Approach for Economic Valuation of Environmental Conditions and Impacts

Final Report to CALTRANS and the Multi-Disciplinary Team

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I Executive Summary

Many decisions related to transportation infrastructure are based upon economic considerations. SAFETEA-LU Section 6001 places more emphasis on including environmental information early in transportation planning and decision-making. In order to consider both environmental and economic benefits and costs at the same decision point, it is important to put them on the same scale to ease comparisons. One way to do this is to convert changes in environmental conditions and processes to fiscal equivalents ($). For example, safety and human health considerations could be converted to a common fiscal scale to allow joint consideration in decision-making.

Economic valuation, the process of converting environmental conditions and processes to a economic scale, can be conducted using a variety of methods and at a variety of scales. The primary methods in the literature are the focus of this report and the basis for the recommended approach. We focus on two transportation planning scales as both examples and important scales in their own right: corridor planning and regional planning. Valuation information obtained at these scales could be useful for project ranking and prioritization, project impact analysis, and analysis of project alternatives.

The aim of this project is to contribute to a more complete accounting of environmental impacts of transportation in decision-making. The current report is a compendium of guidance from the scientific and technical literature on approaches for economic valuation, impacts from transportation systems, and approaches for combining disparate information in single assessments to support decisions. The report is organized into the following sections: an introduction to valuation approaches from the literature (II), a framework for containing the valuation analysis (III), decision making process and scale (IV), implementation plan (V), and conclusions (VI).

Project Goal

The goal of the project is to develop an approach for valuation of environmental conditions and impacts in the context of regional and corridor scale planning and project development. The project objectives are the following:

Objective 1: Develop a multi-disciplinary working group to define a preferred economic valuation methodology in the planning process, identify relevant research and current work on other valuation methods, and give direction and scope to the project.

Objective 2: Develop planning level economic evaluation method for consideration of impacts and benefits to environmental resources in the context of long-range transportation planning such as Regional Transportation Plans and Corridor System Management Plans.

Objective 3: Develop recommendations to management for the preferred methodology and an implementation plan.

II Introduction to Valuation Approaches for Environmental Conditions and Attributes

There are several existing approaches for evaluating the contribution of environmental systems to human well-being in an economic framework. Some approaches measure the value of "ecosystem services" provided while others capture the value individuals may have for natural systems exclusive of actual use. By measuring impacts to natural systems, decision-makers can compare outcomes that will emerge depending on the types of actions that are taken at the scale of a single project, or a whole system (e.g., Metropolitan Planning Organization (MPO)-area highway network). There are several possible systems of analysis that we consider here. We also introduce and discuss other approaches for valuation of non-market goods, such as stated preference and revealed preference methods. These recognize that natural systems can have social value even in the absence of a direct market value. An analytically rigorous economic approach to characterizing the value of environmental changes can improve the balancing among potentially competing issues in a decision-making process (e.g., choosing among projects or project alternatives), because a common value scale can be created to compare economic/ecological costs and economic/ecological benefits.

We describe possible approaches here to meet needs at two primary scales-extents. These are the corridor planning scale, which has a typical linear geographical extent of 10 - 50 km, and the regional planning scale, which has a typical extent on the order of ~10^4 km^2. These two planning scales also have different time scales associated with them. Regional plans often include projects recommended for funding that may not be built for many years (greater than 10 years). Corridor plans often include projects that are already approved and funded and may be built in less than 10 years. Regional plans are developed by metropolitan planning organizations, in consultation with municipal transportation agencies and Caltrans. Corridor plans are developed by Caltrans, usually in consultation with local transportation agencies.

A Types of Values Associated with Environmental Goods and Services

The main purpose of economic valuation is to inform the decision- and policy-making processes. A taxonomy of values associated with environmental goods and services is useful because it helps the practitioners to identify what types of value may be impacted by transportation activities. It will also help in the understanding of various valuation methodologies that target a particular subset of the total economic value of an environmental attribute.

Economists define value based on an anthropocentric, utilitarian approach, which focuses on measures of individual well-being. The economic value of changes in environmental attributes and services is derived from measuring the effects of these changes in human welfare. Total economic value (TEV) is a framework to account for the multiple values of ecosystems. TEV is composed of use values and nonuse values. Figure 1 summarizes the classification of total economic value and commonly used valuation methods. The valuation methods for environmental goods and services are discussed in the next section. The list of valuation methods is not exhaustive.

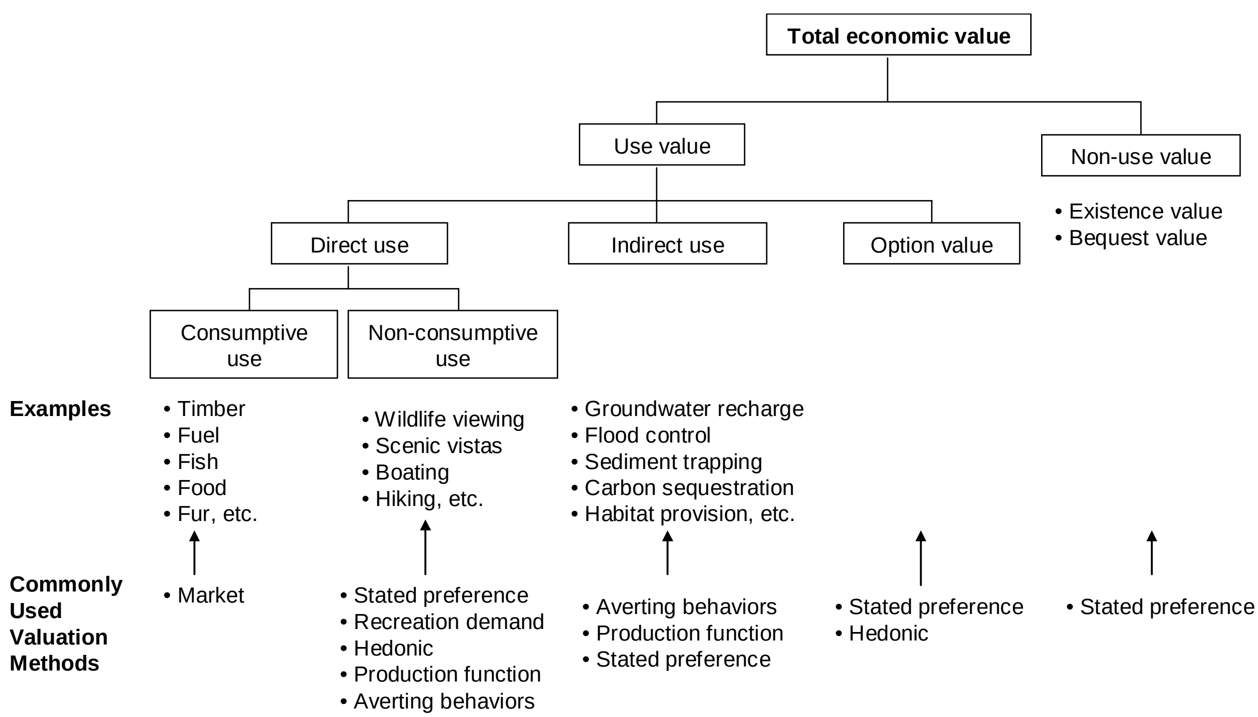

Figure 1. Classification of total economic value and commonly used valuation methods.

Use values refer to those values associated with the use of an environmental attribute by individuals. Use values can be grouped into direct or indirect uses. Direct use values refer to the values that involve direct human interaction with the environment, including both consumptive and non-consumptive uses. Consumptive uses involve extracting resources from an ecosystem for human consumption, such as timber and food harvesting. Non-consumptive uses are the services provided by ecosystems without extraction, such as the provision of recreational opportunities and scenic vistas. Indirect uses are derived from ecological functions such as flood control, groundwater recharge, and water filtration. Option value is the value obtained from keeping the option of having a use value at a later date.

Nonuse values are sometimes defined as all remaining values aside from consumptive and non-consumptive use. Nonuse values include existence value, where people benefit from the knowledge that a particular environmental attribute exists (and will continue to exist) and bequest value, where the benefit stems from the preservation of an environmental attribute for future generations.

B Valuation Methodologies for Environmental Goods and Services

Various methods have been developed to value changes in environmental assets. These include several revealed preference and stated preference methods listed in Table 1. These two categories of valuation methods are described in-depth below, but in short they differ in the following ways. Revealed preference approaches depend on a connection between the non-market good of interest (e.g. local water quality) and a market good (e.g. residential housing). They take advantage of an observed "behavior trail", that is, data related to actual decisions (e.g. prices paid for property). Reliance on observed (versus hypothetical) choices is a perceived strength but also a limitation in that, environmental scenarios for valuation are limited to those that exist (or for which data has been collected). In contrast, stated preference techniques elicit values for hypothetical scenarios. The benefit of greater flexibility is achieved at the cost of effort needed in survey design to minimize bias stemming from the survey instrument and hypothetical nature of the exercise. While both revealed and stated preference methods can capture use values, only stated preference can be used to estimate nonuse values.

Table 1. Commonly used valuation approaches for non-market goods and services.

Revealed Preferences	**Stated Preferences**
Hedonics Recreation Demand Averting behavior Market prices	Contingent valuation Conjoint analysis

The discussion in this report focuses on the *economic* value of environmental conditions and impacts. A summary of alternative approaches to characterizing value is available from the EPA Science Advisory Board (SAB, 2009)[1]. The report outlines the various ways in which value can be conceptualized, including the following: community-based, constructed, bio-ecological, energy-based and attitudes and judgments.

Terms:

Market goods – Goods in a market economy are sold for prices which reflect the equilibrium between supply and demand. **Market price** is observable.

Non-market goods – Goods that are not bought or sold directly in the market (in other words, goods that are not traded in the market). Non-market goods do **not** have observable monetary values.

Valuation of non-market goods – Since there is no market price for non-market goods, valuation of non-market goods involves assigning monetary values to those goods. **Non-market goods valuation methods** rely on information from the markets for related goods (revealed preference methods) or on direct information on people's preference (stated preference methods). (**Non-market goods valuation** does not mean using a non-monetary scale to valuate non-market goods.)

Matching Economic and Environmental Valuation

Economic costs are usually expressed in monetized terms. A critical need is to know how to compare economic and environmental benefits and costs. One way to do this is a re-scaling of benefits and costs to a common scale. Re-scaling is the process of taking values from one scale (e.g., area in acres) and converting to another scale (e.g., monetary value in $). This new scale could be unitless, for example a -1 to 1 scale, or a 0 to 100 scale. A unitless scale would have lower and upper boundaries set by the user to correspond to some thresholds or desired conditions. The value of conducting valuation initially in a unitless scale is that this scale can still be converted to a monetary scale, which allows valuation and decision-support to occur with and without a monetary conversion. If all parameters are only converted to a monetary scale, then an assumption is made that enough is known to convert social (e.g., traffic) and ecological (e.g., habitat quality) parameters to the monetary scale. The valuation methods described in ensuing sections are different ways to re-scale changes in environmental conditions to an economic or fiscal scale.

[1] The EPA Science Advisory Board (SAB) was established by Congress in 1978 with a mandate to advise the EPA on technical matters.

B.1 Revealed preference methods

Revealed preference methods are based on the choices individuals make in the market. In other words, they are based on observed behaviors of individuals. Examples of revealed preference methods include hedonics, recreation demand, averting behavior models, and market price methods.

Hedonic models

Hedonic models attempt to explain price variations using information on the different characteristics of a marketed good, including environmental quality or amenities. Hedonic prices are defined as the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them (Rosen 1974). If the hedonic price function can be estimated accurately, the estimates represent an individual's marginal willingness to pay for the environmental quality (Leggett and Bockstael 2000). For example, the willingness to pay extra for a house adjacent to water or open space provides at least a minimum estimate of the value the buyer places on that amenity. Hedonic models have been used widely to estimate how environmental problems affect property values.

When to use the hedonic model?

A hedonic model can be used when an environmental attribute directly affect the price of a marketed good. It is commonly used to value environmental attributes, such as noise, air quality, water quality, and open spaces that directly affect the price of residential properties[2]. To use this method, data on the transactions of residential properties and the environmental attribute of concern must be available.

Application of the hedonic model

The first step in the hedonic model is to collect data on residential property sales in the study region. The required data includes property sales data, property characteristics (e.g. lot size

[2] In principle, hedonic analysis can be applied to any place-based purchase, not just housing.

and number of rooms), neighborhood characteristics (e.g. distance to business center, quality of schools and crime rates) and the environmental characteristics that affect property prices. A regression analysis is then used to estimate the relationship between property values and property characteristics. The results can be used to calculate the value of a change in an environmental characteristic but the methodology is only appropriate for small shifts.

Recreation demand models

Environmental quality can affect recreation opportunities at a site. Recreational uses include, for example, aesthetic amenities, wildlife viewing, boating, and hiking. Recreation demand models, including the standard travel cost model and the travel cost random utility model (RUM), are used to value recreational uses provided by the environment. A classic travel model considers the number of visit to a particular site. It involves inferring non-market value of environmental attributes and conditions by using the travel and time costs that an individual incurs to visit a recreation location. The travel cost RUM looks at an individual's decision to choose a specific recreation site as compared to alternative sites.

When to use the recreation demand model?

The recreation demand model is often used if the environmental attribute of concern influences recreational use. This method might be appropriate if a transportation project affects the environmental quality at a recreational site, affects the traveling costs to the site, decreases the recreational opportunity of an existing site, or creates new recreational sites.

Application of the recreation demand model

The simplest travel cost model considers trips to a single site. The travel cost model generally involves the following steps. The first step is to collect information on the travel behavior of visitors. The required data include, for example, distance that visitors travel to the site, the frequency they visit the site, the amount of time they spent at the site, travel expenses, purposes of the trip, perceptions of the quality of an environmental attribute at the site, and demographic and socioeconomic characteristics of the visitors. Analysts then use the data to estimate the relationship between the number of visits and explanatory variables such as travel costs. The relationship can be used to construct a demand function, which relates the number of trips from a particular area and the travel costs of reaching the site. Finally, analysts can use the demand function and travel cost to estimate the consumer surplus, or the economic benefit, of the site to visitors.

Averting behavior models

Averting behavior models attempt to infer values of non-marketed environmental characteristics based on individuals' willingness to pay to either reduce the likelihood or the impact of a loss of health or wellbeing from environmental degradation. Averting behavior models assume that individuals engage in defensive behaviors to achieve a desired level of health while accounting for the cost of defensive action. By analyzing the expenditures associated with the actions taken to reduce the risk of the undesirable health consequences, the value individuals place on small changes in risk can be estimated (USEPA 2000).

When to use the averting behavior models?

Since the motivation for the averting behavior is to protect health and general well-being, the most common application of the averting behavior models is to estimate the values for morbidity risk (risk of an illness). It would be difficult to apply this method to estimate the economic values for other ecosystem functions or attributes.

Application of the averting behavior models

Averting behavior is based on observed voluntary behavior from individuals. Analysts collect information on the expenditures people spend on a market good that is used for health protection or is used as a substitute for an environmental good or service. The value of an environmental attribute is inferred from those defensive or averting expenditures. For example, water purification to protect health when clean water is perceived to be unavailable is an example of such behavior.

Market price method

If environmental goods and services can be bought and sold in a market, then market price methods can be used. This approach uses the information about productivity and price changes in marketed goods to infer the value of the changes in an environmental attribute or process that contributes to the production of the marketed good. As this method involves using environmental conditions as an input in the production of the marketed good, it is referred to production function approach. Many of the applications of the production function approach involve the habitat and fishery linkages. For example, wetlands are considered as inputs to fish harvest, since wetlands support the growth of fish populations (Lynne, Conroy, and Prochaska, 1981; Barbier, 1994).

When to use the market price method?

Market price method can be used when an environmental attribute or an ecosystem service contributes to the production of a marketed good. As the change in the quality or the quantity of the environmental conditions affects the cost of producing the marketed good, the value of the environmental attribute can be related to the production cost or the price of the marketed good.

Application of the market price methods

Analysts need to specify the production function of a market good. Production function is the relationship between the inputs and the output. By using the production function, analysts can estimate how the supply and the price of the market good change when the quality or quantity of the environmental input changes. The economic benefits of protecting the environmental attribute or process can be estimated by their contribution to the market value of the output.

B.2 Stated preference methods

Stated preference methods characterize preferences based on intentions stated by individuals in hypothetical market situations (Boyle, Bell, and Rubin 2006). Stated preference methods are based on survey for eliciting values people place on goods, services, and amenities. The two main groups of stated preference methods are contingent valuation approaches and conjoint analysis (also referred to as choice modeling). Both of these techniques involve construction of a simulated market or simulated referenda. The valuation will depend in part on people's exposure to the issue and the level of education and information on the issues they have received (Alexander, Schneider, and Lagerquist 1997). In addition, willingness to pay can depend on an individuals' income level.

A principal advantage of these methods is that they are the only economic valuation methods capable of capturing nonuse values. As such they can be used to collect information on the value placed on attributes by those who value their existence, availability if needed, or who feel a stewardship responsibility in the form of an environmental ethic, religious beliefs, or a responsibility to future generations.

Contingent valuation

The contingent valuation method typically focuses on estimating the value of one particular environmental change scenario. A contingent valuation survey begins with a statement describing the change in environmental goods or services. Then it asks individuals to reveal how much they would be willing to pay for the change. For example, analysts might ask ratepayers whether they would accept various-sized increases in their water bills in order to protect an upstream water source or watershed.

When to use the contingent valuation method?

The contingent valuation method is typically used to provide an estimate on how much people are willing to pay or willing to accept for a specific change in an environmental attribute or an ecosystem service. In theory the method can be used to estimate values for a wide array of environmental attributes and ecosystem services, including those supporting both use and non-use values. However, respondents must understand the nature of what is being valued as well as have a sense for how they would be willing to trade off between changes in the environmental attribute and their income.

Application of the contingent valuation method

The contingent valuation method involves surveys. Like any other survey, researchers would need to decide whether to use in-person, mail or phone surveys, the sample size, sampling method, and who will be surveyed. The survey process involves survey design, pre-testing the survey, the actual implementation, and analyzing the results. Questions in the survey can be open-ended or closed-ended. As respondents are asked to state their willingness to pay for an environmental attribute or environmental quality on a hypothetical scenario, it is important to describe clearly the context and the change in the environmental attribute that is being evaluated.

Conjoint analysis

Conjoint analysis (also referred to as contingent choice or choice modeling) is typically used to estimate values over a set of attributes of an environmental amenity. It is particularly useful for valuation questions that involve multiple dimensions, each of which may vary over a range. In conjoint analysis, the questionnaire describes the item in terms of key attributes. Individuals would be asked to choose from or rank the items created from a combination of the attributes. Researchers can then predict how changes in attributes will change the prices individuals are willing to pay for the item.

When to use the conjoint analysis method?

Like contingent valuation, conjoint analysis method can be used to estimate the values for a wide array of environmental attributes and ecosystem services, including both use and non-use values. The same caveats pertaining to information and understanding of the change are relevant here. As conjoint analysis considers tradeoffs among different dimensions, this method can be use to rank policy options that would have various impacts over multiple attributes of the environmental amenity of concern.

Application of the conjoint analysis method

The applications of the conjoint analysis and contingent valuation are similar. The main difference is that conjoint analysis does not directly ask respondents' willingness to pay for an environmental attribute. In conjoint analysis, the value of an environmental attribute is inferred from the tradeoffs that respondents make in different scenarios.

C Secondary Approach: Benefit Transfer

Boyle and Bergstrom (1992) define a benefit transfer as the transfer of existing estimates of non-market values to a new study which is different from the study for which the values were originally estimated. They describe benefit transfer as the application of secondary data to a new policy issue. This method is commonly used in policy analysis. Benefit transfer applications can be divided into three broad types: estimates based upon (1) expert opinion (2) revealed preference methods, and (3) stated preference methods (Brookshire and Neill 1992). The attraction of benefit transfer is that it is less costly than conducting a new study. Johnson and Button (1997) suggest that benefit transfers may remain legitimate if appropriate adjustments can be made to allow for specificity in individual case studies. Navrud and Pruckner (1997) suggest that benefit transfer is best suited for tasks where the need for accuracy is low, i.e. to stimulate awareness and screening (i.e. rough, back-of-the-envelope cost analyses of public projects and regulations). NRC (2005, p. 124) suggests benefit transfer is generally considered a "second best" valuation method because benefit transfers involve reusing existing data, and a benefit transfer does not provide an error bound for the value in the new application after the transfer.

When to use benefit transfer method?

Benefit transfer may be appropriate for a first-order characterization of welfare impacts, for example to inform an assessment of which impacts might be important or warrant further scrutiny. The approach might be the only feasible choice given budgetary or time constraints. However, benefit transfer should always be used with caution and with clear caveats describing the degree to which the primary estimates being transferred are suitable for the current application. Estimates are unlikely to be as accurate as a well-conducted primary study.

Application of the benefit transfer approach

Benefit transfer approach generally involves the following steps:

1. Select existing literature

The first step in applying benefit transfer is to select existing literature. There are large numbers of studies that estimate the values of environmental attributes and conditions.

Analysts have to use their judgments to select the appropriate literature. Some considerations should be kept in mind when selecting the existing studies. The environmental attributes should be similar in type in the projects being considered. In addition, it is preferable to select studies that have similar socioeconomic characteristics, affected population and geographic locations to the project being evaluated. It is also important to review the quality of the existing studies, as it will affect the quality of benefit transfer. The quality of the existing studies for example, depends on data collection, economic and scientific theories, and empirical methods. Estimates can change considerably over time, so more recent studies are desirable.

2. Transfer the estimates and adjust values

After existing studies have been identified, the next step is to transfer the values to the case that is being evaluated. There are different ways to transfer the estimates. Analysts can use a range of reported values (or the mean value) from the original study and apply them to the new case. Alternatively, analysts can use the benefit function to transfer the values. In the benefit function approach, analysts substitute the values of the variables from the new case into the WTP function from the original study. This can be done only if the parameters in the original study and the data for the variables in the new study are available.

3. Discuss uncertainty

Benefit transfer studies have inherent uncertainties. The values reported in the existing literature can vary greatly and their application outside of the original study area will result in uncertainty. Adjustments are usually needed when transferring the estimates from the original study to the new study in order to account for regional differences. The whole process would require sound judgments on the part of the professional ecologists and economists involved. Analysts should describe all the assumptions, justifications and judgments, and explain how they would affect the final estimates.

