operations three trains in each direction are permitted in the tube, if the number of trains in each direction increases then flow into the tube is metered.

Electrical system capacity is another significant capacity constraint. The tube is currently fed remotely by separate PG&E feeds in Oakland and San Francisco. Due to the distance of the Transbay Tube, there are very limited opportunities to bring power to BART. The specific issue within the Transbay Tube itself is that below 750v at the third rail, cars can begin to self-cut-out. If there is a major delay and trains are stopped in the tube, trains should not be restarted at the same time. Restarting all trains at the same time would result in the voltage dropping. The new train car fleet is expected to have a higher ability to tolerate voltage drop, although there are no guarantees it will be achieved.

Additional traction power system remedies under construction or in planning stage are:

- A new transmission cable being constructed between West Oakland and Embarcadero as part of the Earthquake Safety Project (ESP).
- There is industry precedent for a capacitor back-up or some mid tunnel voltage regulation or metering of reported third rail voltage to manage the voltage drop issue from BART's Operations Control Center.
- BART Operations Planning staff have suggested linking the Transbay Tube West (MTW) substation to the new PG&E facility located near the San Francisco waterfront in the Dogpatch neighborhood using a submarine cable. The new PG&E facility receives a high voltage DC feed from eastern Contra Costa County via a submarine cable and was constructed to help offset the recent decommissioning of outdated power generation facilities on the Peninsula.

With the new fleet, until the power demands of the new cars are known, it is difficult to identify if the new cars will draw more power from the third rail for auxiliary services on the cars. There is currently no planned upgrade of increase of supplementary electrical power feeds to the Transbay Tube. PG&E's power capacity in San Francisco and San Mateo County may be affected by the electrification of Caltrain.

Finally, during an emergency event the trains are metered into and out of the tube. From the moment an incident is reported in the tube, trains are slowed down from entering into the tube. Events require establishing tunnel isolation, with the entire stretch from West Oakland to Embarcadero effectively removed from circulation during that time as a result of not being able to operate two ventilation paths simultaneously. With the current vehicle specifications and power supply within the Transbay Tube, BART staff believe that it will be possible to operate 30 trains per hour through the Transbay Tube, as long as the system is running fluid and trains can make consistent runtimes through the tube; existing data identified that West Oakland station does have occurrences of 2m headways (excluding dwell times) and so it should therefore be possible to run scheduled services through West Oakland at around 2m:30s headways (24 trains per hour).

Berkeley Hills Tunnel

In the Berkeley Hills Tunnel CPUC mandates a limit of two trains in each direction at any one time. The reason for the restriction is that during an emergency event, a ventilation path needs to be established. Thereby if the secondary train reports an emergency within the tube, the first train can be removed from the tunnel, restrict other trains from entering, and then establish a ventilation path. The running time between Rockridge and Orinda is 318 seconds (5m:18s). This could be a factor if running express service on the C-Line east of Rockridge.

The Berkeley Hills Tunnel has substations at both ends of the tunnels and therefore power feed to the tunnel is good and the tunnel is shorter than the Transbay Tube. There is a steep grade through the tunnel rising from Rockridge to Orinda of 2.1%, however trains are generally carrying enough momentum in the tunnel, so significant power draw isn't a major problem. There is a potential opportunity for increasing the power supply at the west end of the tunnel.

Speed Restrictions

There are several miles of speed restriction on the L-Line (Dublin Pleasanton) where the speed has been reduced from 70mph to 50mph. This speed restriction has been enforced for the last 10 years. The speed reduction is due to foreign objects incurring into the track way, mainly the result of tire blowouts on the adjacent stretch of I-580. Reconstruction of the Jersey barrier, a higher fence and/or some form of fence impact alarm system that could detect the incursion may be one possibility of addressing the track incursion problem. Some selective reconstruction of the wall has been completed, but no plan has been prepared to comprehensively address the problem.

Certain sections of the BART system are designed for 80 mph operations, however the maximum operating speed BART currently uses today is 70 mph. It is unlikely that 80 mph operating speeds will be used again due to the increase in motor wear and propulsion failures at the higher rate. There are also higher impacts on track maintenance. In addition, the 80 mph segments tend to be short, and the higher speed benefits are limited as train speeds become inconsistent.

New train control technologies would allow BART to utilize more dynamic speed profiles. This technological upgrade would allow BART to select any speed level as opposed to the “fixed gears” of 0, 6, 18, 27, 36, 50 and 70 mph.

Power Supply and Train Control System

Several critical segments of BART’s power supply system and communications/ signaling system are nearing the end of their useful lives. The following provides a summary of power supply and train control within the BART system, more information is contained in Appendix A3.

Train Control – A new modernized train control system is a critical element required to increase system capacity, with an estimated cost for upgrade and replacement of between $600 to $800 million. STEP (System Throughput Enhancement Project) was implemented on M-Line and C-Line sections to reduce block lengths and increase train frequency. Block shortening on the A-Line should be considered to increase capacity on the upper A-Line.

SORS (Sequential Occupancy Release System) is a CPUC imposed secondary block system overlaid on the existing block system. A replacement of SORS with a moving block system or removal in its entirety will require CPUC agreement. Certain segments within the system that contain long blocks limit higher train frequencies. The Systra study identified that SORS is unnecessarily restrictive in many locations around the system, and need not be more restrictive than the underlying signaling.

System Performance is operating at maximum within the current BART system. Capacity investments are required to maintain a state of good repair and provide increased system capacity to ensure that BART can still provide a reliable and stable system.

Power Distribution will require upgrades and capacity improvements to meet the projected 500,000 or greater passengers. Previous studies identified power upgrades but did not distinguish between capacity improvements or state of good repair projects. Power distribution capacity increase and state of good repair projects are estimated to cost about $500 million. Without improvements failures may occur at a greater frequency leading to reliability issues.

Power Supply impacts will need to be studied to ensure that sufficient power needs are provided from the utility providers, especially considering planned electrification of Caltrain and the California High Speed Rail projects. An estimated 33% increase in ridership will likely require a power supply increase around 20% with a peak hour requirement of around 75MW. Power supply capacity increases on the L-Line may be required with higher train frequencies (10 / 12 minute headways) to operate 10 car consists as the original system was only designed to operate 7 car consists.

Yards, Storage and Train Make/Breaks

There is currently restricted storage within the yards during the day, especially on the Peninsula at Daly City and Millbrae, which requires trains to essentially deadhead to the East Bay. With the increase in trains on the Berryesssa – Daly City Line and increasing all trains up to 10 cars all reserve yard capacity on the Peninsula would be used.

There are no restrictions for getting trains into revenue service. For the removal of a train from service due to equipment malfunction, (and assuming reserve trains are available), then the train is replaced in kind at the end of its service, but does require having the reserve trains deployed at key locations around the system. Existing train storage capacity at 6 locations is presented in Table 3.

Table 3: Existing (2013) BART Vehicle Storage

Yard	Storage Capacity
Millbrae	3 Trains at the Platforms 4 TM Zones each can handle 10 car train 3 Storage tracks (2 x 8 cars long; 1 x 7 cars long) Full at night During day 2 train consists stored from the Pittsburg line and 4 short consists from the Richmond Line (full)
Dublin Pleasanton	Storage tracks are 28 cars long Full as this is the location for the makes and breaks for the Dublin Pleasanton Line
Daly City	Full at night During day 7 train consists stored from the Pittsburg line (full) in the yard Daly City midday storage restricts operations at the Daly City shop. Cars being stored are Concord trains which prevents servicing of the Concord shop trains in Daly City
Concord	Trains can no longer be stored at Bay Point, so these are now stored at Concord using some of the spare capacity
Hayward	Hayward used to make and break the Richmond Line trains during the day Hayward does have some reserve capacity
Richmond	Full during the day as a large number of makes and breaks done at Richmond

Downtown Oakland Opportunities

BART does have capacity to carry more riders to existing job centers such as to downtown Oakland as well as to Berkeley, Fremont, and Central Contra Costa County Cities such as Walnut Creek, Pleasant Hill and Concord. Oakland has three downtown BART stations and robust AC Transit bus service and Capitol Corridor train stations. The cities have a walkable street grid as well as supportive zoning. More jobs in downtown Oakland would be well served by the transit system. BART has joined others in advocating for more employment to be located in downtown Oakland as one strategy to optimize use of the existing transit services, although any increase in Oakland employment must be supported by market demand, and likely will occur over a long time period.

Downtown Oakland Challenges

Any service delay (malfunctioning doors, medical emergency, etc.) at 12th or 19th Street on Track 2 (to Fremont / San Francisco) means all westbound/southbound traffic through the Wye halts until the CX (upper level) reversible track can be cleared and passengers moved from lower platform to upper platform. Adding a fourth track would provide additional system redundancy and reduce the impact of the occasional delays. The Systra study identified the C2 Southboun Track between MacArthur and Oakland Wye as a key track segment requiring the highest possible capacity increase to facilitate future growth. In addition all tracks radiating from Oakland Wye are key segments also requiring capacity increases to facilitate future growth. Figure 10 provides a overview of the track configuration at the Oakland Wye.

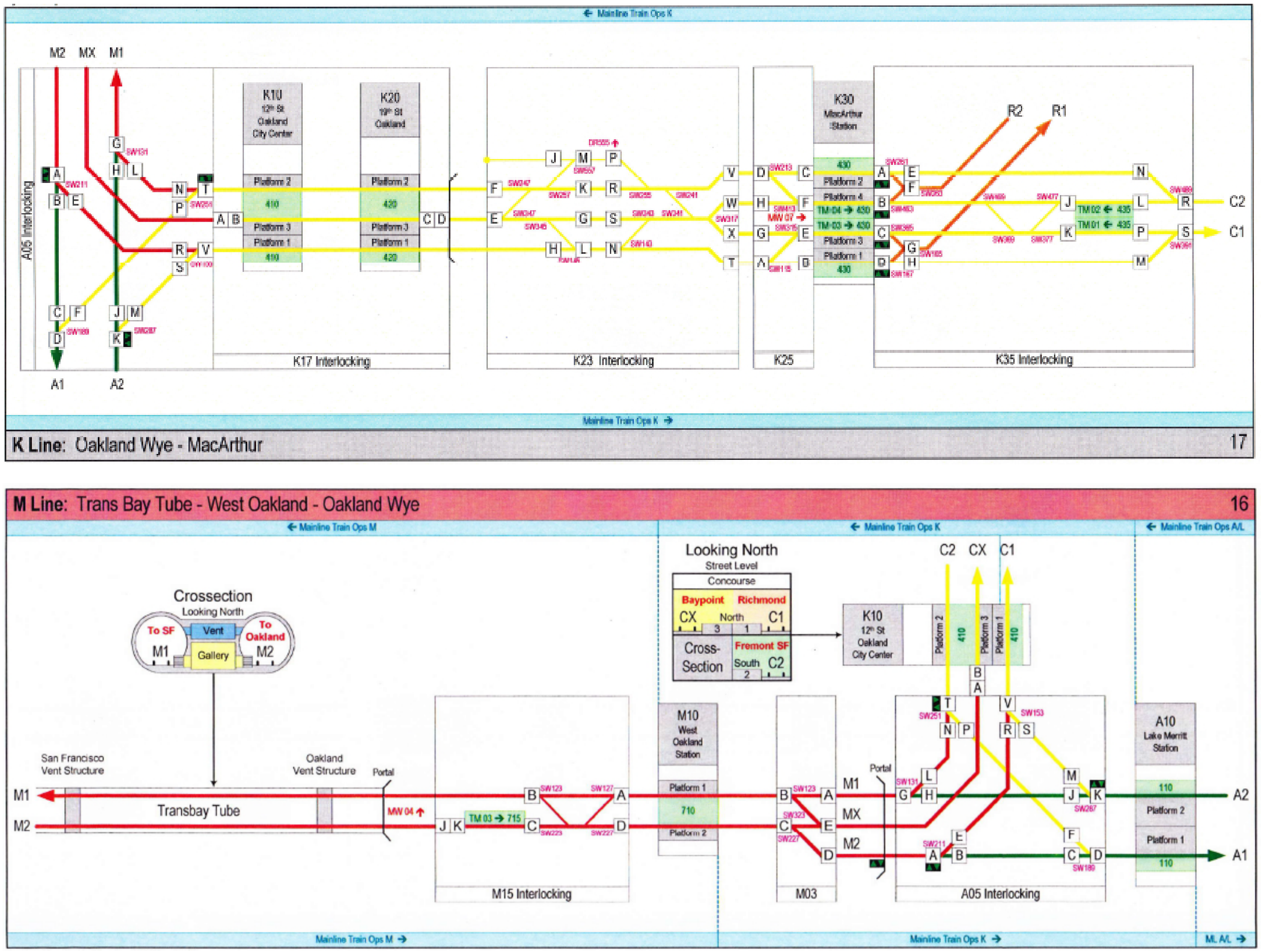


Figure 10: Oakland Wye BART System Track Names

Emergency Operations

The BART Metro zone as envisioned in this document creates a strong foundation for lifeline regional transit service after a major regional emergency such as an earthquake. Investments in this zone can be leveraged to reinforce the BART network and minimize the impact after a disaster. Specifically, SOGR (State of Good Repair) and other strategic investments assist in creating a resilient system, which can maintain service after a regional emergency event.

In the event of an earthquake, the Earthquake Safety Program (ESP) ensures vulnerable parts of the system are safe for riders and BART employees. The ESP work will ensure that portions of the system are upgraded to maintain operations for service from North Berkeley, Rockridge and Coliseum to SF and San Mateo County (see Figure 11). The Berkeley Hills Tunnel is not currently part of the plan.

In the event Transbay Tube service is interrupted or suspended, there would be an enhanced Transbay bus bridge via 19th Street BART station. 20th Street / Broadway / 19th Street BART station (Uptown Transit Center) would be major bus transfer hub in the event of no Transbay service with 2-route service turning at Embarcadero in the West Bay.

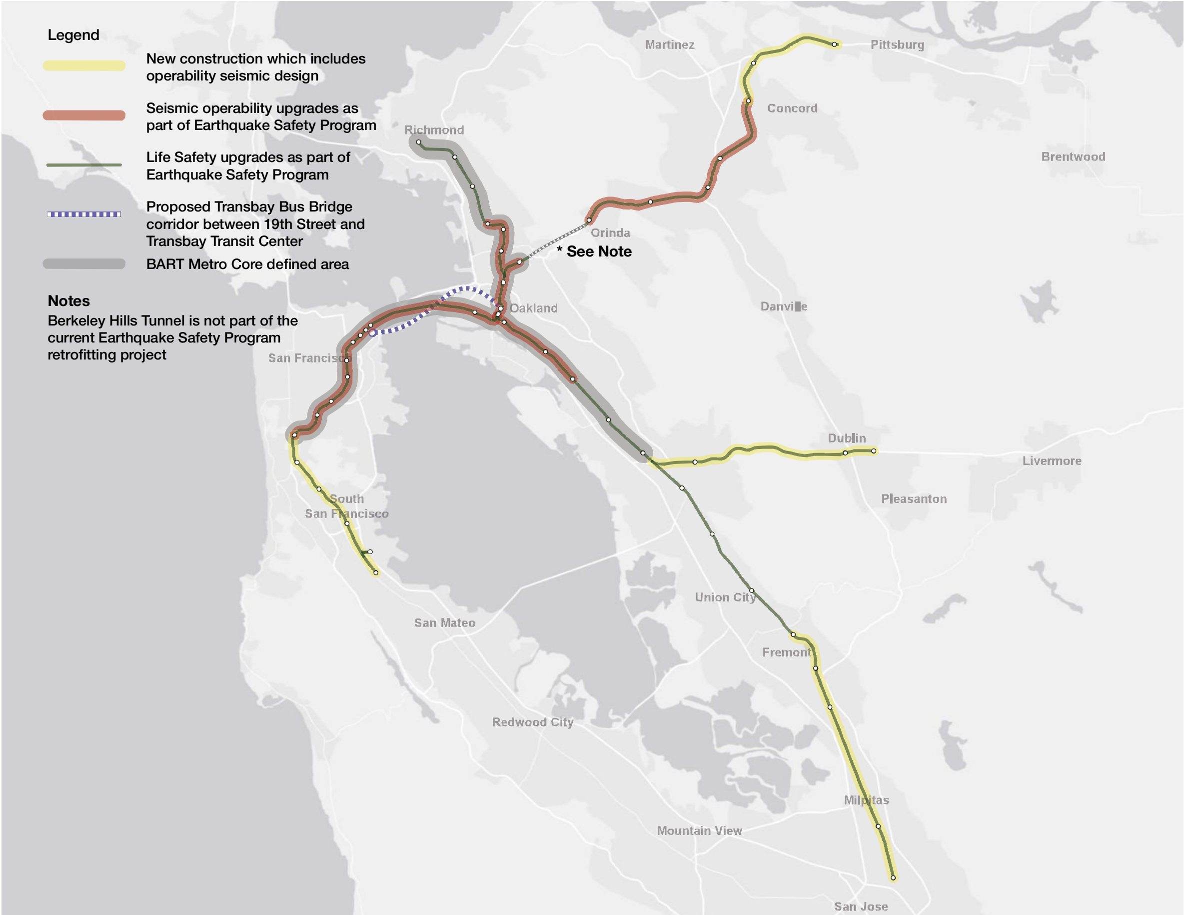


Figure 11: Earthquake Safety Program (2013) and Metro Core

3. Land Use and Forecast Ridership

Plan Bay Area Land Use

The California Legislature, in response to previous legislation to reduce the state's carbon emissions, has mandated through SB375 that regions develop coordinated land use and transportation plans. These Sustainable Communities Strategies (SCS) attempt to reduce vehicle miles traveled (VMT) by clustering new development in areas where people can make more walking, cycling and transit trips.

In the Bay Area, the SCS is called Plan Bay Area[1]. Plan Bay Area makes the regional forecasts as presented in Table 4.

In the past, much of the Bay Area's growth has occurred on the fringes of the region. Plan Bay Area recommends focusing new growth along transit corridors in Priority Development Areas (PDAs). About 65 percent of the Bay Area's employment growth is forecast to occur in PDAs. Figure 12 presents the Priority Development Areas and locations of existing BART stations.

Of these new jobs, about 170,000 are located in East Bay PDAs in cities with BART service, and another 65,000 jobs are projected in San Francisco's PDAs convenient to BART. As a result, about 45 percent of all the new jobs in the East Bay will be convenient to BART, and about 35 percent of all the new jobs in San Francisco. The BART routes in San Mateo County will experience modest employment growth, according to the forecast.

Housing unit growth around BART lines is forecast to be even more concentrated around BART-served PDAs. About 56 percent of new housing units in the East Bay will be nearby to BART, according to the Plan Bay Area forecasts. In San Francisco, about one-third of the forecast housing could be in PDAs convenient to BART. In total, 150,000 to 200,000 housing units could be built around BART stations.

