State Route 37 Integrated Traffic, Infrastructure and Sea Level Rise Analysis: Final Report

Road Ecology Center
University of California, Davis
http://hwy37.ucdavis.edu

State Route 37 Integrated Traffic, Infrastructure and Sea Level Rise Analysis

Task 4 Technical Memo: Community and Environmental Benefits of SR 37 Scenarios

Fraser Shilling

Co-Director, Road Ecology Center

University of California, Davis 95616

February 15, 2016

Table of Contents

Executive Summary 3
What are Benefits? 3
How are Benefits Measured? 3
What are the Community Benefits/Impacts Associated with the Current and Future State Route 37? 4
What are the Environmental Benefits/Impacts Associated with State Route 37? 4
Moving Forward 5
Introduction 5
Community Benefits and Impacts 5
Transportation 5
Equity 7
Economy 7
Environment 9
Benefits 9
Impacts 9
Approach 10
Measuring Benefits Using Valuation 10
Select (Dis)Benefits Indicators 12
Findings 13
Benefits/Impacts 13
(Dis)Benefits Likely from Constructed Scenarios 15
Conclusions 19
Literature Cited 20

Executive Summary

As planning to modify State Route SR 37 (SR 37) goes forward, it will be important to understand and plan for the best outcomes for society and the environment. In order to do that, indicators of these outcomes must be developed, broadly accepted and measured. One way to talk about outcomes is as benefits to society, either directly through tangible goods and services to members or the whole of society, or indirectly through benefits to the environment, which in turn benefits society. Not all transportation projects are automatically good for society and to make good decisions about them, the benefits they provide must be compared to the impacts and the financial cost of the project. This report describes the types of benefits and impacts that could result from modifying SR 37 in response to sea level rise and associated impacts. Because almost every transportation agency and municipal government involved in planning associated with this highway claims to want to act sustainably, this principle is used to the frame the discussion. In this case, sustainability is defined primarily as the set of actions that support meeting the needs of current and future generations in the areas of community (equity, economy) and environment.

What are Benefits?

When members of society, or all of society, receive an advantage from human or natural processes, they are receiving benefits. This could be a tangible good or service (such as flood control), or something less tangible (such as a beautiful view). Benefits can be measured in a variety of ways, but they usually fall into two main types: economic/financial value and non-economic values. Quantification of benefits is usually restricted to economic values, but peoples' preferences for a particular process or attribute could be considered a quantified, but not economic/financial benefit.

How are Benefits Measured?

There are wide array of possible ways to measure benefits. One way is to calculate the economic advantages of a result of an action or from carrying out particular courses of action. Because there are not reliable or widely-accepted methods to calculate economic or financial equivalents for many equity, social well-being, or environmental attributes, sometimes benefits are expressed in their native units, or in % reaching goals and targets. The exact metrics used in measuring benefits can vary with the user's preference and with the attributes of the process or system being analyzed.

What are the Community Benefits/Impacts Associated with the Current and Future State Route 37?

Community benefits are defined here as advantages in equity or economy realized by the community as whole, or by individuals. The current configuration of SR 37 provides travel between Solano, Marin and Sonoma Counties, as well as through these counties from elsewhere in the region and state. This travel includes single and multiple-occupancy vehicles and truck traffic. It does not include regular, public transit services. As with most state highways, it provides this service cheaply, because actual costs of operations and maintenance are borne by a larger population than just those using the highway. Because there is no transit service, travel is not equitable as people without vehicles, or the ability to drive, can only use the highway when transportation is provided by someone else. Economic benefits are realized in two primary ways by people using SR 37: 1) driving to and from work and 2) moving goods within the regions and among regions. There are other benefits, such as access to recreation, school, and shopping that may not have readily-defined economic benefits. All of the future scenarios that have been considered for SR 37 are likely to maintain or expand these benefits.

What are the Environmental Benefits/Impacts Associated with State Route 37?

All roads and highways carrying traffic cause impacts to surrounding habitats and human communities. Although impacts from the initial construction may be mitigated to some degree, most traffic impacts will not be, which is typical of highway construction/expansion. In other words, most transportation agencies treat the initial construction and the finished facility as the only environmental impact. Research has shown that traffic impacts are important and long-lasting effects of highways. However, these impacts are usually only seriously considered in the case of human health, and even in that case may not be mitigated completely.

SR 37 bisects marsh, agricultural, riparian, and grassland environments. It is also surrounded by existing and proposed areas for marsh restoration and is likely to be influential in how marshes adapt to changing sea levels and wave action. There have been measurements of traffic noise impacts to surrounding habitat and traffic-caused mortality of wildlife and birds on SR 37. There have been fewer measurements of the potential effects of the highway on marsh adaptation, or restoration activities. It is likely that elevation of the highway onto a causeway would permit changes in the tidal marshes and associated uplands and mud flats to occur more naturally than on a berm, or than if the highway remained on its current berm. Other impacts from SR 37 would be from traffic noise, air pollutants (e.g., nitrogen-compounds and metal pollutants in automobile exhaust), carbon dioxide emissions and possibly stormwater runoff.

Moving Forward

I propose that alternatives are developed with component parts (e.g., number of lanes, presence of transit, marsh/tidal permeability) and impact/benefit values calculated for these components within a transparent stakeholder process. Responsible agencies would then commit to making the decision based upon maximizing benefits of as many components as possible.

Introduction

Modifying SR 37 to adapt to sea level rise and relieve congestion, at least in the short term, could provide additional benefits and impacts to surrounding communities and ecosystems, beyond what is already present. This report identifies these benefits and impacts, describes ways to measure them, and discusses how to include them in decision-making when choosing possible futures for the highway. It uses as a foundation, previous work associated with SR 37, as well as other technical and scientific literature. It builds upon this foundation by providing new ways that transportation agencies and others can support usually-costly decisions to adapt coastal infrastructure to sea level rise (e.g., Kagan et al., 2014). It relies upon the extensive literature available on benefits and impacts (costs) to the environment and communities from transportation-related activities (e.g., review by Poor et al., 2009).

