Benefit-Cost Analysis Guidance for TIGER and INFRA Applications

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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
INFRA	Infrastructure for Rebuilding America
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
TIGER	Transportation Investment Generating Economic Recovery
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 Infrastructure for Rebuilding America (INFRA) and Transportation Investment Generating Economic Recovery (TIGER) discretionary grant programs[1] with guidance on completing a benefit-cost analysis[2] (BCA), as is required under those programs. BCA is a systematic process for identifying, quantifying, and comparing expected benefits and costs of a potential investment. 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 program 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.

While generally similar in its mechanics, this document makes a number of changes to BCA guidance issued in prior years for the two programs, and thus should be considered to supersede those documents. This document includes both technical guidance on preparing a BCA and recommended values for key parameters, issues that have previously been covered in separate documents. It also includes values for several additional parameters that may be relevant for certain types of benefit and cost estimates.

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 and non-users of the facility, value in monetary terms.[3]

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.

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[1] For information on the Department's TIGER and INFRA grant programs, please see https://www.transportation.gov/policy-initiatives/tiger and https://www.transportation.gov/INFRAgrants.

[2] "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.

[3] 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.

This guidance:

- Describes an acceptable methodological framework for purposes of preparing BCAs for TIGER and INFRA 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 illustrative calculations to assist applicants in preparing many of the quantitative elements of a BCA (see Appendix B).

BCAs vary greatly in complexity and workload 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 TIGER and INFRA from applicants of all sizes, we also believe that a transparent, reproducible, thoughtful, and reasonable BCA is possible for all projects. The goal of a well-produced BCA is to provide a more 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 until the final application deadline has passed.

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 the TIGER and INFRA 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), the Office of Management and Budget (OMB) Circular A-94 (Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs), and OMB Circular A-4 (Regulatory Analysis). Circular A-4 also 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 the benefits, the sponsor should describe the benefits 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 and well-documented.

The following section outlines general principles of BCA that applicants should incorporate.

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 infrastructure and ensure that it continues to meet the needs of a growing population and economy.

Before investing in transportation infrastructure improvements, 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 and of the transportation system and society as a whole.

Carefully identifying the different impacts a project will 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 against which to measure the incremental benefits and costs of a proposed project. A baseline is sometimes referred to as the "do-nothing base case" or "no-build alternative," although it is perhaps more accurately characterized as a "do minimal" scenario that allows for ongoing operations and maintenance of the facility. A baseline defines the world without 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 simply accelerate the already planned replacement of a deteriorating bridge, it would be incorrect for the baseline to be the bridge replacement project occurring later (i.e. only calculating the benefits of positive project outcomes occurring sooner). The point of the BCA is to evaluate benefits and costs of the project itself, not whether accelerating the project is cost-beneficial (it is possible that the project would not be cost beneficial under either timeframe). A more appropriate baseline would thus be a world 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.

Applicants should 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. 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, individuals would ship cargo only by truck for thousands of miles to its final destination as the only alternative to the spur project. A 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. Where traffic forecasts (such as corridor-level models or regional travel demand models) are used that go beyond the use of 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, and 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 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.

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. Applicants should take extra care in extrapolating beyond the years covered in a travel demand forecast, especially given projected long-term declines in national-level travel growth. In many cases, it would be more appropriate to cap the analysis period at the year for which a reliable travel growth forecast is available, rather than extrapolating beyond that point.

3.3. Inflation Adjustments

The discussion above and throughout this document focuses on real dollars, also known as constant dollars. 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. In the real world, inflation does tend to exist, which thus causes the purchasing power of a dollar to erode from year to year.

Nominal dollars reflect the effects of inflation, and are sometimes also called current or year-of-expenditure dollars. To meaningfully compare the benefits and costs associated with a transportation improvement project, it is important that those values be expressed in common terms. Doing so requires that all costs and benefits be denominated in real dollars. In practice, this means that all monetized values used in a BCA should be expressed in a common base year, with the effects of inflation netted out. Applicants should note that this treatment in BCA likely differs from the way in which costs are presented in a project’s budget or plan of finance, in which such expenditures are generally presented in nominal terms.

Data obtained for use in BCAs is sometimes expressed in nominal dollars from several different years. These dollar amounts can readily be converted into real dollars of a common base year, so that they will measure equivalent purchasing power. BCAs submitted for projects seeking funding from the TIGER or INFRA programs during 2017 should use a 2016 base year.

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.[4] Table 10 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 2016 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 provide documentation to that effect and indicate the index values used to make the adjustments.

