# Performance Metrics

This section describes the metrics used to analyze to what extent the studied alternatives achieve the five Key Considerations. These metrics have been developed with the goal of judging preferred ways for governing bodies and independent groups to:

1) Decide between project alternatives;
2) Allocate resources and funding sources developed from the project; and
3) Monitor and evaluate the selected project throughout its planning, financing, building, operating, maintenance, and governing phases.

The metrics build directly off of the five Key Considerations of Social Equity, Accessibility and Connectivity, Land Use Planning Coordination, Climate Change Mitigation, and Resilience and Adaptation. They were developed by consulting scholarship regarding transportation infrastructure evaluation, as well as by researching indicators and metrics used by agencies and organizations in the transportation, planning, public health, resource management, and environmental science fields. System performance was also included as a sixth metric to measure how efficiently the alternative addresses issues of system capacity, but the metric must be considered along with the five Key Considerations.

These metrics, presented in Table 4, should be viewed as a starting point for considering how to measure projects and should be augmented and developed over time in response to changing needs and availability of reliable data.

Quantitative results were calculated for some measures using travel demand and/or land use models used by MTC (see Model Methodology section), while others utilized existing data. We also applied qualitative assessments in combination with quantitative results in recognition of the inherent limitations of these models.

Metric descriptions, the ways in which they align with the key considerations, and potential limitations are briefly explained below. Look to Appendix D for additional information regarding methodology, data sources, and resources.

*Table 4: Summary of project metrics*

| *Key Consideration* | *Metrics* |
|---|---|
| **Social Equity** | 1. Health Equity<br>2. Displacement |
| **Accessibility & Connectivity** | 1. Transit Access<br>2. Jobs Access<br>3. Healthcare Access<br>4. Recreational Access<br>5. Intermodal Connectivity |
| **Resilience and Adaptation** | 1. Redundancy<br>2. Vulnerability to Sea Level Rise/Flooding<br>3. Seismic Vulnerability |
| **Climate Change Mitigation** | 1. Emissions from Transportation Network<br>2. Energy Efficiency of Land Use |
| **Land Use Planning Coordination** | 1. Population Growth<br>2. Job Growth<br>3. Land Development Opportunities Adjacent to Stations |
| **System Performance** | 1. Time Periods that Demand Exceeds Capacity<br>2. Westbound to Eastbound Person Trip Balance<br>3. Net Investment Cost of Alternative |

## Social Equity

Social Equity refers to the ability of the proposed project to equally distribute opportunities and burdens to low-income communities and communities of color. The Social Equity metrics specifically aim to measure the impacts the proposed project will have on health outcomes and housing and transportation costs (a proxy for potential for displacement) in impacted communities. The data these metrics require cannot be attained through the use of existing travel demand and land use models, therefore other quantitative and qualitative measurement methods are necessary. These metrics have a limitation in that individual longitudinal data, which are hard to collect, are needed to develop a comprehensive understanding of the displacement impacts of the project or project alternative (i.e. who is displaced and where they are displaced to). For more information on the methodology, data sources, and other metric resources, see Appendix D.

1) **Health Equity** - This metric measures the benefits and harms the project will have in terms of changes in a) active transportation b) traffic safety, and c) exposure to air and water pollutants and noise in communities impacted by the development and operation of the

project. This metric includes measuring the distribution of health benefits and harms by racial and income make-up of the communities impacted.[267]

2) **Displacement -** This metric measures areas that are at risk of changes in affordability and compares this to areas in the region that have high proportions of low income groups and minorities and areas that have high access to opportunity, in terms of housing, transportation, and other services near stations. The metric is comprised of a) changes in housing and transportation costs for households, b) vacancy rates of residences, small businesses, and community services in impacted communities, c) access to opportunities related to economic well-being, education, transit, civic infrastructure, and public health.[268]

Social equity metrics are integrated into a number of metric categories, including Accessibility and Connectivity, Resilience and Adaptation, and Land Use.

## Accessibility and Connectivity

Accessibility refers to how easily people can reach different opportunities in terms of time and travel costs.[269] These opportunities can include access to employment centers, schools, and services and amenities, such as hospitals, retail centers, parks and recreation. Accessibility is important for all travelers, but particularly for communities that depend on transit as a primary mode of travel. In the Bay Area, many trips depend on connecting across different modes or service providers. Therefore, travel time reliability of service connections is a critical factor in determining the accessibility of a system. The metrics below provide indicators of how accessible a system is, in terms of time and cost, as well as connectivity. While these metrics are intended to be useful indicators of access, some limitations exist. It is difficult with healthcare and parks to identify if services or amenities are comparable; for instance, large parks with walking trails are not the same as small pocket parks, but may be considered the same in an accessibility analysis if weighting is not given to different amenity types. For more information on the methodology, data sources and other metric resources, see Appendix D.

