BART Metro 2030

BRIEFING BOOK—DECEMBER 2022

Introduction

Caltrans awarded BART grant funding in 2019 to update the BART service vision in light of significant forecast future growth, changes to ridership travel patterns, and potential system capacity constraints. The grant's goal was to produce future BART service strategies that address these trends and identify capital projects that would leverage planned system improvements to improve operational efficiency and financial stability, maximize ridership, reduce greenhouse gases (GHG) emissions, and mitigate regional congestion. At the time, trains during peak hours in the peak directions were already crowded, forecasts indicated significant future growth and BART was responding with capacity enhancements (e.g., Transbay Corridor Core Capacity project). Additionally, the Bay Area's severe housing shortage suggested changes in regional travel patterns, potentially impacting BART's ridership distribution.

Subsequently, the COVID pandemic resulted in substantial declines in transit ridership. The long-term consequences of increased remote work trends and shifting travel patterns remain unknown. Current ridership levels are far lower and passenger distribution is different than prior to the pandemic and the proliferation of remote work. BART must consider how to respond to these changes in markets and ridership while continuing to look to the future, and position the system to provide reliable service for Bay Area residents.

PROJECT TEAM

Funding Partners

- Caltrans (grantor)
- MTC (project applicant)

BART Project led by Strategic & Operations Planning

Consultant Support

- Arup
- Connetics (now Nelson Nygaard)
- Civic Edge
- Hatch

Technical Advisory Committee

Role: Provide technical input and help guide the study direction at key junctures

- Caltrans
- Metropolitan Transportation Commission
- Alameda County Transportation Commission
- Contra Costa Transportation Authority
- San Francisco County Transportation Authority
- Valley Transportation Authority
- City/County Association of Governments of San Mateo County (C/CAG)
- San Francisco Municipal Transportation Agency
- Capital Corridor
- SamTrans
- Caltrain
- AC Transit

By evaluating strategies to better match BART service with forecasted future regional travel demand patterns the study seeks to understand how BART can better respond to evolving post-pandemic ridership trends, help implement Plan Bay Area 2050 (PBA), improve access to jobs, school, shopping, and recreation for all communities, support equitable outcomes in the region, and reduce GHG emissions.

The Study aims to achieve the following objectives:

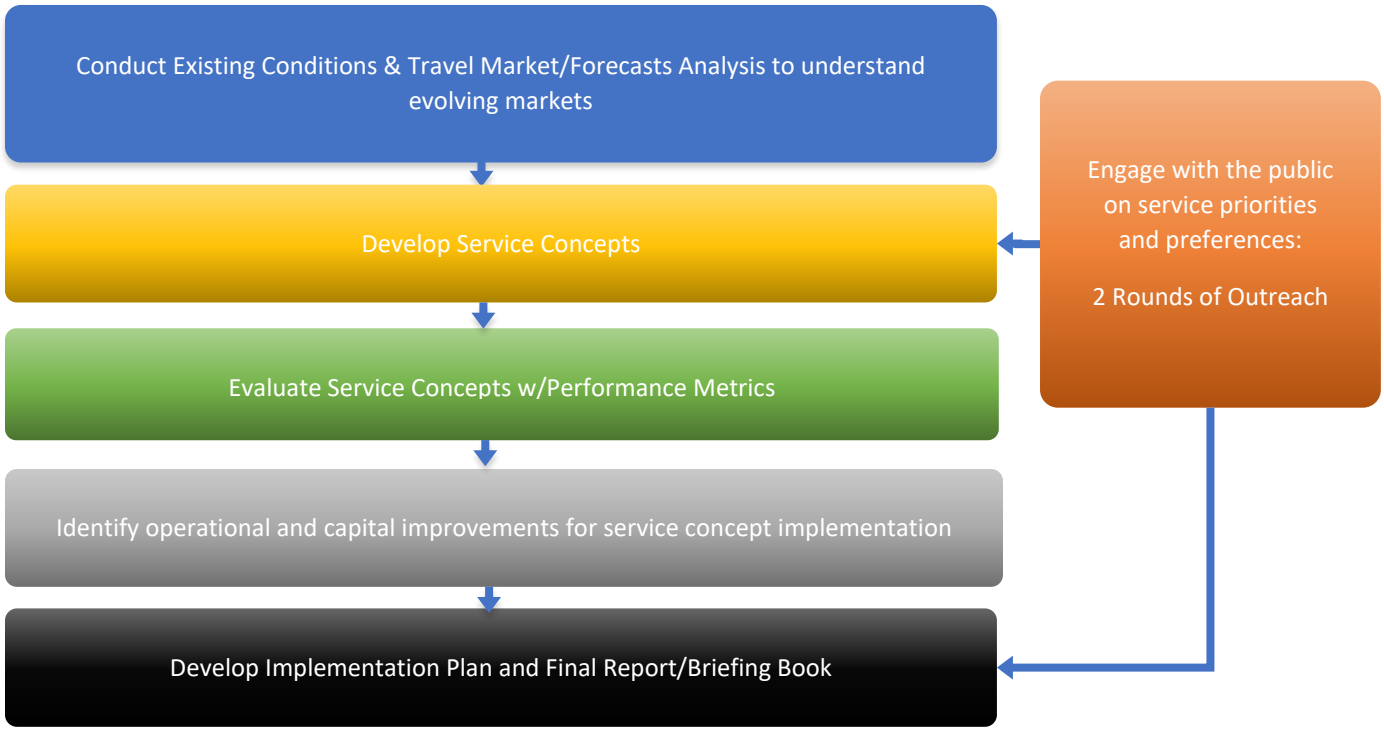
- **Support Regional Growth:** Provide sustainable transit service that supports forecasted regional housing and job growth, aligned with regional equity and GHG reduction goals.
- **Increase Capacity and Improve Service:** Build on the current efforts to increase capacity and service (i.e., Core Capacity Program, Silicon Valley extension) to further enhance the customer experience, improve operational efficiency, and ensure financial stability.
- **Respond to evolving ridership trends:** Grow ridership and respond to new markets, including travel pattern changes related to the pandemic, emphasizing off-peak, weekend, and reverse commute trips.
- **Identify the necessary operational and capital improvements to implementation.**

Study Approach/Methodology

Figure 1 describes the stepwise study Approach. The Study uses a "scenario planning" approach, identifying alternative BART service plans that could be deployed as the market and conditions change. This approach allows BART to be nimble and thoughtful as ridership recovers in unanticipated ways in the wake of the pandemic. The Study also identifies an associated capital project list (such as new storage facilities and bypass tracks) that would leverage planned system investments while improving operational reliability and efficiency and increasing capacity. BART's overarching objectives continue to be matching BART service with regional demand patterns, supporting the Plan Bay Area 2050 goals, improving job access for all communities, and reducing greenhouse gases.

The remainder of this Briefing Book is organized into sections that summarize the corresponding steps shown in Figure 1; more details of each step are available in the Study's Final Technical Report.

Figure 1. Study Approach Steps



Existing Conditions and Travel Market Analysis

In 2019, BART had approximately 410,000 weekday riders. Pre-pandemic, BART operated over-capacity (exceeding BART's service criteria for passengers per car) in the peak-hour, peak direction, notably in the Transbay Tube. Forecast regional population and employment growth were projected to result in more intensive development within the urban core; overall peak period ridership was projected to increase between 25 to 30 percent from peak pre-pandemic levels over the next 20 to 30 years (see ridership demand scenarios descriptions below). However, ridership remains diminished in the wake of the pandemic, challenging BART's financial outlook. As of November 2022, BART systemwide ridership is around 40 percent of pre-pandemic levels; ridership recovery has been stronger during off-peak periods, reflecting the importance of serving these markets as part of overall ridership recovery strategy and to respond to evolving post-pandemic regional ridership patterns. Ridership forecasts developed by BART's Financial Planning Department show ridership levels substantially below pre-pandemic forecasts, stabilizing in 2026 at 80% of pre-COVID forecast in the Upside scenario, in 2027 at 70% in the Base Case scenario, and in 2029 at 60% in the Downside scenario (See Figure 3)[1]. The overall reduction in ridership is consistent with survey findings of the Bay Area Council's monthly surveys of employers in the region. The survey shows that many businesses expect that their "new normal" will have employees reporting to the office an average of three days per week. Further, employers indicate that many employees may be working outside of typical 9am to 5pm schedules. This shift, or reduction, in work travel patterns is particularly important to a commuter-oriented service like BART.