3.4. Discounting

After accounting for 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

[4] 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.

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. 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 TIGER and INFRA grant programs should use a real discount rate (i.e., the discount rate net of the inflation rate) of **7 percent** per year to discount streams benefits and costs to their present value in their BCA.[5] 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.

3.5. Analysis Period

The selection of an appropriate analysis period is a fundamental consideration in any BCA. By their nature, transportation infrastructure improvements 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. This operational period will generally correspond to the expected service lifetime of the improvement, which can vary significantly for different types of investments.

USDOT recommends that applicants set their analysis period based on the number of years until they would anticipate having to take the same type of action again (i.e., reconstruction, replacement, capacity expansion, etc.). As a rule of thumb, the analysis period should cover of the full development and construction period of the project, plus at least 20 years after the completion of construction during which the full operational benefits and costs of the project can be reflected in the BCA.

Applicants may encounter situations where a longer or shorter analysis period is appropriate. For example, if the project’s useful life is less than 20 years (as is the case for many technology or vehicle purchase investments), a shorter timeframe matching that useful life would be appropriate. Conversely, 20 years of operations may be insufficient to provide a full assessment of the benefits of assets, such as major structures or tunnels, which are often designed for a useful life of 50 or more years. 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 40

[5] Applicants may also provide a sensitivity analysis showing how the results would differ if a 3 percent discount rate were to be used.

years of full operations. Instead of extending the analysis period indefinitely, applicants should establish their reasonable horizon year and then consider an assessment of the value of the remaining asset life in situations where project assets have useful lifetimes that continue beyond the end of the analysis period (as described in Section 5.3 below).

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.

3.6.Scope of the Analysis

A BCA should include estimated benefits and costs covering 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 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 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 allows for packages of projects to be included in a single grant application. In many cases, each of these projects may be related, but have independent utility in their own right. 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 are the economic value of positive outcomes that are reasonably expected to result from the implementation of a project, and can 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 (if 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 necessarily an exhaustive list of all the relevant benefits that may be expected 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 flows or provide new connections that result 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 traffic flows. Such improvements may reduce the time that drivers and passengers spend traveling, including both in-vehicle time and wait time.

USDOT publishes guidance on the appropriate value of travel time savings (VTTS) for use in evaluating the benefits of transportation infrastructure investments.[6] Recommended values, presented in dollars per person-hour, are reproduced in Appendix A, Table 6 of this document. The table includes values for travel by both private vehicle and by commercial vehicle operators. Private vehicle travel includes both personal travel and business travel; the table also includes a blended value for cases where the mix of personal and business travel are unknown. The values are also applicable for in-vehicle travel time; as noted in the table, non-vehicle personal travel time such as waiting or transfer time should be valued at twice this rate.

Applicants should note the values provided in Table 6 are on a per person basis. However, many travel time estimates are based on vehicle-hours, thus requiring additional assumptions about vehicle occupancy in order to estimate person-hours of travel time. Applicants are encouraged to rely on localized data or analysis that is specific to the corridor being improved and, where available, by time of day (particularly when travel time savings are being generated by reductions in peak-period delay) in generating assumptions about vehicle occupancy factors, and document those sources and assumptions in the BCA. In the absence of such data, applicants may use the more general vehicle occupancy factors included in Appendix A, Table 7.

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 in the area of freight movement, in addition to the value that they may place on reductions in mean travel times.

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

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[6] See U.S. Department of Transportation, Office of the Assistant Secretary for Policy, *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. Applicants preparing a BCA may wish to read this guidance document for a discussion of the appropriate application and potential limitations on value of travel time savings research.

different 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 the BCA. If applicants nevertheless choose to present monetized reliability improvements 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.Vehicle Operating Cost Savings

Vehicle operating cost savings frequently result from both freight-related and passenger-related projects. Freight-related projects that improve roads, rails, and ports frequently generate savings to carriers (e.g., reduced fuel consumption and other operating costs). Passenger-related improvements can also reduce operating costs for service providers and users of private vehicles by reducing the operating costs of vehicles or dispatching.

If applicants are projecting these savings as benefits, they need to carefully demonstrate how the proposed project would generate such benefits. Applicants are encouraged to use local data on vehicle operating costs where available, if such assumptions are justified and sources are documented. For analyses where such data is not available, USDOT provides standard values from the American Automobile Association and the American Transportation Research Institute for the marginal vehicle operating costs for both light duty vehicles and commercial trucks in Appendix A.