1) **Transit Access** - this metric identifies the number of households within a quarter mile of a proposed transit station. Transit accessibility can be measured in several ways: gravity models, utility models, and cumulative access.[270] Transit access can be further analyzed by income and race to identify gaps in services for communities of concern.

2) **Jobs Access** - this metric identifies the location of major employment centers and the number of jobs available to households in different locations. Jobs access can be further analyzed according to income group and job type / education to quantify employment

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[267] Andrew L. Dannenberg, “A Brief History of Health Impact Assessment in the United States”; “Road Pricing Health Impact Assessment (HIA).”
[268] Chapple, “Mapping Susceptibility to Gentrification: The Early Warning Toolkit”; Seattle Office of Planning & Community Development, “Equitable Development Implementation Plan”; “California Transportation Plan 2040.”
[269] Handy, “Accessibility-vs. Mobility-Enhancing Strategies for Addressing Automobile Dependence in the US.”
[270] LaMondia, Blackmar, and Bhat, “Comparing Transit Accessibility Measures.”

opportunities for residents. Affordable housing near jobs centers is key, especially for low income populations.[271] If there are not sufficient employment opportunities for the income groups in the neighborhood, that suggests a jobs-housing imbalance.

3) **Healthcare Access -** this metric identifies the location of primary care doctors and the access to these facilities by transit. While primary care doctors are not fully reflective of access to healthcare more generally, it can serve as an initial indicator of how easy it is for populations to reach healthcare. Studies have shown that transit access can be a major barrier to healthcare access, especially for low-income populations.[272] As such, access can be further analyzed according to communities of concern, such as seniors or populations with disabilities. Access to healthcare is a standard measure in public health.

4) **Recreational Access -** this metric identifies the location of parks and the access to these amenities by transit. Parks are associated with opportunities for improved mental and physical health, but can be inaccessible to some communities of concern.[273] One challenge in measuring this metric is that it can be difficult to weigh the value of parks by size or amenities. Access can be further analyzed according to communities of concern, such as low-income populations.

5) **Intermodal Connectivity -** this metric combines local and regional connectivity considerations to measure efficacy of stations in connecting between local and regional transit. This measure reflects the number of intermodal connections available and whether or not overnight service is provided. Additional features could be added in the future, including availability of information and average wait time.[274] One challenge in measuring this metric is accounting for service delays as part of the frequency of service. Connectivity can be further analyzed by race and income to identify gaps in service.

## Resilience and Adaptation

Resilience can be understood in the context of this project as addressing the vulnerability of critical assets in the transportation network based on various risks including natural disasters and maintenance failure. In addressing resiliency, the scale of both specific assets and the larger transportation network as it relates to the transbay corridor are used to provide a more robust understanding of the issues and possible interventions. In understanding flexibility of a system, redundancy in service is vital to providing service after unexpected incidents that affect components of the transportation network. Additionally, the availability of modes within different communities located near existing and proposed sections of the transportation network must be considered in defining criticality to ensure the resilience of all communities in the region. This

[271] Levine, “Rethinking Accessibility and Jobs-Housing Balance.”
[272] Syed, Gerber, and Sharp, “Traveling Towards Disease.”
[273] “Disparities in Park Space by Race and Income | Active Living Research.”
[274] Chowdhury, Ceder, and Velty, “Measuring Public-Transport Network Connectivity Using Google Transit with Comparison across Cities.”

includes understanding how race, income, and other factors increase vulnerability. For more information on the methodology, data sources, and other metric resources, see Appendix D.

1) **Redundancy -** This metric considers a transportation system's flexibility in the event of a sudden or planned closure of part of the network.[275] In the context of the transbay corridor, this is considered in terms of a possible closure of the current transbay tube for maintenance and/or a sudden disaster. This will be measured in terms of ridership capacity. The difficulty of predicting exactly how a potential disaster might affect the corridor presents a limitation in terms of assessing the overall redundancy of the system.[276]

2) **Vulnerability to Sea Level Rise/Flooding -** This metric considers the relationship between proposed alternatives, current infrastructure and projected effects of sea level rise and flooding. This is addressed by looking at infrastructure location in relationship to sea level rise scenarios.[277] It is important to consider that sea level rise scenarios do not always include possible mitigation efforts such as seawalls. While this is useful for assessing the overall risk of infrastructure in terms of its location, it does not account for the exact interaction of water inundation in existing and proposed infrastructure.[278]