[1] Forecasted ridership outlook developed in the Fall of 2022 represents an optimistic scenario; ridership projection has since been adjusted downward.

Figure 2. AM Peak Hour Transbay People Throughput by mode (2016)

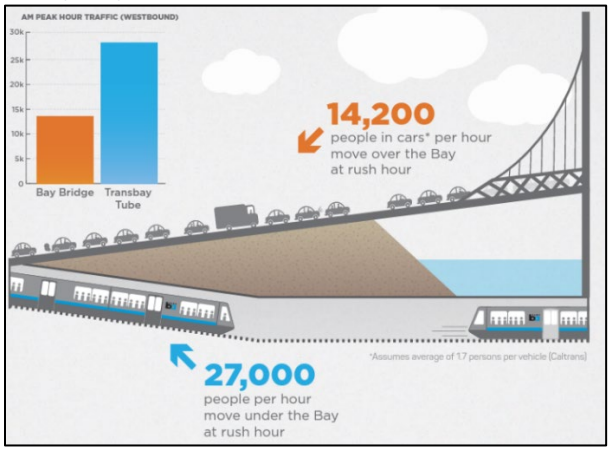
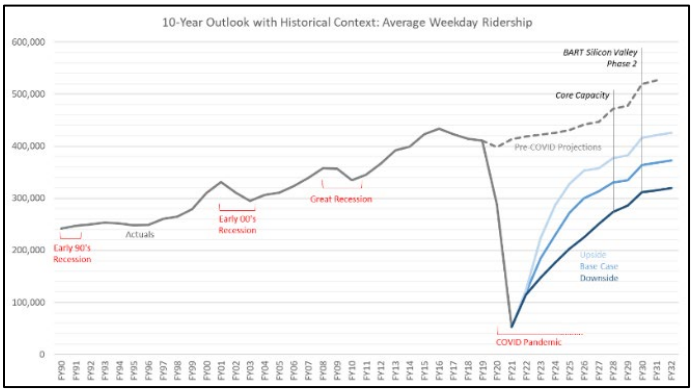


Figure 3. Average Weekday Ridership with Historical Context and 10 Year Outlook



This study evaluated two future ridership demand scenarios. Given the current context of uncertainty on ridership trends, these scenarios may be better understood as growth along a trajectory over time. The study identified service concepts and related improvements to improve how BART service these scenarios in the mid to long-term, oriented around post-Communications-based Train Control (CBTC) implementation but before a second transbay crossing as part of Link21:

- **COVID Recovery Scenario:** 415k daily ridership; BART's "upside" scenario for ridership recovery stabilizing at 80% of 2030 forecasts made pre-COVID as reflected in BART's long-range financial planning ridership forecast.
- **Plan Bay Area Growth Scenario:** 785k daily ridership; Plan Bay Area 2050 (modeled for the year 2040), more off-peak ridership and more growth focused around BART stations. In particular, travel to downtown San Francisco and Oakland become smaller proportions of commute destinations (although still the largest ridership in absolute numbers), with trips to Daly City, 16th Mission, the Peninsula, and the western East Bay Corridors accounting for higher proportions of systemwide AM and PM peak trips.

Figure 4 and Figure 5 compare ridership demand distribution between the two scenarios by time period.

*Figure 4. COVID Recovery Scenario: Station Exits by Time Period (AM, PM, and Off-Peak)**

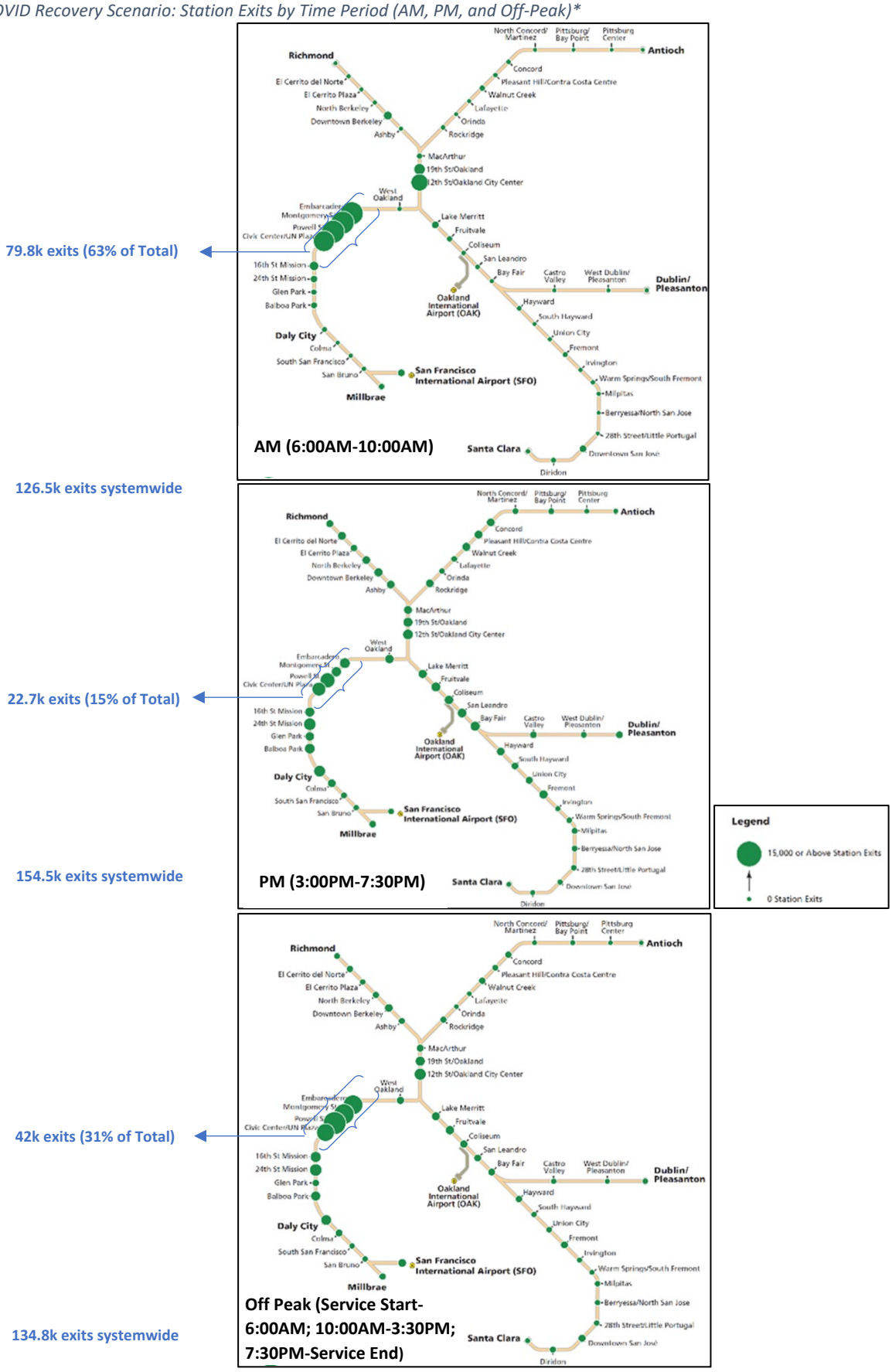
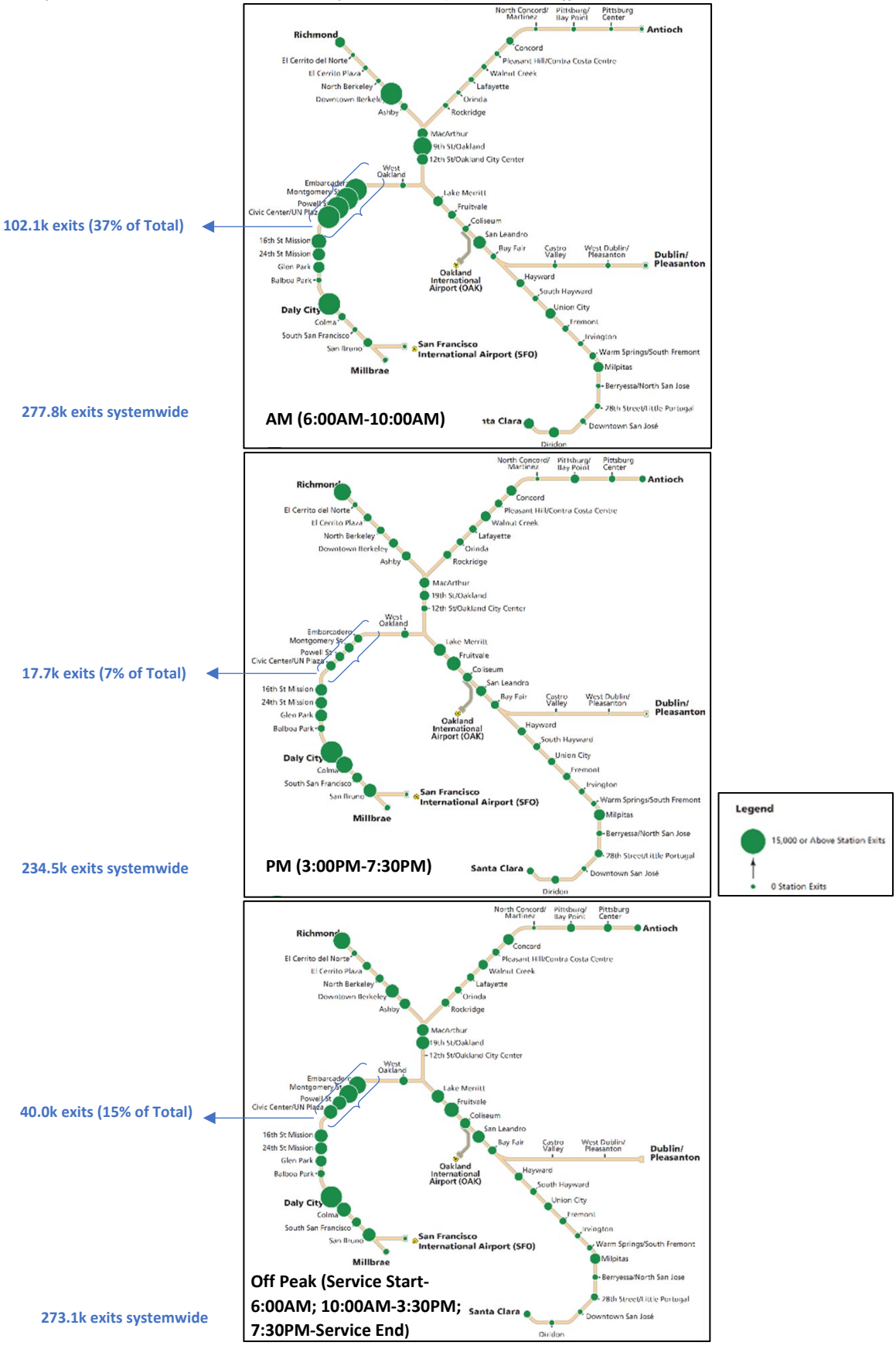