4.3. Safety Benefits

Transportation infrastructure improvements can also reduce the likelihood of fatalities, injuries, and property damages that result from crashes on the facility, both by reducing the number of such crashes and/or their severity. To claim safety benefits for a project, applicants need to clearly demonstrate how a proposed project targets and improves safety. 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 needs to determine the type of crash the project is likely to effect, and the effectiveness of the project by reducing the frequency or severity of such crashes. Severity of prevented crashes is measured through the number of injuries and fatalities, and the extent of property damage. 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 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 CMF Clearinghouse.[7] An example calculation using CMFs is included in Appendix B.

USDOT provides guidance on the monetized values for the value of reducing fatalities (the "value of a statistical life", or VSL), injuries, and property damage in transportation incidents.[8] These values are summarized in Appendix A, Table 3, with corresponding references for additional information.

Injury Severity Scales

USDOT recommends converting data on injuries to the Maximum Abbreviated Injury Scale (MAIS) to monetize the value of reducing them. However, USDOT recognizes that accident data that are available to applicants may not be reported as MAIS numbers. Law enforcement data may frequently be reported using the KABCO scale, which is a measure of the observed severity of the victim's functional injury at the crash scene. In some cases, the applicant may only have a single reported number of accidents on a particular project site, but have no injury and/or injury severity data for any of those accidents. With accidents reported in KABCO scale or with unknown injury/severity information, it is necessary for the applicant to convert the available data into MAIS.

The National Highway Traffic Safety Administration (NHTSA) provides a conversion matrix that allows KABCO-reported and generic accident data to be re-interpreted as MAIS data.[9] Table 1 on the following page provides a comparison of the KABCO and MAIS injury severity scales, and monetization factors for injuries reported on the KABCO and MAIS injury severity scales are included in Appendix A.

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

[8] U.S. Department of Transportation Department of Policy, *Guidance on Treatment of the Economic Value of a Statistical Life*, https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis.

[9] 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
6	Unsurvivable

Alternatively, when only a few cases are involved, the applicant should provide a description of the incidents and demonstrate the linkage between the proposed project and crash reduction. Once the applicant has established a reasonable count of the incidents that the project will likely prevent, it should apply the Department's guidance on VSL and injuries to monetize them. For an example calculation of safety benefits, please see Appendix B.

4.4. Emissions Reduction Benefits

Transportation activities contribute significantly to localized air pollution, and some transportation projects offer the potential to 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 these. By lowering these costs, transportation projects that reduce emissions may 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 (PM), and volatile organic compounds (VOC).[10] The recommended economic values for reducing emissions of various pollutants are shown in Appendix A, Table 9.

[10] 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.

Note that previous BCA guidance from USDOT has included a discussion of approaches to valuing reductions in carbon dioxide (CO_2) emissions and other greenhouse gases (GHGs) and provided recommended values. However, the guidance documents on which those estimates were based have recently been rescinded.[11] As a result, USDOT does not currently have recommended unit values for reductions in these pollutants. Any such estimates provided in a BCA under the TIGER or INFRA programs, however, should be discounted at the same rate as costs and other benefits quantified in the BCA, and should be based on the domestic damages of such emissions, rather than using global values.

If applicants wish to include monetized values for additional categories of environmental benefits (or disbenefits) in their BCA, then they should also provide documentation of sources and details of those calculations. Similarly, applicants using different values from the categories presented in Appendix A should provide sources, calculations, and rationale for divergence from 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 should 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 as a result of the proposed improvement.[12]

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 as one-half the reduction in average user costs, multiplied by 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.

If some new users are expected to be drawn from facilities or services that compete with or substitute for the improved facility or service, remaining users of those alternatives or the economy as a whole can experience additional benefits. However, any such secondary or indirect benefits should be small relative to those experienced by users of the improved facility, and the analysis should focus on the proposed project's benefits to continuing and new users.

[11] See Executive Order 13783, Promoting Energy Independence and Economic Growth, March 28, 2017.

[12] 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.

Modal Diversion

Improvements to transportation infrastructure or services may often 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.[13] 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 in their BCAs.

At the same time, however, reductions in external costs from the use of competing alternatives 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 several harmful by-products, including delays to occupants of other vehicles during congested travel conditions, emissions of air pollutants, and potential damage to pavements or other road surfaces. These by-products 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*[14] in their BCAs in previous rounds of the two 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

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[13] 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.

[14] *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 2016 base year dollars using a factor of 1.510 to reflect changes in the level of the GDP deflator over that period of time.

