Metropolitan Transportation Commission
Association of Bay Area Governments

PLAN BAY AREA 2050+

Project Performance Assessment Methodology

Background

This memorandum presents the methodology for evaluating transportation project performance for Transit 2050+[1] and Plan Bay Area (PBA) 2050+. The methodology builds upon the approach from the Horizon/Plan Bay Area 2050 Project Performance Assessment[2] developed in 2018 and 2019. Given that this iteration of the regional plan was a minor update, the project performance methodology remained similar to the prior cycle, with the primary updates being refreshes to benefit-cost valuations (see Attachment B) and the restoration of Equity Priority Community access as the primary equity metric used in plan development.

Project Performance Assessment Methodology Overview

The Project Performance Assessment provided a key lens to understand the potential future benefits and limitations (across three possible 2050 future scenarios) of major transportation infrastructure and service projects in a fiscally constrained planning context, focusing on investments with total lifecycle costs[3] of $250 million or more (in 2019 dollars). Committed projects – fully-funded projects with environmental clearance, as well as 100% locally funded projects – remained exempt from the Project Performance Assessment, similar to prior cycles.

Projects were evaluated using the following assessments:

1. **Benefit-Cost Assessment** – primary assessment
    - Compares societal benefits against anticipated project costs over
    - Explores project performance against all three Horizon "futures" ("what if" scenarios)[4]
2. **Guiding Principles Assessment** – secondary assessment
    - Evaluates alignment with the five Guiding Principles using specific project-focused criteria
3. **Equity Assessment** – secondary assessment
    - Determines if transportation investments have the potential to benefit residents in Equity Priority Communities (geographic assessment)
    - Examines distributive impacts of project-level accessibility benefits across income groups in all three Horizon "futures"

All three assessments seek to evaluate the impacts of projects on the nine-county Bay Area region and provide information that was used to develop the investment strategy for Transit 2050+ and PBA 2050+.

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[1] Transit 2050+ was a parallel planning effort that undertook a major update of the Plan Bay Area transit strategies. All other Plan Bay Area strategies underwent a limited and focused update as part of Plan Bay Area 2050+.

[2] The findings and methodology for the Plan Bay Area 2050 Project Performance Assessment are detailed in the Plan Bay Area 2050 Performance Report: https://planbayarea.org/sites/default/files/documents/Plan_Bay_Area_2050_Performance_Report_October_2021.pdf.

[3] Costs include capital as well as operation and maintenance costs, in assumed year of expenditure dollars through 2080. All costs were then normalized to 2019 dollar values.

[4] For further detail on Horizon, see https://mtc.ca.gov/sites/default/files/Horz_Futures_OppsChallenge_031519.pdf.

Attachments:

- **Attachment A: Benefit Estimation Methodology**
- **Attachment B: Benefit Valuations**
- **Attachment C: Cost Estimation Methodology**
- **Attachment D: Benefit-Cost Ratio Calculation Methodology**
- **Attachment E: Guiding Principles Assessment**
- **Attachment F: Equity Assessment**

Attachment A – Benefit Estimation Methodology

Benefits Estimation

Benefit estimation uses Travel Model 1.5[5], an activity-based model that simulates travel decisions over a typical workday for the entire Bay Area in the horizon year of 2050. Travel Model 1.5 captures effects of transit crowding, transportation network companies (TNCs), and autonomous vehicles (AVs). Benefits (or disbenefits) of the project relative to a baseline, no-project scenario were determined using outputs from this model for each of the three Horizon futures, reflecting different external forces, control totals, and land use patterns. Table A.1 details the benefits/disbenefits that were estimated and the underlying methodologies.

Table A.1 Methodology for Estimating Project Benefits

Benefits / Disbenefits	Includes	Methodology	Accrual	Data sources
Accessibility[a,b] (logsums, expressed in hours/dollars)	• Travel time savings ○ Across all modes (auto, TNC, truck, transit, bike, ped) ○ Free-flow time and recurring delay ○ Includes in-vehicle and out-of-vehicle time (waiting, transfer) • Travel costs ○ Tolls, fares, parking fees[c] ○ Vehicle operating costs (fuel, maintenance, repair)	Accessibility is a measure of how easily people can get to the destinations of their choice. Change in accessibility at the individual level is measured using the logsum methodology in Travel Model 1.5. Logsum represents the consumer surplus that results from a given set of choices available to an individual. The aggregate of logsum measures across individuals measures the total change in the consumer surplus due to the project, representing accessibility benefits of the project.	Increase in logsums, which can be converted to a dollar value, is accrued as a positive benefit	Travel Model 1.5
Travel Time Reliability (hours)	• Auto travel time reliability • Freight travel time reliability	The number of hours lost due to unreliable travel time is measured as the sum of incident delay across all roadways. Incident delay is calculated as a function of volume-to-capacity ratio and number of lanes on a roadway. Assumptions on safety benefits that may result from autonomous vehicles (Avs) in the fleet are detailed in the endnotes[f]. This will consequently impact incident delay.	Increase in hours is a negative benefit	Travel Model 1.5

[5] Travel Model documentation is available at https://github.com/BayAreaMetro/modeling-website/wiki/TravelModel.