D Cost-based Methods

Methods based on costs may be used as an alternative way to monetize environmental conditions, though they are different from the primary valuation approaches. As costs are often readily observable, they may be used as proxies for economic values. However, costs often do not equal value. Costs can underestimate values when costs are incurred by consumers (ADB 1996). However, costs may greatly exceed the value if society makes a decision to restore a natural condition at great cost (ADB 1996). Cost-based methods lack the welfare-theoretic underpinnings of other methods discussed above. Generally, cost-based methods should be considered last resort proxies for economic values (Shabman and Batie 1978).

Avoided cost, replacement cost and cost of treatment

Avoided cost, replacement cost or cost of treatment approach is used to approximate the benefits of a service by the cost of artificially providing it. It is sometimes used when an ecological service is unique to a specific ecosystem and is difficult to value by other methods, and there is no existing estimate to apply the benefit transfer approach (NRC 2005, p. 125). However, this method suffers from the problem that the replacement cost might not be something that individuals would voluntarily accept in the absence of the environmental amenity and therefore might be a misleading estimate of value. In applying this method, at minimum the following conditions must be met: 1) the alternative considered has to provide the same service as the original service provided by the ecosystem; 2) the least-cost alternative among the alternatives used for cost comparison should be used; 3) there should be evidence that the society would accept the least-cost alternative as a replacement of the ecosystem service being evaluated (Shabman and Batie 1978).

A well known example is the Catskills watershed in New York. Instead of building a new drinking water filtration plant, New York City decided to invest in watershed protection. In this case, the natural water purification service is represented by the cost of building the new filtration plant. However, avoided cost approach is not preference-based and is not a measure of economic value. Goulder and Kennedy (1997) note that the avoided cost method is a fairly good measure of an ecosystem service if the ecosystem service in question is a perfect substitute for the same service offered by an alternative.

When to use the avoided cost, replacement cost and cost of treatment method?

These methods use the costs to restore or replace an environmental attribute as an estimate of its economic value. Since the avoided costs or replacement costs are often observable, these methods can provide proxies for values when analysts cannot use other methods to estimate the willingness to pay.

E Comparison of Economic Valuation Methods for Non-market Goods and Services

Typically, a particular valuation method will only target a subset of the total economic value of an environmental asset. Each valuation method discussed in Section II. B, C, and D depends on a particular set of economic assumptions, for example, pertaining to individual preferences, market behavior and the connection between market and non-market goods. Table 2 provides a comparison of different valuation methods.

An exhaustive accounting of total economic value is usually not possible with a single approach. For example, wetlands serve several functions that can be measured using the production-function approach. They also can provide recreational and other aesthetic benefits, which can be measured using recreational demand methods. Of course, there will be significant overlap among types of impacts among project and plan types and therefore overlap among methods used to account for costs of these impacts. It is not possible in guidance reporting like this to anticipate every combination of method and environmental attribute; instead we provide general guidelines and suggest referring to the literature for examples of valuation and guidance for the appropriate use of environmental impacts analysis and valuation (Litman 2009; NRC 2005; Bateman et al. 2002; Champ et al. 2003; USEPA 1996, Freeman 1993).

Table 2. Comparison of valuation methods for non-market goods and services.

Method	Advantage	Disadvantage
Primary Methods **Revealed Preference Methods** Hedonic model	Use observed housing, property, or labor market behavior to infer values for environmental quality changes	Measures use values only Requires extensive market data

Method	Advantage	Disadvantage
Hedonic model		Assumes market prices capture the value of the environmental good Hedonic results have limited transferability Difficult to describe the benefits associated with discrete (non-marginal) environmental improvements
Travel cost	Use observed tourist and recreation trip-taking behavior Travel cost model involves trips to a single site	Measures use values only Expensive and time-intensive to collect data
Travel cost RUM (random utility model)	Travel cost RUM focuses on travel cost and ecological characteristics associated with all competing sites	Measures use values only Expensive and time-intensive to collect data
Averting behavior	Infer values of non-marketed environmental characteristics based on individuals' WTP to avoid undesirable health consequences Can estimate the value individuals place on small changes in risk by analyzing he expenditures associated with the actions taken to reduce the risk of the undesirable health consequences	Rarely provide estimates of economic values of ecosystem services

Method	Advantage	Disadvantage
Stated Preference Methods	The only method that can estimate non-use values and can also estimate use value	Expensive and time-intensive to implement Challenges in framing survey questions Potential response biases Valuation is subjective Opinion depends in part on people's exposure to the issues
Contingent valuation	Estimating the value of a single, given environmental change scenario	WTP depends on individuals' income level
Conjoint analysis	Can estimate values over a set of attributes of an environmental amenity Questions may be easier to answer than contingent valuation	Difficult to compute and requires large samples

Method	Advantage	Disadvantage
Secondary Method Benefit transfer	Resource and time saving, less costly than conducting a new study, can be applied without extensive modeling or time-intensive research Can be adapted to a variety of project types and countries When carefully applied, benefit transfer will be adequate for many project economic analyses	Problems may arise in adjusting values from the original project/site to project/site under consideration Sometimes produce less defensible estimates of damages or benefits than the results from primary research methods Does not provide an error bound for the value in the new application after the transfer May not be appropriate for large projects, or projects with potentially large and irreversible consequences
Cost-Based Methods	Costs are observable	Provides only a partial measure of value. No methods will provide a complete measure of value
Cost of Productivity Loss	Production relationships understood for many economic sectors	Changes in productivity and/or the associated value of productivity loss may be difficult to observe or estimate

Method	Advantage	Disadvantage
Replacement or Restoration Cost	May be based on simple engineering calculations or actual expenditures	Complicated if complex set of ecological relationships are to be restored, or if only partial restoration is feasible. Even the existence of a replacement market (e.g., conservation banks) does not guarantee that complex ecosystems can be replaced. Restoration costs may be less than or exceed benefits or damages

Sources for Primary and Secondary Methods: ADB (1996), USEPA (2000) and NRC (2005).
Source for Cost-Based Methods: ADB (1996).

The choice between primary and secondary methods often depends on data and resource availability. It may also depend upon the degree to which better economic data is likely to influence the choice among alternatives. Low-cost, rapid valuation methods (e.g., literature-derived rules of thumb) may suffice if the associated costs are low or highly asymmetrical (e.g., fisherman-hours lost are a tiny fraction of commuter-hours gained), as the decision-maker is unlikely to change their decision through monetizing the costs and benefits. The benefit transfer method is possible and decision-makers believe that any error stemming from application of the method is justified by the time and monetary cost savings. In addition, when there is sufficient information about quantity of impacts and regionally relevant equivalent values for these impacts, then the benefits transfer method may be appropriate. However, when the impacts can be quantified, but certain or all equivalent values are unknown, then benefits transfer may not be appropriate. Conversely, investment in higher-precision methods (revealed preference and stated preference methods) may be justified if the policy process is contentious or the potential cost of a poor decision is high. See Section V.A.2 on the discussion on tradeoffs between cost and accuracy or completeness of an analysis.

F Issues in Valuation

Many issues need to be considered in the process of valuation of environmental attributes. These issues can affect the results of an analysis. These issues include timeframes, discounting, double-counting, and equity.

F.1 Timeframes

Timeframes play a critical role in the valuation studies. The magnitude of each impact could vary within a specific timeframe, for example, some impacts occur only in the construction stage, while other impacts occur throughout the lifespan or even after the lifespan of a project. It is important to define the timeframe for the analysis, and to provide the justifications for choosing the timeframe. Since the impacts can accrue over different time periods, discounting becomes relevant in the valuation process (see Section II.F.2 for more discussion regarding discounting). World Bank (1998) recommends extending the time horizon of an analysis so as to include all the benefits and costs associated with environmental impacts, even if they go further into the future than the normal life of a project. It also mentions that the effective length of the time horizon of an analysis is determined by both the number of actual years included in the analysis and the discount rate used.

F.2 Discounting

When dealing with payoffs that occur over time in valuation, a common assumption is that the present value of a payoff received today is greater than the present value of the same payoff received years in the future. Discounting is the process used to convert payoffs that occur in the future into present values so that a single figure of aggregate present value can be calculated. The social discount rate should reflect in general the degree to which society is willing to trade off between wellbeing in the present and the future. The selection of a social discount rate can be controversial since it can exert a strong influence over the present value calculation. The higher the discount rate the greater is the preference for the present payoffs over the future payoffs. Historically, a wide range of discount rates have been used by government agencies (Revesz and Stavins 2007) and there is no general consensus on what particular rate should be used. However, in a summary of benefit-cost analysis practices for evaluating environmental regulations, a well-respected group of economists from Resources for the Future (Kopp et al. 1997) have argued that the appropriate real, riskless rate[3] for inter-temporal consumption tradeoffs in the U.S. is generally taken to be around 3 percent. In 2003 the U.S. Office of Management and Budget revised their recommended discount rate for intragenerational analyses from 7 percent to 3 percent, with lower, undetermined rates for longer time horizons (OMB 2003). In general, economists typically recommend a social discount rate in the range of 2 to 3 percent (Revesz and Stavins 2007). However, since the particular rate chosen is in part a matter of judgment, it is important to assess the sensitivity of benefit-cost analysis conclusions to the discounting parameter assumption.

F.3 Equity

To fully understand the impacts of any regional and corridor transportation plans, policy makers not only need to evaluate the social benefits and costs (including environmental benefits and costs), but also need to consider the distributional consequences of those plans. Equity assessment addresses the distributional outcomes. Equity considers who gets the benefits and who pays the costs from society's point of view. It is possible that the costs and/or benefits of a particular policy option or management action (e.g., freeway expansion for single-driver vehicles vs. transit investment) affect a particular group of individuals more than the others. Groups of special concerns, for example, can include infant and children, elderly populations, low-income populations and minorities. Equity may be a factor in considering the project alternatives. The valuation process discussed in this document does not address the equity issue directly, but provides tools whereby distributions of costs and benefits can be estimated for various segments of society.

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[3] Discounting is not intended to address inflation—before discounting all figures should be expressed in real terms (adjusted for inflation). Issues of risk (e.g. the likelihood of a stochastic event that would drastically affect the setting of the analysis) should also be accounted for separately.

F.4 Double counting

When multiple valuation methods are used to value an environmental impact it is possible that a particular component of the impact could be captured more than once. Similarly, it is not necessarily appropriate in general to assume that willingness to pay is independent and additive. For example, given a willingness to pay to conserve two different species considered in *isolation* from each other, it is not necessarily the case that the sum of these two independent values will reflect willingness to pay to simultaneously conserve *both* species. It is important to sort out the components of the environmental change to be valued and express what values are captured by each valuation methodology used. Clear listing and identification of mutually exclusive environmental attributes and ecosystem services can decrease the likelihood of double counting.

III Framework for Valuation of Environmental Conditions in Transportation Planning

A Background

Transportation systems provide many benefits to current society, as well as many impacts to human and natural systems. Accounting for the benefits and costs requires a combination of understanding these benefits and costs and converting them into scales that are useful in decision-making. Because financial limitations and logistics are a large part of decision-making, a fiscal scale is often employed. By normalizing transportation planning concerns to a common scale (e.g., fiscal value), decision-making about transportation networks and individual projects is facilitated. As sustainability research has grown, normalizing disparate attributes to common scales has become more common. Often the scale in economic and environmental studies is monetary, which is the focus of this report and recommended approach.

Valuation is a useful way to inform transportation decision-making for multiple needs:

- For informing decisions related to regional planning networks (spatially connected elements) and sequences (temporally connected) of projects that are efficient relative to goals (e.g., high total benefits)
- For comparing among project/route alternatives for best total benefits
- For developing mitigation alternatives (avoid, minimize, compensate/offset) and estimates based on valuation information
- To integrate this information into Regional Transportation Plan development/analysis to inform decisions.

An approach is desired that informs planning alternatives and decisions at multiple scales.

Valuation is a process that is based on indicators of benefit and cost and results in an assessment of the relative value to the observer on a scale useful to the observer for decision-making.

B Framework Description

This section describes elements of a framework that can be used to support a valuation approach for environmental conditions. It contains a proposed flow for the valuation process, and the basic steps of valuation of environmental attributes.

There are many possible decision-making processes that could entail valuation of environmental conditions and comparison with economic considerations. A generic valuation process diagram is shown in Figure 2. Many infrastructure development, operation, and maintenance activities can affect the environment to different degrees and at different spatial and temporal scales. The influential agents on environmental conditions associated with the activities are often described as stressors. People, wildlife and plants are possible receptors of the stressors. The consequences in receptors after the changes in their exposures to the stressors are the impacts.

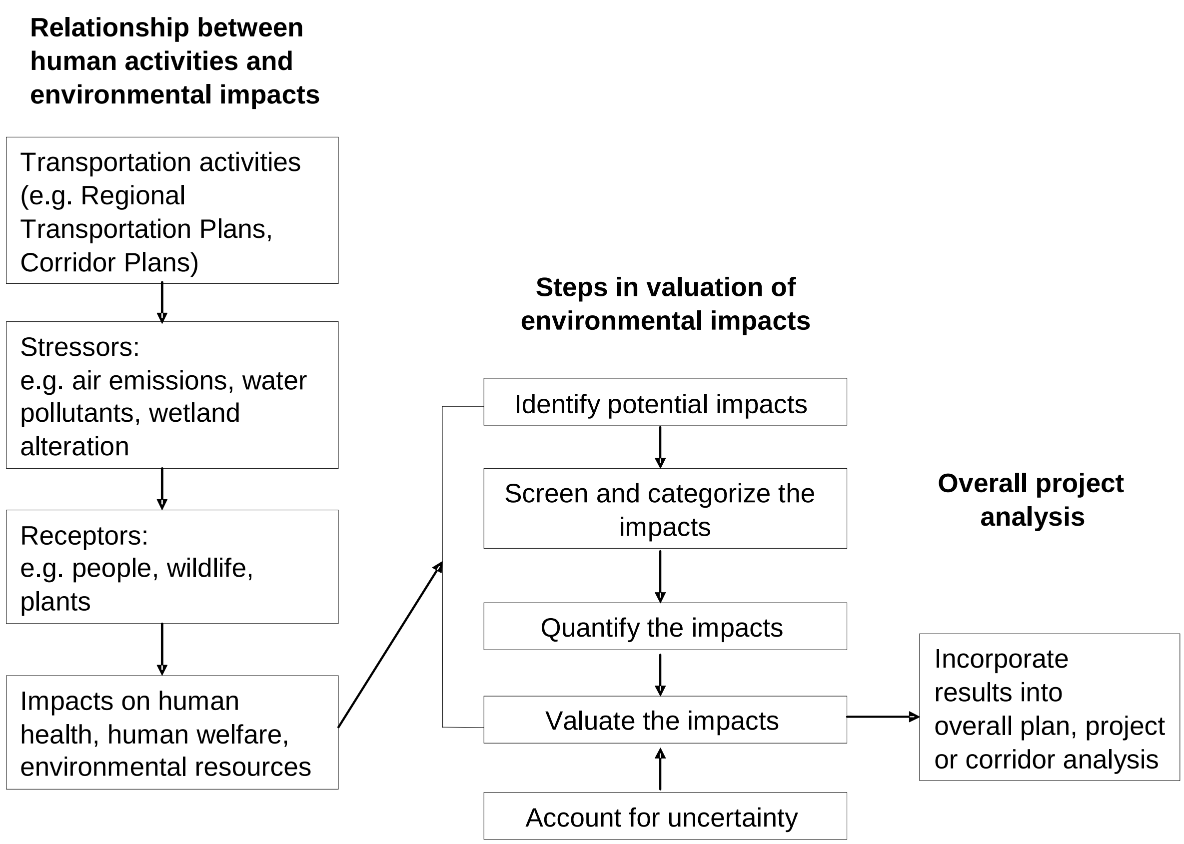

Figure 2. Information flow for environmental accounting in economic decision-making. -

In this proposed process flow, transportation system impacts are first identified and quantified. An equivalent economic value is attributed to these impacts, based upon new data collection, or values from the literature. These values are incorporated into the overall project (plan or program) analysis.

There are potential evaluation-scale effects on this process (project, corridor, and region) – it may be desirable to develop different flows of valuation process and 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.

C Valuation Process for Transportation Planning and Programming

There are four basic steps to analyzing and valuing ecological and health impacts from transportation planning and projects. The first is identification of potential positive and negative impacts of proposed actions. The second is screening and categorizing the impacts. The third is quantification of the impacts using available or newly-collected data. The fourth is valuation of the impacts. The details of each step are as follows:

C.1 Step 1: Identify potential environmental impacts

The first step in environmental valuation is to identify a plan, corridor, or project's environmental impacts. These impacts are determined by comparing the "with project" and the "without project" impacts related to the baseline information for environmental conditions available in a region or corridor. The methods used for identifying potential impacts are essentially the same used in environmental impacts analysis carried out in transportation planning, with additional impacts that may not be typically considered. The identified impacts are useful for both quantifying the total costs and keeping track of impacts and benefits after implementation. We assume here that the transportation agency has sufficient expertise on staff to identify potential environmental impacts of transportation actions, or can recruit expertise through consultants. We make no attempt here to reproduce the methods Caltrans already uses to identify potential impacts; instead, the approach described uses these existing methods as a source of information about potential impacts.

Impacts from transportation to specific aspects of the natural and human environment have been well-studied and reported in the scientific and technical literature. Appendix A lists and details some of these impacts. We sort impacts from the literature into several categories: landscape, species, human health, energetic, and material. Not all potential impacts have been studied, but enough have to give a sense of the types and nature of potential environmental costs of transportation.

Some agencies provide a list of impacts or guidance that analysts can refer to during impact identification process. Categorizing potential impacts provides a systematic way for analysts to identify the actual and potential environmental consequences. It also helps analysts to identify what types of value may be impacted by transportation activities. In addition, clear listing and identification of mutually exclusive environmental attributes and ecosystem services can decrease the likelihood of double counting.

Different agencies and statues use different categories or checklists for environmental impacts assessment. While each list may not cover all the possible environmental impacts, a cross-referenced checklist can help analysts to identify the potential environmental impacts as thoroughly as possible. Table 3 summarizes the main categories of environmental impacts used by the following agencies and statues:

- Caltrans (2009) provides guidance on impact identification and analysis on a number of topics. The guidance pertains to federal laws, state laws, Executive orders, and regulations applicable to transportation projects. [4]
- California Environmental Quality Act (CEQA) – The environmental checklist of CEQA is listed in Appendix C.
- National Environmental Policy Act (NEPA) – The impact categories of the Environmental Impact Statement (EIS) in NEPA used by the Caltrans are in Appendix D.[5]
- The Asian Development Bank (ADB 1996) checklist is in Appendix E.

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[4] See Caltrans website for detail: http://www.dot.ca.gov/ser/vol1/vol1.htm.

[5] See Caltrans' NEPA EIS Annotated Outlines: http://www.dot.ca.gov/ser/downloads/templates/NEPA_EIS_4_08.doc

Table 3. The main categories of environmental impacts used by different agencies and statues. -

	Caltrans (2009) guidance	CEQA categories	NEPA as done by Caltrans	ADB (1996)
Biological	Biological resources	Biological resources - Candidate, sensitive, or special status species - Riparian habitat or other sensitive natural community - Wildlife movement - Any conflict with local policies that protect biological resources - Any conflict with provisions of approved local, regional, or state habitat conservation plan	Biological environment - Natural communities - Plant species - Animal species - Threatened and endangered species - Invasive species	Environmental resources Terrestrial ecosystems Biodiversity/ endangered species
Water	Wetlands and other waters Floodplains Coastal zone Wild and scenic rivers	Wetlands Hydrology and water quality - Groundwater - Drainage pattern - Runoff - 100-year flood hazard	Wetlands and other waters Hydrology and floodplain Coastal zone Wild and scenic rivers Water quality and storm water runoff	Coastal and other marine ecosystems Freshwater ecosystems Groundwater

	Caltrans (2009) guidance	CEQA categories	NEPA as done by Caltrans	ADB (1996)
Land	Land use Farmlands Topography/ geology/soils/ seismic Paleontology	Land use and planning - Any conflict with land use plan - Any conflict with habitat conservation plan or natural community conservation plan Agriculture and forestry - Farmland conversion - Zoning for agricultural use - Zoning for forest land Geology/soils Mineral resources	Land use - Existing and future land use - Consistency with state, regional, and local plans and programs Farmlands/ timberlands Geology/soils/ seismic/topography Paleontology	Resource use (changes in productivity or value of commercial, subsistence, or recreational uses of natural resources)
Air	Air quality	Air quality - odors	Air quality	Hazardous chemicals and gases that affect environmental resources (including different types of ecosystems) odor

	Caltrans (2009) guidance	**CEQA categories**	**NEPA as done by Caltrans**	**ADB (1996)**
Noise	Noise	Noise	Noise and vibration	Aesthetics: noise
Com-munity	Community impacts Environmental justice Visual and aesthetics review	 Population and housing Transportation/ traffic Public services Utilities and service systems Recreation Aesthetic - Scenic vista - Scenic resources (including, but not limited to trees, rock outcroppings, and historic buildings within a state scenic highway)	Community impacts Growth Traffic and transportation/ pedestrian and bicycle facilities Utilities/emergency services Community character and cohesion Relocations and real property acquisition Parks and recreation Environmental justice Visual/aesthetics	Human welfare - Dislocations, loss of homeland, forced relocation of people - Effects on subpopulations (e.g. farmers, indigenous people) - Aesthetics: Visual, and other aesthetic impacts

	Caltrans (2009) guidance	CEQA categories	NEPA as done by Caltrans	ADB (1996)
Com-munity **cont'd.**	Cultural resources	Cultural resources	Cultural resources	- Impacts affecting religious beliefs, or cultural tradition - Materials: Damage to, and soiling of, buildings, etc.
Health		Any environmental effects which will cause substantial adverse effects on human beings	Human health (mentioned under the invasive species, and the hazardous waste and materials sections; the hazardous waste section also mentions federal laws that address human health)	Human health (under all air, land and water categories) - Mortality: Death or increased probabilities of death - Morbidity: Illnesses including cancer, malaria, respiratory diseases, headaches, etc.