3) **Seismic Vulnerability -** This metric considers the relationship between proposed alternatives, current infrastructure and seismic hazards. Soil liquefaction susceptibility in the Bay Area will be used as proxy for seismic vulnerability.[279] While this metric can demonstrate the risk of a general area, this does not account for the wide range of variation in soil that can occur even within a single parcel.[280]

## Climate Change Mitigation

The Climate Change Mitigation metrics aim to measure the impacts that project alternatives will have on transportation-related and building development-related $CO_2$ emissions. These metrics align with California Senate Bill 375 of 2008, which required each region in California to create a strategy to reduce GHG emissions.[281] SB 375 led to the goal adopted by Plan Bay Area to reduce GHG emissions in the Bay Area by 15% of 2005 levels by 2035.[282] For more information on the methodology, data sources, and other metric resources, see Appendix D.

[275] Ta, Goodchild, and Pitera, "Structuring a Definition of Resilience for the Freight Transportation System."
[276] "Open Data « ABAG Resilience Program."
[277] Nicholls et al., "Constructing Sea-Level Scenarios for Impact and Adaptation Assessment of Coastal Areas."
[278] "Open Data « ABAG Resilience Program."
[279] IASME/WSEAS International Conference on Geology and Seismology and International Association of Mechanical Engineers, "Assessment Risk of Soil Liquefaction."
[280] "Open Data « ABAG Resilience Program."
[281] Steinberg, SB 375. Transportation planning: travel demand models: sustainable communities strategy: environmental review.
[282] Metropolitan Transportation Commission and Association of Bay Area Governments, "Plan Bay Area: Final Performance Assessment Report."

1) **Emissions from Transportation Network –** Plan Bay Area established a $CO_2$ emissions per-capita reduction goal for cars and light-duty trucks.[283] To account for cleaner public transit options and active transportation, and to provide a more direct comparison of the project alternatives, the current metric uses MTC travel demand model output data to measure the daily per-capita $CO_2$ emissions across all travel modes within the region. How the project alternatives will impact the $CO_2$ emissions produced within communities of concern relative to other census tracts should also be analyzed.

2) **Energy Efficiency of Land Use –** The building sector emits up to 30% of the world's annual GHG emissions.[284] The current metric uses land use model output data to measure the per-capita $CO_2$ emissions released by buildings that would be developed within the region due to an additional transbay crossing. How the project alternatives will impact the $CO_2$ emissions produced by buildings in communities of concern relative to other census tracts should also be analyzed.

## Land Use Planning Coordination

The Land Use Planning Coordination metrics are intended to capture the relationship between transit and where residents and business are located in the Bay Area, as well as understand what happens to different populations and communities over time. Where possible, similar land use change data was included in the current conditions analysis to highlight historic trends. The selected metrics build on this to consider future patterns of growth to evaluate alternatives. Two of the three measures are designed as differences over time - growth in population and growth in jobs to capture changes in response to proposed alternative plans. Some of this data can be modeled with existing land use and travel models, however, such results are highly dependent on assumptions related to current conditions and market assessments, which could change significantly in the future. Models are imperfect tools that are not always well suited to capture local variations in real estate markets, nor are they able to predict larger national economic trends that impact regional economic and population growth. For more information on the methodology, data sources, and other metric resources, see Appendix D.

1) **Population Growth** - This metric compares projected population growth near transit in response to new transit service using MTC land use model outputs. The models project population at multiple geographic scales. This is important for determining whether population changes around stations reflect a redistribution of population growth or are part of a larger trend across the Bay Area that would have occurred without new transit. This metric analyzes changes in income, allowing for basic analysis of population changes associated with changing incomes and redistributions of areas of poverty and wealth that are estimated to result from new transit.[285] This analysis can be done with Travel Model One and the UrbanSim land use model, as well as with data from the American Community

[283] Ibid.
[284] United Nations Environment Programme, "Buildings and Climate Change: Summary for Decision-Makers."
[285] Metropolitan Transportation Commission and Association of Bay Area Governments, "Plan Bay Area Equity Analysis Report: Including Title VI, Environmental Justice and Equity Analysis for Plan Bay Area."