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 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 into using standard methodologies for doing so, as noted in Section 4.4 above.

Work Zone Impacts

An example of "disbenefits" commonly 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. Work zones may also be significant in the out years under a no-build base case, under which an aging facility might require more frequent and extensive maintenance in order 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.

Resilience

Some projects are aimed at improving the ability of transportation infrastructure to withstand adverse weather and seismic events and other threats and vulnerabilities Conducting BCA that incorporates an evaluation of resilience benefits requires an understanding of both the expected frequency with which different levels of each stressor will 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 severity 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 can draw on previous experiences with facility outages to calculate the value of reduced infrastructure and service outages, such as costs incurred by commuters and operators when bridges are closed, and include those potential impacts in their estimates of the user benefits associated with the project.[15] Where such incidents are projected to occur with some estimated probability over a given time period, those probabilities should be factored into the estimated benefits, rather than implicitly or explicitly assuming that the triggering incident will occur with certainty.

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[15] 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/

Noise Pollution

Noise pollution is defined as the form and level of environmental sound that is generally considered likely to annoy, distract or even harm people and animals. Noise can affect human health and well-being, reduce productivity and damage the natural environment. Where relevant, applicants should 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 (e.g. in the case of freight or commuter rail, for instance) will increase 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 have significant noise benefits.

Currently, USDOT has not developed reliable means to estimate the public value of noise reductions for U.S. projects, 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 likelihood of delays to emergency services, such as ambulance and fire services, can create benefits in terms of reduced damages resulting from those emergencies. This type of benefit is often attributed to grade separation projects in instances where emergency vehicles must seek alternative routes when crossing gates are down.

The Federal Emergency Management Agency (FEMA) has developed a methodology to aid in the monetization of such benefits.[16] That methodology is based on the observation that delays to fire services can cause a generalizable increase in property damage when fires burn longer; 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 should take care not to assume unreasonably excessive delays to emergency services in the baseline scenario, as this will lead to an overestimate of project benefits. 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 overestimate the emergency service delay reduction. Furthermore, applicants should carefully consider the size of the population assumed to be affected by such lapses in emergency services, as well as thoroughly justify and document such assumptions.

Property Value Increases

Transportation projects can also increase the accessibility or otherwise improve the attractiveness of nearby land parcels, resulting in increased property values. Such increases would largely result from reductions in travel times or other benefits described elsewhere in this guidance. As a result, if projected increases in property values are to be included in a BCA, great care must be taken to avoid double-

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

counting the same benefits. Such projections should also only count the net increase in land value as a 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. Applicants should also note that any claimed societal benefit from a property value increase would be only a one-time "stock" benefit, rather than a stream of benefits accruing annually.

USDOT expects any applicant claiming these types of benefits to provide a rigorous justification of the rationale for considering them in their BCA. To the extent possible, applicant should use survey methods to estimate the value of the estimate the value of the expected property value increase from transit or other transportation improvements. If an applicant uses benefit transfer methods, it should take great care to satisfy the selection criteria and the disqualifying criteria noted in OMB Circular A-4 (p. 25). The basis for the benefit transfer should be a peer reviewed study with the expectation that the proposed project shares similar characteristics with the original project studied. For example, this could include transit type (e.g. light rail), number of stations, number of track miles, type of neighborhood, retail activity, general demographic characteristics (e.g. per capita income), size of municipality, and geographic region. Meeting all these criteria is difficult, but an applicant should be able satisfy most of them before applying this approach. If they cannot do so (as will often be the case), applicants should limit themselves to only a qualitative discussion of these types of benefits.

Additionally, some transportation projects may have impacts on real property. For example, a freeway interchange reconfiguration may free up land that could be sold off for development once the project has been completed. If the applicant can reliable estimate the value of selling such property, the value of such a sale can be netted out of the project costs. Some projects may also include the creation of new spaces that are valued by the public, such as in the case of a park on top of a freeway cap project. Applicants may attempt to monetize the value of such assets to include in their BCA based on local values of land with similar uses, or describe them qualitatively when such benefits cannot be easily or reliably monetized.

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. Many of these benefits would be expected to be captured in increased property values. 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.

5. Costs

Project costs may be defined as the economic resources (in the form of the inputs of capital, land, labor, and materials) needed to develop and maintain proposed projects over their lifecycle. In a BCA, these costs are usually measured by their market values, as those costs 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 categories (including costs paid for by State, local, and private partners or the Federal government), as well as identify the distribution between public expenditures and privately-borne costs. If the requested grant is to help pay for only part of the project, but the project is indivisible (i.e., no one part of the project would have independent utility), then the applicant should compare the benefits of the whole project to the costs of the whole project. Cost data should include all funded and unfunded portions of the project when considering all funding sources, 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.