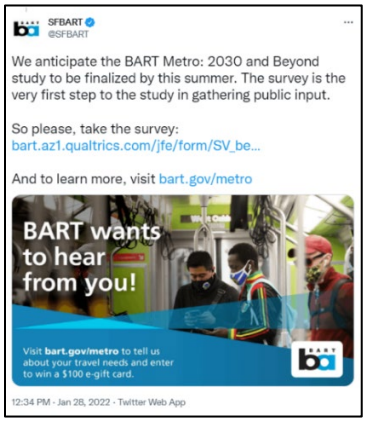
Figure 5. Plan Bay Area Growth Scenario: Station Exits by Time Period (AM, PM, and Off-Peak)



Public Outreach Round 1

From January 28 to February 22, 2022, the project team conducted the first round of outreach to obtain community feedback on travel needs, priorities, and potential service scenarios in response to changes in travel and work patterns and the need to plan for changing ridership.

- Public input was encouraged via a survey e-mailed to a random sample of riders, in-station promotion via electronic sign messaging, social medial promotions, and emails to Community Based Organizations (CBOs). Due to the COVID Omicron Surge, no in-station engagement was conducted.
- 1,101 surveys were completed.
- Results:
    - Riders prioritized service improvements based on frequency of ridership: Frequent riders value increased weekday commute and evening service, while relatively infrequent riders value increased Saturday service.
    - Riders' trade-off of frequency vs. direct service: Direct service is preferred when wait time is 10 minutes, but more frequent service with a transfer is preferred if direct service requires a 15-minute wait.
    - Most respondents are willing to wait up to 9 minutes to transfer between trains. Among those who forego certain trips on BART due to having to transfer, transfer wait time is the most common reason.



Service Concept Development

Based on the travel market analysis and feedback from the first round of public engagement, the project team developed 8 service concepts, with different headways and route configurations. Overall, these service concepts would provide higher service frequency (all peak-service achieves CBTC enabled 30 transbay trains per hour) and better customer experience than BART's existing service. For reference, BART's current 2022 daytime service provides 5 lines of service, each operating at 15-minute headways. BART's current evening service (after 9:00 pm) provides 3 lines with 30-minute headways. The daytime service concepts are described in the following table:

Concept	Service Characteristics	Rationale
Concept 1	Existing 5-Line service (See Figure 6) with 12-minute headways	Service concept at this frequency can be implemented after BART's implementation of the Communications-based Train Control. This is considered the study baseline
Concept 2	Existing 5-Line service with 10-minute headways	Higher service frequency over Concept 1
Concept 3	6-Line Enhanced East Bay service (See Figure 7) with 12-minute headways	Service concept designed to provide more direct intra-East Bay travel and improve experience for non-Transbay commute patterns
Concept 4	6-Line Enhanced East Bay service with 8-minute headways	Higher service frequency over Concept 3 and the system's theoretical maximum throughput throughout the day

Concepts 1, 2, and 3 also include peak service on top of the base headways to achieve 30 Transbay trains per hour, which aligns with expected service level with the implementation of BART's Core Capacity Program.

