Alternatives Analysis

This section assesses the performance of the four alternatives across the five Key Considerations. The data used to compare the alternatives is based on analysis of current conditions and outputs generated using the MTC's Travel Model 1 and Bay Area UrbanSim land use model. The methodology for the modeling work is described in the Modeling Methodology section. A more detailed description of the metrics used as well as metrics worth considering in future analysis can be found in the Performance Metrics section and Appendix D.

Based on our analysis, we find that the four alternatives provide distinct tradeoffs, with different benefits and visions:

- **New Opportunities:** Serves growing areas downtown San Francisco and Oakland, while creating a more resilient corridor
- **Critical Needs:** Serves highest density areas of San Francisco and Oakland, while building similar resilience
- **Connecting the Megaregion:** Creates new regional connections and job access, and a critical step in the state rail system
- **Performance Pricing:** Flexible response to an immediate need, with revenue to support regional goals

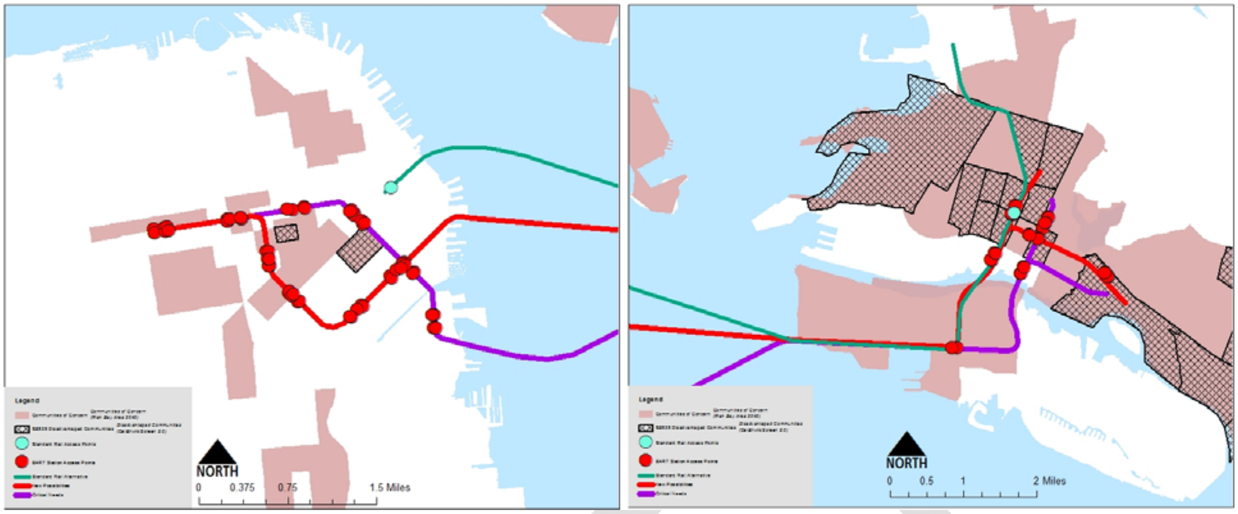
Social Equity Analysis

The proposed alternatives should improve transportation options and conditions for historically disadvantaged communities in the region and increase the overall social equity of regional distribution of resources. For additional information on the current state of social equity in Bay Area transportation, see the Current Conditions section. While all sections provide information and base their analysis on how to deliver a project in a socially equitable way, the Social Equity Opportunities section offers an additional look at specific social equity-oriented projects.

Communities of Concern

Transit projects can increase freedom of movement, reduce pollution, and provide access to new economic opportunities. However, they can also have the potential to drive growth that can result in displacement. It is critical to ensure that the opportunities and drawbacks of a transit project of this magnitude are distributed in a socially equitable way. The map below overlays MTC's Communities of Concern and areas designated by the State of California as "Disadvantaged Communities" with the studied third crossing alternatives. See the Current Conditions for further description of each designation.

Figure 40: Communities of Concern and Disadvantaged Communities near proposed stations



Source: Map produced by students in the Fall 2016 Transportation Planning Studio using data from MTC's Communities of Concern and areas designated by the State of California as "Disadvantaged Communities"

All three crossing alternatives have stations located in areas designated as both Communities of Concern and Disadvantaged Communities, though the New Opportunities BART alternative contains significantly more than the other two alternatives. This is due to having multiple stations in Downtown Oakland, as well as building new stations in the mid-Market and Tenderloin neighborhoods of San Francisco and a new station east of Lake Merritt in Oakland.

- **New Opportunities (BART):** Eastlake, 11th/Broadway, 14th Street, 8th/Howard, Hyde/McAllister, Van Ness, Fillmore
- **Critical Needs (BART):** 15th/Franklin, Van Ness, Fillmore
- **Connecting the Megaregion (Standard Rail):** 14th Street, Richmond *(existing station)*

Travel Accessibility and Reliability for Disadvantaged Communities

By placing new stations in disadvantaged communities, these alternatives have the potential to improve residents' access to services, activities, and jobs. However, as the new transit service provided by these alternatives focuses on transbay travel, it represents significantly less of an improvement for local trips, and these areas are already well-served by Muni and AC Transit (Redhill Group, Inc, 2013).[162] As a result, accessibility improvement for these communities from the crossing alternatives is largely represented by improved access to jobs in San Francisco and the Peninsula.

