U.S. Department of Transportation

Benefit-Cost Analysis Guidance for Discretionary Grant Programs

Office of the Secretary

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Benefit-Cost Analysis Guidance

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Acronym List

BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
CMF	Crash Modification Factor
CO_2	Carbon Dioxide
dBA	Decibels Adjusted
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gas
MAIS	Maximum Abbreviated Injury Scale
NHTSA	National Highway Traffic Safety Administration
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrogen Oxides
NPV	Net Present Value
O&M	Operating and Maintenance
OMB	Office of Management and Budget
PDO	Property Damage Only
PM	Particulate Matter
SO_2	Sulfur Dioxide
YOE	Year-of-Expenditure Dollars
U.S.	United States of America
USDOT	The United States Department of Transportation
VOC	Volatile Organic Compounds
VSL	Value of a Statistical Life
VTTS	Value of Travel Time Savings
YOE	Year of Expenditure

1. Overview and Background

This document is intended to provide applicants to USDOT's discretionary grant programs with guidance on completing a benefit-cost analysis[1] (BCA) for submittal as part of their application. BCA is a systematic process for identifying, quantifying, and comparing expected benefits and costs of a potential infrastructure project. The information provided in the applicants' BCAs will be evaluated by the United States Department of Transportation (USDOT) and used to help ensure that the available funding under the programs is devoted to projects that provide substantial economic benefits to users and the Nation as a whole, relative to the resources required to implement those projects.

A BCA provides estimates of the anticipated benefits that are expected to accrue from a project over a specified period and compares them to the anticipated costs of the project. As described in the respective sections below, costs would include both the resources required to develop the project and the costs of maintaining the new or improved asset over time. Estimated benefits would be based on the projected impacts of the project on both users of the facility and non-users, valued in monetary terms.[2]

While BCA is just one of many tools that can be used in making decisions about infrastructure investments, USDOT believes that it provides a useful benchmark from which to evaluate and compare potential transportation investments for their contribution to the economic vitality of the Nation. USDOT will thus expect applicants to provide BCAs that are consistent with the methodology outlined in this guidance as part of their justification for seeking Federal support. Additionally, USDOT encourages applicants to incorporate this BCA methodology into any relevant planning activities, regardless of whether the sponsor seeks Federal funding.

This guidance:

- Describes an acceptable methodological framework for purposes of preparing BCAs for discretionary grant applications (see Sections 3, 4, and 5);
- Identifies common data sources, values of key parameters, and additional reference materials for various BCA inputs and assumptions (see Appendix A); and
- Provides sample calculations of some of the quantitative elements of a BCA (see Appendix B).

Key changes in this version of the guidance include updated parameter values and additional guidance and recommended values on vehicle occupancy, analysis period assumptions, and the use of available crash data and crash modification factors.

BCAs vary greatly in complexity and depth from one project to the next. USDOT is sensitive to the fact that applicants have different resource constraints, and that complex forecasts and analyses are not always a cost-effective option. However, given the quality of BCAs received in previous rounds of discretionary

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[1] "Benefit-cost analysis" and "cost-benefit analysis" are interchangeable names for the same process of comparing a project's benefits to its costs. The U.S. Department of Transportation uses "benefit-cost analysis" to ensure consistent terminology and because one widely used method for ranking projects is the benefit-cost ratio.

[2] As described in Section 6 on Comparing Benefits to Costs, however, it may be appropriate to use a slightly different accounting framework than this when comparing the ratio of benefits to costs.

grant programs from applicants of all sizes, the Department also believes that a transparent, reproducible, thoughtful, and well-reasoned BCA is possible for all projects. The goal of a well-produced BCA is to provide an objective assessment of a project that carefully considers and measures the outcomes that are expected to result from the investment in the project and quantifies their value. If, after reading this guidance, an applicant would like to seek additional help, USDOT staff are available to answer questions and offer technical assistance up until the final application deadline for the respective program.

This guidance also describes several potential categories of benefits that may be useful to consider in BCA, but for which USDOT has not yet developed formal guidance on recommended methodologies or parameter values. Future updates of this guidance will include improved coverage of these areas as research on these topics is incorporated into standard BCA practices.

2. Statutory and Regulatory References

This guidance applies to a wide range of surface transportation projects (e.g., highways, transit, rail, ports) under USDOT's discretionary grant programs.

USDOT will consider benefits and costs using standard data and qualitative information provided by applicants, and will evaluate applications and proposals in a manner consistent with Executive Order 12893 (Principles for Federal Infrastructure Investments, 59 FR 4233) and Office of Management and Budget (OMB) Circular A-94 (Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs). OMB Circular A-4 (Regulatory Analysis) also includes useful information and cites textbooks on benefit-cost analysis if an applicant wants to review additional background material. USDOT encourages applicants to familiarize themselves with these documents while preparing a BCA.

3. General Principles

To determine if a project's benefits justify its costs, an applicant should conduct an appropriately thorough BCA. A BCA estimates the benefits and costs associated with implementing the project as they occur or are incurred over a specified time period.

To develop a BCA, applicants should attempt to quantify and monetize all potential benefits and costs of a project. Some benefits (or costs) may be difficult to capture or may be highly uncertain. If an applicant cannot monetize certain benefits or costs, it should quantify them using the physical units in which they naturally occur, where possible. When an applicant is unable to either quantify or monetize such benefits, the sponsor should describe them qualitatively.

In this guidance document, USDOT provides recommended nationwide average values to monetize common sources of benefits from transportation projects (see Appendix A). USDOT recognizes that in many cases, applicants may have additional local data that is appropriate or even superior for use in evaluating a given project. USDOT supports analyses that blend these localized data with national estimates or industry standards to complete a more robust analysis, so long as those local values are reasonable, well-documented, and generally consistent with the values outlined in in this document.

The following section outlines general principles of benefit-cost analysis that applicants should incorporate in their submission.

3.1. Impacts of Transportation Infrastructure Improvements

An efficient, highly functioning transportation system is vital to our Nation's economy and the well-being of its citizens. Infrastructure forms the backbone of that system, and both the public and private sectors have invested substantial resources in its development. At the same time, transportation infrastructure requires ongoing capital improvements to rebuild and modernize aging facilities and ensure that they continue to meet the needs of a growing population and economy.

Before pursuing a transportation infrastructure improvement, a project sponsor should be able to articulate the problem that the investment is trying to solve and how the proposed improvement will help meet that objective. This is particularly important when the project sponsor is seeking funding from outside sources under highly competitive discretionary programs. One of the primary benefits of conducting a BCA is the rigor that it imposes on project sponsors to be able to justify *why* a particular investment should be made, by carefully considering the impact that that investment will have on users of the transportation system and on society as a whole.

Carefully identifying the different impacts a project is expected to have is the first and perhaps most important step in conducting a BCA. Doing so will help frame the analysis and point toward the types of benefits that are most significant to a particular project, allowing the applicant to focus its BCA efforts on those areas. Applicants should clearly demonstrate the link between the proposed transportation service improvements and any claimed benefits. It is important that the categories of estimated benefits presented in the BCA be in line with the nature of the proposed improvement and its expected impacts. When there are significant discrepancies, this can serve to undermine the credibility of the results presented in the analysis.

3.2. Baselines and Alternatives

Each analysis needs to include a well-defined baseline to measure the incremental benefits and costs of a proposed project against. A baseline is sometimes referred to as the "no-build alternative." A baseline defines the world without the proposed project, and would typically include routine maintenance that would occur in the absence of the proposed project. As the status quo, the baseline should incorporate factors—including future changes in traffic volumes—that are not brought on by the project itself and would occur even in its absence.

Baselines should not assume that the same (or similar) improvement will be implemented later. For example, if the project applying for funding would accelerate the already planned replacement of a deteriorating bridge, it would be incorrect for the baseline to include the bridge replacement project occurring at a later date. The point of the BCA is to evaluate benefits and costs of the project itself, not whether accelerating the project is cost-beneficial (note that it is possible that the project would not be cost-beneficial under either timeframe). A more appropriate baseline would thus be one in which the bridge replacement did not occur, but could include the (presumably) increasing maintenance costs of ensuring that the existing bridge stays open or the diversion impacts that could occur if the bridge were to be posted with weight restrictions or ultimately closed to traffic at a future date.

Similarly, the baseline should not incorporate an alternative improvement on another mode of transportation that would accomplish roughly the same goal, such as reducing congestion or moving larger volumes of freight. The intent of benefit-cost analysis is to examine whether the proposed project is justified given its expected benefits; simply comparing one capital investment project to another does not indicate whether either project would be cost-beneficial in its own right.

Applicants should also be careful to avoid using "straw man" baselines that use unrealistic assumptions about how freight and passenger traffic would flow over the Nation's transportation network in the absence of the project, particularly when alternate modes of travel are considered. Such assumptions should assume that users would choose the next best (i.e., least costly) alternative, rather than an overtly suboptimal one. For example, if a project would construct a short rail spur from a railroad mainline to a freight handling facility, it is unrealistic to assume that, in the absence of the project, firms would ship cargo only by truck for thousands of miles to its final destination as their only alternative. A more realistic description of current traffic would more likely have current cargo traffic going by rail for most of the distance, and by truck for the relatively short distance over which rail transportation is not available.

Demand Forecasting

Applicants should clearly describe both the current use of the facility or network that is proposed to be improved (e.g., current traffic or cargo volumes) and their forecasts of future demand under both the baseline and the "build case." Forecasts of future economic growth and traffic volume should be well documented and justified, based on past trends and/or reasonable assumptions of future socioeconomic conditions and economic development.[3] Where traffic forecasts (such as corridor-level models or regional travel demand models) are used that cover areas beyond the improved facility itself, the geographic scope of those models should be clearly defined and justified. Other assumptions used to translate the usage forecasts into estimates of travel times and delay (such as gate-down times at grade crossings) should also be described and documented.

Forecasts should be provided both under the baseline and the improvement alternative. Applicants should take care to ensure that the differences between the two reflect only the proposed project to be analyzed in the BCA and not impacts from other planned improvements. Forecasts should incorporate indirect effects (e.g., induced demand) to the extent possible. Applicants should be especially wary of using simplistic growth assumptions (such as a constant annual growth rate) over an extended period of time without taking into account the capacity of the facility. It is not realistic to assume that traffic queues and delays would increase to excessively high levels with no behavioral response from travelers or freight carriers, such as shifting travel to alternate routes, transfer facilities, or time periods.

