Crash Costs for Highway Safety Analysis

FHWA Safety Program

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Safe Roads for a Safer Future
Investment in roadway safety saves lives

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16. Abstract

Highway safety benefit-cost analysis is a critical component of improving safety on our roadways. Highway safety improvement projects—including those implemented through the Highway Safety Improvement Program (HSIP)—must be economically justified such that their expected benefits exceed the costs. To determine the economic benefits of safety treatments, analysts use crash costs to quantify the impacts of crashes reduced by the safety improvement project. Additionally, crash costs are often used as part of network screening to identify the roadway locations with highest potential for safety improvement by quantifying the potential reductions in crash costs to roadway users.

This guide documents a literature review and the results of a questionnaire sent to all FHWA Division Offices regarding crash unit costs and their application. Currently, there is no nationally recommended set of crash unit costs for use in highway safety benefit-cost analysis. States independently select, modify, and update crash unit costs from one or more sources for their highway safety analyses.

The Crash Costs for Highway Safety Analysis guide describes the various sources of crash costs, current practices and crash costs used by States, critical considerations when modifying and applying crash unit costs, and an exploration of the feasibility of establishing national crash unit cost values. This guide proposes a new set of national crash unit costs for the FHWA Highway Safety Benefit-Cost Analysis Guide and Tool as well as procedures to (1) update the crash unit costs over time, and (2) adjust the crash unit costs to States based on State-specific cost of living, injury-to-crash ratios, and vehicle-to-crash ratio.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACCRA	Cost of living index developed by U.S. Chamber of Commerce researchers
AIS	Abbreviated Injury Scale
BCA	benefit-cost analysis
BCR	benefit-cost ratio
CDS	Crashworthiness Data System
CPI	consumer price index
CPI-U	consumer price index for all urban consumers, current series
DOT	Department of Transportation
EB	empirical Bayes
ECI	employment cost index
EMS	emergency medical services
EPDO	equivalent property damage only
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GDP	gross domestic product
GES	General Estimates System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
KABCO	scale used to represent injury severity in crash reporting
MAIS	Maximum Abbreviated Injury Scale
MMUCC	Model Minimum Uniform Crash Criteria
MUWE	Median Usual Weekly Earnings
NASS	National Automotive Sampling System
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NSC	National Safety Council
PCI	per capita income
PCR	police crash report
PDO	property damage only
QALY	quality-adjusted life years
SPF	safety performance function
TRB	Transportation Research Board
USDOT	United States Department of Transportation
VSL	value of a statistical life

EXECUTIVE SUMMARY

Safety practitioners and researchers use crash costs to determine if safety improvement projects are economically justified and to quantify economic impacts of crashes. Estimating the cost of crashes has been a relevant topic in highway safety for decades. The development of the second edition of the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) and the variance in the crash costs used by States in safety benefit-cost analysis (BCA) has reignited discussion regarding the crash costs used in the Highway Safety Improvement Program (HSIP), HSM, and highway safety research projects. There are currently no universally recommended national crash costs for highway safety analysis, although this guide explores the feasibility of national crash costs. National costs would provide consistency in project decisions and research, while lessening the burden on States to each adopt and maintain their own crash costs.

This guide summarizes literature that reports crash cost estimates, synthesizes current State practices to select and update crash costs, and presents the major issues surrounding crash cost estimation and application. A questionnaire sent to Federal Highway Administration (FHWA) Division Offices showed that State procedures in selecting, updating, and applying crash costs vary widely. However, the variance in States' practices has a greater impact on comparisons between States than on the effectiveness of programs and projects within each State.

The following crash cost considerations are discussed throughout the guide:

- Differences in crash cost estimation methodologies.
- Difference in economic and comprehensive crash unit costs.
- Impact of injury scale on crash unit costs, including the translation between injury scales.
- Crash unit cost values by type and severity.
- Weighted crash unit costs.
- Conservativeness in crash costs.
- Converting between crashes and injuries or vehicles.
- Differences in crash costs among jurisdictions and how to account for those differences.
- Importance of consistent crash costs in application.
- Feasibility of recommending national crash cost values.

Regarding those considerations, the guide identifies the following recommendations for practice:

- In general, it is only practical to use estimated crash unit costs in safety BCA.
- It is critical to account for the comprehensive costs of crashes.
- Analysts should strive to estimate the long-term average predicted or expected crash frequency and apply unweighted crash unit costs, rather than continue to use observed crash frequency in safety BCA and attempt to fix the results with weighted crash unit costs (e.g., combining fatal and serious injury costs).
- Using weighted crash unit costs in safety BCA is acceptable if developed with an actual crash severity distribution from the jurisdiction to which they will be applied.
- Regardless of injury scale, analysts should use comparable data from only one injury scale in safety BCA and translate between the scales if needed.
- It is important to use accurate estimations, rather than arbitrarily using high or low crash unit costs without considering the accuracy of the estimation methodology.
- Analysts should consider costs of all crash severities and types in safety BCA.
- Crash unit costs should be applied to the number of crashes, and person-injury unit costs should be applied to the number of involved-persons in crashes, throughout BCA.
- Analysts should adjust for differences in crash unit costs from national estimates to State-specific estimates when possible.
- Analysts should use and apply consistent crash unit costs for all projects.

This guide presents the following national crash unit costs for use as default crash unit cost values in the FHWA Highway Safety BCA Guide and Tool, as well as procedures to adjust these costs to States.

Severity	Comprehensive Crash Unit Cost (2016 dollars)
K	$11,295,400
A	$655,000
B	$198,500
C	$125,600
O	$11,900

CHAPTER 1. INTRODUCTION

Safety improvement projects are investments that aim to reduce crash frequency or severity at one or more locations. Each project should be economically justified, such that the benefits of the project (e.g., predicted crash reduction) outweigh the sum of costs incurred as a result of the project (e.g., engineering, construction, maintenance, change in user costs). Crash costs are the means to monetize the change in crashes (i.e., benefits) for economic comparison to costs.

There is no universally standard set of crash costs to use in safety economic analysis. Each State typically establishes crash costs for use internally or across their jurisdiction, which has led to a great disparity in crash costs between States.

1.1 OBJECTIVES

The objective of this guide is to present the various sources of crash costs, the methods used to estimate crash costs, current practices at State Departments of Transportation (DOT), considerations when applying crash costs in safety analysis, and the feasibility of establishing national crash cost values for safety programs and research. The guide does the following to achieve this objective:

- Summarizes the methodologies used by State agencies to determine crash cost values.
- Describes the impacts of the different crash cost estimation methodologies and values on road safety program development and research.
- Discusses the advantages and disadvantages of a national set of crash cost values.
- Recommends crash unit costs for the FHWA Highway Safety BCA Guide and Tool.

Based on a review of literature and practice, this guide also presents procedures for analysts to adjust national crash unit costs to States as well as information on how analysts could improve the accuracy and consistency of safety economic analysis.

1.2 GUIDE ORGANIZATION

This guide begins by defining terms and concepts used throughout the document such as injury scales, crash cost types, and crash cost components. The following sections synthesize relevant literature and practice before discussing various crash cost considerations. This guide concludes with recommended default crash unit costs for use in the FHWA Highway Safety BCA Guide and Tool as well as suggestions for future practice and research.

CHAPTER 2. TERMS AND CONCEPTS

This chapter presents terms and concepts used throughout the guide. The chapter begins with a list of definitions and terminology, followed by crash cost concepts and injury scales used in the guide.

2.1 DEFINITIONS AND TERMINOLOGY

This section defines important terminology and conventions used throughout the guide.

Crash: An event that may involve multiple vehicles, vehicle occupants, and non-occupants. Each crash involves at least one involved person and may include one or more injuries. The maximum injury severity of the victims in each crash defines the overall severity of the crash.

Crash costs: For the purpose of this guide, this term describes some general valuation of the impacts of crashes in monetary terms. Such valuation may represent the cost of a crash, cost per injury, or otherwise.

Crash cost components: The individual aspects of crash costs (e.g., medical costs, property damage costs).

Equivalent Property Damage Only (EPDO): A method of weighting crashes by severity using the equivalent number of property damage only (PDO) crash costs to develop the weights. For example, given a fatal crash unit cost of $10,000,000 and PDO unit cost of $10,000, the fatal EPDO weight would be 1,000, as a fatal crash unit cost is equivalent to the cost of 1,000 PDO crashes. EPDO is similar to crash costs and is less dependent on annual updates; however, it cannot be compared to other monetary benefits or costs.

Incidence: The frequency of crashes or injuries in a jurisdiction for a given period.

Injury: Each person in a crash may sustain several injuries of various severities. The injured person is typically classified by their most severe injury. Injury typically refers to the individual injuries a person sustains. However, most of this guide discusses injuries on a per-person basis. In most cases, the guide uses the term person-injury, discussed below, to clarify this point.

Involved person: Someone included in the crash event as a driver, passenger, bicyclist, or pedestrian (i.e., not simply a witness), who may be injured or have no injury from the crash.

Person-Injury: Data for an injured person. While a person may sustain multiple injuries in a crash, the term person-injury serves to clarify that each injured person is counted once and that such costs are on a per-injured-person basis, rather than considering each of a person's many potential injuries separately. Person-injuries are classified by the most severe injury incurred by each person.

State: For ease of writing, this guide refers to "States" or "State-specific" in many contexts that could also include District of Columbia, Puerto Rico, and potentially other United States territories.

Unit costs: The specific cost values per crash (i.e., crash unit costs) or cost values per injury or involved person (i.e., person-injury unit costs). Unit costs may be disaggregated by severity, type, or both.

Unweighted costs: The estimated costs of crashes by disaggregate severity and type (i.e., without weighting, as described next).

Weighted costs: Estimated crash unit costs or person-injury unit costs that are averaged or blended across two or more crash types or severity levels. For example, a weighted average fatal and serious injury cost averages the fatality cost and serious injury cost by the proportion of respective crashes to develop one weighted cost for all fatal and serious injuries. The weighted cost is then applied to both fatal and serious injury crashes. Weighted costs are indicated using notation such as K/A for a fatal and serious injury weighted cost or A/B/C for a weighted non-fatal injury cost (in the KABCO scale, which is defined later). Although most weighted costs are developed for multiple crash types or severity levels, they could be developed for other combinations of crash characteristics. Weighted costs are discussed further in Chapter 5.

2.2 CRASH COSTS

Crashes result in tangible and intangible consequences. The tangible consequences—or economic costs—can be directly measured in monetary terms (e.g., medical bills, lost wages). The intangible consequences—such as the physical pain and emotional suffering of people injured in crashes and their families—comprise the other impacts of crashes. The intangible consequences can be monetized as quality-adjusted life years (QALY).

2.2.1 Economic Costs

Economic costs (a.k.a., human capital costs) are the monetary impacts of crashes including goods and services related to the crash response, property damage, and medical costs. Economic costs are the direct and indirect costs to individuals and society from a decline in general health of crash victims, including the following components:

- Emergency services provided by police, emergency medical services (EMS), fire services, and incident management services at the scene of the crash.

- Medical services provided in the emergency rooms, in hospitals as inpatients and outpatients, out of hospital costs (e.g., physical therapy, rehabilitation, prescriptions, prosthetic devices, home modifications), and coroner services in the event of fatal injuries. Some studies include EMS costs within medical costs.
- Market productivity loss due to lost wages and fringe benefits over the victim's remaining life span, expressed in present value.
- Household productivity loss due to the lost ability to perform one's normal household responsibilities (i.e., related to the injured or killed victims and other family members caring for the crash victim), equivalent to the present value of hiring a person to accomplish the same tasks.
- Insurance administration to process insurance claims (e.g., medical expenses, liability, disability, worker's compensation, welfare payments, sick leave, property damage, life insurance) resulting from the crash, and the cost of defense attorneys.
- Workplace costs due to an employee's absence (e.g., new employee retraining, overtime to accomplish work of the injured employee, administration of processing personnel changes).
- Legal costs due to operating courts and fees during civil litigation resulting from the crash.
- Congestion impacts due to travel delay to those not involved in the crash, added fuel consumption, and increased pollution.
- Property damage to vehicles, cargo, roadways, and roadside furniture.

2.2.2 Quality-Adjusted Life Years

The lost quality-of-life due to death or injury can be quantified by estimating the value that people put on their lives (i.e., by determining the price they would pay to avoid risk of death or injury, often based on revealed preferences from marketplace choices such as deciding to purchase safer, more expensive protective gear or equipment) and then quantifying the portion of a full life lost due to the crash. An estimated value based on willingness to pay is referred to as the value of a statistical life (VSL). VSL is the monetary valuation of risk reduction in terms of the cost corresponding to the prevention of one fatality. VSL is not a valuation of life (i.e., an average actual life); rather it is a valuation of risk reduction. VSL does not include economic costs.

The intangible consequences due to a non-fatal injury are referred to as the lost quality-of-life. The metric to value these losses is the QALY. QALY costs are determined by the duration and severity of the health problem. A numerical scale for rating health-related quality-of-life ranges from death with a value of 0 to perfect health with a value of 1. The VSL guidance from United States Department of Transportation (USDOT), described in Chapter 3, establishes relative disutility factors for non-fatal injury levels using the maximum abbreviated injury scale (MAIS). Relative disutility factors are relative fractions of VSL adopted for a given analysis year.(1)

2.2.3 Comprehensive Costs

Comprehensive crash costs (a.k.a., societal crash costs) are the combination of tangible impacts (i.e., economic costs) and the monetized pain and suffering (i.e., QALY). Comprehensive costs are meant to capture all the impacts that result from crashes.