Benefits / Disbenefits	Includes	Methodology	Accrual	Data sources
Transit Crowding	• Disbenefit associated with traveling in crowded transit	People experience a higher value of time when travelling in crowded transit, and hence there is an associated disbenefit. While the forthcoming Travel Model 2 is able to account for this higher value of time, Travel Model 1.5 is not. Hence this benefit was estimated with an off-model methodology, using a 'crowding penalty factor'. The crowding factor is a multiplier of in-vehicle travel time, calculated using a formula at the transit link level, and based on the load factor on the particular link. The formula is detailed in the endnotes[d]. The difference between the in-vehicle travel time multiplied by the crowding factor with and without the project represents the (dis)benefit of the project with respect to crowding relief. Projects can bring about crowding relief by increasing service frequency or the seated capacity or by providing alternate travel paths to existing crowded paths. However, a project may have an unintended effect of crowding disbenefit if it increases attractiveness of a transit option (e.g. extension of a rail line) but does not tie this with measures to relieve crowding (e.g. increase service frequency).	Increase in crowded penalty hours is a negative benefit	Travel Model 1.5, Metrolinx, DfT
Collisions (number of victims for fatality/ injury, number of collisions for PDO)	• Fatalities due to collisions • Injuries due to collisions • Property damage only (PDO) collisions	Change in the number of collisions due to a project is calculated by multiplying the change in vehicle miles traveled (VMT) (by area type, i.e. urban/rural, facility type, and number of lanes) with an estimate of the number of collisions by type per VMT. These include transit and bicycle/pedestrian related collisions. Incremental to the above change, the reduction in number of collisions due to specific safety improvements is estimated separately, since the VMT method does not capture such benefits.	Increase in number of victims / collisions is a negative benefit	Travel Model 1.5, SWITRS, CMF Clearing-house (FHWA)

Benefits / Disbenefits	Includes	Methodology	Accrual	Data sources
		This is based on a crash reduction factors (CRF), sourced from research compiled by FHWA. Methodology and CRFs for specific safety improvements are detailed in the endnotes[e]. Further, assumptions on safety benefits that may result from AVs in the fleet are detailed in the endnotes[f].		

GHG Emissions and Air Quality
 	
(metric tons)
	• CO2 (global social effects)
	• Air pollutants (negative health effects)
	  ○ PM2.5
	  ○ Other volatile organic compounds (e.g. NOx, SO2, Acetaldehyde, Benzene)
		Change in emissions is measured as the sum of VMT, multiplied by an estimate of future emission levels per VMT forecasted by EMFAC. These estimates depend on time period of the day, vehicle class (including electric vehicles), and speed.
		
		The emission level would be zero in the case of electric vehicles (EVs), and hence futures with higher levels of EV adoption will have significantly lower levels of emissions benefits. Assumptions on EV penetration are detailed in the endnotes[g].
			Increase in metric tons is a negative benefit	Travel Model 1.5, EMFAC

Benefits from Physical Activity[9] (active individuals and premature deaths)	• Morbidity benefits from increased walking/cycling • Mortality benefits from increased walking/cycling	Morbidity benefits are equivalent to the health care cost savings for every new 'active' individual. An active individual is one that walked (including to/from transit) and/or biked for 30 minutes a day[h]. Mortality benefits are equivalent to a risk reduction of mortality of 11% for walking and 10% for bicycling for 'active' individuals, applied to Bay Area mortality rates.	Increase in active individuals and decrease in premature deaths is a positive benefit	Travel Model 1.5
Noise (VMT)	• Impact of change in noise levels due to change in auto/truck VMT	Change in VMT due to the project, by auto and truck.	Increase in VMT is a negative benefit	Travel Model 1.5
Auto Ownership (vehicles)	• Change in number of vehicles induced by project	Predicted change in the number of vehicles owned by households, based on VMT and household demographics.	Increase in vehicles represents	Travel Model 1.5

Benefits / Disbenefits	Includes	Methodology	Accrual	Data sources
			higher ownership costs and is a negative benefit	
Loss of Natural Land (acres)	• Loss of natural land that is converted to transportation infrastructure, by land type: ○ Wetland ○ Forestland ○ Pastureland ○ Farmland	Estimation of the land area impacted by a project is based on the methodology used in EIR project footprint analyses – 100ft buffer around linear projects (e.g. road/rail extensions) and 150ft - 500ft buffer from center of point projects (e.g. interchanges, transit centers), depending on the size of the project. The type of land converted is determined using the fishnet database sourced from Bay Area Greenprint. Project GIS shapefiles are overlaid on this database, by which we can obtain number of acres of wetlands, pastureland, and farmland impacted. (www.bayareagreenprint.org) This disbenefit would primarily apply to projects in non-urbanized areas, and projects that would have construction impacts on wetlands along the coast.	Increase in acres is a negative benefit	Bay Area Greenprint

Table A.1 Endnotes:

a. A small number of trips are not captured by accessibility logsums – interregional trips (i.e. trips between the Bay Area and other surrounding regions), trips to/from the airports, and freight trips. Impacts of projects on these trips are measured using the value of time saved and operating cost savings per VMT.

b. Accessibility is a measure of the ease with which transportation users can 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, consider 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.

c. Tolls, fares and parking fees are an economic transfer between users and operators. They represent neither an economic benefit nor an economic cost of projects and are hence omitted from benefit-cost framework. Since user travel costs factor into travel decisions, they are part of the accessibility logsums. However, they are added back again for a net zero benefit to society in the calculation of the benefit-cost ratio.

d. The crowding penalty factor (or multiplier to the in-vehicle travel time) is calculated using a formula borrowed from Toronto's Metrolinx Business Case Guidance:

Equation 5.6: Calculating crowding impacts

$$Crowding\ Factor = \left[\frac{\left(\gamma_1 + \alpha_1 \cdot \left(\frac{V_t}{C_t}\right)^{\beta_1}\right) \times N_{seat} + \left(\gamma_2 + \alpha_2 \left(\frac{V_t}{C_t}\right)^{\beta_2}\right) \times N_{stand}}{N_{seat} + N_{stand}}\right]$$

where

- V_t = transit segment volume;
- C_t = transit segment capacity;
- N_{seat} = number of seated passengers;
- N_{stand} = number of standing passengers;
- γ_1, γ_2 = IVT weights under ideal conditions for seated (1.0) and standing (1.4) passengers;
- α_1, α_2 = additional IVT weights at full capacity for seated (0.1) and standing (0.2) passengers; and
- β_1, β_2 = curves for seated (1.4) and standing (3.4) passengers.