[1] ABAG / MTC's Preferred Plan Bay Area, released in May 2012 was used for this analysis

Table 4: Plan Bay Area 30 Year Forecasts (nine counties)

	2010	2040	Growth	Rate
Population	7,152,000	9,299, 000	2,147,000	30%
Housing Units	2,786,000	3,446,000	660,000	24%
Jobs	3,385,000	4,505,000	1,120,000	33%

Source: May 2012 Preferred Plan Bay Area

Table 5: Summary Table-BART PDA Growth 2010-2040 (MTC/ABAG)

Location	Jobs	Housing Units
San Francisco	65,000	25,000
East Bay	170,000	140,000
TOTAL BART Service Area (3 counties)	235,000	165,000
Percent of TOTAL BAY AREA Growth in BART Service Area PDAs	21%	25%

Source: May 2012 Preferred Plan Bay Area

Land Use and Forecast Ridership

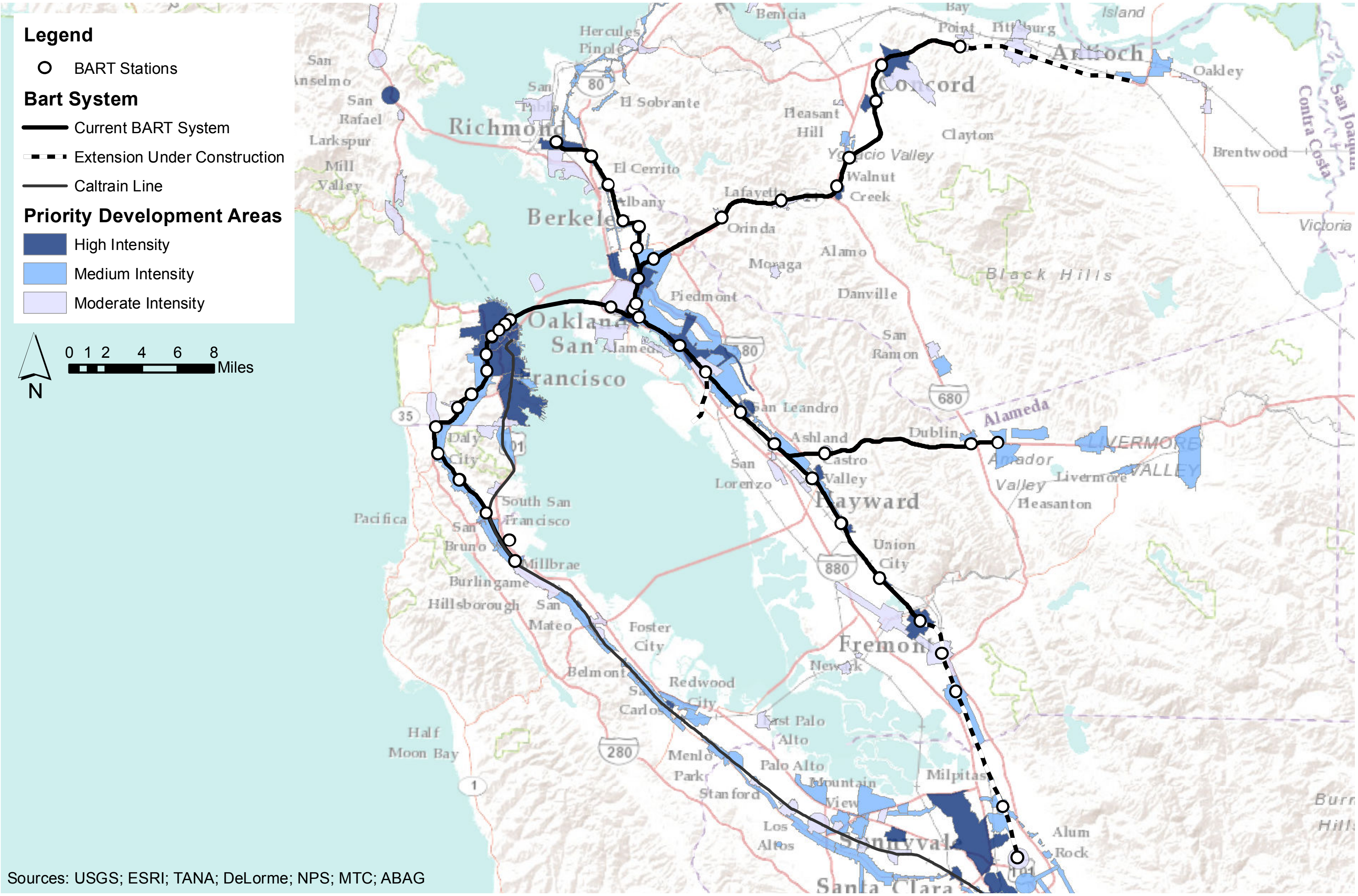


Figure 12: Plan Bay Area Priority Development Areas

Plan Bay Area Forecast Ridership

Using the Plan Bay Area land use assumptions, BART prepared future 2025 ridership forecasts that would be used as a basis for comparing different service plan and operating conditions. Table 6 presents a comparison of current and forecast ridership to identify the main increases in ridership. Ridership forecasts project a 36% increase in ridership from existing (November 2012) ridership, during all time periods throughout the day.

The areas and stations that see the largest increases in daily ridership are focused in the Downtown San Francisco stations. The four Downtown San Francisco stations (Embarcadero, Montgomery, Powell and Civic Center) have a daily combined increase in ridership of around 36,500 riders and are consistent with the high intensity of development projected around the Downtown San Francisco stations. To successfully develop future Service Plans peak hour ridership will be a key driver for the amount of service required. Within the Downtown San Francisco stations, ridership during the AM Peak Hour increases from 32,700 passengers in 2012 to 42,500 (30% percent increase in passengers). During the PM Peak hour, ridership at the Downtown San Francisco stations increases from 34,000 passengers to 45,500 (34% increase in passengers).

Outside of the Downtown San Francisco stations, Balboa Park experiences a dramatic increase in ridership; future projections indicate a daily increase of nearly 8,000 riders, and during the AM Peak Hour ridership increases from 2,900 to 5,400 (82% increase) and during the PM Peak Hour increases from 2,600 to 4,500 (74% increase).

In the East Bay, the downtown Oakland stations see significant increases in daily riders, consistent with planned development. During the AM Peak Hour passenger demand increases from 7,000 to 9,200 (30% increase) and PM Peak Hour increases from 6,700 passengers to 10,000 (48% increase). In addition, Oakland Airport / Coliseum station sees a significant increase in ridership with nearly double the current daily ridership, increasing to 11,500 daily riders. A list of the top 20 stations with the highest ridership increases can be found in Appendix B1 (a separate document).

Table 6: Comparison of Existing and Future Ridership Forecasts (MTC/ABAG)

Time Period	2012	2025	Change %
AM Peak Hour (08:00 to 09:00)	48,092	65,363	35.9%
Midday (10:00 to 16:30)	107,814	146,295	35.7%
PM Peak Hour (17:30 to 18:30)	49,744	70,440	41.6%
Daily	411,872	560,013	36.0%

Source: May 2012 Preferred Plan Bay Area

Travel Demand Management

During the morning peak hour, BART carries close to 20,000 riders through the Transbay Tube, running 23 trains in the peak direction. In total 212 train cars pass through the tube in the peak direction in the AM Peak Hour, with a total carrying capacity of nearly 22,700 passengers. As ridership continues to grow peak hour demand will start to exceed current capacity, resulting in overcrowded trains and the likelihood of passengers not being able to board a train. Additional service will require significant investment, initially in rolling stock and later in facilities. A first step is to investigate options to mitigate or manage peak period demand.

In 2010, BART undertook a Demand Management Study to analyze the effectiveness of demand management strategies that would complement other investments in increasing system capacity. Through implementation of these demand management strategies, BART may be able to postpone costly capacity upgrades in the short term. While demand management strategies will not eliminate the overall need for long term capacity improvements, by managing peak demand, BART may be able to maintain reliable service and operations without the immediate capacity upgrades. The demand management strategies looked to increase productivity of the BART system by:

- Managing peak demand: Spreading peak hour ridership to increase travel in the "shoulder" periods on either side of the peak hour
- Increasing off-peak ridership
- Increasing reverse-peak direction ridership to regional sub-centers
- Considering using any increased revenues to pay for currently unfunded capacity improvements and access enhancements in order to provide higher quality service.
- Investigating approaches to a transit type of "distributed generation." Electric utilities often work with outside providers to use peak only, distributed generation facilities to supplement peak capacity. In the transit context, peak only bus service may provide the same supplemental capacity.

While the SCOA study looks to identify the capital investments that are required to provide significant capacity increases within the BART system, these improvements should be considered in tandem with travel demand management strategies to ensure that BART maximizes its current capacity to its full potential, before investing in costly capacity upgrades.

Transit Competitiveness Analysis

BART Metro is premised on eventual implementation of a service pattern that consists of "Metro Core" and "Metro Commute" services sharing tracks and stations. Metro Core services would, as the name suggests, provide additional service within the core of the system and would operate relatively frequently. Metro Commute services, as the name suggests, is focused on peak periods while still providing systemwide service at other time periods.

A computer tool called the Transit Competitive Index (TCI) was used to analyze potential transit use around all of BART's station areas. Using an array of factors, the TCI tool generates "transit-competitiveness" scores for travel between Transportation Analysis Zones (TAZs) and groups of TAZs as defined by MTC. The TCI tool is neither a ridership model nor a predictor of future ridership; rather, the scores are measures of the attractiveness of transit, relative to autos, for trips between origin-and-destination pairs. Consequently, results from the TCI tool will not necessarily match current BART ridership trends, and should not be expected to predict future BART travel behavior.

In its role as an evaluator of the comparative strength of transit competitiveness between selected origin and destination pairs, the TCI is a relatively sophisticated tool. TCI inputs include standard measures of transit-competitiveness such as population and employment density, but also factors that are not often included in analysis of travel demand, such as parking prices. Analysis was done using demographic information for the year 2005 and for the year 2035. The 2035 scenario was based on the Association of Bay Area Governments 2009 projections with factors applied to forecast 2035 land uses.

A TCI score of 100 represents the regional average and is generally speaking viewed as the "dividing line" between transit un-competitiveness and competitiveness. Thus, any score over 100 should be considered a strong transit travel market. However, TCI scores also demonstrate orders of magnitude of transit competitiveness, and TCI scores in especially transit-competitive markets can exceed 10,000

It is important to note that the TCI is "transit-agnostic," meaning that the tool does not differentiate between transit providers or types of transit service for trips between selected origins and destinations (O/D). This assumption allows the tool "to focus on the comparison between automobile and transit," rather than among transit providers. Regardless, the tool is of particular value to BART Metro for its insights into strong successive station O/D pairs and its ability to identify emerging markets.

TCI Findings and Observations for 2005

In general, year 2005 TCI scores for station areas, when considered for multiple destinations, conform to available data on station usage. However, the analysis provides additional insight into patterns of travel between BART stations:

- The "Downtown SF Core" (the Embarcadero, Montgomery, Powell and Civic Center/UN Plaza combined station areas) is a top destination for trips originating in station areas throughout the system (a perhaps unsurprising finding given that these stations account for fully one-third of all BART weekday station exits)

- The "Downtown Oakland Core" is a top destination from many East Bay station areas

- However, long trips to Downtown San Francisco and Oakland from outlying station areas are not particularly transit-competitive outside of travel during the two peak periods. Indeed, transit is competitive for few trips from outer-ring suburban station areas.

- In general, the shorter the trip, the likelier it is that transit will be competitive. Even medium-distance trips that do not have Downtown San Francisco, Downtown Oakland or Berkeley as a destination do not generally score well

- While average trip lengths on BART are, as one might expect, relatively long, the market for travel between adjacent BART stations, especially those in urban areas, is highly transit-competitive: in fact, the highest overall transit-competitiveness score was for travel between 16th Street Mission and the Downtown SF Core (16,692), and the Ashby-Downtown Berkeley origin-destination pair (4,340) ranked first in the East Bay. High-scoring short trips such as these would appear to support the concept of more frequent "Metro Core" service between nearby urban stations

- Corroborating previous analysis, a strong secondary market for reverse commutes appears to exist between San Francisco and the urban East Bay, with all Peninsula and City stations north of San Bruno registering high TCI scores for trips to Downtown Oakland, and all Market and Mission Street stations exhibiting high scores for trips to Berkeley (a strong market also appears to exist for trips from North Berkeley and North Oakland to 16th Street Mission)

- The analysis revealed the relative strength of smaller but relatively dense employment and educational centers outside of Downtown San Francisco and Oakland, particularly Berkeley, Walnut Creek and Concord. The highest TCI scores at both North Berkeley (2,842) and Ashby (4,340) were for trips to Berkeley, while in central Contra Costa County, the highest scoring TCI for trips originating in Pleasant Hill origins was to Walnut Creek (601) , and North Concord to Concord scored at a similar level (585).

TCI Findings and Observations for 2035

In most cases, origin-and-destination pairings performed similarly in the 2005 and 2035 analyses. Modest growth in transit demand was common, major changes somewhat less so. The following findings focus on these areas of major change, and on areas around new stations. It should be noted and taken into account that future BART stations may have long-term effects on surrounding land uses, and on the market for transit, that are not necessarily accounted for by current land use projections.

- Some trips from outlying stations to Downtown San Francisco that were not transit-competitive in the 2005 analysis are competitive in 2035

- Some origin-destination pairs perform notably better in 2035 than 2005. In particular, the North Concord to Concord pair scores nearly 3,800, compared to a score of 585 in 2005. This likely assumes redevelopment of the Concord Naval Weapons station. Likewise, scores from other station areas that may see extensive transit-oriented development– such as MacArthur and Union City – are higher than before

- The market for travel between central Contra Costa County (Pittsburg/Bay Point line) stations in general, which was relatively strong in 2005, becomes much stronger in 2035

- Along the SVRT extension, demand for travel between Downtown San Jose stations (including Diridon/Arena) and remaining stations is very strong. Interestingly, strong demand also exists between Berryessa and Alum Rock, likely because of anticipated TOD at Berryessa

- High-scoring trips from San Francisco and Peninsula origins to SFO appear more consistently in 2035

- Rockridge by 2035 becomes a more pronounced transit-competitive destination from origins along the Richmond line from North Berkeley to MacArthur

- The Fremont station area shows marked improvement in 2035, for travel to both remaining Fremont line and Warm Springs extension stations as well as to Downtown San Francisco, Oakland and San Jose.

Stations for the Metro Core Service

Based on the TCI market analysis for 2005 the Metro Core service would extend from all the stations between and including El Cerrito del Norte to Coliseum and between and including MacArthur to Daly City. The TCI is just one tool used in this SCOA study to determine potential service turn back points for Metro Core service. Existing infrastructure and potential future infrastructure for turn back tracks is among the other criteria in assessing the boundaries for Metro Core service. Figure 13 shows the Metro Core and Metro Commute area.

Of the 44 existing BART stations, 24 of those stations would be defined in the Metro Core, with the remaining 20 stations in the Metro Commute area. Based upon existing ridership data from 2011, about 75% of the daily demand uses a station within the core, versus only 25% using a station in the commute area. Therefore service should be tailored so that the Metro Core has sufficient capacity to meet the demand, while also ensuring that the stations within the commute area are not over served.

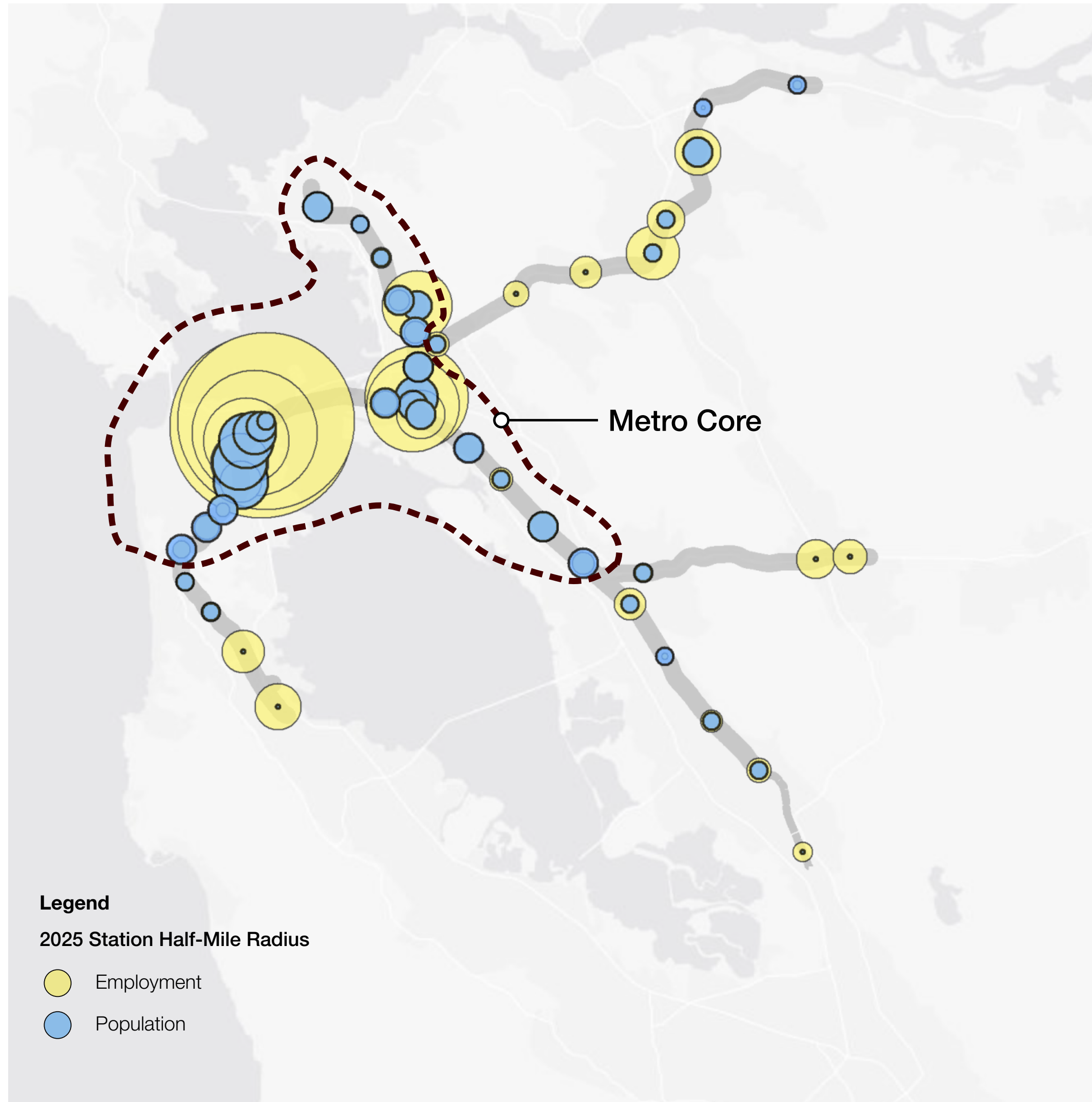


Figure 13: BART Metro Core Area

Station Access Mode

In June 2008 BART completed a comprehensive Station Profile Study documenting the results of a survey of BART customers. One of the components of the study was access mode to BART stations. For BART to realize the potential ridership growth there needs to be sufficient access capacity to the stations.