2.3 INJURY SCALES

Crash costs are most often reported by crash severity. Crash severity is reported using injury scales. This guide presents two injury scales: KABCO and Abbreviated Injury Scale (AIS). Some States may use a variation of one of these injury scales and other injury scales exist. Brief descriptions of each injury scale are provided next.

2.3.1 KABCO

Most police crash reports (PCR) use the KABCO scale to report crash and injury severity. Differences are found when reviewing each State's definitions of the severity attributes of KABCO.(2) KABCO is defined in the Model Minimum Uniform Crash Criteria (MMUCC), a standardized set of data elements and attributes for crash reporting.

MMUCC 5th edition retains the same KABCO definitions from the 4th Edition.(3) MMUCC 5th Edition provides the following definitions:(4)

> **Fatal Injury (K)**: A fatal injury is any injury that results in death within 30 days after the motor vehicle crash in which the injury occurred. If the person did not die at the scene but died within 30 days of the motor vehicle crash in which the injury occurred, the injury classification should be changed from the attribute previously assigned to the attribute "Fatal Injury."
>
> **Suspected Serious Injury (A)**: A suspected serious injury is any injury other than fatal which results in one or more of the following:
>
> - Severe laceration resulting in exposure of underlying tissues/muscle/organs or resulting in significant loss of blood.
> - Broken or distorted extremity (arm or leg).
> - Crush injuries.

- Suspected skull, chest, or abdominal injury other than bruises or minor lacerations.
- Significant burns (second and third degree burns over 10% or more of the body).
- Unconsciousness when taken from the crash scene.
- Paralysis.

Suspected Minor Injury (B): A minor injury is any injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include lump on the head, abrasions, bruises, minor lacerations (i.e., cuts on the skin surface with minimal bleeding and no exposure of deeper tissue/muscle).

Possible Injury (C): A possible injury is any injury reported or claimed which is not a fatal, suspected serious, or suspected minor injury. Examples include momentary loss of consciousness, claim of injury, limping, or complaint of pain or nausea. Possible injuries are those which are reported by the person or are indicated by his/her behavior, but no wounds or injuries are readily evident.

No Apparent Injury (O): No apparent injury is a situation where there is no reason to believe that the person received any bodily harm from the motor vehicle crash. There is no physical evidence of injury and the person does not report any change in normal function.

Non-fatal injuries include A, B, and C codes. Non-fatal crashes include A, B, C, and O codes. The "O" code is also often called PDO, indicating that property damage was the highest severity impact of the crash. Some States also include a "U" code, which may mean either there was an injury and the severity of that injury is unknown or it is unknown if there was an injury in the crash, depending on the State and their definition.

The National Highway Traffic Safety Administration (NHTSA) compiled the State Serious Injury Conversion Tables to assist States not already using MMUCC 5th Edition.[4]

2.3.2 Abbreviated Injury Scale

AIS is an integer scale developed by the Association for the Advancement of Automotive Medicine to rate the severity of individual injuries. AIS includes current medical terminology, providing an internationally accepted anatomically-based tool for ranking injury severity.[5] AIS classifies individual injuries per their relative severity on a six-point scale, as shown in Table 1, with 1 meaning very minor and 6 meaning currently untreatable injuries. A value of 0 indicates no injury, while the value of 9 means the injury level is unknown or not classifiable. Hospitals and motor vehicle crash investigators (e.g., NHTSA, Insurance Institute for Highway Safety) use AIS to classify actual injuries and improve vehicle design, respectively.

While the AIS scale is a measurement tool for single injuries, the MAIS is the score of the most severe injury suffered by an injured person in a crash.

Table 1. AIS injury codes.[5]

AIS Code	Injury	Example	Probability of Death (%)
0	None	No injury	0
1	Minor	Superficial laceration	0
2	Moderate	Fractured sternum	1 – 2
3	Serious	Open humerus fracture	8 – 10
4	Severe	Perforated trachea	5 – 50
5	Critical	Ruptured liver with tissue loss	5 – 50
6	Maximum	Total severance of aorta	100
9	Not further specified	N/A	N/A

2.4 NATIONAL CRASH DATABASES

Several national crash databases have been used to develop the crash costs discussed in Chapter 3. These crash databases describe the incidence of samples of national crashes (i.e., crash distributions by types, severity, and location characteristics). The following is a brief description of the main databases used in crash cost estimation.

2.4.1 National Automotive Sampling System

NHTSA established the National Automotive Sampling System (NASS) in 1979. The original NASS included the General Estimates System (GES) and the Crashworthiness Database System (CDS). The GES and CDS were subsequently replaced with the Crash Report Sampling System (CRSS) and the Crash Investigation Sampling System (CISS), respectively, which together make up the current NASS.

During the initial years of the NASS (also referred to as GES at that time), the crash records included both KABCO and AIS codes. Even recently, researchers have used NASS data from 1984 to 1986 to estimate crash costs due to the ability to convert between the two injury scales. The CDS also contains both injury scales, but CDS only examined tow-away crashes involving passenger vehicles. These older NASS files contain medical descriptions of injuries suffered by victims found in a representative sample of PCRs of medium and heavy truck and bus occupants, non-occupants, and other crash victims. The data from 1984 to 1986 are still used for crash analysis and developing injury scale translator tables because no more recent national sampling with KABCO and AIS exists for all crashes in such a data set. When used in new research, NASS data are reweighted based on the latest CRSS data, which is described in the next section.

2.4.1.1 Crash Report Sampling System

In 2014, the Crash Report Sampling System (CRSS) replaced the GES that was established in 1997. The CRSS provides data on a representative sample of all police-reported crashes with KABCO ratings. Data collectors make weekly visits to approximately 400 police jurisdictions in 60 areas across the United States, where they randomly sample about 50,000 PCRs each year. These 60 areas reflect the national geography, roadway mileage, population, and traffic density. The collectors obtain copies of the PCRs and send them to a central contractor for coding. CRSS records injury severity by crash victim on the KABCO scale.

2.4.1.2 Crash Investigation Sampling System

In 2014, the Crash Investigation Sampling System (CISS) replaced the CDS, which began with the establishment of the NASS in 1979. The CISS provides detailed crash investigation data that focuses on a few thousand crashes annually involving passenger cars, pickup and light trucks, and vans. CISS does not include heavy vehicle, pedestrian, and non-motorist records.

2.4.2 Fatality Analysis Reporting System

The Fatality Analysis Reporting System (FARS) is a national database of all fatal crashes. It includes complete data from all States, District of Columbia, and Puerto Rico. The data comprise crashes that resulted in a fatality within 30 days of the collision event and occurred on a public road. Since 2011, FARS and CRSS have been reconciled with MMUCC and are fully compatible.

CHAPTER 3. SYNTHESIS OF LITERATURE

This literature synthesis is limited in its scope, covering solely recent and relevant publications to the objectives of this guide. Each section is a resource that directly proposes crash costs or has made substantial advances in estimating crash costs. The literature covers the following aspects:

- Crash costs by MAIS.
- Crash costs by KABCO.
- Injury scale translators.
- Costs by crash type.
- Estimates for cost components.
- Procedures to update crash costs over time.
- Procedures to adjust crash costs to States.

The literature is presented in the following sections by chronological order.

3.1 CRASH COST ESTIMATES BY MAXIMUM POLICE-REPORTED INJURY SEVERITY WITHIN SELECTED CRASH GEOMETRIES (2005)[6]

The FHWA report *Crash Cost Estimates by Maximum Police-Report Injury Severity within Selected Crash Geometries*, by Council et al., developed estimates for the economic and comprehensive costs per crash using the KABCO scale. The NASS, GES, and CDS national databases were used for the development of the crash cost components for the FHWA study. KABCO and AIS data were matched in an injury severity estimation procedure. All costs were in 2001 dollars. Crash cost estimates were reported extensively in 6 levels for 22 crash geometries, as described in the FHWA report:[6] (*Appendix A: Selected Crash Geometries* lists the 22 crash geometries and types.)

- Level 1 – For each of 22 crash geometries—categorized by two speed limit categories as a surrogate for urban/rural locales, and all combined—estimates of cost were made for crash severity levels K, A, B/C, and O.
- Level 2 – For each crash geometry, estimates of cost for K/A, B/C, O—all with and without categorization by speed-limit.
- Level 3 – For each crash geometry—with and without speed limit categorization—two subgroups were formed, recognizing the two definitions that police use for C injury: a minor injury (thus, K/A/B/C and O) or possible injury (thus, K/A/B and C/O).

- Level 4 – For each crash geometry—with and without speed limit categorization—crash costs were estimated without regard to crash severity (i.e., for all severities combined).
- Level 5 – For each level of crash severity—with and without speed limit categorization—crash costs were estimated without regard to crash geometry (i.e., for all crash geometries combined).
- Level 6 – Level 5 cost estimates for the K/A, K/A/B, K/A/B/C, B/C, and C/O combinations of crash severity.

In addition to the KABCO levels and combinations in each level, the following two unknown severity levels were developed for crash cost estimates:

- Injury, severity unknown: At least one injury in the crash, but the severity was not recorded on the police report.
- Unknown severity: No injury severities were recorded on the police report, and the severity of the crash is unknown.

Standard errors were presented in the FHWA report, which represent the variance in crash costs "caused by differences in the number of people involved in crashes of the same type, the severity of injuries suffered (as described by AIS, body part, and fracture status of the injury), and the age and sex of the victims (very important for the magnitude of lost productivity and QALYs)."(6)

The FHWA report provided important conclusions and recommendations regarding the use of the crash costs, at the different levels, for safety BCA. The authors of the FHWA report recommended using comprehensive cost estimates. This recommendation was supported by the fact that "comprehensive cost estimates include not only the monetary losses associated with medical care, other resources used, and lost work, but also nonmonetary costs related to the reduction in the quality of life. Since human capital costs do not capture the full burden of injury, comprehensive costs are generally used in analyses related to not only safety issues, but also other public health issues (e.g., effects of the environment on health) and by other non-transportation federal and State agencies."(6)

The choice of cost level (i.e., 1 through 6) is dependent on the number of fatal and serious injury crashes in the FHWA study. Level 1 estimates may be more appropriate for national samples of data. Using Level 1 estimates with a small sample of data (e.g., for a single intersection study) may lead to distortion in the economic results when applied to one or two fatal crashes.

Another aspect to consider is the selection of crash type and severity of interest to the analyst. In general, the report recommends that analysts "should use the highest (least detailed) cost level possible that can still provide information on the study question of interest. For example, the research information needed may require that specific crash types be analyzed, but may not require categorization by speed limit. Other studies may not require categorization by crash type, and available sample sizes of fatal crashes may allow the use of crash-cost for each KABCO severity level (i.e., as in Level 5 estimates)."[6]

The FHWA study noted that the estimates will require adjustments for future years. The adjustment procedure is as follows.

1. Multiply the economic costs provided in the tables in the report by the ratio of the consumer price index (CPI)—using the consumer price index for all urban consumers current series (CPI-U) for all items, annual average indexes, unadjusted for the year of interest—divided by the CPI for 2001.
2. The difference between the comprehensive cost and the economic cost (i.e., QALY cost) for a given crash unit cost is multiplied by the ratio of the employment cost index (ECI)—not seasonally adjusted, total compensation, total private industry for the year of interest—divided by the ECI for 2001.
3. Add the two results to get an updated comprehensive crash unit cost.

Further, "this procedure should provide adequate cost estimates for roughly 5 years or until the next major DOT update of unit crash cost data and methods."[6]

3.2 AASHTO HIGHWAY SAFETY MANUAL, FIRST EDITION (2010)[7]

The AASHTO HSM "provides analytical tools and techniques for quantifying the potential effects on crashes as a result of decisions made in planning, design, operations and maintenance. …. The information in the HSM was provided to assist agencies in their effort to integrate safety into their decision-making process." Crash costs are important to HSM chapters 4, 7, 8, and 9, which cover network screening, economic appraisal, project prioritization, and safety effectiveness evaluation, respectively.[7]

The HSM crash unit costs were sourced from the previously discussed FHWA report *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries*. HSM Chapter 4 listed the costs in Table 2 of this guide for applying the EPDO average crash frequency performance measure in network screening.

Table 2. HSM crash costs for EPDO crash frequency (2001 dollars).[7]

Crash Severity Level	Comprehensive Crash Unit Cost
Fatality (K)	$4,008,900
Injury (A/B/C)	$82,600
PDO (O)	$7,400

HSM Appendix 4A listed more crash unit costs for crash severities and types as shown in Table 3 and Table 4, respectively. The crash unit costs by severity in Table 3 were repeated in HSM Chapter 7, along with a weighted K/A/B crash cost value. HSM Appendix 4A also outlined the procedure to update the crash unit costs to current dollars, as described previously in the 2005 FHWA study.[6] The recommended procedure applied a CPI adjustment ratio to the economic cost portion and an ECI adjustment ratio to the QALY costs.

While not explained in detail in the HSM or the 2005 FHWA report *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries*, analysts can use the CPI and ECI ratios for either the December indexes for each year or the annual average indexes (i.e., the unweighted average of all 12 monthly index values or four quarterly index values). Annual average indexes are more reliable; however, the difference in the trend between the December ratio to annual average ratio is usually negligible. The annual average CPI for 2001 is 177.1 and the annual average ECI for 2001 is 86.2.

The sum of the updated economic cost and QALY cost portions yielded the updated comprehensive crash unit cost. An example was provided in HSM Appendix 4A. When using only economic costs, the ECI adjustment ratio is not needed.