- **New Opportunities and Critical Needs (BART):** The studied BART alternatives provide minor time savings on existing service lines due to decreased headways. They do, however, significantly reduce travel times for trips beginning or ending in areas that previously did not have a station nearby. These areas include Eastlake and the Brannan St stations in New Opportunities and Mission Rock in Critical Needs, as well as Van Ness and Fillmore in both

[162] Redhill Group, Inc. (2013). *AC Transit 2012 Passenger Survey* (Final Survey Findings). Metropolitan Transportation Commission & AC Transit. Retrieved from http://www.actransit.org/planning-focus/reports/2012-on-board-passenger-survey/

alternatives. Additionally, by reducing intermodal transfers, these alternatives should increase travel time reliability, which is particularly important for those working hourly jobs.

- **Connecting the Megaregion (Standard Rail):** This alternative significantly improves travel times to job centers on the Peninsula from the disadvantaged communities of Richmond and West and Downtown Oakland. However, as long-distance Caltrain service is typically much more expensive than BART and terminates in suburban locations, the extent of this benefit is dependent on the cost of tickets and availability of transit between Peninsula train stations and jobs.
- **Performance Pricing (No New Crossing):** This alternative decreases travel times for transbay bus riders by increasing reliability and decreasing headways. Since low-income individuals are typically less able to adjust their schedules, the increased tolls would save time, but could also create a significant burden for those who must continue to drive across the bridge. In contrast, most white collar high paying jobs in San Francisco are located in downtown and accessible by BART, bus, and ferry. The social equity impact of this alternative on accessibility is therefore largely dependent on implementation of a financial support system for low-income drivers. If such a system is implemented, these low-income drivers may even experience a net benefit, as they would gain from improved travel time reliability.

Land Use and Displacement

As will be discussed in the land use component of this section, there is limited evidence that any of these alternatives would on their own lead to a substantive increase in the rate of development. That finding, however, is primarily a result of the fact that the binding constraint on San Francisco development is restrictive zoning rather than transit accessibility. Given those supply constraints, the increased demand created by a nearby rail station will increase already-high displacement pressures significantly above what they would have otherwise been. However, even land use scenarios that substantially relax zoning near transit do not improve the displacement pressure for those at-risk communities. Although the increased supply reduces regional pressures, there is a higher risk of direct displacement from increased development in those station areas.

As a result, the degree to which development and/or displacement occurs will depend to a very large degree on the details of how the project is delivered and what steps are taken to help local communities leverage the investment. Details can be found in the Social Equity Opportunities section. This is perhaps most important for the two alternatives that would remove Interstate 980, as specific investments to take advantage of this project could dramatically shift the purpose and use of the land, and which groups of people, services, and jobs are attracted to the new area.

Air Quality

As discussed in the Current Conditions section, there are high rates of asthma and asthma-related hospitalizations in the low-communities along Interstates 580 and 880. West Oakland experiences particularly poor environmental conditions, as it is also bounded by Interstate 980. Air quality could be improved by reducing the number of vehicles traveling these roads. While the New Opportunities and

Connecting the Megaregion alternatives would provide some direct air quality benefits by removing Interstate 980, the Performance Pricing alternative offers greatest promise for improving overall air quality. Increased tolls would likely reduce the total number of vehicles, but even more importantly, could lead to large reductions in particulate matter by eliminating congestion and the idling that accompanies it (Barth and Boriboonsomsin). As the stretch of roads approaching the entrance to the Bay Bridge experience the heaviest and longest-lasting congestion, the low-income communities nearby would disproportionately benefit from this policy.

Funding Concerns

Bus systems in the Bay Area currently receive substantially smaller subsidies than rail systems, at $3 and $6-$14 per trip, respectively.[163] This is problematic from a social equity perspective because bus ridership has a higher percentage of racial minorities and low-income individuals than does rail service. The three crossing alternatives would continue this inequitable funding situation by directing a massive amount of regional funds to a rail system built to serve suburban commuters (Deka, 2004).[164] Funding a third crossing might diminish political will to properly fund for bus services like AC Transit that depend on voter approval and regional funds for operating costs, capital projects, and system improvements. In contrast, the Performance Pricing alternative require minimal public funds to implement and would generate revenue specifically for the purpose of improving bus service.

Accessibility and Connectivity Analysis

In our accessibility and connectivity analysis, we evaluate the performance of the alternatives in relation to decreasing travel times and cost and in improving comfort and experience.

Travel Time Reductions

In general, the alternatives generate time savings by providing more direct routes, reducing headways, and by reducing delays caused by crowding and congestion. However, they differ in the level and geographical distribution of those time savings.

- **New Opportunities (BART):** This alternative provides projected travel time savings of 15-20 minutes between most of the East Bay and the Brannan St stations in SoMa compared to baseline, which required the extra time and expense of transferring to/from Muni bus or metro. Travel times between the East Bay and the Van Ness and Fillmore stations would also be reduced by 15-20 minutes. Stations at 14th Street and Howard Terminal would reduce travel times to San Francisco from parts of West Oakland and the Jack London district by about 15 and 5 minutes, respectively. Eastlake station would experience approximately a 10-minute travel time reduction to Downtown San Francisco. Alameda would gain a one-stop ride to SoMa, which before would have been an extremely long trip.

[163] Golub, A., Marcantonio, R. A., & Sanchez, T. W. (2013). Race, Space, and Struggles for Mobility: Transportation Impacts on African Americans in Oakland and the East Bay. *Urban Geography*, *34*(5), 699–728. https://doi.org/10.1080/02723638.2013.778598
[164] Deyaiyoti Deka. (2004). Social and Environmental Justice Issues in Urban Transportation. In *The Geography of Urban Transportation* (pp. 332–355).

