Appendix A

Details on Economic Valuations

Introduction

With the economic perspective, historic data on the use and economic value of an asset serve to mark trends for the current economic value. With this perspective, the current asset is presented as the baseline, and changes to the asset are valued relative to the benefits and costs they provide to the public. In the cases of roadway construction or decommission, an asset's value is assessed by comparing the total future opportunities an asset generates with the opportunities created by alternative land uses.

The public experiences advantages or disadvantages based on a variety of variables but primarily their proximity to the asset and the accessibility it provides them. If an asset change improves access to a nearby business district, it could reduce local traffic congestion and raise property values. However, the same asset could hurt businesses in another district by improving access to potential lower-cost retailers and increasing their competition.

Determining the value of each roadway or transit service is a challenge because, except for toll roads, pricing information is not explicitly available. Instead, the value of each use must be inferred from observations about travel behavior. Aside from travel volumes, the most significant, observable aspect of travel is the travel time. The value of reaching a destination faster (i.e., travel time savings) is handled in conventional practice as a single value of time derived from a median hourly wage.

In most cases, this value is applied to all trips regardless of user income, time saved, trip length, or trip frequency. The rationale for this approach is that a single value of time represents a system-wide average across all users, trip purposes, timing, distances, and opportunity costs. It also creates a sense of equity because all travelers are treated the same regardless of income or other factors.

However, there are limitations to this ap-

With- and Without-Project Contexts

The basic formula for the economic approach to valuation is the comparison of a baseline scenario to another proposed scenario. With-project contexts and impacts refer to the scenario where the proposed action occurs. Similarly, the without-project contexts and impacts relate to the case where the proposed action does not take place.

proach. For people who value their free time more than their wages, the cost of travel time exceeds their hourly wage. Additionally, most people are unlikely to notice a reduction in travel time if the savings are a small fraction of their overall trip time. On any given trip, typical traffic conditions could cause travel time to vary by as much as the potential savings caused by a change to the highway asset, resulting in worse travel conditions than before. While theoretical research continues to explore these issues related to income and the impact of small travel time savings, standard practice remains in place. The value of time and other categories of benefits are discussed in more detail in the sections that follow.

The remainder of this appendix focuses on the major elements of economic valuation. It discusses key measures of mobility that contribute significantly to economic value, including travel time, vehicle operating costs, safety, and other features. In addition, standard features of an analysis are explored including the with- and without-project impacts, the determination of a present value comparison, and the metrics for comparing benefits and costs.

Comparison with Other Perspectives

The economic perspective differs significantly from the cost and market perspectives due to the way it compares the value of an improvement to a baseline. With each perspective one sets a baseline value, but with the economic perspective the baseline is not a starting point for future valuation via treatments or depreciation. Instead, the baseline is compared to the improvement value, or the total net incremental value to the public brought about by building a given asset or facility relative to not doing so. Depreciation and the impact of treatments are included inherently within the user and externality values. Furthermore, unlike the case of the other perspectives, the economic perspective incorporates both user and non-user impacts, positive and negative.

The standard economic approach considers six main categories of user and non-user impacts, these are: travel time, vehicle operating cost, safety, facility maintenance, emissions, and wider community impacts. While travel time, vehicle operating cost, and safety are all direct user impacts, the other three are externalities perceived by the broader community regardless of how much they personally use the transportation asset. **Table A-1** compares how the economic, cost, and market approaches to valuation account for these user and non-user elements.

Only the economic perspective accounts for externalities such as emissions, noise pollution, and broader impacts to the community like economic growth and prosperity. The economic perspective also explicitly considers safety, which the other two methods do not. These differences in perspective mean that the economic perspective will often value parallel road corridors higher than the market or cost perspective, since they enable users to avoid congestion and potentially reduce crash risks or they disperse the negative and positive externalities across a greater population.