Of the Downtown San Francisco stations, Walk, Bike and Transit access are the primary access modes for accessing stations with between 85% and 98% of passengers using one of these modes to access the stations. For the Downtown Oakland stations between 79% and 87% of passengers access the stations via Walk, Bike or Transit access.

In the Eastbay core stations Walk, Bike and Transit access ranges between 22% and 90%, with an average 48% of passengers using one of these access modes to access the stations.

For the East Bay commute stations, the primary access mode is Drive Alone, Carpool or Drop-off which range between 54% and 93% of passengers accessing the station through one of these modes. Walk, Bike and Transit access at these stations is significantly lower than the downtown stations, ranging between 7% and 45%.

For the San Francisco commute stations, the primary access modes are Drive Alone, Drop Off or Carpool with between 69% and 80% of passengers using one of these access modes to access the stations.

Downtown and Core stations access modes are closely tied to walk, bike and transit access. As ridership continues to grow, station area planning becomes critical. Walk and bike access are the easiest modes to accommodate, and land use decisions can enhance those opportunities. Beyond that initial area, transit service to BART reinforces good system access.

Table 7: Summary of Station Access Modes

	Walk / Bike / Transit Access Modes	Drive Alone / Drop-off / Carpool
Downtown San Francisco Stations	85% to 98%	14% to 32%
Downtown Oakland Stations	79% to 87%	13% to 21%
East Bay Core Stations	22% to 90%	10% to 78%
East Bay Commute Stations	7% to 45%	54% to 93%
San Francisco Core Stations	34% to 96%	5% to 67%
West Bay Commute Stations	20% to 32%	69% to 80%

Service Strategies Considered

A main theme of the Sustainable Communities Operations Analysis identifies service changes as a means to better align train service with where people travel and how travel relates to land use. BART's current service design is simple – train routes generally begin and end at the ends of the lines, even when there is little ridership on the fringes of the routes. A key service strategy objective is to reduce unproductive service miles as much as possible while still maintaining an attractive rapid transit service.

In preparing the conceptual service plans for analysis, a series of service strategies have been considered based upon industry standard service strategies in use on similar systems. The main service strategies that had been considered are:

- Express and Limited-Stop Service
- Skip-Stop Service
- Zone-Based Service
- Short Line Service
- Coupling
- Timed Transfers
- Schedule Optimization
- Differentiation Between Services
- Service Reconfiguration

The service concepts that have been included in the development of the service plans are summarized in more detail over the following sections.

BART exclusively operates local-stop service making all station stops. Most scheduled trips are "long" trips operating from terminal to terminal (e.g., Pittsburg/Bay Point to San Francisco International Airport). However, some are "short" trips terminating at an interim station (e.g., Pleasant Hill to Montgomery).

BART lines overlap in many segments, and during peak and mid-day "base" periods as many as four lines may combine to provide headways of as little as two minutes in some segments. Headways of individual lines are generally 15 minutes during peak and mid-day periods and 20 minutes evenings and weekends.

By policy, BART schedules include layover and recovery time equivalent to line headway.

Timed transfers are provided at 19th Street Oakland and MacArthur. Transfers are made cross-platform between trains headed in the same direction, but toward different terminuses. This allows BART to operate substantially less service (only three of its five lines) evenings and Sundays while still maintaining a relatively high level of customer service (e.g., trips between Berkeley and San Francisco take only slightly more time, and the physical act of transferring is not especially onerous).

BART trains are of varying lengths, from three to ten cars.

The system is closed for a few hours overnight to allow for maintenance.

A number of infrastructure constraints create challenges for BART to operate more complex service patterns. These include:

- A lack of passing tracks. BART was designed primarily as a "two-track" network with limited opportunities for overtakes of one train by another.
- A lack of turn-back facilities. Similarly, while there are crossover and pocket tracks at several locations, there are a limited number of locations where trains may effectively turn around without impacting opposing traffic.
- Lack of a modernized train control system. BART's attempts in recent years to upgrade to an Advanced Automatic Train Control (AATC) system have not been successful. BART's original fixed-block signaling system remains in operation although major wayside electronic components have been upgraded. The cable plant is perhaps the most vulnerable and is now more than forty years old. This aging system imposes constraints in terms of both capacity (train spacing and speed), flexibility of operations and costs due to the lack of industry support for legacy electronic equipment.
- A highly constrained segment, the Oakland Wye (A05), where all lines converge.
- The southbound C2 track from MacArthur to 12th Street through downtown Oakland is also constrained.
- The high ridership Market Street stations in San Francisco which have very congested platforms during the PM peak period.

Appendix C1 (a separate document) contains further information on the different service strategies considered as part of the study.

Alternatives Considered to Meet Future Demand

Service Reconfiguration

Options for reconfiguration are limited by a number of factors, including cost and scheduling as well as infrastructure constraints. Networks built with redundancy and flexibility in mind – with passing tracks, switches, crossovers, pocket tracks and track connectors – may present an array of routing options. The New York City subway famously reconfigures service on a regular basis to accommodate rotating maintenance requirements. After the events of September 11, 2001, temporary service configurations were developed and implemented using track connectors that had not seen revenue service for decades.

The BART system, of course, does not provide a great deal of redundancy or flexibility. Nonetheless, the agency has operated a number of different service patterns over time, including a series of configurations for SFO/Millbrae service and three distinct system-wide configurations that are in current operation (during weekdays, evenings and Sundays, and Saturdays).

There are two basic reasons to consider service reconfiguration:

- Changes to ridership patterns
- Productivity and cost-effectiveness considerations

An agency that is in many ways BART's closest peer, the Washington Metropolitan Area Transportation Authority (WMATA), recently approved changes to Blue, Yellow, Orange and Green Line service (precursor for the Phase 1 Silver Line service) designed to alleviate peak-period crowding and reliability problems and to reflect changing ridership patterns. Route changes involved peak hour train diversion to different corridors and termini. These changes, it has been estimated, should provide direct benefits to 43 percent of all peak period travelers and result in a net reduction in aggregate passenger wait time of 612 hours per peak period.

WMATA's changes will require no additional infrastructure. However, costs will be incurred in the form of communication of changes, including replacement signage and new maps.

5. Service Plan Development

The Sustainable Communities Operations Analysis considered both best practices in rail service design and future year demand to develop a suite of service options.

In development of the service plans, a Base Case service plan was developed based upon the year 2025 within the BART 2012 Fleet Management Plan, and various options were also identified, some with more vehicles. The Base Case was used to provide a baseline comparison for the test scenarios. A number of test service plan scenarios were developed to identify strategies that would provide the best gains against the key performance indicators and would be suitable for implementation. A brief summary of the test scenarios follows.

Base Case Service Plan

Service plan development began with a constrained system:

- Total fleet size of 775 (2012 New Vehicle Procurement with All Options)
- 24 trains per hour in Transbay Tube

The service plan operates in a similar pattern to current 2013 service plus the extension of service to Berryessa. Trains lengths were increased to fleet capacity to minimize crowding on trains and an additional Transbay peak hour train was assumed.

Base Case – Peak Commute Period

During the peak commute period, service is provided on base 15 minute headway with additional peak hour overlay service. The following provides a summary of the peak commute period service:

- Red Line - 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Berryessa
- Yellow Line – 4 trains per hour between Pittsburg / Bay Point and SFO; 2 trains per hour between Pittsburg / Bay Point and Daly City; and 4 trains per hour between Pleasant Hill and Daly City
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 4 trains per hour between Berryessa and Daly City; and 2 trains per hour between South Hayward and Daly City

Figure 14 presents a schematic plan showing peak hour service during the peak period for the Base Case.

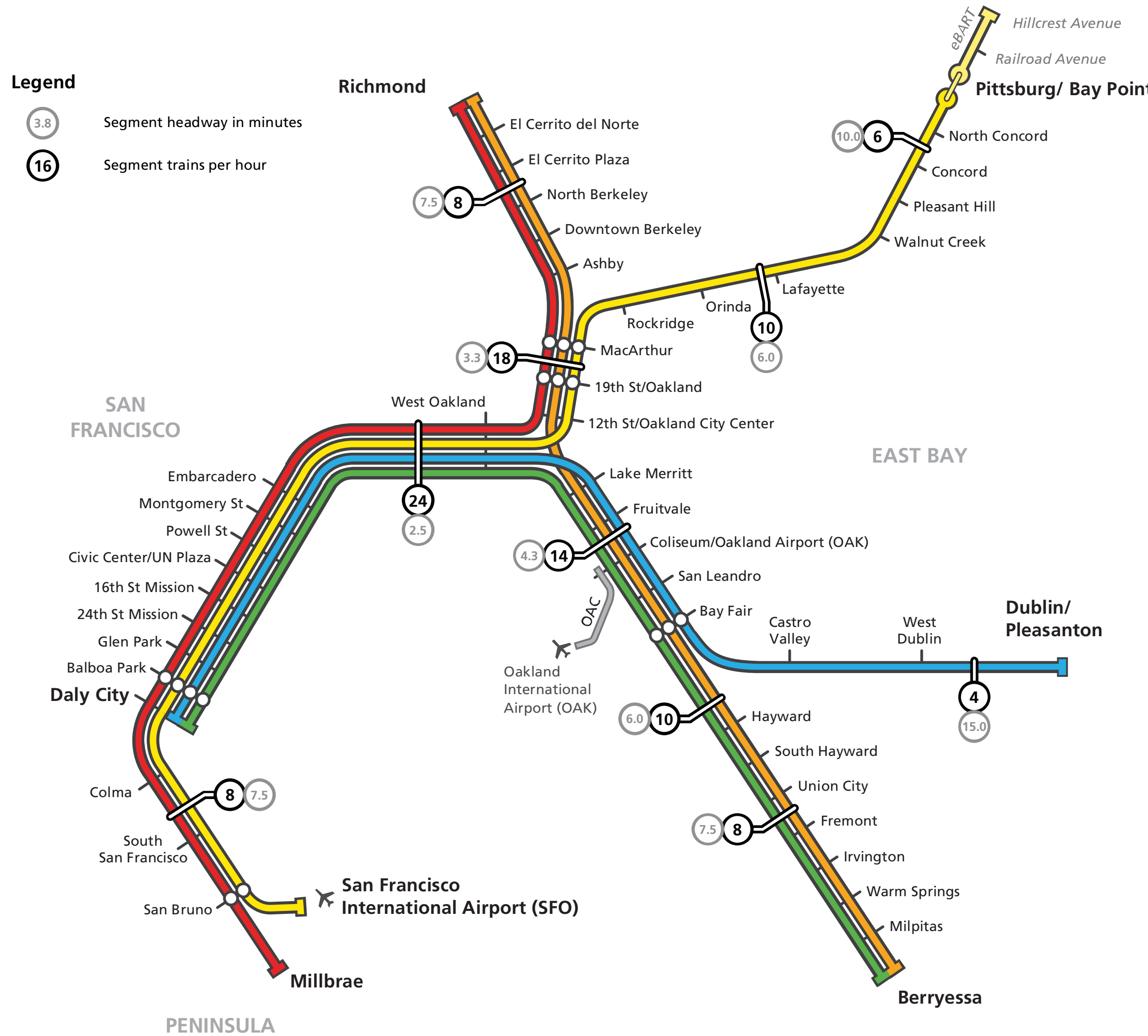


Figure 14: Base Case Peak Period Service Plan

Base Case – Midday

The midday service uses a base headway of 15 minutes on all routes, with train lengths optimized to provide sufficient capacity while minimizing car miles. The following summarizes service during the midday:

- Red Line - 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Berryessa
- Yellow Line – 4 trains per hour between Pittsburg / Bay Point and SFO
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 4 trains per hour between Berryessa and Daly City

Figure 15 presents a schematic plan showing hourly midday service for the Base Case.

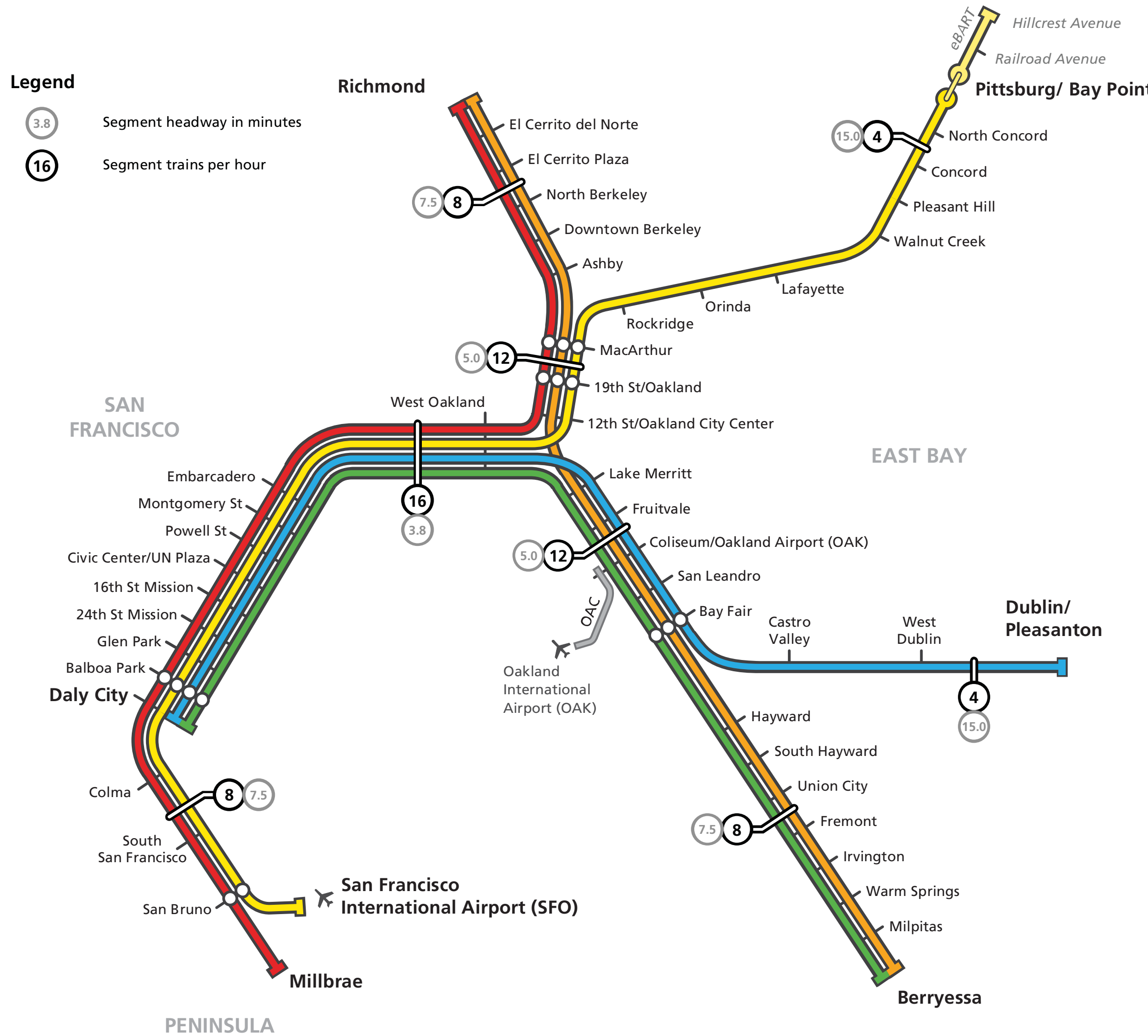


Figure 15: Base Case Midday Service Plan

Base Case – Evenings and Weekends

During the evenings and weekends under the Base Case service plan, service is provided on base 20 minute headway on all routes and mirrors BART's September 2012 schedule. Service on the Red Line between Richmond and Millbrae will cease after 8:00pm with service to Millbrae provided by extension of the Yellow Line. The Green Line will also cease service after 7:00 pm with passengers transferring from the Blue Line to the Orange Line at Bay Fair to reach stations towards Berryessa. The following summarizes the service during evenings and weekends:

- Red Line - 3 trains per hour between Richmond and Millbrae (until 8pm)
- Orange Line – 3 trains per hour between Richmond and Berryessa
- Yellow Line – 3 trains per hour between Pittsburg / Bay Point and SFO (extends to Millbrae after 8pm)
- Blue Line – 3 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 3 trains per hour between Berryessa and Daly City (until 7pm)

Figure 16 presents a schematic plan showing hourly service during evening / weekends for the Base Case.