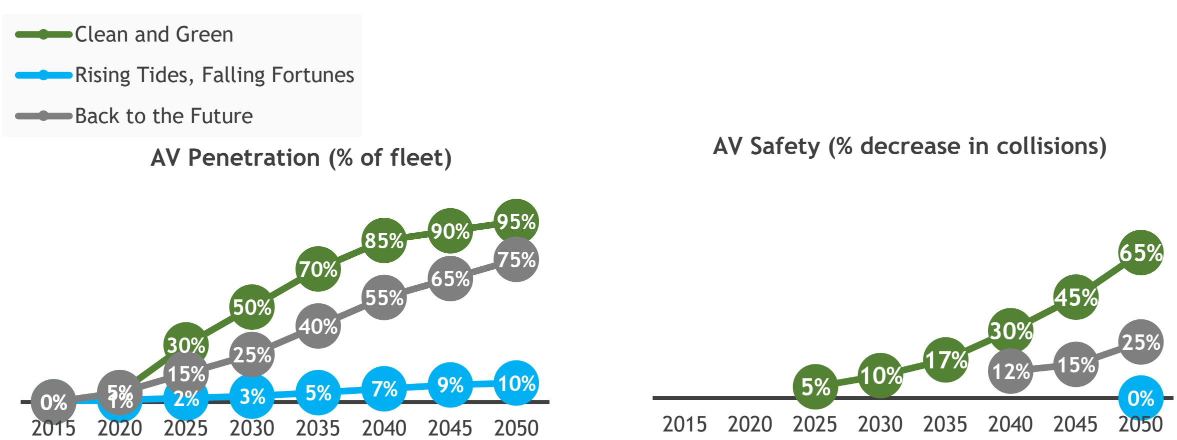
(http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/Metrolinx-Business-Case-Guidance-Volume-2.pdf). The formula calculates a crowding factor at the transit link level, which is calculated with and without the project. The inputs from Travel Model outputs into the formula are as follows: person volume, number of seated and standing passengers, and the load factor (calculated using seated vehicle capacity). Coefficients and in-vehicle travel time weights for seated and standing passengers are sourced directly from the Metrolinx Guidance. The multiplier is capped at 2.5, which is aligned with values used by peer agencies including Metrolinx, London's DfT and LA Metro.

e. A finite list of safety improvements, as shown in Table A.2, will be considered for the estimation of a reduction in collisions. This list is meant to capture major safety improvements within all projects that are evaluated, given that design details of the projects are not readily available. For each of those improvements, the following method is applied. First, the average annual number of collisions within the physical limits of the project site is obtained from SWITRS for the five-year period 2012-2016. In the case of transit grade separations, this number was obtained from project sponsors (Caltrain, VTA, SF Muni). This number is then multiplied by a crash reduction factor (CRF) for the specific safety improvement (obtained from the CMF Clearinghouse, FHWA) to determine the annual decrease in number of collisions as a result of the project. CRF denotes the percentage reduction in crashes that may be expected because of the countermeasure. For more information, please refer to http://www.cmfclearinghouse.org/faqs.cfm#q2. CRF averages listed in Table A.2 are averaged over multiple data points that are related to the safety improvement and have a rating of three stars or higher. The averages are meant to be indicative and are not authoritative estimates.

Table A.2 Crash Reduction Factors (CRF) by Safety Improvement
(Source: CMF Clearinghouse)

Safety Improvement	CRF average
Freeways: New auxiliary lane addition	20%
Freeways: New lane addition (GP/HOV/Express)	0% (data points indicate both positive and negative effects)
Freeways: Existing HOV to express lane conversion	5%
Freeways: Interchange reconfiguration	40%
Local street design improvements (e.g. transit lanes, bike/ped)	20%
Grade separation of transit	100% (for transit-related crashes only; not based on CMF research)
Change in collisions due to impacts such as - increase/decrease in auto miles - mode shift to auto/transit/other modes - decrease in vehicle ownership - speed limit changes (e.g. conversion of arterial to freeway)	Covered by VMT-based methodology

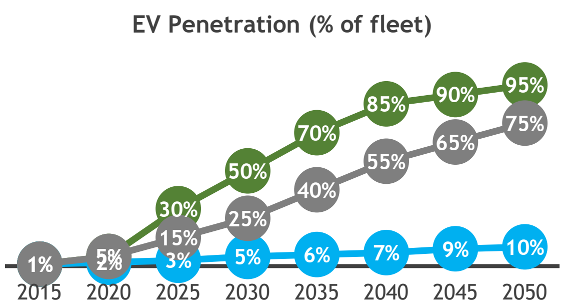
f. Assumptions on AV penetration for each future are shown in the charts below. The assumptions for AV penetration in the horizon year were determined when the three diverging futures were ascertained. This process involved peer exchange, gathering feedback from partners, and developing what-if scenarios. Safety benefits of AVs will be considered in the “Clean and Green” and “Back to the Future” Futures, where the AV fleet penetration is 95% and 75% by the horizon year, respectively. Safety assumptions are sourced from MTC’s Future Mobility Research Program work, including a Delphi survey conducted with subject area experts (40% to 90% reduction in collisions in fully automated future based on survey results). The trend towards this reduction in collisions is shown below and is not assumed to be linear to reflect research on the potential disbenefits of mixing human and AV fleets.