Table A-1. Comparison of the Value Categories Used in Each Valuation Perspective

Categories of Asset Value	Economic Perspective	Cost Perspective	Market Perspective
Travel Time	User Value	Implicit in Condition	Perceived User Value
Vehicle Operating Cost	User Value	Implicit in Condition	Perceived User Value
Safety	User Value	Implicit in Condition	Unlikely User Value
Asset Maintenance	Externality	Cost to Maintain Condition	Cost to Retain Users
Emissions and Pollutants	Externality	Not Included	Not Included
Wider Community Impacts	Externality	Not Included	Not Included

Note that externalities may represent a variety of user and non-user impacts. Asset maintenance in the economic approach considers the damage and wear that a traveler inflicts upon the asset as a result of their use. The emissions and pollutants category tracks criteria air contaminant emissions[1], which impact the health of people who work or reside in the vicinity of the facility, as well as other pollutants such as noise. From a public agency perspective, each traveler using the asset incrementally increases the total damages inflicted upon the community for each mile they travel.

Wider community impacts refer to impacts beyond the direct use of an asset, typically associated with quality of life or business productivity. They include broad ramifications, such as increased productivity and the agglomeration of businesses, as well as localized effects, such as work zone adjustments, environmental resiliency, ecological impacts, and changes in property values, which require site-specific assessments to determine their cost or benefit to the with- and without-project scenarios. The wider community impacts are difficult to monetize, and it is often challenging to directly attribute them to a transportation asset because they originate under a series of complex, interlocking relationships. However, if sufficient information is available, these benefits can be included to capture a more complete perspective on the value of a roadway.

In summary, the economic perspective assesses the value users gain or lose for changes in travel time, operating costs, safety, emissions, pavement damage costs, and the other non-user benefits. Despite the complexities in determining the benefits of each value category, the economic method takes a systematic approach to analyzing travel behavior observations. The economic perspective

---

[1] Criteria air pollutants are a set of common pollutants found across the US and tracked by the Environmental Protection Agency (EPA). The six pollutants defined in the US Clean Air Act are ground-level ozone, particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide.

can evaluate different types of projects and can be adjusted for different types of impacts on users and non-users. Results are comparable across different traffic volumes, types of users, and types of improvements or changes to a variety of asset types. The key elements of this systematic approach are discussed below.

Principles of Economic Valuation

Several important principles are applied in all economic valuations. First, it is important to identify the potential effects of a project which are attributable to its costs. A clear definition of the with-project impacts is crucial for correctly estimating the benefits. This serves to avoid double counting the project's benefits and disbenefits. Another principle of economic valuations is to compute the present value of future costs and benefits, enabling comparisons with a common basis of understanding. The discount rate, which brings future values into present value, can have a non-trivial influence on the analysis of different projects, depending on the timing and magnitudes of the project impacts. As a result, the selection of the discount rate becomes an important policy decision and consideration for sensitivity analyses.

Comparative Contexts in Economic Valuation

An economic valuation of roadways involves establishing a comparative context because the economic value of a roadway is derived from its use and is calculated by observing a change in use. Typical economic analyses of a proposed project (e.g., roadway widening, asset decommissioning, safety enhancements) entail a comparison between the current, or baseline, conditions and the forecasted future conditions of the asset and other connected assets. Oftentimes, the baseline is a ***counterfactual*** context that enables changes in mobility to be compared against the context where a project is not implemented. In all cases, the same characteristics of mobility are developed for the baseline and with-project conditions to determine the change in value. This constructed valuation approach is then applied to assess if a project should be pursued.

The value of the proposed project is calculated from how it changes key characteristics of the asset's use. Depending on the analysis, these characteristics may be disaggregated by vehicle type (e.g., passenger vehicles, buses, and trucks) and time of day (e.g., peak and off-peak periods). The cost and facility use in the baseline are compared to an alternative forecast that shows the impacts of the project implementation.

The demand for a new asset (or changes to an existing asset) are estimated from a travel demand model that account for route and modal shifts as well as induced demand. Sound analysis of project value is grounded in a clear delineation of the changes attributed to the project so that the costs can be compared to the gains. For example, consider a highway widening project to relieve congestion. The benefits for existing users are based on the marginal increase in congestion-constrained speeds compared to what would have occurred if traffic remained burdened by congestion.

Comparative Contexts for Economic Valuations of Asset Management

Asset management assessments differ from capital projects involving new construction, but still require a comparison to reveal their value. Asset value may need to be calculated in several different contexts including:

- Maintenance activities for one or more assets
- Physical changes to a particular asset that could impact its future uses
- System-wide assessments for an entire class of transportation assets (e.g., Interstate).