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[3] The Department recognizes that some transportation improvements may be specifically targeted at supporting future economic development that is not yet "locked in" or underway. This is often particularly the case in rural areas without a strong existing economic base or at potential brownfield redevelopment sites. In such cases, and to the extent possible, applicants should document how the specific improvements proposed in the application are expected to facilitate the projected development (such as by lowering travel time costs or operating costs) and how this will lead to increased use of the improved transportation facility, as well as the expected timing of those impacts.

Applicants should not simply use traffic and travel information from the forecast year to estimate benefits. Instead, benefits should be based on the projected traffic level for each individual year. Given the nature of most traffic demand modeling, in which traffic levels are provided only for a base year and a limited number of forecast years, interpolation between the base and forecast years may be necessary to derive such numbers. However, applicants should exercise extra caution when extrapolating beyond the years covered in a travel demand forecast, given the additional uncertainties and potential errors that such calculations bring; in many cases, it would be more appropriate to cap the analysis period at the final year for which a reliable travel growth forecast is available, rather than extrapolating beyond that point.

3.3. Inflation Adjustments

In order to ensure a meaningful comparison between benefits and costs, it is important that all monetized values used in a BCA be expressed in common terms; however, data obtained for use in BCAs is sometimes expressed in nominal dollars from several different years.[4] Nominal dollars reflect the effects of inflation over time, and are sometimes also called current or year-of-expenditure dollars. Such values must be converted to real dollars (also referred to as constant dollars), using a common base year[5], to net out the effects of inflation.

OMB Circular A-94 and OMB Circular A-4 recommend using the Gross Domestic Product (GDP) Deflator as a general method of converting nominal dollars into real dollars. The GDP Deflator captures the changes in the value of a dollar over time by considering changes in the prices of all goods and services in the U.S. economy.[6] Table A-8 in Appendix A provides values based on this index that could be used to adjust the values of any project costs incurred in prior years to 2018 dollars. Appendix B also provides a sample calculation for making inflation adjustments. If an applicant would like to use another commonly used deflator, such as the Consumer Price Index, the applicant should explicitly indicate that and provide the index values used to make the adjustments.

3.4. Discounting

After accounting for the effects of inflation to express costs and benefits in real dollars, a second, distinct adjustment must be made to account for the time value of money. This concept reflects the principle that benefits and costs that occur sooner in time are more highly valued than those that occur in the more distant future, and that there is thus a cost associated with diverting the resources needed for an investment from other productive uses in the future. This process, known as discounting, will result in future streams of benefits and costs being expressed in the same present value terms.

In accordance with OMB Circular A-94, applicants to the discretionary grant programs should use a real discount rate (the appropriate discount rate to use on monetized values expressed in real terms, with the

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[4] This is particularly common for project cost data. See Section 5.1 below for more discussion of the treatment of project costs in BCA.

[5] A real dollar has the same purchasing power from one year to the next. In a world without inflation, all current and future dollars would be real dollars; however, inflation does tend to exist, which thus causes the purchasing power of a dollar to erode from year to year.

[6] Note that both the GDP Deflator and the Bureau of Labor Statistics' Consumer Price Index also adjust for changes in the quality of goods and services over time.

effects of inflation removed) of **7 percent** per year to discount streams benefits and costs to their present value in their BCA. Applicants should discount each category of benefits and costs separately for each year in the analysis period during which they accrue. Appendix B provides more information on the formulas that should be used in discounting future values to present values, and presents a simplified example table. Additionally, the chart below illustrates the current value of a single dollar a given number of years in the future (discounting at 7 percent).
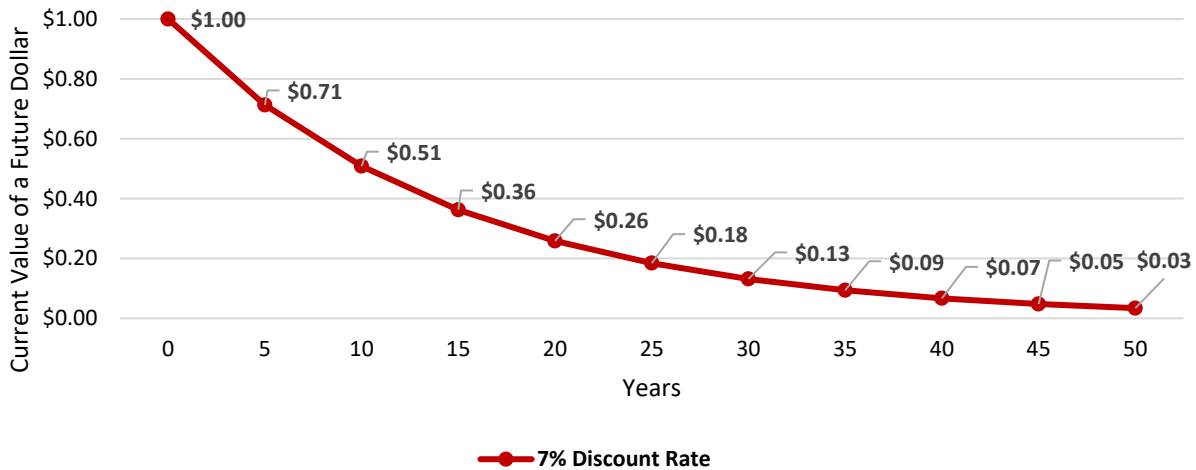
3.5. Analysis Period

The selection of an appropriate analysis period is a fundamental consideration in any BCA. By their nature, transportation infrastructure improvements typically involve large initial capital expenditures whose resulting benefits continue over the many years that the new or improved asset remains in service. To capture this dynamic, the analysis period used in a BCA should cover both the initial development and construction of the project and a subsequent operational period during which the on-going service benefits (and any recurring costs) are realized. Applicants should clearly describe the analysis period used in their BCA, including the beginning and ending years, and explicitly state their rationale for choosing that period.

Analysis periods should typically be set based on the expected useful service life of the improvement, which would in turn reflect the number of years until the same type of action (reconstruction, capacity expansion, etc.) would be anticipated to take place again. The analysis period should cover the full development and construction period of the project, plus an operating period after the completion of construction during which the full benefits and costs of the project can be reflected in the BCA. The appropriate analysis period will depend on both the type of improvement and its magnitude. For example, some types of capital improvements (such as equipment purchases) will have a shorter economically useful life than longer-lived investments such as structures. Repairs or resurfacing would also have a shorter useful life than the full reconstruction or replacement of a facility. Longer analysis periods may also help to capture the full impact of construction programs involving multiple phases or phased-in operations.

There is a limit, however, to the utility of modeling project benefits over very long time scales. General uncertainty about the future, as well as specific uncertainty about how travel markets and patterns may shift or evolve, means that predictions over an exceedingly long term begin to lose reliability and perhaps even meaning. Additionally, in a BCA, each subsequent year is discounted more heavily than the previous year, and thus each subsequent year is less and less likely to impact the overall findings of the analysis. For these reasons, USDOT recommends that applicants avoid any analysis periods extending beyond **30 years of full operations**. Where project assets have useful lifetimes greater than this period[7], the applicant should consider including an assessment of the value of the remaining asset life (as described in Section 5.3 below).

Additional guidance on expected service life/operating periods for different types of transportation infrastructure improvements in BCA includes:

- Projects involving the initial construction or full reconstruction of highways or similar facilities should use an analysis period of 30 years.
- Projects aimed primarily at capacity expansion or to address other operating deficiencies should use an operating period of 20 years (even if the useful physical life of the underlying infrastructure is greater than this). This is intended to correspond to the typical "design year" for such improvements.
- Expected service lives for intelligent transportation systems and similar investments are generally somewhat less than 20 years, and may be as short as 7-10 years for some types of technologies. Similarly, the average service life of transit buses in the U.S. is 14 years. Where these types of investments are the primary capital improvements in the project, the BCA should use a corresponding operating period. Where these are components of a larger improvement (such as a highway reconstruction project or new bus rapid transit line) that includes longer-lived assets, the analysis should include a recapitalization cost for the shorter-lived assets at the appropriate time within the analysis period.

While these guidelines on service lives are meant to be general rules of thumb, rather than hard and fast requirements, applicants should be sure to clearly justify the use of analysis periods that differ significantly from the recommended lengths.

3.6. Scope of the Analysis

A BCA should include estimates of benefits and costs that cover the same scope of the project. For example, if the funding request is for a sub-component of a larger project, it would be incorrect to include only the cost of the sub-component but estimate the benefits based on outcomes that depend on the completion of the larger project. In projects with multiple sub-components, the applicant must make clear exactly what portions of the project form the basis of the estimates of benefits and costs.

The scope should also be large enough to encompass a project that has independent utility, meaning that it would be expected to produce the projected benefits even in the absence of other investments. In some

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[7] This would generally be limited to bridges (both road and rail) or other structures.

cases, this would mean that the costs included in the BCA may need to incorporate other related investments that are not part of the grant request, but which are necessary for the project to deliver its promised benefits.

USDOT discretionary grant programs typically allow for a group of related projects to be included in a single grant application. In many cases, each of these projects may be related, but also have independent utility as individual projects. Where this is the case, each component of this package should be evaluated separately, with its own BCA. However, in some cases, projects within a package may be expected to also have collective benefits that are larger than the sum of the benefits of the individual projects included in the package. In such cases, applicants should clearly explain why this would be the case and provide any supporting analyses to that effect.

4.   Benefits

Benefits measure the economic value of outcomes that are reasonably expected to result from the implementation of a project, and may be experienced by users of the transportation system or the public at-large. Benefits accrue to the users of the transportation system because of changes to the characteristics of the trips they make (e.g., travel time reductions).

All of the benefits reasonably expected to result from the implementation of the project or program should be monetized to the extent possible and included in a BCA. This section of the guidance document describes acceptable approaches for assessing the most commonly included benefit categories, but it is not intended to be an exhaustive list of all the relevant benefits that may be expected to result from all types of transportation improvement projects.