- **Critical Needs (BART):** This alternative offers an additional improvement over New Opportunities for the travel times to/from Van Ness and Fillmore due to a more direct route in San Francisco and fewer stops in the East Bay. Alameda and the Jack London district also benefit, as they gain a direct trip to Downtown San Francisco with no transfers. The most significant time savings are experienced in going between the East Bay and Mission Bay, reducing travel times by at least 20 minutes. While both BART alternatives offer the possibility by reducing platform congestion at Embarcadero and Montgomery, the impact is likely larger in the alternative due to additional direct service to the financial district.
- **Regional Connections (Standard Rail):** This alternative opens up new commute possibilities by dramatically reducing the travel time between the East Bay and the job centers of the Peninsula. Travel time from Richmond and Downtown Oakland to the Peninsula would be reduced by around 30 and 25 minutes, respectively, while also eliminating a BART-Caltrain transfer. Largest potential time savings come from those living near the Berkeley and Emeryville stations, though, because of longer distances from BART stations. Trips from the outer East Bay and beyond would also be reduced by the connection of Capitol Corridor and high-speed rail to Downtown San Francisco.
- **Performance Pricing (No New Crossing):** This alternative provides the largest time savings for drivers and carpoolers who choose to pay the toll. Currently, delay on the Bay Bridge can add up to 30 minutes to the commute during the morning peak, a figure likely to increase over time. Transbay bus service should also see time savings from decreased headways and improved transit infrastructure on the bridge. BART riders, on the other hand, may experience increased delay if former drivers begin taking BART, further straining the system.

Initial Modeling Results

The relative importance of the time savings around each station area depends on how many travelers are impacted. In order to compare the overall time and cost savings experienced as a result of each alternative, we used MTC's Travel Model One to calculate the change in average travel times and costs for commuters traveling to San Francisco. The results are preliminary and somewhat limited, as the model is not able to account for changes in travel time due to crowding on BART. This ignores a significant benefit of the BART alternatives and hides one of the major drawbacks of the Performance Pricing alternative. In addition, our analysis did not account for trips to/from outside the nine-county Bay Area enabled by the standard rail alternative.

The two BART alternatives each reduced the average travel time for San Francisco-bound transbay BART trips by about a minute. This metric, however, does not capture the time savings experienced by riders who start using BART instead of another slower alternative. Ideally, we would compare travel times for similar trips (i.e. same origin, destination, trip purpose, and traveler demographics) between different alternatives, but unfortunately, time constraints prevented this analysis.

The Performance Pricing alternative resulted in the largest time savings for drivers, reducing the average travel time of driving trips by three minutes. Drivers earning less than $30,000 experienced the largest time savings, while drivers earning more than $100,000 experienced the largest cost increase, likely the result of a lower propensity to carpool or time-shift. However, average travel costs over the entire system were roughly similar across all four alternatives.

Comfort and Experience

Transbay BART trains are currently over capacity during commute hours, leading to significant crowding issues that can cause delays as well as discomfort. The BART alternatives address crowding most directly, either by diverting enough riders to provide relief in New Opportunities, or by providing additional direct service to the San Francisco Financial District in Critical Needs. The standard rail alternative, however, would divert a much smaller portion of riders from the existing tube. Still, moderate relief may be sufficient depending on regional growth patterns. The impact of the Performance Pricing alternative requires additional research to determine how former drivers react, but it likely makes BART crowding worse.

Each of the three third crossing alternatives also provide the benefit of allowing more residents to complete their trips on a single ride, or at least within a single system. This simplifies trips and reduces potential delay and stress from waiting for a connection. This benefit is particularly notable at many of the new San Francisco BART stations, as while the stations are relatively close to existing transit service, reaching those destinations from the East Bay requires riders to transfer between BART and Muni.

Land Use Planning Coordination Analysis

As described in the Key Considerations section, a primary goal of a new crossing should be to further a connection between the transportation system and land use patterns. It can do this by connecting existing areas of dense commercial and residential activity, as well as by encouraging further growth in underutilized core areas.

Methodology

To assess land use changes caused by the addition of potential new stations, we identified parcels within a ½ mile walking (network) distance. We used a nearest neighbor analysis in the Pandana python package along with an OpenStreetMap walking network (provided by MTC) to assign parcels to the nearest station up to ½ mile away without double-counting parcels.

Existing Conditions

The existing conditions around potential stations in the BART and standard rail alternatives were compared using three metrics: (1) current population, (2) current jobs, and (3) percentage of parcels that are either vacant or containing buildings with less than 67% of the allowed density under current zoning, also known as "soft sites."[165] Population and jobs indicate whether existing land use supports new service, and the percentage of soft sites offers a rough approximation of the ability to increase land use intensity without changing zoning. Although there is only one new station in the standard rail

[165] https://github.com/MetropolitanTransportationCommission/bayarea_urbansim/blob/master/output/capacity.md

alignment, existing stations expected to have significant new service patterns were included for analysis.