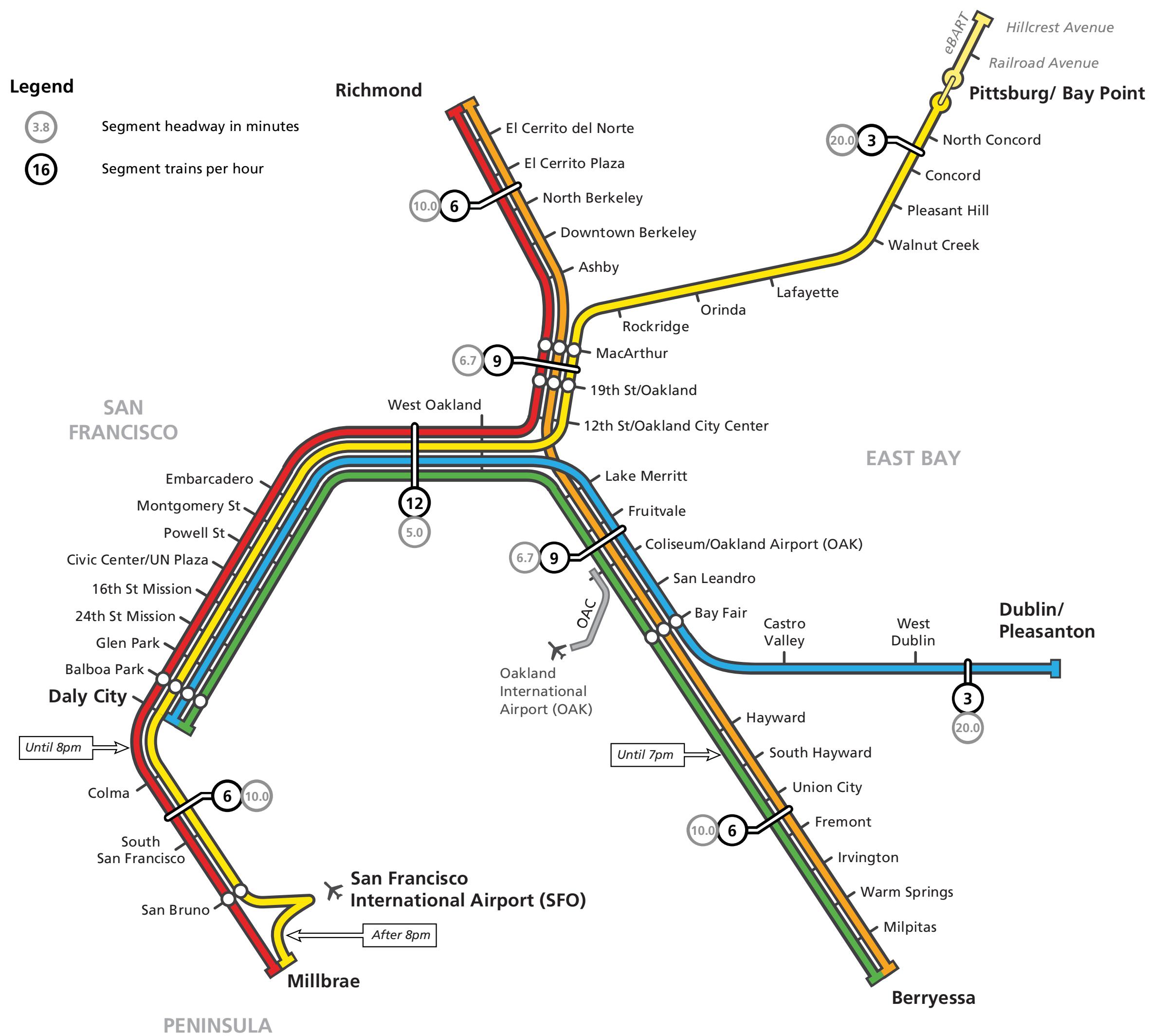


Figure 16: Base Case Evenings / Weekends Service Plan

Base Case results

The key findings from the Base Case analysis indicates that 775 peak vehicles is not adequate to accommodate the projected ridership and causes significant crowding levels, particularly on service through the Transbay Tube. In addition there is limited flexibility for special events and adding extra trains. A fleet of around 850 vehicles would reduce crowding by allowing more 10 car trains to operate, in addition to allowing more flexibility for adding special event service.

During the off-peak times (evenings / weekends) with 20 minutes service, long train lengths are required to meet capacity within the core, but over-serve demand at the outer extents of the system towards Pittsburg / Bay Point; Dublin / Pleasanton; and Fremont / Berryessa.

The Base Case indicates that system capacity utilization would be around 41.5% with annual car miles of 98.2 million miles. Car hours would be 3.0 million hours. With the constrained fleet of 775 cars, average peak hour crowding on all routes at the Transbay Screenline would be approximately 123 passengers per car. Crowding on the Green Line during the peak hour in the peak direction would be 131 passengers per car. Note that the Base Case Scenario provides inadequate Transbay capacity.

Table 8 presents a summary of the Key Performance Indicators (KPI) for the Base Case, further KPI values can be found in Appendix D1 (a separate document).

Table 8: Base Case KPI Results

Performance Measure	Base Case
Capacity Utilization	42%
O&M Cost	$577 million
Farebox Recovery Ratio	84%
Peak Fleet Requirement (cars)	775
Transbay Peak Passengers per Car (Peak Direction)	123*
Transbay Peak Capacity (passengers per hour, peak direction)	23,325

** Exceeds BART Threshold of 107 passengers per car*

Enhanced Base Case Service Plan

The Enhanced Base Case service plan was developed to provide a closer comparison to the future service plans without constraining the overall fleet size. The Enhanced Base Case uses an identical service plan for all time periods to the Base Case, but increases the overall fleet size to 896 vehicles providing 24 trains per hour peak direction with all trains 10 cars long. Adequate Transbay Capacity is provided in the Enhanced Base Case Service Plan. The Enhanced Base Case would require an additional 120 vehicles more than the Base Case. With the additional cars and full 10 car train consists, the average passengers per car reduces to 112 (from 123 in the Base Case).

As identified in the Base Case, during off-peak times, longer trains are required to meet the capacity needs within the core; however this results in an oversupply of service towards to outer lying segments of the system.

Table 9 provides a summary of the Enhanced Base Case KPI Results, further KPI values can be found in Appendix D1.

Table 9: Enhanced Base Case KPI Results

Performance Measure	Base Case Enhanced
Capacity Utilization	40%
O&M Cost	$592 million
Farebox Recovery Ratio	82%
Peak Fleet Requirement (cars)	896
Transbay Peak Passengers per Car (Peak Direction)	112*
Transbay Peak Capacity (passengers per hour, peak direction)	25,680

** Exceeds BART Threshold of 107 passengers per car*

Service Plan Development
Scenario 1 Service Plan

Scenario 1 – Staggered Line

Scenario 1 maintained a similar base service to the Base Case, with the inclusion of short line service on the current yellow line. The current Yellow Line would be split into a long line / short line service operating between Pittsburg Bay Point and 24th Street during the peak period. A new short line service would operate between Pleasant Hill and SFO airport. The Green Line service operates between Daly City and Berryessa during the peak commute period. During midday and evenings, the Green Line service operates between Daly City and South Hayward. The base headway for Scenario 1 would be 15 minute headways, with 24 Transbay trains per hour, peak direction. The following provides a summary of the service for Scenario 1:

Peak Commute Period

- Red Line - 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Berryessa
- Yellow Line – 4 trains per hour between Pittsburg / Bay Point and 24th Street; and 2 trains per hour between Pittsburg / Bay Point and Daly City
- Purple Line – 4 trains per hour between Pleasant Hill and SFO
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 4 trains per hour between Berryessa and Daly City; and 2 trains per hour between South Hayward and Daly City

Midday

- Red Line - 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Berryessa
- Yellow Line – 4 trains per hour between Pittsburg / Bay Point and 24th Street
- Purple Line – 4 trains per hour between Pleasant Hill and SFO
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 4 trains per hour between Berryessa and Daly City

Evenings / Weekends

- Red Line - 3 trains per hour between Richmond and Millbrae (until 9pm)
- Orange Line – 3 trains per hour between Richmond and Berryessa
- Yellow Line – 3 trains per hour between Pittsburg / Bay Point and SFO
- Purple Line – Doesn't operate Evenings / Weekends
- Blue Line – 3 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 3 trains per hour between South Hayward and Daly City (until 9pm)

Key findings from the Scenario 1 analysis indicate that a fleet size approaching 900 vehicles would be adequate to meet the near to midterm capacity needs. Service hours are extended on the Red and Green lines in the off-peak hours (evenings / weekends) to 9pm, which helps in getting vehicles back to the yards, helping to reduce the non-revenue car miles.

As with the Base Case Enhanced, during off-peak times, longer trains are required to meet the capacity needs within the core, however this results in an oversupply of service towards to outer lying segments of the system.

With a fleet size of 896 vehicles, and operating 10 car trains, with 24 trains per hour Transbay in the peak direction, the average passenger load per car is 112, consistent with the Base Case Enhanced. Figure 17 presents a schematic plan showing peak hour service during the peak period for Scenario 1.

Table 10 presents a summary of the key performance measures for Scenario 1, further KPI values can be found in Appendix D1.

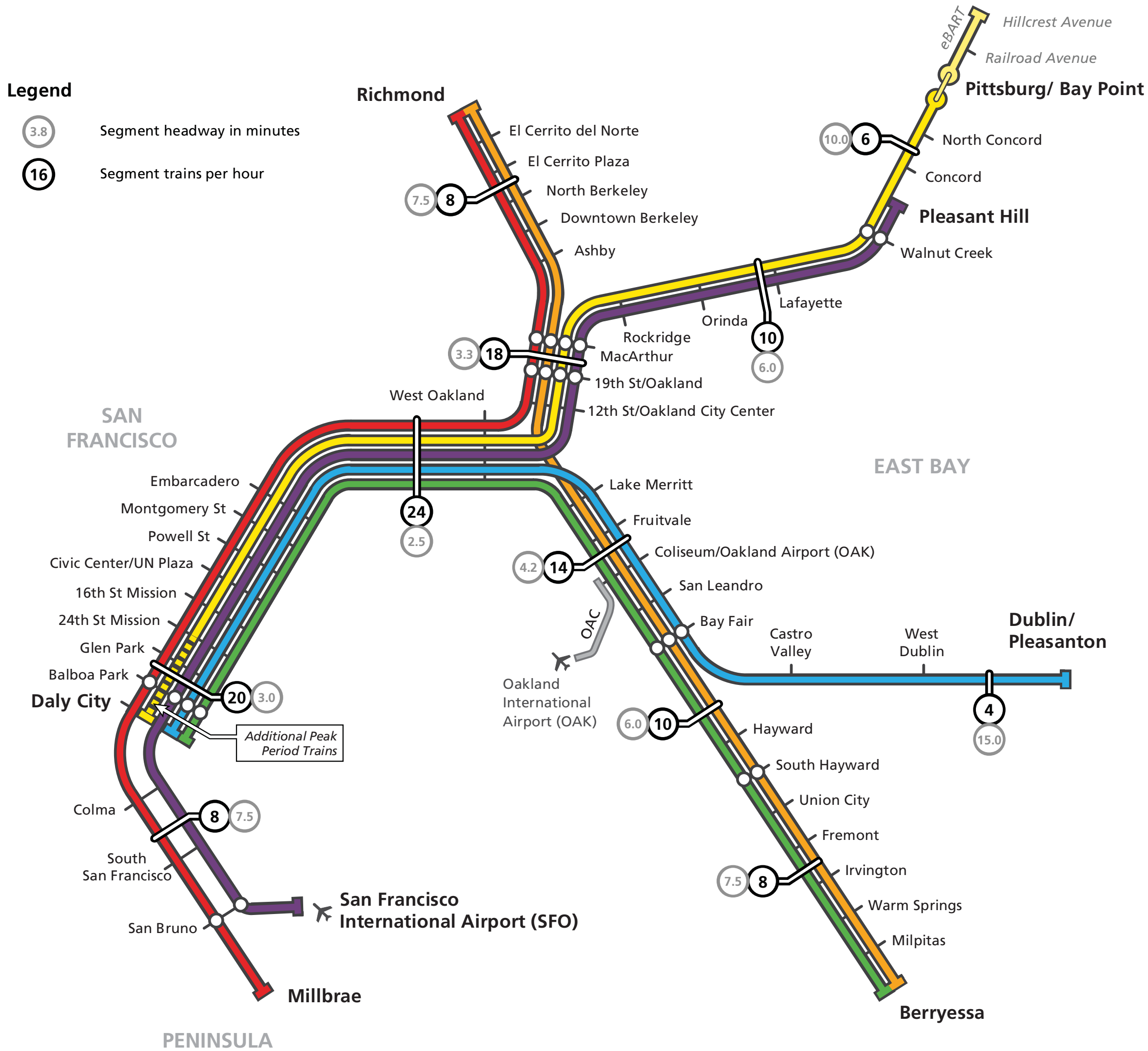


Figure 17: Scenario 1 Peak Commute Period Service Plan

Table 10: Scenario 1 Results

Performance Measure	Base Case Enhanced	Scenario 1 Results
Capacity Utilization	40%	40%
O&M Cost	$592 million	$592 million
Farebox Recovery Ratio	82%	82%
Peak Fleet Requirement (cars)	896	896
Transbay Peak Passengers per Car (Peak Direction)	112*	112*
Transbay Peak Capacity (passengers per hour, peak direction)	25,680	25,680

** Exceeds BART Threshold of 107 passengers per car*

Scenario 2 – Express Service

Scenario 2 builds upon Scenario 1 service plan and introduces express train service on the Yellow and Purple lines. The Yellow Line operates between Pittsburg / Bay Point and Daly City, with the provision of express service skipping Lafayette, Orinda and Rockridge stations. The stations skipped would be served by a local service on the Purple Line. The Purple Line would operate between Pleasant Hill and SFO International Airport. Express service would operate on the Purple Line skipping Colma and South San Francisco stations, these stations would be served by the Red Line. The base headway for Scenario 2 is 15 minute headways, with 24 Transbay trains per hour, peak direction. The following provides a summary of the Scenario 2 service:

Peak Commute Period

- Red Line - 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Berryessa
- Yellow Line – 6 trains per hour between Pittsburg / Bay Point and Daly City
- Purple Line – 4 trains per hour between Pleasant Hill and SFO
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Colma
- Green Line – 4 trains per hour between Berryessa and 24th Street; and 2 trains per hour between South Hayward and Daly City

Midday

- Red Line – 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Berryessa
- Yellow Line – 4 trains per hour between Pittsburg / Bay Point and Daly City
- Purple Line – 4 trains per hour between Pleasant Hill and SFO
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Colma
- Green Line – 4 trains per hour between Berryessa and 24th Street

Evenings / Weekends

- Red Line - 3 trains per hour between Richmond and Millbrae (until 9pm)
- Orange Line – 3 trains per hour between Richmond and Berryessa
- Yellow Line – 3 trains per hour between Pittsburg / Bay Point and SFO
- Purple Line – Doesn't operate Evenings / Weekends
- Blue Line – 3 trains per hour between Dublin / Pleasanton and Colma
- Green Line – 3 trains per hour between South Hayward and 24th Street (until 9pm)

Key findings from the Scenario 2 analysis indicates that the express service would save the average rider (on the express lines) around 3 minutes, but would also cut service to the skipped stations. In addition to the cut in service to some of the stations, trains loads along the Yellow/Purple Lines become unbalanced with more riders preferring to use the express service rather than the local. Express service also requires that other trains within the system are on a compatible sequence which is more difficult to achieve, particularly through Oakland and San Francisco.

Extending the Blue Line service to Colma provides a strategic link to San Mateo County. However, modifications at Colma station completed in the last 10 years require that trains are sequenced in a certain order to avoid conflicting movements and allow the trains to turn at the platform, which has some constraints on the ability to turn the trains at Colma.

As with the Base Case, during off-peak times, longer trains are required to meet the capacity needs within the core, however this results in an oversupply of service towards to outer lying segments of the system.

With a fleet size of 918 vehicles, and operating 10 car trains, with 24 trains per hour Transbay in the peak direction, the average passenger load per car is 112, consistent with the Base Case Enhanced. Figure 18 presents a schematic plan showing peak hour service during the peak period for Scenario 2. Table 11 presents a summary of the key performance measures for Scenario 2, further KPI values can be found in Appendix D1.

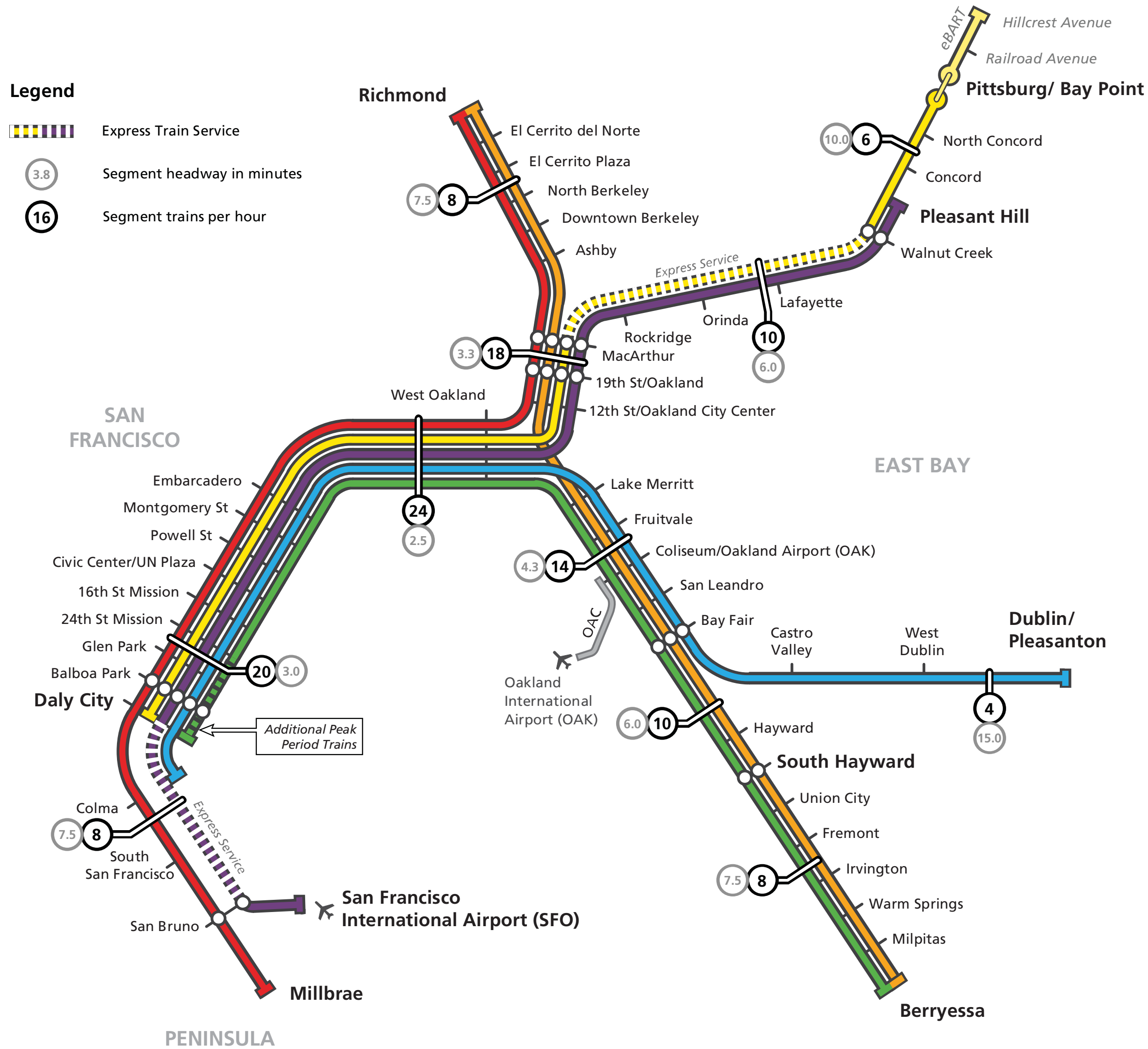


Figure 18: Scenario 2 Peak Commute Period Service Plan

Table 11: Scenario 2 Results

Performance Measure	Base Case Enhanced	Scenario 2 Results
Capacity Utilization	40%	46%
O&M Cost	$592 million	$585 million
Farebox Recovery Ratio	82%	83%
Peak Fleet Requirement (cars)	896	918
Transbay Peak Passengers per Car (Peak Direction)	112*	112*
Transbay Peak Capacity (passengers per hour, peak direction)	25,680	25,680

** Exceeds BART Threshold of 107 passengers per car*

Scenario 3 – 10 minute Base Headway

Scenario 3 changes the base headway on all routes to 10 minutes and provides 30 Transbay trains peak hour and peak direction during the peak commute period. The Yellow Line would operate between Pittsburg / Bay Point and Glen Park, using a new turn back at Glen Park. Express service would skip Lafayette, Orinda and Rockridge stations on the Yellow Line. The stations skipped would be served by a local service on the Purple Line. The Purple Line would operate between Pleasant Hill and SFO International Airport. Express service would operate on the Purple Line skipping Colma and South San Francisco stations. The Orange Line would operate between Richmond and Bay Fair every 10-minutes or six times per hour in each direction.

