

A photograph of a cable-stayed bridge at night. The bridge's central pylon and stay cables are illuminated with a cool blue light. The roadway below is filled with traffic, with the red taillights of cars and buses creating a warm glow. The sky is dark, and the overall scene is a blend of modern infrastructure and urban activity.

CROSSINGS

TRANSFORMATIVE
INVESTMENTS FOR AN
UNCERTAIN FUTURE

NOVEMBER 2019

A graphic element for the Horizon logo, consisting of a solid blue rectangle with a white, wavy line at the bottom, resembling a horizon or a stylized wave.

H O R I Z O N



CROSSINGS

TRANSFORMATIVE INVESTMENTS FOR AN UNCERTAIN FUTURE

NOVEMBER 2019



ASSOCIATION OF BAY AREA GOVERNMENTS
METROPOLITAN TRANSPORTATION COMMISSION



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INTRODUCTION

The construction of any new travel route across San Francisco Bay — whether for cars, trucks and buses; for BART or other rail services; or for a combination of auto and rail uses — certainly would have a transformative effect on the Bay Area, reshaping both the region's transportation network and its broader growth pattern. And while many of the direct impacts on both transportation and land use that such a multi-billion-dollar undertaking would have can be anticipated, there also would be indirect impacts, on everything from the character of individual neighborhoods to regional construction activity, that may not become clear until decades after a project of this scale has been put into service.

Crossings: Transformative Investments for an Uncertain Future is one in a series of Perspective Papers developed as part of the Horizon initiative, led by the Metropolitan Transportation Commission and the Association of Bay Area Governments (MTC/ABAG). Horizon is a planning effort that, for the first time in the Bay Area, comprehensively addresses transportation, housing, economic development, and environmental resilience. In order to expand the traditional long-range planning process and incorporate uncertainty from a wide range of external forces, Horizon considers multiple “futures”, what-if scenarios for the future of the region. Additional information on Horizon, as well as previous Perspective Papers and Futures Reports, is available at <https://mtc.ca.gov/our-work/plans-projects/horizon>.

The *Crossings* Perspective Paper was developed to embrace the uncertainty and to test the extent to which potential new crossings of San Francisco Bay can be expected to perform in each of the three “futures” considered as part of the Horizon process. These include a future known as “Rising Tides, Falling Fortunes” in which the nine-county Bay Area's population rises by just 1 million people over the next 30 years; a “Clean and Green” future in which the region's population increases by a bit more than 3 million; and “Back to the Future” in which, by 2050, some 6 million more people call the Bay Area home.

Crossings makes observations about the relative merits of seven different potential Transbay crossings with respect to mode and performance under these different futures, and it includes recommendations about which crossings should be analyzed further in the coming months and years. The report does not provide specific conclusions about the selection of any specific crossing. Rather, the findings and conclusions of this Perspective Paper will help inform the preparation of *Plan Bay Area 2050*, the region's long-term blueprint for transportation, housing, the economy, and the environment. In addition to *Plan Bay Area 2050* — which is slated for adoption by MTC/ABAG in 2021 — BART, Caltrans and other transportation agencies also may use the *Crossings* Perspective Paper to shape their own planning and project development efforts.

This Perspective Paper is organized as follows:

- Section 2 provides the regional context: in effect, the problem statement that a new crossing investment would be intended to address;
- Section 3 describes the crossing concepts selected for analysis, and how the selection process was undertaken;
- Section 4 describes the evaluation framework;
- Section 5 presents the evaluation summary;
- Section 6 presents the findings;
- Section 7 presents the conclusions; and
- Section 8 presents the next steps.

SECTION 2: CONTEXT

Crossings is neither the first nor the last effort to weigh the pros and cons of new options for Transbay travel. Indeed, scores of ideas for new bridges across and/or tunnels beneath San Francisco Bay have been put forth since Joshua Abraham Norton, the self-proclaimed Emperor of the United States and Protector of Mexico, famously issued his “edict” that such a crossing be established in the 1860s. The Transbay crossings that actually advanced from concept to construction in the intervening years have been so well used that the completion of one often leads to proposals for another. Barely a decade after the 1936 opening of the San Francisco-Oakland Bay Bridge, designers including Frank Lloyd Wright had developed detailed drawings for a new span that would have carried auto traffic across the bay south of the Bay Bridge and north of the San Mateo-Hayward Bridge. More than 70 years later, no such bridge has been built.

Any new Transbay crossing would create an enormous opportunity for the Bay Area: enhancing the region’s economic competitiveness; improving mobility and access to jobs for many thousands of current and future residents; and in several of the considered alternatives even reducing greenhouse gas emissions. Bay Area residents make some 500,000 trips across or under the bay on a typical workday. The San Francisco-Oakland Bay Bridge is the region’s workhorse bridge, carrying one-third of the traffic — some 270,000 vehicles — on all of the Bay Area’s state-owned toll bridges. The Transbay Tube accounts for more than half — some 230,000 passengers — of BART’s average daily ridership. A new Transbay crossing would create redundancy to these vital assets in the event of a natural disaster or other unforeseen circumstances, while also making it easier to accommodate routine maintenance.

Along with enormous opportunity, any new crossing also would create enormous challenges: financial, environmental and social. Construction costs alone would run into the tens of billions of dollars. And while environmental and social costs may be harder to calculate, these would be similarly steep.

Nonetheless, the time is ripe for a fresh appraisal of both the costs and the benefits of a new Transbay crossing. With the Bay Area economy’s strong rebound from the Great Recession in 2008 and 2009 — and especially with an associated concentration of job growth in San Francisco and Silicon Valley — travel demand in the Transbay corridor has grown rapidly over the past decade, resulting in overcrowded highways and transit systems. The Bay Bridge and BART alike are operating at or even over capacity for much of the day, as are U.S. Highway 101 and Interstate 280 into and out of San Francisco.

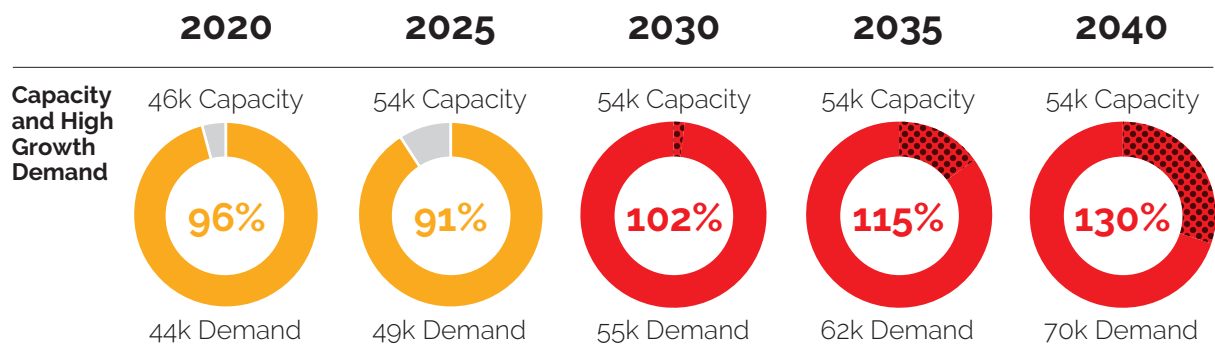
The Bay Bridge Forward initiative adopted by MTC in 2016 includes a mix of highway improvements and transit investments designed to help move more people through the Transbay corridor in fewer

vehicles. Yet the Bay Bridge and its approaches still occupy the top two spots on the region's list of most-congested freeway corridors, with the eastbound afternoon commute from the U.S. 101/I-280 interchange out to Yerba Buena Island topping the charts, and westbound I-80 from Hercules to the Bay Bridge toll plaza ranking number two.

Near-term BART improvements include the ongoing purchase of new "Fleet of the Future" cars to replace and expand the agency's existing fleet. A later procurement will further enlarge the fleet to allow for more frequent Transbay service and expansion into Santa Clara County. The new cars have reconfigured seating to increase passenger space and have three doors per car and allow faster boarding. BART also is modernizing and enhancing its train control and its traction power systems. The new system will provide more reliable service and allow more trains per hour through the Transbay Tube.

While BART's near-term improvements will provide some relief to the system, MTC's 2017 Core Capacity Transit Study indicates these and other short- and medium-term transit investments aimed at easing overcrowding in the Transbay corridor will only help the region buy some time, as shown in Figure 1, below. Under a high-growth forecast, travelers could expect to face severe overcrowding as early as 2030. While congestion relief on the Bay Bridge itself is unlikely even with new infrastructure, the only long-term solution to transit overcrowding in the corridor is construction of a new crossing.

Figure 1. Transbay Corridor Capacity and Demand with Recommended Short- and Medium-Term Improvements



SECTION 3: CROSSING CONCEPTS

This Perspective Paper picks up where the Core Capacity Transit Study left off, folding study of a possible new Transbay crossing into the Horizon framework, and ultimately informing the handling of a potential crossing in the context of *Plan Bay Area 2050*. While this will mark the first time the region's long-term planning document has considered a new crossing with this level of detail and specificity, multiple studies over the past three decades have tackled the question or highlighted the importance of a new Transbay crossing. In addition to the Core Capacity Transit Study, the most comprehensive of these include:

- San Francisco Bay Crossing Study (MTC; 1991)
- San Francisco Bay Crossing Study (MTC; 2002)
- San Francisco Bay Area Regional Rail Plan (MTC; 2007)
- Potential Alternatives Report - San Francisco Bay Crossing Study Update (Bay Area Toll Authority; 2012)
- 2018 California State Rail Plan - Connecting California (Caltrans; 2018)

In total, these studies evaluated nearly 20 unique potential crossings, with other ideas explored by academic institutions, the public and others. Many of these concepts also were captured as part of the Horizon initiative through a public call for ideas, known as the Request for Transformative Projects. As with the studies cited above, the *Crossings* effort was led by MTC/ABAG and the Bay Area Toll Authority (BATA) with the support of partner agencies.

Development of the *Crossings* Perspective Paper began with a long list of concepts based on all these sources, followed by BART, Caltrans and other transportation agency refinement to a shorter list of those concepts that best demonstrated benefits in relieving congestion and increasing accessibility in the Transbay corridor, while also providing a diversity of travel modes and geographic spread. This analysis intentionally excluded concepts focused on ferry service and/or bus service expansion, given that these improvements are already reflected in the short- and medium-term investment priority list from the Core Capacity Transit Study.

Ultimately, seven concepts were selected for further evaluation in this Perspective Paper, which involved identifying a full range of capital improvements (number of highway lanes, new transit lines and stations, etc.) and rail service improvements (hours of operation, frequency of departures, etc.). Costs were then estimated for each concept's capital and/or rail service improvements.



Figure 2. **Map of Crossing Concepts**

For the purposes of the *Crossings* evaluation, the seven concepts were deemed deliverable solutions. Future efforts necessarily will include more robust assessment of the feasibility of any alternatives advanced for further consideration and will take a harder look at the limitations of what capital projects realistically can be built or what services realistically can be operated. While the seven concepts analyzed in this Perspective Paper focus on improvements within the Bay Area proper, and the analysis of benefits is centered on the nine-county region, a new crossing also could benefit Sacramento or other areas beyond the Bay Area's borders. The study of any concept's outside-the-region benefits also could be a subject for future analysis.