Benefits should be estimated and presented in the BCA on an annual basis throughout the entire analysis period. Applicants should not simply assume that the benefits of the project will be constant in each year of the analysis, unless they can provide a solid rationale for doing so. For projects that are implemented in phases, the types and amount of benefits may phase-in over a certain period of time as additional portions of the project are completed. Any phasing and implementation assumptions made by the applicant should be thoroughly described in the supporting documentation for the BCA.

Some transportation improvements may result in a mix of positive and negative outcomes (e.g., an increase in travel speeds that may be accompanied by an increase in emissions). In such cases, those negative outcomes would be characterized as "disbenefits" and subtracted from the overall total of estimated benefits.

4.1. Value of Travel Time Savings

One of the most common goals of many transportation infrastructure improvement projects is to improve traffic flow or provide new connections that result in reduced travel times. Estimating travel time savings from a transportation project will depend on engineering calculations and a thorough understanding of how the improvement will affect the operations of the transportation facility. Such improvements may reduce the time that drivers and passengers spend traveling, including both in-vehicle time and wait time.

Recommended values of travel time savings (VTTS), presented in dollars per person-hour, are provided in Appendix A, Table A-3 of this document. The table includes values for travel by both private vehicle and by commercial vehicle operators. Private vehicle[8] travel includes both personal travel and business travel[9]; the table also includes a blended value for cases where the mix of personal and business travel is unknown. The values are also applicable for in-vehicle travel time; as noted in the table, non-vehicle personal travel time such as waiting time, transfer time, time spent standing in a crowded transit vehicle, walking, or cycling should be valued at twice this rate. Also, where applicants have specific data on the mix of local and long-distance travel on a facility, they may develop a blended estimate using the long-distance VTTS values provided in the table; however, where applicants do not have this information, they should apply the general in-vehicle travel time values to all travel in their BCA. The travel time savings parameters in Table A-3 should also be applied to all years over the analysis period.

Vehicle Occupancy

Applicants should note that the values provided in Table A-3 are on a per person basis. However, many travel time estimates are based on vehicle-hours, and thus require additional assumptions about vehicle occupancy to estimate person-hours of travel time. Assumptions about vehicle occupancy factors should be based on localized data or analysis that is specific to the corridor being improved where at all possible (such as for large-scale capacity expansion projects on congested urban arterials and freeways where expected travel time savings are largely tied to reductions in peak-period delay), and those sources and values should be documented in the BCA.

For other projects where no such data is available, applicants may use the more general, national-level vehicle occupancy factors included in Appendix A, Table A-4. The occupancy factors in Table A-4 include both an overall value for all travel and separate factors that differentiate among weekday peak, weekday off-peak, and weekend travel. The more detailed factors should be applied where applicants have such information about the composition of travel, or where estimated travel time savings resulting from the project would be concentrated in peak periods.

Occupancy rates may also need to be applied to other modes of transportation besides passenger cars. For public transportation (including buses, urban transit rail, and intercity passenger rail), applicants should apply occupancy factors that are specific to the locality, corridor, or specific service where the proposed improvements would take place. For freight-hauling vehicles, applicants should use typical crew sizes (such as one driver per truck) and apply the appropriate hourly time rates.

Reliability

Reliability refers to the predictability and dependability of travel times on transportation infrastructure. Improvements in reliability may be highly valued by transportation system users, particularly for freight movement, in addition to the value that they may place on reductions in mean travel times.

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[8] In this context, "private vehicle" travel would also include passengers in commercial or public transit vehicles.
[9] Business travel includes only on-the-clock work-related travel. Commuting travel should be valued at the personal travel rate.

Although improving service reliability can increase the attractiveness of transportation services, estimating its discrete quantitative value in a BCA can be challenging. Users may have significantly varied preferences for different trips and for different origin and destination pairs. How people value reliability may relate more to how highly they value uncertainty in arrival times or the risk of being late than to how they value trip time reductions. At the same time, heavily congested facilities may experience both longer average travel times and greater variability, as the effects of incidents become magnified under those conditions; as a result, reliability and mean travel times may be correlated. Thus, assessing the value of improving reliability is generally more complex than valuing trip time savings, and a perfect assessment in a BCA is unlikely.

At this time, USDOT does not have a specific recommended methodology for valuing reliability benefits in BCA. If applicants nevertheless choose to present monetized values for improvements in reliability in their analysis, they should carefully document the methodology and tools used, and clearly explain how the parameters used to value reliability are separate and distinct from the value of travel time savings used in the analysis.

4.2. Operating Cost Savings

Operating cost savings commonly result from transportation infrastructure projects. Freight-related projects that improve roads, rails, and ports frequently generate savings in vehicle operating costs to carriers (e.g., reduced fuel consumption and other operating costs). Project improvements may also lead to efficiencies that reduce other types of operating costs, such as terminal costs (e.g., those associated with lifts of cargo containers). Passenger-related improvements can also reduce vehicle operating or dispatching costs for service providers and for users of private vehicles. If applicants project these types savings in their BCA, they should carefully demonstrate how the proposed project would generate such benefits.

Applicants are encouraged to use local data on vehicle operating costs where available, appropriately documenting sources and assumptions. Data related to specific components of vehicle operating costs (such as fuel consumption) are also generally preferred. For analyses where such data is not available, this guidance document provides standard national-level per-mile values for marginal vehicle operating costs from the American Automobile Association (for light duty vehicles) and from the American Transportation Research Institute (for commercial trucks) in Appendix A, Table A-5. These values apply to operating costs that vary with vehicle miles traveled, such as fuel, maintenance and repair, tires, and depreciation. For trucks, these costs may additionally include truck/trailer lease or purchase payments, insurance premiums, and permits and licenses. The values exclude other ownership costs that are generally fixed or that would be considered transfer payments in the context of BCA, such as tolls, taxes, annual insurance, and registration fees. For commercial trucks, the values also exclude driver wages and benefits (which are already included in the value of travel time savings).

Other types of operating cost savings should be calculated using facility-specific data where possible. If values are used from other sources, they should be carefully documented, and the applicant should explain why those values are likely to be representative of the operating cost impacts associated with the proposed project.

4.3. Safety Benefits

Transportation infrastructure improvements can also reduce the likelihood of fatalities, injuries, and property damage that result from crashes on the facility by reducing the number of such crashes and/or their severity. To claim safety benefits for a project, applicants should clearly demonstrate how a proposed project targets and improves safety outcomes. The applicant should include a discussion about various crash causation factors addressed by the project, and establish a clear link to how the proposed project mitigates these risk factors.

To estimate the safety benefits from a project that generates a reduction in crash risk or severity, the applicant should determine the type(s) of crash(es) the project is likely to affect, and the expected effectiveness of the project in reducing the frequency or severity of such crashes. The severity of prevented crashes is measured through the number of injuries and fatalities, and the extent of property damage. Various methods exist for projecting project effectiveness. Where possible, those measures should be tied to the specific type of improvement being implemented on the facility; broad assumptions about effectiveness (such as assuming safety improvements will result in a facility crash rate dropping to the statewide average crash rate) are generally discouraged.

For road-based improvements, estimating the change in the number of fatalities, injuries, and amount of property damage can be done using crash modification factors (CMFs), which relate different types of safety improvements to crash outcomes. CMFs are estimated by analyzing crash data and types, and relating outcomes to different safety infrastructure. Through extensive research by USDOT and other organizations, hundreds of CMF estimates are available and posted in the online CMF Clearinghouse sponsored by the Federal Highway Administration.[10] If using a CMF from the CMF Clearinghouse, USDOT encourages applicants to verify that the CMF they are using is applicable to the proposed project improvements and to provide the CMF ID # in the application materials. Applicants should ensure that the CMF is matched to the correct crash types, crash severity, and area type of the project. For an example, a CMF specifically associated with a reduction in fatal crashes in an urban setting would generally be inappropriate to use in monetizing the safety benefits of a project for crash types in a rural area. When the search yields multiple applicable CMFs, applicants should further filter using the quality ratings provided in the Clearinghouse, and should document the process and provide justification as to why the selected CMF is the appropriate one for their project.[11] An example calculation using CMFs is included in Appendix B.

To estimate safety outcomes from the project, the effectiveness rates of safety-related improvements must also be applied to baseline crash data. Such data are generally drawn from the recent crash history on the facility that is being improved, typically covering a period of 3-7 years. Applicants should carefully describe their baseline crash data, including the specific segments or geographic areas covered by that

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[10] http://www.cmfclearinghouse.org/

[11] If a use is considering two or more CMFs that are the same on all major factors (e.g., crash type, crash severity, etc.), the star quality rating can be used to indicate which CMF is the highest quality and therefore should be selected. Further discussion is available at http://www.cmfclearinghouse.org/userguide_identify.cfm.

data; links to the source data are also often helpful, where they can be provided. The baseline data should be closely aligned with the expected impact area of the project improvements, rather than reflecting outcomes over a much larger corridor or region.[12]

Injury Severity Scales

USDOT-recommended values for monetizing reductions in injuries are based on the Maximum Abbreviated Injury Scale (MAIS), which categorizes injuries along a six-point scale from Minor to Not Survivable. However, the Department recognizes that accident data that are most readily available to applicants may not be reported as MAIS-based data. For example, law enforcement data is frequently reported using the KABCO scale, which is a measure of the observed severity of the victim's functional injury at the crash scene. In other cases, data may be further limited to the total number of accidents in the area affected by a particular project, perhaps also including a breakdown of those that involved an injury or fatality.

Table 1 on the following page provides a comparison of the KABCO and MAIS injury severity scales. Monetization factors for injuries reported on both the KABCO and MAIS injury severity scales are included in Appendix A, Table A-1, based on a conversion matrix provided by the National Highway Traffic Safety Administration (NHTSA), which allows KABCO-reported and generic accident data to be re-interpreted as MAIS data.[13] The table also provides guidance on the recommended monetized values for reducing fatalities (the "value of a statistical life", or VSL), injuries, and property damage in transportation safety incidents, with corresponding references for additional information.

Table A-1 also includes corresponding values for cases whether the available data includes injury accidents and fatal accidents more broadly, rather than total injuries and fatalities. These values account for the average number of fatalities and injuries per fatal crash, as well as the average number of injuries per injury crash.