Figure 6. Existing 5-line Service with Silicon Valley Extension

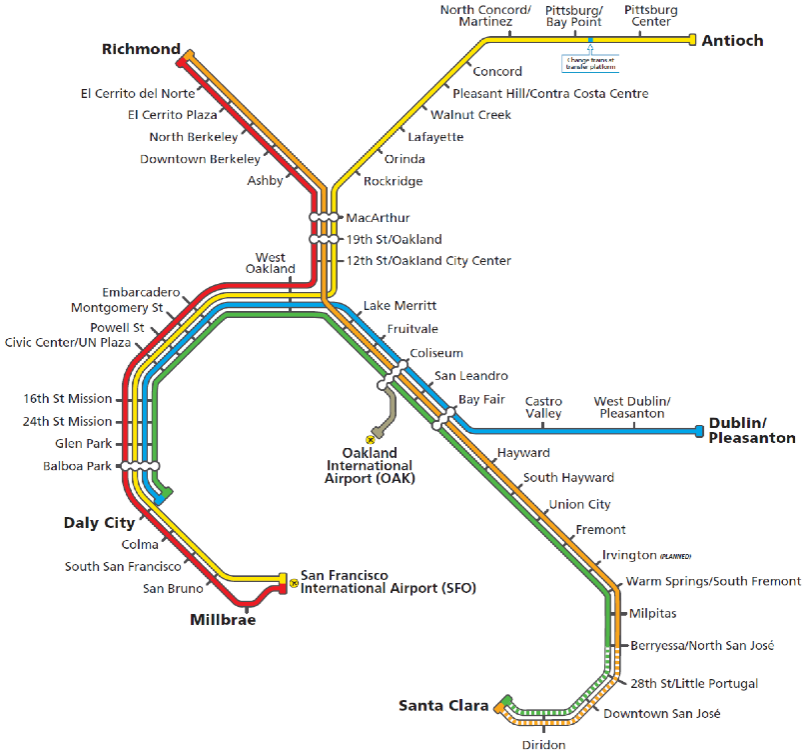
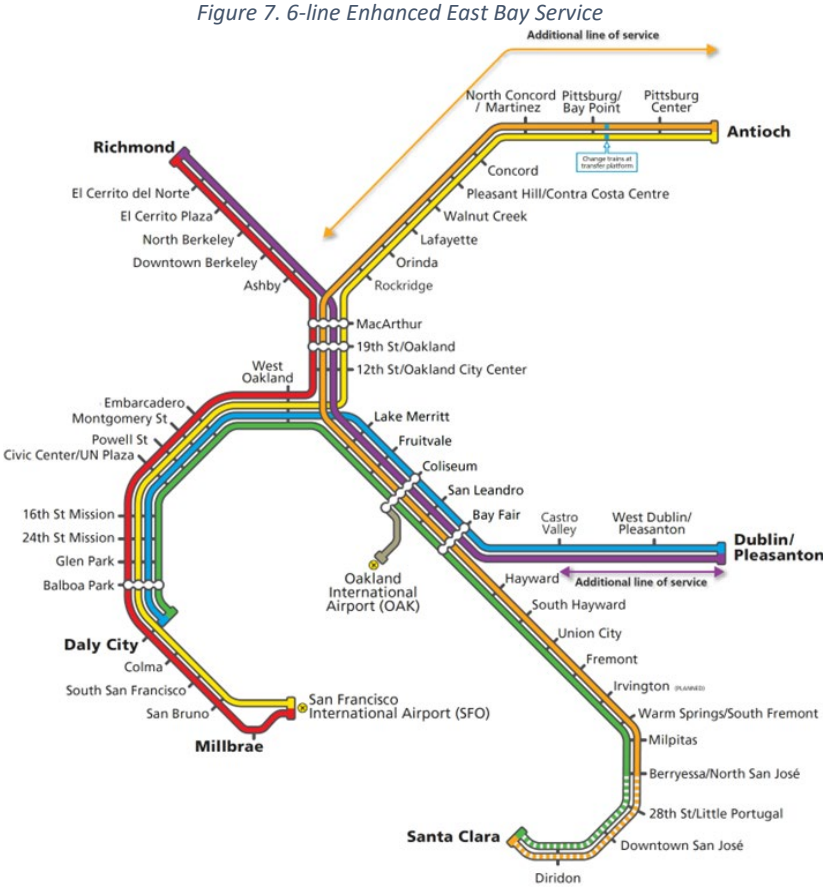


Figure 7. 6-line Enhanced East Bay Service



For off-peak service/evening period, service concepts include:

Concept	Service Characteristics	Rationale
3-line/20 minute	Existing 3-Line evening service (Figure 8) with 20-minute headways	Historic evening service, 3-Line with 20-minute headways
Enhanced Core/20 minute	3-line/20-minute concept overlaid with additional service between Daly City and Richmond and between Daly City and Bay Fair, also at 20-minute frequencies (See Figure 9)	Additional overlaid service targets higher ridership in the system core; extents defined by demand and operational characteristics including ridership, demand/transit competitiveness, equity, efficiency, and feasibility. Overlaid service benefits over half of off-peak and weekend trips
Full 5-line	Full 5-Line service (shown in Figure 6) at 30-minute frequency	Provide direct service to the system's outer extents, while providing higher service in the core
Full 6-line	Full 6-Line service (shown in Figure 7) at 30-minute frequency	Provide more direct service specifically for intra-East Bay travel, and with higher core service

Figure 9. Existing 3-line Evening Service with Silicon Valley Extension

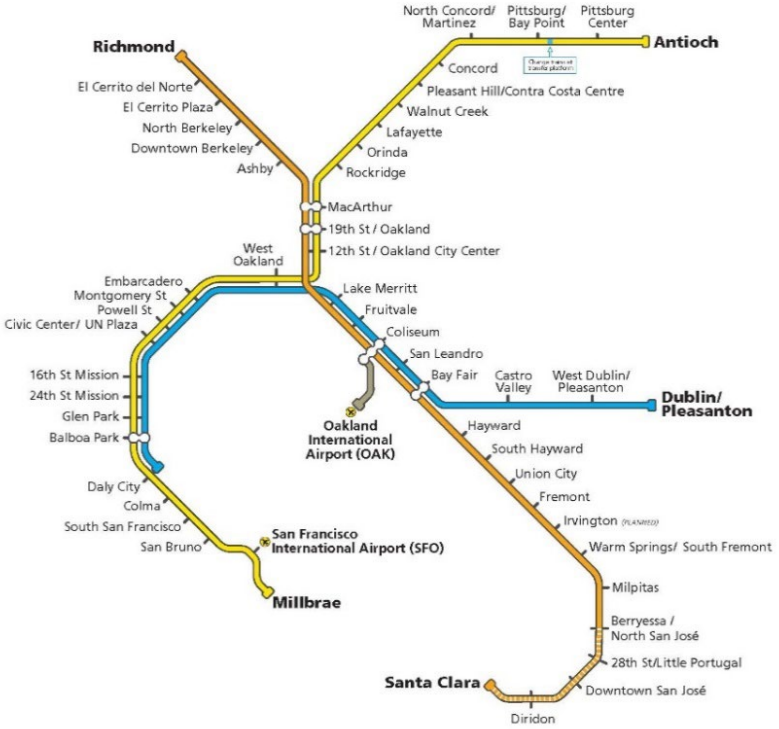
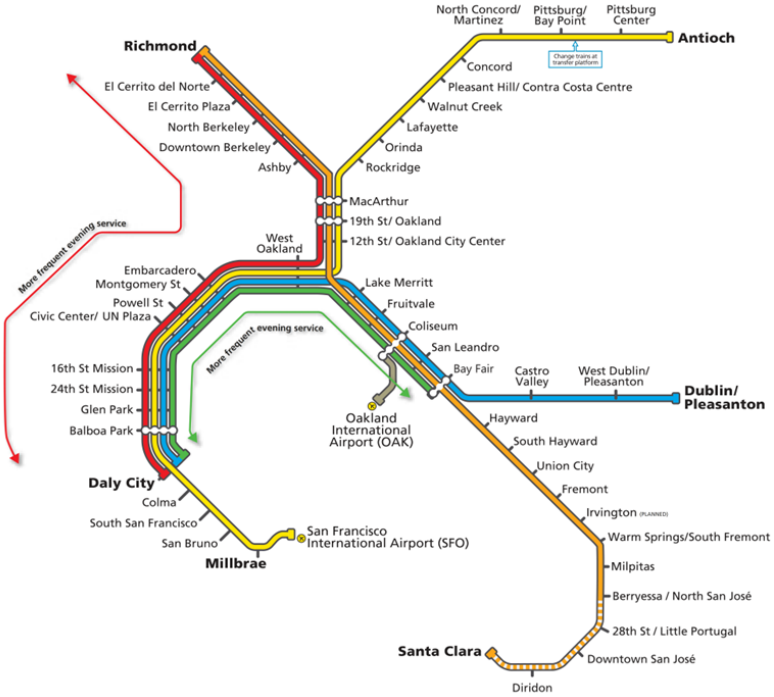


*Figure 8. Enhanced Evening Core Service**

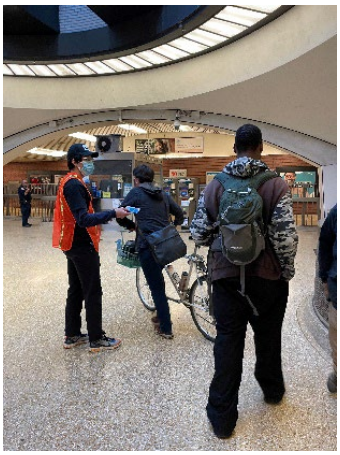


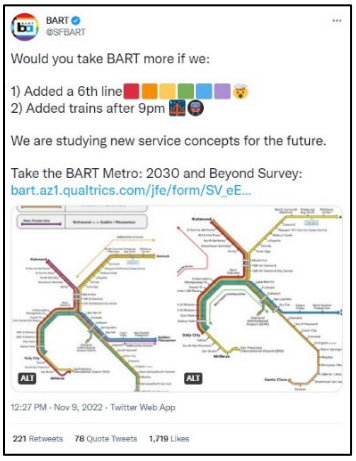
* An equivalent evening concept was developed to pair with the 6-line daytime concept. Instead of the Orange and Blue Lines in Figure 8, it has base service from Dublin/Pleasanton to Richmond (Purple) and Santa Clara to Daly City (Green) as illustrated in Figure 9. Additional core service continues from Bay Fair to Daly City (shortened Blue).