A summary of the seven selected crossing concepts is shown in Table 1. These include two auto-only concepts; two BART-only concepts; one conventional rail concept; one combined auto+BART concept; and one combined BART+conventional rail concept. More detail on each concept is provided in Appendix A.

While the *Crossings* Perspective Paper focused on the Transbay corridor — roughly defined as the area between the existing Bay Bridge and the existing San Mateo-Hayward Bridge — additional projects, including other crossings, are being assessed as part of the broader Horizon and Plan Bay Area 2050 process. Project evaluation methodologies were consistent across all projects to enable the relative comparison of the seven *Crossings* concepts to other projects, such as Dumbarton Rail (project A in Figure 2 above); SMART to Richmond and Solano County (projects B and C); a possible Richmond-San Rafael Bridge Replacement (project B); and the State Route 37 elevation and widening projects (project C).

In the coming years, BART and its partners will evaluate Transbay rail crossing alternatives and provide more in-depth analysis on capacity, operational feasibility, and potential station site viability.

Table 1. Summary of Crossing Concepts

#	Concept Name	SUMMARY	KEY FEATURES IN 2050	CAPITAL COST RANGE ESTIMATES (2019 DOLLARS)
1	New San Mateo-Hayward Bridge	The San Mateo-Hayward Bridge is rebuilt, increasing the number of auto travel lanes in each direction from three to four. The CA-92/US-101 freeway interchange is rebuilt, along with expansion of CA-92 in Foster City and in Hayward.	<ul style="list-style-type: none"> 4 general purpose lanes in each direction Bridge toll assumptions align with Bay Bridge in RM3 (\$9 peak hour toll) 	\$10-\$15B <ul style="list-style-type: none"> Crossing: 95% Landside Projects: 5%
2	Mid-Bay Bridge	New auto bridge connects I-380 in San Bruno to I-880 and I-238 in San Lorenzo. I-880/I-238 interchange is rebuilt to accommodate new connection point, and North Access Road near San Francisco International Airport ("SFO") is redesigned to accommodate a new connection to US-101/I-380.	<ul style="list-style-type: none"> 2 general purpose lanes in each direction HOV lane (3+) in each direction Bridge toll assumptions align with Bay Bridge in RM3 (\$9 peak hour toll) 	\$15-\$20B <ul style="list-style-type: none"> Crossing: 87% Landside Projects: 13%
3	BART Market Street Redundancy	New BART crossing connects Oakland and other East Bay cities with San Francisco. New Franklin Street tunnel serves downtown Oakland and Jack London Square, converging in Alameda with a new tunnel from the San Antonio district before crossing to San Francisco. Downtown San Francisco is served by a new Mission Street tunnel. New service extends into western San Francisco and connects to existing BART mainline at Daly City.	<ul style="list-style-type: none"> 15 new stations (5 East Bay, 10 San Francisco) 8-minute headways in peak/15-minute off peak 	\$32B-\$48B <ul style="list-style-type: none"> Crossing: 17% Foundational Projects: 5% Landside Projects: 64% Vehicles: 14%
4	BART New Markets	New BART crossing connects Oakland and other East Bay cities with San Francisco. New Franklin Street tunnel serves downtown Oakland and Jack London Square, converging in Alameda with a second tunnel from the San Antonio district before crossing to San Francisco and a new Third Street tunnel serving Mission Bay, South Beach and Downtown San Francisco. New service extends into western San Francisco and connects to existing BART mainline at Daly City.	<ul style="list-style-type: none"> 16 new stations (5 East Bay, 11 San Francisco) 8-minute headways in peak/15-minute off peak 	\$33B-\$49B <ul style="list-style-type: none"> Crossing: 16% Foundational Projects: 5% Landside Projects: 65% Vehicles: 14%
5	Greater Regional Rail	New conventional rail crossing connects Oakland and other East Bay cities with San Francisco and Peninsula/South Bay cities by integrating Caltrain and Capitol Corridor service through the Salesforce Transit Center. Integrated service includes a standardized and reduced fare structure. Caltrain service is extended to Salesforce Transit Center and improvements are made along existing corridor to accommodate more frequent service. Frequent service extends north to Richmond and south to a new East Bay Hub near Fremont, providing a one-seat ride from South Bay/Peninsula to East Bay. Additions include new multimodal stations at Jack London Square and at East Bay Hub, plus infrastructure improvements at Salesforce Transit Center.	<ul style="list-style-type: none"> 16 Peninsula trains per hour from San Jose to Salesforce Transit Center 12 Transbay trains per hour from Salesforce Transit Center to Jack London Square 4-minute headways in peak at Salesforce Transit Center 	\$43B-\$49B <ul style="list-style-type: none"> Crossing: 12% Foundational Projects: 73% Landside Projects: 13% Vehicles: 2%
6	BART + Auto ("Southern Crossing")	New paired BART and auto crossing connects Oakland and other East Bay cities with San Francisco. New BART and auto tunnels connect the East Bay to India Basin, Mission Bay and South of Market. New BART service extends into western San Francisco and connects to existing BART mainline at Daly City. New auto tunnel connects I-880 and I-980 in Oakland to I-280 in San Francisco, requiring new interchanges at both connection points.	<ul style="list-style-type: none"> Auto: 2 lanes in each direction BART: 17 new stations (5 East Bay, 12 San Francisco) BART: 8-minute headways in peak/15-minute off peak 	\$39B-\$53B <ul style="list-style-type: none"> Crossing: 27% Foundational Projects: 4% Landside Projects: 58% Vehicles: 11%
7	BART New Markets plus Regional Rail	A new paired BART and conventional rail crossing connects Oakland and other East Bay cities with San Francisco and Peninsula/South Bay cities. The crossing combines the alignments from Concept 4 (BART New Markets) and Concept 5 (Greater Regional Rail).	<ul style="list-style-type: none"> BART: 16 new stations (5 East Bay, 11 San Francisco) BART: 8-minute headways in peak/15-minute off peak Rail: 4-minute headways in peak at Salesforce Transit Center 	\$76B-\$98B <ul style="list-style-type: none"> Crossing: 14% Foundational Projects: 41% Landside Projects: 38% Vehicles: 8%

SECTION 4: EVALUATION FRAMEWORK

Nearly 100 proposed major transportation projects will be evaluated as part of the development of *Plan Bay Area 2050*. Analysis of the seven crossing concepts detailed in this Perspective Paper used the same evaluation framework that will be used for other projects, as noted above.










This evaluation included a performance assessment under each of the three “futures” envisioned as part of the Horizon initiative. This was done to study the comparative strength of each concept in the face of uncertain future conditions. More details on the Horizon futures are provided in Table 2 and Table 3.

The merits of each of the seven crossing were assessed at the project level using the MTC travel model (for more detail, see Appendix B). This means travel outcomes were simulated for each of the seven concepts across each of three futures in order to evaluate the impacts of a new crossing of San Francisco Bay.

Table 2. **Horizon Futures Descriptions**

 Rising Tides, Falling Fortunes	 Clean and Green	 Back to the Future
What if...the federal government cuts spending and reduces regulations, leaving more policy decisions to states and regions?	What if...new technologies and a national carbon tax enabled greater telecommuting and distributed job centers?	What if...an economic boom and new transportation options spur a new wave of development?

Table 3. **Horizon Futures Characteristics (Year 2050)**

	 Rising Tides, Falling Fortunes	 Clean and Green	 Back to the Future
 Immigration and Trade	Reduced +20,000 Immigrants Annually	Similar to Today +80,000 Immigrants Annually	Increased +240,000 Immigrants Annually
 National Growth	Limited +1.6% Annual Productivity +0.4% Annual U.S. Population	Similar to Today +2.8% Annual Productivity +0.7% Annual U.S. Population	Rapid +1.1% Annual U.S. Population +1.6% Annual Productivity
 National Taxes and Funding	Lower Funding Due to Tax Cuts	Higher Funding Via Carbon Tax	Similar to Today
 Land Use Preferences	Housing More Urban	Housing More Urban	Housing More Dispersed
	Jobs Similar to Today	Jobs More Dispersed	Jobs More Urban
 National Environmental Policy	Relaxed Regulations +3-foot Sea Level Rise 10% Electric Vehicles	Stricter Regulations +1-foot Sea Level Rise 95% Electric Vehicles	Stricter Regulations +2-foot Sea Level Rise 75% Electric Vehicles
 New Technologies	More Limited 10% Autonomous Vehicles 10% Telecommute Share	Widespread 95% Autonomous Vehicles 30% Telecommute Share	Widespread 75% Autonomous Vehicles 15% Telecommute Share
LEGEND	LOWER	SIMILAR TO TODAY	HIGHER

These 21 “build” model runs (seven concepts multiplied by three Horizon futures) were compared against three more “no-build” runs that simulated the impacts across all three futures of not adding a new crossing. This was done to understand whether a proposed new crossing would make it easier for people to get where they need to go. These net travel outcomes were key inputs into the performance assessment.

Any new Transbay crossing will reshape the region’s land use pattern by altering existing development plans and by leading to discussions about new development plans that may only be presumed if a project of this scale comes to fruition. Though these important discussions about land use development have yet to occur, they will have a significant role in future efforts to refine crossing alignments and evaluate their success.

Rather than envisioning new development plans, the *Crossings* evaluation assumed a continuation of the region’s existing focused growth strategy, adopted in both the original Plan Bay Area (2013) and Plan Bay Area 2040 (2017). This strategy encourages infill growth in Priority Development Areas (PDAs) — locations supported by high quality transit and identified by city or county governments as preferred locations for new housing and commercial construction. While retaining this existing growth strategy, *Crossings* also contemplated how the three Horizon futures alter the intensity of future development across the PDAs.

Plan Bay Area 2050 evaluates major transportation projects to identify their benefit-cost ratios, their equity scores, and their alignment with the Horizon Guiding Principles. These core metrics were the foundation of the *Crossings* evaluation but were supplemented by additional analyses related to system overcrowding and traffic congestion. Ultimately, assessing the performance of each concept focused on five key questions:

1. Does the crossing adequately accommodate future Transbay travel demand?
2. Is the crossing resilient enough to deliver benefits under multiple future conditions?
3. Does the crossing align with the Horizon initiative's guiding principles?
4. Does the crossing improve accessibility for lower-income populations?
5. Do the crossing's benefits outweigh its costs?

Table 4. **Key Evaluation Questions**

#	KEY QUESTION	METRIC OR INDICATOR
1	Do the crossings adequately accommodate Transbay travel demand?	<ul style="list-style-type: none"> • Transbay transit use • Bay Bridge vehicle delay • Accessibility and transit-crowding reductions
2	Are the crossings resilient enough to deliver benefits under uncertain future conditions?	<ul style="list-style-type: none"> • Impact of external forces • Station locations' impact on ridership
3	Do the crossings align with Horizon's guiding principles?	<ul style="list-style-type: none"> • Guiding Principles Score
4	Do the crossings improve accessibility for low-income populations?	<ul style="list-style-type: none"> • Equity Score
5	Do the crossings' benefits outweigh their costs?	<ul style="list-style-type: none"> • Benefit/Cost Ratio

In addition to these questions, the overall performance of each concept was measured by assessing its impact on increasing or decreasing regional auto travel (also known as vehicle-miles traveled or VMT), and its impact on increasing or decreasing regional transit ridership.