Blue Line service operates between Daly City and Dublin / Pleasanton at all times. The Green Line service operates between Daly City and Berryessa at all times. However, during midday and evenings / weekends, the Blue and Green lines would couple / de-couple at Bay Fair station. Between Daly City and Bay Fair a 10 car train would be in service, at Bay Fair station the train would de-couple with 5 cars proceeding towards Dublin / Pleasanton and 5 cars proceeding towards Berryessa. In the reverse direction the 5 cars from Berryessa and the 5 cars from Dublin / Pleasanton would couple at Bay Fair and proceed to Daly City as a single 10 car train. This would require the Bay Fair Connector project to be completed to enable coupling / de-coupling of service.

Orange Line service would operate between Richmond and Berryessa during the peak commute period, during midday and evenings / weekends Orange Line service would terminate at Bay Fair. The following provides a summary of the Scenario 3 service:

Peak Commute Period

- Red Line - 6 trains per hour between Richmond and Millbrae
- Orange Line – 6 trains per hour between Richmond and Bay Fair
- Yellow Line – 6 trains per hour between Pittsburg / Bay Point and Glen Park
- Purple Line – 6 trains per hour between Pleasant Hill and SFO
- Blue Line – 6 trains per hour between Dublin / Pleasanton and Daly City
- Green Line – 6 trains per hour between Berryessa and Daly City

Midday

- Red Line – 6 trains per hour between Richmond and Millbrae
- Orange Line – 6 trains per hour between Richmond and Bay Fair
- Yellow Line – 6 trains per hour between Pittsburg / Bay Point and Glen Park
- Purple Line – 6 trains per hour between Pleasant Hill and SFO
- Blue Line – 6 trains per hour between Dublin / Pleasanton and Daly City (couples with Green Line at Bay Fair)
- Green Line – 6 trains per hour between Berryessa and Daly City (couples with Blue Line at Bay Fair)

Evenings / Weekends

- Red Line - 4 trains per hour between Richmond and Millbrae
- Orange Line – 4 trains per hour between Richmond and Bay Fair
- Yellow Line – 4 trains per hour between Pittsburg / Bay Point and SFO
- Purple Line – Doesn't operate Evenings / Weekends
- Blue Line – 4 trains per hour between Dublin / Pleasanton and Daly City (couples with Green Line at Bay Fair)
- Green Line – 4 trains per hour between Berryessa and Daly City (couples with Blue Line at Bay Fair)

Key findings for the Scenario 3 analysis indicate that 10 minute service during the peak commute period may over-serve the projected demand at the outer extents of the system.

The express service performs better in balancing loads between the Yellow and Purple lines with the increased frequency, however the express service still requires that other trains are sequenced properly and carefully. This is difficult to achieve in the Oakland and San Francisco regions, and is made more complex with the increased train frequencies.

Higher train frequencies restricts the ability to turn trains in opposing traffic (24th Street and Montgomery) and therefore requires a dedicated pocket track in San Francisco, a suitable location identified is close to the Glen Park station.

Higher train frequencies puts more wear on the vehicles and track systems which in turn results in greater maintenance requirements. The higher train frequencies will also result in a greater power requirement within the system and significantly improved train control system.

Coupling of service at Bay Fair during midday and evenings / weekends helps to provide sufficient capacity to the core, while also providing a greater frequency of service to the outer lying portions of the system (Colma-Dublin/

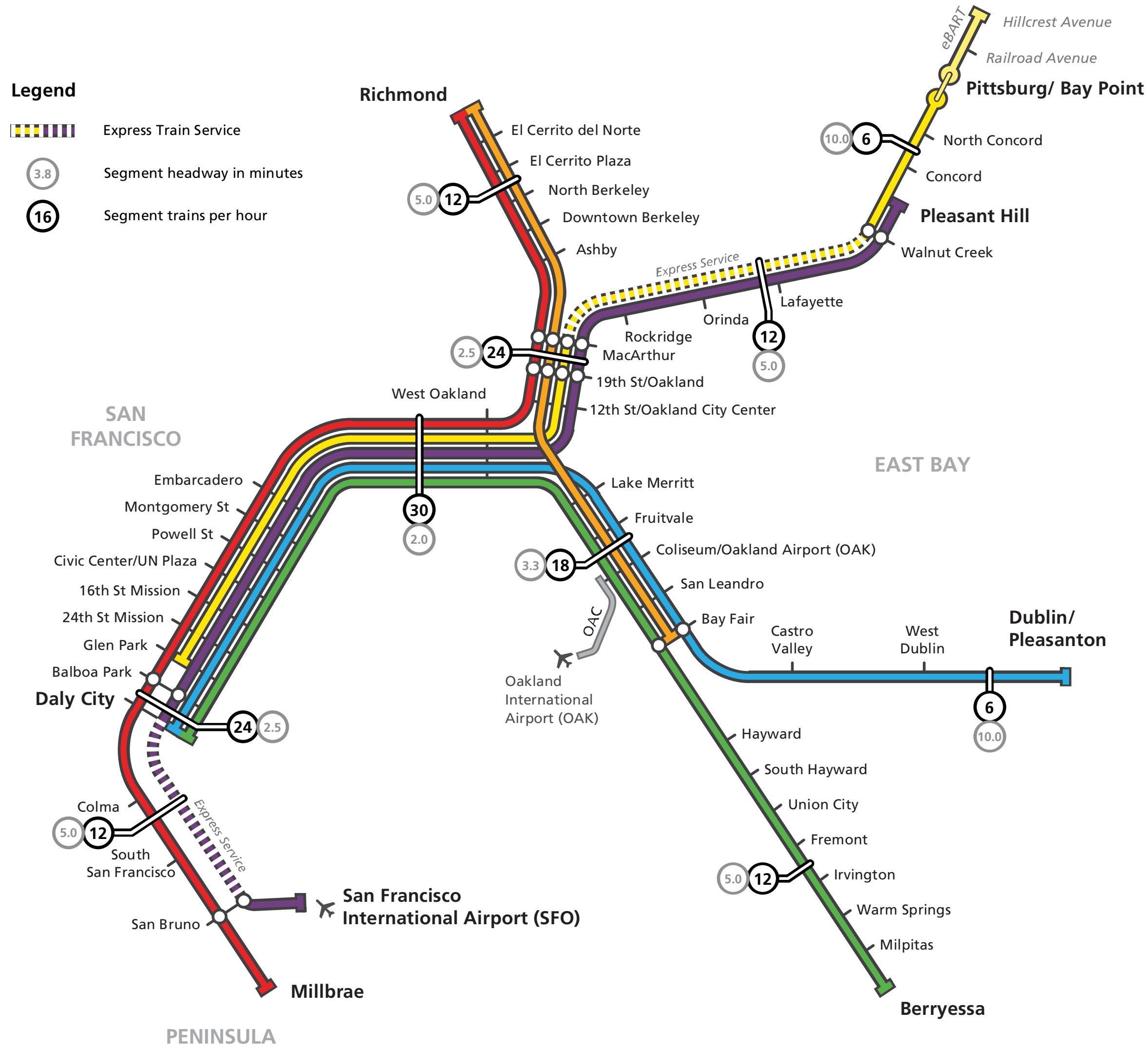


Figure 19: Scenario 3 Peak Commute Period Service Plan

Pleasanton, Hayward-Berryessa). To accommodate the coupling of service at Bay Fair, the station would require significant modifications and expansion to a 3 track station with two island platforms.

With a fleet size of 972 vehicles, and operating 10 car trains, with 30 trains per hour Transbay in the peak direction, the average passenger load per car is 90, significantly lower than the Base Case Enhanced, this indicates that spare capacity would be available on the cars during the peak period. This service plan would be more suited to higher ridership than the analyzed 560,000 daily trips. Figure 19 presents a schematic plan showing peak hour service during the peak period for Scenario 3. Table 12 presents a summary of the key performance measures for Scenario 3, further KPI values can be found in Appendix D1.

Table 12: Scenario 3 Results

Performance Measure	Base Case Enhanced	Scenario 3 Results
Capacity Utilization	40%	39%
O&M Cost	$592 million	$643 million
Farebox Recovery Ratio	82%	76%
Peak Fleet Requirement (cars)	896	972
Transbay Peak Passengers per Car (Peak Direction)	112*	90
Transbay Peak Capacity (passengers per hour, peak direction)	25,680	31,886

** Exceeds BART Threshold of 107 passengers per car*

6. Development of Phased Service Plans

In the development of the Scenarios tested, there are two important components that relate to how the service plans are developed. The first component relates to the scheduling of service, and the second is developing a schedule that meets the travel demand requirements. These two key components are discussed further in the following sections.

Schedule Development

In the development of the schedules it is important to consider how trains serving different markets are sequenced to provide even train headways and a reliable service. In the East Bay, trains serve two distinct areas North (Richmond and Pittsburg / Bay Point) and South (Dublin / Pleasanton and Berryessa). The branches of service converge as they get closer to the Transbay Tube to provide a trunk service through Downtown San Francisco and beyond towards the Peninsula.

The schedules are developed by providing a North-South-North-South train pattern through the Transbay Tube. By operating the North-South pattern, even train headways can be achieved in the East Bay when these branches merge. In addition, the sequencing of trains in these patterns also helps to provide a consistent flow of passengers on the platform and at the stations, reducing congestion and queuing within the stations; this is done by providing an even headway between services particularly serving the core stations (MacArthur – Bay Fair – Daly City). This pattern of service helps also speed up the recovery time after a delay in service. The North-South sequencing of trains also works well with service to SFO Airport and Millbrae by extending the North service to these destinations, as this then provides even headways for service between Daly City and SFO / Millbrae. Each of the scenarios developed, maintained this sequencing pattern and these are continued through into the Phase 1 and 2 service plans. This sequencing of trains works well for the BART system and is a core service design criteria in all options.

Travel Demand

The travel demand component of the service plans relates to how much train service is provided to meet the projected demand. BART has different demand patterns depending upon the time of the day and location within the system. During the morning commute patterns there is high demand on the branches of the system coming into San Francisco. During the midday the key areas of demand are within the core sections (MacArthur – Bay Fair – Daly City), with significantly lower demand on the outer sections of the system. There are two ways in which train capacity can be tailored to meet the demand; the first is to vary the length of train consists (up to the maximum of 10 cars per consist), the second is to provide more trains. Both methods require a train fleet that has sufficient cars to provide enough service during the peak times.

The service planning goal for developing the service plans is that during midday, evenings / weekends sufficient capacity is provided so that on average every seat is occupied (loads of around 60 passengers per car on average), while during the peaks some standees should be accommodated increasing the average load to around 100 passengers per car.

Development of Future Service Plans

The findings from Scenarios 1 and 2, both operating 24 trains per hour peak direction during the peak commute period, found that average crowding on all peak direction Transbay service during the peak period exceeded BART's threshold of 107 passengers per car. Scenario 3 increased peak direction Transbay service to 30 trains per hour during the peak commute period, which provided too much service during the peak period.

As ridership increases over the coming years, BART should adopt a phased increase in train capacity to ensure that it can still maintain acceptable levels of crowding and service for riders. The first stage will require increasing the train fleet to around 900 cars. This enables BART to operate 24 trains per hour peak direction; with all Transbay trains during the peak commute period in 10 car consists. Under this assumption, BART could provide sufficient service to meet an estimated 500,000 riders systemwide. However as ridership increases beyond 500,000 these two scenarios do not have sufficient Transbay service and the number of Transbay trains per hour would need to be increased.

The findings of Scenarios 1 to 3 informed and shaped the two service plans that could be considered for future operations. Phase 1 service plan is an interim service plan that can be implemented with an increase in the overall vehicle fleet in excess of 775 vehicles, with ridership levels of up to 500,000 average weekday riders. Phase 2 service plan considers a further increase of fleet size to around 1,000 vehicles and could accommodate ridership levels between 500,000 and 750,000 riders.

Phase 1 Service Plan – Key Projects

The Phase 1 service plan aims to optimize the current BART system with necessary capital investment projects that can be implemented in the near to mid-term. The service plan would require additional turn-back locations and would provide more direct Transbay service nights and weekends in the urban core.

The key component projects required for the Phase 1 service plan include:

- 24th Street / Mission turn back upgrade to reliably accommodate the turning of up to 4 trains per hour during the peak period
- Richmond Crossover project, enabling service to turn at the Richmond station platforms rather than using the transfer tracks in Richmond Yard
- Provision to allow turn back of service at South Hayward (north end of the Hayward Maintenance Complex)
- Full utilization of Pleasant Hill turn back during peak period service

In addition to the key component projects, State of Good Repair (SOGR) projects needed to operate Phase 1 service plan successfully will include the upgrade of the following components at key locations:

- Traction Power Substation and Cable Transmission renovation
- Communication system upgrades
- Initial phases of Train Control Modernization Project (TCMP)

With the increase in Fleet size train storage capacity will need to be increased, storage capacity increase projects will include extending the Millbrae tail tracks to accommodate full 10 car trains without impacting other operations, and extension of the Dublin / Pleasanton tail tracks. Additional storage will be provided at the Hayward Maintenance Complex with Phase 1 expected to be completed with the introduction of the Phase 1 service plan, this would provide additional storage capacity for up to 250 cars.

With the implementation of the Phase 1 service Plan, the following extensions are expected to be complete and operational:

- Oakland Airport Connector (2014)
- Warm Springs Extension (2016) – New stations at both Warm Springs and Irvington
- eBART Phase 1 (2017) – New eBART stations at Pittsburg Railroad Avenue, and Hillcrest Avenue
- Silicon Valley Berryessa Extension (2017), New stations at Milpitas and Berryessa

While the Irvington and Pittsburg Railroad Avenue Stations are not yet funded, they are assumed to be in place by the year 2025 for this analysis.

Note that previously considered plans for a downtown San Francisco turnback or a fourth downtown Oakland track are not considered as SCOA projects. Both of these projects are high cost and while having operational benefit, they are more properly considered as part of BART's vision strategy.

Phase 1 Service Plan Description

The Phase 1 service plan, builds on the current system infrastructure that is available today with some component improvement projects and increased fleet. Service is tailored during the peak commute period, midday and evenings / weekends to provide reliable and efficient service to me projected demand.

Phase 1 and 2 Service Plans

Phase 1 Service Plan

Phase 1 Service Plan – Peak Commute Period

The Phase 1 service plan would provide base 15 minute headway and with 24 Transbay trains during the peak commute period, peak direction. All Transbay peak direction, peak period service would use 10 car trains on all lines, to minimize train crowding to the extents possible, with Train Control limits on Transbay peak direction train flow. The primary change to service is from the rebranding of the current Yellow and Green Lines into distinct service types. Yellow Line Commute would operate between Pittsburg / Bay Point (with timed transfer to eBART) and SFO Airport. Yellow Line Core is an overlay service that operates during the peak period commute hours between Pleasant Hill and Daly City. The Green Line Core would operate between South Hayward and Daly City. Figure 20 presents a schematic plan showing peak hour service during the peak period for Phase 1.The following provides a summary of Phase 1 Peak Commute Period service:

- Red Line Base - 4 trains per hour between Richmond and SFO via Millbrae
- Orange Line Base – 4 trains per hour between Richmond and Berryessa
- Yellow Line Base – 4 trains per hour between Pittsburg / Bay Point and SFO
- Yellow Line Commute – 2 trains per hour between Pittsburg / Bay Point and Daly City
- Yellow Line Core – 4 trains per hour between Pleasant Hill and Daly City
- Blue Line Base – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line Base – 4 trains per hour between Berryessa and 24th Street
- Green Line Core – 2 trains per hour between South Hayward and Daly City

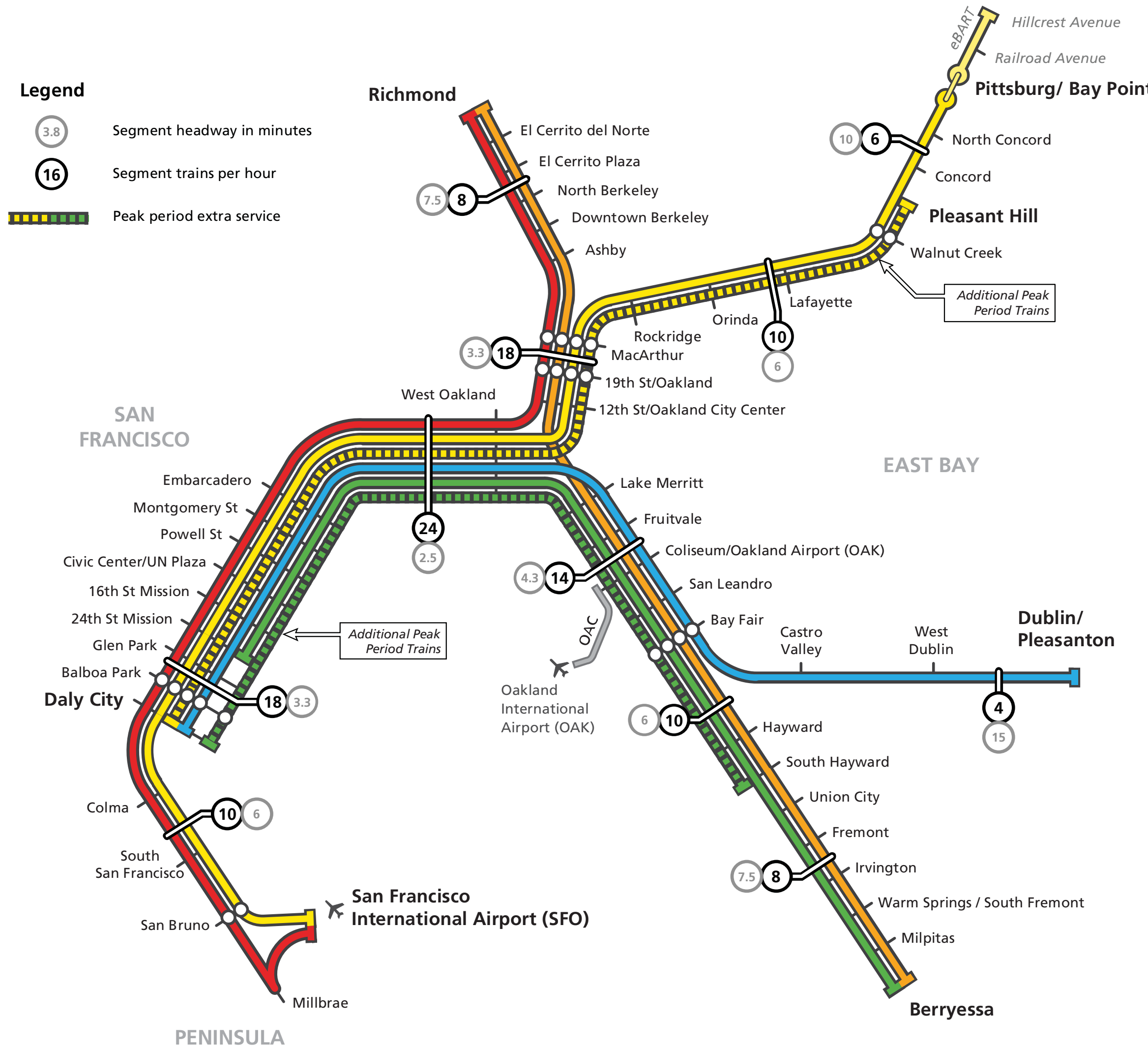


Figure 20: Phase 1 Peak Commute Period Service Plan

Phase 1 Service Plan – Midday (Base Service Only)