Maintenance Activities. An economic measure of value can assess the difference in value obtained by users at different levels of service for roadway surfaces or safety features. The user value is measured by comparing an enhanced level of maintenance against the current conditions. Principal measures of user value are travel speeds and vehicle operating and maintenance costs, which increase with poor road quality. There is an extensive collection of literature studying the impacts of road quality on users ***(51)***. However, in practice, the incremental economic value of improved maintenance is relatively low compared to the value measured via the cost approach.

Physical Changes. This second case is the most common form of economic analysis since it involves an evaluation of physical changes to an asset that affect its use. Changes include user-oriented improvements such as capacity (e.g., widening, overpasses, and truck lanes), operational improvements (e.g., interchange improvements, shoulders, and auxiliary lanes), and access (e.g., decommissioning, one-way streets, ramps) that aim to alleviate congestion, improve safety, or serve other agency goals. Economic valuations of such physical changes rely on forecasted changes in traffic patterns compared to a baseline that accounts for future uses under the current design. The value of these physical changes is estimated by differences in benefit categories (e.g., time savings, operating costs) over the life of the projects.

System-Wide Assessments. The value of an asset can be evaluated from a system-wide perspective by examining the next best alternative road class. However, this is usually a contrived exercise, and offers limited benefit outside of the theoretical. Consider the value of a state's major arterial facilities. From an aggregated asset perspective, the next best option would be the minor arterials. Each type of roadway has a common set of characteristics, including average travel speeds per mile, intersection crossings and signals, and potential levels of normal traffic congestion. In this hypothetical case, the value of the major arterial is derived from the differences in value categories between the major and minor arterials. Since major arterials permit faster speeds, their value is expected to be higher, provided that the value of this reduced travel is not overcome by potentially increased travel cost or crash risk. This same approach could be applied for other roadway classes too. The use of local neighborhood roads in a car can be compared with an option to ride a bike or walk to a destination. These with- or without- asset evaluations require data on the use of a facility as well as data on opportunities created by eliminated vehicle use.

As a practical matter, only the second context (physical changes to a roadway) is commonly evaluated today using the economic approach. Typically, this evaluation takes the form of a benefit-cost analysis used to justify the physical improvement. However, the discussion of the three contexts illustrates the range of perspectives from which a value can be considered. The remainder of this section describes the evaluation of physical changes to an existing roadway, but a similar approach can be taken with respect to the other two contexts.

Measurement of Value

The economic measure of asset value accounts for the costs and benefits accepted by people choosing to use a transportation facility and the externalities that such use places upon others. Since transportation assets are a public good, users gain no intrinsic value from a roadway or other transportation asset, rather they value the asset for enabling them to reach a place faster and more safely, given some implicit or explicit operating cost. At the same time, externalities, such as those related to air and noise pollution, can negatively affect the health and well-being of people living near the facility. The time savings and operating, ownership, crash, and emissions costs are all common elements of asset value in a benefit-cost analysis. Additional value categories, such as work zone impacts, resiliency, and property value impacts, can be relevant depending on the project, but tend to be smaller in magnitude and require site-specific assessments.

A conceptual model assessing the value of an asset recognizes user benefit as the ability to reach a destination in less time. In exchange, a user would accept any associated vehicle use and ownership costs and their vulnerability to crashes while using this asset. The full public welfare impact also accounts for the user-caused pollution externalities and marginal damage to the asset (e.g., pavement deterioration). In a more functional form, the value on an asset would be estimated as:

User Value = Personal travel time savings and reliability (by type of vehicle, occupancy)

Less Personal out-of-pocket vehicle use and ownership costs

Less Personal crash risk (including the probability of being in a crash by type)

Less Public air and noise pollution costs (including GHG)

Less User damage cost on public infrastructure (roadway deterioration)

Following this framework, all costs and benefits from using an asset under without- and with-project changes are estimated to determine a net value per user. After applying this value per user across all users for the project evaluation period and then discounting, the net present value of with- and without-project contexts can be compared.