Table 6: MTC UrbanSim analysis for proposed new station areas in 2010

	City	Station	Residents	Jobs	Soft Sites
BART 1: New Possibilities	Oakland	Eastlake	7,252	2,872	51%
	Oakland	11th/Broadway	3,903	13,797	87%
	Oakland	14th Street	4,642	13,122	74%
	Oakland	Howard Terminal	290	3,035	74%
	Alameda	Alameda	2,184	673	21%
	San Francisco	4th/Brannan	3,141	6,837	34%
	San Francisco	6th/Brannan	2,526	10,112	31%
	San Francisco	8th/Howard	9,592	13,538	68%
	San Francisco	Hyde/McAllister	16,080	29,618	60%
	San Francisco	Van Ness	14,856	13,101	64%
	San Francisco	Fillmore	13,972	10,669	53%
		Total	78,438	117,374	
BART 2: Critical Needs	Oakland	15th/Franklin	5,402	26,362	82%
	Oakland	Jack London Square	2,527	3,607	84%
	Alameda	Alameda	2,184	673	21%
	San Francisco	Mission Rock	1,213	1,766	4%
	San Francisco	Ballpark	4,174	4,710	40%
	San Francisco	3rd/Mission	3,622	36,474	91%
	San Francisco	Union Square	20,693	35,354	66%
	San Francisco	Van Ness	14,856	13,101	64%
	San Francisco	Fillmore	13,972	10,669	53%
		Total	68,643	132,716	
Standard Rail	Berkeley	Berkeley	2,097	4,383	43%
	Emeryville	Emeryville	2,673	5,347	38%
	Oakland	14th Street	4,642	13,122	74%
	Richmond	Richmond	3,767	2,143	61%
	San Francisco	Transbay Transit Center	4,139	108,690	86%
		Total	17,318	133,685	

Source: Table produced by students in the Fall 2016 Transportation Planning Studio using data from the MTC UrbanSim model.

Despite having far fewer stations, the Critical Needs alternative brings more jobs and nearly the same number of residents to within a ½ of station areas. The New Possibilities alternative, on the other hand, includes more total soft sites, which is in part explained by the higher number of stations along the line. In all cases, the stations in Downtown Oakland and Downtown San Francisco have the highest percentage of soft sites. Of course, total available square footage is not considered when counting soft site parcels. Parcel counts likely under represent opportunities in areas like Mission Bay, which has considerable redevelopment potential.

While the Performance Pricing alternative does not result in new stations, it still has the potential to affect land use. A higher toll on the Bay Bridge would further incentivize East Bay commuters to move to San Francisco or look for jobs in the East Bay. Its effect on job location, however, is unclear. While it might make the East Bay more appealing as an employment center for companies with a large number of East Bay workers, it might also cause a stronger business preference for a San Francisco location due to decreased travel times and increased reliability on the bridge (Leape, 2006).

Land Use Change Model Results

A new crossing may lead to additional development around new stations by improving accessibility. That said, it is not clear that lack of accessibility is significantly restricting development in San Francisco or Oakland. According to the CCTS San Francisco Market Assessment, the primary limiting factor on growth in downtown and around proposed stations is tight zoning and Proposition M, which restricts total commercial square footage. The CCTS Oakland Market Assessment, on the other hand, found growth in the core to be limited mostly due to less favorable financial conditions for developers compared to San Francisco, as the area is already very well served by regional rail.

The studio used the UrbanSim land use model to conduct model runs for each of the third crossing alternatives under two zoning and land use scenarios: (1) a business-as-usual scenario, and (2) the Plan Bay Area preferred scenario. Each result was then compared to a business-as-usual scenario with an unchanged transit network. We did not run a land use model for the Performance Pricing alternative, as MTC had not implemented a zoning scenario that aligned well with the scenario we designed and a custom implementation was not possible due to time constraints.

The models largely confirm our prior intuition that transit accessibility is not the binding constraint on development in these areas. With zoning held constant, none of the crossing alternatives significantly boosted residential growth compared to what would be otherwise expected through 2035. For non-residential development, only the “New Possibilities” BART alternative had a notable effect, though the additional 1.4 million square feet it created is not that large when considered over the entire modeled timeframe. Full results can be found in Appendix E.

Based on the results of this land use model, a new crossing will not by itself spur significant additional development without changes to existing zoning. Furthermore, it is possible that pent up demand for development in the Bay Area is so strong that additional transit accessibility does not make a significant difference even with the looser zoning of the Preferred land use scenario. A new crossing should therefore not be viewed as a vehicle that increases development except to the extent to which it drives zoning changes. If zoning decisions are considered to be external to the decision to build a new crossing, then the Performance Pricing alternative would offer a similar level of development while generating revenue that could be used to directly encourage desired development patterns.

Climate Change Mitigation

The alternatives each provide an opportunity to reduce regional greenhouse gas emissions by decreasing the number of private vehicle trips across the transbay corridor.

Expectations

The modeled alternatives provide two primary methods for reducing greenhouse gas emissions by personal vehicles. The BART and standard rail alternatives shift driving trips to transit through new and improved service. The Performance Pricing alternative uses increased toll pricing to discourage single occupancy vehicle trips, shifting many travelers to carpool or use transit. Although emissions reduction would be somewhat tempered by new drivers seizing the additional capacity, the eventual equilibrium represents a definite decrease in emissions.

Relative Reductions in Emissions

We used the MTC travel model to estimate emissions changes for Bay Area travel in 2035. We evaluated each alternative in comparison to baseline, using VMT as a proxy for emissions.[166] The standard rail alternative reduces 1.5 million miles of vehicle travel on an average weekday, roughly three times the reduction from other alternatives. This estimate does not include trips outside the region, potentially undercounting VMT reduction for long rail trips formerly made by driving. The Performance Pricing reductions are likely overestimated: the toll prices chosen resulted in peak morning travel well below the Bay Bridge's capacity. Any real implementation would eventually result in a lower toll price than was modeled, yielding more driving and somewhat higher VMT levels.