The midday service plan would provide a base headway of 15 minutes on all lines and would provide 16 Transbay trains per hour. The Yellow and Green Line Core and Commute service would not operate during the midday. Traincar lengths would be tailored to ensure that sufficient capacity would be provided to meet the projected demand. Figure 21 presents a schematic plan showing midday service for Phase 1. The following provides a summary of the Midday Phase 1 service:

- Red Line Base - 4 trains per hour between Richmond and SFO via Millbrae
- Orange Line Base – 4 trains per hour between Richmond and Berryessa
- Yellow Line Base – 4 trains per hour between Pittsburg / Bay Point and SFO
- Blue Line Base – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line Base – 4 trains per hour between Berryessa and 24th Street

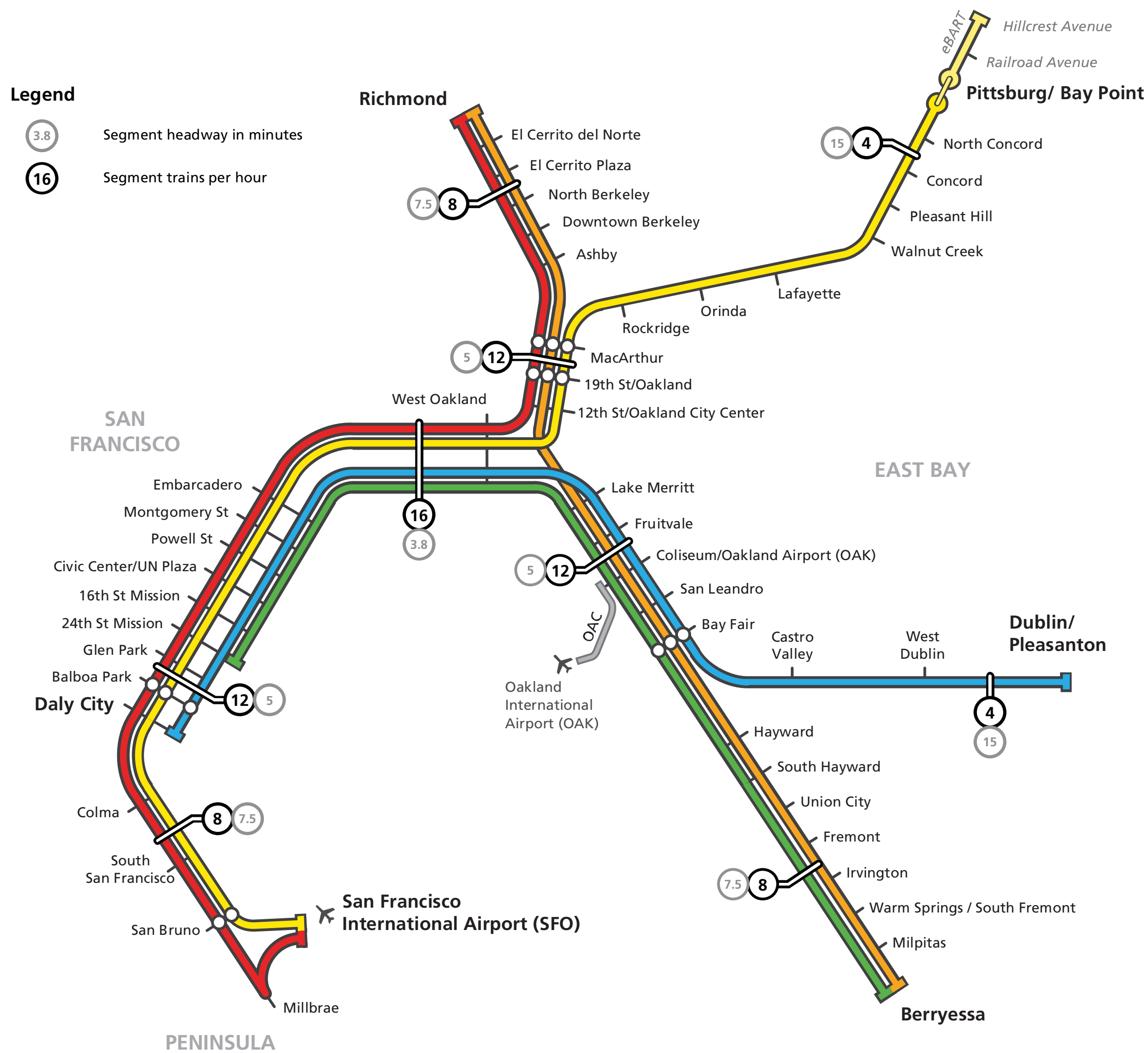


Figure 21: Phase 1 Midday Service Plan

Phase 1 and 2 Service Plans

Phase 1 Service Plan

Phase 1 Service Plan – Evenings and Weekends

The evening and weekend service plan for Phase 1 provide a 20 minute service on all lines and would provide 12 Transbay trains per hour into the evening. The extents of service would be similar to the midday service; with the exception of the Green Line which operate between South Hayward and 24th Street until 9pm and the Red Line which would operate between Richmond and Millbrae until 9pm (core services). Saturday and Sunday service would be identical service, with train car lengths adjusted to meet demand requirements. Figure 22 presents a schematic plan showing evenings / weekend for Phase 1. The following provides a summary of the Phase 1 Evenings and Weekend service:

- Red Line Core - 3 trains per hour between Richmond and Millbrae (until 9pm)
- Orange Line Base – 3 trains per hour between Richmond and Berryessa
- Yellow Line Base – 3 trains per hour between Pittsburg / Bay Point and Millbrae via SFO (after 9pm)
- Blue Line Base – 3 trains per hour between Dublin / Pleasanton and Daly City
- Green Line Core – 3 trains per hour between South Hayward and 24th Street (until 9pm)

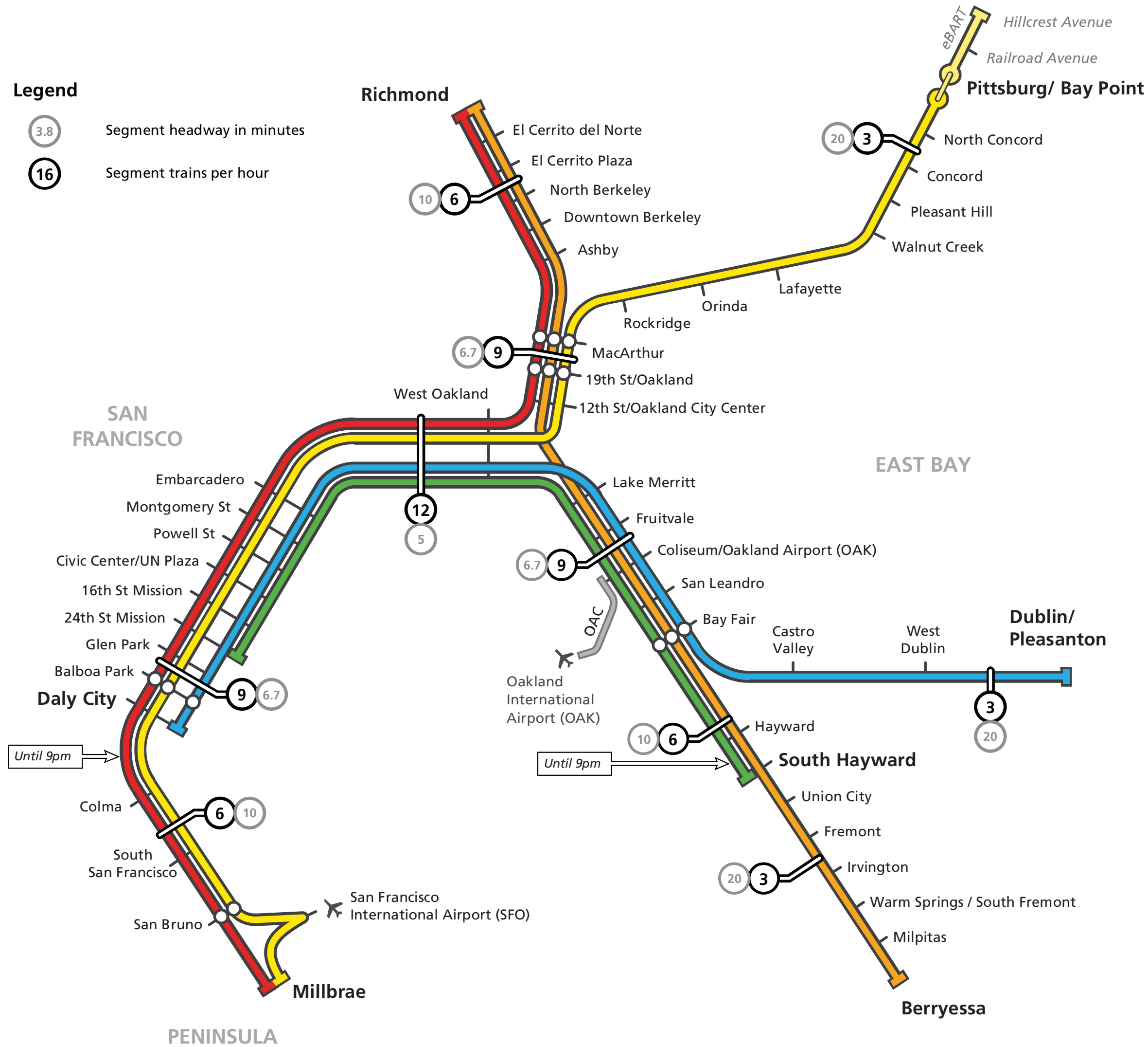


Figure 22: Phase 1 Evenings / Weekends Service Plan

Phase 1 Service Plan Results

The Phase 1 Service Plan was analyzed using the BART Service Planning Model to provide an estimation of likely service requirements. The results are summarized and compared against the Base Case condition to identify service impacts and benefits.

Assuming reliable turnback functions at the existing 24th Street and Pleasant Hill switches, and adding new turnback facilities at South Hayward and the new Richmond crossover, Phase 1 service works well, and compared to the Enhanced Base Case:

- Operating Costs are Lower
- Farebox Recovery is Higher
- Capacity Utilization is Higher
- Fleet requirements are Less

The proposed Richmond crossover facility reduces the train turn time from about 8 minutes down to around 3 minutes, which results in a train saving on both the Red and Orange Lines, with a reduction in the fleet requirement. It also saves time in operational savings associated with yard activity.

With Evenings / Weekend service a similar service plan operates on both Saturday and Sunday, which may require some additional overlay service in the core on Saturdays to meet demand, but provides more service weeknights and Sundays over what is currently provided. The additional service on Weeknights and Sundays also allows BART greater flexibility in providing additional service to meet special events, by allowing the extension of service to meet the special event requirements when required.

The Phase 1 Service Plan would provide a system capacity utilization of 43% and would require an overall fleet of 878 vehicles. Further KPI values can be found in Appendix D1 (a separate document).

Table 13: Phase 1 KPI Results

Performance Measure	Base Case Enhanced	Phase 1 Results
Capacity Utilization	40%	43%
O&M Cost	$592 million	$582 million
Farebox Recovery Ratio	82%	84%
Peak Fleet Requirement (cars)	896	878
Transbay Peak Passengers per Car (Peak Direction)	112*	112*
Transbay Peak Capacity (passengers per hour, peak direction)	25,680	25,680

** Exceeds BART Threshold of 107 passengers per car*

With the Phase 1 Service plan, crowding levels on the trains through the tube will be on average 112 passengers per car in the peak direction, consistent with Enhanced Base Case. The Phase 1 Service plan would also reduce operating costs over the Enhanced Base Case by about $10.5m annually as a result of the reduction in car miles and car hour costs. Capacity utilization also improves by about 3% increase compared to the Enhanced Base Case condition. In addition to the operating cost savings, the Phase 1 service plan would require a smaller train fleet (18 fewer cars, potential savings of $45 million). The capital projects required for Phase 1 implementation are summarized in Table 14.

The Phase 1 service plan provides some minor changes to service over what is currently operated today and BART should continue to provide good passenger information for the destination of services to ensure that passengers board the correct service to reach their destination.

With the changes in service for the Phase 1 service plan, prior to its implementation, further studies will be required to identify any potential impacts on access capacity, together with impacts on station capacity. With the capacity improvements from the increased fleet and the proposed service changes, it is critical that access to the stations also have sufficient capacity to ensure that BART maximizes the potential of increasing its ridership. Previous BART station capacity should be reviewed in coordination with the Phase 1 service plan to determine any additional station capacity or emergency egress requirements that may be required.

Table 14: Phase 1 Capital Projects

Phase 1 Capital Project	Rough Order Magnitude (ROM) Cost (2012 $)
Additional Crossovers (or improvements to existing crossovers) at 24th/Mission, Richmond, South Hayward, Lafayette pocket track and Pleasant Hill	$55 - $60 million
Tail Track Extensions at Millbrae and Dublin	$4 - $6 million
Highway Barrier Improvement, Dublin Line	$10 - $12 million
Total Cost	**$69 - 78 million**

Phase 1 and 2 Service Plans
Phase 1 Service Plan

Phase 1 Title VI Analysis

To ensure that Minority or Low-Income service is not significantly reduced, an initial Title VI Analysis compared planned service against current service (2012). The analysis indicated no significant changes in service provision at stations. BART's FTA-approved method for performing a Title VI Service Equity Analysis examines in detail the changes in travel time of station pairs (origins and destinations) which would be affected by the service change. The more robust analysis will be required before implementing such service changes. Results from the initial Title VI Analysis can be found in Appendix E1 (a separate document).

Phase 2 Service Plan – Key Projects

The Phase 2 Service Plan builds upon the Key Projects implemented under Phase 1 and is projected to operate between 2025 and 2050. The key change in Phase 2 service plan is the increase in service frequencies with a base headway of 12 minutes on all routes during the peak period, and higher frequency service during the midday and evenings / weekends. The key projects that would be required for implementation of Phase 2 include:

- Glen Park Turnback required to short turn service on the Yellow Commute line
- Bay Fair Connection new platform and track to provide ability to couple / decouple service between Green and Blue lines during evenings / weekends.

In addition to the capital projects required, State of Good Repair (SOGR) projects will also need to be implemented for Phase 2 and include:

- Traction power capacity upgrades
- Full implementation of systemwide Train Control Modernization Project (TCMP)

Phase 2 will also require an increase in fleet to around 1,000 vehicles and will require further storage capacity. The key improvements to storage capacity will be the implementation of Hayward Eastside Yard (Hayward Maintenance Complex Phase 2). Further storage capacity upgrades would also be implemented at Millbrae and include relocation of the carwash facility currently at Colma station to a new facility at Millbrae.

Under the Phase 2 service plan, ridership is expected to increase to between 500,000 to 750,000 (likely occurring after 2020). With the increase in train throughput and increased ridership levels, station capacity improvements will also need to be provided, these include:

- Capacity improvements at Embarcadero and Montgomery stations
- New 3rd Platform at Bay Fair station as part of the Bay Fair Connector project
- Downtown Oakland stations capacity improvements
- Fire and Life Safety improvements at key high volume urban stations

Phase 2 Service Plan Description

The Phase 2 service plan builds on the Phase 1 service plan and includes increased frequencies with a base headway of 12 minutes. Service is tailored to ensure that sufficient service can meet the projected demand during peak periods, midday and evenings / weekends. In addition to the increase in base service, express service will be provided on the Yellow Commute Line during peak and midday. During significant system delay occurrences, with heavy crowding conditions on the Yellow Commute line, service could skip MacArthur station to help alleviate crowding on trains. During evenings / weekends service to / from Dublin / Pleasanton and Berryessa will be provided via a coupled train service, maximizing service frequency, creating a one-seat ride to more stations while minimizing fleet requirements and car miles.