Public Outreach Round 2

A second round of outreach was conducted between November 9 and November 22, 2022, to seek feedback on these two new service concepts Enhanced East Bay and Enhanced Evening Core Services.

- Strong enthusiasm to provide feedback on future service concepts and positive feedback on both new concepts.
- Public input was solicited and collected via the same means used for Round 1 with the addition of flyer distribution at 6 stations.
- 5,864 surveys were completed.
- Results:
    - Pluralities of respondents indicated that both service concepts would serve their needs better than the existing service, and that they would definitely or probably ride BART more often if these concepts were implemented.
    - The Enhanced Evening Core received more positive response than did Enhanced East Bay service.
    - Low-income, frequent riders and younger riders consistently had more positive responses to both service concepts.
    - Riders who use BART between 4:00 am and 6:00 am also consistently indicated that the Enhanced East Bay service concept would better serve their needs and would lead to increasing ridership.





Evaluation of Service Concepts & Benefits to the Region

The project team developed two problem statements that guide the evaluation of service concepts:

1. **Post pandemic, BART needs to respond to evolving ridership, particularly those of the off-peak travel and non-transbay commute markets.**
2. **BART needs to plan for the region's future by increasing system capacity and identifying potential future constraints.**

To address these project statements, service concepts were evaluated using both the COVID Recovery and Plan Bay Area Growth Demand scenarios. The tables below organize this evaluation by demand scenario and daytime versus off-peak/evening service. A color scheme of red (relatively lower performing concepts), yellow (neutral performing concepts), and green (relatively higher performing concepts) serve as ways to compare the different service concepts relatively and not as a comparison to existing BART service. Note that the project team evaluated service concepts where applicable to the demand scenario. For instance, under the COVID Recovery Demand, Concept 3 did not see crowding or extensive high transfer rate/wait time, so evaluating Concept 4 (which only differs by higher frequency) would not likely provide additional insights. The same rationale explains why Concept 1 was not evaluated under the PBA Growth Demand scenario, since it was operating above many thresholds under the COVID Recovery Demand.

COVID Recovery Demand *Daytime Service - Customer Experience Metrics*

Metric	Performance Indicators	Concept 1 5-line/12-minute	Concept 2 5-line/10-minute	Concept 3 6-line/12-minute
	Note: lower is better, except for Regional Connnectivity indicator	Best Performing Service Concept	Neutral Performing Service Concept	Worst Performing Service Concept
Regional Connectivity	• Average trains per hour serving key regional transit hubs[2]	Lowest frequency (27-35)	• Highest frequency during the mid-day (32) • Just below Concept 3 in the Peaks	Highest frequency during the AM and PM Peak (37-38)
Loading / Crowding	• Percent of passenger hours above crowding threshold: 115 peak passengers per car • Average and Max passengers per car at screen lines	Crowding above threshold only in AM peak: • At 2 San Francisco bound East Bay screen lines • 3-5% of passenger hours		No crowding observed above threshold in any time period
Transfer Rate / Wait Time[3]	• Percent of trips that transfer • Average Transfer Wait Time	• Highest transfer rate (10-13%) • Transfer wait time (~2 min)	• Transfer rate (10-11%) • Lowest transfer wait time (~1.5 min)	• Lowest transfer rate (6-7%) • Highest transfer wait time (~3.5 min) • Transfer rate for trips beginning in some East Bay end of lines (Richmond, Dublin, Pittsburg/Bay Point) improved
Travel Time	• Average Travel Time • Average Preboarding Wait Time	• Travel time (28.8-30.5 min) • Pre-boarding (3.2-3.7 min)	• Lowest travel time (28.2-30.2 min) • Lowest pre-boarding time (~3.0 min)	• Highest travel time (28.9-30.9 min) • Highest pre-boarding wait (3.4-3.8 min)

Both Concept 2 and Concept 3 perform better than Concept 1 under the COVID Recovery Scenario, with different parts of the region being impacted differently by each. The higher transfer rates of Concept 1 and 2 as compared to Concept 3 are due more to passengers using advantageous transfer opportunities to save time rather than to lack of direct service. These savings show up in the average travel time. While the differences are small enough on a per-person basis to have relatively little impact on the

[2] Transit hubs are defined by availability of connecting transit service and level of Clipper transfer activity.
[3] Transfer Rate/Wait Time metrics are not color coded for performance comparison as they may be indicators of advantageous transfers to save travel time and not necessarily required for passengers to complete trips.

decision to travel, aggregating those minutes across 415,000 passengers makes those differences more significant.

Crowding issues associated with Concept 2 are due to the ordering of the Green and Blue Line service and not necessarily due the fact that the Lake Merritt – Bay Fair corridor does not have peak service in that concept. Were they switched, having the Blue Line precede the Green Line, loads would stay below the crowding threshold.

That said, passengers traveling to/from Antioch – Rockridge and Dublin/Pleasanton – Castro Valley see significant improvements from Concept 3's 6-Line service, while Richmond – Ashby and Peninsula passengers end up with longer pre-boarding wait times due to the system's inability to evenly distribute services on all system extremities.

COVID Recovery Demand *Daytime Service – Operational Benefit Metrics*

Metric	Performance Indicators	Concept 1 5-line/12 minute	Concept 2 5-line/10 minute	Concept 3 6-line/12-minute
	Note: lower is better, except for Passenger hours per car hour indicator	Best Performing Service Concept	Neutral Performing Service Concept	Worst Performing Service Concept
Fleet Requirement	• Within BART's current planned fleet of 1,200 cars	Yes	Additional 58 cars needed	Yes
Resource Efficiency	• Train hours • Car hours • Passenger hours per car hour	• Lowest train and car hours • Highest passenger hours per car hour	• Similar train hours as Concept 3 but requires 15% more car hours • Lowest passenger hours per car hour	• Requires 16% more train hours than Concept 1, but similar car hours (due to shorter 5-car trains on East Bay routes) • Passenger hours per car hours similar to Concept 1

While Concept 2 looks like the worst daytime service concept when looking at the operational metrics, it is important to note that they are highly correlated to train length assumptions made for each concept. Concepts 1 and 2 assumed 8-car trains on Orange Line service and 10-car trains on all other lines; Concept 3 assumed 5-car trains on Purple and Orange Line service and 10-car trains on all other lines. Were Concept 2 to be able to accommodate ridership with 5- or 6-car trains on the East Bay Richmond – Santa Clara Route, it could be accommodated within the planned 1,200 car fleet.

Additionally, because demand was assumed static across all scenarios, those service concepts with higher car hours had lower passenger hours per car hour. In reality, more frequent service is expected to result in more ridership and therefore better utilization of higher-frequency service. That said, all service concepts provided more capacity than needed during the mid-day.