This Perspective Paper is a high-level review of the seven concepts. The combined 24 model runs (21 "build" runs plus three "no-build" runs) yielded extensive data that will remain available for further analysis and refinement of the crossing concepts. It is expected that benefit-cost data and information about equity impacts and accessibility will be especially useful in the months ahead.

SECTION 5: EVALUATION DETAILS AND RESULTS

Question #1:

Do the proposed crossings adequately accommodate future Transbay travel demand?

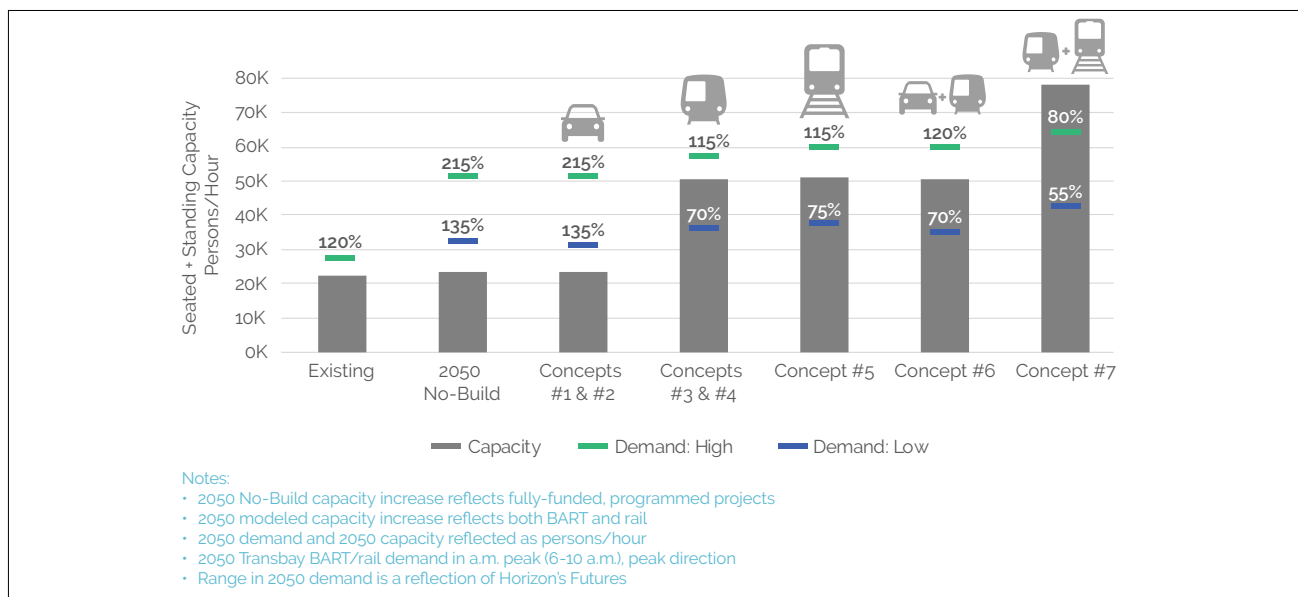
For Question #1, the *Crossings* evaluation focused on understanding:

- Modeled Transbay rail transit use in 2050
- Forecasted levels of congestion-related delay on the San Francisco-Oakland Bay Bridge
- Average benefits across the three Futures

Transbay Rail Transit Use: Demand for space to either sit or stand on BART cars in the Transbay corridor currently outstrips capacity by 20 percent during weekday peak periods. Analysis of future conditions centered on understanding modeled 2050 Transbay transit capacity versus modeled 2050 transit demand. The range of demand reflects variations across the three Horizon futures. The results, shown in Figure 3 below, indicate that in 2050, the two auto-only crossing concepts (#1 and #2) would provide little to no relief for crowding in the existing BART tube, while the transit-only crossing concepts (#3, #4 and #5) would ease transit-crowding. Lastly, while Concept #7 reduces crowding, it also may deliver more capacity than needed in 2050 in any of the three Horizon futures.

Figure 3. **Transbay Rail Transit Use**

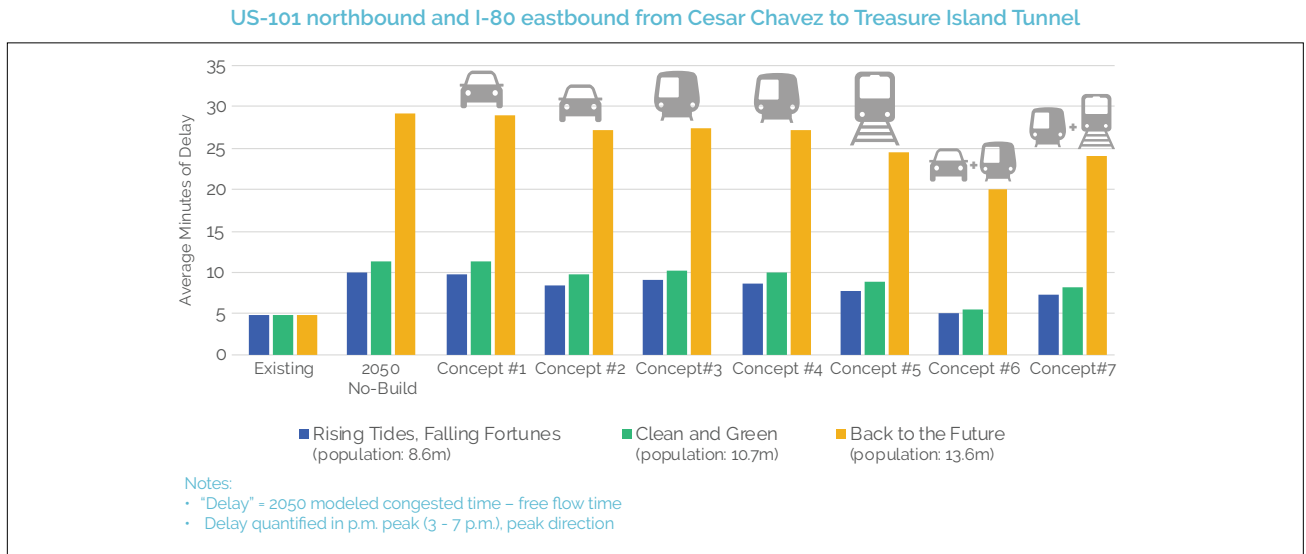
Transbay BART/Conventional Rail – 2050 Modeled Capacity vs Demand



Bay Bridge Vehicle Delay: The *Crossings* evaluation analyzed the extent to which any of the concepts would relieve auto congestion in the San Francisco-Oakland Bay Bridge corridor in 2050.

Figure 4 below shows that, when compared to doing nothing, reductions in the time afternoon commuters in 2050 would spend in congestion while traveling eastbound from the U.S. 101/I-280 interchange out to Yerba Buena Island would range from nearly 10 minutes for Concept #6 in a high-growth future all the way down to zero for Concept #1 in any of the three futures.

Figure 4. **Bay Bridge Vehicle Delay**



Though Concept #6 is best suited to relieve congestion-related delays through the Bay Bridge corridor in 2050, the results also highlight the impact of latent demand for limited roadway space. When compared to current conditions, any new crossing — either auto-only, rail-only, or a combination of rail and auto — may be unable to deliver meaningful congestion relief under any of the Horizon initiative's three futures. The combination of a new crossing and more aggressive complementary transportation-demand strategies may be effective in relieving congestion-related delays.

Average Benefits: To further assess the seven *Crossings* concepts, the benefits of each option were monetized and measured for their impacts on accessibility, transit-crowding, freeway reliability, vehicle ownership, health, safety, and the environment. The monetized value of these benefits vary across each of the three Horizon futures. For clarity of presentation, Figure 5 below illustrates the average of each concept's benefits across the three futures. These findings indicate that transit-only crossing concepts (#3, #4 and #5) would deliver significantly greater accessibility and transit-crowding benefits than would the auto-only crossing concepts (#1 and #2). Future efforts should analyze how refined quantification of benefits from reduced transit crowding and improved reliability can affect the performance of a crossing.

Figure 5. **Summary of Benefits (billions of dollars)**

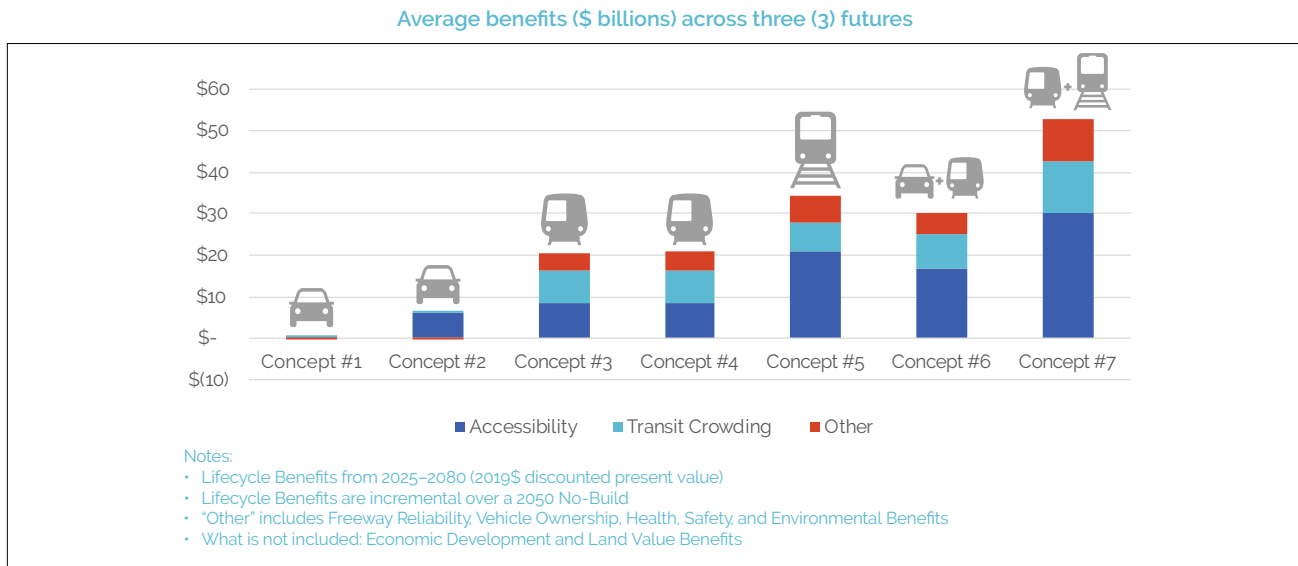


Table 5. **Question #1 Findings**

MODE	CROSSING #	QUESTION 1
	Concept 1	○
	Concept 2	○
	Concept 3	●
	Concept 4	●
	Concept 5	●
	Concept 6	●
	Concept 7	●

Summary Performance in Response to Question 1:

Neither Concept #1 nor Concept #2 satisfies the need to accommodate future Transbay travel demand, providing no relief for peak-period crowding in the existing BART tube and only minimal relief at best for congestion-related delays in the Bay Bridge freeway corridor. Concepts #1 and #2 also returned the lowest average monetized benefits of all the *Crossings* options evaluated.

Question #2:

Are the proposed crossings resilient enough to deliver benefits under uncertain future conditions?