All costs of the project (or that sub-component requesting funding if the project is a sub-component of a larger project) should be included, including costs already expended. 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 INFRA and TIGER 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.

Projects will likely incur costs in multiple years across the analysis period of the BCA. Costs should be recorded in the year in which they are expected to be incurred, regardless of when payment is made for those expenses (such as repayments of any principal and interest associated with financing the project). Costs should also be stated in real terms, which may thus require applicants to adjust any cost estimates prepared in year-of-expenditure (YOE) dollars (see Section 3.3 above). Similarly, if the project uses cost estimates developed in earlier years (e.g., a 2013 estimate for expenditures starting in 2016), the 2013 estimate should be adjusted to dollars of the base or analysis year established for the project before being used in the BCA (see Section 3.3 above). Any future year costs should also be appropriately discounted to the baseline analysis year to allow for comparisons with other BCA elements.

5.1. Capital Expenditures

The capital cost of a project is the sum of the monetary resources needed to build the project or program and/or acquire the project's assets. 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 or real estate acquisition, 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.[17]

[17] 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.

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

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 INFRA or TIGER discretionary grant programs (see Section 6 below).

5.3. Residual Value and Remaining Service Life

As noted above, the BCA analysis period should be tied to the expected useful life of the infrastructure 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 any reasonable analysis period for BCA. At the same time, 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.

Some projects assets may also have several years of useful service life remaining at the end of the analysis period. This could include both assets with expected service lives longer than the analysis period, and shorter-lived assets that might have been assumed to be replaced within the analysis period.[18] One approach to accounting for such situations in BCA is to net out the discounted remaining value of those assets at the end of the analysis period from the overall cost of the project. This is sometimes also referred to as the *residual value* of the project.

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.[19] An asset with an expected useful life of 70 years would thus retain half of its value after 35 years in service, while an asset with a 50-year life would retain 30 percent of its value at that point in time.[20] Those residual values would then be discounted to their present value using the discount rate applied elsewhere in the analysis. Also, as noted above, long-lived assets may also require extensive rehabilitation at certain points in their service lives. If such treatments would be projected to occur outside of the analysis period window, then the discounted costs of those activities should also be accounted for as part of the residual value calculation.

Applicants interested in applying the residual value methodology in their BCA should detail their useful life assumptions in carrying out these cost estimates, including their reasoning for any expected variations from typical useful life assumptions that reflect project-specific factors (e.g., local climate conditions, quality of asset used, expected usage levels, etc.). An example calculation of residual value in 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 INFRA or TIGER discretionary grant programs (see Section 6 below).

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:

<u>Net present value (NPV)</u> 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 is worth pursuing. Policy priorities, perceived risk, and funding availability, however, may lead to the selection of an alternative with a lower, positive NPV.

The <u>benefit-cost ratio (BCR)</u> 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

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[18] For example, a component might be assumed to require replacement every 20 years. If the analysis period is 30 years, 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.

[19] Other approaches would also be allowed, so long as the methodology used is adequately described and justified in the BCA.

[20] In this example, if the construction period is five years, then the overall analysis period would be 40 years (5 years construction plus 35 years of operation).

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.[21] 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 TIGER and INFRA discretionary grant programs are being made under similar circumstances, this is the approach that should be used to calculate the BCR for BCAs 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, and property values. Economic impact analyses often take a strictly positive view, (i.e., increased jobs, spending) and do not examine how the resources used for a project might have benefitted alternative societal uses of the resources (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 local government. 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

[21] 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.

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 is important to understand how a project may affect a particular economy or region, but this analysis should be done as an independent follow-on exercise after 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 a negative net benefit could generate positive regional economic benefits simply by increasing spending or employment within a specific geographic area even if, from a national standpoint, its overall economic impacts would likely be negative.

7.2. Transfers

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 with a stake in the project. As such, they do not represent a net increase in societal benefits and thus are not legitimate benefits to be included in a benefit-cost analysis. Examples could include increases in local wages and property tax revenues. While these are benefits for 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 these changes are 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.