Table 3. HSM crash unit costs by severity (2001 dollars).[7]

Crash Severity	Economic Crash Unit Cost	QALY Crash Unit Cost	Comprehensive Crash Unit Cost	EPDO Weights
Fatality (K)	$1,245,600	$2,763,300	$4,008,900	542
Disabling Injury (A)	$111,400	$104,600	$216,000	29
Evident Injury (B)	$41,900	$37,100	$79,000	11
Possible Injury (C)	$28,400	$16,500	$44,900	6
PDO (O)	$6,400	$1,000	$7,400	1

Table 4. HSM crash unit costs by type (2001 dollars).[7]

Crash Type	Economic Crash Unit Cost	Comprehensive Crash Unit Cost
Rear-End, Signalized Intersection	$16,700	$26,700
Rear-End, Unsignalized Intersection	$10,900	$13,200
Sideswipe/Overtaking	$17,600	$34,000
Angle, Signalized Intersection	$24,300	$47,300
Angle, Unsignalized Intersection	$29,700	$61,100
Pedestrian/Bike at an Intersection	$72,800	$158,900
Pedestrian/Bike, Non-Intersection	$107,800	$287,900
Head-On, Signalized Intersection	$15,600	$24,100
Head-On, Unsignalized Intersection	$24,100	$47,500
Fixed Object	$39,600	$94,700
Other/Undefined	$24,400	$55,100

Using the procedure described in the HSM Appendix 4A, with 2016 annual average CPI of 240.0 and ECI of 126.4, values of the 2016 HSM crash unit costs rounded to the nearest $100 are shown in Table 5.[8,9]

Table 5. Updated HSM crash unit costs (2016 dollars).

Crash Severity	Economic Crash Unit Cost	QALY Crash Unit Cost	Comprehensive Crash Unit Cost	EPDO Weights
Fatal (K)	$1,688,100	$4,052,000	$5,740,100	568
Disabling injury (A)	$151,000	$153,400	$304,400	30
Evident injury (B)	$56,800	$54,400	$111,200	11
Possible injury (C)	$38,500	$24,200	$62,700	6
PDO (O)	$8,700	$1,400	$10,100	1

3.3 ESTIMATING THE COSTS TO STATE GOVERNMENTS DUE TO HIGHWAY-RELATED FATAL AND NON-FATAL INJURY CRASHES (2011)[10]

Estimating the Costs to State Governments Due to Highway-Related Fatal and Non-Fatal Injury Crashes, by Bahar, was prepared for National Cooperative Highway Research Program (NCHRP) Project 20-24, Task 68. The NCHRP report detailed a methodology to disaggregate the crash cost components and calculate crash costs borne by the State governments. Part of the methodology included an adjustment of costs from national crash unit costs to State-specific crash unit costs or from State-specific crash unit costs to those in another State, which accounts for differences in cost of living and medical costs.

The national economic crash unit costs by KABCO severity levels from the NCHRP report are shown in Table 6, rounded to the nearest $100.

Table 6. National crash unit costs (2009 dollars).[10]

Crash Severity	Economic Crash Unit Cost
K	$1,587,000
A	$132,600
B	$48,700
C	$34,100
K/A/B/C	$90,500
O	$6,100
K/A/B/C/O	$31,200

The national economic crash unit costs from Table 6 of this guide required adjusting to represent the State-specific price levels. The adjustment factors used in this process are as follows:

- Per capita income (PCI).
- Federal medical assistance percentages.
- Tax revenue as a percent of personal income by State.
- Medicaid and CPI adjusters.

The NCHRP study offered the following text regarding the State-specific adjustments:

> "To perform the adjustment, multiply the national mean State (generic) unit costs by the ACCRA … medical price and all-items price adjusters and PCI (wage-related) adjusters

and then divide by the national average value (1.0 for the ACCRA adjusters, national average PCI of $40,152 [2008 dollars] for the wage adjuster)."[10]

The NCHRP study also developed a calculator tool to help State DOTs estimate the crash costs borne by their State DOT when focusing on relevant target crash types and maximum crash severity injury level. The tool calculates the cost of expected annual crashes entered by the analyst, based on a set of pre-defined site and safety attributes. The site attributes refer to the posted speed limit, geometry/traffic control in terms of segment, or signalized or unsignalized intersection. Subsequently, the analyst enters potential treatment(s) to the site and respective CMFs and target crashes, and the tool calculates the State DOT's potential savings in terms of the treatment's safety effect in future crash occurrence following implementation.

3.4 THE ECONOMIC AND SOCIETAL IMPACT OF MOTOR VEHICLE CRASHES, 2010 (REVISED) (2015)[11]

NHTSA's 2015 report *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*, by Blincoe et al., documented the most recent and comprehensive study of the costs incurred by society due to the consequences of crashes. The total economic cost of crashes in 2010 was estimated to have been $242 billion. Of this total, the most significant economic costs were lost productivity costs of $77.4 billion (i.e., for market and household combined), property damage of $76.1 billion, congestion costs of $31.5 billion, and medical costs of $23.4 billion. The QALY cost estimate was $594 billion, yielding a total comprehensive cost estimate of $836 billion in 2010 dollars.[11] To develop these estimates of the total crash burden on society, the NHTSA report estimated the cost of economic crash components and QALY costs, including the costs of reported and unreported crashes. NHTSA's Table 1-3 provides national 2010 MAIS injury incidence data, shown in Table 7.[11]

Table 7. National police-reported MAIS person-injury incidence in 2010.[11]

Severity	Police-Reported Person-Injuries
Fatal (MAIS 6)	32,999
MAIS 5	5,749
MAIS 4	17,086
MAIS 3	96,397
MAIS 2	271,160
MAIS 1	2,578,993
MAIS 0	2,147,857

3.4.1 Crash Components

Descriptions of the estimation methodologies for each component were explained in detail in NHTSA's report. The economic cost components were medical care, EMS, market productivity loss, household productivity loss, insurance, workplace loss, legal, congestion, and property damage.[11] The estimation of these cost components relied on records of the number of people and vehicles involved in each crash, the severity of each person's injuries, the costs of those injuries, and damage to each vehicle.

Intangible consequences included the physical and emotional anguish of victims who were injured, may have suffered permanent disability that could profoundly limit a person's life, or result in dependence on others for daily physical care, among others. For an individual, these non-monetary outcomes can be the most devastating aspect of a motor vehicle crash. The QALY estimates used new relative disutility factors stratified by MAIS to estimate the QALY for non-fatal injuries, presented later in Table 14.[12]

The NHTSA study recommended that "for the analysis of crash impact and injury countermeasures, it is important to include only those cost components that are applicable to the specific programs addressed. For example, programs that encourage seat belt use may reduce costs associated with injuries, but would not have an effect on property damage or congestion costs."[11]

3.4.2 Reported and Unreported Crashes and Their Costs

The NHTSA study found that approximately 60 percent of all PDO crashes and approximately 40 percent of all non-fatal injury crashes were not reported to police. Overall, police-reported crashes were estimated to account for 83 percent of all economic crash costs. Crash unit costs for police-reported and unreported crashes were documented in the report. For analyses of safety countermeasures based on police-reported crashes, the analysis should be based on unit costs that are specific to police-reported crashes. Crash costs from Tables 1-9, 1-10, and 1-11 of the NHTSA report are synthesized in Table 8 (economic) and Table 9 (comprehensive) of this guide.[11]

Unit costs were expressed on a per-person basis for all injury levels. PDO costs were expressed on a per-damaged vehicle basis. Generally, all MAIS 4, 5, and fatal injuries were believed to be police-reported, but unreported injury values were still included for reference to cover any exceptional case where unreported crashes might have been found for these injury severity categories.[11]

A discount rate of 3 percent was used in the NHTSA report for lifetime cost impacts such as lost productivity and medical care. This discount rate was established by the Office of

Management and Budget. For consistency, the discount rate of 3 percent was used for VSL (i.e., QALY) estimates as well.

In Chapter 6 of the NHTSA study, economic crash cost burdens were also estimated for each State. Crash costs were given in terms of total State crash costs in 2010 dollars, percentage of total national crash costs, cost per capita, and percentage PCI. The report also described a procedure to adjust national costs to State-specific costs.

At the national level, the NHTSA study developed KABCO to MAIS and MAIS to KABCO translator tables for the estimation of total economic crash costs for several crash scenarios.

Table 8. MAIS economic person-injury unit costs and property damage per-vehicle unit costs, for reported and unreported crashes (2010 dollars).[11]

Severity	Police-reported Crashes	Unreported Crashes	All Crashes
Fatal (MAIS 6)	$1,398,916	$1,393,654	$1,398,916
MAIS 5	$1,001,089	$999,740	$1,001,089
MAIS 4	$394,608	$393,277	$394,608
MAIS 3	$187,128	$175,731	$181,927
MAIS 2	$58,754	$51,731	$55,741
MAIS 1	$20,701	$14,127	$17,810
MAIS 0	$4,380	$1,337	$2,843
PDO (per vehicle)	$6,076	$1,928	$3,862

Table 9. MAIS comprehensive person-injury unit costs and property damage per-vehicle unit costs, for reported and unreported crashes (2010 dollars).[11]

Severity	Police-Reported Crashes	Unreported Crashes	All Crashes
Fatal (MAIS 6)	$9,145,998	$9,140,736	$9,145,998
MAIS 5	$5,579,614	$5,578,265	$5,579,614
MAIS 4	$2,432,091	$2,430,760	$2,432,091
MAIS 3	$992,825	$980,940	$987,624
MAIS 2	$399,626	$392,603	$396,613
MAIS 1	$43,942	$37,368	$41,051
MAIS 0	$4,380	$1,337	$2,843
PDO (per vehicle)	$6,076	$1,928	$3,862

3.4.3 KABCO Person-Injury Unit Costs

In recognition of the police-reported data using KABCO, the NHTSA study provided a KABCO non-fatal injury unit cost table, abbreviated in Table 10 of this guide, which were costs per injured person. To determine the unit costs per crash, the number of people involved in a crash by KABCO severity would need to be tabulated, and subsequently multiplied using the injury unit costs. This procedure is explained in detail in Chapter 5 of this guide. While K costs are not shown in Table 10, the economic and comprehensive K person-injury unit costs shown in Table 8 and Table 9, respectively, pair with the costs in Table 10 because a fatality is the same in KABCO and MAIS. The person-injury unit costs in Table 10 do not factor in the many uninjured cases that are documented as injuries in police reports.

Table 10. KABCO-based non-fatal person-injury unit costs (2010 dollars).[11]

Cost Type	O	C	B	A
Economic	$10,439	$19,494	$23,742	$82,048
QALY	$31,859	$108,274	$252,268	$919,158
Comprehensive	$42,298	$127,768	$276,010	$1,001,206

3.5 ESTIMATING THE COSTS OF UNINTENTIONAL INJURIES (2015)(14)

The National Safety Council (NSC) publishes annual estimates of economic and comprehensive crash and person-injury unit costs in their *Estimating the Costs of Unintentional Injuries* briefs. NSC's costs "represent income not received or expenses incurred because of fatal and nonfatal unintentional injuries."(13) The cost estimation procedure determined benchmark unit costs for each cost component (e.g., property damage costs, medical costs, lost quality of life) from other literature or available data, adjusts each benchmark cost to current value, and estimates the proportion of crashes or persons that each cost component applies to. The total crash impacts were determined by multiplying the cost components by the number of crashes they apply to, and then summing the products across all components and crashes. From that point, the average costs per crash and per injury can be calculated.(13)

The latest available estimates were from 2015, which are shown in Table 11 (economic person-injury costs) and Table 12 (comprehensive person-injury unit costs) of this guide.

Table 11. Average economic person-injury unit cost by injury severity and per-vehicle unit cost for PDO (2015 dollars).(14)

Severity	Person-Injury or Per-Vehicle Unit Cost
Death (K)	$1,542,000
Disabling (A)	$90,000
Evident (B)	$26,000
Possible (C)	$21,400
No injury observed (O)	$11,400
PDO (cost per vehicle)	$4,200

Table 12. Comprehensive person-injury unit cost by severity (2015 dollars).(14)

Severity	Person-Injury Unit Cost
Death (K)	$10,082,000
Disabling (A)	$1,103,000
Evident (B)	$304,000
Possible (C)	$141,000
No injury observed (O)	$46,600

3.6 UPDATED DEFAULT CRASH COST ESTIMATES FOR USE IN SAFETY ANALYST (2016)[15]

AASHTOWare Safety Analyst™ is a software package that assists State and local highway agencies in implementing the HSM roadway safety management process.[16] Among other input variables, crash costs are needed for network screening with EPDO weights, economic appraisal, and project prioritization procedures. *Updated Default Crash Cost Estimates for Use in Safety Analyst*, a white paper, presented at the 2016 Transportation Research Board (TRB) ANB25 Highway Safety Performance Committee midyear meeting in 2016, recommends that "…the HSM crash cost values be used as a basis for crash cost estimates in Safety Analyst, but that they be updated to current cost levels."[15]

Prior to the publication of the white paper, the default crash unit costs had not been updated in Safety Analyst since its release in 2010. Safety Analyst users can also enter their own crash unit costs to override the default costs.