	Caltrans (2009) guidance	CEQA categories	NEPA as done by Caltrans	ADB (1996)
Hazards	Hazardous materials and waste, and contamination	Hazards and hazardous materials	Hazardous waste and materials	Hazardous chemicals to air, land, and water
Climate	Energy	Greenhouse gas emissions	Energy	Global systems: Changes in weather patterns and global climate, ozone depletion

The Council of Environmental Quality's (CEQ) Regulations for Implementing the Procedural Provisions of NEPA [40 CFR 1500-1508] clarify the requirements by defining direct effects, indirect effects, and cumulative effects.[6] The definitions are as follows:

- Direct Effects. Those effects caused by the action and occurring at the same time and place. [40 CFR 1508.8].
- Indirect Effects. Those effects caused by the action and occurring later in time or farther removed in distance, but still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. [40 CFR 1508.8].
- Cumulative Impacts. Those impacts on the environment, which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. [40 CFR 1508.7].

Table 3 does not include a classification of whether the impacts are direct, indirect, or cumulative as the direct, indirect and cumulative impacts are case specific. It is recommended that analysts classify the potential impacts into direct, indirect or cumulative in the impact identification step. It is important to identify the cumulative impact, especially in the regional

[6] See U.S. Department of Transportation website for more detail: http://www.dot.gov/execorder/13274/workgroups/icireport.htm#97528703.

scale. While some environmental impacts of each individual project in the RTP might appear insignificant, the cumulative environmental impacts from multiple projects in the region and contained within the RTP might be significant. For example, a project may have small impacts on a riparian habitat in the project area, but riparian habitats may be severely limited and threatened in the region and further impacts may be irremediable. Similarly, wildlife movement may be impacted in a region by many individual roadways, but is best understood at the regional scale.

All the impacts listed in Table 3 can occur at different scales (e.g., regional and corridor) of analysis. However, the availability of finely-scaled information may be limited or it may be prohibitively costly to gather at a large scale (e.g. regional scale). For example, at a larger scale impacts on habitat type may be used as a proxy for impacts on a particular species; at a project scale, a level of detail, such as a particular species might be assessed. Since the decisions made at the regional scale are different than those made at the project scale, the way in which information is used in decision-making will change, which will influence the degree of effort warranted to assess impacts. In addition, as the scope widens, expectations for accounting for interdependencies between projects grows (cumulative impacts), though the interdependencies ideally would also be considered at the project scale.

Table 3 lists the major categories of environmental impacts and does not include a detailed breakdown of impacts. Analysts can further breakdown the impacts based on the main categories in Table 3. For example, one way to break biological impacts down would be by referencing the impacted habitat type such as terrestrial, aquatic attributes (or wetlands), then deconstructing that impact:[7]

Example: Proposed road going through vernal pool complex

Wetlands or Aquatic Conditions
- Vernal pools
    - Changes in hydrology
    - Breaking hardpan integrity
    - Changes to vegetation—non-native invasives
    - Filling/altering pool
    - Mortality of threatened vernal pool fairy shrimp, endangered slender orcutt grass

[7] Roberta Gerson at the U.S. Fish and Wildlife Service provided the examples in this section.

Streams
- Sedimentation
- Erosion
  - Salmon
    - Breeding habitat destroyed
      - Recreational and commercial fishing losses
      - Loss of endangered species

Example: Road through late successional mixed conifer/hardwoods forest

Forest ecosystem
- Water quality – runoff, sedimentation, erosion
  - Salmon spawning area – spawning impacts to sedimentation (covering gravel bed)
    - Loss of endangered species; commercial, recreational fishing loss
- Fisher habitat – cutting old growth hardwoods means cutting potential den trees
- Raptors – cutting conifers – nest trees, perching trees
  - Loss of mature trees and stands
    - Timber production value, recreational value-bird watching, hiking
  - Mortality of threatened, rare, endangered species
- Change in forest stand to smaller, denser stands – fire risk
  - Cost of protecting high risk forests
- Increase in deer use in open areas for foraging

Another way to breakdown the impact is to categorize the actual biological attributes that may be impacted by project. Using the forest example above:

Water quality – runoff, sedimentation, erosion

Rare/threatened endangered species – breeding stream for listed salmon

Wildlife – fisher, raptors – change in forest composition = loss of denning and nest trees, higher fire risk due to smaller trees, shrubs, grasses; increase deer use foraging

Rareness of habitat – Last remaining disease-free stand of spruce trees in drainage; damage to roots – leads to disease = loss; or cut down trees = loss

Soils – Soil type that compacts easily – increased runoff, difficulty replanting-change in vegetation.

C.2 Step 2: Screen and categorize the impacts

After the impacts are identified, analysts need to screen the impacts and decide how to evaluate the different types of impacts. Figure 3 illustrates the impact screening and categorizing process. At the impact screening stage, ADB (1996) recommends that if the impact will be fully (or largely) mitigated, the mitigation costs incurred will be included in the regional transportation plan, corridor plan, or project's estimated cost. In fact, this is consistent with SAFETEA-LU and the Caltrans BCA approach to include mitigation cost in the cost of the project (for example, to include the cost of noise abatement in the cost of the project).[8] If mitigation activities are not carried out, the value of the environmental attributes (willingness to pay or willingness to accept) would need to be included as a "disbenefit."[9] In addition, if the impacts are relatively small, they may not warrant further evaluation. However, analysts need to provide their justifications why the magnitudes of those impacts are small.

The EPA Science Advisory Board (SAB) (2009) recommends that the potential effects can be categorized into the following five categories:

Category 1: Effects that can be assessed and monetized using available ecological models and appropriate economic valuation methods, including benefits transfer.

Category 2: Effects that cannot be monetized, but that can be quantified in biophysical terms using available ecological models and for which some indicators of economic benefits exist.

Category 3: Effects that can be quantified in biophysical terms but for which no indicators of economic benefits exist.

Category 4: Effects that can be qualitatively described and generally related to benefits based on available ecological and social science, even if they cannot be quantified.

Category 5: Effects that are likely to generate important non-economic values.

SAB (2009) notes that some effects might fall into multiple categories.

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[8] See Caltrans' website for more detail:
http://www.dot.ca.gov/hq/tpp/offices/ote/benefit_cost/benefits/noise/index.html

[9] At the Caltrans, external impacts are termed "benefits" if the external impacts are positive, and "disbenefits" if the external impacts are negative.

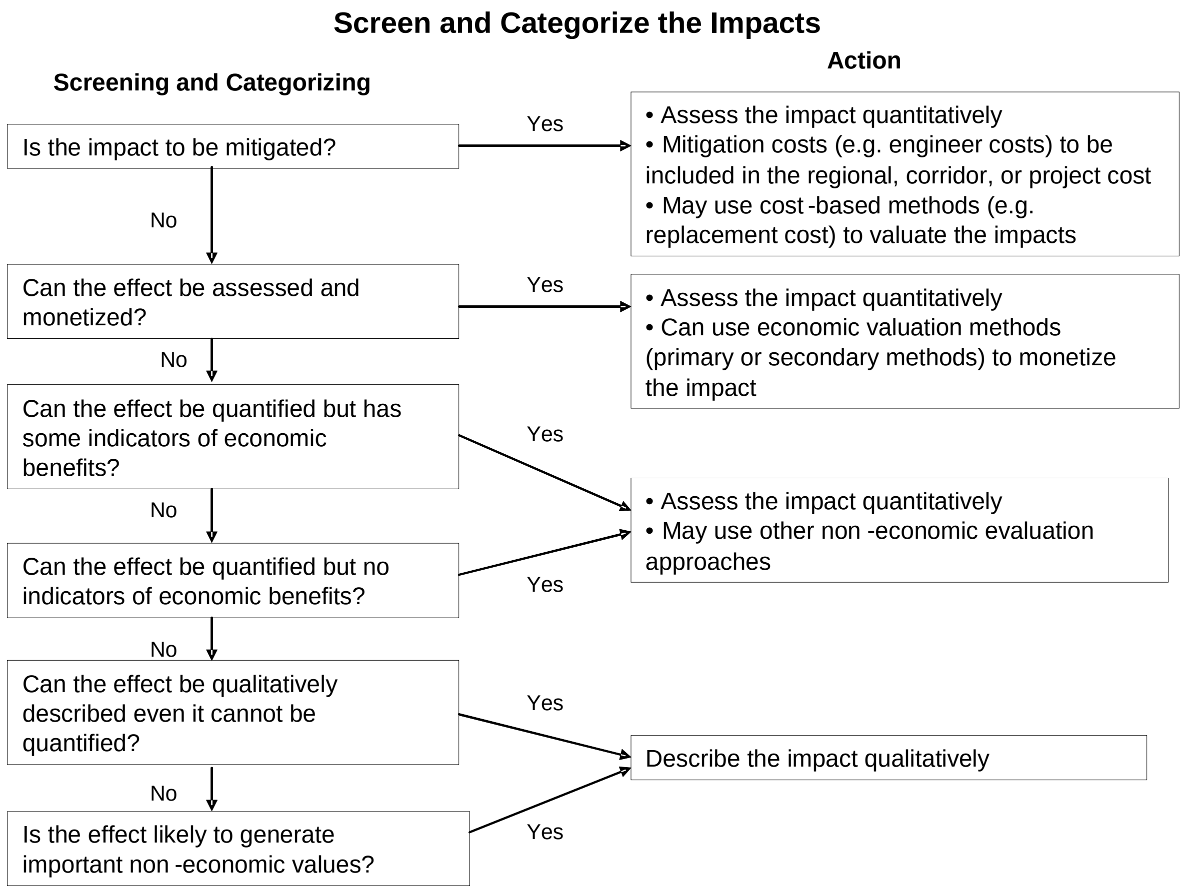

Figure 3. The impact screening and categorizing process.

Figure 3 also illustrates the actions analysts can proceed with after the impacts are screened and categorized. If an impact is to be mitigated, the impact should be assessed quantitatively, and the mitigation costs should be included in the plan or project cost. Cost-based methods, such as replacement cost method, may be used to valuate the impacts. However, cost-based methods should be used with caution (see Section II.D). If an impact is not mitigated, and the impact can be assessed and monetized, the impact can be assessed quantitatively, and economic valuation methods can be used to monetize the impact. If an impact can be quantified, but has limited or no indicators of economic benefits, the impact can still be assessed quantitatively. It may be possible to use other non-economic evaluation approaches discussed in the EPA SAB (2009) (see Section II.B). If an impact cannot be quantified or if an impact is likely to generate important non-economic values, the impact should be describe qualitatively.

C.3 Step 3: Quantify the impacts

This step involves quantifying the impacts that are measurable. Analysts would need to express the impacts in the physical units in order to quantify the magnitude of each impact. To do this, it is important to be able to show a relationship between an impact and a quantifiable well-being or ecological outcome at an appropriate scale. For example, there is an extensive literature on both air pollution production by transportation and the increase in disease and mortality that accompanies that production at municipal and regional scales. Our focus is on environmental conditions, in the context of regions and districts and possibly larger project/plan decision-making. In some cases, quantification might be based upon existing, accepted models of impacts in a region, in other cases, impacts would need to be measured directly.

Impact quantification involves identifying and assessing the magnitude of the stressors and receptors, and it requires data on potential risks, geographical and temporal extents of the impacts, and severity. Impacts quantification requires the expertise from scientists, engineers, and other specialists. Scientists would need to use models, such as dose-response functions, human health risk assessment models, ecological risk assessment models, and ecological models to quantify the impacts. The EPA has provided guidance on the assessment of human health and ecological risks.[10] If impacts are too uncertain for a quantitative assessment, it may be necessary to use qualitative assessment.

However, the physical data would also need to be in a form that is suitable for monetization when analysts carry out an economic valuation study. Bateman et al. (2009) provide an example of the physical data on water quality: 'a reduction of X tons in biochemical oxygen demand (BOD)' in a river. Individuals do not have measurable preferences for BOD. What they have preferences for is more or less water quality. This is the so-called correspondence problem, where the 'object' of preferences does not correspond to the physical measure of the environmental change (Bateman et al. 2002).

A relevant concept in the sustainable transportation literature is the use of indicators as planning tools. An indicator is a variable selected and defined to measure progress toward an objective (TRB 2008). TRB (2008) identifies indicators that can be used for sustainable

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[10] Please see the EPA's National Center for Environmental Assessment for the guidelines for human health and ecological risks assessment: http://cfpub.epa.gov/ncea/cfm/nceaguid_human.cfm and http://cfpub.epa.gov/ncea/cfm/nceaguid_ecological.cfm (accessed February 2010).

transportation evaluation (Table 4). These indicators can be considered as a way to quantify the impacts. Table 4 (starting on the left and continuing to the right) shows impact factors sorted into categories and sub-categories, and coded for utility in various circumstances. A common approach in evaluating impacts or conditions of a system is to create categories for issues of concerns and list indicators that correspond to those categories. The column labeled "Disaggregation" lists the exact metrics that could be used to measure conditions or impacts.

Table 4. Possible sustainable transportation indicators.

Category	**Subcategory**	**Indicator**	**Disaggregation**
Travel Activity	Vehicles	Motor vehicle ownership	By type of vehicle, owner demographics, location
	Mobility	Motor vehicle travel	Trip type, traveler type, travel conditions
	Mode split	Portion of trips by auto, public transit, and non-motorized modes	Trip type, traveler type, travel conditions
Air Pollution Emissions	Emissions	Total vehicle emissions	Type of emission, model, location
	Air pollution exposure	Number of days of exposure per year	Demographic groups affected
	Climate change	climate change emissions (CO2, CH4)	Mode
	Embodied emissions	Emissions from vehicle and facility construction	Type of emission and mode
Noise Pollution	Traffic noise	People exposed to traffic noise above 55 LAeq,T	Demographic group, location, transport mode
	Aircraft noise	People exposed to aircraft noise above 57 LAeq,T	Demographic group, location, transport mode
Traffic Risk	Crash casualties	Crash deaths and injuries	Mode, road, type and cause of collision
	Crashes	Police-reported crashes	Mode, road, type and cause of collision
	Crash costs	Traffic crash economic costs	Mode, road, type and cause of collision

Category	Subcategory	Indicator	Disaggregation
Economic Productivity	Transport costs	Consumer expenditures on transport	Mode, user type, location
	Commute costs (time and money)	Access to employment	Mode, user type, location
	Transport reliability	Per capita congestion costs	Mode, location
	Infrastructure costs	Expenditures on roads, public transit, parking, ports, etc.	Mode, location
	Shipping costs	Freight transport efficiency	Mode, geographic area
Overall Accessibility	Mobility options	Quality of walking, cycling, public transit, driving, taxi, etc.	Trip purpose, location, user
	Land use accessibility	Quality of land use accessibility	Trip purpose, location, user
	Mobility substitutes	Internet access and delivery service quality	Trip purpose, location, user
Land Use Impacts	Sprawl	Per capita impervious surface area	By location and type of development
	Transport land consumption	Land devoted to transport facilities	By mode
	Ecological and cultural degradation	Habitat and cultural sites degraded by transportation facilities	Type of habitat and attribute, location

Category	Subcategory	Indicator	Disaggregation
Equity	Affordability – Transport	Portion of household budgets needed to provide adequate transport	Demographics, especially disadvantaged groups
	Affordability – Housing	Affordable housing accessibility	By demographic group, especially low income and disabled groups
	Basic accessibility	Quality of accessibility for people with disabilities	By geographic area, mode, type of disability
Transport Policy and Planning	Pricing efficiency	Cost-based pricing	By mode, type of cost (road, parking, etc.)
	Strategic planning	Degree to which individual planning decisions support strategic goals	By mode, agency
	Planning efficiency	Comprehensive and neutral planning	By mode, agency
	User satisfaction	User survey results	By group (disabled, children, low income)

USEPA (1996) organizes indicators into three different groups: outcome, output, and activity indicators (Table 5). Outputs are differentiated from outcomes because the former tends to reflect a change in structure (e.g., land affected) and the latter relates more directly to the functional change in response to infrastructure or traffic. Activity refers to the infrastructural or travel change as a result of system management. The relationship to quantification of impacts is that the activities listed lead to the outputs and outcomes that are the basis for quantifying the changes due to transportation projects.

Table 5. Outcome, output, and activity indicators for potential environmental impacts of transportation (Source: EPA, 1996).

Indicators of the Environmental Impacts of Transportation: Highway Transportation			
Activity	**Outcome Indicators**	**Output Indicators**	**Activity Indicators**
	Health of Ecological Results Measure	**Emissions, Habitat Change, or Exposure Measure**	**Infrastructure, Travel, or Other Action Measure**
Road Construction and Maintenance			
Habitat disruption and land take for road and right-of-way	States reporting highway-related wetland losses	Cumulative land area covered by roads	New road mileage and lane mileage constructed
		New land area taken for roadway use	
Emissions during construction and maintenance	Percent of surface waters degraded from land development projects	Changes in surrounding water quality conditions near typical construction site	Acres sprayed with herbicide
		States reporting contamination problems at maintenance facilities	Energy used in construction
Releases of deicing compounds	States reporting degraded wetlands integrity due to salinity	(Data unavailable)	Quantity of road salt used
	States reporting road salting as a significant source of ground water contamination		
Highway runoff	River miles, lakes, and ocean shore miles impaired by urban runoff (not just highways)	Average pollutant concentrations of various metals, suspended solids, and toxic organics in road runoff	Percentage of roads that are paved
		Quantity of oil and grease loading via road runoff	

Activity	Outcome Indicators	Output Indicators	Activity Indicators
	Health of Ecological Results Measure	**Emissions, Habitat Change, or Exposure Measure**	**Infrastructure, Travel, or Other Action Measure**
Road Vehicle Travel			
Tailpipe and evaporative emissions	Cases of chronic respiratory illness, cancer, headaches, respiratory restricted activity days, and premature deaths due to motor vehicle pollution	Quantity of CO, NOX, VOC, SO2, PM, Pb, CO2, CH4, N2O, Benzene, Butadiene, and Formaldehyde released	
Fugitive dust emissions from roads	Cases of chronic respiratory illness, asthma attacks, respiratory restricted activity days, and premature deaths due to particulates associated with motor vehicles	Quantity of fugitive dust (PM10) emitted	
Emissions of refrigerant agents from vehicle air conditioners	(Data unavailable)	Quantity of CFCs, HFCs emitted from all sources	Quantity of CFCs consumed in autos
		Percentage of emissions attributable to motor vehicles	
Noise	Percentage of population exposed to levels of roadway noise associated with health and other effects (1980 only)	Typical noise emissions levels by vehicle type and road type	
Hazardous materials incidents during transport	(Data unavailable)	Type and quantity of material reported released	
Roadkill	Number of animals killed		

Activity	Outcome Indicators	Output Indicators	Activity Indicators
	Health of Ecological Results Measure	Emissions, Habitat Change, or Exposure Measure	Infrastructure, Travel, or Other Action Measure
Motor Vehicle and Parts Manufacture, Maintenance, Support, and Disposal (not for immediate use)			
Toxic releases and other emissions	(Data unavailable)	Quantity of reported releases of toxic chemicals included in TRI database	
		Quantity of CO, NO2, PM10, TP, SO2, VOC released to air	
Releases during terminal operations: tank truck cleaning, maintenance, repair, and refueling	(Data unavailable)	Quantity of VOCs emitted	Number of terminals and types of materials used during terminal operations
Releases during passenger vehicle cleaning, maintenance, repair, and refueling	(Data unavailable)	(Data unavailable)	Percentage of transit agencies that wash bus fleets daily
Leaking underground storage tanks (USTs) containing fuel	States reporting leaking USTs to be a significant source of groundwater contamination	Number of confirmed releases from storage tanks	Number of active petroleum USTs
Scrappage of vehicles	(Data unavailable)	(Data unavailable)	Number of vehicles scrapped, quantity of various materials in vehicle, percentage of mass landfilled
Motor oil disposal	(Data unavailable)	(Data unavailable)	Quantity of used motor oil improperly disposed
Tire disposal	(Data unavailable)	(Data unavailable)	Quantity of used tires landfilled of stockpiled
Lead-acid batteries disposal	(Data unavailable)	(Data unavailable)	Quantity of lead-acid batteries discarded into waste stream

C.4 Step 4: Valuate the impacts

The final step in the valuation process is the valuation of the impacts, quantified in step 3. This includes the outputs and outcomes represented by the various indicators in Table 5. Different valuation methods are available to valuate non-markets goods and services (Section II. B, Table 1). Primary valuation methods require more time and resources investment than secondary valuation method, such as benefit transfer. When time and resources are limited, benefit transfer approach can be used. The discussion on benefit transfer method and the procedures to carry out a benefit transfer study are discussed in Section II.C. The preferred valuation approaches depend also on the needs for accuracy, precision, and completeness of an analysis. For more discussion on accuracy and completeness, please see Section V.A.2.

Though the costs of environmental impacts from the transportation sector have been widely studied in the literature, only limited sets of environmental impacts are evaluated by using economic valuation methods. The available estimates do not fully characterize all costs for all transportation modes (Delucchi and McCubbin 2010). Table 6 shows the quality of estimates of external costs by cost categories (Delucchi and McCubbin 2010). Litman (2009) provides extensive literature review on the costs of environmental impacts from the transportation sector, including air pollution, greenhouse gas emissions, noise, land use, water pollution and waste disposal (Appendix B). Again, it is a limited set of all the potential impacts that are summarized in Table 3.

Table 6. Quality of estimates of external costs by cost category.

	Road	
	Passenger	**Freight**
Congestion delay	Good	Good
Accident	Good	Good
Air pollution, health impacts	Good	Good
Air pollution, other impacts (visibility, agriculture, materials, forestry)	Good	Good
Climate change	Good	Good
Noise	Good	Good
Water Pollution	Poor	Poor
Energy security	Fair	Fair

Source: Delucchi and McCubbin (2010) -

IV Decision Making Process and Scale

A Scale of Process

Decision-making is different at different geographic scales, affecting the types of economic costs and benefits considered, and the types of decisions made. We consider two scales in this report and study – the regional or district scale and the project/local scale. At the District and regional scale, transportation networks are planned, built, and improved in order to facilitate goods and people movement in a large area and between large areas. The local scale may be where ideas for projects originate to populate regional plans. It is also the scale at which projects are built and provide many benefits and costs. There may be emergent impacts to natural processes from regional transportation plan implementation that are not apparent at the local scale (e.g., regional air quality impacts or landscape fragmentation). There may also be benefits from analyzing and planning at the regional scale (e.g., dealing with the system as a network, rather than an assemblage of segments upon projects are carried out).