Survey in conjunction with geographic transit location data. MTC tracks similar data with its Population Vital Sign.[286]

2) **Job Growth** - This metric compares projected job growth by location (including within a distance of transit stations) and by job type using the MTC land use model outputs. Similar to the population growth metric, it allows for geographic consideration to determine where and how job growth shifts under different alternatives. Ideally this metric includes analysis of jobs by wage to understand the type of jobs that are growing and where. This analysis can be done with Travel Model One and the UrbanSim land use model, as well as with LEHD employment data with geographic transit location data. MTC tracks similar data with its Jobs Vital Sign.[287]

3) **Land Development Opportunities Adjacent to Stations** - This metric is focused on identifying alternatives where station locations are surrounded by low-intensity development, such as parking lots or low-rise strip mall construction. This metric is drawn from the market assessment reports produced as part of the Core Capacity study. The reports used soft site analysis data from the San Francisco Planning Department and research on downtown Oakland conducted by SPUR to determine the capacity of areas for new growth.[288] SPUR also conducted a similar analysis for downtown Oakland by analyzing satellite imagery to identify vacant parcels and surface parking lots.[289]

## System Performance

The System Performance metrics are intended to evaluate how the transportation system operates under a proposed alternative. They were selected with the goal of providing a basic understanding of the impact of transportation infrastructure investments on the efficiency and finances of transportation agencies. The metrics are central to understanding the impact of any alternative on specific transit agencies; however, the metrics must be considered in relation to performance of the alternative on the other measures. It is entirely possible to do well on each one of the system performance metrics without solving any of the problems a transbay crossing or alternative project could attempt to address. For more information on the methodology, data sources, and other metric resources, see Appendix D.

1) **Time Periods that Demand Exceeds Capacity** - This metric provides a measure of how many hours per week the transit and highway systems are operating beyond capacity. Collection and reporting of this data also allows analysis of *which* hours of the week have capacity issues to clearly state the scale of crowding issues. This allows a more nuanced understanding of both when and where there is and isn't additional capacity transportation capacity, which could much better inform future regional transportation demand

[286] Metropolitan Transportation Commission, "Vital Signs: Population."
[287] Metropolitan Transportation Commission, "Vital Signs: Jobs."
[288] Nadine Fogarty, Alison Nemirow, and Flavio Coppola, "Core Capacity Transit Study Memorandum: Final San Francisco Market Assessment"; Nadine Fogarty, Alison Nemirow, and Flavio Coppola, "Core Capacity Transit Study Memorandum: Revised Oakland Market Assessment."
[289] "A Downtown for Everyone: Shaping the Future of Downtown Oakland."

management and land use strategies (e.g. encouraging polycentric growth with more balanced commute patterns). Although the Bay Area has struggled to successfully implement regional growth incentives or controls, even the most extreme land use strategies that better take advantage of existing capacity could be cheaper than building additional transbay capacity. This metric lends itself well to transit service analysis, whereas the MTC Travel Time Reliability and Time Spent in Congestion metrics are focused on highway users.[290] This metric can also provide insight into service quality—that is, when transit riders are likely to be on an overcrowded vehicle. Serious consideration must be given to defining capacity for transit services: especially during off-peak hours, there is a difference between the passenger capacity at current levels of transit service versus maximum potential capacity if more vehicles were operated. A partial analysis was done for the MTC Core Capacity Transit Study using BART data.[291]

2) **Westbound to Eastbound Person Trip Balance -** This metric is a comparison of westbound to eastbound trips in the transbay corridor, including all persons traveling between San Francisco and Oakland/Alameda on the current Bay Bridge, the BART transbay tube, or the ferry lines. The primary focus is looking at travel during the morning commute when crowding is most extreme, though the metric would ideally be calculated for different times of day (including AM and PM peak periods) on all days of the week to account for varied travel patterns and allow more comprehensive planning around achieving transit investment efficiency, which is a key measure that MTC tracks.[292] To fully track this metric on an ongoing basis would require coordination for data collection from BART, BATA, WETA and MTC.

3) **Net Investment Cost of Alternative -** This metric is based on a net present value analysis of each possible transbay alternative project based on upfront costs, operating losses or revenues (for example, increased tolling), and long-run maintenance costs. The goal of the metric is to show the cost of alternatives in a comprehensive manner. This metric is outside of the scope of this report, but will need to be fully evaluated in future research. Such analysis would require coordination for data collection from MTC, BART, BATA, Caltrans, and other transit operators. Some estimates of project costs have been analyzed by MTC.

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[290] "Travel Time Reliability | Vital Signs"; "Time Spent in Congestion | Vital Signs."
[291] Data is not publicly available. See p. 24 of "Core Capacity Transit Study: Briefing Book."
[292] "Transit System Efficiency | Vital Signs."