Community Benefits and Impacts

Community benefits and impacts from different possible scenarios for SR 37 can be considered in the categories: vehicle traffic, transit, equity, and economy. Currently, the 3 primary scenarios for SR 37 vary only in the way that they are elevated above future sea levels. Previous scenarios have considered moving SR 37 to align with other highways, building a tunnel or bridge to cross San Pablo Bay, and retaining the existing highway alignment and elevation. For the current scenarios, benefits and impacts can be thought to vary with how the scenarios are designed and built. For example, the type of transit included could impact who uses it, whether and how it benefits local communities, and the cost as a subsidy associated with the project (e.g., construction of a transit hub in Vallejo). The sections below describe some ways to think about benefits from different points of view.

Transportation

Estimating the values (defined as "valuation") of transportation's impacts on environmental attributes can be used as a guide to allocate resources to lessen the total environmental costs of projects, and as part of a benefit-cost analysis of optimal investment in transportation modes and infrastructure (Delucchi and McCubbin, 2010). The valuation of environmental attributes, and corresponding benefits, may be used at several points during the transportation planning process: in the regional planning process, in the system planning process, in corridor planning, at the project development stage, and at the programming stage. Measuring the actual benefits at these different planning stages is likely to require different tools or methods appropriate for the spatial-temporal scale of analysis and level of detail needed.

Transportation agencies conduct system planning and establish long-term corridor plans. The corridor scale implicitly includes the project scale and is a sub-unit of the regional and district scales. Planning for this scale provides an important means for reducing the harm from transportation impacts and an opportunity to remediate current harm and mitigate future harm. The corridor scale also provides an opportunity to organize more multi-disciplinary planning that looks at the whole range of changes in the transportation system, along with long-term operations and maintenance and the environment and human communities. At this scale, estimating benefits and impacts could tier from the regional system and consist of: 1) comparing benefit-values among projects proposed along a single corridor; 2) comparing benefit-values among corridors in a regional network; 3) seeking agreement on corridor-specific value or benefit tradeoffs among involved parties; and 4) programming long-term actions along and among corridors based on benefit-values and corresponding costs.

SOV, HOV, and Truck Traffic

Currently, SR 37 supports 1 or 2-lane travel in each direction, supporting single-occupancy vehicles, trucks, and other vehicles in combined traffic. New scenarios could include high-occupancy vehicle lanes, transit lanes, toll lanes, or other structures that benefit concentrated movement of people and goods. Because of concerns about continued and new greenhouse gas production from highway projects, state and federal agencies are starting to emphasize designs that encourage less carbon-intensive travel, for example HOV lanes or transit. Project designs that provided benefits such as lower carbon-pollution could receive more emphasis than more typical SOV-oriented projects.

Transit

There are many possible public transit scenarios for SR 37. These were discussed in a meeting on 4/9/2015 among all 4 CMAs, Caltrans, SMART (rail) and Golden Gate Transit. At this meeting, a study of travelers using SR 37 was discussed; the study was sponsored by the CMAs and carried out by AirSage. The main findings were that most travelers on SR 37 originated from throughout the North Bay and <25% originated from the East Bay and from the Central Valley. For transit to be included in the current proposals for SR 37, several factors would have to be considered: 1) who are the riders (most trips originate and end near either end of SR 37)? 2) would they switch to transit given the chance, 3) would transit have a dedicated lane/facility on the expanded highway? 4) how would the “last-mile” for travelers be resolved (from transit hub to their final destination)? Many of these problems have arisen and been solved in other cases, so to provide transit benefits, it may be more of a question of planning and funding.

The transit alternative for SR 37 that seems to the most feasible is for buses operated by a transit authority or district. Other possibilities include: light rail, subway-rail, ferry, elevated monorail, and subsidized van pools. All of these could provide the following benefits: 1) enhances individual mobility options for work, school, and recreation; 2) saves fuel and reduces congestion (depending on ridership rates); 3) has a >1 ratio of economic benefit to investment for the community; 4) can save money for the traveler; 5) reduces gasoline consumption by individuals and households; 6) reduces individual and jurisdictional carbon emissions/footprint (APTA, 2015); 7) reduces traffic accidents; and 8) reduces costs and congestion associated with parking (VTPI, 2015). Developing transit provides a mode option to travelers and usually has a fixed cost associated with construction/implementation. Beyond the benefit of having another option, the benefits and some portion of operating costs depend almost entirely on ridership (VTPI, 2015). This suggests that incentives for transit use must be part of the planning process for a particular transit project to provide benefits.

Equity

This component of sustainability is one of the hardest to measure, but is also one of the most socially-important. Equity is often thought of in terms of social and environmental justice, where the term has been given definition and substance (Swyngedouw, 2005). Equity standards may be met if benefits are distributed equally among potential recipients and impacts are not disproportionately distributed among recipients. A classic and well-studied case of inequitable distribution of benefits and impacts is from freight-movement on I-710 in Los Angeles County. Profits from goods movement are primarily derived from parties who do not live near the highway, while those who do live near receive high levels of air pollution. SR 37 is used and flanked by poor neighborhoods (e.g., parts of Vallejo) and wealthy ones (e.g., parts of Marin County). Equitable distribution of the benefits and impacts from modification of SR 37 could require careful planning and discussions with impacted communities.

Economy

Economic benefits from coastal ecosystems include: coastal-infrastructure protection, fishery nurseries, recreation, and property value. In the Bay Area, various entities and programs have identified important benefits that Bay ecosystems, including shoreline ecosystems, provide to the regional economy (e.g., Battelle Memorial institute, 2008). In an analysis of privately and federally-funded infrastructural projects, Conathan et al (2014) found that coastal ecosystem restoration projects can provide up to twice as many jobs per 1 million dollars invested (17-36 jobs) as transportation projects (15 jobs). These restoration jobs can in turn protect natural and human systems on coastlines from damaging storms and potentially from impacts from sea level rise. This means that shoreline restoration projects could provide more jobs and improve protection for transportation and other infrastructure on the shoreline. Benefits may or may not accrue to local communities. For example, if companies, workers, and benefitting parties (e.g., international fishing companies) are from outside a community or region, then economic benefits to the local area may not be direct or substantial. Santa Clara County calculated the benefits from ecosystem services (the attributes of nature that provide benefits to people) to the County (SCCOSA, 2014). Their estimate was that nature in the County provided fiscal value to the people and economy in the range $1.6 billion to $3.9 billion/year and total asset value of $45 billion to $107 billion (accounting for depreciation), or $162 billion to $386 billion when calculated as non-depreciating assets. For the special case of flood protection for coastal property in the face of SLR as an ecosystem service, restoration of marshes combined with levees is twice as cost-effective per mile as levee construction alone, over 50 years (ESA/PWA, 2013).