COVID Recovery Demand *Off-Peak/Evening Service - Customer Experience Metrics*

Metric	Performance Indicators	3-Line/20-minute	Enhanced Core /20-minute[4]	Full 5-Line service/ 30-minute	Full 6-Line Service/ 30- minute
	Note: lower is better, except for Regional Connnectivity indicator	Best Performing Service Concept	Neutral Performing Service Concept		Worst Performing Service Concept
Regional Connectivity	• Average trains per hour serving key regional transit hubs[5]	Lowest trains per hour (13)	Highest trains per hour (19-20)	Similar trains per hour (15-16)	
Loading / Crowding	• Percent of passenger hours above crowding threshold: 80 off-peak passengers per car • Average and Max passengers per car at screen lines	No crowding observed above thresholds		Crowding above threshold at one screen line due to transition from higher daytime demand	No crowding observed above thresholds
Transfer Rate/ Wait Time[6]	• Percent of trips requiring transfers • Average Transfer Wait Time	• Highest transfer rate (18%) • Transfer wait time (4 min)	• Transfer rate (11-15%) • Transfer wait time (3-4 min)	• Transfer rate (14%) • Transfer wait time (2 min)	• Lowest transfer rate (11%) • Transfer wait time (4 min)
Travel Times	• Average Travel Time • Average Preboarding Wait Time	• Travel time (34.7 min) • Pre-boarding wait (6.4 min)	• Lowest travel time (32.6-33.1 min) • Lowest pre-boarding wait (4.6-5.1 min)	• Travel time (33.3 min) • Pre-boarding wait 5.6 min)	• Highest travel time (33.8 min) • Highest pre-boarding wait (5.7min)

The off-peak/evening service concepts were evaluated for passengers completing their trips from 8:00 PM to 8:59 PM. The project team chose this hour to better stress test the schedules relative to demand. In the COVID Recovery Scenario Demand profile, there are approximately 12,100 trips associated with this hour; this value also better represents possible peak weekend service. Pre-COVID, Saturday ridership could exceed 8,000 trips per hour from 9:00 AM to 8:00 PM peaking at just under 14,000 trips per hour. Sundays exceeded 8,000 trips per hour from 10:00 AM to 6:00 PM peaking at 10,000. Unfortunately, the comparison of schedules was impacted by uneven transitions from the base daytime

[4] Results aggregated for 5-Line and 6-Line Enhanced Evening Core Services.
[5] Transit hubs are defined by availability of connecting transit service and level of Clipper transfer activity.
[6] Transfer Rate/Wait Time metrics are not color coded for performance comparison as they may be indicators of advantageous transfers to save travel time and not necessarily required for passengers to complete trips.

service schedules across the service concepts. While service from the end of the line starts to transition to evening service levels by 7:30 PM, some trips operating at the daytime service frequency may not reach their terminal stations until after 8:30 PM due to the length of the trips.

Similar to the daytime evaluation, the 6-Line service concepts (Enhanced Core and Full 6-Line) have the lowest transfer rates, but higher transfer and preboarding wait times as compared to their equivalent 5-Line service concepts. Overall, the off-peak/evening service concepts have longer preboarding wait time compared to the daytime service concepts due to lower service frequency. Average travel time is impacted by the longer wait times as well as differences in evening travel patterns as compared to daytime.

While the study did not quantify perceived safety that passengers would experience across the different service concepts, survey efforts by LA Metro[7] has shown that perceived safety at station and on trains are related to numerous factors; the only one that would vary across the service concepts would be the amount of people nearby. While crowding above the off-peak threshold could be a proxy of the number of other passengers nearby in-vehicle, the average pre-boarding and transfer wait time could also be a proxy (i.e., the longer the wait time between trains may result in more passengers waiting in station or on platform). Further evaluation would be needed to compare perception of safety.

[7] According to LA Metro 2020 Gender Action Plan – Understanding How Women Travel (p. 94 & 97 of pdf): Among women who took transit at time of survey, the top 3 changes that would make them feel safer: transit police nearby, lighting, and other people nearby. Among women who previously took transit at time of survey, the top 3 changes: Other people nearby, security cameras, lighting.

Metric	Performance Indicators	3-Line / 20-minute	Enhanced Core/ 20-minute[8]	Full 5-Line Service/ 30-minute	Full 6-Line Service/ 30-minute
	Note: lower is better, except for Passenger hours per car hour indicator	Best Performing Service Concept	Neutral Performing Service Concept	Worst Performing Service Concept	
Fleet Requirement	Within BART's current planned fleet of 1,200 cars	Yes	Yes	Yes	Yes
Resource Efficiency	• Train hours (lower is better) • Car hours (lower is better) • Passenger hours[9] per car hour (higher is better)	• Lowest train and car hours • Highest passenger hours per car	• Highest train and car hours required • Lowest passenger hours per car hours	Train hours and Car hours roughly halfway between 3 line/20 minute and Enhanced Core	Train hours required similar to Enhanced Core, but car hours similar to Full 5-line

Overall, the Enhanced Core concepts provide the most train service calculated by train hours and service frequency, followed by the Full 5-Line and 6-Line concepts. There are some segments that benefit most from the Full 5-Line and 6-Line concepts while others have less service in the Full 5-Line concept as compared to the 3-Line/ 20-minute service. Car hours are more generally proportional to train hours in the service concepts, since most lines of service were modeled with 10-car trains. Across service concepts, average trains lengths are within a half car per train (9.1-9.6) except for the Full 6-Line service which has an average of 8.2 cars.

Passenger demand, represented approximately by passenger hours, was assumed to be fixed across all scenarios so those service concepts with fewer car hours perform better when looking at utilization (passengers hours per car hours). In reality, more frequent service should result in higher ridership improving the utilization rate of those services that best align frequency with demand.

[8] Results aggregated for 5-Line and 6-Line Enhanced Evening Core Services.
[9] Passenger hours/demand assumed to be fixed across scenarios. In reality, more frequent service may result in higher hours/demand.

Equity Analysis:

The project team compared the customer experience metrics for trip patterns associated with Priority Populations, which includes passengers of color and low-income populations, with those associated with the remainder of the population. This analysis included comparing daytime and off peak/evening service concepts under the Covid Recovery Demand scenario and is summarized below:

- Daytime service concepts:
    - Passengers of color experience: slightly less crowding across service concepts; lower transfer rates in Concept 1; and slightly higher transfer rates in Concept 3 during the mid-day and PM period.
    - Low-income residents experience: crowding level consistent with the remainder of the population; higher transfer rate in the AM and lower transfer rate in the PM peak across service concepts. Average travel time and preboarding wait time for low-income riders consistently shorter than the rest of the population.
- Off-peak/Evening service concepts:
    - Passenger of color experience: shorter pre-boarding wait time and average travel time across service concepts.
    - Low-income residents experience: lower transfer rates, average travel time and pre-boarding wait time relative to the rest of the population.

Plan Bay Area Growth Demand *Daytime Service - Customer Experience Metrics*

Metric	Performance Indicators	Concept 2 5-Line/10-minute	Concept 3 6-Line/12-minute	Concept 4 6-Line/8-minute
	Note: lower is better, except for Regional Connnectivity indicator	Best Performing Service Concept	Neutral Performing Service Concept	Worst Performing Service Concept
Regional Connectivity	• Average trains per hour serving key regional transit hubs[10]	Similar frequency in AM and PM Peak (36-37) and during mid-day (30-32)		Highest (44) trains per hour
Loading / Crowding	• Percent of passenger hours above crowding threshold: 115 peak passengers per car • Average and Max passengers per car at screen lines	• Crowding above threshold only in AM peak (22%) • Most balanced average load at Northbound San Francisco & Colma screen lines in AM peak	• Crowding above threshold in AM and PM peaks (22% and 6%) • Most balanced average load at San Francisco bound Transbay screen line in AM Peak • PM crowding on the Southbound Richmond line due to shorter (5-car) Purple Line trains	• Highest crowding above peak threshold in AM and PM peaks (24% and 5%) • PM crowding on the Northbound Antioch line due to shorter (5-car) Orange Line trains
Transfer Rate / Wait Time[11]	• Percent of trips requiring transfers • Average Transfer Wait Time	• Transfer rate (13-14%) • Lowest transfer wait time (1.5-1.7min)	• Lowest transfer rate (8-9%) • Highest transfer wait time (3.6 min)	• Highest transfer rate (16-20%) • Transfer wait time (1.8-2.3)
Travel Time	• Average Travel Time • Average Preboarding Wait Time	• Travel time (27.9-29.9 min) • Pre-boarding (2.9-3.2 min)	• Highest travel time (28.6-30.6 min) • Highest pre-boarding time (3.5-4.0 min)	• Lowest travel time (27.1-29.4 min) • Lowest pre-boarding wait (2.2 min)