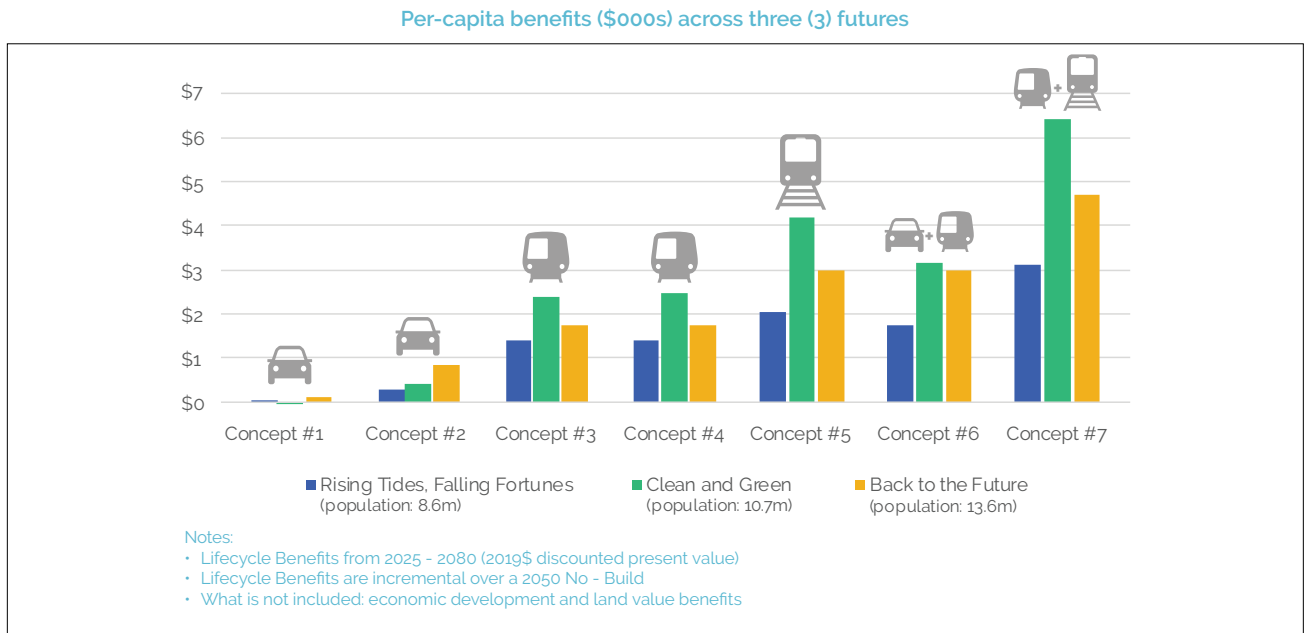
For Question #2, the *Crossings* evaluation focused on understanding:

- The impact of external forces
- Station locations' impact on transit ridership.

Impact of External Forces: The term "external forces" refers to the characteristics that define the three distinct Horizon futures. Because each future makes different assumptions about overall growth rates and other key factors, which in turn would create different levels of demand on the transportation system, this analysis measured the per-capita benefit of each crossing concept across the three Horizon futures to assess the effects of the external forces. The findings in Figure 6 show that transit-only crossings (Concepts #3, #4, #5 and #7) in the Clean and Green future deliver the highest per-capita benefits. This is due in part to the higher auto operating costs in the Clean and Green future, which is defined in part by a national carbon tax that increases the cost of driving.

Future analyses of Transbay crossing proposals might consider how complementary transportation-demand strategies such as pricing in adjacent corridors or incentives for telecommuting can affect the performance of a crossing.

Figure 6. **Impact of External Forces**



Station Locations' Impacts on Ridership: This analysis sought to better understand how transit ridership is influenced by development patterns and density. To measure this relationship, the evaluation analyzed whether ridership demand would rise or fall if new rail stations were located in priority development areas (as noted in Section 4 above, these are neighborhoods supported by high quality transit and identified by city or county governments as preferred locations for new housing and commercial construction), or if the stations were in areas that do not carry a PDA designation. Figure 7 below — which compares Concept #4 (BART) with new stations in both all-PDA and non-PDA locations, and an all-PDA configuration of Concept #5 (conventional rail) — illustrates that locating stations in areas that are likely to see new development will be critical to attracting higher ridership across all three of the Horizon futures.

Figure 7. Stop Location Impacts Ridership

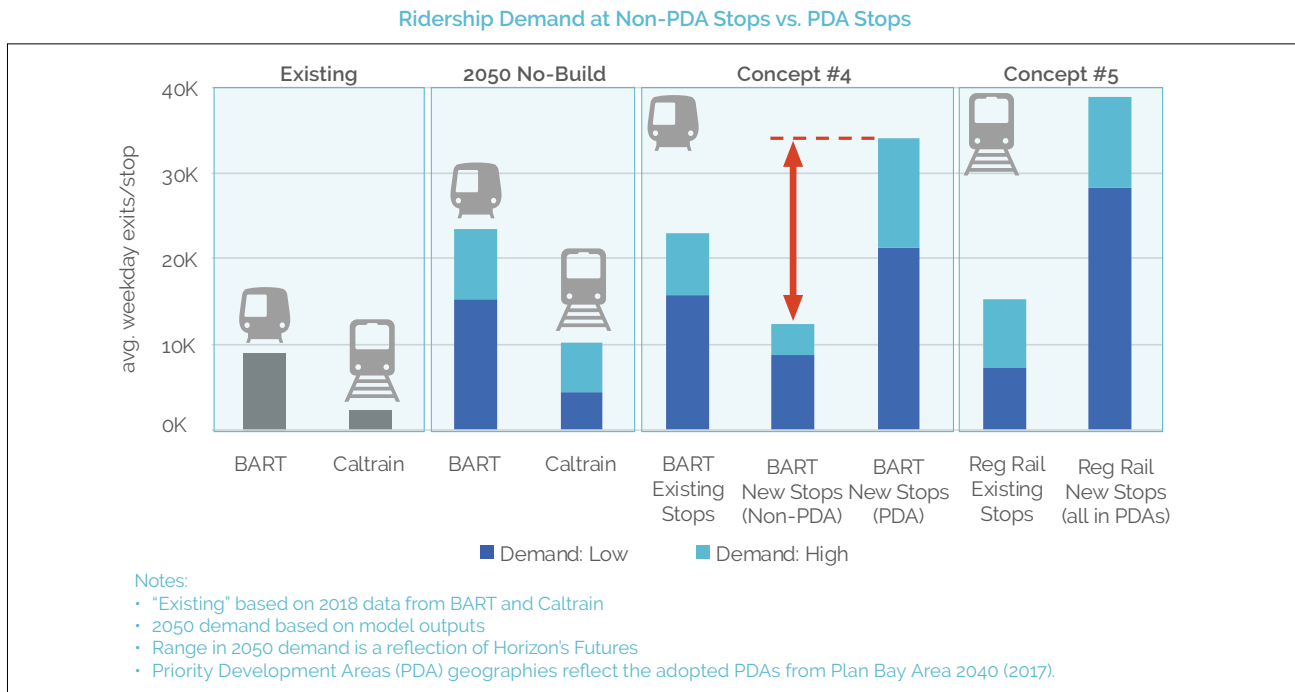


Table 6. Question #2 Findings

MODE	CROSSING #	QUESTION 2
	Concept 1	●
	Concept 2	●
	Concept 3	●
	Concept 4	●
	Concept 5	●
	Concept 6	●
	Concept 7	●

In the future, more detailed analysis of Transbay crossing proposals should consider how existing and new development plans would affect a crossing's performance.

Summary Performance in Response to Question 2: Each of the seven *Crossings* concepts are sufficiently resilient to deliver benefits across all three Horizon futures.

Question #3:

Do the proposed crossings align with Horizon's Guiding Principles?

The *Crossings* evaluation tested each of the seven crossing concepts against the question associated with the Horizon initiative's Guiding Principles depicted in Figure 8.

Figure 8. **Horizon Guiding Principles and Associated Evaluation Questions to Identify Adverse Impacts**

Crossings will be flagged as "Does not support Principle" if they meet any of the following conditions:











	AFFORDABLE	All Bay Area residents and workers have sufficient housing options they can afford – households are economically secure.	Does the project increase travel costs for lower-income residents?
	CONNECTED	An expanded, well-functioning, safe and multimodal transportation system connects the Bay Area – fast, frequent and efficient intercity trips are complemented by a suite of local transportation options, connecting communities and creating a cohesive region.	Does the project increase travel times or eliminate travel options?
	DIVERSE	The Bay Area is an inclusive region where people from all backgrounds, abilities and ages can remain in place – with full access to the region's assets and resources.	Does the project displace lower-income residents or divide communities?
	HEALTHY	The region's natural resources, open space, clean water and clean air are conserved – the region actively reduces its environmental footprint and protects residents from environmental impacts.	Does the project significantly increase emissions or collisions?
	VIBRANT	The Bay Area is an innovation leader, creating quality job opportunities for all and ample fiscal resources for communities.	Does the project eliminate jobs?

Figure 9, below, depicts that the two auto-only Concepts (#1 and #2) do not support the Healthy principle, due mainly to the added number of vehicle trips induced by a new auto crossing and by the expected increase in emissions and collisions. The transit-only crossings, by contrast, are expected to reduce emissions and collisions. Concept #2 also fails to support the Vibrant principle, as part of the conceptual alignment would cross through established employment areas. Concept #6 is in conflict with the Diverse principle because portions of the conceptual alignment would cut through and divide residential communities or lead to the displacement of lower-income residents. Crossing concepts #3, #4, #5 and #7 support each of the Horizon Guiding Principles. Future development plans should consider strategies to mitigate the effects of the localized displacement of people and jobs.

Figure 9. **Guiding Principles scores**

Alignment with the five Guiding Principles using specific project-focused criteria

Mode	Crossing	Affordable	Connected	Diverse	Healthy	Vibrant
	Concept #1	–	–	–	X	–
	Concept #2	–	–	–	X	X
	Concept #3	–	–	–	–	–
	Concept #4	–	–	–	–	–
	Concept #5	–	–	*	–	*
	Concept #6	–	–	X	–	–
	Concept #7	–	–	*	–	*

X Does not Support Principle

* Impacts to this Guiding Principle occur outside the Transbay corridor due to grade separations on the Peninsula, which are required to maximize frequencies through a conventional rail crossing.

Question #4:

Do the proposed crossings improve accessibility for low-income residents?

For Question #4, the evaluation used the Horizon initiative's equity-scoring methodology (described in more detail in Appendix B) to assess the seven crossing concepts' impact on lower-income communities' ability to get where they need to go (compared to higher-income communities). Figure 10 shows that while none of the proposed concepts makes the transportation system more equitable, Concepts 3 through 7 would provide benefits evenly to all population groups across the three Horizon futures.

Figure 10. **Equity Scores**

Distributive impacts of project level accessibility benefits across income groups

Mode	Crossing	Rising Tides, Falling Fortunes	Clean and Green	Back to the Future
	Concept #1	Challenges	Challenges	Even
	Concept #2	Even	Challenges	Even
	Concept #3	Even	Even	Even
	Concept #4	Even	Even	Even
	Concept #5	Even	Even	Even
	Concept #6	Even	Even	Even
	Concept #7	Even	Even	Even

Equity Score: Challenges Equity: <40% | Even Distribution: 40-60% | Advances Equity: >60%

Question #5:

Do the proposed crossings' benefits outweigh their costs?