The white paper explained the preferred update procedure, which uses the CPI and ECI as prescribed in the HSM. Table 13 lists new costs for Safety Analyst as presented in the white paper, updated by applying the 2015 CPI index to the economic crash unit cost and 2015 ECI index to the QALY component. The software only uses comprehensive crash unit costs in analysis, unless changed by the user. The white paper suggested these default values be replaced every two years in Safety Analyst with newly updated crash unit costs, per the HSM procedure.[15]

Table 13. Updated AASHTOWare Safety Analyst crash unit costs (2015 dollars).[15]

Crash Severity	Economic Crash Unit Cost	QALY Crash Unit Cost	Comprehensive Crash Unit Cost
Fatal (K)	$1,674,100	$4,048,200	$5,722,300
Disabling injury (A)	$149,700	$153,200	$302,900
Evident injury (B)	$56,3000	$54,400	$110,700
Possible injury (C)	$38,200	$24,200	$62,400
PDO (O)	$8,600	$1,500	$10,100

3.7 GUIDANCE ON TREATMENT OF THE ECONOMIC VSL IN USDOT ANALYSES – 2016 ADJUSTMENT (2016)[12]

The USDOT produces an annual update of guidance on the VSL. The 2016 guidance memorandum, *Guidance on Treatment of the Economic VSL in USDOT Analyses – 2016 Adjustment*, considered recent studies on VSL and their applicability in modifying, or not, past VSL guidance.[12]

The primary purpose of the USDOT guidance is to provide a basis for which the USDOT evaluates—in monetary terms—the costs and benefits of their regulations, investments, and administrative actions. The guidance adopts the annually-updated VSL and the relative values of preventing injuries of varied severity, each as a fraction of the VSL, for this purpose. The VSL is suited for these applications as it is a valuation of risk reduction, which such regulations try to achieve.

In the 2016 guidance memorandum, the VSL was based on nine empirical studies that provided estimates of VSL for a wide cross-section of the population.[12] These studies (dated 1997-2003 and updated to current dollars) were selected because they used data from the Bureau of Labor Statistics Census of Fatal Occupational Injuries, which comprises a complete census of occupational fatalities classified by both industry and occupation. The studies' analysts used advanced statistical econometric modeling techniques to process the data and estimate VSL values based on "the wage differential that employers must pay workers to accept riskier jobs."[12]

The USDOT adopted the following methods and recommended values:

1. Prevention of an expected fatality is assigned as single, nationwide value in each year, regardless of age, income, mode of travel, nature of risk, and other factors. The VSL of $9.6 million is provided for analyses in 2016.

2. The VSL is updated from the year of the source data using growth in median real income and monetary inflation, for the last full year before the date of the guidance.

   Projection of VSL from the base year to a future year should be estimated with the equation in Figure 1.

$$VSL_t = VSL_0 * (P_t / P_0) * (I_t / I_0)^E$$

Figure 1. Equation. VSL update equation.

Where: 0 = Original base year

t = Updated base year

P_t = CPI in year t

P_0 = CPI in year 0

I_t = Real incomes in year t, measured by Median Usual Weekly Earnings (MUWE)

I_0 = Real incomes in year 0, measured by MUWE

E = Income elasticity of VSL, with respect to increases in real incomes (value of 1.0 adopted until more comprehensive studies are completed).

3. The VSL will be published annually.
4. Sensitivity analyses (for low and high estimates) should be conducted for the two VSL of $5.4 and $13.4 million (in 2015 dollars).
5. The value of preventing non-fatal injuries will be calculated by multiplying the disutility factor of the MAIS level for each injured person, as shown in the third column of Table 14, by the VSL value in year *t*. Each relativity disutility factor means the relative fraction of VSL based on the expected injury outcome for a given MAIS level. The values shown below can be used for analyses using 3 percent or 7 percent discount rates. They were calculated using an intermediate rate of 4 percent.

The method to update the VSL values from year to year differs from that in the HSM. In the HSM, the economic cost portion is multiplied by a CPI ratio and the QALY portion—represented by the difference between the comprehensive cost and the economic cost—is multiplied by an ECI ratio. In the VSL guidance, the ECI is replaced by the MUWE, and the entire VSL is multiplied by the CPI ratio and the MUWE ratio. The VSL guidance notes the ECI is less appropriate than MUWE because the ECI assigns fixed weights to employment categories, while the MUWE uses a median employment cost for all wage and salary workers over the age of 16. The median value better indicates the factors influencing typical travelers, whereas some extremely high incomes increase the mean above what most people make. The MUWE index also does not factor in employer contributions to retirement, health insurance, and other workplace savings plans. These fringe benefits (included in the ECI) are not likely significant for average earners. The values in Table 14 do not include economic cost components.

Table 14. Person-injury unit costs based on 2016 VSL (2016 dollars).[12]

MAIS Level	Severity	Fraction of VSL	Person-Injury Unit Cost
Fatal (MAIS 6)	Unsurvivable	1.000	$9,600,000
MAIS 5	Critical	0.593	$5,692,800
MAIS 4	Severe	0.266	$2,553,600
MAIS 3	Serious	0.105	$1,008,000
MAIS 2	Moderate	0.047	$451,200
MAIS 1	Minor	0.003	$28,800

The relativity disutility factors in Table 14 have two applications. First, "as a basis for establishing the value of preventing non-fatal injuries in [safety] BCA. The total value of preventing injuries and fatalities can be combined with the value of other economic benefits not measured by VSLs, and then compared to costs to determine either a benefit/cost ratio or an estimate of net benefits."[12] Second, "the values in [Table 14] may be used to translate non-fatal injuries into fatality equivalents which, when added to fatalities, can be divided into costs to determine the cost per equivalent fatality."[12]

3.8 TIGER BCA RESOURCE GUIDE (2016)[19]

The TIGER BCA Resource Guide is a supplement to the USDOT's *Benefit-Cost Analysis Guidance for TIGER Grant Applicants*.[18, 19] As of May 2017, the most recent version of the BCA Resource Guide was posted in November 2016.[19] The TIGER BCA Resource Guide provides key values for different types of benefits and costs that grant applicants must use in their safety BCA.

Regarding crash analysis, the TIGER BCA Resource Guide recommends the 2016 (i.e., current) VSL value as well as monetized values of injuries by MAIS levels, as described previously. Further, it recommends the cost of $4,198 per damaged-vehicle (in 2015 dollars) for PDO crashes. The PDO cost value originates from the $3,862 cost for all crashes, shown in Table 1-9 of *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*, described in an earlier section, updated to 2015 dollars.[11] This PDO cost is consistent with NSC as well.

Typically, crash data originating from law enforcement records are provided in KABCO scale. The TIGER BCA Resource Guide provided a translator table to convert person-injuries from KABCO to MAIS, as shown in Table 15. The table reads with KABCO as the input and MAIS as the output, such that for each O injury in KABCO there is a 92.53 percent probability that injury was indeed MAIS 0 (i.e., no injury), but there is a 7.257 percent probability of a minor injury, 0.198 percent probability of moderate injury, and so on. The distributions in columns are the focus of the table; row distributions are meaningless. Multiplying a sum of KABCO injuries by the translation factors by severity yields an equivalent number of MAIS injuries, to which

MAIS costs can be applied. The translator table can also be used in reverse to convert person-injury unit costs. The use of translator tables is discussed further in Chapter 5.

Table 15. KABCO to MAIS translation factors.[19]

Severity	O	C	B	A	K	U	Unknown if injured
MAIS 0	0.92534	0.23437	0.08347	0.03437	0.00000	0.21538	0.43676
MAIS 1	0.07257	0.68946	0.76843	0.55449	0.00000	0.62728	0.41739
MAIS 2	0.00198	0.06391	0.1088	0.20908	0.00000	0.10400	0.08872
MAIS 3	0.00008	0.01071	0.03191	0.14437	0.00000	0.03858	0.04817
MAIS 4	0.00000	0.00142	0.00620	0.03986	0.00000	0.00442	0.00617
MAIS 5	0.00003	0.00013	0.00101	0.01783	0.00000	0.01034	0.00279
Fatality	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
Total	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

The TIGER BCA Resource Guide does not explicitly propose the procedure to monetize the cost of all injuries per KABCO crash.[19]

3.9 SUMMARY OF LITERATURE

Table 16 presents a consolidated summary of the literature review, comparing the topics covered by each resource. The authors reviewed the following resources during the literature. The numbered list below corresponds to the columns in Table 16.

1. Crash Cost Estimates by Maximum Police-Report Injury Severity within Selected Crash Geometries (2005)
2. AASHTO HSM (2010)
3. Estimating Costs to State Governments Due to Highway-Related Fatal and Non-Fatal Injury Crashes (2011)
4. The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised) (2015)
5. Estimating the Costs of Unintentional Injuries (2015)
6. Updated Default Crash Cost Estimates for Use in Safety Analyst (2016)
7. Guidance on Treatment of the Economic VSL in USDOT Analyses (2016)
8. TIGER BCA Resource Guide (2016)

Table 16. Literature review summary.

Topic	1	2	3	4	5	6	7	8
Costs by MAIS				•			•	•
Costs by KABCO	•	•	•	•	•	•		
Economic costs	•	•	•	•	•	•		
QALY costs		•	•	•		•	•	•
Comprehensive costs	•	•	•	•	•	•		
Injury scale translators				•				•
Costs by crash type	•	•	•	•				
Cost component estimates			•	•				
Procedures to update crash costs over time	•	•	•	•		•	•	•
Procedures to adjust crash costs to States			•	•				

CHAPTER 4. SYNTHESIS OF PRACTICE

In April 2017, FHWA circulated a questionnaire to all FHWA Division Offices regarding crash costs that States use in safety analyses, to which 42 responses were received. Figure 2 shows a map of the United States, District of Columbia, and Puerto Rico with the Division Offices that responded highlighted in green (or darker shade when viewed in grayscale). *Appendix B: State Crash Cost Questionnaire* presents the questionnaire form.

Any references to States, their responses, and their perspectives throughout this guide are based on the FHWA Division Office responses. The authors of this guide did not contact States, District of Columbia, or Puerto Rico directly for their input. However, in some cases the FHWA Division Office did coordinate with the State DOT on the response.

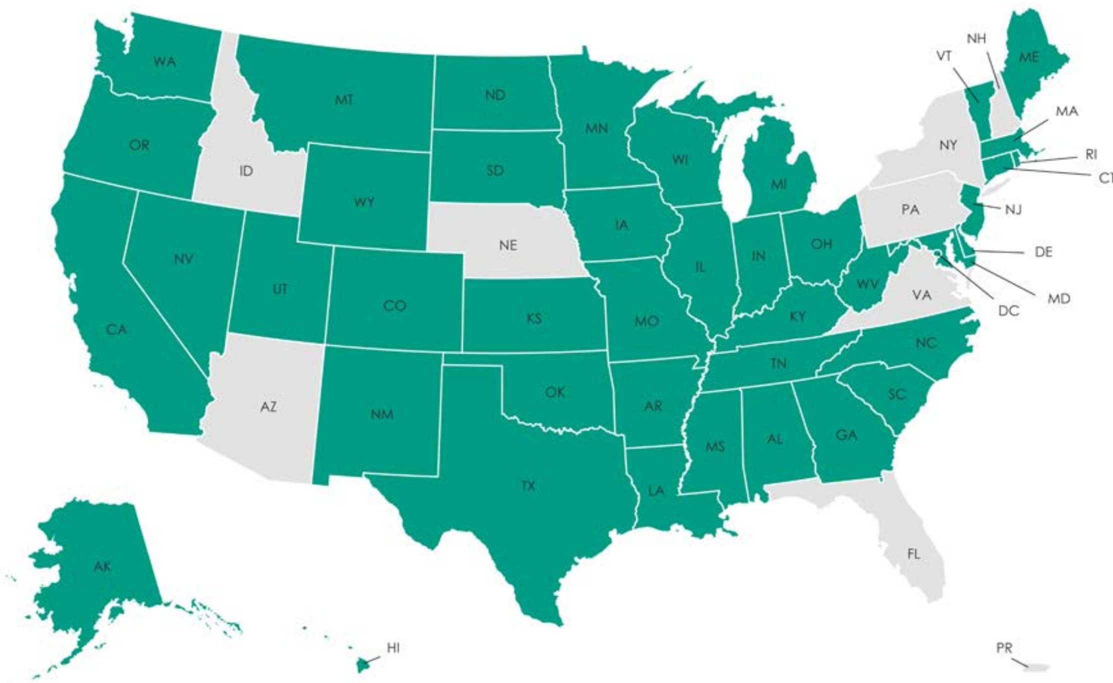

Figure 2. Graphic. Map of crash cost questionnaire respondents.

The following questions were the focus of the questionnaire:

1. Does your State use crash costs in safety analysis?
2. Please provide the crash cost values used in the HSIP and for other purposes.
3. How does your State develop/establish crash cost values?
4. Does your State regularly update their crash cost values?

5. What crash cost components are included in your State's crash cost values?
6. How does your State apply crash cost values in economic analyses?
7. Would adopting a set of national crash costs be advantageous or disadvantageous to your State?

This chapter summarizes current practice through a synthesis of responses from the crash cost questionnaire, supplemented by an online search for relevant information. The purpose of this chapter is to present States' practices in selecting, updating, and applying crash costs.

4.1 STATE PRACTICES IN SELECTING AND UPDATING CRASH COST VALUES

This section summarizes the crash cost values States use in safety analyses and practices to update their crash costs, as described in the crash cost questionnaire responses and as documented online. The first subsection presents the most commonly used national crash cost values. The second subsection summarizes the crash costs States apply in their analyses as well as the implications of variation in State practices.

4.1.1 National Crash Costs

Based on the questionnaire responses and online research, 72 percent of States use or derive their crash costs from the crash cost values presented by AASHTO in the HSM, NSC in their annual injury cost publications, or USDOT in the annual VSL guidance memoranda. Figure 3 presents the distribution of crash costs sources used by States.