The Napa-Sonoma marshes ringing San Pablo Bay provide regional benefits, including recreational opportunities. Access to these sites is fairly limited and for some sites, no public access is allowed (Figure 1). At a meeting of regional recreation experts on 5/19/2015, support was given to the idea of continued access to marshes from the highway and minor roads connecting to the highway. All participants expressed that marsh restoration projects have included public access of some kind. Building and maintaining the Bay Trail through the North Bay may depend on how SR 37 is modified and at least in the short term, whether or not the original SR 37 roadbed is retained as a possible trail alignment. In order to retain the recreational access to regional marshes from SR 37, considerable effort may be needed to plan for access points and retain connections to minor roads that access protected areas.

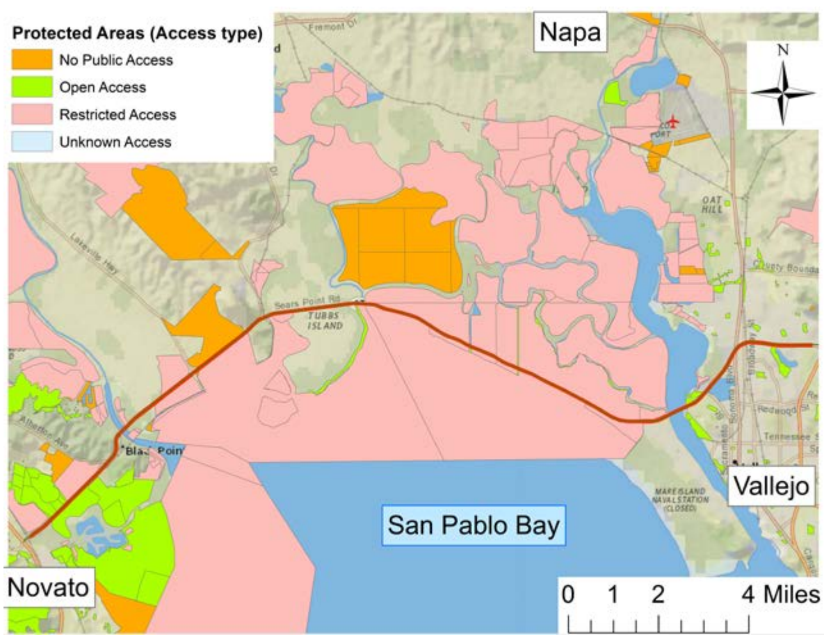


Figure 1.Access to protected areas along SR 37 corridor (map data from the California Protected Area Database).

Environment

Benefits

There are many benefits that could accrue to coastal ecosystems from restoration and protection actions taken along SR 37, including the act of raising the highway onto a causeway. Some of these could be thought of immediately related to benefits to people (e.g., increased bird-watching opportunities and related economic benefits to nearby communities), while others could be seen as only indirectly related to people (e.g., the bequest value of natural systems to alter generations). Some of these benefits have been estimated for marsh restoration in the Bay Area. For example, Conathan et al (2014) reported that restoration of 2,751 acres of former salt ponds in the South Bay resulted in between 69 and 220 million dollars in total value for ecosystem and community benefits, at a cost of 7.6 million dollars. California state agencies have studied and described the many social and health benefits of outdoor, natural-area recreation for members of the public (CA State Parks, 2005) as part of the California Outdoor Recreation Plan. The state government encourages the development and maintenance of outdoor recreation for youth and disadvantaged communities, which are typically under-served by outdoor recreation sites. More than half of the landscape adjacent to SR 37 is public property, providing ample opportunity to develop trails within view of the marsh and viewing platforms for bird and landscape viewing.

At a meeting on 1/22/2015 among marsh restorationists/managers, the Coastal Conservancy, and Caltrans, the possible impacts to marsh environments were discussed both in terms of future SLR impacts and as a result of highway modification. According to participants, the marsh restoration environment around SR 37 is very active, changing the landscapes in ways that affects its potential inundation and potential impacts that SR 37 might have. There was consensus that the causeway scenario would have the most net benefits for the environment, but may pose challenges for access to the marsh from the highway. In general there was concern that marshes may not adapt fast enough to stay as marshes (instead of tidal mud-flats) and that to keep the benefits of the marshes, various active management may be needed, including designing the highway to at least not contribute to degradation of the marshes.

Impacts

Raising SR 37 onto a berm or a causeway are the primary two scenarios considered by this project. That being said, they are not the only possible ways to adapt the highway and associated goods and people movement to rising sea levels. There are important differences between berm and causeway options in terms of tidal flows across the right-of-way as sea levels rise which could provide impacts to individual species, natural communities/habitats, and natural processes. Berms will tend to inhibit flows of water and thus tidal flows, which could restrict adaptation of marshes to rising sea levels. As wave run-up reaches the foot of berms and higher, wave rebound and resulting turbulence could erode sediments at the foot of the berm, endangering both the berm structure and the mudflats and marshes adjacent to the berm. Causeways tend to allow relatively uninterrupted tidal and other flows beneath them. The disadvantage to this could come from marshes failing to adapt fast enough for the rising water elevations, resulting in inundation and erosion/replacement of the marshes as a result of permitting the advancing sea levels access to what is currently protected by the highway's berm. In addition, each pier/pile footing will create a microenvironment of current disruptions and eddies so that what otherwise would be a natural sheet flow would be changed by the structure.