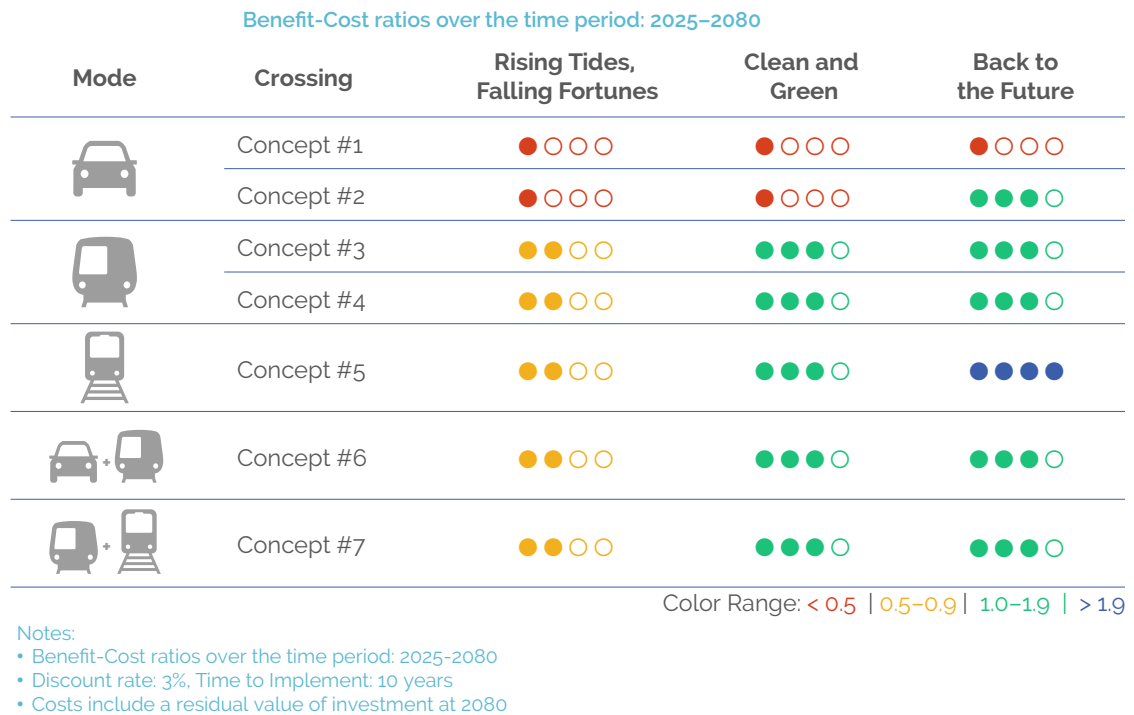
The method by which benefit/cost ratios for the seven *Crossings* concepts are calculated is based on the monetization of social benefit categories (described in more detail in Appendix B). These include transit crowding, freeway reliability, access to mobility, auto ownership, health, safety and the environment. This methodology was developed to reflect feedback received during the development of previous regional transportation plans, including the original Plan Bay Area (adopted in 2013) and Plan Bay Area 2040 (adopted in 2017).

Projects with expected benefit/cost ratios of 1.0 or greater are considered especially strong, while those with ratios below 0.5 rank at the low end of the benefit/cost scale. Results shown in Figure 11 below indicate that in the Horizon future known as Rising Tides, Falling Fortunes, none of the proposed crossings delivers benefits that outweigh costs.

In each of the Horizon futures, the auto-only concepts (#1 and #2) perform poorly when compared to the BART concepts (#3 and #4). The conventional rail concept (#5) has a slightly higher benefit/cost ratio than the two BART-only options because of high housing and job growth forecasts for the conventional rail corridors. Transit-only crossings (#3, #4 and #5) clearly offer the promise of delivering the highest returns on investment. A lack of cost synergies would make concepts that fuse multiple modes (#6 and #7) extremely expensive.

A complete listing of the benefit-cost ratios for each Crossings concept in each Horizon future is provided in Appendix B.

Figure 11. **Benefit-Cost Ratios**



6. FINDINGS SUMMARY & RECOMMENDATIONS

Table 7 summarizes how the seven *Crossings* concepts would address this Perspective Paper's five key questions, and also identifies whether these concepts would result in an increase or decrease in overall vehicle-miles traveled, and an increase or decrease in transit ridership. Table 8 summarizes the seven *Crossings* concepts recommendations.

Recommendations: This Perspective Paper recommends:

- **Do not advance the two auto-only crossing concepts (#1 New San Mateo-Hayward Bridge and #2 Mid-Bay Bridge)** for further analysis during the Horizon/Plan Bay Area 2050 process or in other future Transbay crossing efforts.
- **Advance the three transit-only crossing concepts (#3 BART Market Street Redundancy, #4 BART New Markets and #5 Greater Regional Rail)** as Priority 1 concepts for further analysis in Horizon and contemplated for inclusion in Plan Bay Area 2050. These concepts should be advanced for further analysis in future Transbay crossing efforts.
- **Advance Concept #6 (Paired BART + Auto)** as a Priority 2 concept and considered for further advancement only after additional analysis of equity impacts.
- **Advance Concept #7 (Paired BART + Rail)** as a Priority 2 concept and advanced for further discussions with partner agencies focusing on whether the concept's high cost is a barrier to its inclusion in further studies, and whether its components should be evaluated separately.

Table 7. Findings Summary











MODE	CROSSING #	KEY QUESTIONS					REGIONAL VEHICLE MILES TRAVELED	REGIONAL TRANSIT RIDERSHIP
		Q1	Q2	Q3	Q4	Q5		
	Concept 1	<input type="radio"/>	<input checked="" type="checkbox"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	INCREASE	DECREASE
	Concept 2	<input type="radio"/>	<input checked="" type="checkbox"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	INCREASE	DECREASE
	Concept 3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	DECREASE	INCREASE
	Concept 4	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	DECREASE	INCREASE
	Concept 5	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	DECREASE	INCREASE
	Concept 6	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	DECREASE	INCREASE
	Concept 7	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	DECREASE	INCREASE

Table 8. Finding Recommendations

MODE	CROSSING #	RECOMMENDATIONS
	Concept 1	Not recommended for further analysis
	Concept 2	Not recommended for further analysis
	Concept 3	Priority 1: Recommended for further analysis
	Concept 4	Priority 1: Recommended for further analysis
	Concept 5	Priority 1: Recommended for further analysis
	Concept 6	Priority 2: Considered for further analysis, requires further discussion
	Concept 7	Priority 2: Recommended for further analysis, requires further discussion

7. CONCLUSION

The *Crossings* Perspective Paper contributes to the Bay Area's continuing regional dialogue about the pros and cons of constructing an additional crossing of San Francisco Bay. Conclusions from the *Crossings* evaluation can be grouped into four main points:

- 1. Transit-only crossing concepts should be advanced for further analysis.** Transit-only concepts have benefit/cost ratios close to 1.0 or higher, indicating there may be future opportunities to further improve these scores. By contrast, the auto-only concepts' low benefit/cost scores, even with opportunities to improve, may not rise enough to be realistically feasible.
- 2. Neither BART nor conventional rail significantly outperformed the other.** A decision to select one rail transit mode over the other will be shaped by the continuing evolution of plans for conventional rail in San Francisco and along the Caltrain corridor; and will require more detailed analysis, supported by studies outside the Horizon process. These include BART's upcoming New Crossing study, a multi-year feasibility study expected to begin in 2020. The New Crossing Study will include more in-depth analysis on capacity, operational feasibility (including phasing), and potential station site viability. With participation from the Capitol Corridor Joint Powers Authority, the study will consider a conventional rail crossing as well as a combined BART/conventional rail crossing in its analysis.
- 3. All future crossings analyses must assess land use development and ridership potential.** Future crossings analysis will be incomplete without more thorough analysis of development feasibility in specific station areas.
- 4. Foundational infrastructure can help move the region toward a new crossing.** The Bay Area need not take an "all or nothing" approach to the question of building a new crossing. Because construction of any new crossing would be a long-term, multi-billion-dollar project, the phased delivery of interim capital improvements—and service enhancements—to the existing Transbay travel corridor can not only provide near-term mobility upgrades, but also help lay a foundation for later construction of a new crossing. Among the foundational improvements identified in the *Crossings* study are upgrades to Caltrain's existing Gilroy-to-San Francisco corridor and Caltrain's DTX extension to the Salesforce Transit Center in downtown San Francisco. Because construction of any of the seven *Crossings* concepts would cost so much and take so long, it is virtually certain that any such project would involve multiple phases. Each phase must be carefully scoped to ensure that no decision made early in the construction process precludes any future alternatives.



8. NEXT STEPS

While this Perspective Paper concludes analysis for the *Crossings* study, work will continue through Horizon's Futures Round 2 Analysis in the fall of 2019. This will evaluate the impacts of a Transbay crossing with supportive land use policies. The most resilient strategies identified in the Horizon process — policies, programs and projects — will be recommended for advancement into *Plan Bay Area 2050*.

The start of work in 2020 on BART's New Crossing study will be another critical step forward for consideration of a new crossing of San Francisco Bay. Additional analyses of the *Crossings* concepts may result in higher performance projections. Opportunities for further analysis include:

- Evaluate a wider range of BART and conventional rail crossing alternatives, including shorter, less costly alternatives; segmenting alternatives into smaller components; and longer alternatives that include service beyond the nine-county Bay Area.
- Evaluate land use implications and feasibility, including touch downs and future station sitings.
- Refine cost estimates including investigating potential savings for paired crossings.
- Quantify benefits beyond the nine-county Bay Area of various crossing alternatives.
- Quantify benefits from reduced transit crowding and improved reliability.
- Evaluate regional economic benefits and/or changes in land value.
- Evaluate toll revenue or transit fare revenue generation of crossing alternatives.
- Evaluate resiliency and redundancy benefits.
- Evaluate goods movement benefits.



PART 2

TECHNICAL RESOURCES

1 | Auto

NEW SAN MATEO BRIDGE

The San Mateo-Hayward Bridge is rebuilt, increasing the number of auto travel lanes in each direction from three to four. The CA-92/US-101 freeway interchange is rebuilt, along with expansion of CA-92 in Foster City and in Hayward.

At a Glance

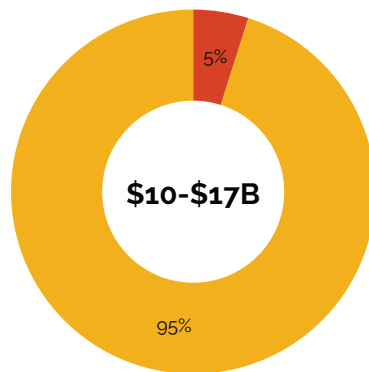
- **4 general purpose lanes** in each direction
- **Bridge toll assumptions** align with Bay Bridge in RM3 (\$9 peak hour toll)

Additional Capacity² (peak hour)



2,000
vehicles

Initial Capital Costs*



- West Bay Landside Improvements
- Crossing Infrastructure

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*



— Auto crossing

2 | Auto

MID-BAY BRIDGE

New auto bridge connects I-380 in San Bruno to I-880 and I-238 in San Lorenzo. I-880/I-238 interchange is rebuilt to accommodate new connection point, and North Access Road near San Francisco International Airport ("SFO") is redesigned to accommodate a new connection to US-101/I-380.