7.3. Avoided Costs

Transportation improvements may sometimes be justified by describing the costs of an alternative, more costly improvement (often on another mode of transportation) that would accomplish roughly the same goal, such as reducing congestion or moving larger volumes of freight. However, applicants should not include the “avoided cost” of such alternative capital improvement projects when estimating benefits the BCA. For example, if a metropolitan area found that the cost of expanding an existing commuter rail line to accommodate future growth in travel demand was less than a corresponding investment in a new freeway facility, the applicant cannot include the “savings” of these avoided costs between the two projects in the BCA. The goal of BCA is to examine whether the proposed project is justified given its expected benefits; as noted in Section 3.2 above, simply comparing one capital investment project to another does not indicate whether either project would be cost-beneficial in its own right. Note, however, that reductions in ongoing operating and maintenance costs of a transportation facility would be a valid impact to quantify in a BCA (see Section 5.2).

8. Submission Guidelines

The BCA submitted by the applicant should include both a narrative 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 should provide enough information so that a qualified third party can reproduce the results. The applicant should include all data sources in addition to information on how each source feeds into the analysis.

Applicants should clearly describe the current baseline and how the proposed project would alter the baseline. This description 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 make clear to the reviewer what the status is and how the proposed project will change the baseline. If an application contains multiple separate projects that are linked together in a common objective, each of which has independent utility, the applicant should provide a separate description and analysis for each project.

The BCA should include a high-level summary of the key components of the BCA, including the benefits, costs, and major assumptions with accompanying discussion. Costs should include the full cost of the project, including Federal, State, local, and private funding, as well as expected operations and maintenance costs, and not simply the requested grant amount or the local amount. Table 2 provides an example of a matrix format that could be used to help summarize this information.

Table 2: Example of an Executive Summary Matrix

Current Status/Baseline and Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts
Stop light at lightly used (non-peak) rural intersection with excess waiting time and safety hazard	Replace with roundabout /signal phasing improvement	Reduce wait times for vehicles (non-peak) & reduce accidents (peak)

8.1. Transparency and Reproducibility

As OMB Circular A-4 emphasizes, BCA analyses should be transparent so 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 as well as a summary of the final results for each cost and benefit category. The analysis should also identify any assumptions that heavily influence the results and could change the outcomes if varied, as well as the source documentation (with links as appropriate) for assumptions made in the analysis. 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 reaches back to the applicant for more information. Applicants may submit a written description of their analysis to aid in review of the Excel workbook, but it is not required as part of the submission.

Note that if an applicant uses a “pre-packaged” economic model to calculate net benefits, the applicant is still responsible for providing sufficient information so that a Department reviewer can follow the general logic of the estimates and reproduce them. In particular, the Department is looking for 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

BCAs will be 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 assumptions of crash risk reduction. Submission of an unprotected Excel spreadsheet with embedded calculations will allow USDOT reviewers to conduct sensitivity analyses, as necessary. 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 Monetized Values

Each project generates unique impacts in its respective community, and the grant evaluation process respects these differences, particularly within the context of benefit-cost analysis. While the impacts may differ from place to place, the Department does recognize certain monetized values (and monetizing methodologies) as standard, such that various projects from across the country may be evaluated and compared on a more equivalent "apples-to-apples" basis. The following tables summarize key values for various types of benefits and costs that the Department recommends that applicants use in their benefit-cost analyses. However, benefits and costs for any reliable analysis 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/cost categories presented below should provide sources, calculations, and rationale for divergence from recommended values.

The values provided in the tables shown below are stated in 2016 dollars, the base year recommended for use in applications submitted pursuant to NOFOs for the INFRA and TIGER grant programs issued in 2017. Note that for the Value of Statistical Life and Value of Travel Time Savings, DOT's most recent official guidance provides values in 2015 dollars, but has not yet been updated to 2016 dollars. USDOT thus recommends that, for consistency across applications, BCAs submitted under TIGER or INFRA should continue to use the most recent values, even when using a 2016 base year. USDOT will take any future updates of the values in these guidance documents into account when evaluating BCAs submitted under the two programs.

Table 3. Value of Statistical Life (VSL)

Recommended Monetized Value(s)	References and Notes
$9,600,000 per fatality ($2016)[1]	*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 1\ As noted in the text, applicants should use the most recently provided VSL as a 2016 value until it has been updated in USDOT's official guidance.

Table 4: Value of Injuries

Recommended Monetized Value(s)				References and Notes
MAIS Level	**Severity**	**Fraction of VSL**	**Unit value ($2016)**	*Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses (2016)*
MAIS 1	Minor	0.003	$28,800	https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis
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	
MAIS 6	Not survivable	1.000	$9,600,000	**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.

