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, and resilience and adaptation. They were developed through by consulting scholarship regarding transportation infrastructure evaluation, as well as indicators and metrics used by agencies and organizations in the transportation, planning, public health, resource management, and environmental science fields. These metrics 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 2. Displacement
Accessibility & Connectivity	1. Transit Access 2. Jobs Access 3. Healthcare Access 4. Recreational Access 5. Intermodal Connectivity
Resilience and Adaptation	1. Redundancy 2. Vulnerability to sea level rise/flooding 3. Seismic vulnerability

Climate Change Mitigation	1. Carbon Dioxide based off of Mode Share 2. Carbon Dioxide based off of Land Use
Land Use Planning Coordination	1. Population Growth 2. Job Growth 3. Land Development Opportunities Adjacent to Stations
System Performance	1. Time Periods that Demand Exceeds Capacity 2. Westbound to Eastbound Person Trip Balance 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 Metric** - 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 (Dannenberg, 2016; "Road Pricing Health Impact Assessment (HIA)," n.d.).[145]
2) **Displacement Metric -** 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

[145] Dannenberg, A. (2016). A Brief History of Health Impact Assessment in the United States. *Chronicles of Health Impact Assessment*, *1*(1), 1–8.

Road Pricing Health Impact Assessment (HIA). (n.d.). Retrieved December 6, 2016, from http://www.sfhealthequity.org/resources/hia-tools/21-elements/transportation/116-road-pricing-health-impact-assessment-hia.

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 (Chapple, 2009; Seattle Office of Planning & Community Development, 2016; Caltrans, 2016).[146]

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 (Handy, 2002).[147] 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. For instance, 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 (LaMondia, Blackmar, and Bhat, 2010).[148] 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 opportunities for

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[146] Chapple, K. (2009). *Mapping Susceptibility to Gentrification: The Early Warning Toolkit*. Center for Community Innovation. Retrieved from http://communityinnovation.berkeley.edu/reports/Gentrification-Report.pdf

Seattle Office of Planning & Community Development. (2016). *Equitable Development Implementation Plan*. Retrieved from http://2035.seattle.gov/wp-content/uploads/2016/05/EDI-Imp-Plan-042916-final.pdf

Caltrans. (2016). *California Transportation Plan 2040*.

[147] Handy, S. L. (2002). Accessibility-vs. mobility-enhancing strategies for addressing automobile dependence in the US. *Institute of Transportation Studies*. Retrieved from https://escholarship.org/uc/item/5kn4s4pb.pdf

[148] LaMondia, Blackmar, and Bhat (2010). Comparing Transit Accessibility Measures: A Case Study of Access to Healthcare Facilities. Retrieved from http://www.caee.utexas.edu/prof/bhat/ABSTRACTS/ComparingAccessibility.pdf

residents. Affordable housing near jobs centers is key, especially for low income populations (Levine, 2007).[149] 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 (Syed, Gerber, & Sharp, 2013).[150] 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 (UC Berkeley, 2011).[151] 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 (Chowdhury, 2014).[152] 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 includes understanding

[149] Levine, J. (2007). Rethinking Accessibility and Jobs-Housing Balance. *Journal of American Planning Association*, *64*(2). Retrieved from http://www.tandfonline.com/doi/abs/10.1080/01944369808975972
[150] Syed, S. T., Gerber, B. S., & Sharp, L. K. (2013). Traveling Towards Disease: Transportation Barriers to Health Care Access. *Journal of Community Health*, *38*(5), 976–993. https://doi.org/10.1007/s10900-013-9681-1
[151] University of California, Berkeley. (2011). *Disparities in Park Space by Race and Income*. Retrieved from http://activelivingresearch.org/disparities-park-space-race-and-income
[152] Chowdhury, S., Cedar, A., & Velty, B. (2014). Measuring Public-Transport Network Connectivity Using Google Transit with Comparison across Cities. *Journal of Public Transportation*, *17*(4). Retrieved from http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1005&context=jpt

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 (Ta, Goodchild, Pitera 2009). 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 ("Open Data - ABAG Resilience Program," n.d.).[153]
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 (Nicholls, Hanson, Lowe, Warrick, Long and Carter, 2011). 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 ("Open Data - ABAG Resilience Program," n.d.).
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 (IASME/WSEAS, 2009). 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 ("Open Data - ABAG Resilience Program," n.d.).