Matching Decision and Analytical Scales

The process of analysis of economic values corresponding to environmental conditions and transportation consists of either using existing values in the literature ("benefits transfer", Section II.C), or determining the values *de novo*. There are three basic steps to this process: determining likely or known costs and benefits of the transportation system at the decision scale (e.g., district), describing or finding relationships between the transportation costs and benefits and ecological outcomes, and describing a relationship between the ecological outcomes and corresponding economic values (Figure 4A). All three steps would be carried out at the same decision scale, which is roughly equivalent to the same geographic extent, or area, and grain, or resolution.

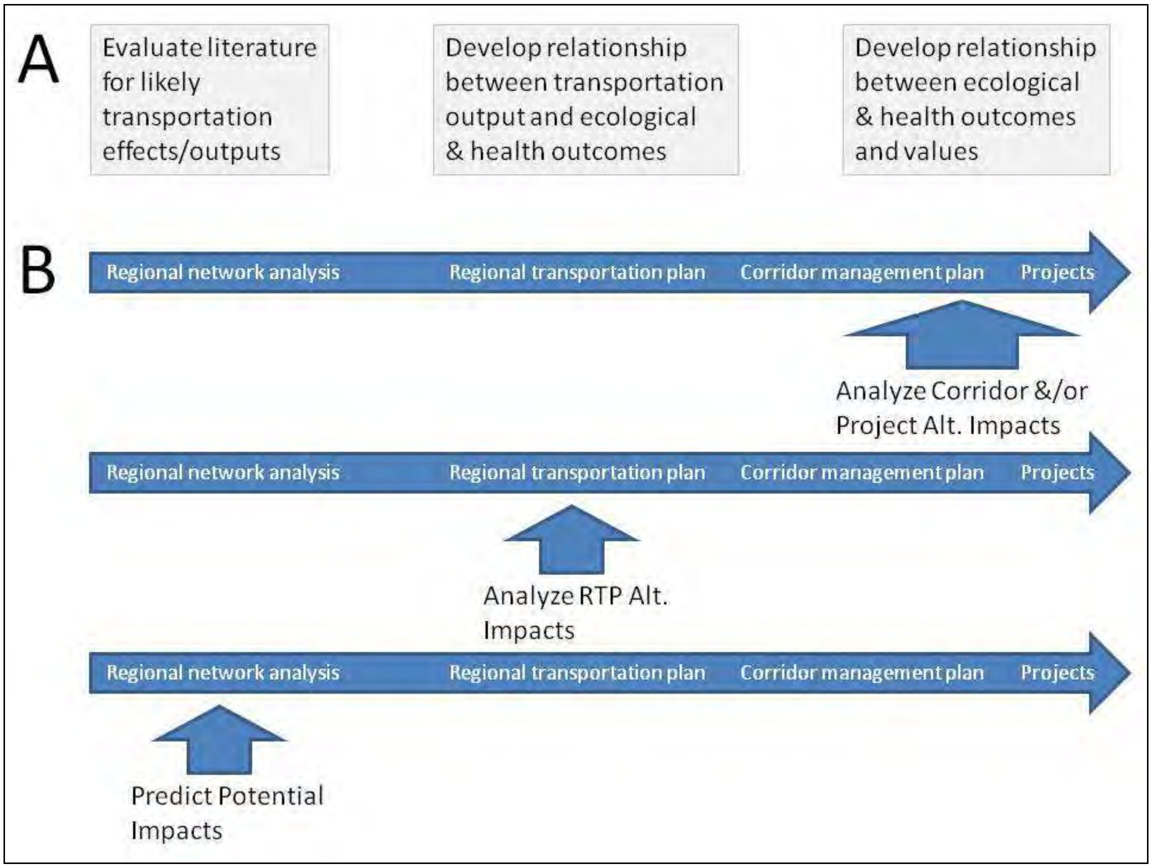


Figure 4. Valuation approaches and decision/geographic scales.

There are many possible decision scales in California, but two common types are regional or district and corridor scales. One analytical approach is to evaluate the entire transportation system within a region as a network with costs associated with each segment, as well as with emergent costs only measurable at this geographic extent (Figure 4B). This analysis can then lead to an optimized regional transportation plan which maintains high total benefits, including high environmental benefits. Finally, the optimized regional transportation plan could inform project development at finer scales, where the projects improve or have a neutral impact on the costs and benefits of the regional network. Paralleling this four step approach are three junctures at diminishing scales at which costs and benefits can be evaluated (Figure 4B). One is in the prediction of potential costs and benefits at the regional scale, the second is analyzing costs and benefits among different alternative regional plans, and the third is analyzing costs and benefits among different corridor and/or project alternatives. Valuation for regional planning may require lower-resolution analysis of impacts and calculation of equivalent values, providing a general but coarse overview. Valuation for corridor or project planning may require higher-resolution analysis of impacts and values in order to select among project alternatives.

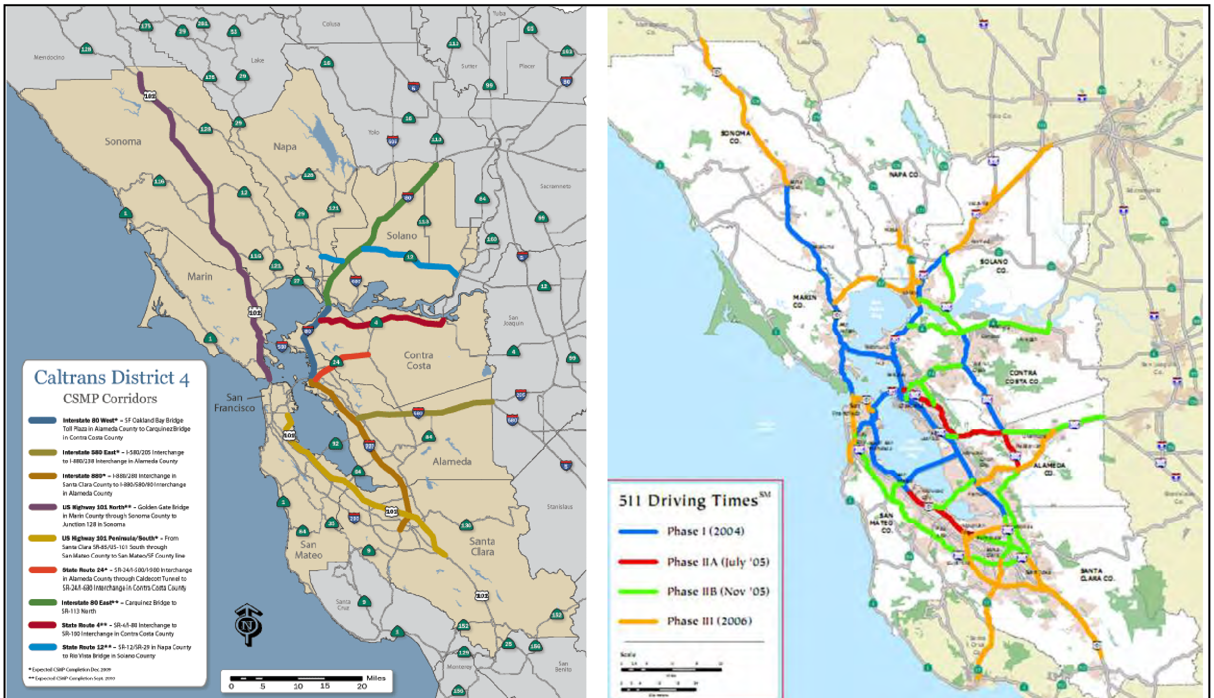
B Decision-Making Scales

Transportation decision-making occurs at many scales. Counties, cities, and metropolitan planning organizations (MPOs) propose specific projects or general changes to Caltrans (or sometimes vice-versa) for various infrastructure associated with the state and interstate highway systems. Caltrans Districts and headquarters pursue specific projects and corridor construction in accordance with short-term needs and longer-term planning. There are many combinations of spatial, institutional, and temporal scales for which decisions are made. Rather than anticipate all of these, we focus on two important scales that are consistent nexuses across all scales – corridors and district/regional planning.

B.1 Districts and regions

MPO regions, such as the San Francisco Bay's Metropolitan Transportation Commission, develop and adopt long-range regional transportation plans (RTPs) that aggregate the transportation system development desires of member municipalities and counties. Caltrans Districts coordinate with MPOs in RTP development as well as pursuing their own objectives for system modification to improve flows of traffic. Figures 5A and 5B show the San Francisco Bay's Metropolitan Transportation Commission (MTC) and Caltrans District 4 areas, which are both the nine-county Bay area region.

Regions are appropriate scales at which to analyze certain impacts from transportation systems (e.g., eco-regional biodiversity and air quality). Through MPOs, they provide institutional frameworks for analysis, decision-making, and programming (Handy, 2010). They are also suitable scales of analysis for almost all surface transportation related impacts and benefits. The air quality impacts of the RTP are analyzed as a part of the conformity process, under federal requirements, but other environmental impacts are not typically analyzed. They are also excellent scales for planning transportation systems as networks of inter-connecting modes and infrastructures. Indeed, it is hard to imagine envisioning and planning for a developed region without analyzing impacts and benefits for a networked transportation system.



A B

Figure 5. Caltrans District 4 (A) and MTC (B) areas.

B.2 Corridors and projects

The corridor scale implicitly includes the project scale and is a sub-unit of the regional and district scales. It is also a scale that Caltrans is using for more of its District planning of infrastructure modification (Figure 5A). At the corridor scale, inter-ties among modes of transportation can be assessed; circulation from one scale of roadway to another can be predicted or measured; and intelligent transportation systems can be planned to modify traffic flows and inform travelers of time of travel and incidents.

Caltrans Districts prepare Transportation Concepts Reports (TCRs), Comprehensive Corridor Plans (CPs) and Corridor System Management Plans (CSMPs) on State Highway System routes.

So far, there has been no significant attempt to include environmental effects of transportation planning at the corridor scale in the various corridor level plans. Environmental impacts are generally dealt with at the individual project scale. However, when considered as a whole, a corridor's use and modification may have important consequences for surrounding natural and human communities. For example, a single freeway corridor may be the primary contributor of fine particles, NOx, polycyclic aromatic hydrocarbons (PAHs), metals, ozone, and other pollutants to surrounding landscapes and neighborhoods. It may also pose the primary barrier to wildlife movement and contributor to wildlife mortality from wildlife-vehicle collision in adjacent natural areas. Planning for this corridor may also provide an important vehicle for reducing the harm from these impacts, an opportunity to remediate current harm and mitigate (avoid, minimize) future harm. The corridor scale also provides an opportunity to organize more multi-disciplinary planning that looks at the whole range of mobility improvements, along with long-term operations and maintenance and the environment and human communities. The corridor-level can provide a framework for collaborative planning and management among various internal Caltrans functions and external partners.

Project development plans are the separate sub-units of corridor plans. If projects are planned first, then aggregated into a corridor plan or CSMP, then the CSMP becomes a highway improvement accounting tool and an opportunity is lost to both account for project costs and benefits and costs and benefits that can only be assessed at the corridor scale. If a CSMP and its attendant impacts analysis is conducted first, then possible project areas and project types can be planned and programmed to suit the transportation and environmental needs of the corridor. In this case, the CSMP can be an accounting tool for both the environmental and circulation/safety costs and benefits for the corridor and by extension, its project are subunits.

C Case Studies

The specific recommended methods appropriate for valuation are tied to the particular place and planning process. This section uses two case studies at different geographic scales (region and corridor) to illustrate the steps in the valuation of environmental attributes in the transportation planning process, which include impact identification, impact screening, impact quantification and valuation. Highway 12 in District 4 (and 10) has been and will be undergoing various modifications to improve circulation and safety. The Sacramento Area Council of

Governments (SACOG) regional transportation plan describes future possible transportation projects in the six-county Sacramento area.

C.1 Highway (State Route) 12

Highway 12 supports interregional, recreational and commuter traffic between the North Bay Area and San Joaquin Valley.[11] Highway 12 is important for recreational travelers destined for Napa and Sonoma counties as well as the Delta. It also serves as a commute corridor and a key interregional goods and movement corridor because of its direct access to I-80.

Caltrans District 4 is developing a CSMP for Highway 12 to cover multiple Corridor Mobility Improvement Account (CMIA) projects planned and programmed for the corridor between Rio Vista and highway 29 (Figure 6). These projects are intended to improve driver safety.

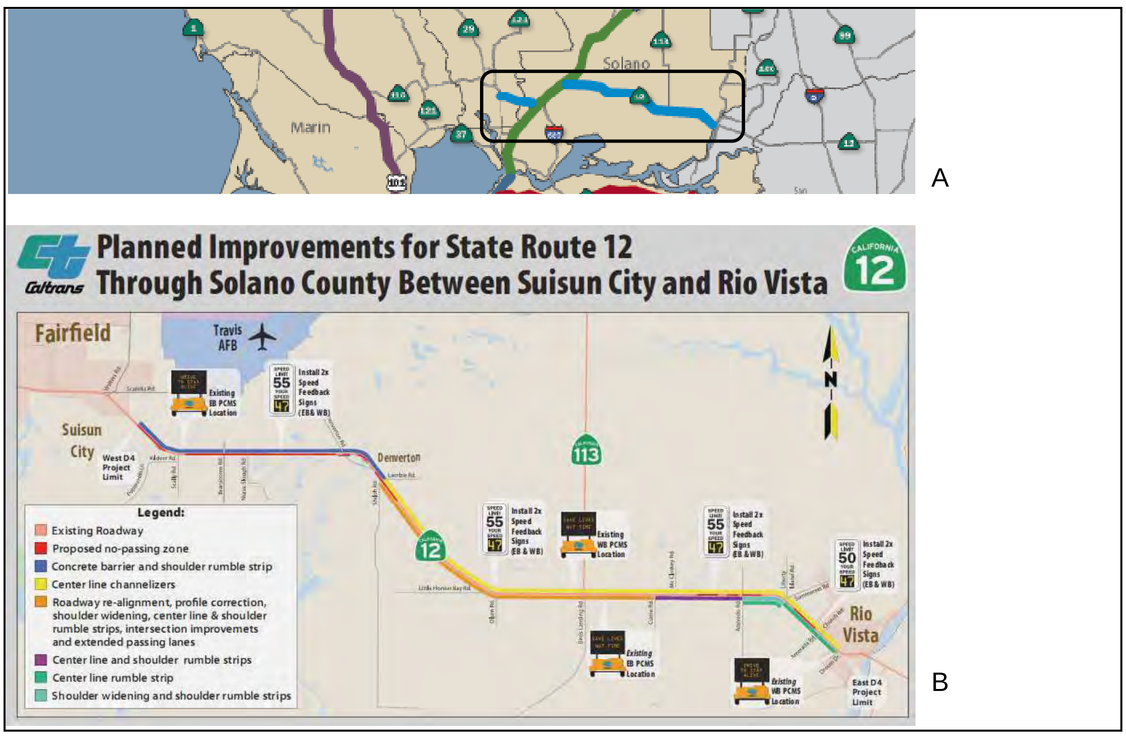


Figure 6. Location of the Highway 12 corridor and project phases.

[11] Detail of the Highway 12 corridor can be found at: http://www.corridormobility.org/Content/10035/SR12.html.

C.2 SACOG Metropolitan/Regional Transportation Plan (RTP)

An RTP covers a larger scale than a corridor plan and usually covers different travel modes and transportation routes, including highways, rail alignments, bicycle trails, state routes, roads, and Caltrans rights-of-way. The environmental impacts from each travel mode are different. The valuation of environmental impacts within a RTP would involve a broad scope of different transportation activities/travel modes. Valuation for regional planning may require lower-resolution analysis of impacts, providing a general but coarse overview.

The SACOG Metropolitan Transportation Plan (MTP) is a 28-year plan for transportation improvements in the six-county region based on projections for growth in population, housing and jobs (Figure 7).[12] This section illustrates how the valuation steps could be used in a regional transportation plan, such as the SACOG MTP. How the valuation information could improve decision-making process will be discussed in Section V.C.1.

Figure 7. SACOG region. -

[12] See SACOG's MTP website for more detail: http://www.sacog.org/mtp/.

C.3 Valuation process cases

The following examples are used to illustrate the valuation process discussed in Section III.C.

Step 1: Identify potential environmental impacts

The first step is to identify the potential environmental impacts. This step uses the existing methods from the transportation agency as a source of information about potential impacts. Analysts could refer to Table 3 as a way to organize the potential impacts. A regional transportation plan and a corridor plan may result in the environmental impacts described below. Please note that impacts on the list can be both the actual and potential impacts. The list is intended to illustrate the concepts presented in the valuation steps, and it does not present a comprehensive list and the detail breakdown of all the potential impacts.

Highway 12 – Identifying potential environmental impacts

	Potential impacts
Biological	Transportation projects could affect wildlife and biodiversity Habitat fragmentation/loss of habitat connectivity
Water	Highway runoff affects aquatic ecosystems Highway runoff could cause groundwater pollution Highway runoff could affect surface water quality Road construction could affect water quality Road construction projects could affect/degrade wetlands
Land	Corridor projects could affect farmlands
Air	(The health impact of air pollution could be listed in the "Health" category.) Changes in visibility due to particulates (PM10)
Noise	Noise effects on the use of adjacent habitats[13] Noise impacts can affect property values
Community	Loss of recreation and ecotourism opportunities if road projects degrade habitats

[13] Though lots of factors affect property values, noise impacts on property values are used extensively in literature to estimate the economic value of noise impacts. Please see the examples in the noise impacts section on the studies relating noise impact to property values.

Community cont'd.	Visual impacts (for example, effects to vistas along highway routes in rural areas are impacts associated with highway improvements such as proposed crash cushions or guard rails). Social/cultural impacts due to land use change/new land area impacted by transportation corridor use
Health	Changes in mortality and morbidity from air pollution Changes in mortality and morbidity from PM10 Changes in morbidity from noise
Hazards	Herbicide, or other hazardous chemicals used in road maintenance Hazardous materials incidents during transport Toxic releases from motor vehicle
Climate	Global climate change due to greenhouse gas emissions

Analysts should also consider which of the above potential impacts are direct, indirect or cumulative impacts. For example, habitat fragmentation/loss of habitat connectivity by roads may be a direct and/or cumulative impact.

SACOG MTP – identifying potential environmental impacts

	Potential impacts
Biological	Habitat fragmentation/loss of habitat connectivity Highway/construction runoff affects aquatic ecosystems, fish and other aquatic species Road/rail construction projects could affect/degrade wetlands, aquatic, or riparian habitats, freshwater marsh, vernal pools and oak woodlands or other natural vegetation/habitats Road/rail projects could affect wildlife and biodiversity
Water	Highway/construction runoff could cause groundwater pollution Highway/construction runoff could affect surface water quality Road/rail projects could affect floodplain through hydraulic and habitat fragmentation
Land	Conversion of prime farmland, unique farmland, or farmland of statewide importance to non-agricultural use The MPT and the residential and employment development would result in an expansion of urban areas and the change in the neighborhoods characteristics in the region

Air	(The health impact of air pollution could be listed in the "Health" category.) Changes in visibility due to particulates (PM10)
Noise	Noise impacts can affect property values Noise effects on the use of adjacent habitats
Community	Loss of recreation and ecotourism opportunities if road/rail projects degrade habitats Aesthetics impacts due to the presence of roads/rail Social/cultural impacts due to land use change due to transportation projects
Health	Changes in mortality and morbidity from air pollution Changes in mortality and morbidity from particulates (PM10) Changes in morbidity from noise from both highway and transit operations
Hazards	Herbicide, or other hazardous chemicals used in road maintenance Hazardous materials incidents during transport Toxic releases from motor vehicle
Climate	Global climate change due to greenhouse gas emissions

As mentioned in the Highway 12 example, analysts should also consider which of the above potential impacts are direct, indirect or cumulative impacts.

Step 2: Screen and categorize the impacts

In this step, analysts need to screen and categorize the impacts to determine how to evaluate those impacts. These impacts and the screening process will be necessarily different at the different project, corridor, and regional scales, though the regional process could use information from the finer project and corridor scales. The process is illustrated in Figure 3.

Highway 12

Impacts that could be mitigated

If a decision-making agency decides to mitigate the impacts, mitigation costs (e.g. engineer costs) should be included in the project cost. Cost-based methods (e.g. replacement cost) may also be used to valuate the impacts.

- Noise impacts can be mitigated, for example, by building sound muffling structures.

- Road construction projects could affect/degrade wetlands – mitigation costs include for example, acquisition costs of land, and the cost of long term management of that land for the conservation of the species.

If these impacts are not mitigated, they should be included in one of the following categories.

Effects that can be assessed and monetized using available ecological models and appropriate economic valuation methods, including benefits transfer.

- Changes in mortality and morbidity from air pollution
- Changes in mortality and morbidity from particulates (PM10)
- Changes in morbidity from noise
- Noise impacts (if not mitigated)
- Road construction projects could affect/degrade wetlands (if not mitigated)
- Changes in visibility due to particulates (PM10)
- Loss of recreation and ecotourism opportunities if road projects degrade habitats
- Global climate change due to greenhouse gas emissions

Effects that cannot be monetized, but that can be quantified in biophysical terms using available ecological models and for which some indicators of economic benefits exist.

- Transportation projects could affect wildlife and biodiversity
- Road construction could affect water quality
- Herbicide, or other hazardous chemicals used in road maintenance could affect near-road biota, water and air quality
- Road construction could affect water quality
- Toxic releases from motor vehicle
- Hazardous materials incidents during transport
- Noise effects on the use of adjacent habitats
- Habitat fragmentation/loss of habitat connectivity

Effects that can be quantified in biophysical terms but for which no indicators of economic benefits exist.

- Transportation projects could affect wildlife and biodiversity
- Noise effects on the use of adjacent habitats
- Habitat fragmentation/loss of habitat connectivity

Effects that can be qualitatively described and generally related to benefits based on available ecological and social science, even if they cannot be quantified.

- Highway runoff affects aquatic ecosystems (it is difficult to quantify the effects contributed by the transportation activities due to the nature of non-point source pollution).
- Highway runoff could cause groundwater pollution (it is difficult to quantify the effects contributed by the transportation activities due to the nature of non-point source pollution).
- Highway runoff could affect surface water quality (it is difficult to quantify the effects contributed by the transportation activities due to the nature of non-point source pollution).