The combined impacts and costs of constructing either the berm or causeway scenario could make the overall approach of elevating the highway in-place (along its current alignment) prohibitive in terms of environmental impact and cost. At some point, it would be worth considering the total costs, benefits, and impacts of other scenarios for adapting coastal infrastructure to SLR. These include, but are not limited to: 1) northward retreat from the dynamic shoreline edge, rather than expensive armoring or elevated options; 2) building a tunnel for combined transit and vehicle traffic under the shortest point between Solano and Marin Counties; and 3) building a bridge across San Pablo Bay for combined vehicle and transit traffic.

Approach

Measuring Benefits Using Valuation

Valuation is a formal process for measuring the value of attributes or processes, where value may have fiscal or non-fiscal expressions. Many decisions related to transportation infrastructure are based on consideration of social preferences and values (e.g., congestion relief), regional economics, and project costs. Valuation is a useful method to apply to transportation decision-making for multiple needs because it can be used to draw equivalencies among dissimilar objects in a decision-space (e.g., driving time, wetland function, air quality). Equivalencies or equivalent values for these dissimilar objects may be on a unitless scale of preference or non-fiscal value, or on a fiscal scale, where cost is articulated for each object. California has developed an approach for valuing ecosystem attributes for use in transportation planning and system change (Lee et al., 2010). Valuation helps inform decisions related to regional planning networks (spatially connected elements) and temporally connected sequences of projects that are efficient relative to goals (e.g., have high total benefits). Valuation potentially also allows for comparisons among project and route alternatives to maximize total benefits. In addition, valuation information facilitates the development of cost estimates and mitigation alternatives, including avoidance, minimization and compensation. Finally, valuation may inform corridor and regional plan development analyses that set a framework for project-level decision-making.

When impacts are measurable, the next step is to find equivalent values for the impacts. Different methods are available to value ecosystem attributes. Litman (2009) provides an extensive literature review on the equivalent fiscal costs of environmental impacts from the transportation sector including air pollution, greenhouse gas emissions, noise, land use, water pollution and waste disposal. However, not all impacts can be evaluated by using economic valuation methods or given fiscal cost-equivalents. A review by Delucchi and McCubbin (2010) shows that only congestion delays, accidents, air pollution, climate change and noise impacts have good cost estimates in road transportation. Traffic noise is a well-studied example of impact from transportation and is used here as an example. Traffic noise can affect a wide range of birds, herpetofauna, and mammals. Traffic noise is measured as sound pressure levels using a logarithmic decibel scale. The range of sound frequencies that wildlife are sensitive to is similar to the range of human audibility (FHWA, 2004), which is usually measured as dB(A), a weighting scheme based on human audibility, or L_{eq}, the equivalent continuous sound level. Human-sourced noise can affect wildlife communication (Parris and Schneider, 2009; Owens, 2013), habitat occupancy (Goodwin and Chriver, 2010), vigilance (Shannon et al., 2014), predation efficiency (Siemers and Schaub, 2011), predator avoidance behavior (Meillere et al., 2015) and various other types of behavior (review: Francis and Barber, 2013). These effects vary among wildlife species, leading to differential responses within wildlife communities (Francis and Barber, 2013), which could affect trophic and other interactions. Traffic noise has also been shown to be connected with negative human health outcomes, including increased incidence of hypertension and specific heart ailments (Lercher et al., 2011). This problem increases with age and is inversely related to education and income. "Noise annoyance" (reported annoyance because of noise) has been found to occur at traffic noise levels as low as 40 dBA (Freitas et al., 2012) and has been proposed as a tool for transportation planning (Cik et al., 2012). Because of potential health impacts, noise annoyance, and disruption of sleep, certain countries have developed traffic noise level thresholds for use in assessing existing impacts and in planning highway expansions in open space and residential areas (e.g., 50-55 dBA in Denmark; Bendtsen, 2010; Bendsten and Michelsen, 2012).

Three valuation methods available to value ecosystem attributes are: 1) revealed and stated preference methods, 2) contingent analysis, and 3) benefit transfers. The two main types of valuation for environmental attributes are the revealed preference methods and the stated preference methods. Revealed preference approaches depend on a connection between the environmental attribute of interest (e.g., noise) and a market good (e.g., housing). The method uses data revealed by behavior related to actual decisions (for instance, changes in prices of housing). The major problem of this method is that it is based on existing conditions and so the potential to evaluate alternatives is limited.

In contrast, stated preference techniques are based on hypothetical situations and surveys that determine people's willingness to pay for a situation. Stated preference methods can be used for environmental systems, like a wetland, where there are both use and non-use values. The contingent valuation method is a type of stated preference method usually used to estimate the value of an environmental change scenario. The method uses a survey which begins with a statement describing the change in environmental attributes. Then it asks individuals to reveal how much they are willing to pay for the change. For example, we could ask people how much they are willing to pay to restore wetlands surrounding a highway needing widening.

Benefit transfer allows users to transfer estimates of non-market values from existing studies to new locations or different but related services. An example of this approach is when highway construction results in destruction or modification of habitat of wildlife with social or economic value, such as deer or elk winter range. Compensatory mitigation payments accompanying this project would be based on the equivalent cost of each animal multiplied by the number of animals lost. This method is often used because it saves time and resources. Usually, benefit transfer is best suited for tasks where the need for accuracy is low. It is generally considered a "second best" valuation method because benefit transfers involve reusing existing data and does not provide error bounds for the value in the new application. For example, it has been found that using benefit transfer methods, the cost/ha of wetlands providing a single ecosystem service could vary by two orders of magnitude (Woodward et al., 2001).

When using the valuation approach in transportation, the last step is to incorporate the values of the affected environmental attributes and a qualitative analysis of those non-measurable impacts into the overall transportation plan, project or corridor analysis. Because there are potential evaluation-scale effects on the process (project, corridor, and region), it may be desirable to develop different flows of valuation outputs into a decision process for each scale. Both natural (e.g., watershed, ecosystem) and jurisdictional (e.g., district, county) scales can be used to frame the flow of the valuation process and to determine appropriate scales of analysis.