Not surprisingly, with 89 % more daily trips, the Plan Bay Area (PBA) Growth scenario sees more crowding than the COVID Recovery scenario. The 6-Line service concepts are subject to crowding in the AM and the PM Peak; in the PM peak, this is primarily due to the model having passengers transfer from trains arriving from San Francisco to 5-car East Bay services, which create twice as many trip opportunities for passengers from San Francisco to Richmond and/or Antioch, but which overload the shorter trains. With Peak trains from both Bay Fair and Pleasant Hill, Concept 3 is able to best balance AM Peak loads into San Francisco, although with the demand just at the maximum capacity of the Trasnbay Tube, there are still some trains that hit the crowding threshold. With a more dispersed travel

[10] Transit hubs are defined by availability of connecting transit service and level of Clipper transfer activity.
[11] Transfer Rate/Wait Time metrics are not color coded for performance comparison as they may be indicators of advantageous transfers to save travel time and not necessarily required for passengers to complete trips.

pattern and Antioch-bound trains meeting 8-car trains to Richmond, Concept 2 is able to accommodate the PM Peak in the PBA scenario. All service concepts evaluated in this scenario continue to see crowding during AM peak and/or PM peak, indicating that additional travel demand would need additional strategies, such as a second Bay crossing (currently being studied as part of the Link21 program).

While the 6-Line Concept 3 travel times did not compare favorably to the 5-Line Concept 2 travel times, the 6-Line Concept 4 performs the best on this metric thanks to more even spacing allowed by the lack of peak trains. This is illustrated by it having the lowest pre-boarding wait times. While the loading and transfer rate metrics do not perform as well in Concept 4 as compared to the other service concepts, these high values can be attributed to the short 5-car trains on the East Bay routes and scheduling that allows passengers to take advantage of train meets that allow for relatively low-penalty transfers and faster trip times. Transfer rates are approximately 2% higher for Concepts 2 and 3 in the PBA scenario as compared to the COVID Recovery scenario illustrating the trend toward less San Francisco-focused travel.

Plan Bay Area Growth Demand *Daytime Service: Operational Benefit Metrics*

Metric	Performance Indicators	Concept 2 5-line/10-minute	Concept 3 6-line/12-minute	Concept 4 6-line/8-minute
	Note: lower is better, except for Passenger hours per car hour indicator	Best Performing Service Concept	Neutral Performing Service Concept	Worst Performing Service Concept
Fleet Requirement	• Within BART's current planned fleet of 1,200 cars	Additional 58 cars needed	Yes	Additional 198 cars needed
Resource Efficiency	• Train hours • Car hours • Passenger hours[12] per car hour	• Lowest train hours • Car hours and passenger hours per car hours roughly half way between other two concepts	• Lowest car hours • Highest passenger hours per car hours	• Highest train hours • Highest car hours ; without peak service they stay high throughout day • Lowest passenger hours per car hours

Concept 4 requires significantly higher resources (trains, cars, operators) to run than any of the other service concepts. While Concept 2 may be feasible with the planned car fleet (if shorter train consists were assumed as previously discussed), a new procurement would be needed to operate Concept 4. Of the 3 service concepts, Concept 3 is the most operationally efficiency and does not require additional procurement beyond the planed car fleet.

[12] Passenger hours/demand assumed to be fixed across scenarios. In reality, more frequent service may result in higher hours/demand.

Plan Bay Area Growth Demand *Off-Peak/Evening Service: Customer Experience Metrics*

Metric	Performance Indicators	Enhanced Core/20-minute[13]	Full 5-Line Service/30-minute
	Note: lower is better	Best Performing Service Concept	Neutral Performing Service Concept / Worst Performing Service Concept
Loading / Crowding	• Percent of passenger hours above crowding threshold (80 off-peak passengers per car) • Average and Max passengers per car at screen lines	Crowding above threshold: • 13% of passenger hours • At East Bay bound Transbay screen line	Crowding above threshold: • 22% of passenger hours • At East Bay Bound Transbay and Southbound Lake Merritt screen lines
Transfer Rate / Wait Time[14]	• Percent of trips requiring transfers • Average Transfer Wait Time	• Transfer rate (11.7%) • Transfer wait time (3.2 min)	• Transfer rate (14.3%) • Transfer wait time (2.1 min)
Travel time	• Average Travel Time • Average Preboarding Wait Time	• Travel time (31.4 min) • Pre-boarding wait (5.0 min)	• Travel time (31.6 min) • Pre-boarding wait (5.6 min)

Even with shifts in travel demand, transfer rates, transfer wait time, average travel time, and pre-boarding wait time are all equivalent to their COVID Recovery scenario results with fairly equivalent overall travel times. With the increase in trips from the COVID Recovery scenario, both service concepts experience crowding with the Full 5-Line concept more intensely.

Note that service characteristics do not change between demand scenarios; regional connectivity and operational metrics for evening services under the Plan Bay Area Growth demand are as previously discussed above for COVID Recovery demand. While passenger hour/car hour metrics change with the higher level of ridership demand, the Full 5-Line service concept continues to have slightly higher passenger hours per car hour relatively compared to the Enhanced Core.

Reliability and Resiliency Analysis:

The project team evaluated the three metrics using daytime service Concept 1 and Concept 4 as "book ends" of service levels, and present the following metrics results as ranges, acknowledging that service levels between those book ends would yield results within those ranges.

- Average Delay Per Trip: Systemwide, trips in Concept 4 have 1 additional minute of stopped delay as compared to trips in the Concept 1. This is largely due to the ends of the lines functioning at or above capacity in the service concept. Trips entering terminal areas are frequently delayed by the turns and exits of the preceding trips. The E Linetransfer platform is not able to accommodate Concept 4 due to trains having a 4-minute combined headway in and out of a single platform.

[13] Results aggregated for 5-Line and 6-Line Enhanced Evening Core Services.
[14] Transfer Rate/Wait Time metrics are not color coded for performance comparison as they may be indicators of advantageous transfers to save travel time and not necessarily required for passengers to complete trips.

- Delay Recovery Time: The project team performed a simulation with a 10-minute dwell time for a single train for each of the 3 stations reached directly upon exiting the Oakland Wye (where three key system segments come together: MacArthur-12th St/Oakland, Montgomery-West Oakland, and Coliseum - Lake Merritt). In general, higher volume service levels will have longer recovery times due to operating volumes closer to the capacity threshold. At West Oakland and 12th St/Oakland Platform 3 (trains from San Francisco), the two service concepts are equivalent because they have the same volumes through these stations. At Lake Merritt and 12th St/Oakland Platform 1 (trains from Santa Clara), Concept 4 has much higher volumes than Concept 1, which is reflected in higher recovery time.