Effects that are likely to generate important non-economic values.

- Social/cultural impacts due to land use change/new land area impacted by - transportation corridor use -

SACOG MTP

Impacts that could be mitigated

If a decision -making agency decides to mitigate the impacts, mitigation costs (e.g. engineer costs) should be included in the project cost. Cost-based methods (e.g. replacement cost) may also be used to valuate the impacts.

- Noise impacts can be mitigated, for example, by building sound muffling structures.
- Road/rail construction projects could affect/degrade wetlands, aquatic, or riparian habitats, freshwater marsh, vernal pools and oak woodlands or other natural vegetation/habitats

If these impacts are not mitigated, they should be included in one of the following categories.

Effects that can be assessed and monetized using available ecological models and appropriate economic valuation methods, including benefits transfer.

- Changes in mortality and morbidity from air pollution.
- Changes in mortality and morbidity from particulates (PM10)
- Changes in morbidity from noise from both highway and transit operations
- Noise impacts (if not mitigated)

- Road/rail construction projects could affect/degrade wetlands, aquatic, or riparian habitats, freshwater marsh, vernal pools and oak woodlands (if not mitigated)
- Loss of recreation and ecotourism opportunities if road/rail projects degrade habitats
- Changes in aesthetics, material damages due to particulates (PM10)
- Aesthetics impacts due to the presence of roads/rail
- Global climate change due to greenhouse gas emissions

Effects that cannot be monetized, but that can be quantified in biophysical terms using available ecological models and for which some indicators of economic benefits exist.

- Road/rail projects could affect wildlife and biodiversity
- Herbicide, or other hazardous chemicals used in road maintenance
- Road/rail projects could affect floodplain
- Toxic releases from motor vehicle
- Hazardous materials incidents during transport
- Noise effects on the use of adjacent habitats
- Habitat fragmentation/loss of habitat connectivity

Effects that can be quantified in biophysical terms but for which no indicators of economic benefits exist.

- Road/rail projects could affect wildlife and biodiversity
- Noise effects on the use of adjacent habitats
- Habitat fragmentation/loss of habitat connectivity

Effects that can be qualitatively described and generally related to benefits based on available ecological and social science, even if they cannot be quantified.

- Highway/construction runoff affects aquatic ecosystems, fish and other aquatic species (it is difficult to quantify the effects contributed by the transportation activities due to the nature of non-point source pollution).
- Highway/construction runoff could cause groundwater pollution (it is difficult to quantify the effects contributed by the transportation activities due to the nature of non-point source pollution).
- Highway/construction runoff could affect surface water quality (it is difficult to quantify the effects contributed by the transportation activities due to the nature of non-point source pollution).

Effects that are likely to generate important non-economic values. -

- Social/cultural impacts due to land use change due to transportation projects
  - conversion of prime farmland, unique farmland, or farmland of statewide importance to non-agricultural use
  - The MPT and the residential and employment development would result in an expansion of urban areas and the change in the neighborhoods characteristics in the region

Steps 3 and 4: Quantify the impacts and valuate the impacts

The next steps are to quantify and valuate the impacts. The following discussion focuses on *the impacts that can be assessed and monetized* (impacts that are listed under the category "effects that can be assessed and monetized using available ecological models and appropriate economic valuation methods" in Step 2). The valuation methods discussed below are primary valuation methods, which require more time and resources investment than secondary valuation method. These are the commonly used methods and the list of methods is not exhaustive. Impacts would often be quantified differently at different scales and it is critical that it be done correctly so as not to over or under-estimate impacts. Because there are dozens of different impacts, some of which are only expressed at certain scales, no attempt is made here to anticipate the scale dependencies of individual impacts. This would presumably fall under the expertise of the Caltrans environmental employee or contractor.

<u>Air pollution: human health impacts</u>

Air pollutants affect both human health and environmental attributes (e.g. biodiversity). Since the cost to human health represent the major part of the economic value due to changes in air pollution levels, the costs of human mortality and morbidity are often used to represent the value of the changes in air pollutants.

Quantification

The quantifications of air pollution impacts on health proposed by the USEPA (1996) include cases of chronic respiratory illness, cancer, headaches, respiratory restricted activity days, and premature deaths due to motor vehicle pollution.

Delucchi and McCubbin (2010) outline the steps in quantifying the health impacts of air pollutants due to emissions from transportation sources:

1. - Estimate the relationship between changes in transportation activity (e.g. vehicle miles of travel) and changes in emissions of air pollutants.

2. - Estimate the relationship between changes in emissions and changes in air quality; this can be done with sophisticated three-dimensional atmospheric chemistry models, or, more crudely, with simple functions relating air quality to emissions.

3. - a) Estimate the relationship between changes in air pollution and changes in human exposure to air pollution.

3. - b) Estimate the relationship between changes in exposure and changes in health impacts such as mortality, chronic illness, and asthma attacks. This step often is combined with step 3a, so that one estimates the relationship between changes in air pollution and changes in health impacts.

4. - Estimate the relationship between changes in health impacts and changes in economic welfare. This step typically is called "valuation," because the objective is to estimate the dollar value of the physical health impacts.

The California Air Resources Board (ARB) also provides guidance on quantification of health impacts of air pollution exposure.[14] ARB's EMFAC model is used to calculate emissions rates from all motor vehicle operating on highways, freeways, and local roads in California.

Valuation

The economic approaches for estimating monetary values for changes in health include, for example, cost of illness (wage lost due to lost productivity and medical costs) and human capital approach (lost contribution to national income due to mortality and morbidity). Though the valuation methods of health impacts are not the focus of this report, the values of human health is an important part in the valuation of environmental impacts.

Examples: Studies that estimate the health impacts from air pollutants

As the main social costs of air pollution are negative human health impacts. Many studies use the health costs to estimate the value of air pollution. Deng (2006) describes the three steps to evaluate motor vehicle-related health costs in monetary term: 1) assess the exposure of the residential population; 2) conduct an epidemiological study to evaluate the exposure-response

[14] Please see the California Air Resources Board for more detail: http://www.arb.ca.gov/research/health/qhe/qhe.htm (Accessed on March 14, 2010).

relationship between air pollution and effects on health; 3) convert the quantified health impacts into monetary terms. Deng (2006) uses two approaches to estimate the monetary values of the health effects: willingness-to-pay (WTP) and human capital methods. WTP, such as contingent valuation and wage risk studies, assess the amount people are willing to pay to reduce the risk of illness or death. Deng (2006) adopts the human capital approach, which is a cost approach, used by the World Bank. The cost approach values mortality and morbidity impacts according to the loss in income plus out-of-pocket expenditure. Small and Kazimi (1995) attempt to measure the costs of regional air pollution from motor vehicles. Their estimates measure the health costs from particulate matter and ozone. They discuss some of the analytical and empirical issues involved in estimating such numbers, and provide some estimates for the Los Angeles region under a variety of alternative assumptions. See more examples in the literature in Appendix B.

Air pollution: Visual impacts

Other than health impacts, air pollutants, such as particulates can have visual impacts due to the change in visibility level.

Quantification

The visual impacts of air pollution can be quantified in different ways. Visibility level can be used to represent the emission level of particulates. It is important to quantify the impact in a way that can be used in economic valuation models (see discussion in Section III.C.3).

Valuation

Both hedonic model and stated preference methods can be used to valuate the visibility due to air quality at both regional and corridor scale. To apply the hedonic model, there must be variation in the visibility levels in order to examine the public's willingness to pay for visibility as revealed residential properties sale prices. This method would require dataset for visibility levels, residential sale prices, and housing, location, and socio-economic characteristics. The value estimates from the corridor scale may not be added up to obtain the value for the regional scale since impact zones of air pollutants are likely to be larger than the corridor boundaries. Hence, the visual impact zones due to air pollutants from different corridors may be overlapped.

To apply the stated preference methods, respondents can state their willingness to pay to have - a certain visibility level. This can be done, for example, by showing respondents pictures of different visibility levels.

The data requirement and the procedures for both the hedonic and stated preference methods are discussed in Section II.B.1.

Examples: Studies that estimate the health impacts from air pollutants

A number of studies use hedonic models to valuate air pollutions. For example, Delucchi et al. (1996) apply a hedonic model from Smith and Huang (1995) to estimate the visibility cost of all anthropogenic total suspended particulate matter (TSP) pollution, and of motor-vehicle TSP pollution in every county in the U.S. in 1990. Smith and Huang (1993) examined 167 hedonic models of the marginal willingness to pay for reducing particulate matter in the air, and their meta-analysis relies on 86 studies. Their results show that market conditions and the procedures used to implement the hedonic models were important in explaining variations in the values individual studies produced. Stated preference is also a common approach to valuate air pollution impacts. Wardman and Bristow (2004) use conjoint analysis (a stated preference method) to estimate households' valuations of noise and air quality of residential choice in Edinburgh. They compare the stated preference approach with the open-ended form of contingent valuation method. Their results show that the open-ended contingent valuation method provides low values than the stated preference approach. Ortúzar and Rodríguez (2002) estimated the WTP for reducing the amount of atmospheric pollution associated with transport projects in a group-based residential location context in Santiago, Chile by using a stated preference ranking experiment. See more examples in literature in Appendix B.

<u>Noise Impacts – human impact[15]</u>

Noise can affect property values, although it is somewhat subjective and depends on the area and the real estate market. The areal extent and magnitude of the effect will depend on vegetation type, topography, prevailing wind direction and speed, humidity, vehicle types, and road surface. Hedonic method to relate noise level and property values is a widely used approach to evaluate the noise impact (see the examples in literature below).

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[15] Please note that the noise impact discussed here pertains only to human health and welfare. The noise effects on the use of adjacent habitats are grouped under the category of effects that can be quantified in biophysical terms, which may need to use other non-economic valuation methods to evaluate the impacts.

Quantification

The recommended method to quantify noise impacts by the EPA is the percentage of population exposed to levels of roadway noise associated with health and other effects (EPA 1996). The TRB (2008) proposes to use people exposed to traffic noise above 55 LAeq, T[16] as a way to quantify.

Valuation

Noise is a local impact and the affected receptors will be within a defined range within a corridor. As noise can affect property values, hedonic model is a commonly used method. To conduct a hedonic property value study, analysts need to collect the data on the transactions of the residential properties, and the different noise levels in the study area. The data requirement and the procedures are discussed in Section II.B.1. As noise is a localized impact, the value of noise impacts at corridor scale can be aggregated to regional level.

Examples: Studies that estimate the noise impacts

Both stated preference and revealed preference methods can be used to estimate the value of noise impact. Hedonic model is a widely used approach for traffic noise. Navrud (2002) provides an overview of the economic valuation of noise undertaken for the European Commission, and Vainio and Paque (2002) provide a summary of the discussion. In the report, Navrud comments that the main strength of hedonic model is that it is based on the actual behavior in the housing market where individuals willingness to pay (WTP) for noise and other environmental characteristics of the house can be observed. The general weakness is that the implicit price of the environmental factor (e.g. noise impact) is very sensitive to modeling decisions and the conditions in the local housing markets (Navrud 2002). Navrud (2002) also suggests that one reason for the relatively few contingent valuation studies on noise could be the difficulties in constructing a good survey for valuing noise level reductions. Bue Bjørner (2004) comments that the disadvantages associated with the hedonic model is that traffic noise is positively correlated with other disturbances from traffic, and it is likely that the hedonic model provides an upward biased estimate of the value of noise reduction. Bue Bjørner (2004) comments that contingent valuation method may produce too high an estimate of willingness to pay, because of its hypothetical nature. Delucchi et al. (1996) also have a comparison between the contingent valuation and hedonic methods.

A large number of studies use hedonic model to estimate the value of traffic noise. For example, Kim, Park, and Kweon (2007) use a hedonic model to estimate the value of traffic

[16] 55 LAeq, T is a defined acceptable threshold level.

noise on property values in Seoul, Korea. They use zone-based data that includes traffic noise levels, official land price, land use classification, distance to roadways, type of nearby roadway facilities, and traffic characteristics. Bellinger (2006) uses a hedonic model to provide a property value-based estimated of the dollar cost of train horn noise in a residential neighborhood in a small town in Pennsylvania. Cushing-Daniels and Murray (2005) use a hedonic model to investigate the tradeoff between housing values and railroad safety due to the noise from train whistles in Wisconsin. Brons et al. (2003) provide an overview of studies on the economic valuation of railway noise. They summarize the dollar values of railway noise impacts in Europe by using different evaluation methods, including hedonic model, contingent valuation and abatement costs approach. Johnson and Button (1997) conduct a meta-regression assessment of 18 economic studies deploying hedonic models. Their result suggests low overall degree of explanation for variations in the noise nuisance values. They conclude that there is little justification for applying benefit transfer procedure for their case from their examination of a range of values obtained for noise nuisances associated with airports.

Stated preference methods are also commonly used in the valuation of noise impacts. For example, Arsenio, Bristow, and Wardman (2006) use the stated choice method to valuate the road traffic noise. Stated choice is a stated preference method in which non-market goods are assessed relatively to each other and not in absolute amounts as with contingent valuation (Sælensminde 1999). In the Arsenio, Bristow, and Wardman (2006) study, households rated the perceived noise levels associated with different apartments. Households were asked to choose between apartments with different level of traffic noise, view, sunlight and cost. Stated choice models were then developed on both perceived and objective measures of traffic noise. They found that there is considerable systematic variation in valuations according to income level, household composition and exposure to noise. In their study, the stated choice models based on perceived noise are superior to the one base on objective measures of noise. Bue Bjørner (2004) uses a combination of a socio-acoustic survey on self-reported noise annoyance and a contingent valuation questionnaire to estimate the willingness to pay for noise reduction for urban residents living in Copenhagen. Carlsson, Lampi, and Martinsson (2004) analyze the marginal willingness to pay for changes in noise levels related to changes in the volume of flight movements at a city airport in Stockholm by using a choice experiment. Sælensminde (1999) use stated choice approach to estimate the values of noise, air pollution and carbon dioxide in Norway. Sælensminde (1999) acknowledges the uncertainty in the study.

Delucchi and Hsu (1996) estimate the total external damage cost of direct motor-vehicle in the U.S. in 1990. In their model, the external damage cost is equal to dollars of damage per excess decibel, multiplied by the annualized value of housing units exposed to motor-vehicle noise above a threshold, multiplied by the density of housing units exposed to motor-vehicle noise above a threshold, multiplied by the amount of motor-vehicle noise over a threshold, multiplied by a scaling factor to account for costs in non-residential areas.

Recreation Impacts

Quantification

Environmental impacts of a recreational site can change visitors' demand for visiting the site. Quantification of an impact depends on the types of environmental conditions or attributes in question.

Valuation

Transportation projects along the corridor or in a region can affect the environmental quality or habitats, and travel cost to a recreation site. Recreation demand models, including travel cost and travel cost RUM, can be used at both the regional and corridor scales to valuate the recreational impacts due to change in environmental quality or habitats at a recreation site. Recreational values of an environmental quality of a location can be derived from the information on the expenditures incurred to visit. Analysts would first need to identify and define the recreation sites to be studied, for example, a wildlife refuge or a state recreation area. The required data and the steps in conducting a recreation demand method are described in Section II.B.1.

Biodiversity or special status species impacts[17]

A regional transportation plan and a corridor plan can affect biodiversity due to an alteration or a loss of habitat, and degradation of habitats through pollution.

Quantification

Quantification of biodiversity impacts is often challenging due to the complex relationship between the biodiversity and habitats change. Some indices can be used as biodiversity indicators, for example, species richness, number or percent of endemic species, and number

[17] Special status species cover federal, state, and other rare species categories different agencies use. Biodiversity and special status species are different impacts, but they are grouped in the same heading in the example here for the purpose of the discussion of economic valuation methods. Both biodiversity and special status species impacts can be valued by using stated preference methods.

or percent of threatened and endangered species. Estimation of biodiversity impacts may - require extensive field research and computer modeling because of the scientific uncertainty about the effects of regional and corridor transportation plans on biodiversity.

Since measuring the level of impacts on special status species is difficult, the courts have agreed that it is appropriate for the U.S. Fish and Wildlife Service to use other criteria other than number of species impacted. Often used for measurements to species are associated with physical environmental impacts such as number of acres, number of ponds, acreage of pools, number of host plants, feet/miles of streams, number of nest or den trees, etc.[18]

Valuation

Biodiversity has both use and nonuse values, such as existence and bequest values. Use values reflect recreational opportunities (hunting, fishing, birding, wildlife photography), which can be estimated by recreation demand models. Stated preference methods can also be used to estimate the use values.

Non-use values (e.g., the importance of stewardship) are much more controversial to measure, both because of the deeply held moral values often expressed and for technical reasons such as choosing appropriate discount rates. These values are usually estimated by stated preference methods.

At a corridor scale, transportation projects may involve fewer species along the corridor than at a regional scale. A stated preference survey at a corridor scale, for example, could ask the respondents their willingness to pay to support the conservation of a particular species or species groups (e.g., grassland birds). At a regional scale more species are involved. The survey could ask respondents their willingness to pay to support regional habitat conservation efforts instead of a particular species as in the corridor case. See Section II.B.2 regarding the data requirement and the steps in conducting a stated preference method.

Examples: Studies that estimate the species values

Richardson and Loomis (2009) point out that one of the most accepted methods used to estimate the TEV provided by species is the contingent valuation method. They conduct a meta-analysis of studies using contingent valuation method to value threatened, endangered and rare species. They summarize the estimated values of a number of threatened, endangered and rare species from 31 studies (see Appendix B).

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[18] Personal communication with Roberta Gerson at the U.S. Fish and Wildlife Service.

Global Climate Change Impacts

Transportation sector is one of the contributors of greenhouse gases (GHG) emissions. The Intergovernmental Panel on Climate Change (IPCC) suggests that there is strong evidence that most of the warming observed over the last 50 years is attributed to human activities (IPCC Synthesis Report 2001). The social costs of GHG emissions cannot be overlooked.

Quantification

To estimate the costs of GHG emissions, the volume of GHG emissions needs to be estimated from the existing condition and for each proposed change in condition (additional traffic). GHG emissions can be expressed in tons of CO2 equivalent (t CO2). The total GHG emissions at a regional scale may be simply the sum of all corridor emissions considered individually, unless alternative regional network modifications confer a reduction or increase in traffic speed and frequency of congestion, in which case the regional total may be more or less than the sum of separately-measured corridors.

Valuation

Many studies estimated the cost of per ton CO2 emissions (Appendix B). One can also use carbon prices on carbon markets to estimate the cost of a ton of CO2. The most established carbon market is the European Union's Emissions Trading Scheme, where GHG is denominated in a ton of CO2 equivalent and is referred to as European Allowance (EUA). The transaction volume and price of carbon can be obtained from a carbon trading platform.

Monetizing GHGs is more complex, but proposed carbon markets and a rapidly growing literature on climate-change economics will undoubtedly provide new tools. Policy developments, such as proposed national and international climate legislation and treaties, and development of procedures under California law (e.g., AB 32 and SB 375) will undoubtedly make climate-change economics a more important facet of future transportation planning.

Valuation Results -

When the environmental valuation results are incorporated in the regional, corridor or project analyses, analysts should exercise cautions when adding the different values together. Analysts need to ensure the environmental attributes and ecosystem services are mutually exclusive when aggregating the values of those environmental attributes. As mentioned in Section II.F.4, willingness to pay for environmental benefits is likely to be non-additive, so that a stated willingness to pay a small fee, either to protect wildlife or for cleaner air does not imply that a higher fee to do both would be accepted. It is important to define and sort out the different environmental attributes and ecosystem services to be valued.

V Implementation Plan

A General Guidelines for the Implementation of Environmental Impact Analysis and Valuation

Environmental impact analysis and valuation is part of the decision making process and the goal is to provide information for making policy choices. In this section we discuss the roles of valuation and Benefit Cost Analysis (BCA) and implications of the decision context, including the necessity and sufficiency of BCA as well as considerations of accuracy and completeness. We conclude with general guidelines for the implementation of valuation and BCA, including expectations for practice, reporting and quality assurance.

A.1 The role of valuation and BCA

Although this report develops a framework for incorporating BCA more fully in transportation planning it should be acknowledged that BCA is neither necessary nor sufficient for making effective corridor or regional transportation choices. Ethical considerations and institutional constraints may be considered alongside economic assessments. Alternatively, existing tools may prove insufficient for any credible valuation in a particular context, motivating the use of alternative methods.

In general however, BCA provides a powerful structure for synthesizing and comparing disparate information and as such can serve to enhance "the process and, hence, the outcome of policy analysis" (Arrow et al. 1996, p. 201). Of course, since the focus of BCA is on characterizing net social benefits, the approach should increase the efficiency of transportation decisions. While BCA encourages consideration of this economic "bottom line", the value of conducting a formal analysis extends beyond this simple metric. BCA can inform questions of equity by identifying the probable winners and losers of decisions, characterize the effect of uncertainty on estimates of welfare and provide a structure to understand the value of new information (Hahn and Dudley, 2007; Stokey and Zeckhauser, 1978; Raiffa, 1970). The framework can highlight important shortcomings in current understanding and make it easier to perceive the degree of sensitivity of results to assumptions and uncertainties (Viscusi and Hamilton, 1999).

A.2 Managing tradeoffs between cost and the accuracy or completeness of an analysis

Since it is costly to transition from benefits transfer to primary valuation techniques and to increase either the scope or the amount of data used in valuation, it is natural to ask to what length accuracy, completeness and primary methods should be pursued. Primary revealed and stated preference methods can be customized to the particular location and set of environmental changes to be considered. However, these methods are both time and resource intensive, typically taking at minimum several months to complete. Costs will be context and methodology specific. For example, the cost of a stated preference study will depend primarily on the survey design, including sample size, interview mode, interviewer, survey complexity and spatial distribution of sample points (Bateman et al. 2002, p. 69). Each valid and completed questionnaire could cost $50 to $100.[19] The costs include, for example, administering the survey, survey design and development, and utilizing a focus group to pre-test a survey. Additional costs include procuring technical expertise to conduct the study. Stated preference surveys can be particularly time-intensive to design, pre-test, administer and analyze.[20] Alternatively, a benefit transfer approach can offer substantial time and monetary savings over primary methods. However, the quick and rough estimates provided may vary widely in their accuracy at the project, corridor, or regional scales.