Select Impact Indicators

Marshes/wetlands (adapted from Conathan et al., 2014)

Social/Economic Metrics: Job creation, coastal hazard protection (storm-damage reduction), property values, non-consumptive recreation, fisheries, maintenance of traditional tribal areas and practices, visual relief, regulatory requirements

Environmental Metrics: Reduce nutrient pollution, migratory bird habitat provision, fish species nursery, intact native communities, absorb tidal/wave energy, adaptation rate and trajectory to sea level rise

Highways

Social/Economic Metrics: Goods movement, people mobility, access to services and other areas, convenience, job access, community fragmentation, maintenance costs

Environmental Metrics: Traffic noise, air pollutants (especially N pollution), habitat fragmentation, stormwater runoff (amount and quality), greenhouse gases, barrier to ecological flows, invasive species

Findings

Benefits/Impacts

To be functional, an accounting or credit system would provide a way to both indicate relative or absolute effects or impact and to measure potential performance of credits, usually in the context of mitigation. Credits in this study were proposed as scores on a unit-less scale from 0 to 100, given to scenarios, for 5 themes: Transportation, Environment, Cost, Community and Reversibility (Kagan et al., 2015). Each theme was accompanied by indicators of impact within each theme, which allowed the development of stewardship-oriented scenarios, as well as evaluation of the actual impacts that accompanied each scenario. The normalization of impacts to a 0 to 100 credit scale was both an end itself and would also serve as an intermediate step for subsequent conversion to fiscal equivalents for system attributes for which fiscal equivalents are known. Because these equivalents are usually approximate at best, the unit-less credit scale permits valuation without the inexactness of monetizing benefits and impacts (including costs) of various project choices. For the environmental theme for this corridor, the nearby tidal and freshwater wetlands provide both constraints and opportunities for stewardship planning. Because of the unique potential for wetland restoration in the SR 37 corridor, there may be few possibilities for mitigation bank strategies or payment for ecosystem services.

The valuation and crediting approach described here was based upon quantification of impacts within the effect-area of the highway in question. It was also based upon expert and public evaluations of how well a given project alternative met particular transportation and non-transportation needs. The berm scenario (a rough doubling of the right-of-way onto wetlands) provided desired transportation benefits, but would require additional action to improve or mitigate environmental impacts. In comparison, the causeway scenario (expanding the right-of-way, but on a causeway across the wetlands) provided similar transportation benefits, but may require little if any environmental credits or mitigation.

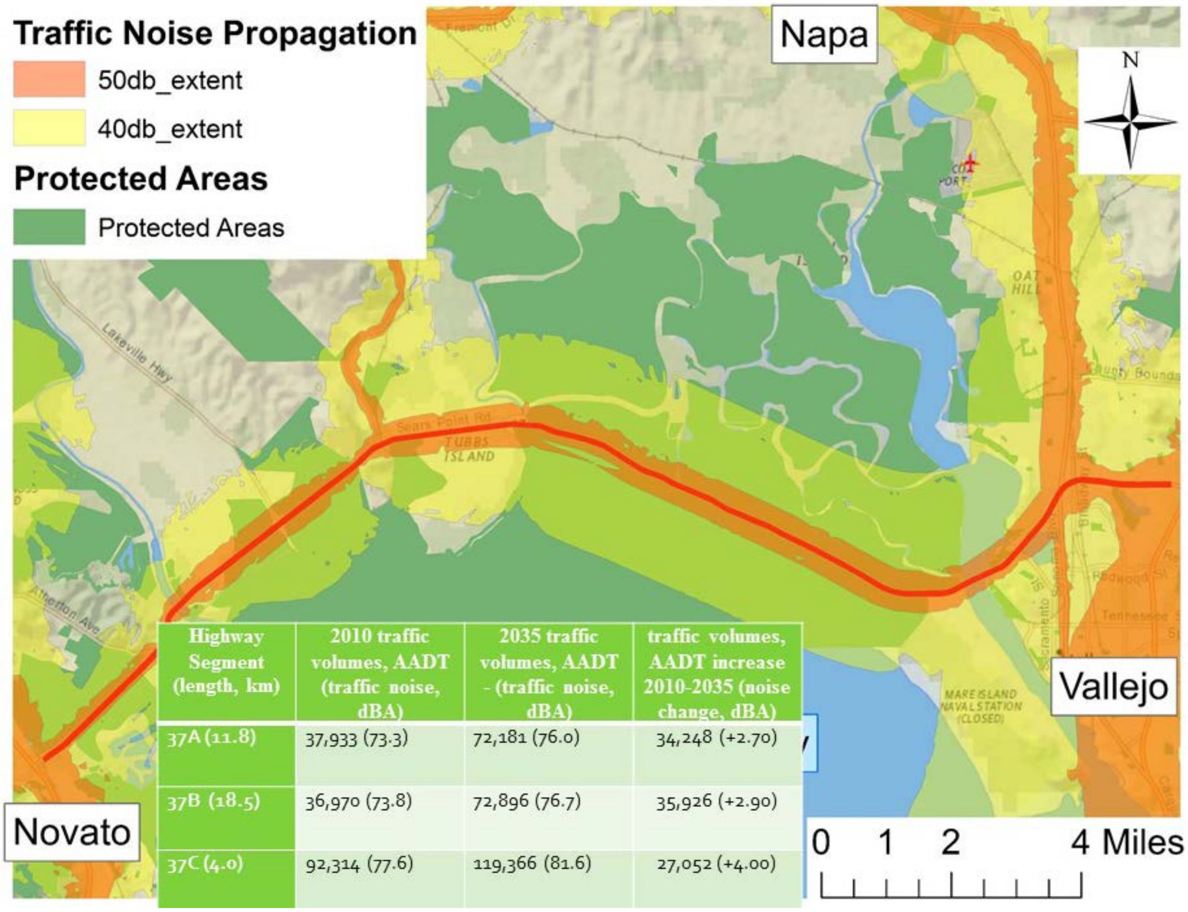
One outcome of the stakeholder-group process that we used for this and the previous phase of this project was the general agreement on the causeway scenario as providing the most benefits to the environment, economy and transportation. This "greatest good" finding was based on discussions among stakeholders about different possible ways of solving the combined problem of providing a feasible and construct-able route improvement across the marshes which did not in turn harm the marshes. The benefit of this outcome is that one constituency understands the basis for this constructed scenario and can provide support for programming funding. The weakness of this approach is that not all information was available at the time of group decision. For example, the increased traffic associated with an expanded structure and unknown transit options may increase GHG and other emissions, traffic noise propagation across the marshes, and other impacts.