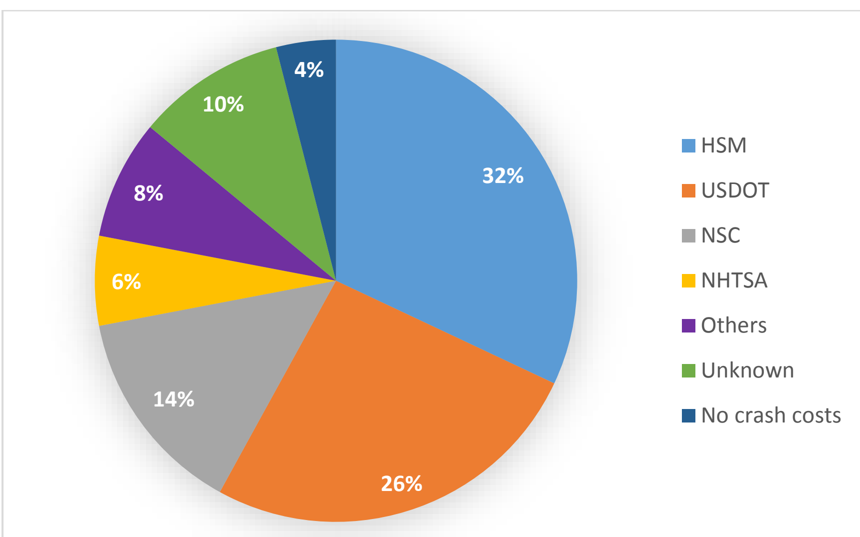

Figure 3. Chart. State crash cost sources.

Table 17 (economic) and Table 18 (comprehensive) compare the values presented in the three most common resources, rounded to the nearest $100. USDOT values, which are presented as person-injury unit costs for MAIS scale, were converted to KABCO person-injury unit costs for comparison using the translation table in the TIGER BCA Resource Guide, shown in Table 15.(19) The translation procedure is explained in detail in Chapter 5.

The latest published values (i.e., HSM updated with annual average 2016 CPI and ECI, 2015 NSC publication, 2016 USDOT guidance) are presented in Table 17 and Table 18. While the HSM has only one set of published values (i.e., there is only one version), the others have newly published values annually or as revisions are available. In some cases, States reported using crash cost values from earlier NSC or USDOT publications directly or as the basis for annual updates with economic factors.

Table 17. National economic crash cost sources.(7,13)

Severity	HSM 2016 Crash Unit Costs	NSC 2015 Person-Injury Unit Costs
K	$1,688,100	$1,542,000
A	$151,000	$90,000
B	$56,800	$26,000
C	$38,500	$21,400
O	$8,700	$11,400

Table 18. National comprehensive crash cost sources.(7,12,13)

Severity	HSM 2016 Crash Unit Costs	NSC 2015 Person-Injury Unit Costs	USDOT 2016 Person-Injury Unit Costs*
K	$5,740,100	$10,082,000	$9,600,000
A	$304,400	$1,103,000	$459,100
B	$111,200	$304,000	$125,100
C	$62,700	$141,000	$63,900
O	$10,100	$46,600	$3,200

*The USDOT costs do not include economic costs.

4.1.2 State Practices

The actual crash cost values that States use in safety BCA—as identified from the questionnaire responses and online research—are listed in *Appendix C: State Crash Costs by Severity*. Table 19 and Table 20 present summaries of responding States' crash unit costs and person-injury unit costs, respectively. Five States responded using both crash and person-injury costs (but did not indicate which type of costs they apply in safety BCA) and three States' cost types are unknown. Those eight States are not included in these summary tables. Additionally, two States indicated that they do not use crash costs, and two others did not provide complete responses and could not be included in the summary statistics.

The dollar costs in the summary tables are not updated to a consistent year, although they do represent the crash costs currently used by States. In other words, even if older crash costs are not updated to current dollars, the old crash costs are still being compared to construction costs in current dollars in States' BCA.

Table 19. Crash unit cost summary of 33 States.

Severity	Minimum Cost	Mean Cost	Maximum Cost
K	$190,200	$4,288,422	$10,100,000
A	$89,200	$781,094	$3,300,000
B	$0	$174,335	$955,500
C	$0	$98,188	$955,500
O	$0	$10,582	$42,298

Table 20. Person-injury unit cost summary of seven States.

Severity	Minimum Cost	Mean Cost	Maximum Cost
K	$1,542,000	$7,119,608	$10,133,000
A	$90,000	$611,932	$1,429,846
B	$26,000	$137,117	$304,000
C	$7,620	$55,993	$141,000
O	$3,048	$11,579	$46,600

The following statistics represent a summary of the other responses in the questionnaire.

- 48 percent of responding States adapt cost values from the source values, 34 percent use the source values directly, and the other 18 percent indicated they have other practices, did not indicate their practice, or do not use crash costs.
- 66 percent of responding States indicated they use crash unit costs, 14 percent of States reported using person-injury unit costs, and the other 20 percent use both types, did not indicate, or do not use crash costs. However, the responses to this question in some cases seem to contradict other responses, particularly related to the source and the type of costs they provided, which may imply some confusion about the sources' values. Some States also appear to apply person-injury costs as crash costs without making a conversion.
- 62 percent of responding States update their crash costs at least annually or as new publications are released (e.g., new annual NSC or USDOT guidance memos), 8 percent do not update or update infrequently, 6 percent update biennially, and the other 24 percent of States did not indicate their update frequency or do not use crash costs.
- 61 percent of responding States said they use comprehensive costs, 21 percent of States indicated they use economic costs, and the other 18 percent use both, did not indicate their practice, or do not use crash costs.

The implications of these findings vary. When considering the implications of these statistics across several or all States, the wide-ranging procedures and policies create difficulties when comparing research, eligibility and funding decisions, and effectiveness evaluations for projects, countermeasures, and programs. The actual differences in project, countermeasure, or program effectiveness between States or research reports can be difficult to discern when compounded by the following differences:

- Crash cost type (i.e., economic or comprehensive, crash or person-injury).
- Crash cost estimation methodologies.
- State-specific adaptations (often at least partially subjective).
- Update frequency and procedure.

It is often difficult or impossible to work backward to account for differences in crash costs among two or more BCA results if the details of the costs and calculations were not provided.

In terms of quality of an individual State's program, such differing practices across States is not as concerning. The most important factor within a State is that a single set of crash costs—or a single set with appropriate adjustments based on economic factors or differences in severity and type—is used to analyze all projects, such that all projects are analyzed equally and fairly. Applying crash costs in an unintended or inappropriate way may lower the accuracy of BCA results and shift the threshold of project eligibility, but this concern is not as critical as applying those costs consistently. Most sources of crash costs produce costs that represent approximately the same proportion of cost to each severity (i.e., roughly equal EPDO weights). Slightly dissimilar weights may have a marginal effect on project priority, but if crash costs are applied consistently then the relative priority of projects should be mostly consistent, regardless of the values used in the analysis.

4.2 WEIGHTED CRASH COST METHODS AND VALUES

Although more than 75 percent of States indicated that they use crash costs from the HSM, NSC, USDOT, or NHTSA in Figure 3, the majority of States noted that they do not use these values directly. Most States adjust or weight the original unit cost values to obtain values that represent combinations of severities, omit severities, or convert the costs to suit their preferences. States' intentions for weighting costs is typically to lessen the impact of high fatal crash costs in safety BCA or to adjust the values to something they are more comfortable using for analysis of project eligibility and in prioritization decisions.

Many States use a base set of crash cost values and adapt the values into severity-weighted crash costs. Figure 4 shows the equation for developing a K/A/B severity-weighted crash cost, although any set of two or more severities can be used in a similar way. The weight for each severity is the number of crashes of the severity (e.g., K crashes) divided by the number of crashes of interest (e.g., K/A/B crashes).

$$SWC_{KAB}=C_K\frac{N_K}{N_{KAB}}+C_A\frac{N_A}{N_{KAB}}+C_B\frac{N_B}{N_{KAB}}$$

Figure 4. Equation. Severity-weighted costs.

Where: SWC = severity-weighted cost for two or more severities.

C = crash unit cost or person-injury unit cost for a given severity.

N = number of crashes or person-injuries (depending on the type of cost) of a given severity or group of severities.

There are numerous possible combinations for developing severity-weighted costs (e.g., weighted K/A costs or A/B/C costs). Some States also develop weighted person-injury costs based on the AIS scale using the same mathematical procedure shown in Figure 4.

Table 21 lists the States that develop weighted costs and the severity levels they have costs for, as indicated in the questionnaire and online documentation. Some States use the severity-weighted method in Figure 4, while others did not indicate how the weighted values are developed. A few States developed their own weighting procedures. (*Appendix D: Practices in Developing and Updating Crash Costs* contains several detailed explanations of State practices for developing and updating crash costs.)

Table 21. State severity-weighted cost levels.

State	Severity Levels
Alabama	K/A/B, C, and O
Colorado	K, A/B/C, and O
Delaware	K/A/B/C and O
Georgia	K, A/B/C, and O
Indiana	K/A, B/C, and O
Kentucky	K/A/B and C/O
Ohio	K/A, B, C, and O
Oregon	K/A, B/C, and O
Puerto Rico	K and A/B/C
Rhode Island	K/A, B, C, and O
South Dakota	K/A/B/C and O
Texas	K/A and B
Utah	K/A, B, C, and O
Washington	K/A, B, C, and O
Wisconsin	K/A/B, C, and O
Wyoming	K/A, B/C, and O/U

4.3 PERSPECTIVES ON NATIONAL CRASH COSTS

There are several considerations to adopting national crash cost values. Many advantages and disadvantages were highlighted in the crash cost questionnaire responses. Figure 5 presents a summary of the responses. *Appendix E: Questionnaire Responses to the Feasibility of Recommending*

National Crash Costs lists each response to explain whether recommended national crash costs would be advantageous or disadvantageous.

The opinions on the topic of national crash costs vary, and respondents had different reasons for why they view national costs as advantageous or disadvantageous. In addition to those reasons raised by the respondents, there are other advantages and disadvantages discussed in Chapter 5.

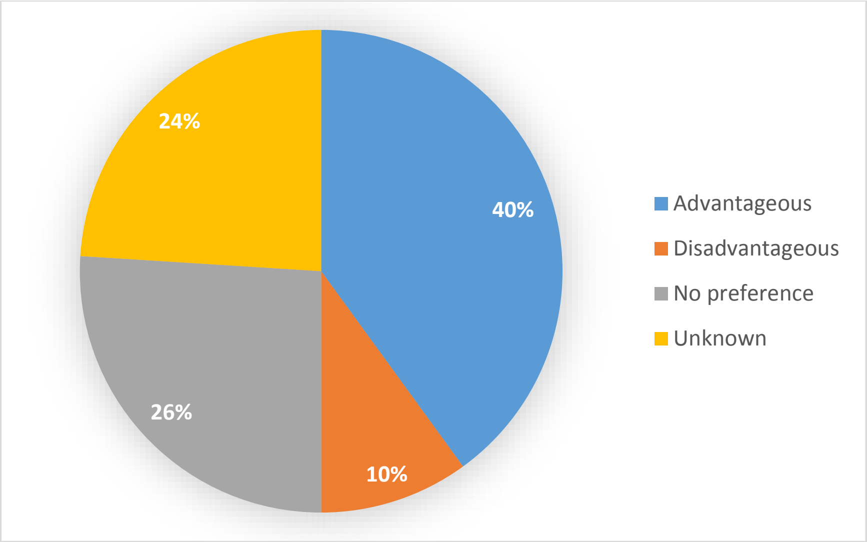

Figure 5. Chart. Summary of preferences on recommending national crash costs.

CHAPTER 5. CRASH COST CONSIDERATIONS

This chapter presents considerations relating to estimating, selecting, updating, and applying crash costs. Each section discusses a separate issue concerning crash costs and includes insights regarding current practices, and, when appropriate, provides recommendations for consideration. Table 22 lists the sections of this guide that analysts can refer to for common crash cost considerations, translations, conversions, and adjustments that may be needed when performing safety analysis and conducting research.

Table 22. Common uses for crash cost considerations and calculations.

Crash Cost Considerations and Calculations	Section
Analyst is considering using actual crash costs in BCA rather than estimated average crash costs	5.2
Analyst is considering whether to use economic or comprehensive crash unit costs in BCA	5.3
Analyst has some data in KABCO and other data in MAIS	5.4.1
Analyst has number of KABCO injuries and is interested in understanding the distribution of those injuries in MAIS	5.4.2.1
Analyst has MAIS person-injury unit costs and needs to translate to KABCO for BCA of KABCO crash data	5.4.2.2
Analyst is considering crash costs by crash type or by crash type and severity for BCA	5.5
Analyst would like to develop severity-weighted crash costs for application with observed frequencies or to emphasize program goal	5.6
Analyst is considering using conservative crash cost values in BCA	5.7
Analyst needs to perform basic conversion between number of person-injuries or vehicles and number of crashes	5.8.1
Analyst has person-injury unit costs or vehicle unit costs and would like to convert to crash unit costs within the same injury scale for analysis of crash-level benefits	5.8.2
Analyst would like to adjust national crash costs to State-specific crash costs for more accurate BCA	5.9
Analyst needs to update crash costs from year to year	5.10

The final section of the chapter summarizes the advantages and disadvantages of recommending national crash costs. **Recommendations for practice are highlighted in bold text throughout this chapter.**

5.1 DIFFERENCES IN CRASH COST ESTIMATION METHODOLOGIES

As discussed throughout Chapter 3, there are several methodologies that researchers employ to estimate the unit cost of crashes and injuries. While there are differences, there is not necessarily a preferred method. Each provides some advantages and disadvantages over the others. For safety BCA and government use, it is likely that costs developed with as many measurable economic components as possible will be preferred. However, not all components have been fully quantified to date and the intangible consequences are difficult to completely and accurately estimate.

5.2 DIFFERENCE IN ESTIMATED AND ACTUAL COSTS

Actual crash costs differ in every crash due to the specific circumstances related to each crash event—the damage, injuries, response, and lasting effects. It is unlikely that future crashes, even at the same site, will bear the same economic or societal costs as previous crashes. Further, it is extremely difficult, costly, or impossible to quantify and consistently know the finite costs of each individual crash. For these reasons, estimating average crash unit costs for certain circumstances provides a more practical, consistent, and reliable way to estimate the impact of past crashes and predict the impacts of future crashes.