In practice, guidance for estimating facility benefits is available from the United States Department of Transportation (USDOT) in relation to benefit calculations for INFRA and BUILD grants (called RAISE grants beginning in 2021) ***(48)***. The guidance aims to help stewards of infrastructure assets determine if a project's benefits justify its costs and understand if the value society assigns to an asset exceeds the cost to provide it. This guidance monetizes user benefits and estimates the value an asset. The list of benefits described by the guidance includes:

- **Travel time** is one of the most common and important considerations people make when planning their route. An asset that offers travel time savings over its next best alternative provides a benefit to users that can be measured and monetized. Asset improvements can increase vehicle speeds and reduce travel times.
- **Travel time reliability** also impacts how users experience and value an asset. While travel time savings are largely dependent on the distance of the route provided, reliability captures the operational performance of an asset based on design and physical condition. USDOT guidance does not cover travel time reliability, but additional guidance on estimating travel time reliability is available from the Second Strategic Highway Research Program (SHRP 2) research.
- **Vehicle use and ownership** relates to changes in fuel consumption, wear and tear on vehicles due to poor condition roads, and any trip costs such as tolls or parking. It captures some of the benefit that users gain from an asset in good physical condition.
- **Safety** refers to any changes in likelihood and severity of crash events (i.e., fatality, injury, and property damage) on an asset. Benefits are derived from the reduction in crash frequency or severity in the with-project context as compared to the current conditions. Crash Modification Factors (CMFs) associated with safety improvements provide a means to calculate the magnitude of the with-project benefits.[2]
- **Asset Maintenance** is the damage and general wear-and-tear that a vehicle inflicts upon the asset. Though it could be broadly applied to all types of assets by converting the rate of decay over time into a rate of decay per vehicle, it typically refers only to those assets that a user vehicle has direct contact with (roads and bridges).
- **Air and Noise Pollution Externalities** include criteria air contaminants, greenhouse gas emissions, and noise from vehicles. While criteria air contam-

---

[2] Note that FHWA maintains a Crash Modification Clearinghouse with CMFs associated with safety improvement types.

inants and noise largely affect people and businesses near a roadway, greenhouse gas emissions contribute to the widespread threat of climate change. The monetary values of each type of air pollutant are determined on a per unit basis and are combined with emissions rates to estimate the cost of a with-project context. Noise pollution is estimated as a function of the impact on property values near a facility.

A systematic approach to estimating the values of the major classes of benefits is outlined in **Table A-2**. The key elements affecting each value category are the impact scale, qualifying factors, and value per unit. More detail on how to calculate these benefits is provided in Appendix B.

Table A-2. . Elements of Economic Value, by Category of Value

Value Category	Scale of Impact	Impact Factors	Impact Value per Unit
Travel Time	Numbers of travelers by mode, and time period	• Travel times, by mode and time period	Value of time
Vehicle Operating Cost	Numbers of vehicles, by type	• Travel distance • Vehicle speed, by facility	Fuel and non-fuel operating costs for autos and trucks
Safety	Numbers of vehicles, by type	• Travel distance • Crash Rates, by severity	Crash costs, by severity
Asset Maintenance	Numbers of vehicles, by type	• Travel distance	Cost of asset damage per mile for autos and trucks
Emissions and Pollutants	Numbers of vehicles, by type	• Travel distance • Vehicle speed • Pollutant emissions rates per vehicle type	Valuation per unit of emissions, by pollutant type Noise pollution in $ per mile for autos and trucks
Wider Community Impacts	Number of vehicles, by type Size of asset	• Asset proximity • Geographic conditions • Other factors	Cost of impact per unit of asset (e.g. mile of roadway)

The scale of impact represents the number of people affected by the project. The most common scale is per vehicle, as vehicles are the easiest unit to measure, but conversion factors for the average number of passengers per vehicle are often applied, so all benefit categories are measured in number of travelers. Impact factors refer to the physical measures of change caused by the project, and they are typically provided in terms of the scale for reference (per person, per vehicle). Lastly, the impact value per unit is the rate of conversion to transfer the impact factors into a common monetary value. Both the scale of impact and impact factors differ between without- and with-project contexts, while the impact value per unit remains fixed. Through these three steps, each value category is converted into a common monetary amount and unit.