For an example calculation of safety benefits, please see Appendix B.

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[12]The Fatality Analysis Reporting System (FARS) provides a useful, nationwide source for data on roadway fatalities. FARS data are available at https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars. Where an applicant is using local safety data that may not be consistent with FARS, it is helpful to explain any reasons for such discrepancies in the BCA narrative.

[13] National Highway Traffic Safety Administration, July 2011. The premise of the matrix is that an injury observed and reported at the crash site may end up being more/less severe than the KABCO scale indicates. Similarly, any accident can – statistically speaking – generate several different injuries for the parties involved. Each column of the conversion matrix represents a probability distribution of the different MAIS-level injuries that are statistically associated with a corresponding KABCO-scale injury or a generic accident.

Table 1. Comparison of Injury Severity Scales (KABCO vs MAIS vs Unknown)

Reported Accidents (KABCO or # Accidents Reported)	
O	No injury
C	Possible Injury
B	Non-incapacitating
A	Incapacitating
K	Killed
U	Injured (Severity Unknown)
# Accidents Reported	Unknown if Injured

Reported Accidents (MAIS)	
0	No injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
Fatal	Not Survivable

4.4. Emissions Reduction Benefits

Transportation infrastructure projects may also reduce the transportation system's impact on the environment by lowering emissions of air pollutants that result from production and combustion of transportation fuels. The economic damages caused by exposure to air pollution represent externalities because their impacts are borne by society as a whole, rather than by the travelers and operators whose activities generate those emissions. Transportation projects that reduce overall fuel consumption, either due to improved fuel economy or reduction in vehicle miles traveled, will typically also lower emissions, and may thus produce environmental benefits.

The most common local air pollutants generated by transportation activities are sulfur dioxide (SO_2), nitrogen oxides (NO_X), fine particulate matter (PM2.5), and volatile organic compounds (VOC).[14] The recommended economic values for reducing emissions of these pollutants are shown in Appendix A, Table A-6. Additionally, the recommended economic values for reducing carbon dioxide (CO_2) emissions is included in Appendix A, Table A-7.

Applicants that wish to include monetized values for additional categories of environmental benefits (or disbenefits) in their BCA should also provide documentation of sources and details of those calculations. Similarly, applicants using different values from the categories presented in Appendix A, Table A-6 and

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[14] Some of these are chemical precursors to local (or "criteria") pollutants that are synthesized during chemical reactions that occur in the Earth's lower atmosphere, rather than pollutants themselves.

Table A-7 should provide sources, calculations, and the applicant's rationale for diverging from those recommended values. For an example calculation of emission reduction benefits, please see Appendix B.

4.5. Other Issues in Benefits Estimation

Benefits to Existing and Additional Users

The primary benefits from a proposed project will typically arise in the "market" for the transportation facility or service that the project would improve, and would be experienced directly by its users. These include travelers or shippers who would utilize the unimproved facility or service under the baseline alternative, as well as any additional users attracted to the facility due to the proposed improvement.[15]

Benefits to existing users for any given year in the analysis period would be calculated as the change in average user costs multiplied by the number of users projected in that year under the no-build baseline. For additional users, standard practice in BCA is to calculate the value of the benefits they receive at one-half the product of the reduction in average user costs and the difference in volumes between the build and no-build cases, reflecting the fact that additional users attracted by the improvement are each willing to pay less for trips or shipments using the improved facility or service than were original users, as evidenced by the fact that they were unwilling to incur the higher cost to use it in its unimproved condition. See Appendix B for a sample calculation of benefits to new and existing users.

Modal Diversion

Benefit-cost analysis should generally focus on the proposed project's benefits to continuing and new users of the facility or mode that is being improved. While improvements to transportation infrastructure or services may draw additional users from alternative routes or competing modes or services, properly capturing the impacts of such diversion within BCA can be challenging and must be examined carefully to ensure that such benefits are truly additive within the analysis.

First, it is important to note that any savings in costs or travel time experienced by travelers or shippers who switch to an improved facility or service are not an accurate measure of the benefits they receive from doing so, and do not represent benefits in addition to the benefits received by additional users of the improved alternative. The generalized costs for using the competing alternatives from which an improved facility draws additional users are already incorporated in the demand curve for the improved facility or service.[16] Applicants should thus avoid such approaches as comparing operating costs for truck and rail when estimating the benefits of a rail improvement that could result in some cargo movements being diverted from highways to railroads in their BCAs.

Reductions in external costs from the use of competing alternatives, however, may represent a source of potential benefits beyond those experienced directly by users of an improved facility or service. Operating both passenger and freight vehicles can cause negative impacts such as delays to occupants of other

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[15] The number of "additional users" would be calculated as the difference in usage of the facility at any given point in the analysis period. Note that this is different from volume growth over time that would be expected to occur even under the no-build baseline.

[16] This follows from the usual textbook description of the demand curve for a good or service: it shows the quantity that will be purchased at each price, while holding prices for substitute goods constant.

vehicles during congested travel conditions, emissions of air pollutants, and potential damage to pavements or other road surfaces. These impacts impose external costs on occupants of other vehicles and on the society at large that are not part of the generalized costs drivers and freight carriers bear, so they are unlikely to consider these costs when deciding where and when to travel.

A commonly cited source of external benefits from rail or port improvements is the resulting reduction in truck travel. Many factors influence trucks' impacts on public agencies' costs for pavement and bridge maintenance, such as their loaded weight, number and spacing of axles, pavement thickness and type, bridge type and span length, volume of truck traffic, and volume of passenger traffic. Consequently, estimating savings in pavement and bridge maintenance costs that result from projects to improve rail or water service is likely to be difficult and would ideally require detailed, locally specific input data. Where this has not been available, some applicants have used broad national estimates of the value of pavement damage caused by trucks from the 1997 *Federal Highway Cost Allocation Study*[17] in their BCAs in previous rounds of USDOT discretionary grant programs. If applicants choose to use estimates from that study, they should take care to use the values for different vehicles and roadway types (e.g., urban/rural) that most closely correspond to the routes over which the diversion is expected to occur. Applicants should also net out any user fees paid by trucks (such as fuel taxes) that vary with the use of the highway system from the estimates of reduced pavement damage.

Similarly, estimating reductions in congestion externalities caused by diversion of passenger and freight traffic from highway vehicles to improved rail or transit services is empirically challenging, usually requiring elaborate regional travel models and detailed, geographically-specific inputs, and should only be incorporated where such modeling results are available. Applicants should not use any broad, national level data to estimate such benefits. Estimates of net air pollutant emission reductions resulting from diverted or reduced truck travel may also be incorporated using standard methodologies for doing so, as described in Section 4.4 above.

Work Zone Impacts

A common example of potential "disbenefits" associated with transportation projects is the impact of work zones on current users during construction or maintenance activities, such as traffic delays and increased safety and vehicle operating costs. These costs can be particularly significant for projects that involve the reconstruction of existing infrastructure, which may require temporary closures of all or a portion of the facility or otherwise restrict traffic flow. Work zone costs may also be a significant component of ongoing costs under a no-build base case, under which an aging facility might require more frequent and extensive maintenance to keep it operational. Work zone impacts should be monetized consistent with the values and methodologies provided in this guidance, and assigned to the years in which they would be expected to occur.

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[17] *FHWA, Addendum to the 1997 Federal Highway Cost Allocation Study Final Report, 2000.* Available at https://www.fhwa.dot.gov/policy/hcas/addendum.cfm. As the estimates found in that report are stated in 1994 dollars, they should be inflated to the recommended 2017 base year dollars using a factor of 1.537 to reflect changes in the level of the GDP deflator over that period of time.

Resilience

Some projects are aimed at improving the ability of transportation infrastructure to withstand adverse events such as severe weather, seismic activity, and other threats and vulnerabilities that can severely damage or even destroy transportation facilities. Incorporating resilience benefits into a BCA requires an understanding of both the expected frequency with which different levels of each stressor are expected to be experienced in the future, and the economic damages that different stressor levels are likely to inflict on specific infrastructure assets. This includes the anticipated frequencies of events such as extreme precipitation, seismic events, or coastal storm surges, as well as the range of potential severities of each event and the estimated cost of the resulting damages to specific assets, expressed as dollar figures.

Benefits for increasing resilience may be difficult to calculate due to the unpredictable occurrence of disruptive events, some of which could occur many decades in the future. Applicants may draw on previous experiences with facility outages to calculate the value of reduced infrastructure and service outages, such as costs incurred by travelers when bridges are closed, and include those potential impacts in their estimates of the user benefits associated with the project.[18] The expected probability of the disruptive event(s) occurring within a given year should also be factored into the projected benefit stream of the improvement.

Noise Pollution

Noise pollution occurs from high levels of environmental sound that may annoy, distract or even harm people and animals. Where relevant, applicants may wish to consider whether a proposed project will significantly lower levels of noise generated by current transportation activity, as well as the extent to which more frequent service (such as freight or commuter rail) will increase cumulative noise levels. An applicant would have to determine the change in noise level (often measured in decibels adjusted or dBA), and whether the change is expected to occur during the daytime or nighttime, as nighttime includes sleep disturbance, which typically has a higher value associated with it. Projects that reduce the need to sound train whistles, for instance, can generate noise reduction benefits.

USDOT does not currently have a reliable means of estimating the public value of noise reductions for transportation projects in the U.S., and thus recommends that they be dealt with qualitatively in BCA until more definitive guidance on this issue is developed. Where quantified estimates are included in an applicant's BCA, the underlying methodology and values used should be carefully explained and documented.

Loss of Emergency Services

Transportation projects that reduce the frequency of delays to emergency services, such as ambulance and fire services, can create benefits by reducing the damages resulting from those emergencies. For example, highway-rail grade separation projects can reduce or eliminate delays where emergency vehicles

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[18] The National Oceanic and Atmospheric Administration (NOAA) database on storm surges and floor risks is one possible tool that applicants could use to estimate flood risk potential. See
http://www.nhc.noaa.gov/surge/inundation/

must seek alternative routes (or are prevented from accessing locations on the other side of the tracks entirely) when crossing gates are down.