However, estimating average crash unit cost values is not a simple feat either. Most of the numerous cost components are not quantified or logged in an accessible database, and, if they are, the data only exist for sample sets of crashes. Developing average crash unit cost values based on actual injuries, damage, and other factors is difficult due to complexities with accessing, integrating, and analyzing injury surveillance databases and other information with crash data. States may not have adequate resources, nor the capability, to quantify accurate crash unit cost estimates specific to their State. **In general, it is only practical to use estimated average crash unit costs.**

5.3 ECONOMIC AND COMPREHENSIVE CRASH COSTS

Economic crash costs are more intuitive than costs that include the intangible impacts of pain and suffering because of the straightforward accounting methods to estimate economic costs. Intangible QALY costs are derived from choices that people make about safety or the value they place on an increase in safety, regardless of whether they have a level of income that would allow them to pay for such an increase in safety. Even with an understanding of the methodology and the number of influencing factors that are accounted for in estimating the pain and suffering costs of crashes, it can be difficult to place a high degree of confidence in these numbers (i.e., at least at the same level of confidence in economic costs). However, the methodologies used in most recent studies are the best methods that have been developed to estimate these costs, and **it is critical to account for the comprehensive costs of crashes in safety BCA.**

5.4 IMPACT OF INJURY SCALE ON CRASH COSTS AND TRANSLATING BETWEEN KABCO AND MAIS INJURY SCALES

Crash costs are most commonly developed and presented by severity for a specific injury scale (e.g., AIS), which can be a problem for States when the crash cost injury scale does not align with the severities reported by police officers in their State. Translator tables allow analysts to convert between the scales, although the conversion is not exact and introduces error in the analysis. Further, not all States use a conversion and instead sometimes directly apply MAIS costs to KABCO severity levels, introducing potentially more error into the analysis.

5.4.1 Impact of Injury Scale

The presence of two injury scales creates complications not only in comparing disaggregate crash costs, but also the total burden of certain injuries in projects or across a State, particularly when characterizing serious injuries differently. Generally, while there is some variation in the allowable period from time of crash to time of death (e.g., 30 days or 12 months), there is agreement on what level of injury constitutes a fatality between databases and injury scales (e.g., FARS, KABCO, AIS, and others). However, the KABCO level A, B, and C injuries (and U in some States) do not align with 5, 4, 3, 2, and 1 injuries in the AIS. Research has shown that each of the KABCO injury types, even those coded as "O" indicating no injury, result in some of each of the AIS injuries once doctors medically assess the injuries that victims incurred. **Regardless of injury scale, analysts should use comparable data from only one injury scale in analysis and translate between the scales when needed.** There is no need to translate fatal or PDO crash costs or number of non-injured persons between injury scales.

Consistency in injury scale between all State crash reports and crash costs would alleviate the confusion and inconsistency created by two separate conventions. The KABCO scale is notably inaccurate, and the AIS scale is as good as injury data will likely get; however, there is not a clear path forward without both scales. Not all injured persons can be assessed in MAIS. **Reconciling the impact of injury scale on crash cost is an important consideration for future crash cost estimates and for safety analysis in general.**

5.4.2 Translating Between KABCO and MAIS

As noted throughout Chapter 3 and other sections of this chapter, analysts regularly need to translate costs and injury counts between KABCO and MAIS injury scales to get comparable data. Translator tables are available that allow analysts to convert between the two injury scales. Translator tables are not updated regularly, and they do not need to be. The tables are developed from crash databases with KABCO and AIS injury scales reported for each crash record. Few databases contain both injury scales. Updates to translator tables are only necessary every few years as new data are included in these databases or as new databases become available. **Translator tables only work for police-reported crashes and person-injuries; those not reported by the police are typically not included.**

Table 23, reorganized from Table 15, converts data between KABCO and MAIS injury scales. The translator table provides two translation capabilities, listed below. Translating in reverse of these is complicated and not necessary in practice. The following subsections of this chapter provide examples demonstrating these procedures.

1. Translate number of person-injuries from KABCO to MAIS.
2. Translate person-injury unit costs from MAIS to KABCO.

Crash unit costs do not work accurately with the Table 23 translator. The translation between person-injury unit costs and conversion to crash unit costs should be accounted for separately.

Analysts should not translate the number of PDO crashes and PDO crash unit costs between scales; they are equivalent in AIS and KABCO. Including KABCO "O" and MAIS 0 in the translation process accounts for the cases when injuries were reported, but were later determined (e.g., by physicians) to be not injured, and when persons were determined to have an injury, but were reported by police to have no injury.

Table 23 presents the translation table factors from the *TIGER BCA Resource Guide*.[19] Analysts can convert between person-injuries and person-injury unit costs with either injury scale. The following sections illustrate the translation procedures and example translations.

Table 23. Translation factors to translate between KABCO and MAIS.[19]

Severity	MAIS 6	MAIS 5	MAIS 4	MAIS 3	MAIS 2	MAIS 1	MAIS 0
K	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	0.00000	0.01783	0.03986	0.14437	0.20908	0.55449	0.03437
B	0.00000	0.00101	0.0062	0.03191	0.10898	0.76843	0.08347
C	0.00000	0.00013	0.00142	0.01071	0.06391	0.68946	0.23437
O	0.00000	0.00003	0.00000	0.00008	0.00198	0.07257	0.92534

5.4.2.1 Translating Number of Person-Injuries Example

The following example illustrates a translation from KABCO person-injuries to MAIS person-injuries. **In Table 23, the translation reads horizontally. The apparent distributions in the columns are meaningless.** For example, each reported KABCO level A person-injury has a 1.783 percent chance to result in MAIS 5 person-injury, 3.986 percent chance to result in MAIS 4, and so on. Conversely, the factors also represent the cost proportions for each injury, such that 1.783 percent of a KABCO level A person-injury unit cost is from MAIS 5 costs, 3.986 percent from MAIS 4, and so on. These proportions are used to directly translate number of person-injuries from KABCO to MAIS and person-injury unit costs from MAIS to KABCO.

Table 24 contains an example KABCO person-injury distribution to translate into MAIS person-injuries. An analyst could perform this type of translation to examine the average MAIS outcomes from a given KABCO injury distribution. Table 25 displays the intermediate results by multiplying each number of KABCO injuries in Table 24 by the factors horizontally in Table 23 (e.g., for A level injuries, multiply 1,003 by 0.00000, 1,003 by 0.01783, 1,003 by 0.03986, and so on, continuing for each row). The final translation results are shown in the bottom row of Table 25, and are calculated by summing down each column to obtain the total MAIS injuries by severity, rounded to the nearest whole injury.

To check that the person-injury translation was performed correctly, the total number of injured persons of all severities (i.e., before rounding) should be equal in KABCO and MAIS. In this case, the KABCO and MAIS person-injury totals each equal 131,310, indicating the calculation was performed correctly.

Table 24. Example KABCO person-injury distribution.

Severity	Number of Injured or Involved Persons
K	202
A	1,003
B	11,481
C	5,006
O	113,618

Table 25. Translating KABCO person-injuries to MAIS person-injuries (using data in Table 23 and Table 24).

Severity	MAIS 6	MAIS 5	MAIS 4	MAIS 3	MAIS 2	MAIS 1	MAIS 0
K	202	0	0	0	0	0	0
A	0	17.88	39.98	144.80	209.71	556.15	34.47
B	0	11.60	71.18	366.36	1251.20	8822.34	958.32
C	0	0.65	7.11	53.61	319.93	3451.44	1173.26
O	0	3.41	0	9.09	224.96	8245.26	105135.28
Total	202	34	118	574	2,006	21,075	107,301

5.4.2.2 Translating Person-Injury Unit Costs Example

Translating person-injury unit costs from MAIS to KABCO is an important step in determining accurate crash unit costs in the KABCO scale. Person-injury unit costs are usually developed using the MAIS scale (MAIS is rarely used for crashes), in which injury severity—the largest influence on costs—is more accurately known than with KABCO. The translator table is used to bring the MAIS person-injury unit costs to KABCO person-injury unit costs that are later converted into KABCO crash unit costs for BCA.

To translate person-injury costs, the translator table is used in reverse. Considering Table 23 and the information in the previous section for translating number of person-injuries, an average KABCO level A person-injury will result in 0.0 MAIS 6 person-injuries, 0.0178 MAIS 5 person-injuries, 0.03986 MAIS 4 person-injuries, and so on.

While Table 23 can translate KABCO level A person-injuries to MAIS person-injuries, when translating MAIS costs to a KABCO level A cost, the distribution listed above also serves as the weights for proportioning the MAIS person-injury unit costs. For example, MAIS 5 costs make up 1.78 percent of a KABCO level A person-injury unit cost, MAIS 4 person-injury unit costs makes up 3.986 percent of a KABCO level A person-injury unit cost, and so on.

Table 26 shows the calculations for determining a KABCO level A person-injury unit cost from the comprehensive, police-reported, MAIS person-injury unit costs listed in Table 9 and the translator table in Table 23. The comprehensive, police-reported MAIS person-injury unit costs from Table 9 are multiplied by the translation factors in Table 23 to determine the portions of the KABCO level A person-injury unit cost accounted for by each MAIS level. In other words, the translator values are used to develop a weighted average KABCO level A person-injury unit cost based on the MAIS person-injury costs multiplied by the MAIS person-injury proportions. The sum of the cost portions (i.e., $447,831.55) represents the translated KABCO level A comprehensive person-injury unit cost. This procedure could be repeated for each injury level to determine a full set of KABCO person-injury unit costs by severity.

Table 26. MAIS to KABCO comprehensive person-injury unit cost translation for KABCO level A (2010 dollars).

Severity	MAIS Person-Injury Unit Costs	KABCO A Injury Translation Factors	A Person-Injury Unit Cost Portions
Fatality	$9,145,998	0.00000	$0.00
MAIS 5	$5,579,614	0.01783	$99,484.52
MAIS 4	$2,432,091	0.03986	$96,943.15
MAIS 3	$992,825	0.14437	$143,334.15
MAIS 2	$399,626	0.20908	$83,553.80
MAIS 1	$43,942	0.55449	$24,365.40
MAIS 0	$4,380	0.03437	$150.54
Total	N/A	1.00000	$447,831.55

Although the MAIS 4 and 5 injuries in Table 26 carry high person-injury unit costs, MAIS 4 and 5 injuries are quite rare—as shown in Table 7 and demonstrated in the Table 25 translation—and do not contribute to a large portion of KABCO level A person-injury unit costs. While Table 23 indicates that over 85 percent of MAIS 5 person-injuries result in KABCO level A person-injuries, the third column in Table 26 indicates that less than two percent of A person-injuries are MAIS 5. This fact is due in part to the low incidence of MAIS 5 injuries (i.e., it may be more likely for either a lower injury severity or death to occur, with few persons surviving with such severe injuries) and the unreliable nature of the KABCO scale as reported by police, which is demonstrated by the translation values in Table 23.

5.5 CRASH COST VALUES BY TYPE AND SEVERITY

Most crash costs are only reported by severity levels for several reasons. Crash costs vary more by severity than by crash type; a higher severity injury adds exponentially more cost as other cost components come into play. For this reason, it is more important to account for severity in BCA than crash type, for which unit costs do not vary as much. Estimates of crash type inherently involve consideration of crash severity, which is not as much the case in reverse. Sample size of some crash types may also preclude investigation into their costs, and national crash databases are limited in certain crash types. Sometimes it is difficult to assign a single crash type to a crash or ensure consistent reporting of crash types. However, there are a few studies that report costs by crash type.[6,7,10,11] Although not explored in this guide, those costs could potentially be updated or calibrated to more recent costs.

The use of crash unit cost values by crash type, however, can be important in some analyses. Particularly, when either the severity of future crashes is uncertain (i.e., the past crash experience is not an indicator of future crash experience) or when there is reason to question the reported severity of historical crashes, crash unit costs by type allow analysts to monetize crashes relatively accurately without needing severity. Additionally, crash type analysis can be important for certain treatments—such as traffic signal installation—where some crash types are increased and others are reduced. However, at present, safety performance functions (SPFs) are less frequently developed for specific crash types (CMFs by type are more frequently available), and crash type distributions may be needed to apportion predicted or expected crash frequency into crash type components.

Crash unit costs disaggregated by both type and severity provide arguably the most accurate estimates, but there is a similar concern that distributions are needed to apportion crash frequency into crash type and severity components. When analyzing observed crash frequency in safety BCA there is often a limited or zero sample for some crash type and severity combinations, potentially leading to deceiving results if the past crash experience is not representative of future crashes. **The recommended practice is to use EB or other SPF-based methods to estimate the long-term average crash frequency by type and severity to serve as the basis of safety BCA.**

5.6 WEIGHTED CRASH COST VALUES

As discussed in Chapter 4 and *Appendix D: Practices in Developing and Updating Crash Costs*, there is variation in how analysts develop severity weighted crash costs. Some use a weighted average based on an actual injury or severity distribution and others develop subjective injury severity weights (e.g., based on EPDO weights they deem more fitting or realistic). Although less common, crash cost values may be weighted by crash type as well.

States, analysts, and researchers develop weighted crash or person-injury unit cost values for several reasons. The three primary reasons for weighting crash costs in safety BCA application are as follows.