Estimation of Present Value

The costs and benefits of with- and without-project scenarios accrue over a set period of time. Often, it is the length of time that an asset is improved above a given baseline or the expected lifespan of the asset, and it varies depending on the type of project. For example, maintenance timing decisions may be best to value over the time between potential resurfacings or other treatments. The time span for a physical change (e.g., a bypass) is more challenging to determine because the accuracy of forecasts weaken over time due to a variety of contexts that can change in unpredictable ways (e.g., economic activity, demographic shifts, new community developments, and travel preferences).

Conventional practice establishes a 20- or 30-year project horizon when accounting for future benefits and costs. According to USDOT's Benefit-Cost Analysis (BCA) guidelines, the value of a project should be represented by 30 years of operation, except in the case of transportation facilities (e.g., bridges and structures) that have a much longer lifespan ***(48)***. In such instances, a residual value of the remaining project lifespan is estimated at the end of 30 years and included in the measure of total value. A fixed period of analysis is suitable for an asset valuation measure for an entire road class. Alternatively, the analysis period can be set equal to the estimated lifecycle for the asset being evaluated.

Economic analysis converts all future streams of benefits into present values. A present value is computed by discounting future benefits and costs based on when they occur using a discount rate. The discount rate reflects the social rate of time preference. A positive discount rate indicates a preference for benefits to occur sooner rather than later. A discount rate equal to zero implies that a person is just as happy to wait for a future improvement as they are to experience the same improvement now. Conceivably, if a person feels stronger about a bequest of value for future generations, than to gaining the value for his or her own personal benefit, a negative discount rate is possible ***(52)***, though this is more likely to occur in projects will not yield benefits in the near term. Naturally, nearly all discount rates are positive with the variation only arising in the magnitude of the rate.

At first glance, the concept of discounting future benefits does not seem reasonable for transportation projects, since some benefits, such as time savings, only occur in the future and have no discernible worth in the present. Think about it. Travelers would place a high value on the opportunity to reach their destination faster on a trip that occurs today or tomorrow. But, what about a trip next year or the year after? A ***time-traveled*** future version of one's self would likely value any time savings in the future in the same way as she or he would in the present. However, since it is impossible to ***physically*** benefit from a future time savings while in the present, discounting appears inappropriate. By contrast, discounting certainly applies in the context of a choice between consumption of a good or the potential to earn money, both of which can be accumulated at almost any time. In those cases, discounting accounts for an opportunity cost of waiting.

To overcome such incongruities in future transportation valuation, it is helpful to interpret the discount rate as reflecting a willingness-to-pay for benefits that occur in the future. That is, if a person is offered an opportunity to realize 10 minutes of time savings today, a traveler may be willing to pay some fraction of their wage rate today for that time. However, that same person would likely value the same amount of time savings in one year at a lower value, in part because of general preferences for the present over the future and the higher risks in realizing the future value.

Ultimately, the discount rate simplifies into a single parameter the value that decision-makers today, including both implementation agencies and the people and businesses that decide to use a road, place on future travel conditions. In practice, it is assumed that most individuals would be willing to pay less for benefits that occur in the future than they do in the present, and higher discount rates reflect greater demand for benefits in the near term. In a project evaluation, positive discount rates will lower the present value of the future stream of benefits and costs. In the economic approach to valuing assets, the discount rate represents the value people place today on the ability to go faster in the future.

A significant amount of theoretical research has explored the question about what discount rate to use for different types of benefits and contexts. This research has documented significant disagreements among economists regarding the appropriate value ***(53)***. While many of these discussions have important theoretical value, practical approaches to asset valuation can rely on standard guidelines. USDOT BCA guidelines, for example, draw from the US Office of Management and Budget (OMB) standards for public investments ***(54)***. In OMB Circular A-94, the rationale is established for using a 7% real discount rate (which approximates the marginal pretax rate of return on an average investment in the private sector) for regulatory analysis or benefit-cost analysis of public investment. The OMB guidance also suggest conducting sensitivity analysis by applying different discount rates. In previous years, USDOT has suggested using a 3% real discount rate as part of sensitivity analysis in applications to discretionary grant programs.