KABCO Level	Monetized Value
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

Table 5: Property Damage Only (PDO) Crashes

Recommended Monetized Value(s)	Reference and Notes
$4,252 per vehicle ($2016)	*The Economic and Societal Impact of Motor Vehicle Crashes, 2010* **Note:** Basis is PDO value of $3,862 ($2010) per vehicle involved in a PDO crash, which itself is an updated value currently used by NHTSA and based on the methodology and original 2000-dollar value referenced in *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 2016 dollars using the GDP Deflator.

Table 6: Value of Travel Time Savings

Recommended Monetized Value(s)		References and Notes
Recommended Hourly Values of Travel Time Savings (2016 U.S. $ per person-hour)[1]		*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 1\ As noted in the text, applicants should use the most recently provided value of time as a 2016 value until it has been updated in USDOT's official guidance.
Category	**Hourly Value**	
Private Vehicle Travel*		
Personal**	$13.60	
Business	$25.40	
All Purposes***	$14.10	
Commercial Vehicle Operators****		
Truck Drivers	$27.20	
Bus Drivers	$28.30	
Transit Rail Operators	$46.10	
Locomotive Engineers	$41.60	
* Values for personal travel based on Local Travel values presented 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 Intercity Travel values found in the USDOT guidance. **Values apply to all combinations of in-vehicle and other transit time on surface transportation modes. Walk access, waiting, and transfer time in personal travel should be valued at $27.20 per hour for personal travel when actions affect only those elements of travel time. *** Weighted average based on a typical distribution of local travel by surface modes (see USDOT guidance) ****Includes only the value of time for the operator, not passengers or freight.		

Table 7: Average Vehicle Occupancy

<table>
<tr><th>Recommended Monetized Value(s)</th><th>References and Notes</th></tr>
<tr><td>

Vehicle Type	Occupancy
Passenger vehicles	1.39
Trucks	1.00

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Federal Highway Administration Highway Statistics 2015, Table VM1

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Table 8: Vehicle Operating Costs

<table>
<tr><th>Recommended Monetized Value(s)</th><th>References and Notes</th></tr>
<tr><td>

Vehicle Type	Recommended Value per Mile ($2016)
Car*	$0.40
Truck**	$0.96

* Car value is based on an average sedan 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).
** Truck 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 2016 dollars using the GDP deflator.

</td><td>

American Automobile Association, Your Driving Costs – 2016 Edition (2016)

http://exchange.aaa.com/automotive/driving-costs/#.WVZdF02oupp

American Transportation Research Institute, An Analysis of the Operational Costs of Trucking: 2016 Update (2016)

http://atri-online.org/wp-content/uploads/2016/10/ATRI-Operational-Costs-of-Trucking-2016-09-2016.pdf

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</table>

Table 9: Damage Costs for Pollutant Emissions

Recommended Monetized Value(s)	References and Notes
(see nested table below)	*Corporate Average Fuel Economy for MY2017-MY2025 Passenger Cars and Light Trucks (August 2012), page 922, Table VIII-16, "Economic Values Used for Benefits Computations (2010 dollars)"* http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf **Note:** Values are inflated from 2010 dollars to 2016 dollars using the GDP deflator.

Emission Type	$ / short ton* ($2016)
Carbon dioxide (CO_2)	**
Volatile Organic Compounds (VOCs)	$1,872
Nitrogen oxides (NOx)	$7,377
Particulate matter (PM)	$337,459
Sulfur dioxide (SO_2)	$43,600

*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.

**USDOT does not have a recommended value for the damage costs of CO_2 emissions at this time. See Section 4.4 for more guidance on how such a value should be included in a BCA.

Table 10: Inflation Adjustment Values

Recommended Monetized Value(s)	References and Notes
See inflation multipliers below	*Bureau of Economic Analysis, National Income and Product Accounts, Table 1.1.9, "Implicit Price Deflators for Gross Domestic Product" (March 2016)* https://www.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey&1903=13

Base Year of Nominal Dollar	Multiplier to Adjust to Real $2016
2001	1.3306
2002	1.3105
2003	1.2849
2004	1.2505
2005	1.2115
2006	1.1754
2007	1.1449
2008	1.1229
2009	1.1145
2010	1.1010
2011	1.0787
2012	1.0592
2013	1.0424
2014	1.0240
2015	1.0132
2016	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 2016 of $1,000,000 in expenses incurred in 2001, using the Implicit GDP Deflator multipliers given in Table 10, would be as follows:

$$\begin{aligned}(2016\ Real\ Value\ of\ \$1{,}000{,}000\ in\ 2001) &= \$1{,}000{,}000\ x\ 1.3306 \\ &= \$1{,}330{,}600\end{aligned}$$