- Unweighted crash costs by injury severity place a high cost on fatal and serious injury crashes and related injuries, which is often attributed to skewing the results of safety BCA, particularly when agencies base the BCA on a short-term observed crash history. More reliable methods (e.g., using SPFs) can help to account for the fluctuation in the short-term observed frequency of fatal and serious injury crashes. The AASHTO HSM contains more information about the EB method and reliable procedures for estimating benefits.[7] Weighted costs (e.g., combining K/A or A/B/C costs) may normalize higher severity crashes, but also increases the impact of lower severity crashes that could yield an even stronger bias that may be harder to detect.

- Distrust or misunderstanding of crash unit cost estimates, particularly for higher severity crashes. Several States reference studies (i.e., in their questionnaire responses or HSIP documentation) that indicate there is a small difference in the circumstances of crashes that determines whether a crash results in a fatality or serious injury, and often the factors that contribute to the resulting severity of a crash are not roadway-related. However, in many crash cost estimates (e.g., in Table 5 and many others throughout this guide), there is an order of magnitude difference between the unit cost of a fatal crash and the unit cost of a serious injury crash. Some States use weighted crash costs to help balance the costs of higher severity crashes over a larger sample.

- Weighted crash costs may allow for safety BCA to better reflect the objectives of safety programs. For example, if the objective of the program is to reduce fatalities and serious injuries, a weighted K/A cost will place an equal value on fatal and serious injury crashes in safety BCA, which can lead to projects that best achieve that objective.

The practice noted in the first bullet is common among States. Using observed crash frequency may overestimate the long-term average frequency of less common crash severities and types (e.g., fatal and serious injury crashes). For example, considering a five-year crash history, a site may have 1 fatal crash recorded in the past 5 years, meaning an average of 0.2 fatal crashes per year. For the same site, using the EB method to combine the observed crashes and predicted crashes from an appropriate SPF, the expected frequency of fatal crashes is 0.02 fatal crashes per year for this site. Thus, the monetized value of the fatal crashes per year for this site using the observed versus the expected crash frequencies would overestimate the value by a factor of 10. With the high cost of fatal crashes, this effect can skew economic analyses. Using the EB method to combine the observed crash history of a given site with the crash prediction from an appropriate SPF is a more reliable way to estimate the long-term average frequency of crashes.

Developing and applying weighted crash costs does not fix the problem of using observed crash data. Weighted crash costs can reduce the cost applied to fatal crashes and the potential for scarce fatalities to have a large impact on safety BCA results and project prioritization, but weighted crash costs also increase the costs of lower severity crashes and overestimate the effects of those crashes. For example, a weighted K/A cost may reduce a fatal crash unit cost by five times, but also increase the value of an A-level crash by 2.5 times, which yields a potentially stronger bias when many A-level crashes occur (especially considering A-level crashes are five to ten times more common than fatal crashes). **It is recommended that analysts strive to estimate the long-term average predicted or expected crash frequency and apply unweighted crash costs to these estimates, rather than continue to use observed crash frequency in BCA and attempt to fix the results with weighted crash costs.** A mix of SPF-based and observed crash approaches is viable when SPFs are not available for all sites.

While not the preferred practice, if an agency is using observed crash frequency in safety BCA there are some opportunities to overcome some limitations of this practice with weighted crash costs. **Using weighted crash costs in safety BCA is acceptable as an interim procedure until SPFs are available for the EB method, if the weighted crash costs are developed with an actual crash severity distribution from the jurisdiction to which they will be applied** (i.e., objectively weighted average crash costs). There is potential merit in using weighted crash costs to reflect the objectives of a program, a specific analysis, or research project as described in the third bullet above. Objectively weighted crash costs will result in different valuations of safety benefits on a project-by-project basis than if unweighted crash costs by severity were used, but over time and across many projects, unweighted crash costs and objectively weighted crash costs should present essentially the same net results for a program. While there is flexibility, K/A, K/A/B/C, or K/A/B/C/O objectively weighted costs are preferred. **Weighted crash costs should be developed using the equation in Figure 4.**

5.7 CONSERVATIVENESS IN CRASH COSTS

Conservativeness in crash costs implies the use of lower crash costs for sake of caution in their application. Lower crash costs will result in a lower monetized valuation of crashes in comparison to higher crash costs. When applying a low monetary value to crashes by using low crash costs (i.e., calculating the benefits of projects), a higher level of crash reduction is needed to achieve the same monetary benefits as if higher crash costs were used in the same analysis.

In this sense, using conservative crash costs should improve the chance that projects meeting a certain benefit-cost ratio (BCR) achieve desired results in reducing crashes. However, conservative crash costs will not account for the full benefits of projects. Some projects may not appear economically justified with conservative costs, when they would with actual crash costs. While it is important to fully account for the comprehensive cost of crashes, consider that analysts using economic crash costs in BCA are essentially applying a very conservative estimate of comprehensive costs.

Based on the questionnaire responses discussed in Chapter 4 and listed in *Appendix E: Questionnaire Responses to the Feasibility of Recommending National Crash Costs* relating to State perspectives on national crash costs, some States prefer to use higher crash costs (or the highest estimates available nationally) to economically justify more potential projects (e.g., BCR greater than 1.0). Others prefer to use lower crash costs to be conservative and, therefore, improve the likelihood of actual positive returns on investments (i.e., by using artificially lower calculated benefits as a threshold, the actual benefits should be higher than calculated). **In general, it is important to use accurate estimations, rather than arbitrarily selecting high or low crash costs and disregarding the accuracy and completeness of the crash cost estimation methodology.**

Additionally, some States ignore the costs of certain injury severities (i.e., C and sometimes B injuries) and PDOs in safety BCA (i.e., the crash cost is $0). This practice is another method of conservativeness, and can similarly focus the analysis toward the crash severities, or types, of interest in the analysis. **It is best to consider crash costs of all severities and types in analysis.** Hypothetically, some sites without severe crashes may experience so many minor injuries or PDO crashes that the total crash costs exceed those at a site with only some severe crashes. In addition, setting the crash cost for lower severity injuries to $0 ignores the increase that some countermeasures may cause in those severities (i.e., ignoring negative benefits).

5.8 CONVERTING BETWEEN CRASHES AND PERSON-INJURIES OR VEHICLES

When applying crash unit costs or person-injury unit costs, it is important that each is applied appropriately and the analysis accounts for the differences. In other words, **crash unit costs should be applied to the number of crashes and person-injury unit costs should be applied to the number of injured- or involved-persons.** If an agency has data for person-injury unit costs and numbers of crashes, some conversion is needed to get the data in the same terms before monetizing the benefits.

Crashes always include one or more vehicles and persons, each with injuries of various severity levels (including no injury). The crash is categorized by the maximum severity injury present in the crash, either by KABCO or MAIS, but each crash may involve other persons with equal or lower severity injuries than the maximum injury. This fact also applies at the person-level, with each person classified by their maximum injury (e.g., by MAIS) but also often sustaining various other lower severity injury (e.g., various lower AIS injuries).

5.8.1 Converting Between Person-Injuries or Vehicles and Number of Crashes

The conversion between person-injuries or vehicles and crashes is dependent on the one-to-many crash to person-injury or vehicle relationship. Consider the hypothetical example statewide distributions of KABCO crashes by maximum severity and the person-injuries included in those crashes shown in Table 27. Statewide injury-to-crash ratios should be calculated as the average injuries of each severity occurring in one crash of the selected severity level. Following with the example data in Table 27, for one K crash there are 1.089 fatalities (i.e., 202/186), 0.177 A person-injuries (i.e., 33/186), and so on. Vehicle-to-crash ratios represent the average number of vehicles in a crash, although these are only used for PDO crashes in this guide. **While rounded ratios are shown throughout this guide, practitioners should not use intermediate rounding prior to using the ratios in conversion calculations. Analysts should consider multiple years—at least three to five years—of data when calculating injury-to-crash and vehicle-to-crash ratios.**

Table 27. Example State-specific KABCO crashes and person-injury distribution.

Severity	Crashes	K Injured Persons	A Injured Persons	B Injured Persons	C Injured Persons	O Uninjured Persons
K	186	202	33	50	30	162
A	922	0	970	504	173	718
B	9,718	0	0	10,927	889	8,758
C	3,890	0	0	0	3,914	4,284
O	48,882	0	0	0	0	99,696

Statewide injury-to-crash ratios are used to convert between the number of crashes and person-injuries. Ideally, analysts should work in terms of crashes and crash unit costs.

Typically, States have, or have access to, a crash database as well as a person-injury database that are linked through crash and vehicle identifiers, which together represent the full information about crashes and those persons involved. These databases can be used to develop a table like the example shown in Table 27.

To convert from person-injuries to crashes, divide the number of person-injuries by the injury-to-crash ratio for each severity. To convert from crashes to person-injuries, multiply the number of crashes by the injury-to-crash ratio.

Similarly, vehicle-to-crash ratios are used to convert between number of vehicles and number of crashes for PDOs. Vehicle-to-crash ratios are calculated similarly by determining the average number of vehicles in a crash. To convert from vehicles to crashes, divide the number of vehicles by the vehicle-to-crash ratio. To convert from crashes to vehicles, multiply the number of crashes by the vehicle-to-crash ratio.

5.8.2 Converting Between Crash Unit Costs and Person-Injury Unit Costs

The conversion between crash unit costs and person-injury unit costs works in a similar way. However, rather than converting between the disaggregate numbers of person-injuries by severity within each crash, the person-injuries of multiple severities within a crash severity level can be monetized and divided by the number of crashes to get a crash unit cost. Figure 6 displays the calculation to convert person-injury unit costs into crash unit costs for fatal crashes. **At least three to five years of crash and person-injury data are recommended as a basis for these conversions.** The equation is the same for other crash severities, although the crash unit cost and number of crashes would have to be substituted for the crash severity level of interest. Similarly, the equation form is the same for MAIS, but with MAIS severity levels substituted for KABCO.

$$\text{Cost}_{K,crash} = \frac{\sum_{\alpha=\{K,A,B,C,O\}}\left(N_{\alpha,person} \times \text{Cost}_{\alpha,person}\right)}{N_{K,crash}}$$

Figure 6. Equation. Converting person-injury unit costs into a fatal crash unit cost using numbers of crashes and injuries.

Where: $\text{Cost}_{K,crash}$ = average fatal crash unit cost

$N_{\alpha,person}$ = number of injured persons involved in all fatal crashes for a given injury severity, α

$\text{Cost}_{\alpha,person}$ = person-injury unit cost for a given injury severity, α

$N_{K,crash}$ = total number of fatal crashes

An example calculation is presented later, in Figure 13 of this guide, using crash and person-injury counts from Table 27 as well as KABCO person-injury unit costs from Table 29.

While it is possible to convert crash unit costs into person-injury unit costs using the same equation (assuming the crash unit costs of all severities, number of crashes of all severities, and number of injuries of all severities within each level of crash severity are all known), it is mathematically complicated and impractical to do so. With that said, the set of five equations representing each of the five KABCO crash costs—collectively with five unknown variables (i.e., the KABCO person-injury unit costs)—is mathematically solvable given the available data.

MAIS costs are provided as person-injury unit costs in USDOT and NHTSA research.[11,12,19] NHTSA provides KABCO person-injury unit costs as well.[11] However, to calculate KABCO person-injury unit costs, it is more practical to convert from MAIS person-injury unit costs (i.e., using the translation procedures discussed earlier in this chapter) than to convert from KABCO crash unit costs.

5.9 DIFFERENCES IN CRASH COSTS AMONG JURISDICTIONS

Crash unit costs vary between States—and nationally—due to differences in cost of living, income, and medical costs as well as severity distributions and injury-to-crash ratios. **Analysts should adjust for the State differences in crash unit costs when possible.** The following sections demonstrate the procedures to account for these differences.

5.9.1 Adjusting for Differences in Injury-to-Crash and Vehicle-to-Crash Ratios

Given person-injury unit costs, differences in injury-to-crash and vehicle-to-crash ratios between jurisdictions affect the aggregated crash unit costs developed with the person-injury costs. For example, Figure 6 illustrates that with different proportions of injuries and crashes by severity, the same person-injury unit cost inputs will yield different crash costs. To account for State-specific ratios when converting person-injury unit costs from national sources or from one State to another State, the adjustment is to simply use the Figure 6 equation with the State's data for at least three to five years (like that in the example shown in Table 27) indicating the numbers of crashes and injuries to input into the Figure 6 equation. An example calculation is provided in Figure 13 of Chapter 6.

This adjustment is relatively minor and should not substantially impact crash costs in most situations.

5.9.2 Adjusting for Differences in Cost of Living, Income, and Medical Costs

The primary difference in crash costs among States is based on differences in cost of living, income, and medical costs. Differences in PCI among States and the nation is the simplest approximation of all these factors since it impacts the costs of all crash-related services including wages, goods, and equipment.

To adjust crash costs to account for PCI, all crash costs (i.e., each separate cost by severity and type) should be multiplied by the ratio of a State's PCI to the national PCI. This procedure is applicable to crash unit costs and person-injury unit costs. Figure 7 shows the equation to adjust national costs by severity and type to a State by PCI ratio. *Appendix F: State Cost of Living Adjustment Factors* includes adjustment factors (i.e., PCI ratios) for all States and District of Columbia for 2016.

$$\text{State Crash Cost}_{\text{Sev,Type}} = \text{National Crash Cost}_{\text{Sev,Type}} \left(\frac{\text{State PCI}}{\text{National PCI}}\right)$$

Figure 7. Equation. State-specific crash cost adjustment.

For example, Alabama had a PCI of $39,231 in 2016 and the United States average PCI was $49,571 in 2016. Therefore, Alabama's PCI ratio is 0.79141 for 2016. To adjust a 2016 national fatal crash cost of $10,000,000 to Alabama, an analyst would multiply $10,000,000 by 0.79141. The resulting 2016 Alabama fatal crash cost would be $7,914,100.