Summary of Possible Benefits/Impacts

Environmental: 1a) (Berm) Change in hydraulic connection between Bay and inland marsh and current upland areas. 1b) (Causeway) Change in hydraulic connection …. >> 2) Change in vegetation and habitat value. 3) Geomorphic response to coastal structures and change. 4) Traffic noise impacts to sensitive birds and mammals. >> 5) Changes in population sizes of listed species due to habitat loss/degradation/improvement.

Community/Transportation: 1) Change in aesthetics and recreational access to coastal marshes. 2) Changes in congestion along different portions of 37 and corresponding change in delay. 3) Addition of transit hubs/nodes within or between communities. 4) Change in public transit availability and vehicle travel. 5) Temporarily reduced congestion. 6) Construction-related delays. 7) Reduced travel time and improved travel time reliability. 8) Increased noise and emissions (AQ and GHG). 9) Changed highway-surface runoff. 10) Increased cross-Bay transit use.

Traffic noise is one of the primary disturbances from the existing highway alignment and from predicted new constructed alternatives. Total noise impact can be indexed in a couple of different ways. One is to geographically account for the potentially impacted areas under existing and potential future conditions. Traffic noise levels above 40 dBA can impact the most sensitive wildlife and birds. Noise levels above 50 dBA impact the majority of wildlife and birds and people in residential areas. Traffic noise from SR 37's current configuration extends 1-2 miles (>40 dBA) and <1/2 mile (>50 dBA) from the roadway edge (Figure 2), impacting 2,681 (>50 dBA) to 11,331 Ha (>40 dBA) of various native habitat types (Table 1). By 2035, traffic volumes are expected to double on parts of SR 37 (Figure 2), resulting in a ~30% - 40% increase in affected native habitat (Table 1).



Highway Segment (length, km)	2010 traffic volumes, AADT (traffic noise, dBA)	2035 traffic volumes, AADT - (traffic noise, dBA)	traffic volumes, AADT increase 2010-2035 (noise change, dBA)
37A (11.8)	37,933 (73.3)	72,181 (76.0)	34,248 (+2.70)
37B (18.5)	36,970 (73.8)	72,896 (76.7)	35,926 (+2.90)
37C (4.0)	92,314 (77.6)	119,366 (81.6)	27,052 (+4.00)

Figure 2. Traffic noise propagation from current berm height and current traffic volumes. Insert shows current (2010) and projected (2035) traffic volumes and corresponding traffic noise levels (dBA) and change in noise.

Table 1. Traffic noise affected areas adjacent to study Highway SR 37. Affected area (Ha) calculated for >40 and >50 dBA and for 2010 and 2035 traffic volumes.

	2010 >40 dBA (Ha)	2010 >50 dBA (Ha)	2035 >40 dBA (Ha)	2035 >50 dBA (Ha)
Total Native Habitat	**11,331**	**2,681**	**14,628**	**3,830**

Benefits/Impacts Likely from Constructed Scenarios

Certain impacts and benefits are associated with one or the other constructed scenario, for example marsh adaptation with sea level rise, while others are likely to be very similar with either scenario (e.g., congestion, emissions).

Berm/Embankment

Social/Economic: Goods movement, people mobility, access to services and other areas, convenience, job access, maintenance costs

An expanded highway upon a berm will provide the transportation benefits expected for people and goods movement. Retaining existing connections will provide access to other roads/routes, private property, and recreational sites. Bicycle and pedestrian pathways will provide a wider range of mobility options (where appropriate), as well as greater connectivity among residential and recreational areas. Maintaining the highway upon a berm-like structure may face unanticipated maintenance issues and costs. For example, preventing tidal and storm/wave permeability across the right-of-way may put considerable strain on the outboard/Bay face of segment B, resulting in erosion and increased armoring and maintenance costs. Allowing limited tidal and storm/wave permeability across the right-of-way could relieve pressure from stochastic and periodic flows, but could also result in rapid back-and-forth flows through culverts and bridged channels and possible erosion of the berm's footing.

The transportation benefits from the expanded highway will be immediate reduction in congestion for vehicle drivers and availability of bus-transit options. According to a model of projected traffic flows in 2035, conducted by Caltrans District 4, SR 37 will again be congested by that year in segment C and will have double the current traffic on segments A and B, which is also likely to cause slow-downs at certain times of day (Table 2).

Table 2. Projected changes in traffic between 2010 and 2035 on SR 37 segments with and without increased capacity (4 lanes vs. 2 lanes) on SR 37.

		2010	2035 (existing)	2035 (inc. capacity)
Segment Description	Segment	AADT	AADT	AADT
US-101 to SR121	Segment A	37,933	67,823	72,181
SR121 to Mare Island in Vallejo	Segment B	36,970	66,145	72,896
Mare Island to I-80	Segment C	92,382	114,932	119,366
(Exceeds peak volume/capacity ratio of 1)				

If the highway was not expanded and then failed or was abandoned by 2035, traffic would be displaced to alternate routes in the North Bay Area. Most would go south on I-80 and across I-580/Richmond Bridge (Table 3), while the remainder would use one or more of the inland routes to the north of SR 37 (e.g., SR 12).

Table 3. Traffic volumes for North Bay regional routes in 2035 with and without SR 37 (due to failure or abandonment) and change in volume (%).