The standard rail and BART alternatives achieve VMT reductions by shifting drive alone and carpool trips to transit, reducing drive alone trips both in the peak and throughout the day. In contrast, the Performance Pricing sees an increase in carpooling and significantly reduces VMT in the peak periods. The early morning (3am to 6am) sees an increase in driving that is more than offset by peak period reductions. These results were consistent with our expectations. VMT actually increases among small commercial vehicles, indicating that commercial traffic may increase in response to an overall reduction in congestion.

Takeaways and Context

Further analysis is needed to determine why the standard rail alternative reduces three times as much VMT as the BART alternatives. Standard rail has the potential to move relatively long driving trips to transit by connecting the Capital Corridor and Caltrain lines. However, the land use analysis shows that the new standard rail stations in the East Bay are surrounded by relatively few residents and jobs, minimizing the number of individuals impacted by the new service.

The VMT reductions are substantial but must be considered in the context of total Bay Area travel. Weekday VMT is projected to grow to about 370 million miles on an average weekday, making projected savings less than 0.5% of total VMT. To the extent that this project is focused on commuters, the

[166] A more complete discussion of the modeling is included in the Model Methodology.

modest reduction should not be a surprise. Commute trips are typically the longest regular household trips but only account for 28 percent of household VMT (Santos et al, 2009).

Resilience and Adaptation Analysis

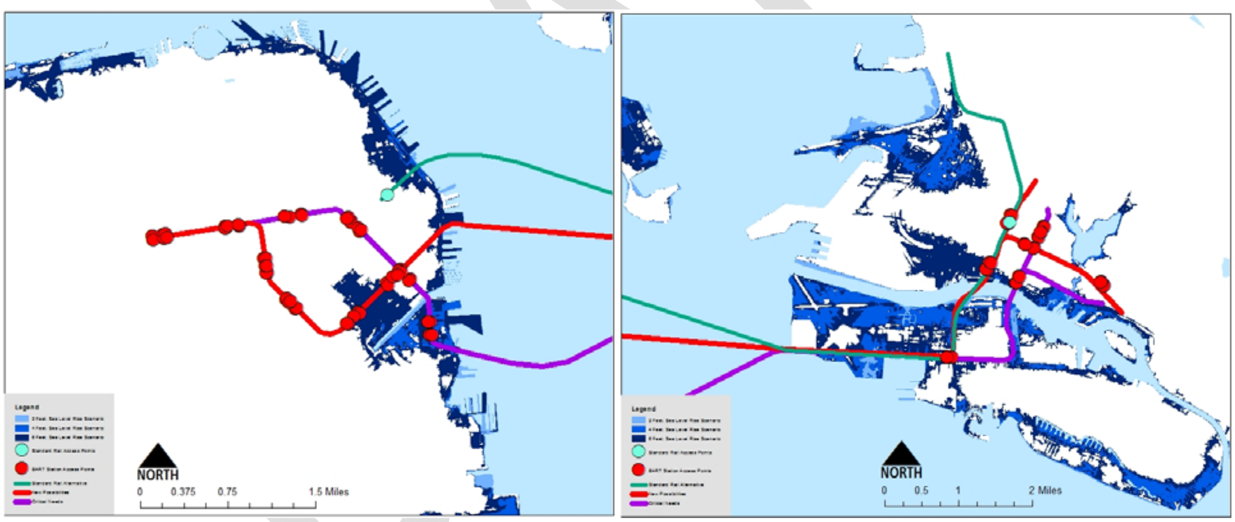
We evaluate the alternatives' contribution to system resilience by analyzing system redundancy as well as vulnerability to sea level rise and liquefaction hazard.

Risk Considerations

Sea Level Rise Analysis

Several of the proposed stations for both East Bay and San Francisco alignments are in areas that are at-risk to sea level rise (see Figure 41). As discussed in the current conditions, the projected sea level rise by 2100 is 4.5 feet. Two, 4, and 6 feet sea level rise from existing shoreline are given in the maps to show a range of possible outcomes. In San Francisco, both BART alignments include stations and track in at-risk areas in and around the Mission Bay area. In the East Bay, both BART alignments include a vulnerable station on Alameda Island.

Figure 41: Set of diagrams of proposed transbay crossing alternatives with flood in San Francisco and Oakland.