At a Glance

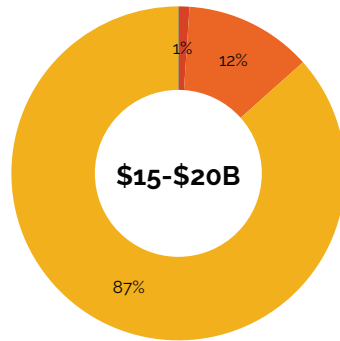
- **2 general purpose lanes** in each direction
- **1 HOV lane (3+)** in each direction
- **Bridge toll assumptions** align with Bay Bridge in RM3 (\$9 peak hour toll)

Additional Capacity (peak hour)



6,000
vehicles

Initial Capital Costs*



- West Bay Landside Improvements
- East Bay Landside Improvements
- Crossing Infrastructure

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*



— Auto crossing

3 | BART


MARKET STREET REDUNDANCY

New BART crossing connects Oakland and other East Bay cities with San Francisco. New Franklin Street tunnel serves downtown Oakland and Jack London Square, converging in Alameda with a new tunnel from the San Antonio district before crossing to San Francisco. Downtown San Francisco is served by a new Mission Street tunnel. New service extends into western San Francisco and connects to existing BART mainline at Daly City.

At a Glance

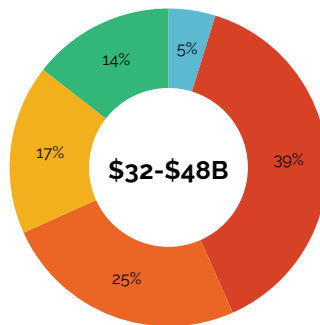
- **15 new stations** (5 East Bay, 10 San Francisco)
- **8-minute headways¹** in peak/15-minute off peak
- **10-car trainsets** in peak/5-car off peak

Additional Capacity² (peak hour)


25,000
new trips

1. Headway per train on new alignment
2. Transit capacity is policy stated capacity of individual train cars from representative operators

Initial Capital Costs*



- Foundational Projects
- SF Landside Improvements
- East Bay Landside Improvements
- Crossing Infrastructure
- Vehicles

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*



- BART crossing
- - - Future phased BART service
- Existing BART lines

4 | BART

NEW MARKETS

New BART crossing connects Oakland and other East Bay cities with San Francisco. New Franklin Street tunnel serves downtown Oakland and Jack London Square, converging in Alameda with a second tunnel from the San Antonio district before crossing to San Francisco and a new Third Street tunnel serving Mission Bay, South Beach and Downtown San Francisco. New service extends into western San Francisco and connects to existing BART mainline at Daly City.

At a Glance

- **16 new stations** (5 East Bay, 11 San Francisco)
- **8-minute headways¹** in peak/15-minute off peak
- **10-car trainsets** in peak/5-car off peak

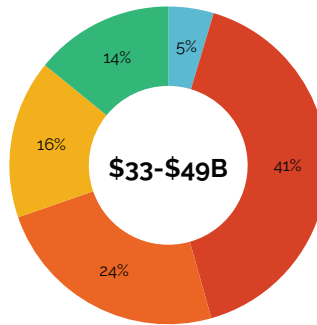
Additional Capacity² (peak hour)



25,000
new trips

1. Headway per train on new alignment
2. Transit capacity is policy stated capacity of individual train cars from representative operators

Initial Capital Costs*



- Foundational Projects
- SF Landside Improvements
- East Bay Landside Improvements
- Crossing Infrastructure
- Vehicles

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*



- BART crossing
- - - Future phased BART service
- Existing BART lines

5 | Rail

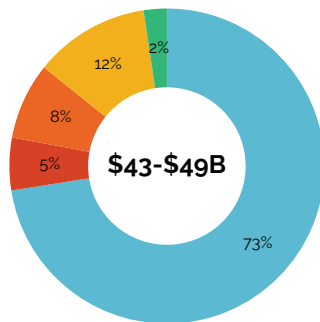
GREATER REGIONAL RAIL

New conventional rail crossing connects Oakland and other East Bay cities with San Francisco and Peninsula/South Bay cities by integrating Caltrain and Capitol Corridor service through the Salesforce Transit Center. Integrated service includes a standardized and reduced fare structure. Caltrain service is extended to Salesforce Transit Center and improvements are made along existing corridor to accommodate more frequent service. Frequent service extends north to Richmond and south to a new East Bay Hub near Fremont, providing a one-seat ride from South Bay/Peninsula to East Bay. Additions include new multimodal stations at Jack London Square and at East Bay Hub, plus infrastructure improvements at Salesforce Transit Center.


At a Glance

- **12 transbay trains per hour** from Salesforce to Jack London
- 8 NB trains to Richmond
- 4 SB trains to Fremont
- **4-minute headways** in peak at Salesforce Transit Center

Initial Capital Costs*



Additional Capacity (peak hour)



28,000
new trips

- Foundational Projects
- SF Landside Improvements
- East Bay Landside Improvements
- Crossing Infrastructure
- Vehicles

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*



- Rail crossing
- Existing regional rail lines

6 | BART + Auto

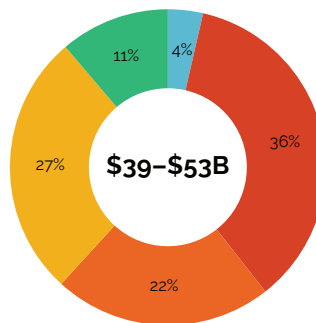
SOUTHERN CROSSING

New paired BART and auto crossing connects Oakland and other East Bay cities with San Francisco. New BART and auto tunnels connect the East Bay to India Basin, Mission Bay and South of Market. New BART service extends into western San Francisco and connects to existing BART mainline at Daly City. New auto tunnel connects I-880 and I-980 in Oakland to I-280 in San Francisco, requiring new interchanges at both connection points.

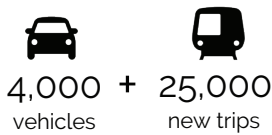
At a Glance

- Auto: **Tunnel** (2 lanes in each direction)
- **Bridge toll assumptions** align with Bay Bridge in RM3 (\$9 peak hour toll)
- BART: **17 new stations** (5 East Bay, 12 San Francisco)
- BART: **8-minute headways¹** in peak/15-minute off peak

Initial Capital Costs*



Additional Capacity² (peak hour)

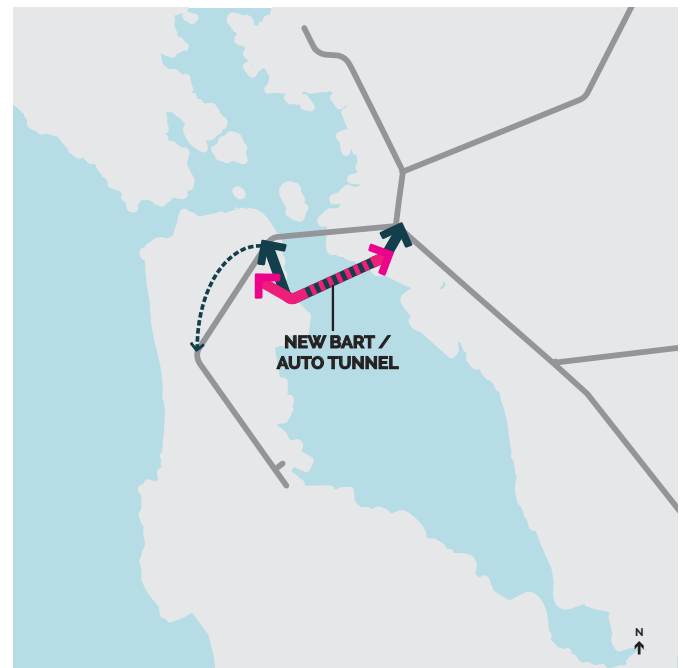


- Foundational Projects
- SF Landside Improvements
- East Bay Landside Improvements
- Crossing Infrastructure
- Vehicles

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*

1. Headway per train on new alignment

2. Transit capacity is policy stated capacity of individual train cars from representative operators



- Auto crossing
- Existing BART lines
- BART crossing
- Future phased BART service

APPENDIX A: CROSSING CONCEPT ADDITIONAL INFORMATION

7 | Rail + BART

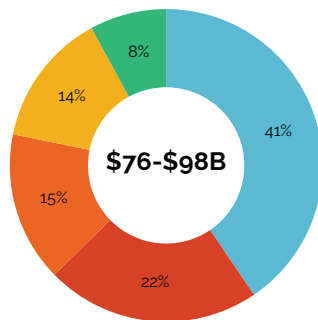
BART NEW MARKETS + GREATER REGIONAL RAIL

A new paired BART and conventional rail crossing connects Oakland and other East Bay cities with San Francisco and Peninsula/South Bay cities. The crossing combines the alignments from Concept 4 (BART New Markets) and Concept 5 (Greater Regional Rail).

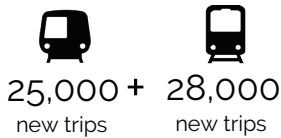
At a Glance

- BART: **16 new stations** (5 East Bay, 11 San Francisco)
- BART: **8 min headways**¹ in peak/15 min off peak
- Rail: **4 min headways** in peak at Salesforce Transit Center
- Rail: Fares at **\$0.18 per mile**

Initial Capital Costs*



Additional Capacity² (peak hour)



- Foundational Projects
- SF Landside Improvements
- East Bay Landside Improvements
- Crossing Infrastructure
- Vehicles