Operating Cost

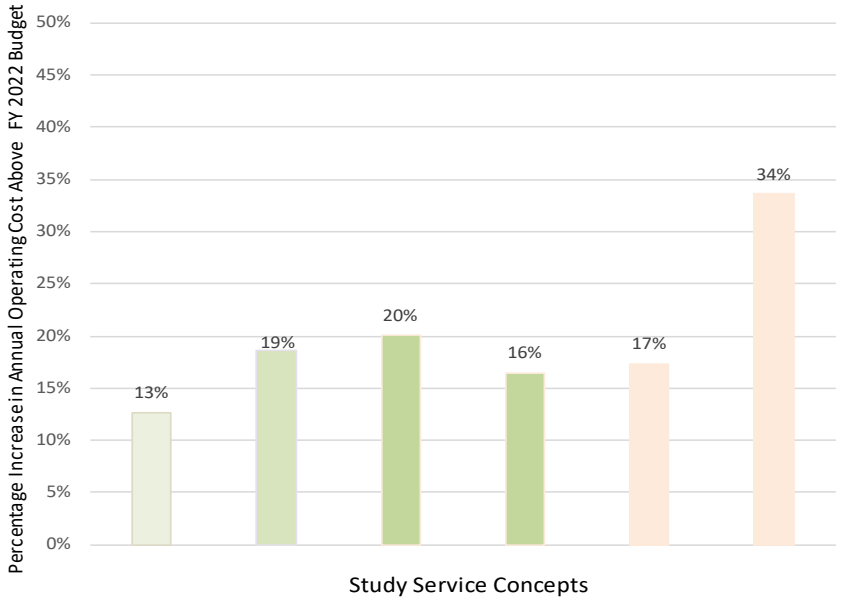
The project team estimated operating costs of the service concepts developed in this study using BART's O&M Cost model, and compared the values to today's operating costs. While the service levels evaluated, and therefore total operating costs, are significantly higher than for BART's budgeted FY 2022 operations, the increases in cost are not proportional to the increase in service (see Figure 10). For instance, compared to BART's FY 2022 actual metrics, the 5-line/12-minute service increases service hours and miles between 60-65%, trains hours increase about 53%, and the total car hours increase by more than 1.5 million hours; however, the annual operating cost only increase by 13%. Overall, because the fixed cost between these service concepts accounts for 70% of total estimated cost, as service goes up across the concepts, the average cost per car hour decreases.

While this model assumed ridership was static, it is expected that ridership would increase with higher service levels. That said, the increase in fares from increased ridership typically does not offset the increase in operational costs. Before service can be increased, additional operating funds will need to be identified.

As shown in Figure 10, the operational full time equivalent staffing (FTEs)[15] required to implement the Study's service concepts would range from 15% to 43% higher than the operational FTEs budgeted in FY 2022. Operational FTEs generally trend with the number of train hours required, with 6-Line/8-Minute service requiring the highest FTEs. The 5-Line/10-Minute and 6-Line/12-Minute concepts require comparable FTEs but note that the Enhanced Evening Core versions of those services require slightly higher FTEs than their Full system service equivalents.

[15] Inclusive of operators and other critical staff for BART train operations (Maintenance and Engineering, Rolling Stock & Shops, Operations Planning, Transportation, and E Line/BART-to-OAK).

Figure 10. Annual Operating Cost and Average Cost per Car Hour of Study Service Concepts



Daytime Service Characteristics	**Concept 1:** 5-line/12-minute	**Concept 2:** 5-line/10-minute	**Concept 2:** 5-line/10-minute	**Concept 3:** 6-line/12-minute	**Concept 3:** 6-line/12-minute	**Concept 4:** 6-line/8-minute
Evening Service Characteristics	3-line/20-minute	Full 5-line Service	Enhanced Evening Core	Full 6-line Service	Enhanced Evening Core	Enhanced Evening Core
Percent Increase in Operational FTEs Required Beyond FY 2022 Budgeted FTEs	15%	23%	25%	22%	23%	43%

Recommended Improvements and Implementation

To implement the service concepts developed in this Study in the mid- to long-term, the project team has identified supportive capital improvements shown in Table 1. Rough Order-of-Magnitude Cost exist for three projects and are shown in parentheses. The capital improvements are organized as follows:

- Existing Needs – These projects address existing needs and would benefit the BART system overall prior to implementation of the study's service concepts. These projects are generally related to operating and supporting a 1,200-car fleet, as required to deliver the assumed baseline service, and to maximize capacity in key corridors.
- Projects specific to service concept implementation: Baseline Service Concept 1, Service Concept 2, 6-Line Service Concepts, and Enhanced Evening Core Concepts.
- Project Benefits: Whether the project has the following primary or secondary benefits:
    - Efficiency & Reliability – These projects increase operational reliability and/or efficiency. Opportunities to improve reliability become more critical as service increases and there

is less buffer in the system to recover from delays. Efficiency projects minimize train hours and focus labor on the most intensively used parts of the system, reducing costs per passenger.

- Capacity Projects- These projects primarily allow for more intense schedules. Without them, reliability can suffer, and some service plans may not be feasible.

Additional analysis and project development are needed in many cases to better scope some of the capital projects, depending on how the agency decides to address demand and funding availability. All projects advanced for implementation would need to be included in BART's Capital Improvement Program and evaluated as priorities among districtwide needs in the capital project prioritization process. Opportunities to advance these projects as part of other capital programs or in coordination with local development processes should be considered. Further, advancing these requires identification of planning and development resources in order to more accurately understand and articulate the benefits as more detailed design, engineering and cost estimation are completed.

The project team has also identified specific evaluations recommended next steps for implementation of each service concept studied.

- **For all Service Concepts:**
  - Microsimulation of operations at Santa Clara terminal.
  - Evaluation of storage capacity on the C Line.
  - Evaluation of West Bay vehicle availability and storage including the potential for new yards and coordinate evaluation with the Link 21 project.
  - Further microsimulation of Daly City as a turnback for service concepts. If deemed infeasible, evaluate Colma as a potential turnback alternative and potential projects necessary for that implementation.
  - Evaluate staffing requirements and facility needs and need for additional traction power.
- **6-Line Service Concepts**
  - Evaluations: further service plan refinement to address slotting and train spacing challenges and terminal capacity issues, particularly at the E Line transfer platform. Additionally, further evaluation of storage capacity on the L Line would be needed.
- **Enhanced-Core Service**
  - Evaluations: microsimulations of operations and evaluation of staffing implications of turning trains at Bay Fair.

Additionally, as part of any change in operational strategy, further analysis of the following should be considered:

- Evaluate service plans with demand levels that respond to changes in service frequency and vehicle crowding.
- Conduct Title VI analysis, as appropriate.

Table 1. Recommended Improvements – Applicability to Existing Needs and Service Concepts Implementation, and Benefits to BART

Applicable Projects	Existing Needs	Service Concepts Implementation				Project Benefits	
		Baseline Service Concept 1 (5-Line/12-Minute)	Service Concept 2 (5-Line/10-Minute)	6-Line Service (Concepts 3 & 4)	Enhanced Core	Efficiency & Reliability	Capacity Projects
Fleet of the Future Maintenance Facility: Vehicle Overhaul Shop	X	X	X	X	x	Primary	Secondary
Hayward Yard M&E Building	X	X	X	X	X	Primary	Secondary
Existing Daly City Terminal Zone Facility Upgrades	X	X	X	X	X		Primary
Augment E Line Fleet	X	X	X	X		Secondary	Primary
Increase West Bay Storage Capacity	X	X	X	X		Secondary	Primary
W-Line Tail Track Extension	X	X	X	X		Secondary	Primary
Intrusion Control	X					Primary	
Colma Turn Back/Terminal Zone Upgrade		X	X	X		Secondary	Primary
Dublin Tail Track Extension		X	X	X		Secondary	Primary
Contra Costa County Storage Capacity			X	X			Primary
Additional breakroom/supervisor towers at Bay Fair and/or MacArthur)				X	X	Secondary	Primary
E Line improvements (car storage and maintenance facilities) and transfer platform reconfiguration				X		Secondary	Primary
E Line electrification						Primary	
Richmond Crossover						Primary	Secondary
'A' Line Siding south of Oakland Yard						Primary	Secondary
Oakland 3rd Track (Wye-West Oakland)						Primary	Secondary
Additional Bay Fair Track/Platform					X	Primary	Secondary
Fleet of the Future: Additional Vehicles Beyond Planned Fleet			X	X		Secondary	Primary
Richmond breakroom/supervisor tower for Richmond Crossover						Primary	
Richmond Yard Storage Track Extension			X	X		Secondary	Primary