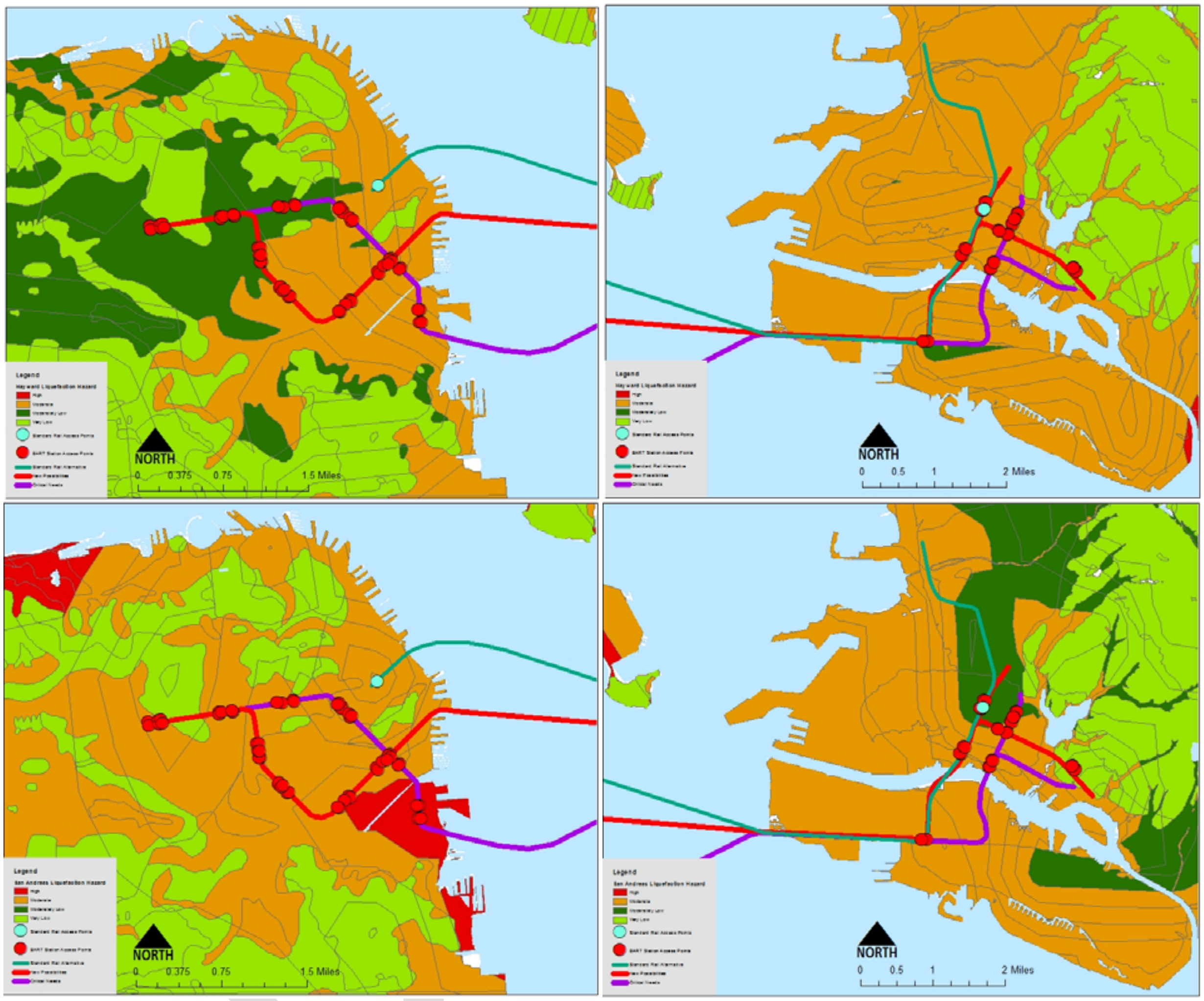
Source: Map produced by students in the Fall 2016 Transportation Planning Studio using sea level rise scenario GIS data provided by ABAG Resilience Program.

Seismic Risk Analysis

We consider seismic risk by evaluating station proximity to soil liquefaction zones. As shown in figures X and X, all of the proposed stations have some degree of risk, which comes with being on the bay. However, similar to the sea level rise risk, the BART stations proposed in New Possibilities and Critical Needs for the Mission Bay area and Alameda Island pose the greatest liquefaction risk because of the

San Andreas and Hayward faults. This is in part due to sections of the San Francisco shoreline and Alameda Island being constructed through man-made infill.[167]

Figure 42: Set of diagrams of proposed transbay crossing alternatives with seismic liquefaction risk posed by the Hayward (top row) and San Andreas (bottom row) faults.



Source: Map produced by students in the Fall 2016 Transportation Planning Studio using data provided by the ABAG Resilience Program

Protecting Critical Assets

The sea level rise and seismic risk analysis does not account for potential mitigation measures. For instance, stations at risk to sea level rise could be coupled with mitigation efforts such as seawalls to improve the long term viability of new transportation infrastructure. It is also important to consider the cost required for protecting at-risk stations. The work required to make stations safe would add significant cost to alternatives that include at-risk stations.

[167] See USGS's discussion of liquefaction and landfill in the Bay Area.

With that in mind, the Performance Pricing alternative has relative promise for protecting critical assets. As explained previously, this alternative generates significant revenue and could therefore pay for protecting the critical assets against such risks.

System Redundancy

Redundancy of service is a particular concern on the transbay corridor, given just one crossing each for transit and driving. Neither crossing could serve the additional demand that would result from a temporary or long-term service disruption. Compounding the issue, the current BART tube will eventually be in need of repairs that may require a significant period of closure.[168] Both BART alternatives and the standard rail alternative improve system redundancy; in contrast, the Performance Pricing alternative does not address this concern.

The BART alternatives provide the best result in responding to a shutdown of the existing tube. Given unexpected disruptions, BART could adjust service in real time. Longer term, BART riders retain the ability to cross the bay. The standard rail alternative would require riders to transfer between systems given a disruption, incurring a new charge and adding substantial travel time.

There is no ideal alternative given the Bay Area's inherent vulnerability to seismic activity, soil liquefaction, and sea level rise. The BART alternatives provide transit system redundancy; standard rail does the same but with less convenience. Neither alternative provides infrastructure adaptation without incurring significant additional cost. The Performance Pricing alternative does not provide redundancy but may generate funds for protecting critical assets.

Model Methodology

This section briefly introduces the methodology used to model changes in land use and travel patterns arising from the alternatives presented in Alternative Development. Limitations of the models are also discussed.