Phase 1 and 2 Service Plans

Phase 2 Service Plan

Phase 2 Service Plan – Peak Commute Period

During the peak commute period, BART will operate on base headway of 12 minutes. The Yellow Commute would be split to provide a short turn between Pittsburg / Bay Point and Glen Park. A new secondary line, Yellow Core would be created running between Pleasant Hill and San Francisco International Airport, and would offer express service skipping Colma, South San Francisco and San Bruno stations. The Red Line would be extended from the current Millbrae terminus, to terminate at SFO Airport and provide connections to the Airport. An additional peak train would operate on the Green Core between South Hayward and Daly City. Figure 23 presents a schematic plan showing peak hour service during the peak period for Phase 2. The following provides a summary of the Phase 2 service during Peak Commute Period:

- Red Line Base – 5 trains per hour between Richmond and SFO via Millbrae
- Orange Line Base – 5 trains per hour between Richmond and Berryessa
- Yellow Line Commute – 5 trains per hour between Pittsburg / Bay Point and Glen Park; and 1 train per hour between Pittsburg / Bay Point and Daly City
- Yellow Line Core – 5 trains per hour between Pleasant Hill and SFO with express service between Daly City and San Bruno
- Blue Line Base – 5 trains per hour between Dublin / Pleasanton and Daly City
- Green Line Base – 5 trains per hour between Berryessa and Daly City
- Green Line Core – 1 train per hour between South Hayward and Daly City

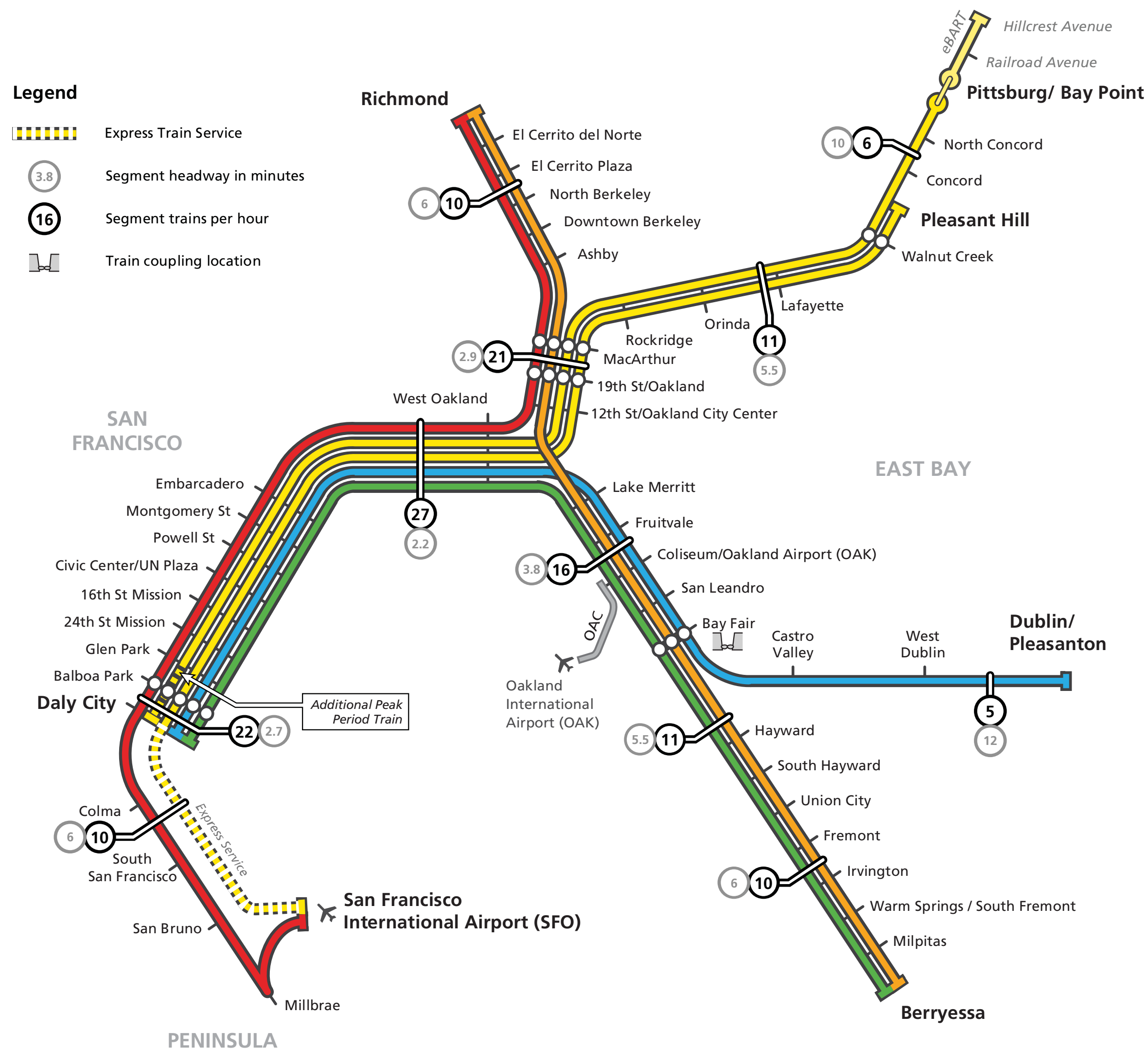


Figure 23: Phase 2 Peak Commute Period Service Plan

Phase 2 Service Plan – Midday

The Phase 2 service plan during midday would provide identical service as the peak commute period, with the exception that the base service would operate on 15 minute headways. The Green Core service would not operate during the midday. Trains lengths would be adjusted to provide sufficient capacity to meet the demand. Figure 24 presents a schematic plan showing midday service during the peak period for Phase 2. The following provides a summary of the Midday Phase 2 service:

- Red Line Base – 4 trains per hour between Richmond and SFO via Millbrae
- Orange Line Base – 4 trains per hour between Richmond and Berryessa
- Yellow Line Commute – 4 trains per hour between Pittsburg / Bay Point and Glen Park
- Yellow Line Core – 4 trains per hour between Pleasant Hill and SFO with express service between Daly City and San Bruno
- Blue Line Base – 4 trains per hour between Dublin / Pleasanton and Daly City
- Green Line Base – 4 trains per hour between Berryessa and Daly City

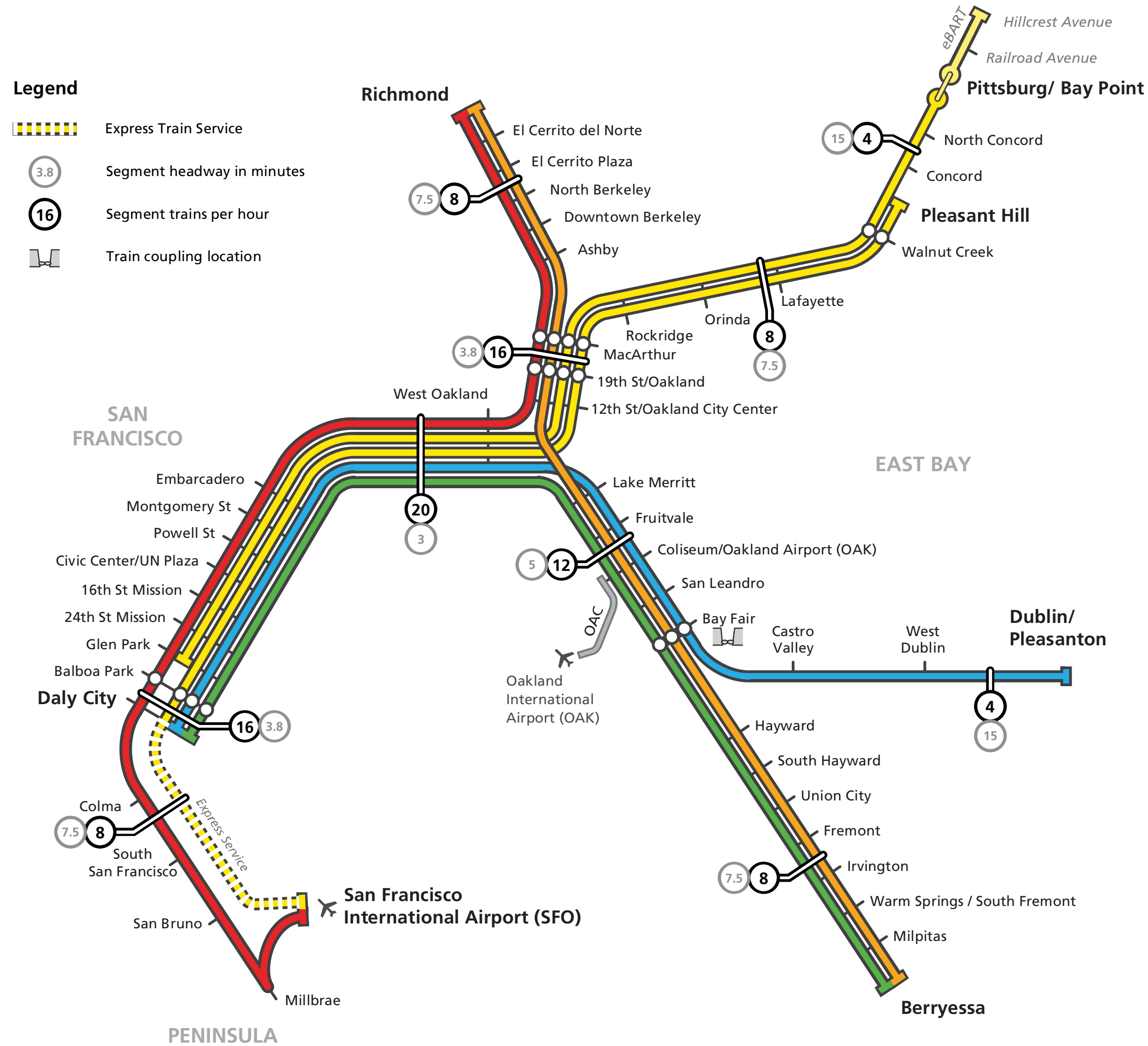


Figure 24: Phase 2 Midday Service Plan

Phase 1 and 2 Service Plans

Phase 2 Service Plan

Phase 2 Service Plan - Evenings and Weekends

For evenings and weekends, the Yellow Commute and Yellow Core service would revert to a single line (Yellow Line Base) operating between Pittsburg / Bay Point and SFO Airport and would provide local stops at all stations (no express service). The Blue and Green lines would be combined with coupled service between Daly City and Bay Fair (Blue / Green Core). At Bay Fair station the train would split with 5 cars proceeding to stations towards Dublin / Pleasanton (Blue Line Base) and the remaining 5 cars would proceed to stations towards Berryessa (Green Line Base). In the reverse direction, the trains would be coupled at Bay Fair station and provide a single 10 car service between Bay Fair station and Daly City (Blue / Green Core). The Orange Line service would be shortened to operate between Richmond and Bay Fair (Orange Core). Service is provided on a base 15 minute headway. Figure 25 presents a schematic plan showing evenings / weekend service during the peak period for Phase 2. The following provides a summary of the Phase 2 Evenings / Weekend service:

- Red Line Core – 4 trains per hour between Richmond and SFO via Millbrae
- Orange Line Core – 4 trains per hour between Richmond and Bay Fair
- Yellow Line Base – 4 trains per hour between Pittsburg / Bay Point and SFO
- Blue / Green Line Core - 4 trains per hour between Daly City and Bay Fair
- Blue Line Base – 4 trains per hour between Dublin / Pleasanton and Bay Fair (couples with Green Line at Bay Fair)
- Green Line Base – 4 trains per hour between Berryessa and Bay Fair (couples with Blue Line at Bay Fair)

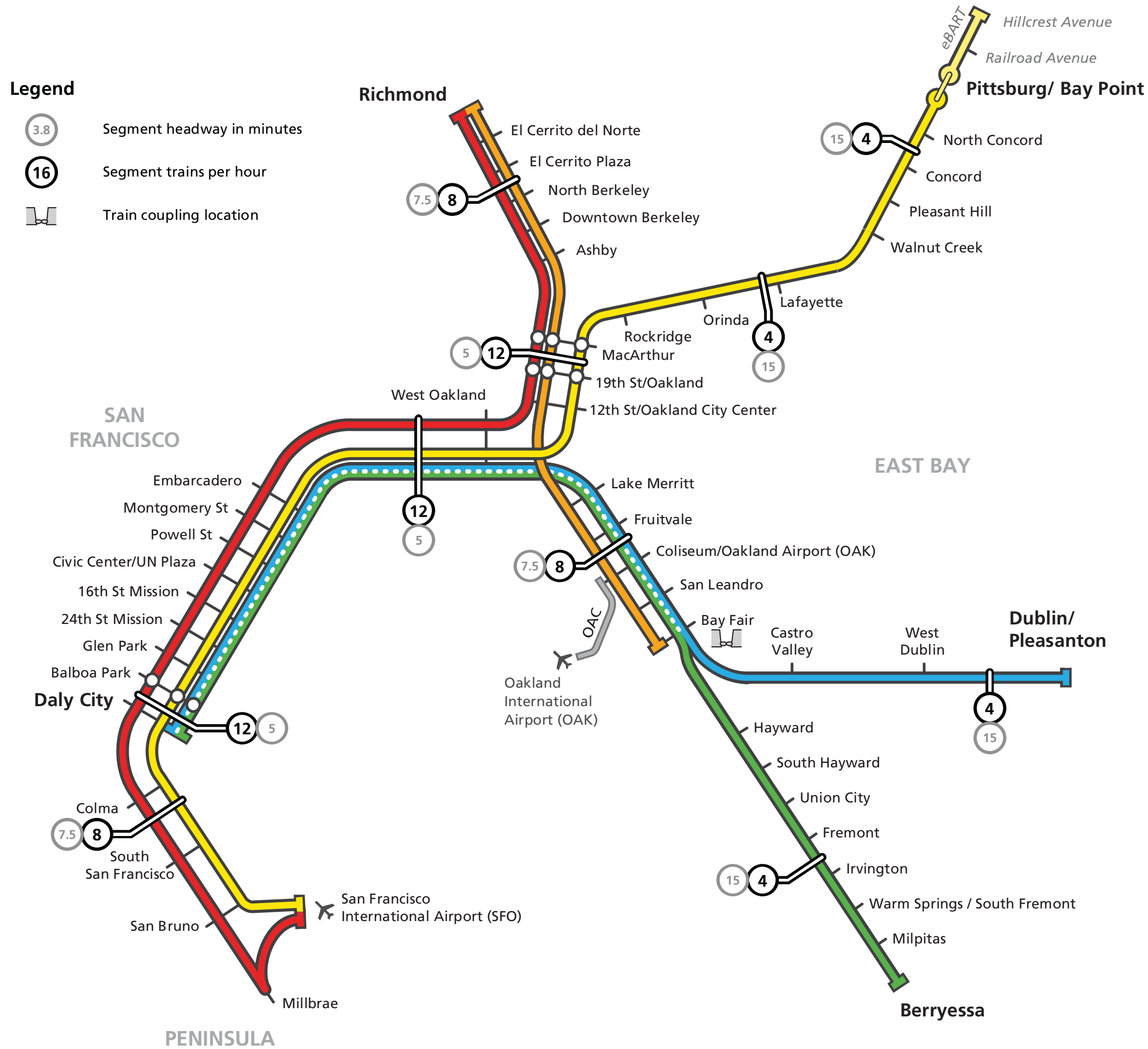


Figure 25: Phase 2 Evenings / Weekends Service Plan

Phase 2 Service Plan Results

The Phase 2 service plan requires that a new turnback facility located in San Francisco as train frequencies increase. With a 12 minute base headway the 24th Street or Montgomery turnbacks will be inadequate as there will be too many conflicts with opposing trains.

During the peak period the 12 minute base service adds one net new train per service route, increasing the number of peak hour trains through the Transbay Tube to 27. The Systra study identified that Transbay peak direction capacity is limited to 24 trains per hour with the current signal and communications system. To allow for the increased Transbay service, significant investment is required to update the train control system to provide this increased capacity.

Storage for trains during midday and overnight will be critical, especially considering that Daly City is already close to its storage capacity. To accommodate storage of trains for two of the West Bay routes, the Millbrae facility should be expanded to accommodate more storage and also to provide additional facilities including car wash and connection to a new rail spur.

With the increased car fleet and service, crowding levels are better managed and consistent with the historic acceptable crowding conditions, and provides sufficient capacity for increased ridership levels over and above the 2025 projected horizon of 560,000 daily riders and is expected to be able to accommodate up to 750,000 ridership with acceptable crowding conditions.

12 minute service during the midday would provide too much service, and is therefore reduced to a 15 minute base service. This reduction is a departure from the assumptions of BART's Fleet Management Plan.

During the evenings and weekends, service is provided on base 15 minute headway. Coupling of the Green and Blue lines ensures that sufficient service is provided to all parts of the system, without running long empty trains to the outer lying portions of the system, significantly reducing car miles. Coupling of service at Bay Fair would require extensive station modifications which would include 3 tracks and 2 center platforms.

The Phase 2 Service Plan does require an increase in the overall fleet requirement, and it is estimated that a fleet of nearly 1,000 vehicles would be required.

With the Phase 2 service plan, annual car miles increases, but it is important to note the service during the peak, midday and evenings has been significantly increased. Further KPI values can be found in Appendix D1.

Table 15: Phase 2 KPI Results

Performance Measure	Base Case Enhanced	Phase 2 Results
Capacity Utilization	40%	40%
O&M Cost	$592 million	$634 million
Farebox Recovery Ratio	82%	77%
Peak Fleet Requirement (cars)	896	993
Transbay Peak Passengers per Car (Peak Direction)	112*	100
Transbay Peak Capacity (passengers per hour, peak direction)	25,680	28,890

** Exceeds BART Threshold of 107 passengers per car*

The Phase 2 service plan is only required once demand exceeds 560,000 weekday passengers, but this analysis assumes the 560,000 passengers threshold. Train crowding levels through the Transbay Tube are 100 passengers per car on average and lower than the Enhanced Base Case. Phase 2 also requires 97 more railcars to operate the enhanced peak period 12 minute headways. The capital projects required to operate the Phase 2 service plan are summarized in Table 16.

Table 16: Phase 2 Capital Projects

Phase 2 Capital Project	Rough Order Magnitude (ROM) Cost (2012 $)
Hayward Maintenance Complex Project (Phase 2)	$169 million
Turnback – Glen Park	$40 - $45 million
Turnback – Bayfair (3rd Track in Station) and new platform to the west	$190 - $210 million
Maintenance Facilities – Millbrae and Colma (allow full 3 track operation at Colma station, move carwash and other maintenance functions to Millbrae).	$167 - $183 million
Total Cost	**$566 - $607 million**

Phase 1 and 2 Service Plans
Phase 2 Service Plan

The Phase 2 Service plan introduces new service strategies not currently used by BART. In particular coupling and de-coupling of trains in service at Bay Fair station. With the coupling strategy, a 10 car train would arrive at Bay Fair station and would then be split into two 5 car trains, one heading to Berryessa and one heading to Dublin/ Pleasanton. BART will need to invest in state of the art passenger information systems to ensure that passengers board the train in the correct position to reach their final destination. Providing in-car passenger information both visual and verbal will ensure that passengers are kept informed of the final destination of the service.

As in Phase 1, additional access capacity to BART stations will continue to surface as an on-going concern and will require continued engagement by BART. Emergency egress will also require additional attention and analysis.

Phase 2 Title VI Analysis

To ensure that Minority or Low-Income service is not significantly reduced, an initial Title VI Analysis compared planned service against current service (2012). The analysis indicated no significant changes in service provision at stations. BART's FTA approved method for performing a Title VI Service Equity Analysis examines in detail the changes in travel time of station pairs (origins and destinations) which could be affected by the service change. The more robust analysis will be required before implementing such service changes. Results from the initial Title VI Analysis can be found in Appendix E2.

8. Capital Projects Triggered by Programmed Projects and Future Demand

Capital projects for BART can be categorized as:

- Prerequisite – Those projects necessary to meet state-of-good-repair requirements and expected demand from normal growth and programmed expansions. These projects are necessary to allow BART to serve 560,000 passengers on its existing system by 2025.
- Enhancement – Those projects necessary to more efficiently meet the 560,000 passenger demand and meet future demand in the existing system.
- Expansion – Those projects necessary to allow the system to expand beyond the programmed system as defined by route miles.