**preliminary cost estimates for crossing infrastructure & landside improvements based on avg. per unit costs*

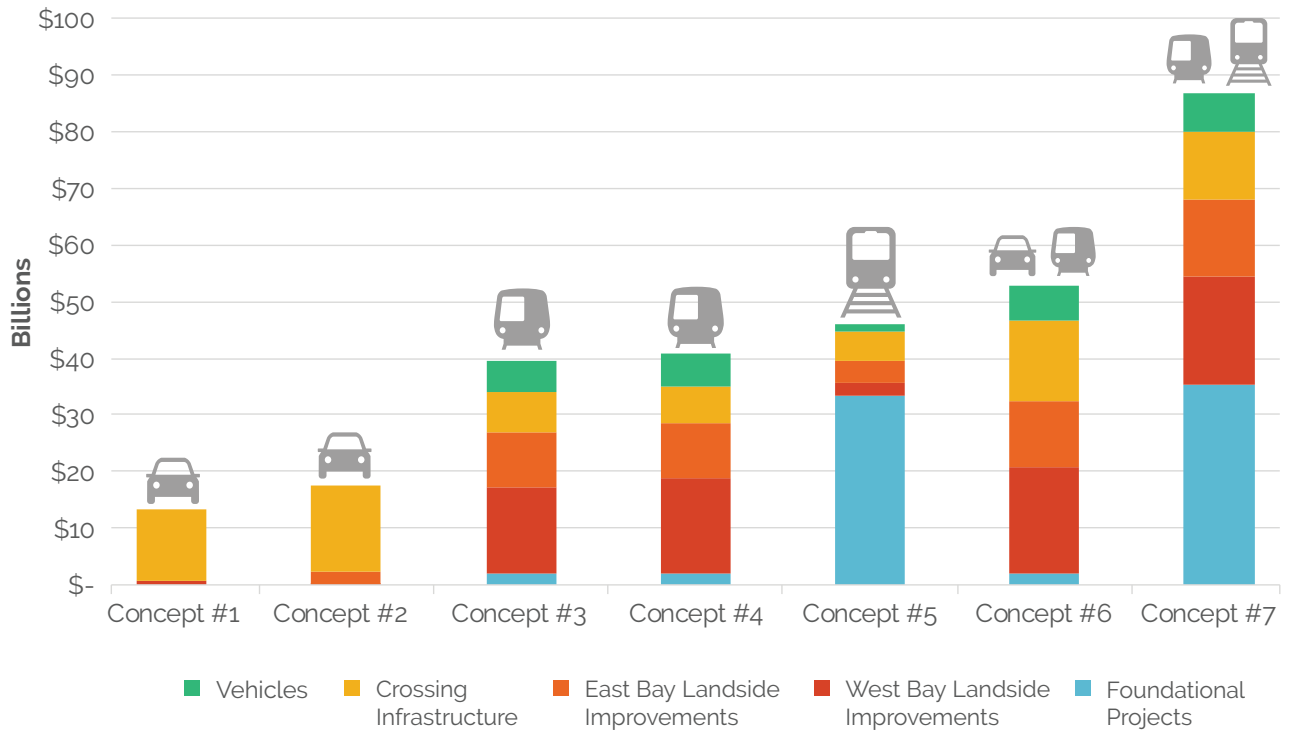
1. Headway per train on new alignment
2. Transit capacity is policy stated capacity of individual train cars from representative operators



- Rail crossing
- BART crossing
- Future phased BART service
- Existing BART lines
- Existing regional rail lines

APPENDIX A: CROSSING CONCEPT ADDITIONAL INFORMATION

Concept Costs: Initial Capital Costs



Note:
 • Costs represent mid-point of range.

APPENDIX B: DOCUMENTATION AND METHODOLOGY

Key Futures Assumptions and Modeling Process

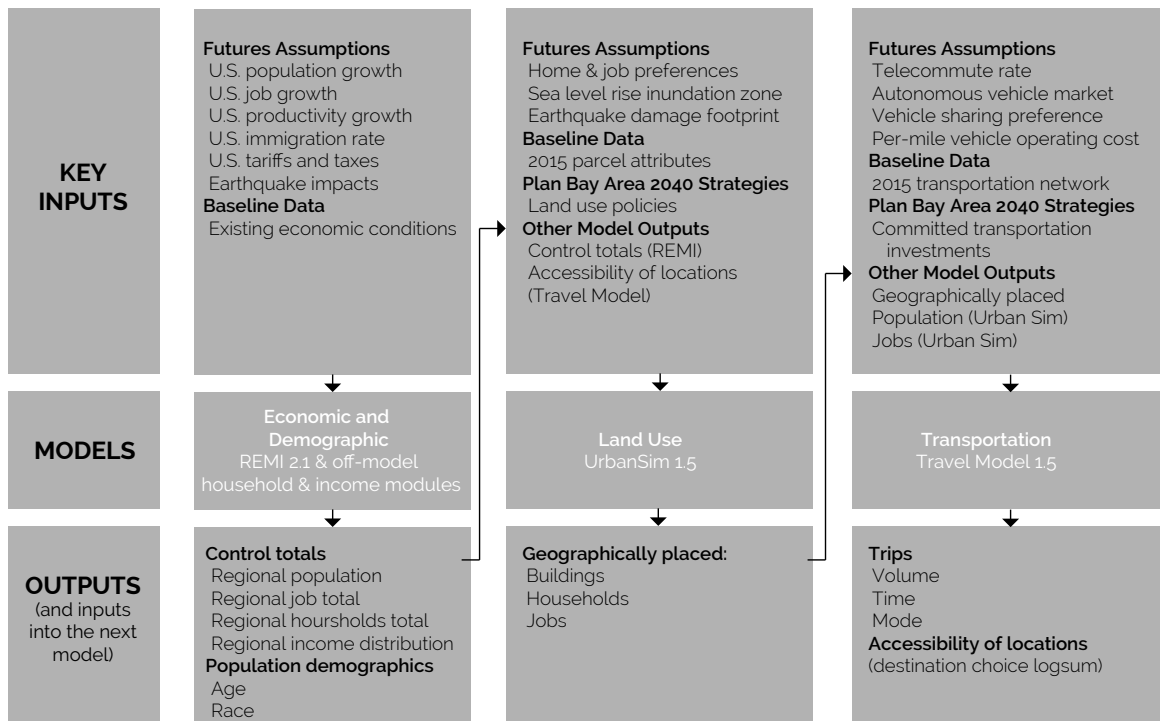
The first phase of Horizon was the development of Futures, comprised of two dozen external forces outside the control of Bay Area policy makers. The external forces include environmental, political, economic, land use and transportation assumptions about the future. Each Future was crafted by stakeholders and experts from the various topic areas of Horizon – transportation, land use, economic development and resilience – to imagine different conditions on the global and national levels in the coming decades. The table below is a summary of these external forces. The next section focuses on the analytic approach, including computer modeling tools used to study how these external forces shape the region.

External Forces			A	B	C
			Clean and Green	Rising Tides, Falling Fortunes	Back to the Future
Environmental	1	Sea Level Rise	1 Foot	3 Feet	2 Feet
Political	3	U.S. Political System	Healthy Democracy	Flawed Democracy	Healthy Democracy
	4	U.S. Standing in the World	Multiple Superpowers	Declining Power	Preeminent Global Power
	5a	U.S. Tax Rates	Higher Tax Rates	Lower Tax Rates	Similar to Today
	5b	U.S. Tax Structure	Carbon Tax	Income Tax (Similar to Today)	Income Tax (Similar to Today)
	6a	U.S. Spending Levels	Higher Expenditures	Lower Expenditures	Similar to Today
	6b	U.S. Spending Distribution	Similar Share to Today	Reduced Share for Metro Areas	Larger Share for Metro Areas
	7	Immigration Policy	80,000 Annual Immigrants (to Bay Area)	20,000 Annual Immigrants (to Bay Area)	240,000 Annual Immigrants (to Bay Area)
	8	Trade Policy	3% Average Tariff Rate	10% Average Tariff Rate	0% Average Tariff Rate
	9	Environmental Policy	Increased Regulations	Reduced Regulations	Similar to Today
Economic	10	U.S. Population Annual Growth Rate	0.7%	0.4%	1.1%
	11	U.S. Jobs Annual Growth Rate	0.4%	0.5%	1.1%
	12	U.S. Jobs Distribution	available upon request	available upon request	available upon request
	13	U.S. Productivity	2.8%	1.6%	1.6%
Land Use	14	Housing Preferences	Greater Preference for Urban Housing	Greater Preference for Urban Housing	Greater Preference for Dispersed Housing
	15	Workplace Preferences	Greater Preference for Dispersed Employment Centers	Similar Preference to Today	Greater Preference for Urban Employment Centers
	16	Telecommute Share	30%	15%	6%
	17	E-Commerce Market Share	50%	20%	50%
Transportation	18	Interregional Volumes	Limited Growth Rates	Current Growth Rates	Faster Growth Rates
	19	Transportation Technologies	High Speed Rail, Autonomous Rail and Buses, Freight Aerial Drones	Autonomous Buses	Hyperloop, Autonomous Rail and Buses, Freight Aerial Drones, Lower-Cost Helicopter Transport
	20	Autonomous Vehicle Market Share	95%	10%	75%
	21	Electric Vehicle Market Share	95%	10%	75%
	22	Sharing Preferences	Greater Preference	Similar Preference to Today	Reduced Preference
	23	Per-Mile Vehicle Operating Cost	\$0.40 per Mile	\$0.20 per Mile	\$0.10 per Mile
	24	Annual Federal Transportation Funding (Bay Area)	\$2.5 Billion	\$0.5 Billion	\$2.5 Billion

Computer Modeling and Analytic Tools

Horizon—and *Crossings*—is based on findings from analytic results and the output of computer modeling tools. Horizon builds on the past analytical work of Plan Bay Area and Plan Bay Area 2040, using Futures Planning as an opportunity to build out new computer modeling functions. At the heart of MTC and ABAG analysis are three analytic stages: a regional level economic and demographic analysis (REMI 2.1 and other tools), a land use model (Urban Sim 1.5), and a transportation model (Travel Model 1.5). The three analytic stages use data on the current conditions of the Bay Area and add in assumptions about future conditions to project what the region would look like in future years should those conditions occur. These analytic stages work together, with key data outputs from one phase passing on as inputs into the next one. Some information flows through feedback loops, but generally data outputs flow from the economic

and demographic analysis, to the land use model, to the travel model. Figure B1 provides a simplified illustration of the inputs and outputs for each model, and the relationships between them. Below is more background information on the models, the upgrades to the models made as part of Futures Planning, and the modeling assumptions for the key external forces.



Economic and Demographic Modeling

Development of population, employment, and household forecasts for Horizon builds upon the framework established for Plan Bay Area 2040, applying the Bay Area version of the REMI model as well as the MTC and ABAG household and income distribution off-model analysis. Regional Economic Models Inc. (REMI) creates comprehensive economic models of regional economies, which the user can customize to reflect the unique characteristics of their area. For Plan Bay Area 2040, staff modified version 1.7.8 of the REMI model to capture the region's innovative position in a range of tech- and social media-based sectors as well as the baseline conditions of very high housing prices. Household numbers are driven from the demographic characteristics of the adult population, while income distribution considers industry and demographic trends.

The REMI version 2.1 model and in-house modules were used to model the three divergent Future forecasts for the Bay Area. These forecasts were based on the external forces that undergird the Futures element of Horizon; external forces are defined as shifts on the global or national levels (beyond the control of the state or region) that affect the region's trajectory. For example, external forces include the rate of national productivity growth, the magnitude of global climate change, and the level of immigration allowed by the federal government. These external forces were defined by stakeholders early in the planning process.

Key external force assumptions that vary for each of the three Futures drove the economic and demographic modeling outputs. These were:

- U.S. population growth rate,

- U.S. job growth rate,
- U.S. productivity growth rate,
- U.S. immigration rate,
- U.S. government spending level,
- U.S. tariffs and taxes, and
- The occurrence of a 2035 regionally significant earthquake (the impacts of an earthquake were excluded from the *Crossings* analysis).

The regional forecast consists of growth totals for the entire nine-county region, whose ultimate distribution to counties, cities, and parcels can be influenced by market conditions and policy interventions (e.g., zoning, subsidies, development requirements) in the UrbanSim 1.5 context. The regional growth forecast outputs become the inputs into the Bay Area UrbanSim 1.5 (discussed below), which then forecasts localized growth patterns based on the overall regional allocation.