Since the desirable level of accuracy and completeness can vary widely depending on the context, in lieu of overly-simplified rules we next discuss the thought process for establishing the level of resources to devote to BCA. The primary utility of assessing and valuing the environmental impacts of potential actions is to generate and organize information that will support better decisions. Therefore, it is important to consider the manner in which an additional unit of effort devoted to BCA has the potential to change a planning decision and what the value of that better-informed decision might be. Before discussing a transportation planning decision-making context in particular we outline a concrete classic example from Fisher et al. (1972) of an instance in which a relatively “quick and dirty” valuation approach was sufficient given the particular decision to be made.

In the early 1970’s, the Snake River in Hells Canyon along the eastern Oregon border was being considered for placement of a dam. This region is a site of significant natural beauty and recreation value while also featuring significant hydro-electric potential. One estimate of the

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[19] Personal communication with Dr. Dan Lew at the National Oceanic and Atmospheric Administration.

[20] For a detailed discussion of survey design and implementation see Dillman (2007).

annual net benefits of locating a hydro-electric dam in Hells Canyon--irrespective of the loss of environmental amenities--was $2.9M. One way to frame the question of whether to approve a Hells Canyon dam is to consider whether the annual value of lost environmental amenities was likely to exceed $2.9M. However, the more appropriate framing in this case considered the decision of whether to build the dam in Hells Canyon or the next best alternative site, one which did not feature the same environmental concerns. The annual cost savings of generating electricity at the Hells Canyon site relative to the next best alternative was estimated to be $80,000. Therefore the appropriate question for this decision was whether the lost annual environmental value in the canyon given a dam would likely exceed $80,000.

Hells Canyon is a source of multiple use values (e.g. hiking, hunting, angling, etc.) and non-use value (e.g. existence). Considering just a subset of use values stemming from angling and hunting, economists estimated a partial (and therefore "conservative") preservation value in the first year of $895,000. It is important to note that this estimate was not considered to be precise or complete. However, it was sufficient to demonstrate that the value of environmental amenities that would be lost from damming Hells Canyon was likely significantly greater than $80,000--the economic advantage of this site over the next best alternative. Largely based on this analysis Congress prohibited further hydro-electric development at this site on the Snake River.

A.3 Expectations for practice, reporting and quality assurance

Practical challenges to the implementation of valuation will include ensuring that internal or external analysts employed to conduct valuation are implementing state of the art techniques with technical rigor. Institutional decisions regarding the scope and scale of the application of valuation should also be evaluated. To support this process of quality assurance and institutional learning we recommend that an outside panel of valuation experts be created to review and provide feedback on the record of decisions on when to apply valuation, the choice of methodology and the way in which the results are interpreted. The panel would be necessary because of the relative newness of this approach to the agency and the large volumes of studies that maintain evolution in the field of valuation. Such a review panel would also serve to ensure that advancements in this rapidly evolving field are being adopted where appropriate in the transportation planning and delivery process.

The following implementation principles apply in general to both stated and revealed preference methods:

a. Economic theories and models of a chosen valuation approach

As discussed in the Section V.A.2, the need for accuracy and completeness would determine the valuation approach. The economics theories and models of the chosen approaches can be complex. However, it is still important to outline and explain the economic model framework in the analysis. The tables shown earlier could be developed as a checklist that the planner would use at this point to determine the best valuation method to apply to the particular scale and transportation planning problem at hand.

b. Data sources

The analysis should describe and document all the data sources used in a specific valuation method, and the methodology for data collection.

c. Assumptions and justifications

Economic models used for valuation are based on assumptions. For example, one assumption with the benefits transfer approach is that equivalent values drawn from the literature apply to the environmental conditions and impacts in a particular evaluation. In addition to data sources, the valuation analysis of each impact should also describe the assumptions and the justifications of using those assumptions.

d. Discuss the ranges of values for inputs data and results

All environmental impact analyses involve uncertainty. Uncertainty can come from both the physical side, such as scientific uncertainty about particular environmental conditions and the human side, such as people's behaviors and values. Sensitivity analysis should be used to test how different values of input data and assumptions could affect the conclusions of an analysis. Planners can use the upper and lower bounds of the input data as the range of values in the sensitivity analysis. Planners should address and communicate the uncertainty even if no formal sensitivity analysis is conducted.

e. Qualitatively describe the effects that cannot be quantified and monetized

If a quantitative assessment cannot be conducted, a qualitative assessment should be provided. Analysts should explain the reasons why the effects cannot be quantified or monetized, and which beneficiaries and value types have and have not been considered.

f. Incorporate the results into the planning process -

The final step is to incorporate the environmental valuation analysis into the overall regional, corridor or project analysis in the planning process. There are several ways this can be done. One is to use the valuation findings to prioritize among proposed actions or projects. Another is to use the findings to propose mitigation costs for projects or sets of projects. A third is to provide full accounting for finished projects to test assumptions about total environmental costs of projects and plans. This could be accomplished as a before and after valuation assessment of individual or sets of projects in a system. A fourth way could be informing the public of the economic and environmental costs of transportation system growth. Another place to use the method is in early route concept planning (Caltrans system planning, corridor-level) prior to any alternatives even being proposed, using a PID or PSSR. A key step from a Caltrans planning point of view would be to incorporate valuation guidance into the new system planning guidelines that will be prepared soon. This would help make clear how and when valuation as a tool could be employed at different time- and decision-points in system planning.

g. Transparency

Valuation of environmental attributes could be a challenging task, and the monetary values of environmental attributes are usually controversial. Therefore, it is important to present the results in a transparent manner. Analysts should clearly describe all the assumptions, data sources, references, and methodology in reaching the results and conclusions. Transparent assessment can provide policy makers and stakeholders with clear information, and allow them to discuss and develop the policy options. Again there would probably be a checklist or template developed eventually that would ensure that this documentation is gathered in one place in the planning and project development process.

B Use of Valuation Information in the Transportation Planning Process

The following discussion focuses on the decision criteria of cost effectiveness, here implemented as selection of the set of projects yielding the greatest net benefit for the particular budget available. While other considerations such as moral judgments, equity concerns and institutional constraints can play an important role, for clarity and simplicity here we will limit the discussion to choice based on the net returns of projects.

There are several different decision points in the programming process—as depicted in stylized form in Figure 8—where assessment and valuation of environmental impacts could be influential. The initial step in this process is the selection of the set of projects to be considered for an RTP, for example projects A1 through A5 (inside the box) in Figure 8. Valuation of environmental impacts could tip the scales so that, for a given region, a project that would otherwise be included is excluded (e.g. A7). In addition, attention to environmental values in their own right could support the inclusion of projects whose primary focus is environmental improvement (such as with wildlife corridors) that might not historically have been included (e.g. B3).

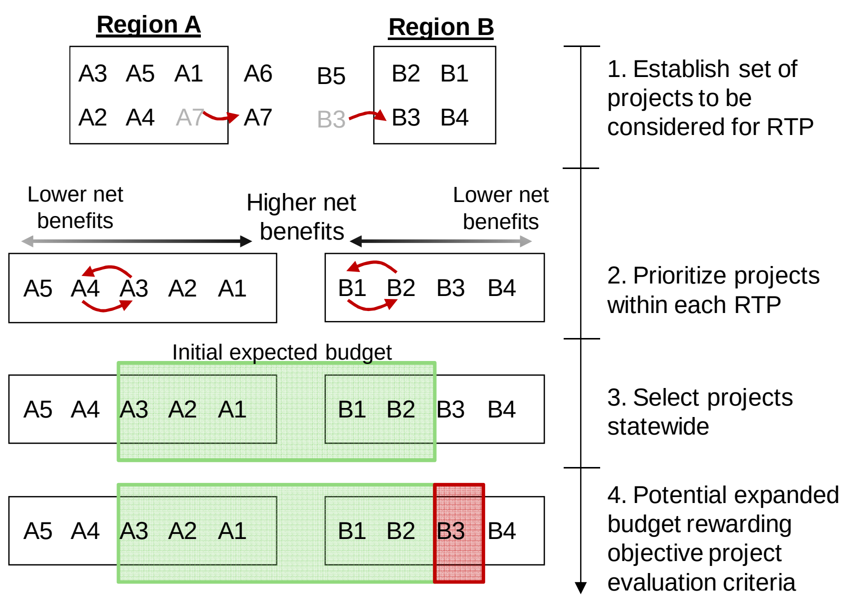


Figure 8. Pre-programming and programming decision points at which valuation can play an important role. Red arrows indicate examples of possible adjustments from incorporating valuation.

The second locus for valuation depicted in Figure 8 is at the prioritization stage within a given region. At this point a region could use valuation to more completely estimate costs and benefits to establish a better informed prioritization of projects from high to low expected returns, e.g. from A1 to A5. Given valuation information the priority of projects within a region might shift (e.g. A3 overtakes A4, B1 overtakes B2). Using this more complete set of evaluation criteria, the state then could better account for environmental impacts in the state-wide consideration of selecting projects. If the allocation of federal funds is increased based on an improvement in accounting for environmental impacts, a further decision at the state level involves allocating this additional funding.[21]

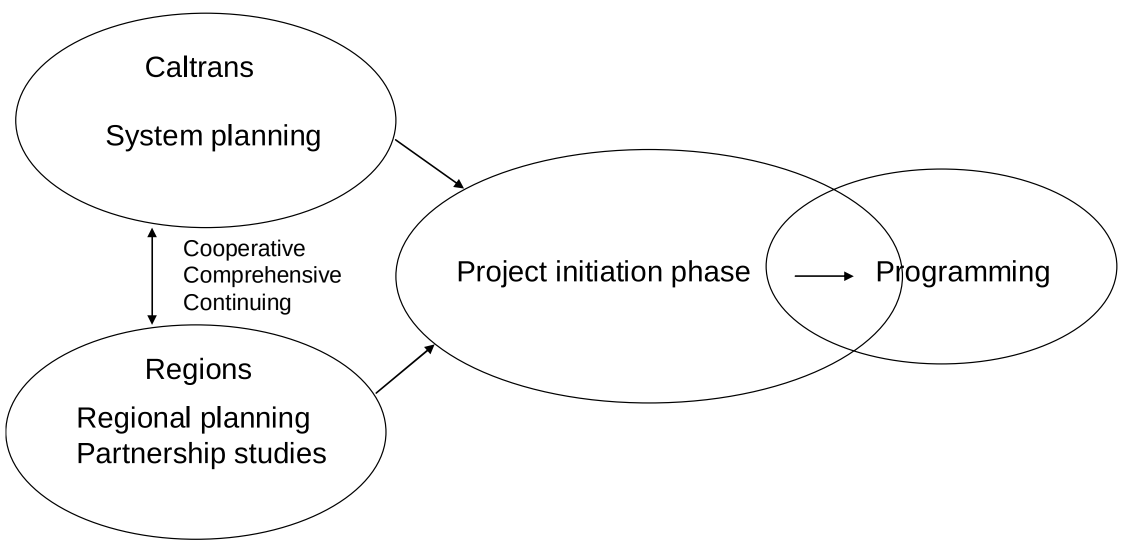
This stylized construction can now be used to highlight the importance of the valuation information that influenced the process. Note that ranking A3 above A4 was of practical importance since A3 was funded and A4 was not. Alternatively, reversing the relative rank of B1 and B2 had no effect since both were included. It is of course not always possible to predict what impact a more full accounting of environmental impacts will have on future decisions. The general insight however is that valuation effort should be prioritized on instances in which the information may play a pivotal role. If a decision is unlikely to be impacted by valuation information then such estimates may lack any utilitarian value. Rough estimates may be entirely adequate in initial scoping phases of a policy process, as they are likely to provide enough information for identifying issues to be address in environmental documents, estimating economic information needs for later decisions, and perhaps for complying with regulatory requirements (e.g., toward reporting climate impacts, or meeting SAFETEA-LU, Section 6001 requirements). Final determinations among a small number of CEQA or NEPA alternatives may require much better, and more expensive, economic data.

Overall, the cost of a valuation study should be considered relative to the benefit from the improved decision making it supports. All else being equal, this benefit is likely to increase with the size of the project and the degree of uncertainty over impacts and their values.

[21] If additional funding is apportioned among regions of the state in a manner that is not transparently correlated with a region's contribution to improving the quality of the valuation process that lead to an increase in federal funding, regions will lack the full incentive to improve their approach to accounting for environmental impacts. If regions perceive that contributing to state-wide valuation quality is similar to contributing to a public good, that is, it leads to increases federal funds in a manner that is dispersed over many regions, then part of the benefit of improving valuation would be external to the region--improvement in valuation may be unsatisfactorily low from a state-wide perspective. To mitigate the effect of this potential externality, a clear and transparent positive relationship should be established between a region's contribution to the quality of valuation in the state's package and that region's allocation of resulting additional federal funding. (Note, however, that there may exist a tradeoff between rewarding contributors for the quality of valuation and statewide selection of the projects of highest value.)

C Possible Use of the Valuation Approach at Different Planning Levels and Decision Points

Estimates of the values of the impacts of environmental attributes can be used as a guide to allocating resources to mitigate 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 may be used at several points during the transportation planning process: in the regional planning process, in the system planning process, in the project initiation document (PID) at the project development stage, and at the programming stage to complement the Cal-B/C model (Figure 9). Use of valuation 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. Valuation for regional planning may require lower-resolution analysis of impacts and calculation of equivalent values, providing a general but coarse overview. Valuation for corridor or project planning may require higher-resolution analysis of impacts and values in order to select among project alternatives. It is possible that regional valuation will provide cost-savings for the valuation process itself because of economies of scale. Once equivalent values are found within a region, they may be more legitimately applied among places within the region using the benefits transfer approach. Calculating the total environmental value or cost of transportation may be more feasible at the corridor or project scale.



Source: Adapted from the Caltrans Project Development Manual

Figure 9. Simplified statewide and regional planning and STIP programming process

C.1 Use of environmental valuation in the regional transportation planning process

Different MPOs follow different processes in developing their regional transportation plans. At SACOG, the preferred Blueprint scenario provides the basis for the long-range regional transportation plan, Metropolitan Transportation Plan for 2035. The preferred Blueprint scenario also serves as a framework to guide local government in growth and transportation planning.[22] In the Blueprint and long-range metropolitan transportation plan development process, SACOG uses planning software, I-PLACE^{3}S, to evaluate different regional planning scenarios. SACOG also uses the I-PLACE^{3}S to develop land use scenarios that feed into travel and air quality modeling.[23] The software tool shows the effects on development patterns, modal choices, redevelopment potential, and livability as land use designations expand or change.[24]

Figure 10 illustrates the SACOG MTP process. Valuation of environmental attributes could be used at the early scenario planning stage to guide the selection of the preferred development scenario for the region. In addition, environment condition and impact valuation could be used in selecting transportation projects to be included in the MTP and in evaluating alternative transportation system plans. In addition, valuation of environmental conditions and impacts could be considered in the prioritization of projects for the Regional Transportation Improvement Program (RTIP),[25] which serves as SACOG's request to the CTC for projects to be funded through the state's transportation funding program.[26] How the use of environmental valuation information could improve the decision making process was depicted in Figure 8.

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[22] See SACOG's Blueprint website for more detail: http://www.sacregionblueprint.org. -

[23] See SACOG's I-PLACE3S website fore more detail: http://www.sacog.org/services/I-PLACE3S/ -

[24] See SACOG's I-PLACE3S website for more detail: http://www.sacregionblueprint.org/technology/ -

[25] RTIP is developed to implement projects and programs listed in the RTP. -

[26] See SACOG's STIP website for more detail: http://www.sacog.org/stip/stip.cfm -

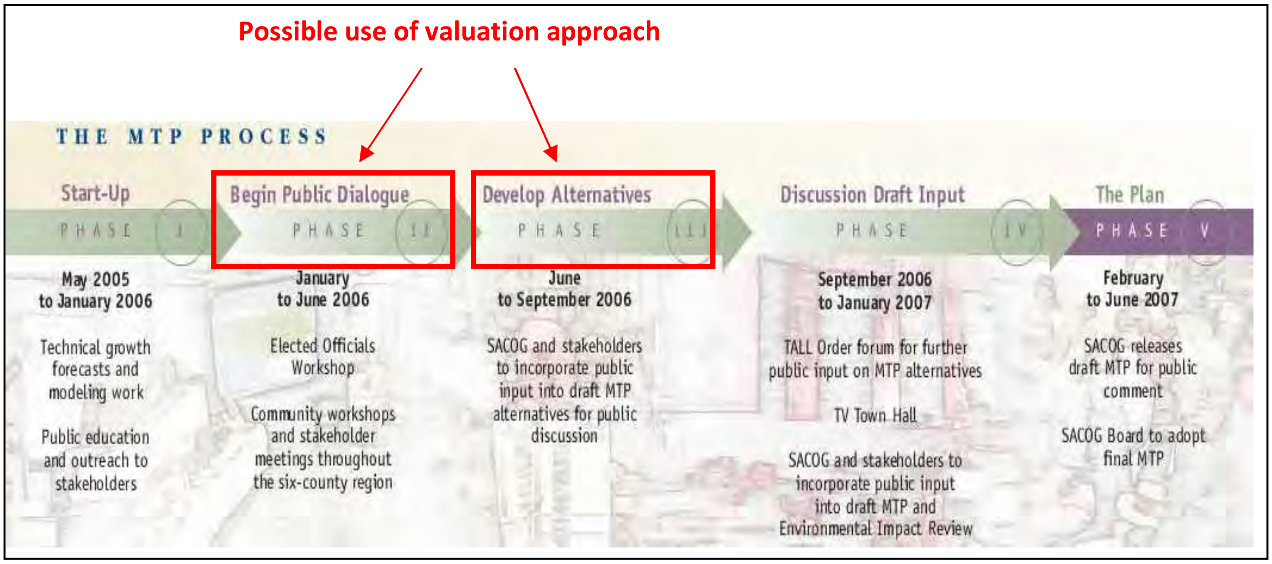

Figure 10. SACOG MTP process. Source: SACOG MTP 2035 Brochure.

C.2 Use of environmental valuation in the system planning process

Each Caltrans District conducts system planning for the District. A core document in the system planning process is a Transportation Concept Report (TCR), which is a 20-year planning document. The TCR describes the characteristics of a state highway, proposed land uses and projected travel demand and, based on this analysis, establishes a future route concept. This route concept is a long-term corridor plan. Valuation information of environmental attributes can inform the corridor planning and decision-making process. Potential corridor alternatives with high environmental benefits values can be selected for corridor preservation.

A part of system planning is Corridor System Management Plan (CSMP), which is a combination of operational analysis and long-range needs for congested urban corridors. CSMP is a comprehensive, integrated management plan for increasing transportation options, decreasing congestion, and improving travel times in a transportation corridor. A CSMP includes all travel modes in a defined corridor – highways and freeways, parallel and connecting roadways, public transit (bus, bus rapid transit, light rail, intercity rail) and bikeways, along with intelligent transportation technologies, which include ramp metering, coordinated traffic signals, changeable message signs for traveler information, incident management, bus/carpool lanes and carpool/vanpool programs, and transit strategies.[27] The goal of a CSMP is to define how a travel corridor is performing, understand why it is performing that way, and recommend system management strategies to address problems within the context of a long-range planning vision.[28]

Valuation of environmental attributes at this stage can guide the decision maker in choosing the set of projects to be included in the corridor plan by comparing the environmental impacts among the different set of recommended strategies and improvement projects. Applying this analysis in the corridor level planning stage can guide the later selection of which strategies will be developed into improvement projects and will be allocated funding in the RTP process. Application of this methodology at this stage could lead to selection and prioritization of those strategies (later projects) that avoid or minimize harm to the environment. This is very early in the process and would be most effective in avoiding impacts.

C.3 Use of environmental valuation at the project development stage

The project initiation phase is the first formal phase at the project development stage (Caltrans 2010). A project study report (PSR) is prepared at the project initiation phase, which includes a need and purpose statement, project alternatives, environmental determination and environmental issues, and funding and cost estimates.[29] The information in the environmental determination and environmental issues section includes brief descriptions of the known inventory of environmental attributes and environmental issues, identification of existing known hazardous material/waste sites adjacent to the proposed project, and descriptions the anticipated type of environmental documents for compliance with CEQA and NEPA.[30]

Valuation of environmental attributes could be used at this stage to evaluate the potential environmental impacts associated with each project alternatives, and to better estimate the mitigation costs of environmental impacts. If considerations of environmental resources were

[27] See California statewide CSMP website for more detail: http://www.corridormobility.org/Content/10027/WhatisaCSMP.html

[28] See Caltrans District 4's website for more detail: http://www.dot.ca.gov/dist4/transplanning/csmp.htm

[29] See Caltrans' Project Study Report (Project Development Support Outlines) at: http://www.dot.ca.gov/hq/oppd/design/07-2001outline.pdf

[30] See Caltrans' Project Study Report (Project Development Support Outlines) at: http://www.dot.ca.gov/hq/oppd/design/07-2001outline.pdf

anticipated by conducting valuation in earlier planning phases, this process will be streamlined and projected estimates can be refined.

C.4 Valuation of environmental conditions and impacts to complement the Cal-B/C model at the programming stage

At the programming stage, the Interregional Transportation Improvement Program (ITIP) prepared by Caltrans and the RTIPs prepared by the MPOs are submitted to the California Transportation Commission (CTC) for consideration. CTC requires each agency and Caltrans to provide a quantitative and/or qualitative evaluation of its RTIP or the ITIP, and to comment on each of the performance indicators and performance measures before they are submitted to the CTC for incorporation into the State Transportation Improvement Program (STIP) (CTC 2009). The CTC performance indicators include safety, mobility, accessibility, reliability, productivity, system preservation, and return on investment/lifecycle cost. Caltrans uses California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) to evaluate the return on investment/lifecycle required by the CTC. Caltrans completes the BCA analysis on all State Highway projects, and this is generally done immediately prior to project submittal.[31]

Cal-B/C is a spreadsheet tool that can be used to analyze highway and transit projects. Highway projects may include general improvements, HOV and passing lanes, interchange improvements, and constructing a bypass highway. Transit projects may include new or improved bus services, with or without an exclusive bus lane, light-rail, and passenger heavy-rail projects.[32]

The benefit categories in the Cal-B/C model includes travel time savings, vehicle operating cost savings, safety benefits (accidents cost savings) and emissions reductions, and the cost categories include direct project costs, mitigation costs and transit agency cost savings. Currently most of the environmental impacts are not valued in the Cal-B/C model, and it is not required to do so under the principal environmental and transportation laws, including CEQA, NEPA, and Endangered Species Act (ESA), that govern the required assessments. However, SAFETEA-LU includes several provisions (specifically, Section 6001) intended to enhance the consideration of environmental issues and impacts within the transportation planning process.