This report deals with only Prerequisite and Enhancement projects. Expansion projects are detailed in the BART Metro Vision study.

Prerequisite Projects include improvements and renovation to the traction power and cabling components, communication system upgrades and improved train control and signaling systems. In addition, several stations, notably Embarcadero and Montgomery and perhaps the downtown Oakland stations may need renovations and capacity improvements to meet peak period 2025 demand. These renovations include additional elevators, escalators and fare collection equipment; studies also indicate that without demand management, platform expansion will also be required in the busiest stations. Many of these projects have been programmed in BART's capital plans.

Table 17: Prerequisite Projects

Project	Justification	Estimated Capital Cost
Hayward Maintenance Project – Phase 1	Allows for a greater focus on scheduled maintenance and mid-life vehicle overhauls, rather than reactive maintenance	$370m
Train Control System Modernization – Initial Phase and Systemwide	Provides additional capacity in system. Replaces system at end of its useful life	$600 - $800m (total project cost)
Selected Station Capacity Improvements	Additional station capacity improvement projects to accommodate increased ridership and some key stations	$250m - $900m
	Prerequisite Projects Total Cost	**$1.2b – $2.0b**

9. Enhancement Capital Projects List

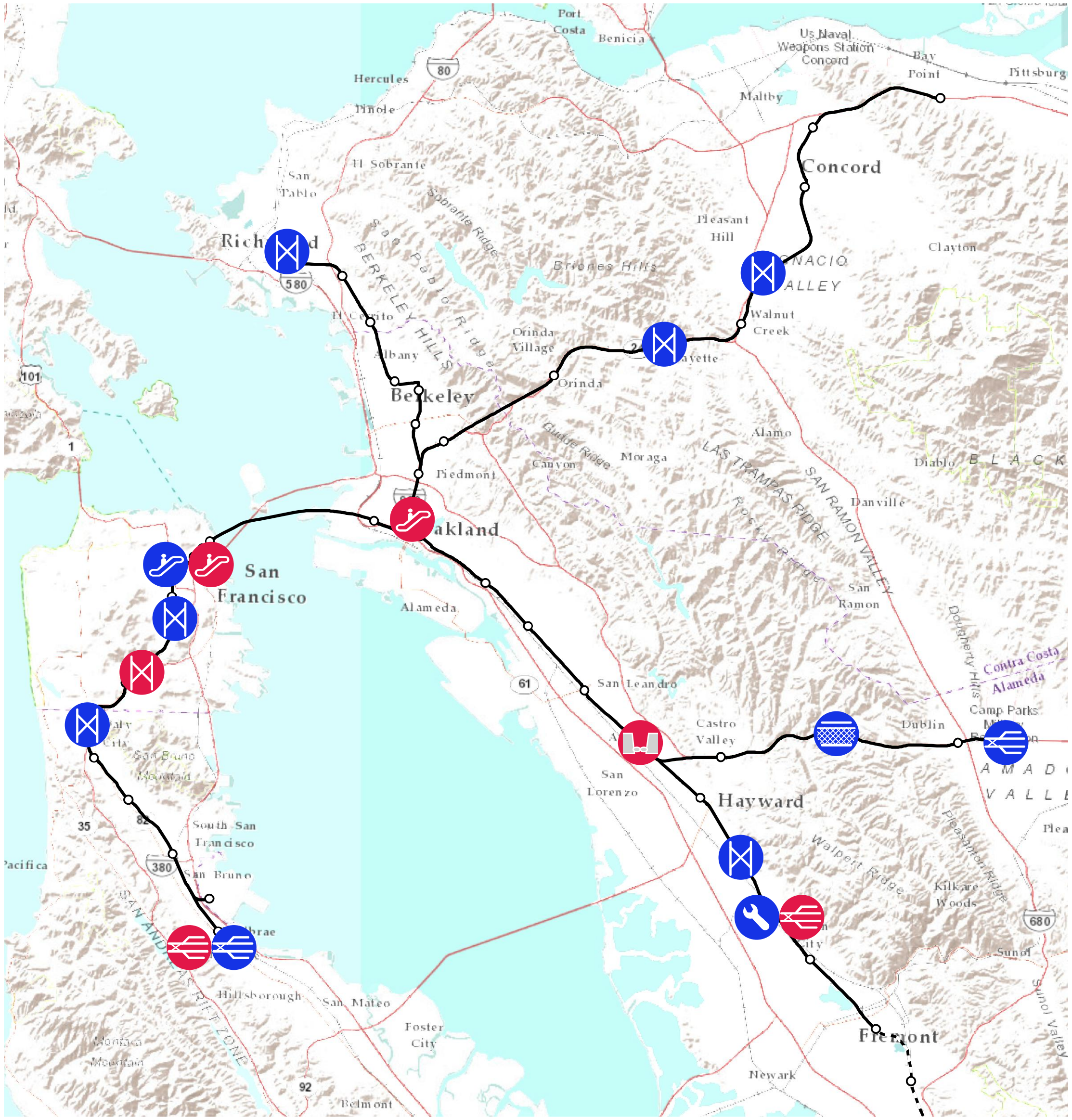
Following on the Prerequisite Projects, Enhancement projects are required to deliver the identified service plans at a lower operations and maintenance cost than the present capital plant can deliver. Table 18 provides a summary of the Enhancement Projects.

These improvements allow the Recommended Service Plan to be implemented in the most cost-effective and reliable manner. Other projects were considered – for example several turnbacks in downtown San Francisco, additional tracks and express tracks in Oakland – and while technically feasible, had a high capital cost. These higher cost turnback projects, while beneficial to day-to-day scheduling and operations are more appropriately considered as part of a broader BART vision that contemplates additional routes within the core of the region to deliver service to expanding infill areas. Figure 26 shows the capital improvement projects that are required under each of the phases.

Table 18: Enhancement Projects

Project	Justification	Improvement Location	Estimated Capital Cost
Phase 1 Capital Projects			
Additional Crossovers (or improvements to existing crossovers) at Daly City- Colma, 24th/ Mission, Richmond, South Hayward, Lafayette pocket track and Pleasant Hill	Allows for quicker-turnbacks, saves consists and reduces fleet, allows for better balance between service and demand	Metro Core	$55m - $60m
Tail track extensions at Millbrae and Dublin	Allows full 10 car consists to be stored midday.	Metro Commute	$4m - $6m
Highway Barrier Improvement, Dublin Line	Allows speed increases on Dublin Line	Metro Commute	$10m – $12m
		Phase 1 Total Costs	**$69m - $78m**
Phase 2 Capital Projects			
Hayward Maintenance Complex Project – Phase 2	Allows for storage of a larger fleet	System Improvement	$169m
Turnback – Glen Park	Reduces consist requirements, saves fleet, allows for better balance between service and demand	Metro Core	$40m - $45m
Turnback – Bayfair (3rd Track in station) and new platform to the west	Reduces consist requirements, saves fleet, allows for better balance between service and demand	Metro Core	$190m - $210m
Maintenance Facilities – Millbrae and Colma (allow full 3 track operation at Colma station, move carwash and other maintenance functions to Millbrae).	Reduces deadhead and other non-revenue movements, allows full use of Colma station platforms and allows trains to terminate at Colma.	Metro Commute	$167m - $183m
		Phase 2 Total Costs	**$566m - $607m**
		Total	**$635m - $685m**

Enhancement Capital Projects List



Capital Projects Required for Phase 1

Systemwide Improvements

Train Control Modernization - Initial Phase
Additional Revenue Vehicles
Traction Power and Cabling Renovation
Communication System Upgrades

Turnbacks and Crossovers

Daly City - Colma: SB High Speed Crossover
24th / Mission Turnback
Richmond Crossover
South Hayward Turnback
Lafayette Pocket Track Upgrade
Pleasant Hill Turnback

Increased Vehicle Storage

Dublin / Pleasanton Tail Track Storage Extension
Millbrae Tail Track Storage Extension

Vehicle Intrusion Barrier

Dublin I-580 High Speed Intrusion Barrier

Station Capacity Improvements

Downtown SF Additional Platform Elevators and AFC Equipment

Increased Vehicle and System Maintenance

Hayward Maintenance Complex - Phase 1

Capital Projects Required for Phase 2

Systemwide Improvements

Train Control Modernization - Systemwide
Traction Power Capacity Upgrade
Additional Revenue Vehicles

Turnbacks, Crossovers and Siding Improvements

Glen Park Turnback
Daly City Maintenance Siding Extension

Increased Vehicle Storage

Hayward Maintenance Complex - Phase 2
Millbrae Transportation Facilities Expansion

Station Capacity Improvements

Embarcadero and Montgomery Station Capacity Improvements
Oakland - 12th Street & 19th Street Station Capacity Improvements

Station Capacity Improvements

Bay Fair Connector

Figure 26: Capital Improvement Projects

10. Findings, Funding and Implementation

Study Findings

BART expects ridership to increase by about 50 percent over the next 12 years, driven by population and employment increases in the BART service area. Just within Priority Development Areas adjacent to BART, more than 235,000 new jobs are forecast.

To provide enough service and capacity to meet these challenges, BART will need to focus on these essential priorities:

- Deploy a modern 1,000 car fleet
- Develop larger and more efficient maintenance facilities
- Procure and deploy a modernized train control system that allows more trains to operate on the system during peak periods
- Adjust routes and provide more frequent service within the region's core
- Preserve BART's current policy headways and on-time reliability
- Bring its infrastructure to a state-of-good-repair with an emphasis on power and communications systems renewal
- Rehabilitate stations and deliver strategic trackway improvements that allow for a more efficient use of trains, cars and train operators.

The recommended reoriented service plans save BART money, reduce crowding in the peak periods, but fill empty seats in the off-peak, and create a highly frequent service in the region's core. The key findings for the two service plans are summarized below:

Phase 1

- 10 car peak period trains
- Peak period base headway of 15 minutes
- 18 fewer cars to provide very similar service compared to the enhanced baseline service
- $10.5 million operating cost savings compared to the enhanced baseline service
- Can accommodate ridership levels up to 500,000 average weekday

Phase 2

- Increased service frequency systemwide at all times during the day, Peak period headway of 12 minutes, base headway of 15 minutes
- Requires an overall fleet size increase to 1,000 vehicles due to the increased train frequency
- Can accommodate ridership levels up to 750,000 average weekday

Table 19: Capital Projects Phasing

BART Metro Phase	Phase 1	Phase 2	Phase 3
Timeline	Short Term	Medium Term	Future Term
Peak Period Base Headways	15 minutes	12 minutes	10 minutes
Service Innovations	Optimization of Current System - additional Turnbacks, more direct Transbay service nights and weekends in urban core	SCOA Vision - Peak period frequency increases, high frequency night and weekend service, potential express services in commute markets	Split service between two tubes and new downtown San Francisco stations
Fleet	880	1000	1000+ (TBD)
Ridership level	Up to 500,000	500,000 to 750,000	Beyond 750,000
Component Projects			
Turnbacks	24th/Mission**, Richmond Crossover, South Hayward** & Pleasant Hill#	Glen Park Turnback, Bay Fair Connection	
State of Good Repair (SOGR)	Traction power and cabling renovation**, communication system upgrades**	Traction power capacity upgrade	
Train Control	Initial phases of TCS Modernization	Full system wide TCS Modernization	
Stations	Downtown SF additional platform elevators & AFC**, Bay Fair Connection (3rd Platform)**	Downtown San Francisco and Oakland platform expansions, fire/life safety improvements at high volume suburban stations	
Train storage	Millbrae and Dublin tail track extensions**	Hayward Eastside Yard, Lafayette Pocket Track Upgrade**	
Trackage / ROW	Dublin Line I -580 Barrier, high speed SB crossover Daly City -Colma		Second Transbay Tube, Downtown Oakland 4th track and station upgrades
Maintenance Facilities	HMC shop and track work	Expansion of Millbrae transportation facilities Daly City maintenance siding extension	

Notes: # Project in place, ** Potential funding identified

Findings, Funding and Implementation

Funding

BART needs capital funding to both maintain the system is a state-of-good-repair and also to provide the resources necessary for expanding service within its core area.

Among the funding possibilities are:

Federal Grants – MAP 21 reorganizes previous federal funding programs into one "State of Good Repair" source (Section 5337) that includes previous rail modernization and similar programs (some bus capital-intensive bus projects are also eligible). Funding is authorized at more than $2 billion over each of the next two years. In addition, formula funding is also still provided (Section 5307).

State Grants – Funding continues to be available through various state funding programs, including the State Transportation Improvement Program (STIP). It should be noted that as the relative value of the gas tax declines, this source is limited. Much of the funding is allocated at the county level.

Bridge Tolls – MTC, acting as the Bay Area Toll Authority, has control of toll bridge revenues on the state owned bridges in the Bay Area. These funds, subject to some restrictions, can be used to fund BART projects where they is a nexus between the BART project and the tolled bridge. The Bay Bridge is the most prominent example of this, where toll funds have been used for many years to support BART projects.

County Sales Tax – All three BART counties are "self-help" counties where the voters have approved a dedicated half-cent sales tax to support transportation projects and programs. These taxes are periodically amended and re-adopted. Alameda County asked voters to re-adopt its half cent tax in 2012, but the measure narrowly lost. BART projects are eligible for funding from this tax.

BART General Obligation Bond – The BART Board of Directors could also directly ask voters to approve (by 2/3 vote) allowing BART to borrow capital funds to build capital projects, and pay those loans off with a supplement on the assessed value of real property. The last BART GO Bond was passed by voters in 2004 for seismic retrofitting of the BART system.

Implementation

Implementation of the capital projects and new vehicle fleet is a key driver to the operation of the Phase 1 and 2 service plans. The key capital projects identified under Phase 1 need to be completed prior to the implementation of the Phase 1 service plan. As ridership continues to grow, the urgency of the capital projects will also increase.

Figure 27 shows the impacts of different projects being implemented over future years. The Oakland Airport Connector and Warms Springs Extension projects are expected to be completed prior to the implementation of the Phase 1 Service Plan. In order to implement the Phase 1 Service Plan the following are required:

- Fleet size to be increased to 775 vehicles;
- Operate 24 trains per hour Transbay in the peak direction during peak hours.
- Transbay Tube train consists will be a mix of 9 and 10 car lengths.

During the Phase 1 service plan, the following will be implemented

- Fleet size will increase to 896 vehicles
- 24 trains per hour Transbay in the peak direction
- Transbay tube train consists will be 10 cars long
- Additional Green and Red Line service at strategic times
- Warm Springs, eBART and Silicon Valley Berryessa Extension projects are expected to be completed

In order to implement the Phase 2 Service Plan, the following are required:

- Fleet size will increase further to 1,000 vehicles for implementation of Phase 2 Service Plan
- Completion of the Train Control Modernization Project (TCMP)

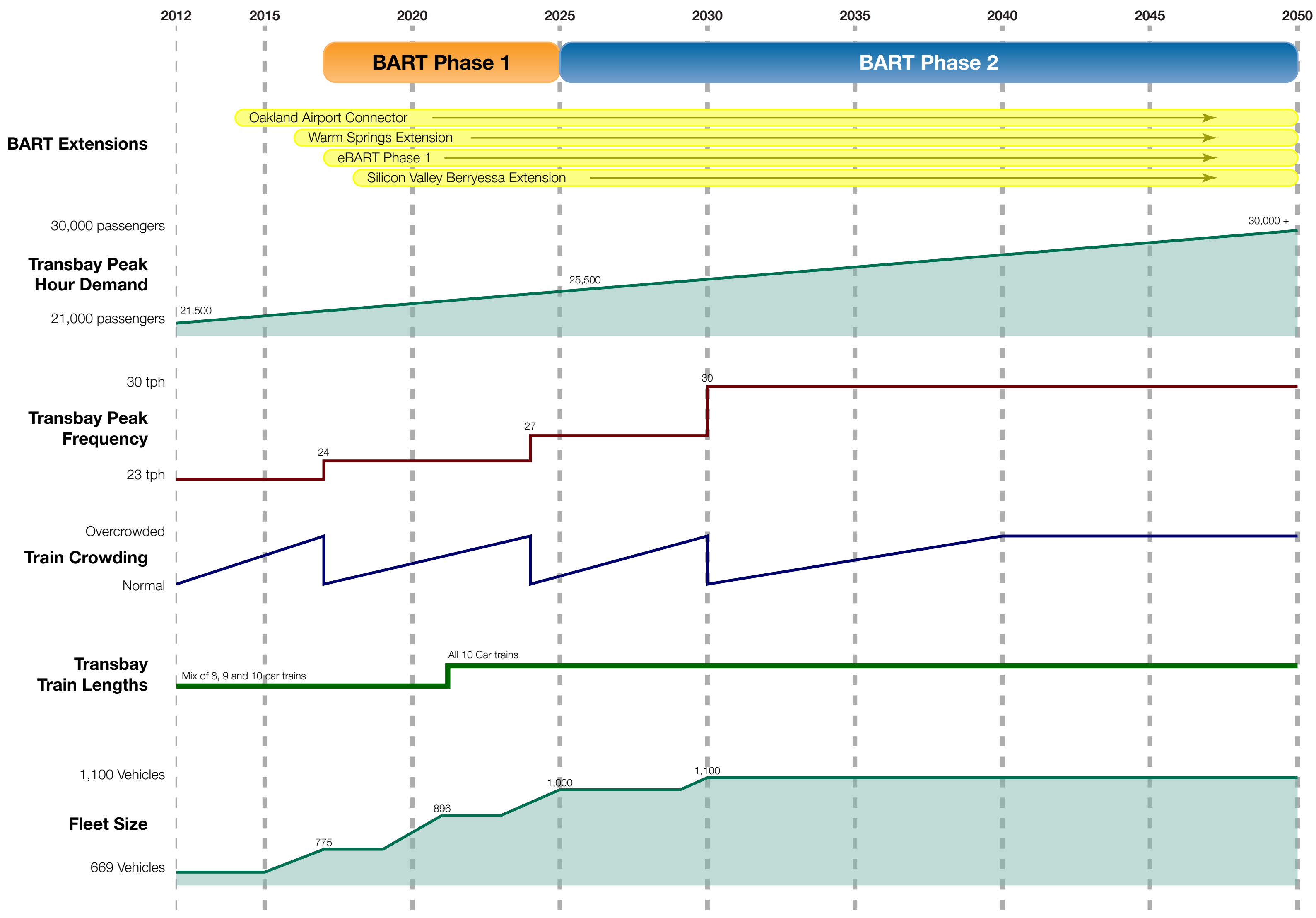


Figure 27: Implementation Timeline