The Federal Emergency Management Agency (FEMA) has developed a methodology to aid in the monetization of such benefits.[19] That methodology is based on the observation that delays to fire services can cause a generalizable increase in property damage when fires burn longer.[20] Likewise, delays to ambulance services have a relatively predictable impact on survival rates for victims of cardiac arrest (one of the most common medical emergencies where time is a critical factor).

The FEMA methodology is based on the complete loss of a fire station or hospital, but can be adapted for use in delays to emergency vehicles. However, applicants applying this methodology should take care not to assume unreasonably excessive delays to emergency services in the baseline scenario (for example, assuming an ambulance will wait the entire time for a passing train at crossing gates when another grade-separated crossing is available nearby will lead to overestimating the expected emergency service delay reduction). Further, applicants should carefully consider the size of the population assumed to be affected by such lapses in emergency services, and should thoroughly justify and document the assumptions used in the analysis. Finally, the methodology should not be used for situations where traffic may be congested, but emergency vehicles would be given priority access over other vehicles and thus likely be able to maintain service levels.

Quality of Life

Transportation projects can provide benefits that cannot easily be monetized but nevertheless may improve the quality of life of local or regional residents and visitors. Applicants should attempt to monetize these types of benefits to the extent possible; where doing so is not feasible, they should provide as much quantifiable data on those impacts as possible, focusing on changes expected to be brought about by the transportation improvement project itself.

Property Value Increases

Transportation projects can also increase the accessibility or otherwise improve the attractiveness of nearby land parcels, resulting in increased property values. However, such increases would generally largely result from reductions in travel times or other user benefits described elsewhere in this guidance. Such benefits should be calculated and monetized directly, rather than being factored into an assumed property value increase benefit; any claimed, monetized benefits based on property values should only capture otherwise unquantified benefits, such as those described elsewhere in this section. Such projections should also only count the one-time net increase in land value as the benefit, and should consider the net effect of both increases in land values induced by the project in some areas and any potential reductions in land values in other areas.

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[19] https://www.hudexchange.info/course-content/ndrc-nofa-benefit-cost-analysis-data-resources-and-expert-tips-webinar/FEMA-BCAR-Resource.pdf

[20] Note that the FEMA methodology for estimating damages due to delays in fire services also includes an adjustment factor for injuries and fatalities; however, USDOT recommends only using the methodology for property damage impacts and adjusting those base year 1993 dollar values for inflation.

Additionally, some transportation projects may free up currently-occupied land for other, non-transportation uses, or may also include the creation of new spaces that are valued by the public (such as a park on top of project to "cap" an existing freeway). If the applicant can reliably estimate the value of such land, based on projected sale values or local values of land with similar uses, then that value could be included as an additional benefit within the BCA, or be described qualitatively when such benefits cannot be easily or reliably monetized.[21]

5. Costs

Project costs consist of the economic resources (in the form of the inputs of capital, land, labor, and materials) needed to develop and maintain a new or improved transportation facility over its lifecycle. In a BCA, these costs are usually measured by their market values, as they are directly incurred by developers and owners of transportation assets (as opposed to categories of benefits such as travel time savings that are not directly transacted in the market).

Cost data used in the BCA should reflect the full cost of the project(s) necessary to achieve the benefits described in the BCA. Applicants should include all costs regardless of who bears the burden of specific cost item (including costs paid for by State, local, and private partners or the Federal government). Cost data should include all funded and unfunded portions of the project, even if Federal funding is a relatively small portion of the total cost of the project with independent utility that is to be analyzed in the BCA.

5.1. Capital Expenditures

The capital cost of a project is the sum of the monetary resources needed to build the project (or program of projects). Capital costs generally include the cost of land, labor, material and equipment rentals used in the project's construction. In addition to direct construction costs, capital costs may include costs for project planning and design, environmental reviews, land acquisition, utility relocation, or transaction costs for securing financing. For large programs that involve multiple discrete projects that are related to one another, and are each integral to accomplishing overall program objectives, applicants should estimate and report the costs of the various component projects of the program as well as summing those projects into a total cost.[22]

Project capital costs may be incurred across multiple years. All costs of the project (or that sub-component requesting funding if the project is a sub-component of a larger project and has independent utility) should be included, including costs already expended.[23] Capital costs should be recorded in the year in which they are expected to be incurred by the parties developing and constructing the project, regardless of when payment is to be made for those expenses by the project sponsor (such as repayments of any

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[21] Applicants should ensure, however, that any expected revenues from land sales have not already been netted out of the project's cost estimate, to avoid double-counting them.

[22] It is generally incorrect to lump unrelated projects into a single BCA. Where projects are unrelated to each other and do not impact each other's individual benefit streams, they should be analyzed using separate BCAs.

[23] While economic decision-making often ignores such costs, treating them "sunk costs" that cannot be recovered, the purpose of including a BCA as part of the grant application for the USDOT discretionary grant programs is to determine whether the cost of project for which funding is being sought is justified by its benefits in its entirety, not whether future expenditures on the project or portion of the project funded by the grant are justified by total benefits of the whole project.

principal and interest associated with financing the project that may occur well after the project has been constructed).

Applications for USDOT discretionary grant programs and their accompanying BCAs will typically provide capital cost information in three distinct forms:

1) Nominal dollars. The cost estimates provided in the project financial plan included in the application narrative will typically be stated in nominal or year-of-expenditure dollars, reflecting the actual costs that have previously been or are expected to be incurred in the future.
2) Real dollars. As noted above in Section 3.3, all costs and benefits used in the BCA should be stated in real or constant dollars using a common base year. Cost elements that were expended in prior years should thus be updated to the recommended base year (2018).[24] Costs incurred in future years should be adjusted to base year based on the future inflation assumptions that were used to derive them.
3) Discounted Real dollars. Any future year constant dollar costs should also be appropriately discounted to the baseline analysis year to allow for comparisons with other BCA elements (see Section 3.4).

5.2. Operating and Maintenance Expenditures

Operating and maintenance (O&M) costs cover a wide array of costs required on a continuing basis to support core transportation functions. The ongoing O&M costs of the project throughout the entire analysis period should be included in the BCA, and should be directly related to the proposed service plans for the project.

O&M costs should be projected for both the no-build baseline and with proposed improvement project. For projects involving the construction of new infrastructure, total O&M costs will generally be positive, reflecting the ongoing expenditures needed to maintain the new asset over its lifecycle. For projects intended to replace, reconstruct, or rehabilitate existing infrastructure, however, the net change in O&M costs under the proposed project will often be negative, as newer infrastructure requires less frequent and less costly maintenance to keep it in service than would an aging, deteriorating asset. Note also that more frequent maintenance under the baseline could also involve work zone impacts that could be reflected in projected user cost savings associated with the project.

Applicants should describe how O&M costs were estimated. Note that the relevant O&M costs are only those required to provide the service levels used in the BCA benefits calculations. For example, the BCA for a project that expands service frequency on an existing ferry route from three ferries per day to five ferries per day may look only at the benefits of the additional two new daily trips. In that case, the O&M analysis would assess only the costs of providing those two additional daily departures, and not the cost of all five daily trips.

Maintenance costs are often somewhat "lumpy" over the course of an asset's lifecycle, with more extensive preservation activities being scheduled at regular intervals in addition to ongoing routine

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[24] Appendix A, Table A-8 provides a list of inflation adjustment factors for such costs going back to 2001.

maintenance. Applicants should make reasonable assumptions about the timing and cost of such activities in accordance with standard agency or industry practices.

If the estimated O&M costs are provided to the applicant in year of expenditure dollars, they should be adjusted to base year dollars prior to being included in the BCA. While the net O&M costs associated with a project may be logically grouped with other project development costs, they should be included in the numerator along with other project benefits when calculating a benefit-cost ratio for a project proposed for funding under the discretionary grant programs (see Section 6 below).

5.3. Residual Value and Remaining Service Life

As noted above, the analysis period used in the BCA should be tied to the expected useful life of the infrastructure asset constructed or improved by the project. However, many transportation assets are designed for very long-term use, such as major structures (e.g., tunnels or bridges), and thus have an expected life that would exceed the maximum analysis period (covering up to 30 years of operations) recommended by USDOT (see Section 3.5 above). A project may also include capital asset components with an expected useful life that is shorter than those of the overall project, but which do not have independent utility themselves. These differences must be carefully considered when accounting for them in BCA.

Where some or all project assets have several years of useful service life remaining at the end of the analysis period, a "residual value" may be calculated for the project at that point in time. This could apply to both assets with expected service lives longer than the analysis period, and shorter-lived assets that might be assumed to have been replaced within the analysis period.[25] Applicants should carefully document the useful life assumptions that are applied when estimating a residual value in their BCA.

A simple approach to estimating the residual value of an asset is to assume that its original value depreciates in a linear manner over its service life.[26] An asset with an expected useful life of 60 years would thus retain half of its value after 30 years in service, while an asset with a 45-year life would retain one third of its value at that point in time.[27] Those residual values would then be discounted to their present value using the discount rate applied elsewhere in the analysis. An example calculation of residual value is included in Appendix B.

While the projected residual value of a project may be logically grouped with other project development costs, it should be added to the numerator when calculating a benefit-cost ratio for a project proposed for funding under the discretionary grant programs (see Section 6 below).

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[25] For example, a component might be assumed to require replacement every 20 years. If the analysis period covers 30 years post-construction, the BCA would have assumed the cost of replacing the asset at year 20, and would have 10 years of remaining service life at year 30.

[26] Other approaches may also be applied, so long as the methodology used is adequately described and justified in the BCA.

[27] In this example, if the construction period is five years, then the overall analysis period would be 35 years (5 years construction plus 30 years of operations).

6. Comparing Benefits to Costs

There are several summary measures that can be used to compare benefits to costs in BCA. The two most widely used measures are net present value and the benefit-cost ratio:

Net present value (NPV) is perhaps the most straightforward BCA measure. All benefits and costs over an alternative's life cycle are discounted to the present, and the costs are subtracted from the benefits to yield a NPV. If benefits exceed costs, the NPV is positive and the project may be considered to be economically justified.