Land Use Modeling

Bay Area UrbanSim 1.5 is a spatially explicit economic model that forecasts future firm and household locations. MTC and ABAG used a version of the Bay Area UrbanSim 1.0 model to inform the environmental assessment for the first Plan Bay Area (adopted in 2013) and both the Plan process and the environmental assessment for the second -Plan Bay Area 2040, adopted in 2017.

Bay Area UrbanSim 1.5 forecasts future land use change (e.g., development or redevelopment) starting from an integrated (across different source data) base year database containing information on the buildings, households, firms and land use policies within the region. Running in five-year steps, the model predicts that some households will relocate, and a number of new households will be formed or enter the region (as determined by the adopted regional growth forecasts developed above). The model system micro-simulates the behavior of both these types of currently unplaced households and assigns each of them to a currently empty housing unit. A similar process is undertaken for businesses. During the simulation, Bay Area UrbanSim 1.5 micro-simulates the choices real estate developers make on how much of, what, and where to build. This adds additional housing units and commercial space in profitable locations (i.e., land use policies at the site allow the construction of a building that is profitable under forecast demand).

In this way, the preferences of households, businesses and real estate developers are combined with the existing landscape of parcels and policies to generate a forecast of the overall land use pattern in future years. The land use policies in place in the base year can be changed later in Futures Planning (e.g., allowable zoned residential density could be increased) and Bay Area UrbanSim 1.5 responds by forecasting a different land use pattern consistent with the constraints or opportunities resulting from the change. For each period, the model produces a zonal output file for the transportation model that contains household counts by income and employee counts by sector. This provides the travel model with information on land use intensity in different locations and the spatial distribution of origins and destinations within the region.

Key improvements between Bay Area UrbanSim 1.0 and Bay Area UrbanSim 1.5 include the following:

- New modeling features that allow for simulation of natural disasters and sea level rise, although this feature was excluded from the *Crossings* analysis.

- Improved implementation of accessibility changes from Travel Model 1.5 into land use pattern shifts.

The following key external force assumptions were incorporated into the model and influenced the land use modeling outputs:

- The preference of households to locate in lower or higher density areas,
- The cost of development associated with changing needs for parking provision in Futures with sharing preferences and autonomous vehicles,
- The proliferation of e-commerce to redevelop aging malls and redistribute the locations of firms,
- The occurrence of a 2035 regionally significant earthquake—excluded from *Crossings* analysis, and
- The occurrence of sea level* rise inundation—excluded from *Crossings* analysis.

Travel Modeling

Travel Model 1.5 is an updated version of Travel Model 1.0, which was used for Plan Bay Area 2040. Travel Model 1.5 is a regional activity-based travel model for the Bay Area. This model is a set of individual models that perform different functions leading to forecasts of Bay Area travel data. In addition to exogenous variables highlighted below, Travel Model 1.5 takes land use inputs from UrbanSim 1.5 for the location of housing and jobs by travel analysis zone (TAZ).

Key improvements between Travel Model 1.0 and Travel Model 1.5 include the following:

- Incorporation of transportation network company (TNC) services – such as Uber and Lyft – as well as the ability to incorporate different levels of autonomous vehicle market penetration,
- Updated calibration and validation for year 2015 using observed data for the new baseline year.

Key external force assumptions that drove the travel modeling outputs were:

- The assumed telecommute rate,
- The availability of autonomous vehicles, the impact they have on roadway capacities and travelers' in-vehicle travel time sensitivities,
- TNC fares and passenger occupancy,
- Zero passenger vehicle travel by TNCs and autonomous vehicles,
- Sharing preferences,
- Per-mile operating costs,
- The occurrence of a 2035 regionally significant earthquake—excluded from *Crossings* analysis, and
- The occurrence of sea level rise inundation—excluded from *Crossings* analysis.

Project Performance Methodology Overview

The project performance assessment for Horizon and Plan Bay Area 2050 evaluates three primary types of transportation projects: capacity-increasing investments, operational strategies, and resilience projects to address sea level rise and seismic hazards. Committed projects—those that have full funding plans and

environmental clearance—are exempt from project performance and will be included in the baseline no-project scenario (“existing + committed”) network. The seven crossings along with all other uncommitted projects—with total costs greater than \$250 million—are evaluated using the same evaluation methodology, detailed below.

1. **Benefit-Cost Assessment – primary assessment**

- Compares societal benefits against anticipated project costs
- Explores project performance against all three futures (“what if” scenarios)

2. **Guiding Principles Assessment – secondary assessment**

- Evaluates alignment with the five Guiding Principles using specific project-focused criteria

3. **Equity Assessment – secondary assessment**

- Examines distributive impacts of project-level accessibility benefits across income groups

Representing the Crossing Concepts in the Model

The seven crossing concepts represent both modernization and expansion improvements. Modernization projects involve upgrading existing assets with infrastructure that provides more service or more capacity. Expansion projects involve physically extending a rail line or adding lanes to a roadway. The seven concepts represent a full range of capital improvements (number of highway lanes, new transit lines and stations, etc.) and rail service improvements (hours of operation, frequency of departures, etc.) that are assessed to understand project-level benefits.

Benefits are estimated using the regional travel demand model, Travel Model 1.5. Each of the seven crossing concepts were coded as its own “build” model run and compared to a “no build” run, across the three Horizon futures. Both the build and no build runs used the same land use assumptions from Futures Round 1 (2050).

Benefit-Cost Assessment

Societal benefits include reduced transit-crowding; and improved freeway reliability, access to mobility, auto ownership, health, safety and environment. Project costs include initial capital costs, operations and maintenance, and capital replacement costs.

Present values of a stream of benefits and costs are used to calculate a benefit-cost ratio (“BCR”), rather than using benefits and costs in the horizon year as in Plan Bay Area 2040. This approach captures advantages of quicker construction and implementation timelines, and long-term benefits of large investments.

Analysis Period

The benefit-cost assessment is primarily concerned in comparing the BCR of projects; as a result, similar project timelines are considered to appropriately compare present values. BCRs are calculated for a 55-year analysis period for all projects, including construction time, discounting all benefits and costs to the first year of construction of the project. The analysis period starts at the same year—2025—for all projects, irrespective of when they may be expected to come online. The BCR uses an analysis period that continues until 2080, thirty years past the horizon year. A residual value of the investment is added as a negative cost in 2080, to reflect the fact that assets with long lifespans would have remaining value

beyond the analysis period.

Approach to Estimate Benefits

The assessment quantifies as many benefits as technically feasible. Benefit estimation leverages Travel Model 1.5. Benefits (or disbenefits) of the crossing concepts relative to a “no-build” run are determined using outputs from this model for each of the three futures, reflecting different external forces, control totals, and land use patterns. Benefits include changes in accessibility (travel time and cost), reliability, emissions, physical activity, and noise.

Typically, the primary benefits of transportation projects are for the user in the form of travel time and cost savings. The assessment for *Crossings* applied a methodology developed by the Federal Transit Administration to estimate user benefits—commonly referred to as “accessibility” benefits. Accessibility is a measure of the ease with which transportation users are able to reach destinations. Improving accessibility is generally accepted as the core objective of transportation investments, since users do not use transportation for the sake of the transportation itself (except in rare cases), but to reach destinations. It represents more than just mobility improvements in terms of travel time. Users, in making travel decisions, take into account not only travel time, but also mode choices available, land use patterns (i.e., destination locations), travel costs, congestion and crowding when making travel decisions. Their decisions are also dependent on their personal characteristics such as age, household income, number of workers/dependents in the household, etc. The methodology monetizes the accessibility benefits—and other benefits—of projects.

Approach to Estimate Project Costs

To complete the assessment, a project’s monetized annual benefits in year 2040 were divided by a project’s annualized total cost using 2017 dollars throughout. Annualized total cost was calculated by taking capital costs and dividing by the expected life of the capital investment (as shown in Table 3) and then adding one year of net operating and maintenance costs in 2040. For roadway projects, MTC staff estimated annual operations and maintenance costs using average per-mile road maintenance costs. For transit projects, the operating costs reflect potential revenues from fares, approximated with each operator’s farebox recovery ratio¹. For tolling projects, staff assumed the tolls would cover the operations and maintenance costs.

Key improvements between PBA 2040 and Horizon/ PBA 2050 include the following:

Benefits

- *Safety*: Incremental to the Plan Bay Area 2040 approach, benefits of specific operational improvements that were not previously captured, such as interchange or street design improvements, will be estimated using crash reduction factors compiled by FHWA.
- *Natural Lands*: Conversion of natural lands (e.g. wetlands, agricultural land) to infrastructure will be estimated as an annual loss of goods, such as farm products and wood, and services, such as climate regulation and habitat provision, based on a per-acre value.
- *Transit Crowding*: The effect of transit crowding will be incorporated in Travel Model 1.5 and its impact would be reflected within the project benefits. This methodology is still under development within the Travel Model 1.5.

Benefit Valuation Updates

- *Accessibility*: Similar to Plan Bay Area 2040, the project performance assessment will utilize the travel model's logsum outputs. Logsum is a metric that measures utility or consumer surplus, and captures mobility benefits (i.e., travel time savings, in-vehicle or out-of-vehicle), travel costs (i.e., tolls, fares, parking, vehicle operating) and the ease of consumers to reach destinations of their choice. These benefits collectively will be termed as "accessibility benefits" this cycle, consistent with the estimation methodology. Logsums can be directly converted to hours and monetized using a consistent value of time for all income classes, acknowledging the implicit judgment that the accessibility is valued the same for all people.
- Updates to Reflect Future-Specific Income Distributions.
- *Travel Time Reliability*: The proposed valuation this cycle incorporates the latest research which indicates a slightly lower ratio against value of time is appropriate for motorists and a higher ratio is appropriate for freight, when compared to Plan Bay Area 2040 valuations.
- *All Other Benefits*: Minor updates are proposed to valuations for all other benefits from Plan Bay Area 2040; no benefits are proposed for removal.

Cost Estimation Updates

- *Lifecycle Costs*: Costs will be divided into four categories: upfront capital investment costs (including planning, design and environmental), annual O&M costs, asset replacement costs over the analysis period and a residual asset value added back at the end of the period. While project sponsors submit cost estimates, all projects will undergo a cost review by an independent cost audit consultant using a uniform methodology.
- *Transfers*: Transit revenues, tolls and parking fees are considered transfers that are neither a net economic benefit nor cost to society, and hence they are not included within the benefit-cost framework as per best practice. In Plan Bay Area 2040, these transfers were eliminated from the benefits. This approach will be standardized across the costs as well.

ADDITIONAL RESOURCES:

For more information on the three **Horizon futures**:

<https://mtc.ca.gov/our-work/plans-projects/horizon/futures-planning>

For more information on Horizon and the Guiding Principles:

<https://mtc.ca.gov/our-work/plans-projects/horizon>

For more information on the region's **integrated model framework**:

<https://github.com/BayAreaMetro/modeling-website/wiki>

- Travel Demand Model:
<https://github.com/BayAreaMetro/modeling-website/wiki/TravelModel>
- Land Use Model:
https://bayareametro.github.io/baus_docs/

For more information on the regional **project performance framework**:

<https://mtc.ca.gov/our-work/plans-projects/horizon/project-performance-assessment>

- Methodology
https://mtc.ca.gov/sites/default/files/ProjectPerformanceMethodology_Nov2018Release.pdf

APPENDIX C: **ACKNOWLEDGEMENTS**

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