The methodology recognizes the uncertainty in the safety assumptions and the potential for greater safety with AVs, as anticipated by various agencies. The assumptions will be tested for sensitivity (by increasing the 2050 percent decrease in collisions to 90% in Clean and Green, 10% in Rising Tides, Falling Fortunes and 40% in Back to the Future, and adjusting preceding years concomitantly).

These safety impacts also affect the estimation of travel time reliability benefits. Travel time reliability is measured by non-recurring delay, whose estimates are based on a function of traffic volumes and the level of congestion (volume-over-capacity ratio) for links containing a specified number of lanes. Given the decrease in the collision rate with AVs, the non-recurring delay will be adjusted using the same factor.

g. Assumptions on EV fleet penetration are shown below. The assumptions for EV penetration in the horizon year were determined when the three diverging futures were ascertained. This process involved peer exchange, gathering feedback from partners, and developing what-if scenarios.



h. Source: World Health Organization's Health Economic Assessment Tool, available online: http://www.heatwalkingcycling.org/.

Attachment B – Benefit Valuations

Update to Benefit Valuation Assumptions for the 2024 Project Performance Assessment

The Transit 2050+/Plan Bay Area 2050+ Project Performance Assessment re-computed all projects' benefit/cost findings using the latest valuation and cost data available to ensure that all findings are consistent with current practice. Per USDOT Guidance, analysts "…may…draw on other [non-USDOT] sources to obtain…values;"[6] consequently, the recommendations use California or Bay Area data to the greatest extent possible. All values are normalized to 2019 dollars to be consistent with the prior Plan Bay Area 2050 methodology.

Because the Project Performance Assessment analyzed each project in each of the three Horizon Futures,[7] some values listed in the following table vary by Future since the value depends upon specific assumptions about population, employment, and household income distribution. Such values in the table below show a "base" number taken from the applicable general literature followed by one row for each Future in which the base value appears adjusted as appropriate to the Future in question.

[6] USDOT. Benefit Cost Analysis Guidance for Discretionary Grant Programs. January 2023.

[7] See https://planbayarea.org/2050-plan/horizon

Table B.1 Benefit Valuations

Benefit and Units	Value in 2019$	Source	Discussion	Reference
Base Accessibility Benefit, Internal & External Passenger ($/hr)	$13.76	BLS. *May 2022 Metropolitan and Nonmetropolitan Area Occupational Employment and Wage Estimates San Francisco-Oakland-Hayward, CA*	USDOT recommends using half the prevailing median wage rate as the passenger travel value of time; the recommended base value is based on the latest available Bay Area MSA data from BLS. This value times the hourly value of the difference in logsums (a modeled accessibility measure) between a project's scenario and a "no build" comparison scenario produces the benefit value.	https://www.bls.gov/oes/current/oes_41860.htm
Clean and Green	$19.33		The three Futures vary the regional population and employment and include different income distributions. The Base value is thus adjusted up or down to properly account for the specific socio-economic factors in each Future.	
Rising Tides Falling Fortunes	$13.08			
Back to the Future	$18.98			
Truck Accessibility Benefit, External (Driver median wage in $/hr)	$25.55	BLS. *May 2022 Metropolitan and Nonmetropolitan Area Occupational Employment and Wage Estimates San Francisco-Oakland-Hayward, CA*	USDOT recommends using the median wage rate paid to truck drivers as the value of commercial travel time saved. The recommended base value comes from the latest available BLS data.	https://www.bls.gov/oes/current/oes_41860.htm

Benefit and Units	Value in 2019$	Source	Discussion	Reference
Clean and Green	$35.89		The three Futures vary the regional population and employment and include different income distributions. The Base wage is thus adjusted up or down to properly account for the specific socio-economic factors in each Future.	
Rising Tides Falling Fortunes	$24.28			
Back to the Future	$35.24			
Auto Operating Cost, $/mi	$0.20	AAA. *Your Driving Costs-2022*.	The 2019 monetization of the operating cost component of the logsums is consistent with current AAA estimates ($0.28/mile in 2022 dollars) and current USDOT per mile cost guidance at the national level.	https://exchange.aaa.com/automotive/aaas-your-driving-costs/
Clean and Green	$0.41		See discussion for the Accessibility benefits Futures values.	
Rising Tides Falling Fortunes	$0.20			
Back to the Future	$0.10			
Truck Operating Costs, $/mi	$1.02	USDOT. *Benefit Cost Analysis Guidance for Discretionary Grant Programs.* January 2023.	The 2019 logsum-derived numbers are consistent with 2023 USDOT guidance which summarizes national average truck operating costs at $1.01/mile in 2021 dollars.	https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance
Clean and Green	$1.58		See discussion for the Accessibility benefits Futures values.	
Rising Tides Falling Fortunes	$1.02			
Back to the Future	$0.71			

Benefit and Units	Value in 2019$	Source	Discussion	Reference
Auto Travel Time Reliability, $/hr	$11.01	SHRP2 research by University of Arizona, Portland Metro, RST International. *Value of Travel Time Reliability in Transportation Decision Making: Proof of Concept— Portland, Oregon, Metro.* 2015.	The value applies a "reliability ratio" of 0.8 to the Accessibility Value of Time discussed above. The ratio used is reasonable per the SHRP2 research and is arguably conservative given the full range of possible values identified in that work.	https://transops.s3.amazonaws.com/uploaded_files/SHRP2_S2-L35A-RW-1.pdf
Clean and Green	$15.47		See discussion for the Accessibility benefits Futures values.	
Rising Tides Falling Fortunes	$10.46			
Back to the Future	$15.19			
Truck Travel Time Reliability, $/hr	$38.32	FDOT. *Examining the Value of Travel Time Reliability for Freight Transportation to Support Freight Planning and Decision-Making*. 2016	As with auto travel reliability, the value applies a reliability ratio to the truck Accessibility Value discussed above. The ratio assumption of 1.5 is reasonable (and arguably conservative) based on the FDOT research.	https://rosap.ntl.bts.gov/view/dot/31708/dot_31708_DS1.pdf
Clean and Green	$53.84		See discussion for the Accessibility benefits Futures values.	
Rising Tides Falling Fortunes	$51.17			
Back to the Future	$70.59			