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[31] Personal communication with Barry Padilla, Economic Analysis Branch, Division of Transportation Planning, - California Department of Transportation. -

[32] Please see Caltrans Cal-B/C website at - http://www.dot.ca.gov/hq/tpp/offices/ote/benefit_cost/models/calbc.html. -

Incorporating the values of the environmental impacts within Cal-B/C at the time of analysis can better account for the benefits and costs that the society may have to bear. To incorporate the environmental valuation information in the Cal-B/C analysis, analysts would need to decide whether to use primary methods (stated and revealed preference methods) or secondary methods (benefit transfer). If a standard spreadsheet tool, similar to the Cal-B/C spreadsheet tool, is to be used to analyze the values of environmental impacts of a project, then it would be necessary to have benefit transfer estimates for the major categories of environmental impacts. However, if high quality estimates of the values of environmental attributes do not exist, then it may be necessary to make an initial investment to carry out primary studies to collect the environmental valuation information.

C.5 Incorporate environmental valuation information into other planning tools and models

Planners and transportation analysts use various models and tools in the transportation planning and evaluation process. One example is the PECAS model, an integrated land use/economic/transportation model. It is a generalized approach for simulating spatial economic systems. It is currently being calibrated for practical use in several contexts in California, including the four major metropolitan regions and the state as a whole. The CalPECAS model will have the ability to assess and depict the interregional effects of major changes to land use patterns, the economy, and the transportation system on energy, the economy and the environment in a variety of ways.[33] Valuation of environmental attributes could be incorporated into the PECAS model as a basic layer of environmental data as one of various types of inputs to the model.

D Limitations and Future Needs

As mentioned in Section V.A.1, valuation of environmental attributes is neither necessary nor sufficient for making effective corridor or regional transportation choices. An agency or an institution would need to have technical expertise and resources to carry out the

[33] See UC Davis PECAS website at: http://pecas.ultrans.ucdavis.edu/doc/pecas.

environmental valuation analyses. Capacity building within an agency would be necessary to successfully implement the valuation approach. However, resource constraints in an agency (e.g. time and budget) may hinder the use of valuation approaches. Philosophical objections to valuation approach can be another barrier to carry out the valuation studies in the decision-making process.

One idea brought up in a Multi-Disciplinary Team meeting that could formulate the basis for next steps is to implement valuation in association with Caltrans District planning activities. For example, as Corridor System Management Planning is initiated and environmental impacts given preliminary analysis at the corridor scale, primary valuation methods could be implemented for specific segments or specific conditions/impacts affected by the transportation projects. District 4 staff have indicated that they would be open to such a model study to both test and validate this approach in CSMP and by extension both project and district scale planning and project delivery. This proof of concept is likely the most viable next step for inclusion of economic valuation of environmental conditions in transportation planning.

VI Conclusions

The UC Davis team, in collaboration with the project Multi-Disciplinary Team and individuals at Caltrans, has provided an approach for economic valuation of environmental conditions and impacts useful and implementable in transportation planning and analysis. The approach is built on a foundation of scientific and economic literature and approaches used in contemporary academic and agency practice. It describes a four-step process that can be easily incorporated into existing analytical practice associated with transportation planning and project delivery. For example, the first step involves identifying potential environmental impacts and effects, which can be drawn directly from existing practice when planning or implementing projects. When decision-making requires only cursory knowledge of environmental impacts, then valuation can in turn be fairly general. For specific estimates of economic value and changes in value with transportation projects, primary valuation methods commonly used in economics of natural systems can be employed. The practice described here draws upon existing and possibly new capacities for transportation and related agencies (e.g., municipal planning organizations). However, even where the capacity for specific steps is not available within the agencies, there are academic and other entities that have this capacity. Once the valuation approach is adopted, then a sequence of building steps can be implemented that are typical of adoption of new approaches – modeling within a test area/district, expansion of ideas within district and to other districts, building capacity for the approach, normalization of the approach within corporate practice.

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Appendices to Draft Report

Appendix A. Effects of transportation systems on certain environmental conditions, drawn from the literature.

Type of Effect	PEAR Category	Citation	Title	Variable Altered	Where is variable monitored in Relation to the Road?	Unit of Effect	Finding of Study
Species	Biological Environment	Adams and Geis 1983	Effects of Roads on Small Mammals	diversity, spatial distribution, and density of small mammals.	Landscape around roadways	abundance in relation to roads	Study states road kill was not detrimental to these populations
	Biological Environment	Angold 1997	The Impact of a Road Upon Adjacent Heathland Vegetation: Effects on Plant Species Composition	Change in plant species composition, Altered species competition dynamics.	Landscape around roadways	Extent of edge effect per traffic flow	Traffic flow is significantly correlated to the extent of change in the near-road plant community
	Biological Environment	Bissonette and Rosa 2009	Road Zone Effects in Small-Mammal Communities	Study showed no effect on Small Mammals	At or near to roadways	Abundance density and diversity effect near roadway	Roads did not effect abundance, density and diversity near roadway
	Biological Environment	Brock and Kelt 2004	Influence of roads on the endangered Stephens kangaroo rat (Dipodomys stephensi): are dirt and gravel roads different	relative abundance, mass and demographic turnover of Dist on dirt vs. gravel roads	Roadway		
	Biological Environment	Carr and Fahrig 2001	Effect of Road Traffic on Two Amphibian Species of Differing Vagility	Leopard frog population density	Roadway	population density per volume of traffic	Vagile frogs are negatively affected by traffic
	Biological Environment	Haskell 2000	Effects of Forest Roads on Macroinvertebrate Soil Fauna of the Southern Appalachian Mountains	Macroinvertebrate fauna of the soil	Landscape around roadways	Macroinvertebrate abundance, Richness and Litter Depth per meters from Road	Macroinvertebrates were less abundant and diverse near forest roads; Leaf litter was decreased near roads;
	Biological Environment	Eigenbrod et al. 2008	The relative effects of rad traffic and forest cover on anuran populations	Anuran species richness	Landscape around the roadways	species richness vs traffic density (AADTm/m2) (did not provide a relationship- only association)	There is a relationship between anuran species richness and traffic density
	Biological Environment	Forman and Deblinger 2000	The Ecological Road-Effect Zone of a Massachusetts (U. S. A.) Suburban Highway	Sensitive grassland bird species composition altered near road	up to 930 m surrounding roadways		
	Biological Environment	Pocock and Lawrence 2005	How far into a forest does the effect of a road extend? Defining road edge effect in eucalypt forests of South-Eastern Australia	Bird Species Richness in forests	up to 900 m surrounding roadways		
	Biological Environment	Forman et al. 2002	Road Traffic and Nearby Grassland Bird Patterns in a Suburbanizing Landscape	Bird species richness and populations	Landscape around roadways		
	Biological Environment	Polomino and Carrascal 2007	Threshold distances to nearby cities and roads influence the bird community of a mosaic landscape	Bird species richness in pine woods, shrublands and pastures	up to 110 m surrounding roadways		
	Biological Environment	Forman and Deblinger 2000	The Ecological Road-Effect Zone of a Massachusetts (U. S. A.) Suburban Highway	Sensitive forest bird species composition altered near road	up to 650 m surrounding roadways		
	Biological Environment	Forman and Deblinger 2000	The Ecological Road-Effect Zone of a Massachusetts (U. S. A.) Suburban Highway	Plant species composition due to exotic planting of road verges	up to 120 m surrounding roadways		
	Biological Environment	Johnston and Johnston 2004	Impacts of Road Disturbance on Soil Properties and on Exotic Plant Occurrence in Subalpine Areas of the Australian Alps	Soil Properties and Exotic plant occurrence	Landscape around roadways	Percent Coverage of Exotic at 3 Roadside Ecotypes	Soils are physically and chemically altered near roads; Yarrow (an invasive species to Australia) were significant in the 3 roadside habitats

Material	Biological Environment	Forman and Deblinger 2000	The Ecological Road-Effect Zone of a Massachusetts (U. S. A.) Suburban Highway	Aquatic system	Watersheds that intersect with roads		
Landscape	Biological Environment	Houlahan and Findlay 2003	The effects of adjacent land use on wetland amphibian species richness and community composition	Amphibian abundance, richness and community composition	Landscape around roadways		...effective wetland conservation will not be achieved merely through the creation of narrow buffer zones between wetlands and intensive land uses, but rather will require maintaining a heterogeneous regional landscape containing relatively large areas of natural forest and wetlands. (Houlahan and Findlay 2003)
Energetic							
Health							
	Air Quality	Kunzli et al. 2000	Public-health impact of outdoor and traffic-related air pollution: a European assessment	Mortality caused by air pollution	Landscape around roadways	Mortality per Area (Austria, France and Switzerland)	"Air pollution caused 6% of total mortality or more than 40 000 attributable cases per year. About half of all mortality caused by air pollution was attributed to mortality caused by air pollution was attributed to motorised traffic, accounting also for: more than 25 000 new cases of chronic bronchitis (adults); more than 290 000 episodes of bronchitis (children); more than 0.5 million asthma attacks; and more than 16 million persondays of restricted activities." (Kunzli et al. 2000)
	Air Quality	Gauderman et al. 2006	Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study	Lung development from ages 10 to 18 years.	Landscape around the roadways	Expiratory Volume in 1 s and maximum midexpiratory flow rate per category (children living 500 m or less away from a large road, 500-1000 meters away from a large road, and children living 1500 m or greater away from a large road)	Children who lived 500 meters away from a freeway had substantially lower lung funtion than those that lived 1500 m or greater away from a freeway.
	Noise and Vibration	Babisch et al. 2005	Traffic noise and risk of myocardial infarction	Risk of Myocardial Infarction	Landscape around the roadways	Risk of Myocardial Infarction per noise category due to traffic	"The results support the hypothesis that chronic exposure to high levels of traffic noise increases the risk for cardiovascular diseases." (Babisch et al. 2005)
	Noise and vibration	Bluhm et al. 2007	Road traffic noise and hypertension	Risk of hypertension	Landscape around the roadways	Risk of Hypertension per noise category due to traffic	There is a relationship between residential traffic noise and hypertension.
	Air Quality	Lai et al. 2007	Exposure to traffic exhausts and oxidative DNA damage	Oxidative DNA damage	At or near to roadways	Magnitude of Oxidative DNA damage at high exhaust conditions	Exposure to exhausts increases oxidative DNA damage.

Appendix B. Values of environmental attributes from the literature.

Willingness to pay per household ($2006) for threatened and endangered species (Richardson and Loomis 2009)

				Willingness to pay (2006$)							
Reference	**Survey date**	**Species**	**Gain or loss**	**Size of change***	**Lump sum**	**Annual**	**CVM method****	**Survey region**	**Sample size**	**Response rate**	**Payment vehicle**
Bell et al. (2003)	2000	Salmon	Gain	100%		$138.64	DC	Grays Harbor, WA households	357	49.1%	Annual tax—high income[+]
						$91.55					Annual tax—low income[++]
			Gain	100%		$141.27		Willapa Bay, WA households	386	61.7%	Annual tax—high income
						$90.64					Annual tax—low income
			Avoid loss	100%		$57.99		Coos Bay, OR households	424	58.4%	Annual tax—high income
						$47.70					Annual tax—low income
			Avoid loss	100%		$91.99		Tillamook Bay, OR households	347	53.2%	Annual tax—high income
						$28.39					Annual tax—low income
			Avoid loss	100%		$134.00		Yaquina Bay, OR households	357	59.7%	Annual tax—high income
						$87.84					
Berrens et al. (1996)	1995	Silvery minnow	Avoid loss	100%		$37.77	DC	NM residents	726	64.0%	Trust fund
Bowker and Stoll (1988)	1983	Whooping crane	Avoid loss	100%		$43.69	DC	TX and US households	316	36.0%	Foundation
		Whooping crane	Avoid loss	100%		$68.55	DC	Visitors	254	67.0%	Foundation
Boyle and Bishop (1987)	1984	Bald eagle	Avoid loss	100%		$21.21	DC	WI households	365	73.0%	Foundation
		Striped shiner	Avoid loss	100%		$8.32	DC				
Chambers and Whitehead (2003)	2001	Gray wolf	Avoid loss	100%	$22.64		DC	Ely and St. Cloud, MN households	352	56.1%	One-time tax
Cummings et al. (1994)	1994	Squawfish	Avoid loss	100%		$11.65	OE	NM	723	42.0%	Increase state taxes
Duffield (1991)	1990	Gray wolf	Reintroduction		$93.92		DC	Yellowstone National Park visitors	158	30.6%	Lifetime membership
Duffield (1992)	1991	Gray wolf	Reintroduction		$162.10		DC	Yellowstone National Park visitors	121	86.0%	Lifetime membership
Duffield et al. (1993)	1992	Gray wolf	Reintroduction		$37.43		DC	ID, MT, WY household	189	46.6%	Lifetime membership
USDOI (1994)	1993	Gray wolf	Reintroduction		$28.37		DC	ID, MT, WY household	335	69.6%	Lifetime membership
USDOI (1994)	1993	Gray wolf	Reintroduction		$21.59		DC	ID, MT, WY household	345	69.6%	
Duffield and Patterson (1992)	1991	Arctic grayling	Improve 1 of 3 rivers	33%	$26.47		PC	US visitors	157	27.3%	Trust fund
		Arctic grayling		33%	$19.84		PC	US visitors		77.1%	Trust fund
Giraud et al. (1999)	1996	Mexican spotted owl	Avoid loss			$68.84	DC	US households	688	54.4%	Trust fund
Giraud et al. (2002)	2000	Steller sea lion	Avoid loss	100%		$70.90	DC	AK and US households	1653	63.6%	Increase federal tax
Hageman (1985)	1984	Bottlenose dolphin	Avoid loss	100%		$36.41	PC	CA households	180	21.0%	Increase federal tax
		Northern elephant seal	Avoid loss	100%		$34.50	PC		174		
Hageman (1985)	1984	Gray-blue whale	Avoid loss	100%		$45.94	PC	CA households	180	21.0%	Increase federal tax
		Sea otter	Avoid loss	100%		$39.80	PC		174		
Hagen et al. (1992)	1990	Northern spotted owl	Avoid loss	100%		$130.19	DC	US households	409	46.0%	Taxes and wood prices
King et al. (1988)	1985	Bighorn sheep	Avoid loss	100%		$16.99	OE	AZ households	550	59.0%	Foundation
Kotchen and Reiling (2000)	1997	Peregrine falcon	Gain	87.50%	$32.27		DC	ME residents	206	63.1%	One-time tax
Layton et al. (2001)	1998	Eastern WA and Columbia River Freshwater Fish	Gain	50%		$210.84	CE	WA households	801	68.0%	Monthly payment
		Eastern WA and Columbia River Migratory Fish	Gain	50%		$146.57					(converted to annual)
		Western WA and Puget Sound Freshwater Fish	Gain	50%		$229.31					
		Western WA and Puget Sound Migratory Fish	Gain	50%		$307.76					
		Western WA and Puget Sound Saltwater Fish	Gain	50%		$311.31					
Loomis (1996)	1994	Salmon and steelhead	Gain	600%		$79.53	DC	Clallam County, WA households	284	77.0%	Increase federal tax
		Salmon and steelhead	Gain	600%		$98.41	DC	WA households	467	68.0%	
		Salmon and steelhead	Gain	600%		$91.67	DC	US households	423	55.0%	

Willingness to pay per household ($2006) for threatened and endangered species (Richardson and Loomis 2009), Table cont'd.

Loomis and Ekstrand (1997)	1996	Mexican spotted owl	Avoid loss			$51.52	MB	US households	218	56.0%	
Loomis and Larson (1994)	1991	Gray whale	Gain	50%		$23.65	OE	CA households	890	54.0%	Protection fund
		Gray whale	Gain	100%		$26.53	OE	CA households	890	54.0%	
		Gray whale	Gain	50%		$36.56	OE	CA visitors	1003	71.3%	Protection fund
		Gray whale	Gain	100%		$43.46	OE	CA visitors	1003	71.3%	
Olsen et al. (1991)	1989	Salmon and steelhead	Gain	100%		$42.97	OE	Pac. NW households	695	72.0%	Electric bill
			Gain	100%		$95.86	OE	Pac NW HH option		72.0%	
			Gain	100%		$121.40	OE	Pac. NW anglers	482	72.0%	
Reaves et al. (1994)	1992	Red-cockaded woodpecker	% chance of survival	99%		$14.69	OE	SC and US households	225	53.0%	Recovery fund
				99%		$20.46	DC		223	52.0%	
				99%		$13.14	PC		234	53.0%	Unspecified
Rubin et al. (1991)	1987	Northern Spotted owl	% chance of survival	50%		$38.61	OE	WA households	249	23.0%	
				75%		$39.99	OE				
				100%		$60.84	OE				
Samples and Hollyer (1989)	1986	Monk seal	Avoid loss	100%	$165.80		DC	HI households	165	40.0%	Preservation fund
		Humpback whale	Avoid loss	100%	$239.53						Money and time
Stanley (2005)	2001	Riverside fairy shrimp	Avoid loss	100%		$28.38	PC	Orange County, CA households	242	32.1%	Annual tax
Stevens et al. (1991)	1989	Wild Turkey	Avoid loss	100%		$11.38	DC	New England households	339	37.0%	Trust Fund
			Avoid loss	100%		$15.36	OE	New England households			
		Atlantic salmon	Avoid loss	100%		$10.00	DC	MA households	169	30.0%	Trust fund
		Atlantic salmon	Avoid loss	100%		$11.12	OE				
		Bald eagle	Avoid loss	100%		$45.21	DC	New England households	339	37.0%	Trust fund
		Bald eagle	Avoid loss	100%		$31.85	OE				
Swanson (1993)	1989	Bald eagle	Increase in populations	300%	$349.69		DC	WA visitors	747	57.0%	Membership fund
				300%	$244.94		OE	WA visitors			
Whitehead (1991, 1992)	1991	Sea turtle	Avoid loss	100%		$19.01	DC	NC households	207	35.0%	Preservation fund

* Size of change - the percentage change in the species population proposed in the survey

** Contingent valuation method (CVM)

DC = surveys which used a dichotomous choice question format

OE = surveys which used an open-ended format

PC = surveys which used a payment card question format

CE = studies using a conjoint, or choice experiment, technique

MB = suveys which used multiple-bounded format

$^{+}$ high income - respondents with incomes not below $30,000

$^{++}$ low income - respondents with incomes below $30,000

Data are cited from Litman (2009).		
Reference	Costs	Cost Value
AIR POLLUTION		
CE Delft (2008)	Urban car	€0.0017 - 0.0024/km (2000)
	Urban truck	€0.106 - 0.234/km (2000)
Delucchi et al. (1996)	Light gasoline vehicle	$0.008 - 0.129/VMT (1990)
	Heavy diesel truck	$0.054 - 1.233/VMT (1990)
Eyre et al. (1997)	Gasoline urban	$0.030/VMT (1996)
	Diesel urban	$0.074/VMT (1996)
FHWA (1997)	Automobiles	$0.011/VMT
	Pickups/vans	$0.026/VMT
	Diesel trucks	$0.039/VMT
AEA Technology (2005)	NH3/tonne Europe	€19750 (2005)
	NOx/tonne	€7800 (2005)
	PM2.5/tonne	€48000 (2005)
	SO2/tonne	€10325 (2005)
	VOCs/tonne	€1813 (2005)
RWDI (2006)	PM2.5/tonne	Canadian $317000 (2005)
	O3 Total	Canadian $1739 (2005)
Wang, Santini and Warinner (1994)	U.S. cities	
	NOx	$4826/ton (1989)
	ROG	$2419/ton (1989)
	PM10	$6508/ton (1989)
	SOx	$2906/ton (1989)
McCubbin and Delucchi (1996)	Air pollution health costs by motor vehicle class	$/VMT (1990)
	Light gasoline vehicle	0.008 - 0.129
	Light gasoline truck	0.012 - 0.188
	Heavy gasoline vehicel	0.024 - 0.495
	Light diesel vehicle	0.016 - 0.225
	Light diesel truck	0.006 - 0.116
	Heavy diesel truck	0.054 - 1.233
	Weighted Fleet Average	0.011 - 0.213
FHWA (2000)	Air pollution costs	Total (Million $) (1990)
	Automobiles	$20,343
	Pickups/Vans	$11,324
	Gasoline vehicles > 8500 pounds	$1,699
	Diesel vehicles > 8500 pounds	$6,743
RWDI (2006)	Human health	Marginal damage costs (Canadian $/tonne) (2005)
	- CO	$205
	- PM2.5	$317,000
	- O3	$1,086
	Visibility	
	- PM10	$3,175
	- NOx	$934
	- VOC	$44
	Agricultural crops	
	- O3	$280
	Exterior materials	
	- O3	$373
	Total	
	- O3	$1,739

Holland and Watkiss (2002)		European Emission Costs (2002 Euros per tonne)			
		SO2	NOx	PM2.5	VOCs
	Rural				
	Austria	7200	6800	14000	1400
	Belgium	7900	4700	22000	3000
	Denmark	3300	3300	5400	7200
	Finland	970	1500	1400	490
	France	7400	8200	15000	2000
	Germany	6100	4100	16000	2800
	Greece	4100	6000	7800	930
	Ireland	2600	2800	4100	1300
	Italy	5000	7100	12000	2800
	Netherlands	7000	4000	18000	2400
	Portugal	3000	4100	5800	1500
	Spain	3700	4700	7900	880
	Sweden	1700	2600	1700	680
	UK	4500	2600	9700	1900
	EU-15 average	5200	4200	14000	2100
	Urban				
	100,000 population	6000		33000	
	500,000 population	30000		165000	
	1,000,000 population	45000		247500	
	Several million pop.	90000		495000	