Travel Demand Model

We used the MTC's travel demand model, Travel Model One (TM1), to estimate quantitative changes in travel patterns. TM1 was specifically developed for the nine-county Bay Area and is currently being utilized in the creation of Plan Bay Area 2040 (PBA 2040). We used the most recent version of TM1 (July 2016, release 0.6) and received significant support in this endeavor from David Ory and the Analytical Services Unit at MTC.

Travel Model One Background

Activity-based Model

TM1 is an activity-based model. An activity-based model is one that simulates the travel decisions of *individual* people and households instead of assigning overall travel flows based on generalized

[168] See SPUR's discussion on page 10 in *Designing the Bay Area's Second Transbay Rail Crossing*

estimates of time and cost. This makes activity-based models both more accurate and more sensitive to changes in the transportation system.

The choice of trip travel mode can demonstrate the decision-making process analyzed in an activity-based model. A traveler has a range of possible modes available for their trip (such as driving alone, driving to rail, walking to a bus, etc.). When choosing among these modes, an individual considers information like travel cost and travel time. The decision-maker's demographic characteristics and personal preferences also influence the choice. Ultimately, the individual chooses the mode that minimizes total costs, both monetary and non-monetary. A well-estimated activity-based model attempts to capture all possible variables that influence individual decisions, as well as how the relative importance of each factor shifts depending on socioeconomic characteristics.

TM1 is also a tour-based model, which considers the fact that people may make intermediate stops along the way to their final destination. One typical tour is the home-based work tour, meaning the journey from home to work and back to home. If there are no intermediate stops, then this tour is composed of two trips: home-work and work-home. If, however, there is a stop to go grocery shopping on the way home from work, then then those three trips (home-work, work-grocery, grocery-home) are chained together for the given tour. This representation of realistic travel behaviors adds complexity to the model but also increases the validity of its results.

Baseline Assumptions

In September 2016, MTC and ABAG released the Draft Preferred Scenario for PBA 2040,[169] and we adopted TM1's travel pattern predictions for 2035 from that scenario as our baseline. This 2035 baseline includes changes to the transportation system like BART frequency and capacity upgrades and extension to Santa Clara, Caltrain electrification and extension to the Transbay Transit Center, and slight Bay Bridge toll increases. Land use assumptions were fixed in different alternatives in the travel demand modeling process and are based on the Draft Preferred Scenario from the Bay Area UrbanSim land use model.

Model Input

Travel demand is generated by a synthetic population of individuals and households that are representative of the Bay Area population in terms of residential locations and various socioeconomic characteristics. The travel preferences of these different groups are estimated by calibrating the model to predict similar travel patterns to what we presently observe. Then, based on these estimated preferences, TM1 predicts how individuals and households respond to changes in the transportation system. We left the demand side of the travel model untouched because the purpose of the exercise is to estimate how the same population responds to different new crossing alternatives in the same timeframe.

The supply side of TM1 is comprised of the highway network and transit network. The highway network is composed of roadway intersections and the links between them that represent the actual roadway network of the Bay Area. These links all contain information such as number of lanes, free flow speed,

[169] http://planbayarea.org/the-plan/Draft-Preferred-Scenario.html

and capacity. Several of the alternatives involve the removal of Interstate 980, which we modeled by re-defining these link characteristics to that of a large boulevard.

The transit network is based on the highway network and is connected to the highway network by special links. TM1 defines six categories of transit modes: local bus, express bus, ferry, light rail, heavy rail, and commuter rail.[170] The BART network, for instance, is defined by stations and links that represent the physical network, with distances and travel times attached to each link. To add a station to the network, we create a node representing the station and connect it with links to the existing BART network, as well as all other ways that people can access the station.

In addition to the physical infrastructure, service patterns are also used by the model. To translate a BART line service, for example, we include all the stations it travels through and how often trains arrive during different time periods. If a new BART station or line is added or changed, we also need to define the time and money cost for all possible trips to/from that station or on that line. In summary, the model inputs are a collection of definitions of the infrastructure and services that determine all possible paths for individuals to travel, as well as the travel time and price associated with each possibility.

Model Output

Once the required inputs are entered, the individuals and households in the model decide which tours and trips they want to make throughout the day. TM1 then initiates an iterated simulation. In each iteration, individuals first make mode choices based on system conditions generated from the previous iteration. Then, the model assigns transit trips to the transit network and utilizes user-equilibrium principles[171] to assign individuals' driving trips to the highway network. These iterations are continued until a stable travel pattern is reached.

The fundamental output of TM1 is all the trips that the synthetic population makes in a typical weekday. For every trip taken by every individual in the model, we know the following information: why the trip was taken, what mode was used, what specific path was followed, and all the associated monetary and non-monetary costs. This information can allow us to summarize ridership estimates, modal splits, VMT impacts, and how effects vary by different income groups, among other possibilities.

Land Use Model

To model the land use impacts of a new crossing, we used UrbanSim, an open-source land use modeling software package, and relied heavily on MTC's existing model specifications and policy scenarios. Modeling support was provided by Mike Reilly and MTC's land use modeling group, as well as Professor Paul Waddell of UC Berkeley and UrbanSim, Inc.[172]

[170] http://analytics.mtc.ca.gov/foswiki/Main/TransitNetworkCoding
[171] http://analytics.mtc.ca.gov/foswiki/pub/Main/Documents/2011_03_22_Release_First_Round_Travel_Model_Technical_Summary.pdf
[172] Additional support was provided by Fletcher Foti (MTC), Sam Maurer (UC Berkeley), and Sam Blanchard (UrbanSim, Inc.).