Benefit and Units	Value in 2019$	Source	Discussion	Reference
Transit Crowding Value, $/hr	$27.52	USDOT. *Benefit Cost Analysis Guidance for Discretionary Grant Programs—January 2023*	This value is set to twice the Accessibility Value of Time discussed above per USDOT guidance that permits crowded ("standing") in-vehicle time to be treated as twice as onerous as uncrowded ("seated") time.	https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance
Clean and Green	$38.67			
Rising Tides Falling Fortunes	$26.16			
Back to the Future	$37.96			
Value of a Fatality Crash Avoided ($/crash)	$12.309 million	USDOT. *Benefit Cost Analysis Guidance for Discretionary Grant Programs—January 2023*	The value of a fatal crash avoided (which is greater than the statistical value of one life due to data showing that fatality crashes typically claim more than one life) has grown in real terms since the prior analysis.	https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance
Value of an Injury Crash Avoided ($/crash)	$290,398	USDOT. *Benefit Cost Analysis Guidance for Discretionary Grant Programs—January 2023*USDOT. Benefit Cost Analysis Guidance for Discretionary Grant Programs—January 2023. 2023	The value of an injury crash avoided has grown in real terms since the prior analysis.	https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance

Benefit and Units	Value in 2019$	Source	Discussion	Reference
Value of a PDO Crash Avoided ($/crash)	$4,529	USDOT. *Benefit Cost Analysis Guidance for Discretionary Grant Programs—January 2023*	The value of a property-damage-only crash avoided has grown in real terms since the prior analysis.	https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance
Value of an Active Adult	$1,421/ year (per newly active adult) $11.133 Million (per life saved)	California Center for Public Health Advocacy/Chenoweth & Associates. *The Economic Costs of Overweight, Obesity, and Physical Inactivity Among California Adults*. 2006.	The CAPCHA research is comprehensive and specific to California. USDOT now offers a per-induced-active-trip valuation. Comparing a trip-based scenario using USDOT values to the CAPCHA annual figure recommended indicates that the latter is reasonable, indeed conservative, compared to the USDOT national guidance. The death avoided figure is taken from current USDOT guidance on the value of a statistical life. (see crash values above for source)	https://saferoutescalifornia.files.wordpress.com/2012/06/costofobesity_brief.pdf
GHGs ($/metric ton)	$66.88	BAAQMD. Spare the Air-Cool the Climate: A Blueprint for Clean Air and Climate Protection in the Bay Area (Clean Air Plan 2017). 2017.	Using the same value as BAAQMD ($62/metric ton in 2015$) ensures consistency with a key Bay Area partner agency.	https://www.baaqmd.gov/plans-and-climate/air-quality-plans/current-plans
Other Air Pollutants ($ per Metric ton)				
Diesel PM2.5	$668,960	BAAQMD. *Spare the Air-Cool the Climate: A Blueprint for Clean Air*	The BAAQMD data is both specific to the Bay Area and covers pollutants not treated in other literature (e.g. USDOT). The BAAQMD 2017 Plan is currently in	https://www.baaqmd.gov/plans-and-climate/air-quality-plans/current-plans
Direct PM2.5	$663,966			
NOx	$7,134			

Benefit and Units	Value in 2019$	Source	Discussion	Reference
Acetaldehyde	$4,756	*and Climate Protection in the Bay Area (Clean Air Plan 2017)*. 2017.	effect and remains the best source of local value data.	
Benzene	$14,982			
1,3-Butadiene	$42,449			
Formaldehyde	$5,588			
All Other ROG	$4,042			
SO2	$22,235			
Noise, auto ($/VMT)	$0.00163	FHWA. *Cost Allocation Study Final Report-V. Highway Cost Responsibility-Cost Occasioned Approach*	While the FHWA study does not offer explicit USDOT "guidance," it remains the best quantification of noise values available. The midpoints of the report's range of possible values are recommended as a reasonable assumption.	https://www.fhwa.dot.gov/policy/hcas/final/five.cfm
Noise, truck ($/VMT)	$0.03652			
Auto ownership ($/vehicle/year)	$5,746.24	AAA. *Your Driving Costs Fact Sheet.* 2022.	AAA provides reputable data updated on an annual basis.	https://newsroom.aaa.com/wp-content/uploads/2022/08/2022-YourDrivingCosts-FactSheet-7-1.pdf
Natural Lands				
Wetland ($/acre/year)	$37,340	Open Space Authority. *Healthy Lands & Healthy Economies: Nature's Value In Santa Clara County*.	The OSA work is the best California valuation for natural lands impacts.	https://www.openspaceauthority.org/system/documents/NaturesValue_SCC_int.pdf
Forestland ($/acre/year)	$5,830			
Pasture ($/acre/year)	$5,210			
Agricultural ($/acre/year)	$1,600			

Attachment C – Cost Estimation Methodology

This attachment describes the methodology that was used to develop lifecycle cost estimates for projects. Attachment D provides further detail on the calculation of both cost and benefit streams.