The benefit-cost ratio (BCR) is frequently used in project evaluation when funding restrictions apply. In this measure, the present value of benefits (including negative benefits) is placed in the numerator of the ratio and the present value of costs is placed in the denominator. The ratio is usually expressed as a quotient (e.g., $2.2 million/$1.1 million = 2.0). For any given budget, the projects with the highest BCRs can be selected to form a package of projects that yields the greatest multiple of benefits to costs.

Deciding which elements to include in the numerator of the BCR and which to include in the denominator depends on the nature of the BCA and the purposes for which it is being used.[28] Where an agency is using BCA to help evaluate potential projects to implement under a constrained budget, the denominator should only include the upfront costs of implementing the project (i.e., capital expenditures). Since project funding decisions under the discretionary grant programs are being made under similar circumstances, this is the approach that should be used to calculate the BCR in analyses developed pursuant to this guidance. Note that under this treatment, net O&M costs and the residual value would be added to or subtracted from the numerator when calculating the BCR, rather than the denominator.

While applicants are welcome to present estimates of a project's NPV or BCR in their BCA, USDOT analysts should be able to make such calculations independently based on the other information on benefits and costs provided in the BCA. What is most important is that applicants clearly present their estimates for each category of benefits and costs in a consistent manner (see Section 8 on Submission Guidelines below).

7. Other Issues in BCA

7.1. Benefit-Cost Analysis vs. Economic Impact Analysis

A common mistake when developing a BCA occurs when applicants conflate economic *impacts* with economic *benefits*. A BCA measures the value of a project's benefits and costs to society, while an economic impact analysis measures the impact of increased economic activity within a region. Common metrics for measuring economic impacts include retail spending, business activity, tax revenues, jobs/wages, and property values. Economic impact analyses often take a strictly positive view, (i.e.,

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[28] Note that this is not a concern for the calculation of net present value, since the results will be the same regardless of which elements are categorized as benefits or costs in that calculation, so long as they are included with the proper sign.

increased jobs, spending) and do not examine how the resources used for a project might have been put to alternative beneficial uses (i.e., they do not assess the net effect on society).

For example, an economic impact analysis views the initial investment in infrastructure as a stimulus to the local economy, rather than as a cost to the project sponsor. In addition, economic impact analyses typically use a regional perspective, while BCA uses an economy-wide or "societal" perspective. Positive impacts in one region may be accompanied by offsetting losses in a neighboring region, reflecting a transfer of spending or jobs that may be a net neutral summation. Similarly, increases in jobs in one industry could reflect a decrease in jobs in a different industry. By contrast, BCAs estimate first order net benefits that result from transportation projects by accounting for losses, costs, cost savings, benefits, and transfers of transportation time savings, investment costs, improved safety, reduced infrastructure maintenance costs, etc. BCA does not quantify second and third order impacts such as jobs or sales that may be generated in part by the first order net benefits. Moreover, second and third order economic impacts typically do not add to the value of first order net benefits measured by BCA, but instead represent impacts into which these first order net benefits are translated as they are transmitted through a complex economy.

Understanding and addressing economic impacts can be important to project how an infrastructure improvement may affect a particular region, but this analysis should constitute an independent exercise that is separate from assessing the benefits and costs of a project through a BCA. BCA is the main tool to determine whether a project generates sufficient value to society, measured as positive net benefits, and used to justify spending on a specific program or project. A project with negative net benefits could generate positive regional economic impacts simply by increasing spending or employment within a specific geographic area even if, from a national standpoint, its overall economic effects would be expected to be negative.

7.2. Transfers

Benefit-cost analyses should distinguish between benefits and transfer payments. Benefits reflect reductions in real resource usage and overall net benefits to society, while transfers represent changes in how those benefits and costs are distributed among various groups affected by the project. As such, they do not represent a net increase in societal benefits and thus are not legitimate additive benefits to be included in a benefit-cost analysis. Examples could include increases in local wages and property tax revenues. While these may be beneficial to local workers and local governments, they also represent costs paid by local property owners, respectively, with no net change in societal welfare.

Projected changes in revenues from fares, tolls, or port fees attributed to a proposed improvement project would also typically be considered as transfer payments, since they reflect both a cost to users and a revenue source to the facility operator. However, in some cases, reductions in fee rates may reflect reductions in operating costs that are passed onto users, and thus may serve as a proxy for such changes where detailed information on operating costs may not be available. If reductions in fees are treated this way, care should be taken to clearly show that this measure is capturing actual benefits resulting from increased efficiency and not simply a transfer payment between the various parties involved, and to avoid double counting any operating cost and fee or fare reductions.

8.   Submission Guidelines

The BCA submitted by the applicant should include both a narrative (such as a technical memo) and the detailed calculations used in the analysis. For the BCA narrative, each section should detail all the assumptions, calculations, and results of the BCA. The narrative and calculations should provide enough information to allow USDOT reviewers to understand the analysis and reproduce the results. The applicant should document and describe all data sources in addition to information on how each source feeds into the analysis.

Applicants should clearly describe the baseline for the analysis and how the proposed project would alter that baseline. This will naturally require a clear description of the elements of the construction project, including their scope and location (this may be provided in the application narrative). The BCA narrative should also include a summary of the estimated impacts (both positive and negative) of the proposed project. This description can be presented in a table or within the text, but it should enable the reviewer to clearly tie the project elements to the expected outcomes. As noted above, if an application contains multiple, distinct projects that are linked together in a common objective, each of which has independent utility, the applicant should provide a separate analysis for each project.

The BCA narrative should include a high-level summary of the key components of the BCA, including the benefits, costs, and major assumptions, with accompanying discussion. The information may be grouped in any way that the applicant deems logical, but should clearly describe each individual cost and benefit category in a way that ties back to what is being estimated and connects to the expected outcomes of the project.

8.1. Transparency and Reproducibility

As OMB Circular A-4 emphasizes, benefit-cost analyses should be sufficiently transparent that a qualified third party can understand all its assumptions, reproduce the analysis with the same results, and would be likely to reach the same conclusions. USDOT recommends that applicants provide the detailed calculations of the analysis in the form of an (unlocked) Excel workbook to allow for a detailed review and sensitivity testing of key parameters by USDOT analysts. The workbook should also include tabs showing key inputs to the analysis, including both parameters and assumptions about the impacts of the project; the sources of those assumptions should also be documented in either the calculations workbook or the BCA narrative. The workbook should also include a summary of the final results for each cost and benefit category. Simply providing summary output tables or unlinked data tables (such as pdf files or hard-coded spreadsheets) does not provide the level of detail needed for a thorough review, and could result in delays in the review as USDOT requests the underlying calculations spreadsheets from the applicant.

Note that if an applicant uses a "pre-packaged" economic model to calculate net benefits, the applicant should still provide sufficient information so that a USDOT reviewer can follow the general logic of the estimates and reproduce them, including key underlying assumptions of the model and annual benefit and cost by benefit and cost types. Where BCAs may have been developed using database-based models or other proprietary tools, applicants should consult with USDOT to help determine a mutually acceptable method of providing the needed detailed information.

8.2. Uncertainty and Sensitivity Analysis

Prospective benefit-cost analyses of transportation infrastructure investments are subject to varying levels of uncertainty attributable to the use of preliminary cost estimates, difficulty of modeling future traffic levels, or use of other imperfect data and incompletely understood parameters. When describing the assumptions employed, BCAs should identify those that are subject to especially large uncertainty and emphasize which of these has the greatest potential influence on the outcome of the BCA.

Sensitivity analysis can be used to help illustrate how the results of a BCA would change if it employed alternative values for key data elements that are subject to uncertainty. A simple sensitivity analysis will take one variable and assume multiple valuations of that variable. For example, if the benefits of a project rely on an uncertain crash risk reduction, a sensitivity analysis should be done to estimate the benefits under different crash reduction assumptions. Submission of an unprotected Excel spreadsheet with embedded calculations will also allow USDOT reviewers to conduct sensitivity analyses, as necessary and warranted. The applicant may also wish to provide suggested alternative values for key parameters that could be used for such sensitivity testing, or provide the results of a broader uncertainty analysis using such methods as Monte Carlo simulation, where this has been conducted.

Appendix A: Recommended Parameter Values

The following tables summarize key parameter values for various types of benefits and costs that the Department recommends that applicants use in their benefit-cost analyses, including both monetization values and other key inputs. These standardized values are intended to ensure greater consistency in how various types of projects from across the country are evaluated. They also provide default values that applicants can use in the absence of having more detailed information readily available for their analysis. However, acceptable benefits and costs for BCAs submitted to USDOT are not limited only to these tables. The applicant should provide documentation of sources and detailed calculations for monetized values of additional categories of benefits and costs. Similarly, applicants using different values for the benefit and cost categories presented below should provide sources, calculations, and their rationale for divergence from recommended values.

The values provided in the tables on the following pages are stated in 2018 dollars, the base year recommended for use in applications submitted pursuant to NOFOs for discretionary grant programs issued in FY 2020.

Table A-1: Value of Reduced Fatalities and Injuries

Recommended Monetized Value(s)				References and Notes

MAIS Level	Severity	Fraction of VSL	Unit value ($2018)
MAIS 1	Minor	0.003	$28,800
MAIS 2	Moderate	0.047	$451,200
MAIS 3	Serious	0.105	$1,008,000
MAIS 4	Severe	0.266	$2,553,600
MAIS 5	Critical	0.593	$5,692,800
Fatal	Not Survivable	1.000	$9,600,000

Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses (2016)
https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

KABCO Level	Monetized Value ($2018)
O – No Injury	$3,200
C – Possible Injury	$63,900
B – Non-incapacitating	$125,000
A – Incapacitating	$459,100
K – Killed	$9,600,000
U – Injured (Severity Unknown)	$174,000
# Accidents Reported (Unknown if Injured)	$132,200

Note:
The KABCO level values shown result from multiplying the KABCO-level accident's associated MAIS-level probabilities by the recommended unit Value of Injuries given in the MAIS level table, and then summing the products. Accident data may not be presented on an annual basis when it is provided to applicants (i.e. an available report requested in Fall 2011 may record total accidents from 2005-2010). For the purposes of the BCA, is important to annualize data when possible.