UrbanSim Background

UrbanSim is a platform that allows users to simulate urban development.[173] Like TM1, it uses microsimulation models, representing decisions made by individual households, businesses, and real estate developers. UrbanSim is a free and open-source platform written in Python, and is used by many local and regional governments around the country and world.

UrbanSim simulates urban development by first applying a hedonic regression, which estimates land values based on each parcel's individual attributes, including transit accessibility, income of the surrounding area, and others. It then simulates real estate development and the location choices of households and businesses based on demand, zoning, and prices.

Model Inputs

Baseline Data and Control Totals:

Each run of the UrbanSim model starts with data files representing individuals, households, jobs, parcels, buildings, and zoning for the entire Bay Area. This data is freely available online courtesy of MTC. As with TM1, households and jobs are represented as synthetic populations that are generated to statistically representative of the Bay Area at various geographic levels. MTC's projected regional growth of households and jobs is treated as exogenous and therefore also provided as an input to the model.

Policy Scenarios

MTC is using the Bay Area UrbanSim model to evaluate potential land use and transportation scenarios as part of the process of developing PBA 2040. MTC released three preliminary scenarios in May 2016 and a preferred alternative in November 2016. We used two of these scenarios ("No Project" and "Preferred") in the evaluation of our alternatives, which are described in Table 7.

Table 7: UrbanSim scenarios used in model analysis

	No Project Scenario	**Draft Preferred Scenario**
Zoning	Existing	Upzoning in some Priority Development Areas
Urban Growth Boundary	Expand by 389 square miles	Existing boundaries/city limits add 68 square miles
Development Caps	Existing	Raises San Francisco office cap to 1.25 million
Subsidies and Fees	Subsidy to approximate SB 743	Subsidy to approximate SB 743, One Bay Area Grants, Inclusionary housing policies, greater profitability for projects in Transit Priority Areas
VMT Fee	None	Assessed on office and retail development
Parking Minimums	Existing	Decreased in core Priority Development Areas

[173]Waddell, P. (2002). UrbanSim: Modeling Urban Development for Land Use, Transportation, and Environmental Planning. Journal of the American Planning Association, 68(3), 297–314. https://doi.org/10.1080/01944360208976274

New Crossing Alternatives

We incorporated our alternatives into the UrbanSim model by modifying land prices within 1000 meters of network distance from new stations. Details are provided in Table 8. Travel times and other accessibility variables were not taken into account, as these variables are not currently included in MTC's official model. While this means that we do not capture the effect of lower travel times on residential or commercial location choice, previous MTC efforts suggest that land use is substantially more sensitive to the mere presence of a station than to specific accessibility variables.

Table 8: Third crossing alternatives modeled in UrbanSim model

Alternatives	Models	Coefficients Used
Alternatives 1 and 2 (BART)	Residential hedonic regression[174], Non-residential hedonic regression	Equal to those used for inner-ring BART stations
Alternative 3 (Standard Rail)	Residential hedonic regression	$15/sq. ft., using standard error and t-statistic for category 2 BART stations

For alternatives that include development of the Interstate 980 corridor, we allowed parcels within the corridor to develop according to zoning for nearby downtown parcels. We chose to simulate development in this corridor starting at the beginning of the model in 2010. While this is an obviously unrealistic assumption, opening parcels up for development later in the simulation yielded little to no development. While this could be due to a relative lack of demand and development profitability, it might also simply be a result of not allowing enough time for development or randomness in the model. In any case, allowing an artificially early start to development allows us to gauge what might happen over time in this corridor, and since the corridor only contains around 17 developable acres, it does not significantly affect overall model results.

Model Output

The model outputs provide estimates of household, job, parcel, and building data for 2035. We summarized results at the census tract, station area (half-mile network distance from new stations), and municipal levels for total population, number of households, number of residential units, number of jobs, non-residential square footage, and proportion of parcels where the existing number of dwelling units is less than 67% of the allowable maximum.

[174] A hedonic regression is a method of estimating value (in this case, the value of real estate) based on observed characteristics.

Limitations

Basic Limitations of the Models

- **Stochasticity:** All UrbanSim and TM1 simulations involve some level of randomness. Because of this, multiple runs of the same model will result in slightly different results. When looking at small subsets of the population, however, this random variation can result in dramatic differences. An ideal solution is to generate many runs of each model specification and report results based on an average or range of values. Unfortunately, due to time constraints, we were able to report on only a single model run for each specification.
- **Interpretability:** The outputs of large agent-based models can be difficult to interpret accurately, as interpretation requires substantial knowledge of the modeling process and a clear understanding of the assumptions embedded in the system. Simulated outcomes are influenced not only by inputs we modify, but also by preset parameters. Results that seem to be driven by a modeled variable of interest might actually be due to artificial parameters or assumptions we make in the modeling process.
- **Feature Limitations:** Model development for this project was an iterative process of creating imperfect models, improving areas that provided implausible results, and fixing mistakes in coding. While we believe our models were specified well enough to provide a general indication of what might happen were a new crossing built, there is always room for further improvement, particularly in terms of estimating the coefficients used for hedonic regression and more accurate estimations of travel times and costs.

Integration of Travel Demand and Land Use Models

Given the strong connection between transportation and land use, an ideal modeling approach would integrate the travel demand and land use models. Unfortunately, due to time and resource constraints, we were not able to perform this integration. As previously mentioned, however, empirical evidence suggests that the impact of changes to transportation infrastructure typically overwhelms the effect of transportation system performance variables on land use patterns. Because of this, our non-integrated methodology likely still captures most of the actual effects.