All project sponsors (i.e. CTAs, city agencies and transit operators) submitted an initial capital cost and annual steady-state O&M (operations and maintenance) costs for their projects. A high-level cost review was conducted by an independent costing consultant, who applied a uniform methodology for all projects. The review used a unit-cost based methodology for capital costs, wherein the consultant estimated the number of units of various asset classes that would be needed by a project (e.g. miles of track, square feet of pavement, etc.), and multiplied this by an average unit cost. Indirect costs of construction and implementation, contractor and agency contingency costs and agency soft costs were all added to the direct costs of construction. For O&M costs, the consultant estimated change in vehicle revenue hours, or number of miles for roadway maintenance, or a similarly appropriate methodology. Projects were flagged when the estimated project costs differed from sponsor-provided costs by over 25%. Cost discrepancies were resolved with project sponsors by sharing our consultant's estimates and discussing input assumptions.

Lifecycle costs were derived from the initial capital cost and annual O&M costs, and are split into four categories, as shown in Table C.1. Calculation of asset replacement costs is based on the split of initial capital costs between major asset classes, as estimated during the cost review, and the useful life of those major asset classes, shown in Table C.2.

Table C.1 Methodology for Estimating Project Costs

Costs	Includes	Methodology
Upfront Capital Costs	Planning, design, environmental, right of way and rolling stock acquisition, and construction/installation	Project sponsors will submit cost estimates to MTC. Before conducting the assessment, MTC will review costs for accuracy and inclusiveness.
Operating and Maintenance Cost	Ongoing costs of operations and maintenance (O&M)	Project sponsors will submit O&M estimates to MTC. MTC will review these estimates for accuracy and inclusiveness. MTC might also add O&M costs to roadway or transit projects that do not submit O&M costs. As mentioned earlier, according to best practices in cost-benefit analyses, project revenues such as tolls or fares only represent economic transfers and hence they will not be netted out of the costs. The impact of this change is discussed at the end of this attachment.
Asset Replacement Costs	Rehabilitation and replacement cost of assets above and	Costs of asset replacement are calculated based on the useful lifetime of assets. For example, bus assets have lifetimes of 14

Costs	Includes	Methodology
	beyond regular O&M costs	years, and hence we assume there would be the same level of initial capital investment at the 14-year mark. The upfront capital investment costs will be split into major asset classes as shown in Table C.1. The purpose is to distinguish between the major asset classes that have different lifetimes. This split was derived from the high-level cost review of all projects. (See Attachment D for further detail on the calculation of cost streams.)
Residual Value	Value of assets in horizon year	Since the analysis year ends in 2080, any remaining value of assets is essentially a negative cost. This is calculated based on straight-line depreciation of major asset components based on lifetime of assets. Real estate assets do not depreciate.

Table C.2 Useful Lives for Major Asset Classes

Category	Asset Class	Expected Useful Life (in years)
Vehicle	Local / BRT Bus	14
	Express Bus	14
	Light Rail Vehicle	25
	Diesel Multiple Unit (DMU) Rail Vehicle	25
	Heavy Rail Vehicle	40
	Ferry	25
Transit Infrastructure	BRT ROW Assets	20
	Guideway (at-grade, aerial)	80
	Guideway (underground)	125
	Trackwork	30
	Stations (at-grade, aerial)	70
	Stations (underground)	125
	Train Systems Technology	30
	Maintenance Facility / Parking Facility	70
Technology / Operations	Tolling Equipment ITS Other Technology Assets	20
Roadway	Pavement (highway, bicycle lanes)	No limit; preventive/restorative maintenance, as % of upfront capital cost (real values): 5th year: 10% 10th year: 20%

Category	Asset Class	Expected Useful Life (in years)
		20th year: 30% Costs repeat every 5th, 10th and 20th year.
	Structures (bridges, tunnels, elevated ramps)	No limit; preventive/restorative maintenance, as % of upfront capital cost (real values): 5th year: 20% 15th year: 20% 35th year: 30% Costs repeat every 5th, 15th and 35th year.
Real Estate	Land Acquisition	Land Acquisition costs were not considered in project cost calculation since they represent a transfer (see below)

Impact of Excluding Transfers from Project Costs

Monetary exchanges that are transfer payments, that is, transactions where money is exchanged without anything of economic value being created or consumed, should neither be included as benefits or costs in a social benefit-cost assessment. Examples of such transactions are tolls, parking fees and transit fares. These charges are financial tools used to transfer some or all of a project's cost to its direct beneficiaries and away from society as a whole. While they may be useful for identifying winners and losers, they do not correspond to net impacts on society as a whole.

In the Plan Bay Area 2040 Project Performance Benefit-Cost methodology, transfers did not appear in the project benefits numerator of the benefit-cost ratio calculation. Specifically, changes in accessibility benefits (logsums) included the travel costs experienced by users in making travel decisions (i.e. tolls, fares etc.), but these charges were added back in as a benefit, thus cancelling each other out. However, the project costs denominator represented net operating costs to the project sponsor. In the case of transit projects, the net operating cost was calculated using the average farebox recovery ratio by operator. In the case of tolling and cordon pricing projects, the operations and maintenance costs (and in some cases a portion of the capital costs) were assumed to be covered by expected revenues. In Horizon/Plan Bay Area 2050, to be consistent with social benefit-cost analysis best practices and associated federal guidance, transfers were removed from the costs denominator as well. This means that the cost denominator would represent the full cost of the project to society. This approach was carried forward as part of the Plan Bay Area 2050+/Transit 2050+ Project Performance Assessment.

Benefit-cost assessments (BCA) seek to calculate the societal benefits of transportation and not benefits to any segment of the population. When projects involve large transfer payments, such as cordon pricing projects, or other projects that may be assessed, such as free transit, the BCA is limited in its ability to measure the effects of the project. The magnitude of transfer payments is irrelevant in a BCA, but it is certainly not irrelevant to the economic impacts of the project/policy.