Crash Type	Monetized Value ($2018)
Injury Crash	$250,600
Fatal Crash	$10,636,600

Note:
Monetization values for injury crashes and fatal crashes are based on an estimate of approximately 1.44 injuries per injury crash and 1.09 fatalities per fatal crash, based on an average of the last five years of data in NHTSA's *National Crash Statistics*. The fatal crash value is further adjusted for the average number of injuries per fatal crash.

Table A-2: Property Damage Only (PDO) Crashes

Recommended Monetized Value(s)	Reference and Notes
$4,400 per vehicle ($2018)	*The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (revised May 2015), Page 12, Table 1-2, Summary of Unit Costs, 2000"* Inflated to 2018 dollars using the GDP Deflator.

Table A-3: Value of Travel Time Savings

Recommended Monetized Value(s)		References and Notes
Recommended Hourly Values of Travel Time Savings (2018 U.S. $ per person-hour)		*Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis* https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic
Category	**Hourly Value**	
In-Vehicle Travel[1]		
Personal[2]	$15.20	
Business[3]	$27.10	
All Purposes[4]	$16.60	
Commercial Vehicle Operators[5]		
Truck Drivers	$29.50	
Bus Drivers	$31.00	
Transit Rail Operators	$50.20	
Locomotive Engineers	$45.70	

1\ Values apply to all combinations of in-vehicle and other transit time on surface transportation modes. Walking, cycling, waiting, standing, and transfer time should be valued at $30.40 per hour for personal travel when actions affect only those elements of travel time.

2\ Values for personal travel based on local travel values as described in USDOT's Value of Travel Time guidance. Where applicants also have specific information on the mix of local versus long-distance intercity travel (i.e., trips over 50 miles in length) on a facility, then the local travel values of time may be blended with the long-distance intercity personal travel value of $21.30 per hour.

3\ Note that business travel <u>does not</u> include commuting travel, which should be valued at the personal travel rate. Travel on high-speed rail service that would be competitive with air travel should be valued at $40.40 per hour for personal travel and $67.30 for business travel.

4\ Weighted average based on a typical distribution of local travel by surface modes (88.2% personal, 11.8% business). Applicants should apply their own distribution of business versus personal travel where such information is available.

5\ Includes only the value of time for the operator, not passengers or freight.

Table A-4: Average Vehicle Occupancy Rates for Highway Passenger Vehicles

Recommended Value(s)	References and Notes
<table><tr><th>Vehicle Type</th><th>Average Occupancy</th></tr><tr><td>Passenger Vehicles (Weekday Peak)[1]</td><td>1.48</td></tr><tr><td>Passenger Vehicles (Weekday Off-Peak)</td><td>1.58</td></tr><tr><td>Passenger Vehicles (Weekend)</td><td>2.02</td></tr><tr><td>Passenger Vehicles (All Travel)</td><td>1.67</td></tr></table> 1\ Weekday peak period values calculated for trips starting between 6:00 AM-8:59 AM and 4:00 PM-6:59 PM.	*2017 National Household Travel Survey*

Table A-5: Vehicle Operating Costs

Recommended Monetized Value(s)	References and Notes
<table><tr><th>Vehicle Type</th><th>Recommended Value per Mile ($2018)</th></tr><tr><td>Light Duty Vehicles[1]</td><td>$0.41</td></tr><tr><td>Commercial Trucks[2]</td><td>$0.96</td></tr></table> 1\ Based on an average light duty vehicle and includes operating costs such as gasoline, maintenance, tires, and depreciation (assuming an average of 15,000 miles driven per year). The value omits other ownership costs that are mostly fixed or transfers (insurance, license, registration, taxes, and financing charges). 2\ Value includes fuel costs, truck/trailer lease or purchase payments, repair and maintenance, truck insurance premiums, permits and licenses, and tires. The value omits tolls (transfers) and driver wages and benefits (already included in value of travel time savings) and is inflated to 2018 dollars using the GDP deflator.	*American Automobile Association, Your Driving Costs – 2018 Edition (2018)* https://exchange.aaa.com/wp-content/uploads/2018/09/18-0090_2018-Your-Driving-Costs-Brochure_FNL-Lo-5-2.pdf *American Transportation Research Institute, An Analysis of the Operational Costs of Trucking: 2018 Update (2018)* http://truckingresearch.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf

Table A-6: Damage Costs for Pollutant Emissions

Recommended Monetized Value(s)	References and Notes
<table><tr><th>Emission Type</th><th>$ / short ton* ($2018)</th></tr><tr><td>Carbon dioxide (CO₂)</td><td>**</td></tr><tr><td>Volatile Organic Compounds (VOCs)</td><td>$2,100</td></tr><tr><td>Nitrogen oxides (NOx)</td><td>$8,600</td></tr><tr><td>Particulate matter (PM2.5)</td><td>$387,300</td></tr><tr><td>Sulfur dioxide (SO₂)</td><td>$50,100</td></tr></table> *Applicants should carefully note whether their emissions data is reported in short tons or metric tons. A metric ton is equal to 1.1015 short tons. **See Table A-7: Social Cost of Carbon (SCC) per metric ton of CO₂.	*The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)"* https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf Values are inflated from 2016 dollars to 2018 dollars using the GDP deflator. **Note:** Fuel saved (gasoline, diesel, natural gas, etc.) can be converted into metric tons of emissions using EPA guidelines available at https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Table A-6: Damage Costs for Pollutant Emissions

Recommended Monetized Value(s)	References and Notes
(see emission table below)	*The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)"*

Emission Type	$ / short ton* ($2018)
Carbon dioxide (CO₂)	**
Volatile Organic Compounds (VOCs)	$2,100
Nitrogen oxides (NOx)	$8,600
Particulate matter (PM2.5)	$387,300
Sulfur dioxide (SO₂)	$50,100

*Applicants should carefully note whether their emissions data is reported in short tons or metric tons. A metric ton is equal to 1.1015 short tons.

**See Table A-7: Social Cost of Carbon (SCC) per metric ton of CO₂.

References and Notes:

The Safer Affordable Fuel-Efficient Vehicles Rule for MY2021-MY2026 Passenger Cars and Light Trucks Preliminary Regulatory Impact Analysis (October 2018)"
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

Values are inflated from 2016 dollars to 2018 dollars using the GDP deflator.

Note: Fuel saved (gasoline, diesel, natural gas, etc.) can be converted into metric tons of emissions using EPA guidelines available at
https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Table A-7: Social Cost of Carbon (SCC) per metric ton of CO$_2$

Recommended Monetized Value(s)	References and Notes
<table><tr><th>Year</th><th>SCC ($2018)</th></tr><tr><td>2017</td><td>$1</td></tr><tr><td>2020</td><td>$1</td></tr><tr><td>2025</td><td>$1</td></tr><tr><td>2030</td><td>$1</td></tr><tr><td>2035</td><td>$2</td></tr><tr><td>2040</td><td>$2</td></tr><tr><td>2045</td><td>$2</td></tr><tr><td>2050</td><td>$2</td></tr></table>	Values based on the Preliminary Regulatory Impact Analysis for the *Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks (July 2018)* https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf Values are inflated from 2016 dollars to 2018 dollars using the GDP deflator. **Note:** The recommended values for reducing CO$_2$ emissions reported in Table A-7 represent the values of future economic damages that can be avoided by reducing emissions in each future year by one metric ton. They were constructed by discounting the domestic damages caused by its contribution to changes in the global climate from *that year* through the distant future, using a 7% discount rate. After using these per-ton values to estimate the total value of reducing CO2 emissions in any *future year*, the result must be further discounted to its present value as of the analysis year used in the BCA, again using the 7% discount rate.

Table A-8: Inflation Adjustment Values

Recommended Value(s)		References and Notes
		Bureau of Economic Analysis, National Income and Product Accounts, Table 1.1.9, "Implicit Price Deflators for Gross Domestic Product" (November 2019) https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=3&isuri=1&1921=survey&1903=11#reqid=19&step=3&isuri=1&1921=survey&1903=11

Base Year of Nominal Dollar	Multiplier to Adjust to Real $2018
2001	1.3839
2002	1.3623
2003	1.3375
2004	1.3024
2005	1.2631
2006	1.2260
2007	1.1939
2008	1.1711
2009	1.1623
2010	1.1489
2011	1.1254
2012	1.1042
2013	1.0852
2014	1.0654
2015	1.0545
2016	1.0437
2017	1.0244
2018	1.0000

Appendix B: Sample Calculations

Example Inflation Adjustment Calculation

Adjusting for inflation requires a value with a known base year and the multiplier to adjust to the desired year dollars. For example, the real value in 2018 of $1,000,000 in expenses incurred in 2001, using the Implicit GDP Deflator multipliers given in Table A-8, would be as follows:

$$(2018 \; Real \; Value \; of \; \$1,000,000 \; in \; 2001) = \$1,000,000 \; x \; 1.3839$$
$$= \$1,383,900$$

Example Discounting Calculation

The following formula should be used to discount future benefits and costs:

$$PV = \frac{FV}{(1+i)^t}$$

Where PV = Present discounted value of a future payment from year t

FV = Future value of payment in real dollars (i.e., dollars that have the same purchasing power as in the base year of the analysis, see the next section for further discussion on this topic) in year t

i = Real discount rate applied

t = Years in the future for payment (where base year of analysis is t = 0)

For example, the present value in 2018 of $5,200 real dollars (i.e., dollars with the same purchasing power as in the 2018 base year) to be received in 2024 would be $3,465 if the real discount rate (i.e., the time value of money) is seven percent per annum:

$$PV = \frac{\$5,200.00}{(1+0.07)^6}$$
$$= \$3,464.98$$

If the discount rate is estimated correctly, a person given the option of either receiving $5,200 in 2024 or $3,465 in 2018 would be indifferent as to which he or she might select. If the real discount rate were three percent, the present value of the $5,200 sum would be $4,355. It should be clear from the formula above that as the discount rate increases, the present values of future benefits or costs will decline significantly.

Applicants should discount each category of benefits and costs separately for each year in the analysis period during which they accrue. Table B-1 provides a simplified example of how this could be done for one category of benefits and one category of costs. Further reading and examples on discounting may be found in OMB Circulator A-94 and OMB Circular A-4.