Climate Change

The climate change mitigation metrics aim to measure the impacts project alternatives will have on transportation-related and building development-related CO2 emissions across all travel modes. These metrics align with California Senate Bill 375 of 2008, which requires major metropolitan areas in California to reduce GHG emissions by 7% by 2020 and 15% by 2035 from 2010 emission rates. These metrics also align with CO2 mitigation metrics used by Plan Bay Area, Bay Area Air Quality Management District, and in MTC's Vital Signs report (Metropolitan Transportation Commission, 2013; Association of Bay Area Governments and Metropolitan Transportation Commission, 2013). For more information on the methodology, data sources and other metric resources, see Appendix D.

1) **Carbon Dioxide based off of Mode Share -** This metric uses travel demand model output data to measure the daily CO2 emissions per capita across all travel modes within the region. CO2 emissions produced within communities of concern should also be analyzed.
2) **Carbon Dioxide based off of Land Use -** This metric uses land use model output data to

[153] Open Data - ABAG Resilience Program. (n.d.). Retrieved December 10, 2016, from http://jmplus.net/vDhGUrCI, http://resilience.abag.ca.gov/open-data/

measure the CO2 emissions released by buildings developed due to the second bay crossing per capita across changed development within the region (United Nations Environment Programme, 2009). CO2 emissions produced by building types in communities of concern should also be analyzed.

Land Use

The land use 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 populations changes associated with changing incomes and redistributions of areas of poverty and wealth that are estimated to result from new transit (ACS data, Metropolitan Transportation Commission, 2013). This analysis can be done with Travel Model One and the UrbanSim land use model, as well as with data from the American Community Survey in conjunction with geographic transit location data. MTC tracks similar data with its Population Vital Sign.[154]
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 job by wage to understand the type of jobs that are growing and where. This analysis can be down 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.[155]
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

[154] MTC Vital Signs: Population. http://www.vitalsigns.mtc.ca.gov/population.
[155] MTC Vital Signs: Jobs. http://www.vitalsigns.mtc.ca.gov/jobs.

assessment reports produced as part of the Core Capacity study. The reports analyze the number of "soft-sites" to determine the capacity of areas for new growth.[156] SPUR also conducted a similar analysis for downtown Oakland by analyzing satellite imagery to identify vacant parcels and surface parking lots.[157]

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 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 are of capacity issues to clearly state the scale of crowding issues. It is a response to the tendency of reports (what reports?) on the transbay corridor to focus on whether services, specifically BART, are ever over capacity. This framing overlooks the fact that the system may only run at capacity during a limited period each week. This data provides a metric that is simple to analyze for transit agencies, where the MTC Travel Time Reliability and Time Spent in Congestion metrics are extremely highway user focused.[158][159] This metric can provide insight into when transit riders are likely to be on an overcrowded vehicle and it also focuses system operations and opportunities: it can provide insight for land use planners as to where additional growth could be accommodated without significant additional system investment. There may be additional analysis opportunities to consider in terms of whether and how to define capacity. Especially during off-peak hours, there is a difference between current levels of transit service versus maximum potential levels of service if more vehicles were operated. Some of this analysis was done for the MTC Core Capacity Transit Study using BART data.[160]
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

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156 SF Market Assessment Report (full citation needed).
157 SPUR. "A Downtown for Every One, Shaping the Future of Downtown Oakland." September 2015. p19. http://www.spur.org/sites/default/files/publications_pdfs/SPUR_A_Downtown_for_Everyone.pdf
158 Metropolitan Transportation Commission. Time Spent in Congestion web page. http://www.vitalsigns.mtc.ca.gov/time-spent-congestion. Accessed 10 December 2012.
159 Metropolitan Transportation Commission. Travel Time Reliability web page. http://www.vitalsigns.mtc.ca.gov/travel-time-reliability. Accessed 10 December 2012.
160 Data is not publicly available. See p. 24 of "Core Capacity Transit Study Briefing Book." http://mtc.ca.gov/our-work/plans-projects/other-plans/core-capacity-transit-study.

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.[161] 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.

[161] Metropolitan Transportation Commission. Transit system efficiency web page. http://www.vitalsigns.mtc.ca.gov/transit-system-efficiency. Accessed 10 December 2012.