Attachment D – Benefit-Cost Ratio Calculation Methodology

Benefit-cost ratio (BCR) was calculated as the ratio of the present value of the stream of benefits of the project, to the present value (PV) of the stream of lifecycle costs, including capital costs, operations and maintenance (O&M) costs, asset replacement/rehabilitation costs, and a reduction in costs based on residual value. The following formula illustrates this calculation:

$$BCR = \frac{PV(Benefits)}{PV(Capital\ Costs) + PV(O\&M\ Costs) + PV(Asset\ Replacement\ Costs) - PV(Residual\ Value)}$$

In this methodology, various assertions and assumptions are made with respect to discounting, the period of analysis, and forecasting cost and benefit streams until the end of the analysis period.

Discount Rate

The real discount rate (discount rate net of the inflation rate) used to calculate the present values of forecasted benefits and costs is 3% per year, based on a review of guidance for benefit-cost analysis applications.

Analysis Period

Since the assessment focuses on comparing the BCR of projects, similar timelines were considered to appropriately compare the present values. BCRs were calculated for a 55-year period for all projects, including construction time, discounting all benefits and costs to the first year of construction of the project. This analysis period accounts for 40-45 years of operation post construction at a minimum, if not more. For convenience of analysis and to compare all projects uniformly, and since the horizon year is fixed at 2050 (i.e. modeled year), the analysis period started at the same year for all projects, irrespective of when they were expected to become operational. This start year chosen for the analysis is 2025, given that project sponsors indicated potential start data of most projects across the entire decade from 2021-2030. The end year of the analysis is 2080, thirty years past the horizon year. A residual value of the investment was added as a negative cost in 2080, to reflect the fact that assets with long lifespans would have remaining value beyond the analysis period.

Cost Streams

The methodology for calculating asset replacement costs over the analysis period and residual value is described in Table C.1 in Attachment C. These costs were based on the lifetime of assets and simplifying assumptions were made to estimate these costs relative to the initial capital cost, based on the asset class.

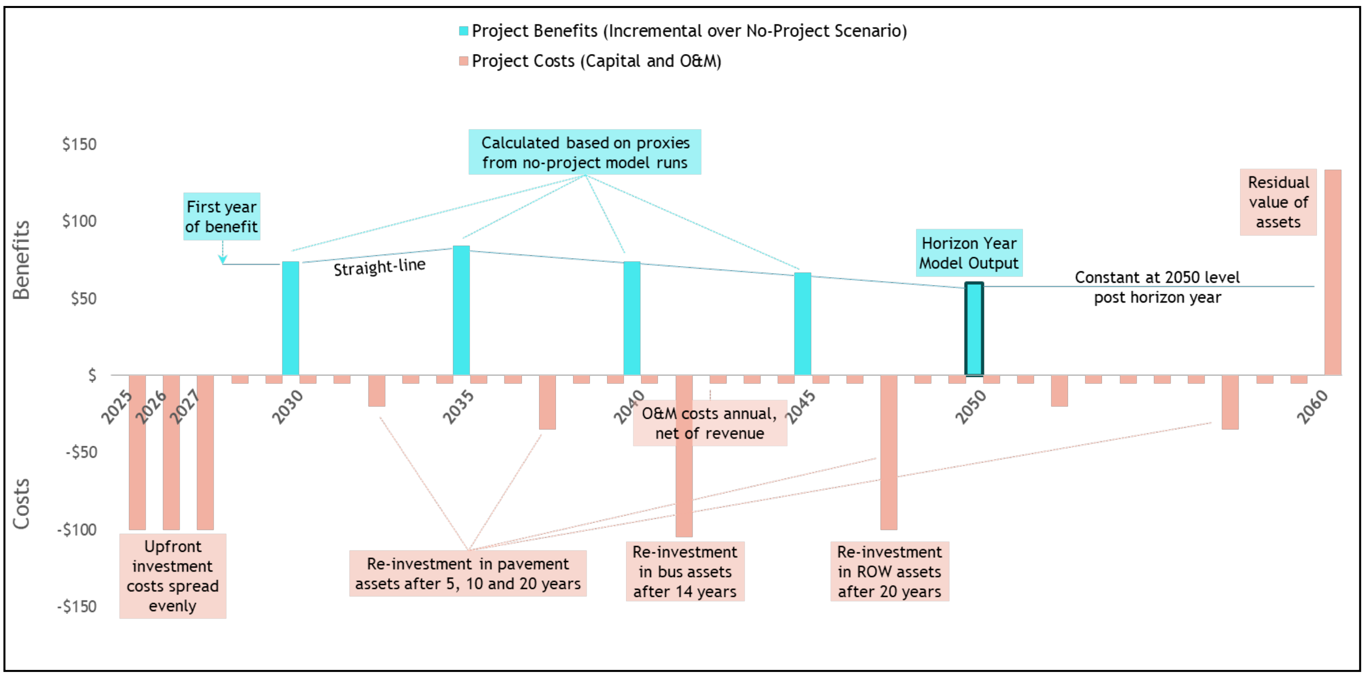
Benefit Streams

The general practice followed in benefit-cost analyses of transportation infrastructure is to assume that benefits are constant or consistently rising with metrics such as ridership over the lifetime of the asset, depending on the type of benefit. However, such assumptions may not be consistent across divergent futures. Consequently, the benefit streams were forecasted using results of the no-project baseline model runs. These model runs included existing and committed projects. TM1.5 and UrbanSim models were run iteratively for a no-project scenario starting in 2015 at the least for every ten-year interval, but if possible, at five-year intervals, until the horizon year 2050. This provided metrics such as auto hours, transit hours, walk/bike hours, air pollutant metric tons and VMT (to estimate number of collisions and noise). The trajectory of these metrics served as proxies to estimate the stream of project benefits over time. While it would be ideal to run the models iteratively for every individual project as well, the compute time requirements would have been prohibitive barring a drastic reduction in run times of the models. REMI outputs have already been generated for every five-year interval until the horizon year. Benefits from 2051 until the end of the analysis period at 2080 were assumed constant at the 2050 level.[8]

For instance, in a future where there are no major external shifts, benefits from lowered emissions due to a major transit investment could be assumed to grow in a straight line over 20 years to the Horizon year value, if maximum ridership is assumed to be reached in the 20th year. However, if electric vehicles are a high percentage of the fleet mix in a given future, then benefits from emissions may rise for the first ten years when the fleet is largely fossil-fuel powered, but eventually drop to a much lower value, as the horizon year benefits would be represented in the output of the Travel Model 1.5. Capturing the benefit that the transit investment provides in the interim period is critical to evaluate the benefit-cost ratio. The assumption for the stream of these benefits from reduced emissions may be tied to the penetration of electric vehicles into the fleet and other related factors.