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 2016 of $5,200 real dollars (i.e., dollars with the same purchasing power as in the 2016 base year) to be received in 2022 would be $3,465 if the real discount rate (i.e., the time value of money) is seven percent per annum:

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

If the discount rate is estimated correctly, a person given the option of either receiving $5,200 in 2022 or $3,465 in 2016 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 11 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 11. Example of Discounting

Calendar Year	Project Year	Value of Travel Time Savings ($2017)	Discounted Travel Time Savings at 7%	Construction Costs ($2017)	Discounted Construction Costs at 7%	NPV at 7%
2017	1	$0	$0	$38,500,000	$38,500,000	-$38,500,000
2018	2	$0	$0	$15,500,000	$14,485,981	-$14,485,981
2019	3	$23,341,500	$20,387,370	$0	$0	$20,387,370
2020	4	$24,570,000	$20,056,439	$0	$0	$20,056,439
2021	5	$25,061,400	$19,119,222	$0	$0	$19,119,222
2022	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:

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

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

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

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:

$$\begin{aligned} VTTS(existing) &= Value\ of\ time\ x\ Change\ in\ trip\ time\ x\ Affected\ trips \\ &= \frac{\$14.10}{hr}\ x\ 0.2\ hr\ x\ 100{,}000\ trips/year \\ &= \$282{,}000/year \end{aligned}$$

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 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.

$$\begin{aligned} VTTS(new) &= Value\ of\ time\ x\ \frac{1}{2}\ x\ Change\ in\ trip\ time\ x\ Affected\ trips \\ &= \frac{\$14.10}{hr}\ x\ \frac{1}{2}\ x\ 0.2\ hr\ x\ 10{,}000\ trips/year \\ &= \$14{,}100/year \end{aligned}$$

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 \$296,100 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:

$$Estimated\ Annual\ Lives\ Saved = Current\ Annual\ Fatality\ Estimate\ x\ \left[\frac{CMF}{1 - CMF}\right]$$
$$Estimated\ Annual\ Injuries\ Prevented = Current\ Annual\ Injury\ Estimate\ x\ \left[\frac{CMF}{1 - CMF}\right]$$

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 0.25 for both fatalities and injuries. Estimating the prevented fatalities and non-fatal injuries would be as follows:

$$\begin{aligned} Estimated\ Annual\ Lives\ Saved &= Current\ Annual\ Fatality\ Estimate\ x\ \left[\frac{CMF}{1 - CMF}\right] \\ &= 16\ x\ \left[\frac{0.25}{1 - 0.25}\right] \\ &= 5.33/year \end{aligned}$$
$$\begin{aligned} Estimated\ Annual\ Injuries\ Prevented &= Current\ Annual\ Injury\ Estimate\ x\ \left[\frac{CMF}{1 - CMF}\right] \\ &= 20\ x\ \left[\frac{0.25}{1 - 0.25}\right] \\ &= 6.66/year \end{aligned}$$

Thus, the rumple strip project would be expected to save approximately five lives per year and reduce injuries by seven 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.[22] 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:

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

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 PM2.5 by 10 short tons annually; using the value from Table 9 above, this reduction would result in $3.4 million in benefits annually over its lifetime. Other emissions should be calculated similarly with their respective monetized value.

$$\begin{aligned} PM\ Reduction\ Benefit &= Quanity\ Reduced\ x\ Monetized\ Value \\ &= 10\ short\ tons\ x\ \$337{,}459/short\ ton \\ &= \$3{,}374{,}590/year \end{aligned}$$

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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[22] 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, the remaining service life at the end of the analysis period, and the cost of any major rehabilitation expected to occur in the remaining service life but outside 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 and $5 million worth of rehabilitation is expected in year 35 of operations. The residual value of the project would thus be:

$$
\begin{aligned}
RV &= \left(\frac{U - Y}{U}\right) x\ Project\ Cost - R \\
&= \left(\frac{40 - 30}{40}\right) x\ \$40{,}000{,}000 - \$5{,}000{,}000 \\
&= \$5{,}000{,}000
\end{aligned}
$$

Where RV = Residual Value
U = Useful Service Life of Project
Y = Years of Analysis Period Project Operation
R = Any Post-Analysis Period Rehabilitation

It's important to note that this $5,000,000 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.