Segment Description	2035 AADT - Existing SR37	2035 AADT - Without SR37	% Increase
I-80: Richmond Parkway to Carquinez Bridge	225,284	259,436	15.2%
I-580: Richmond-San Rafael Bridge	100,770	148,259	47.1%
US-101: I-580 to SR-37	211,016	226,056	7.1%
US-101: SR-37 to SR-116	122,433	129,476	5.8%
SR-121: SR-12 to SR-29	39,992	63,423	58.6%
SR-12: SR 29 to I-80	41,569	42,617	2.5%

Environmental: High traffic noise, air pollutants (especially N pollution), high habitat fragmentation, stormwater runoff (amount and quality), greenhouse gases, very high barrier to tidal flows, very high barrier to adaptation to sea level rise, invasive species

An expanded highway upon a berm would increase traffic noise impacts that are currently propagated across the marshes. Successful mitigation of noise impacts is challenging and typically can only be managed through erection of dense, sound-absorbing structures. Movement of air pollutants could also increase (expand in extent) from an elevated source. The berm scenario would also have low if any permeability, resulting in continuation of the existing habitat and landscape fragmentation. Without stormwater control structures, contaminant-containing stormwater would continue to flow directly to the surrounding landscapes. An expanded highway would increase traffic flows and greenhouse gas production from the route. However, if the increased traffic resulted in lower traffic flows on other highways, then there could be no net increase in greenhouse gases other than that expected from overall increases in traffic. Building and supporting bus and other transit, including transit hubs, bus systems, dedicated transit lanes, and transit management could mitigate the increases in traffic and greenhouse gases. Permeability or impermeability of the berm could significantly alter adjacent and hydrologically-connected marshes, mudflats, and other Bay environments (see section above on socio-economic indicators). Reduced tidal flow access and residence time could reduce the sediment accretion necessary for marshes and other temporarily or frequently-inundated ecosystems to adapt to SLR. This means that affected marshes could become mudflats and existing mudflats could become sub-tidal benthos. A continuous vegetated, or semi-natural berm across the marshes, especially segment B, is likely to result in plant and animal invasion into these ecosystems from adjoining urban and agricultural areas.

Causeway

Social/Economic: Goods movement, people mobility, access to services and other areas, convenience, job access, maintenance costs

An expanded highway upon a causeway will provide the transportation benefits expected for people and goods movement. Retaining existing connections will provide access to other roads/routes, private property, and recreational sites. These connections will add cost to the project, based upon the number and types of access points. This is especially true for the many minor access points associated with recreation and proposed extension of the Bay Trail through the North Bay Area (Figure 3).

Figure 3. Anticipated Bay Trail alignment along the SR 37 corridor (map courtesy of Maureen Gaffney, ABAG).

Bicycle and pedestrian pathways planned for all 3 scenarios will provide a wider range of mobility options (where appropriate), as well as greater connectivity among residential and recreational areas. Maintaining the highway upon a causeway structure may reduce maintenance issues and costs relative to the existing berm, or proposed berm. For example, tidal and storm/wave permeability across the right-of-way will not affect the elevated structure on piers. However, maintenance of the causeway itself may be costly because of access issues.

Environmental: Very high traffic noise, air pollutants (N, VOC, ozone, CO2, and small particles), moderate habitat fragmentation, stormwater runoff (amount and quality), low barrier to tidal flows and adaptation to sea level rise, greenhouse gases

An expanded highway upon a causeway would increase traffic noise impacts that are currently propagated across the marshes. Successful mitigation of noise impacts is challenging and typically can only be managed through erection of dense, sound-absorbing structures.

Movement of air pollutants could also increase (expand in extent) from an elevated source. The causeway scenario would also have unconstrained physical permeability, but traffic noise and visual disturbance is likely to resulting in continuation of habitat fragmentation for sensitive birds and mammals. Without stormwater control structures, contaminant-containing stormwater would continue to flow directly to the surrounding landscapes. An expanded highway would increase traffic flows and greenhouse gas production from the route. However, if the increased traffic resulted in lower traffic flows on other highways, then there could be no net increase in greenhouse gases other than that expected from overall increases in traffic. Building and supporting bus and other transit, including transit hubs, bus systems, and management could mitigate the increases in traffic and greenhouse gases. Permeability of the causeway could significantly alter adjacent and hydrologically-connected marshes, mudflats, and other Bay environments. Increased tidal flow access and residence time could result in increased erosion or could increase the sediment accretion necessary for marshes and other temporarily or frequently-inundated ecosystems to adapt to SLR. This means that affected marshes could become mudflats and existing mudflats could become sub-tidal benthos, or the marshes could adapt fast enough to keep up with SLR.

Conclusions

There is a wide range of benefits and impacts (impacts/costs) that could accrue for each of the berm and two causeway scenarios. These could be more formally and exactly quantified in an assessment and evaluation process that provided decision-support for the choice of scenario. Including valuation approaches described here would allow all evaluation components, including financial cost, to be included in a single decision-space. This is not typical of transportation decision-making, but in the special and urgent case of SLR adaptation in sensitive coastal environments could be an essential step in robust, litigation-proof project delivery.

The primary benefits of widening SR 37 are temporarily reduced congestion (at least until 2035), increased likelihood of transit availability, and maintenance of the status quo for the network. Primary benefits for elevation using the causeway scenario include improved conditions and potentially resilience for tidal marshes. The primary impacts of the berm scenario are inhibition of hydrological connectivity (reducing marsh resilience), and traffic impacts on birds and wildlife. The primary impacts of all raised scenarios are increased traffic, resulting in increased air pollution and noise.

Methods are available to normalize benefits and impacts to the same value scale, which makes it easier to make decisions about structure attributes that differ in type (e.g., traffic vs. SLR resilience). This involves deciding the quantitative and occasionally qualitative targets for each impact/benefit indicator, then comparing the condition that would occur under a given scenario with the defined targets. Carrying this out for all indicators, including project costs (including life-cycle costs), would mean that all benefits and impacts were on the same value scale and alternatives and variants of alternatives could be objectively compared. A weaker version of this idea would be to convert all indicators to fiscal equivalents, then compare alternatives. This approach is weaker because the conversion of most important factors is rife with large uncertainty (e.g., effects of tidal flow on marsh adaptation), which would make the fiscal equivalents virtually meaningless.