Table B-1. Example of Discounting

Calendar Year	Project Year	Value of Travel Time Savings ($2018)	Discounted Travel Time Savings at 7%	Construction Costs ($2018)	Discounted Construction Costs at 7%	NPV at 7%
2019	1	$0	$0	$38,500,000	$38,500,000	-$38,500,000
2020	2	$0	$0	$15,500,000	$14,485,981	-$14,485,981
2021	3	$23,341,500	$20,387,370	$0	$0	$20,387,370
2022	4	$24,570,000	$20,056,439	$0	$0	$20,056,439
2023	5	$25,061,400	$19,119,222	$0	$0	$19,119,222
2024	6	$26,781,300	$19,094,697	$0	$0	$19,094,697
Total			$78,657,728		$52,985,981	$25,671,746

Example Calculation of Benefits to Existing and Additional Users

Estimating the benefits to existing and additional users requires estimates of the reduction in average costs to users resulting from an improvement as well as forecasts of traffic volumes in a given year both with and without the improvement.

For an illustrative example, assume that the current cost of travel and volume of riders is $75 per trip (reflecting the combined value of travel time costs, vehicle operating costs, safety costs, and other user costs) and that there are 200,000 riders projected in that year. The improvement is projected to reduce that generalized cost of travel is to $65 per trip and result in 250,000 riders in that year. First estimate the benefits for the existing users:

$$Existing\ User\ Benefits = Volume\ of\ Existing\ Users\ x\ Change\ in\ Cost$$
$$= V1\ x\ (P1 - P2)$$
$$= 200,000\ x\ (\$75 - \$65)$$
$$= 200,000\ x\ \$10$$
$$= \$2,000,000$$

Next, estimate the benefits for the additional users using the rule of half:

$$Benefits\ to\ Additional\ Users = \frac{1}{2} x\ Volume\ of\ Additional\ Users\ x\ Change\ in\ Cost$$
$$= \frac{1}{2} x\ (V2 - V1) x\ (P2 - P1)$$
$$= \frac{1}{2}\ x\ (\$75 - \$65)\ x\ (250,000 - 200,000)$$
$$= \frac{1}{2}\ x\ \$10\ x\ 50,000$$
$$= \$250,000$$

Summing the two types of consumer benefits, this hypothetical example would generate $2,250,000 in benefits in that year.

Example Value of Time Savings Calculation

A transit line is being improved to allow for a time savings of 12 minutes between a particular origin and destination pair. Current transit line demand between the two stations is 100,000 trips per year for all trip purposes, and the applicant estimates that demand will increase to a total of 110,000 trips per year after the project is implemented.

Existing passengers experience the full 12 minutes (0.2 hours) of travel time savings, as follows:

$$VTTS(existing) = Value\ of\ time\ x\ Change\ in\ trip\ time\ x\ Affected\ trips$$
$$= \frac{\$16.60}{hr} x\ 0.2\ hr\ x\ 100,000\ trips/year$$
$$= \$332,000/year$$

Applicants should repeat this calculation for each of the relevant trip markets along the corridor. The sum of the trip time savings across all origin and destination pairs provides the total trip savings to existing passengers.

In some cases, trip time savings (and/or reductions in fares) would be expected to attract new passengers (or shippers in the case of freight infrastructure improvements) using transit services. New passengers (or shippers) will generally not experience a comparable value of trip time savings on a per passenger basis, since they only start using the transit service once the shorter trip time is available. Thus, some portion of the trip time savings was necessary to attract that passenger to the transit mode from another mode, or to encourage the passenger to make a new trip they previously would not have made. A straightforward assumption is that new passengers were attracted equally by each additional increment of trip time savings, with the first additional passenger realizing almost the full value of benefits as pre-existing passengers, and the last new passengers switching to rail realizing only a small share of the overall benefits of the pre-existing passengers. That is, an equal number of new passengers were attracted by the first minute of savings as by the twelfth, with each new increment experiencing a diminishing share of net benefits. In this case, new passengers will on average value the time savings resulting from the service improvement at one-half of its value to existing passengers.

$$VTTS(new) = Value\ of\ time\ x\ \frac{1}{2}\ x\ Change\ in\ trip\ time\ x\ Affected\ trips$$
$$= \frac{\$16.60}{hr} x\ \frac{1}{2}\ x\ 0.2\ hr\ x\ 10,000\ trips/year$$
$$= \$16,600/year$$

Applicants should also repeat this calculation for each of the relevant trip markets along the corridor. The sum of the trip time savings across all origin and destination pairs provides the total trip savings to new passengers. Total VTTS is then the sum of the VTTS$_{(existing)}$ and VTTS$_{(new)}$, or $348,600 annually in the simplified example above.

Example of Crash Modification Factor Calculation

To use a CMF, an applicant will first need the most recent year estimates of fatalities and injuries along an existing facility, as well as a CMF that correctly corresponds to the safety improvement being

implemented. Once these have been collected, the estimated lives saved and injuries prevents are as follows:

$$Estimated\ Annual\ Lives\ Saved = Current\ Annual\ Fatality\ Estimate\ x\ [1-CMF]$$
$$Estimated\ Annual\ Injuries\ Prevented = Current\ Annual\ Injury\ Estimate\ x\ [1-CMF]$$

Assume a project includes implementing rumble strips on a 2-lane rural road. The stretch of road in question is particularly dangerous and has had an annual average of 16 fatalities and 20 non-fatal injuries. For this example, assume a rumple strip has a hypothetical CMF of 0.84 for both fatalities and injuries. Estimating the prevented fatalities and non-fatal injuries would be as follows:

$$Estimated\ Annual\ Lives\ Saved = Current\ Annual\ Fatality\ Estimate\ x\ [1-CMF]$$
$$= 16\ x\ [1-0.84]$$
$$= 2.56/year$$
$$Estimated\ Annual\ Injuries\ Prevented = Current\ Annual\ Injury\ Estimate\ x\ [1-CMF]$$
$$= 20\ x\ [1-0.84]$$
$$= 3.20/year$$

Thus, the rumble strip project would be expected to save approximately 2.6 lives per year and reduce injuries by 3.2 annually. These estimates can then be monetized as discussed in Section 4.3 and shown in the following example.

Example Safety Benefits Calculation

To demonstrate how to calculate safety benefits, consider a hypothetical grade crossing project that would grade separate the crossing. For this example, the project would eliminate 100 percent of the risk associated with rail-auto crashes (as well as provide other ancillary benefits with regard to surface congestion). To determine the safety benefit, the applicant should estimate a baseline crash risk (the existing conditions risk) to measure the risk reduction of the project.

Depending on the project site and the frequency of crashes, this can be done in several ways. One strategy is to determine the historical crash rate and assume that it would remain constant in the absence of the proposed project; however, this strategy may not be realistic if the historical crash rate has been changing, and is not effective for high consequence/low probability events or in regions with very few events. The applicant may also need to adjust the calculation to consider changes in the frequency of rail service and expected growth in automobile traffic, among other factors.

For example, if there are 10 crashes per year but the train flow is expected to increase by 10 percent over the next 5 years or automobile traffic is projected to increase, the baseline crash risk may also increase over the next 5 years. The most reliable approach to estimating the baseline risk and its reduction because of improving a crossing will depend on the location of the project, the objective of the project, and the data available. The applicant should document all assumptions on baseline crash risk and risk reduction, and how factors (e.g., population growth, expected changes in service, freight growth) impact the risk under the baseline and with the improvements resulting from a proposed project.

There are three main components to estimating the safety benefits: baseline risk; the reduction in risk expected to result from a project that improves a grade crossing; and the expected consequences posed by those risks. For this example, USDOT will assume that without the project (the baseline risk), the site would experience three collisions between trains and automobiles annually, resulting in an average consequence of one fatality and one minor injury per incident.[29] These fatalities and injuries represent the expected consequences of the baseline collision risk. Because the project removes the grade crossing and thereby eliminates all risk of auto-rail collisions, it also eliminates the expected consequences of that risk. Thus, its expected safety benefits include eliminating three fatalities and three minor injuries annually.

The following calculation illustrates the estimated annual safety benefits from removing the grade crossing:

$$Safety\ Benefits = Baseline\ Risk\ x\ Risk\ Reduction\ x\ Expected\ Consequences$$
$$= 3\ crashes/year\ x\ 100\%\ risk\ reduction\ x\ [1\ x\ \$9,600,000 + 1\ x\ \$28,800]$$
$$= \$28,886,400/year$$

When estimating the benefits, it is important to ensure that units align. For example, if risk reduction is defined on an annual basis, baseline risk should also be expressed on an annual basis. If expected consequences are expressed on an annual rather than a per crash basis, the number of crashes should be omitted from the equation.

Example Emissions Benefits Calculation

Benefits from reducing emissions of criteria pollutants should be estimated using the standard benefit calculation; that is, by multiplying the quantity of reduced emissions of each pollutant in various future years by the dollar value of avoiding each ton of emissions of that pollutant. For the example calculation, assume that the project will lower $PM_{2.5}$ by 10 short tons annually; using the value from Table A-6 above, this reduction would result in \$3.9 million in benefits annually over its lifetime. Other emissions should be calculated similarly with their respective monetized value.

$$PM2.5\ Reduction\ Benefit = Quanity\ Reduced\ x\ Monetized\ Value$$
$$= 10\ short\ tons\ x\ \$387,300/short\ ton$$
$$= \$3,873,000/year$$

The economic value of reduced emissions during each year of the project's lifetime would then be discounted to its present value for use in the overall BCA evaluation.

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[29] For simplicity in this example, USDOT assumes population growth, rail traffic, and highway traffic will remain constant.

Example Residual Value Calculation

Residual value should be estimated using the total value of asset and the remaining service life at the end of the analysis period. For the example calculation, assume the analysis period is 30 years of operation but the project has a useful service life of 40 years. The total project cost, in real dollars, is $40 million. The residual value of the project would thus be:

$$RV = \left(\frac{U - Y}{U}\right) x \ Project \ Cost$$
$$= \left(\frac{40 - 30}{40}\right) x \ \$40,000,000$$
$$= \$10,000,000$$

Where RV = Residual Value

        U = Useful Service Life of Project

        Y = Years of Analysis Period Project Operation

It's important to note that this $10,000,000 in residual value benefits would occur in the final year of the analysis and should be discounted the same as other project benefits and costs in the BCA.