Wang, Santini and Warinner (1994)		Estimated emission values (1989$/ton)									
		NOx		ROG		PM10		SOx		CO	
		Damage cost	Control cost	Damage cost	Control cost	Damage cost	Control cost	Damage cost	Control cost	Damage cost	Control cost
	Atlanta	4330	9190	2150	8780	5170	3460	2760	6420	N/A	2280
	Baltimore	4430	10310	2210	9620	4520	3170	2620	5600	N/A	2490
	Boston	4120	7980	2030	7850	5090	3120	2820	5060	N/A	1610
	Chicago	5380	7990	2700	8150	10840	4660	3600	9120	N/A	2440
	Denver	2840	6660	1350	6590	3390	2790	2330	4900	N/A	2960
	Houston	6890	17150	3540	15160	5190	2780	2910	3590	N/A	2680
	Los Vegas	910	5220	320	5100	2450	4190	N/A	11650	N/A	2770
	Los Angeles	9800	21850	5110	19250	17200	6060	3970	13480	N/A	4840
	Milwaukee	3890	11350	1930	10250	2960	2560	2210	4380	N/A	1590
	New Orleans	3880	9190	1910	8670	3600	2400	2471	3130	N/A	1410
	New York	7130	12340	3650	11720	15130	5390	4030	11090	N/A	3910
	Philadelphia	5940	11360	3010	10730	8360	4040	3340	7330	N/A	3160
	Sacramento	3870	11350	1920	10240	3150	2950	2190	5800	N/A	3040
	San Diego	5510	14110	2800	12630	4800	3460	2600	6640	N/A	2740
	San Francisco	3730	5230	1810	5760	5970	3200	2970	4900	N/A	2460
	San Joaquin	4490	10310	2240	9630	6550	5110	2610	12480	N/A	2750
	Wash. DC	4900	9180	2450	8910	6260	3340	3070	5320	N/A	3010
	Average	4826	10634	2419	9944	6508	3687	2906	7111	N/A	2714

Litman (2009)	Non-GHG air pollution costs estimate	Average (2007 USD/VMT)
	Average car	0.04
	Compact car	0.031
	Electric vehicles	0.01
	Van/Light truck	0.071
	Rideshare passenger	0.001
	Diesel bus	0.129
	Electric bus/Trolley	0.05
	Motorcycle	0.061
	Bicycle	0
	Walk	0
	Telecommute	0
GHG		
Tol (2005)	Climate change damage cost estimates	€4 - 53/tonne CO2 (2000)
DLR (2006)	Climate change damage cost estimates	€15 - 280/tonne CO2 (2000)
Jakob, Craig and Fisher (2005)	Climate change damage cost estimates	NZ$270/tonne CO2 (2003)
Hohmeyer and Gartner (1992)	Climate change damage cost estimates	$220/tonne CO2
Bein (1997)	Climate change damage cost estimates	$1000 - 4264/tonne CO2
Bloomberg News (2007)	Climate change control cost estimates - 2007 price of EU CO2 permits for 2008	€21.45/tonne CO2
SEC (2008)	Climate change control cost estimates - 2010	€14/tonne CO2
	Climate change control cost estimates - 2020	€38/tonne CO2
	Climate change control cost estimates - 2030	€64/tonne CO2
	Climate change control cost estimates - 2050	€120/tonne CO2
Stern (2006)	Climate change control cost estimates - 2015	€32 - 65/tonne CO2 (2000)
	Climate change control cost estimates - 2025	€16 - 45/tonne CO2
	Climate change control cost estimates - 2050	€41 - 81/tonne CO2
Maibach et al. (2000)	Climate change control cost estimates	€135/tonne CO2
EC (1998)	GHG damage costs	€74 - 230/tonne C
	GHG damage costs	€20 - 63/tonne CO2
	GHG damage costs	€370 - 710/tonne CH4
	GHG damage costs	€6800 - 36000/tonne N2O
CE Delft (2008)	External costs of GHG emissions	
	2010	€7 - 45/tonne CO2
	2020	€17 - 70/tonne CO2
	2030	€22 - 100/tonne CO2
	2040	€22 - 135/tonne CO2
	2050	€85 - 180/tonne CO2
Point Carbon (2006)	Carbon emission credit prices:	
	Non-firm volume. Buyer buys what seller delivers even if emissions reductions turn out not to qualify as CERs.	€3 - 6/tonne CO2
	Non-firm volume. Contract contains preconditions, e.g. that the underlying project qualifies for the CDM.	€5 - 10/tonne CO2
	Firm volume. Contract contains preconditions (as above). Usually strong force majeure clauses and high credit rating requirements.	€9 - 14/tonne CO2
	Firm volume. No preconditions. Forward spot trades will fit this category.	€12 - 14/tonne CO2
Litman (2009)	GHG control costs estimate	Average (2007 USD/VMT)
	Average car	0.017
	Compact car	0.013
	Electric vehicles	0.004
	Van/Light truck	0.024
	Rideshare passenger	0
	Diesel bus	0.086
	Electric bus/Trolley	0.028
	Motorcycle	0.009
	Bicycle	0
	Walk	0
	Telecommute	0
	GHG damage costs estimate	Average (2007 USD/VMT)
	Average car	0.147
	Compact car	0.11
	Electric vehicles	0.037
	Van/Light truck	0.202
	Rideshare passenger	0.004
	Diesel bus	0.733
	Electric bus/Trolley	0.244
	Motorcycle	0.073
	Bicycle	0
	Walk	0
	Telecommute	0

NOISE		
FHWA (1997)	Noise costs - urban highways	1997 cents/VMT
	Automobile	0.11
	Pickup and van	0.1
	Buses	1.72
	Combination trucks	3.73
	All vehicles	0.24
CE Delft (2008)	Noise costs - urban roads	2000 Euro cents per veh km
	Car - day	0.76
	Car - night	1.39
	Motorcycle - day	1.53
	Motorcycle - night	2.78
	Bus - day	3.81
	Bus - night	6.95
	Heavy truck - day	7.01
	Heavy truck - night	12.78
Delucchi and Hsu (1998)	Noise costs	1991 USD/1000 VMT
	Car (urban arterial)	1.18
	Medium trucks	7.02
	Heavy trucks	20.07
	Buses	7.18
	Motorcycle	8.17
GVRD (1993)	Vehicles	Canadian cents 0.5/km
Delucchi and Hsu (1998)	Marginal noise costs in urban areas	$/1000 VMT (1991)
	Light automobiles - Interstate	2.96
	Light automobiles - other freeways	4.25
	Light automobiles - principle arterials	1.18
	Light automobiles - minor arterials	0.57
	Light automobiles - collectors	0.07
	Medium trucks - interstate	8.5
	Medium trucks - otherfreeways	13.2
	Medium trucks - principle arterials	7.02
	Medium trucks - minor arterials	5.37
	Medium trucks - collectors	1.05
	Heavy trucks - interstate	16.69
	Heavy trucks - other freeways	30.8
	Heavy trucks - principle arterials	20.07
	Heavy trucks - minor arterials	29.93
	Heavy trucks - collectors	4.93
	Buses - interstate	6.36
	Buses - other freeways	9.77
	Buses - principle arterials	7.18
	Buses - minor arterials	6.42
	Buses - collectors	1.22
	Motorcycles - interstate	17.15
	Motorcycles - other freeways	27.03
	Motorcycles - principle arterials	8.71
	Motorcycles - minor arterials	4.67
	Motorcycles - collectors	0.56
FHWA (1997)	Estimated highway noise costs	All highways (cents per vehicle mile) (1997)
	Automobiles	0.02 - 0.2
	Pickup and van	0.02 - 0.17
	Buses	0.3 - 2.79
	Single Unit Trucks	0.2 - 1.85
	Combination Trucks	0.45 - 4.24
	All vehicles	0.05 - 0.42
Maddison et al. (1996)	Noise costs per kilometer	Pence per passenger km (1996)
	Car	0.41
	Bus	0.097
	Motorcycle	1.18
	Heavy goods vehicle	1.96

Litman (2009)	Noise costs estimate	Average (USD per vehicle mile) (2007)
	Average car	0.011
	Compact car	0.011
	Electric car	0.004
	Van/Light truck	0.011
	Rideshare passenger	0
	Diesel bus	0.053
	Electric bus/Trolley	0.032
	Motorcycle	0.106
	Bicycle	0
	Walk	0
	Telecommunte	0
LAND USE		
Maibach et al. (2008)	Estimated annual environmental cost of paving various types of land	Canadian $/hectare (1997)
	Wetlands	30000
	Urban greenspace	24000
	Second growth forest	18000
	Farmland	12000
	Road buffer	6000
Litman (2009)	Estimated land use impact costs associated with motor vehicle use	Estimate (cents/veh mile)
	Environmental	3
	Aesthetic and cultural	0.5
	Social	3
	Minicipal	3
	Transportation	7
	Total sprawl cost	16.5
	Automobile sprawl costs	8.3
Litman (2009)	Land use impact costs estimate	Average (USD per vehicle mile) (2007)
	Average car	0.0664
	Compact car	0.0664
	Electric car	0.0664
	Van/Light truck	0.0664
	Rideshare passenger	0
	Diesel bus	0
	Electric bus/Trolley	0
	Motorcycle	0.0664
	Bicycle	0
	Walk	0
	Telework	0.0664
WATER POLLUTION		
Bray and Tisato (1998)	Pollution	Aust. $0.002 (1996)
Bein (1997)	Pollution and hydrologic	Canadian $0.02/km
Delucchi (2000)	Oil pollution	$0.4 - 1.5 billion/yr (1991)
Chernick and Caverhill (1989)	Tanker spills	$0.10 - 0.47/gallon of imported crude oil
Lee (1995)	Oil spills	$2 billion/yr
Murray and Ulrich (1976)	US road salt impacts	$4.7 billion/yr (1993)
Nixon and Saphores (2007)	Leaking tank clean up in US	$0.8 - $2.1 billion/yr over 10 years
	Highway runoff control in US	$2.9 - $15.6 billion/yr over 20 years
Project Clean Water (2002)	US stormwater management fees	$3.13 - $76.78/1000 sq ft/yr
Washington DOT (1992)	Stormwater quality and flood control	$75 - $220 million/yr
Environment Canada (2006)	Compensation for road salt contamination	Canadian $10,000/well/year
Litman (2009)	Water pollution costs estimate	Average (USD per vehicle mile) (2007)
	Average car	0.014
	Compact car	0.014
	Electric car	0.007
	Van/Light truck	0.014
	Rideshare passenger	0
	Diesel bus	0.014
	Electric bus/Trolley	0.007
	Motorcycle	0.014
	Bicycle	0
	Walk	0
	Telework	0

WASTE DISPOSAL			
Lee (1995)	Automobile external waste disposal cost estimate	Annual volume	Unit costs
	Waste oil	960 million quarts	$0.50
	Scrapped cars	2.82 million	$25
	Tires	300 million	$1
Litman (2009)	Waste disposal costs	Average (USD per vehcile mile) (2007)	
	Average car	0.0004	
	Compact car	0.0004	
	Electric car	0.0004	
	Van/Light truck	0.0004	
	Rideshare passenger	0	
	Diesel bus	0.0004	
	Electric bus/Trolley	0.0004	
	Motorcycle	0.0004	
	Bicycle	0	
	Walk	0	
	Telework	0	

Appendix C. CEQA Environmental Checklist

____________________	____________________	____________________
Dist.-Co.-Rte.	P.M/P.M.	E.A.

This checklist identifies physical, biological, social and economic factors that might be affected by the proposed project. In many cases, background studies performed in connection with the projects indicate no impacts. A NO IMPACT answer in the last column reflects this determination. Where there is a need for clarifying discussion, the discussion is included either following the applicable section of the checklist or is within the body of the environmental document itself. The words "significant" and "significance" used throughout the following checklist are related to CEQA, not NEPA, impacts. The questions in this form are intended to encourage the thoughtful assessment of impacts and do not represent thresholds of significance.

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
I. AESTHETICS: Would the project:				
a) Have a substantial adverse effect on a scenic vista	☐	☐	☐	☐
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway	☐	☐	☐	☐
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	☐
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	☐	☐

II. AGRICULTURE AND FOREST RESOURCES: In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Dept. of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment Project; and the forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board. Would the project:

a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?	☐	☐	☐	☐
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☐

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)), timberland (as defined by Public Resources Code section 4526), or timberland zoned Timberland Production (as defined by Government Code section 51104(g))?	☐	☐	☐	☐
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	☐
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use?	☐	☐	☐	☐
	☐	☐	☐	☐

III. AIR QUALITY: Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	☐
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☐	☐

c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non- attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?	☐	☐	☐	☐
d) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☐
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☐

IV. BIOLOGICAL RESOURCES: Would the project:

a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	☐	☐	☐
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the California Department of Fish and Game or US Fish and Wildlife Service?	☐	☐	☐	☐

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☐	☐	☐	☐
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☐	☐	☐	☐
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☐
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☐

V. CULTURAL RESOURCES: Would the project:

a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?	☐	☐	☐	☐
b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to §15064.5?	☐	☐	☐	☐
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☐
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☐

VI. GEOLOGY AND SOILS: Would the project:

a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:	☐	☐	☐	☐
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42?	☐	☐	☐	☐
ii) Strong seismic ground shaking?	☐	☐	☐	☐
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☐
	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
iv) Landslides?	☐	☐	☐	☐
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☐
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?	☐	☐	☐	☐
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☐
e) Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?	☐	☐	☐	☐

VII. GREENHOUSE GAS EMISSIONS: Would the project:

a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment? b) Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?	An assessment of the greenhouse gas emissions and climate change is included in the body of environmental document. While Caltrans has included this good faith effort in order to provide the public and decision-makers as much information as possible about the project, it is Caltrans determination that in the absence of further regulatory or scientific information related to GHG emissions and CEQA significance, it is too speculative to make a significance determination regarding the project's direct and indirect impact with respect to climate change. Caltrans does remain firmly committed to implementing measures to help reduce the potential effects of the project. These measures are outlined in the body of the environmental document.

VIII. HAZARDS AND HAZARDOUS MATERIALS: Would the project:

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☐
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☐
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	☐

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	☐	☐	☐	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☐
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☐

g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☐
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☐

IX. HYDROLOGY AND WATER QUALITY: Would the project:

a) Violate any water quality standards or waste discharge requirements?	☐	☐	☐	☐
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☐
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☐	☐	☐
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☐	☐	☐
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☐
f) Otherwise substantially degrade water quality?	☐	☐	☐	☐

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☐
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☐	☐

i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☐
j) Inundation by seiche, tsunami, or mudflow	☐	☐	☐	☐

X. LAND USE AND PLANNING: Would the project:

a) Physically divide an established community?	☐	☐	☐	☐
b)Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☐
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☐

XI. MINERAL RESOURCES: Would the project:

a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	☐	☐	☐	☐
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	☐

XII. NOISE: Would the project result in:

a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☐
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?	☐	☐	☐	☐
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☐

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☐
) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☐

XIII. POPULATION AND HOUSING: Would the project:

a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	☐
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☐
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☐

XIV. PUBLIC SERVICES:

a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services:	☐	☐	☐	☐
Fire protection?	☐	☐	☐	☐
Police protection?	☐	☐	☐	☐
Schools?	☐	☐	☐	☐
Parks?	☐	☐	☐	☐

Other public facilities?	☐	☐	☐	☐

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
XV. RECREATION:				
a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☐
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?	☐	☐	☐	☐
XVI. TRANSPORTATION/TRAFFIC: Would the project:				
a) Conflict with an applicable plan, ordinance or policy establishing measures of effectiveness for the performance of the circulation system, taking into account all modes of transportation including mass transit and non-motorized travel and relevant components of the circulation system, including but not limited to intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?	☐	☐	☐	☐
b) Conflict with an applicable congestion management program, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☐
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?	☐	☐	☐	☐
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☐
e) Result in inadequate emergency access?	☐	☐	☐	☐
f) Conflict with adopted policies, plans or programs regarding public transit, bicycle, or pedestrian facilities, or otherwise decrease the performance or safety of such facilities?	☐	☐	☐	☐

XVII. UTILITIES AND SERVICE SYSTEMS: Would the project:

	Potentially Significant Impact	Less Than Significant with Mitigation	Less Than Significant Impact	No Impact
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	☐
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☐
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☐
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	☐
e) Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☐
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☐
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☐

XVIII. MANDATORY FINDINGS OF SIGNIFICANCE

a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, substantially reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☐	☐	☐	☐
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?	☐	☐	☐	☐

c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☐

Appendix D. NEPA Environmental Impact Statement Annotated Outlines

http://www.dot.ca.gov/ser/downloads/templates/NEPA_EIS_4_08.doc

Chapter 3 – Affected Environment, Environmental Consequences, and Avoidance, Minimization, and/or Mitigation Measures

Human Environment

Land Use (p.29)

The following items are discussed under this heading:

Existing and Future Land Use (p. 29)

Consistency with State, Regional, and Local Plans and Programs (p.30)

Coastal Zone

Wild and Scenic Rivers

Parks and Recreational Facilities (p. 33)

Discuss each subsection in its entirety before moving on to the next subsection.

Growth (p. 33)

Farmlands/Timberlands (if applicable) (p. 36)

Community Impacts

The Community Impacts section is broken into the following subsections:

Community Character and Cohesion (p. 39)

Relocations and Real Property Acquisition (p. 41)

Environmental Justice (p. 43)

Discuss each as a separate unit—regulatory setting, affected environment, impacts and avoidance, minimization, and/or compensation measures for one subsection then move on to the next subsection and do the same thing.

Utilities/Emergency Services (p. 45)

Traffic and Transportation/Pedestrian and Bicycle Facilities (p. 46)

Visual/Aesthetics (p. 50)

Cultural Resources (p. 52)

Physical Environment

Hydrology and Floodplain (p. 56)

Water Quality and Storm Water Runoff (p. 58

Geology/Soils/Seismic/Topography (p. 61)

Paleontology (Optional for projects off the State Highway System) (p. 63)

Hazardous Waste/Materials (p. 64)

Air Quality (p. 66)

Noise (and Vibration, if applicable) (p. 79)

Energy (p. 83)

Biological Environment

The Biological Environment section of the EIS is broken into the following subsections. Discuss each subsection in its entirety before moving onto the next subsection.

Natural Communities (p. 84)
Wetlands and Other Waters (p. 85)
Plant Species (p. 88)
Animal Species (p. 89)
Threatened and Endangered Species (p. 91)
Invasive Species (p. 92)

Relationship between Local Short-Term Uses of the Human Environment and the Maintenance and Enhancement of Long-Term Productivity (p. 94)

Irreversible and Irretrievable Commitments of Resources That Would Be Involved in the Proposed Project (p. 95)

Construction Impacts (optional placement) (p. 96)

If construction impacts have not been discussed above and/or the project is likely to have numerous construction impacts, consider having a separate construction impact section. Potential items to include: construction phasing/schedule/work hours, noise, air quality (dust), access issues (pedestrian, cyclists, equestrians, etc.), detours and traffic delays. Remember to discuss proposed borrow/fill and optional disposal sites. Also, identify and assess impacts associated with the staging and storage of equipment.

Cumulative Impacts (optional placement) (p. 97)

If cumulative impacts have not been discussed under each resource section above, then discuss them here.

Appendix E. Asian Development Bank (1996) Impacts List.

ADB (1996) groups the impacts into four major categories, namely, human health, human welfare, environmental resources, and global systems. The definitions of the impact categories are as follows:

- Human health
  - Mortality: Death or increased probabilities of death
  - Morbidity: Illnesses including cancer, malaria, respiratory diseases, headaches, etc.
- Human welfare
  - Materials: Damage to, and soiling of, buildings, etc.
  - Aesthetics: Visual, noise, traffic congestion, and other aesthetic impacts
  - Resource use: Changes in the productivity or value of commercial, subsistence, or recreational uses of such natural resources as forecast (e.g. for timber), agricultural lands (e.g. for crops), fisheries (e.g. for subsistence diets), or wildlife (e.g. for ecotourism). Resource use is categorized as a human welfare impact when a project affects commercial or recreational values. For example, a mangrove conservation project can improve a fishery's yield (a commercial value) and preserve an area for boaters (a recreation value). When a project affects the quality of an ecosystem (e.g. more abundant and diverse populations as a result of the mangrove conservation project), such an impact is classified as an environmental resource impact.
  - Social/cultural: Dislocations, loss of homeland, forced relocation of people, effects on subpopulations (e.g. farmers, indigenous people), impacts affecting religious beliefs, or cultural traditions.
- Environmental resources
  - Coastal and other marine ecosystems: Includes reef, fishery, and other biological resources in saline water
  - Groundwater: Water in the ground
  - Freshwater ecosystems: Includes wetlands, watersheds, and other biological resources in fresh water
  - Biodiversity/endangered species: Impacts on the diversity of flora, and fauna, species that are endemic or unique, and species habitats and corridors (e.g. flyways for birds)
  - Terrestrial ecosystems: Flora and fauna, minerals, soil, forest or grassland habitat
- Global systems: Changes in weather patterns and global climate, ozone depletion

Evaluation of Potential Impacts

Effect Category	**Human Health**		**Human Welfare**				**Environmental Resources**					
Pollutants/Stressors	Mortality	Morbidity	Materials	Aesthetics	Resource Use	Social/Cultural	Coastal & Marine Ecosystems	Groundwater	Freshwater Ecosystem	Biodiversity/Threatened & Endangered Species	Terrestial Ecosystems	Global Systems
Potential Emissions to Air												
Hazardous Chemicals												
Inorganics (nonmetals)												
Metals												
Organics (e.g. VOCs)												
Pesticides												
Gases												
CO												
SO2												
NOX												
Oxidants												
Greenhouse gases												
Aerosols/Particulates (PM10)												
Particulates (>PM10, dust)												
Electromagnetic radiation												
Noise												
Odor												
Potential Emissions to Water												
Hazardous Chemicals												
Inorganics (nonmetals)												
Metals												
Organics												
Pesticides												
Diesease/Pathogens												
BOD/COD												
Exotics												
Acids/Bases												
Fertilizers												
Waste products												
Acid deposition												
Salinization												
Particulates/Sedimentation												
Water diversion/withdrawl												
Channelization/impoundment												
Thermal alteration												
Overharvest												
Odor												
Potential Emissions to Land												
Hazardous Chemicals												
Inorganics (nonmetals)												
Metals												
Organics												
Pesticides												
Acid/Bases (pH)												
Fertilizers												
Waste products												
Acid deposition												
Salinization												
Erosion												
Exotics												
Overharvest												
Land use												

Source: ADB (1996)