I recommend that alternatives are developed with component parts (e.g., number of lanes, presence of transit, marsh/tidal permeability) and impact/benefit values calculated for these components within a transparent stakeholder process. Responsible agencies would then commit to making the decision based upon maximizing benefits of as many components as possible.

Literature Cited

American Public Transportation Association (APTA). 2015. Public transportation benefits. http://www.apta.com/mediacenter/ptbenefits/Pages/default.aspx. Accessed 5/22/2015.

Battelle Memorial Institute. 2008. San Francisco Bay subtidal habitat goals project: Economic valuation of San Francisco Bay natural resources services. Appendix to the San Francisco Bay subtidal habitat goals report to the National Oceanic and Atmospheric Administration.

Bendtsen, H. *Highway Noise Abatement: Planning Tools and Danish Examples*. Report for Caltrans by the Danish Road Institute and the University of California Pavement Research Center. UCPRC-RP-2010-03, 2010.

Bendtsen, H. and L. Michelsen. Effect on Noise Annoyance by Widening Danish Highway. TRB 91st Annual Meeting Compendium of Papers, Transportation Research Board 91st Annual Meeting. 10 p., 2012.

CA State Parks. 2005. The health and social benefits of recreation. This report is an element of the California Outdoor Recreation Planning Program, formulated under the provisions of Chapter 5099 of the California Public Resources Code.

Cik, M., K. Fallast, and M. Fellendorf. Traffic Noise Annoyance on Roads and Rail (TNAR). TRB 91st Annual Meeting Compendium of Papers, Transportation Research Board 91st Annual Meeting. 15 p. 2012.

Conathan, M., J. Buchanan, and S. Polefka. 2014. The economic case for restoring coastal ecosystems. A Report of the Center for American Progress.

Delucchi, M.A., McCubbin, D.R. 2010. External costs of transport in the U.S., In: de Palma, A., Lindsy, R., Quinet, E., Vickerman, R. (Eds.), Handbook of Transport Economics. Edward Elgar Publishing Ltd.

ESA/PWA. 2013. Analysis of the costs and benefits of using tidal marsh restoration as a sea level rise adaptation strategy in San Francisco Bay. A report prepared for The Bay Institute.

Francis, CD and Barber JR (2013) A framework for understanding noise impacts on wildlife: An urgent conservation priority. Frontiers in Ecology and Environment 11(6): 305-313. DOI: 10,1890/120183

Freitas, E., C. Mendonca, J.A. Santos, C. Murteira, J.B. Ferreira. Traffic Noise Abatement: How Different Pavements, Vehicle Speeds and Traffic Densities Affect Annoyance Levels. *Transportation Research Part D*, Vol. 17, 2012, pp. 321-326.

Goodwin SE and WG Shriver (2010) Effects of traffic noise on occupancy patterns of forest birds. Conservation Biology 25(2): 406-411.

Kagan, J.S., F.M. Shilling, and L.J. Gaines. (2014). Valuation and crediting approach for transportation and metropolitan planning agencies. *Transportation Research Record,* 2403: 1-8.

Lee, J.F.J., M. Springborn, S.L. Handy, J.F. Quinn, and F.M. Shilling. 2010. Approach for Economic Valuation of Environmental Conditions and Impacts. Prepared for CALTRANS, University of California, Davis, CA. 123 pp.

Lercher, P., D. Botteldooren, U. Widmann, U. Uhrner, and E. Kammeringer. Cardiovascular Effects of Environmental Noise; Research in Austria. *Noise and Health*, Vol. 13, 2011, pp. 234-250.

Litman, T.A. 2009. Transportation Cost and Benefit Analysis. Victoria Transport Policy Institute, 1250 Rudlin St., Victoria, BC. 20 pp. http://www.vtpi.org/tca/tca01.pdf

Meillere A, Brischoux F, Angelier F (2015) Impact of chronic noise exposure on antipredator behavior: an experiment in breeding house sparrows. Behavioral Ecology doi:10.1093/beheco/aru232

New Zealand Transport Agency (NZTA). 2013. *Economic Evaluation Manual*, http://www.nzta.govt.nz/assets/resources/economic-evaluation-manual/economic-evaluation-manual/docs/eem-manual.pdf. ISBN 978-0-478-40782-2

Owens JL (2013) Effects of traffic noise on the social behavior of tufted titmice (Baeolophus bicolor). PhD dissertation, University of Tenessee. http://trace.tennessee.edu/utk_graddiss/a767.

Parris, KM and A Schneider (2008) Impacts of traffic noise and traffic volume on birds of roadside habitats. *Ecology and Society* **14**(1): 29. [online] URL: http://www.ecologyandsociety.org/vol14/iss1/art29/

Poor, A., K. Lindquist, and M. Wendt. 2009. Environmental and economic cost-benefit analyses for recommendations of the Transportation Implementation Working Group: Synthesis. Prepared for the WSDOT Public Transportation Division

SCCOSA (Santa Clara County Open Space Authority) 2014. Healthy lands & healthy economies: Nature's value in Santa Clara County.

Shannon G, Angeloni LM, Wittemyer G, Fristrup KM, and Crooks KR (2014) Road traffic noise modifies behavior of a keystone species. Animal Behavior 94: 135-141. http://dx.doi.org/10.1016/j.anbehav.2014.06.004

Siemers BM and Schaub A (2011) hunting at the highway: traffic noise reduces foraging efficiency in acoustic predators. Proceesings of the Royal Society, B 278: 1646-1652. doi:10.1098/rspb.2010.2262

Swyngedouw, E., 2005. Governance innovation and the citizen: the Janus face of governance-beyond-the-state. Urban Studies 42 (11), 1991–2006.

Victoria Transport Policy Institute (VTPI). 2015. Evaluating public transit benefits and costs: Best practices guidebook. http://www.vtpi.org/tranben.pdf. Pp. 138.

Woodward, Yong-Suhk Wui, The economic value of wetland services: a meta-analysis, Ecological Economics, 2001. Volume 37, Issue 2, May 2001, Pages 257-270.