All the above assumptions are illustrated in Figure D.1. The example used is a new bus rapid transit (BRT) project, with upfront capital costs of $300M, with a construction timeline of 3 years. The costs are split by major asset class as defined in Table C.2, $100M in buses, $150M in pavement, and $50M in stations.

Figure D.1: Illustration of Benefit and Cost Stream Calculations for Sample BRT Project



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[8] These baseline benefit streams were not recalculated; the same inputs were used and tested to ensure that baseline modeling results were identical to those produced for the Plan Bay Area 2050 project performance assessment.

Attachment E - Guiding Principles Assessment

The Guiding Principles reflect the core aspirations for the Bay Area through 2050 – to create a region that is Affordable, Connected, Diverse, Healthy, and Vibrant. Within the Project Performance Assessment, the Guiding Principles Assessment was integrated as a secondary, qualitative assessment alongside the benefit-cost assessment. Unlike past long-range planning cycles, the assessment was used solely to highlight when project impacts may not be supportive one or more of the Principles. As such, the criteria for the Guiding Principles Assessment were narrowly defined to focus on significant negative impacts associated with the project itself, rather than the performance of the jurisdiction(s) where the project may be located. The intent of the assessment was to highlight potentially significant adverse impacts that projects may have. Table E.1 below shows the criteria for each of the Guiding Principles.

Table E.1 Framework for Guiding Principles Assessment

Guiding Principle	**Evaluation Question** *If yes, the project is **not** supportive of the Guiding Principle*	**Application of Evaluation Question** *For a project to be flagged as not supportive of the Guiding Principle…*
Affordable	**Does the project increase travel costs for lower-income residents?**	• The project would have to actively eliminate a lower-cost travel alternative, rather than just offering a new travel option.
Connected	**Does the project increase travel times or eliminate travel options?**	• The project would have to increase travel time for one mode without decreasing it for another mode; exceptions would be made for projects with significant safety benefits that justify increased travel times, or… • … the project would have to eliminate a modal option from a travel corridor.
Diverse	**Does the project displace lower-income residents or divide communities?**	• The project would have to directly displace lower-income households* through site acquisition, or… • The project would have to build an elevated freeway structure through an existing neighborhood.
Healthy	**Does the project significantly increase emissions or collisions?**	• The project would have to yield a significant long-term net increase in emissions and/or collisions.
Vibrant	**Does the project eliminate jobs?**	• The project would have to directly result in a net reduction of jobs*.

* Threshold of ~100 homes impacted or ~100 jobs displaced.

The assessment reviewed each project for alignment with each principle with respect to no-project conditions. Each project was flagged as either supporting a principle or not supporting a principle.

Attachment F - Equity Assessment

The equity assessment consisted of two components to evaluate project-level impacts. The first component was a geographic assessment. The second component was a quantitative assessment that examined distributive impacts of accessibility benefits across income groups, using Travel Model outputs.

Geographic Assessment

This assessment measured whether projects would serve a Plan Bay Area 2050+ Equity Priority Community (EPC). Using GIS, the assessment reviewed whether a project provided a point of access directly to one or more EPCs and provided a yes/no scoring. EPC definitions used both 2014-2018 and 2018-2022 American Community Survey data.

Accessibility Benefits across Income Groups

This methodology examined the distributive impacts of accessibility benefits across income groups using Travel Model outputs and lends insight into which income groups benefit most from a project's quantified accessibility benefits.

Travel Model 1.5 outputs of changes in accessibility benefits can be split by income group at the Transportation Analysis Zone (TAZ) subzone levels.[9] The income groups were originally defined as approximate quartiles but remained defined by income levels adjusted to 1999 dollars to be consistent with the requirements of the transportation model. The income categories, in 1999 dollars, are less than $30,000; from $30,000 to $59,999; from $60,000 to $99,999; and $100,000 and above. In 2019 dollars, the breakpoints between the categories are approximately $45,000, $90,000 and $150,000.

Average annual accessibility benefits per person can be calculated based on the model outputs and monetized using the same valuations that were used to calculate the benefit-cost ratio. An equity score can then be calculated as the ratio of benefits per person of the two lower income groups to the sum of benefits per person of all income groups, thus lending insight into which income groups benefit most from a project in terms of accessibility. This is illustrated in Figure F.1. A higher equity score means that a project provides more accessibility benefits to persons of the two lower income groups.

There are three scores a project can receive: Advances Equity, when the score is over 60%; Even Distribution of Benefits, when the score is between 40-60%; and Challenges Equity, when the score is less than 40%.

Given the current setup of the model used, accessibility benefits cannot be split based on age, race, gender or disabilities – only income levels.

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[9] TAZ refers to Transportation Analysis Zone; there are 1,454 TAZs in the Bay Area. TAZs are divided into subzones, which include "cannot walk to transit", "short walk to transit", and "long walk to transit".

Figure F.1 Illustration of Equity Score Calculation for Two Sample Projects