PCI ratios should be updated every year. PCIs for this guide were obtained from the United States Department of Commerce Bureau of Economic Analysis "State Personal Income, 2016" webpage under the "Tables Only" link in the Related Links section.[20] Similar PCI updates should be available from the Bureau of Economic Analysis for future years.

This procedure can also be used to adjust crash costs from one State to another (i.e., replacing national PCI with the source State), and can be used for economic costs, QALY, and comprehensive crash unit costs.

5.10 UPDATING CRASH COSTS OVER TIME

Analysts should update crash costs over time to account for inflation and income growth. As noted in Chapter 3, current and past resources employ different economic indexes for annual updates to crash costs. The HSM and 2005 FHWA report *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries* use CPI to update economic cost components and ECI to update QALY costs. CPI closely tracks inflation and ECI tracks income and wage growth.

The 2016 USDOT guidance uses CPI to adjust for inflation, but notes the MUWE index is a better measure than ECI for updating QALY and VSL costs for the following reasons. A median value better accounts for average road users than the ECI, which is a mean value, and as such can be skewed by extremely high incomes. MUWE also does not account for non-wage income, which "is not likely to be significant for the average person affected by [USDOT] rules."[12] However, non-wage income and benefits do contribute to a person's wealth and free up after-tax money for improved safety. The USDOT guidance uses a constant dollar value MUWE index, meaning it does not factor in inflation-related changes, which the USDOT accounts for using CPI separately.

Given these considerations, practitioners should use CPI (i.e., current dollar CPI-U, for all items, annual average index, unadjusted)[8] to update economic costs and the current dollar MUWE index (i.e., current dollar usual weekly earnings of wage and salary workers, total/16 years and older, not seasonally adjusted)[21] to update QALY costs. Previous texts consistently employ CPI to update economic costs, which is still the preferred index. The benefits of the MUWE over ECI are potentially significant, primarily mitigating the bias from very high wage earners. While the USDOT guidance uses constant dollar MUWE along with CPI, as shown in Figure 1, practitioners should use current dollar MUWE for simplicity.

Analysts should calculate CPI and MUWE update ratios based on the annual average indexes in the years of interest and multiply the older crash costs by these ratios to perform the update, as shown in Figure 8 and Figure 9 for updating crash costs from 2010 to 2016.

$$\text{CPI ratio}_{\frac{2016}{2010}} = \frac{\text{CPI}_{2016}}{\text{CPI}_{2010}}$$

Figure 8. Equation. CPI adjustment ratio calculation.

$$\text{MUWE ratio}_{\frac{2016}{2010}} = \frac{\text{MUWE}_{2016}}{\text{MUWE}_{2010}}$$

Figure 9. Equation. MUWE adjustment ratio calculation.

Annual average indexes are calculated by averaging monthly or quarterly index values over the calendar year (or the same 12-month period). Alternatively, it is acceptable to compare the index values in December of each year—rather than calculating an annual average—however, comparing single months is susceptible to short-term spikes that would not influence annual averages.[22]

5.11 IMPORTANCE OF CONSISTENT CRASH COST VALUES IN ANALYSIS

Using consistent crash costs (i.e., for the same crash type, crash severity, facility type, jurisdiction, and other factors) is important to most applications of crash costs. In BCA for safety improvement programs, such as the HSIP, consistent crash costs promote fair and equitable stewardship of safety funding to projects that have the greatest ability to reduce crashes. If potential projects are analyzed with different average crash costs, it may lead to one project artificially favored over the other.

For example, if one project's BCA uses economic crash unit costs, the result will look much less favorable than the same project analyzed with comprehensive crash unit costs. Similarly, if two different comprehensive crash unit cost sources are used, the higher of the two values will make a project artificially appear more beneficial when there is likely no analytical basis for the difference in values. **Agencies should consider adopting a standard set of crash unit costs for use across their agency or within each funding program under which projects are competitively prioritized.**

Consistency in crash costs also has ramifications on research, specifically regarding the evaluation of implemented projects and countermeasure effectiveness. When comparing the efficacy of project decisions and safety treatments between jurisdictions and time periods analyzed with different crash cost values, the results may be misleading unless the difference in crash cost values accurately reflects the difference in incurred crash costs. For example, if two reports evaluating the effectiveness of the same construction project with the same crash reductions used different crash costs, the reports would yield different economic results when intuitively the results should be the same. This effect is amplified when research is compared across jurisdictions where other factors affect the results as well.

However, unlike safety projects where crash costs are usually incorporated in policy, guidance, or a standard BCA spreadsheet, safety research is not standardized and crash costs used in analysis may not be reported at all. It is difficult or impossible to retroactively normalize crash costs in research for a fair comparison of results. **Analysts should use and apply consistent crash costs for all projects and research to the extent possible.**

5.12 NATIONAL CRASH COST VALUES

One objective of this guide is to present the feasibility of establishing recommended national crash cost values. Chapter 4 and *Appendix E: Questionnaire Responses to the Feasibility of Recommending National Crash Costs* present perspectives regarding whether recommended national crash costs would be advantageous or disadvantageous. However, the responses are not inclusive of all the potential considerations identified through the literature and by the authors of this guide.

The following sections discusses the potential advantages and disadvantages, responsibility for, and structure of national crash cost values.

5.12.1 Advantages and Disadvantages

The following is a summary of the key factors identified in the questionnaire and through the synthesis of literature regarding the adoption of national crash costs for safety BCA. The advantages of recommending national crash costs revolve around increased consistency and a reduced burden on States as follows:

- National crash costs would promote consistency in analysis, decision-making, and research.

- National crash costs would promote uniformity in outreach and public expectation.
- Some States are not confident with their current crash costs or method for establishing crash costs. National crash costs could provide more comfort and defensibility in States' economic analysis.
- National crash costs could remove the burden from States to individually establish and update their own set of crash cost values.
- National crash costs may encourage more States to conduct safety BCA.
- National crash costs could encourage more States to implement an advanced analysis capability in safety BCA (especially if the recommended values are accompanied by a reasoning of why observed crash frequency is less reliable than predictive methods such as EB).
- National crash costs could reduce confusion between, or incorrect application of, person-injury unit costs and crash unit costs.

The following disadvantages of recommending national crash costs focus on reducing States' flexibility in analysis and a responsibility to maintain the costs:

- National crash costs may not account for differences in economic analysis methodologies between States.
- Some States try to use relatively higher crash costs to economically justify more projects; others are more comfortable with conservative costs. National crash costs may reduce the appearance of flexibility in States' preferences.
- National crash costs may require States to change how they currently conduct economic analysis, potentially requiring development and implementation of new tools or revisions to existing tools.
- National crash costs may not adequately improve current practice enough to justify the effort. Recommending national crash cost values does not guarantee a substantial step forward in accurately estimating comprehensive crash costs, understanding the full implications of the recommended estimates on analysis, or justification of safety projects (e.g., economic versus comprehensive and what study or method to recommend). It would need to be clear that the national crash costs would improve some States' practices, but not necessarily those of all States, and primarily serve to standardize practices across States.

- Recommending national crash costs for safety BCA may imply that other national crash costs (e.g., those presented throughout Chapter 3) are insufficient or inappropriate.

The following considerations could be considered advantages or disadvantages, depending on the final set of national crash costs (if recommended) and the circumstances of their recommendation:

- National crash costs may not fully account for State-to-State differences (or States may not think adjusting is adequate).
- National crash costs may provide consistency in consideration of injury scale, but may be inconsistent with the injury scales on some States' crash reports.
- National crash costs may discourage subjective weighting and adaptations States make to alter national crash costs to their needs.
- Different costs may be appropriate for different applications (e.g., BCA for projects or impact on State budgets may prefer economic crash unit costs, while societal burden analysis may prefer comprehensive crash unit costs). Economic, QALY, and comprehensive crash unit costs must all be listed when recommending national crash costs so States can update the crash costs appropriately.

Of the five respondents that indicated national crash costs would be disadvantageous in their questionnaire responses, two indicated that there is a need to provide State-specific crash costs or an adjustment to local conditions, two raised concerns about not being able to create weighted fatal and injury costs to prevent fatal crashes from skewing BCA with observed frequency, and one indicated a need to weight crash costs for a program objective. National crash costs can account for these concerns with the ability to adjust the national crash costs to States and the flexibility to develop weighted average costs from the national values.

5.12.2 Feasibility and Responsibility

Currently, there is no universally recommended set of national crash cost values to use for any specific purpose within highway safety analysis. States have several resources available to use at their discretion. Moving forward, there are at least three potential paths:

1. States can continue to adopt and use their preferred crash costs and weighted costs.
2. Develop a national procedure or program to help States calculate crash costs with State-specific economic and injury data.

3. Recommend or require national crash costs, preferably costs that can be adjusted to each State or jurisdiction.

Regarding the first option, the crash cost questionnaire responses indicate the status quo is not preferable given the variability among States, the lack of regular updates, and the variability in applying person-injury and crash unit costs.

The second option would require a substantial amount of funding and place a resource burden on States. It is unlikely that most States have enough data or sufficient access to that data to develop accurate average crash costs independently. Most States use national crash costs for these reasons.

The third option is the preferred path, but it is likely contingent on a national agency taking on the responsibility to update and publish the national crash costs. Option 3 is discussed in more detail in the following sections.

5.12.2.1 Feasibility of National Crash Costs

It is feasible to establish national crash cost values. Most States already use national values directly or adapt national values for their analyses, but only a few seem to have some analytical basis for which national crash costs they select over others (e.g., other than their preference for high or low costs and the source organization or publication). There is no single source of crash costs that the majority of States use, as shown in Figure 3. Only a handful of States establish their own costs or undertake such substantial modifications to national values that their costs no longer bear similarities to any of the national crash cost estimates.

Officially adopting recommended national crash costs for use in the HSIP, safety research, and potentially other purposes would not stray far from current practice. The biggest impediments to adopting national crash costs in most States would be breaking with tradition or convention, performing national-to-State adjustment calculations, and changing the numerical values they use in BCA software tools. A nationally recommended, regularly updated set of crash costs could facilitate more accurate economic analysis than what some States' are currently using, as documented in the questionnaire and available literature. Several States appear to apply only economic costs, apply only QALY costs, apply person-injury unit costs to crashes, or use subjective severity weighting procedures that diminish the accuracy and completeness of their economic analyses.

With adopting national crash cost values and formalizing their recommended use, there is an implication that those costs would be recommended for a reason: values should be accurate, complete, and suitable for analysis in all States.

The questionnaire did not ask States if explicitly requiring the use of such crash costs was desired. However, due to the lack of legislative authority and the wide differences in States' preferences and the availability of several national crash cost values, requiring States to universally apply only one set of crash costs is not feasible or reasonable. Separate crash costs may also be required for specific grant programs. Thus, requiring one set of national crash costs for all projects may not suit all States' needs.

5.12.2.2 Responsibility for National Crash Costs

FHWA and AASHTO are two of the most appropriate organizations to take on the responsibilities of adopting, publishing, and updating national crash cost values.

FHWA oversees the HSIP and publishes the HSIP Manual. USDOT publishes the VSL guidance. The HSIP Manual, a new publication similar to the VSL guidance, a website, or updated technical advisory could potentially include recommended national crash costs for safety analysis. FHWA also has access to the staff and expertise (within FHWA or the USDOT) to maintain and update national crash costs, as is already done with the annual VSL updates.

AASHTO publishes the HSM, and could replace the current recommended crash costs with new values. However, because the HSM is not published every year, the HSM would be best suited to national crash costs that are updated with economic indicators like the current HSM costs, as opposed to costs that require new analysis and publication every year. Additionally, the HSM is not free. Since recommended national crash costs should be available to all users, it would be preferable for those costs to be available for free (e.g., posted online with public access or through a supplemental free publication), separate from the published HSM that is available for purchase.

There is no clear preference for which entity, or another not suggested here, should take on these responsibilities.

As discussed later, a minor effort would be required every year for annual adjustments. Revisions to the injury-to-crash and vehicle-to-crash ratios are more involved, but should be done less frequently, potentially every five years.

5.12.3 National Crash Cost Structure

The crash cost questionnaire and the literature review present a clear indication that just one average crash cost value or crash costs by severity are not sufficient for safety analyses among all States. National crash costs should be structured to account for at least the following aspects (the recommendations in Chapter 6 of this guide account for these aspects):

- Disaggregate crash costs by KABCO severity.

- Methodology to calibrate national crash costs to each State or jurisdiction. Analysts should adjust national crash costs to their severity distribution and cost of living indices if possible.
- Methodology to update national crash costs and recommended period for doing so, and establish a schedule and procedure for releasing newly published values. It would be beneficial if States do not have to conduct these updates themselves to lessen their burden on resources and prevent potential inconsistencies.
- National crash costs should recommend only the use of comprehensive costs. While the economic and QALY costs of crashes would have to be reported for necessary State-specific adjustments, offering the choice between economic and comprehensive crash cost values would allow wide variation in State crash cost values to continue. Widely varying costs would stray too far from the purpose of establishing national values. The QALY costs of crashes comprise a large portion of the burden that the public endures. It is important to account for all impacts when analyzing the benefits of publicly-funded projects that intend to reduce crashes.

Other recommended aspects of national crash costs are as follows:

- Disaggregate crash costs by crash and collision type.
- Disaggregate crash costs by both severity and type.

However, this guide is unable to make specific recommendations on these two aspects.

This guide cannot make a recommendation on whether multiple sets of crash cost values are needed for different analytical purposes due to the limited scope of this effort. Yet, if multiple sets of crash cost values are eventually established for different purposes, the crash costs should be structured as such with corresponding explanation and examples.

CHAPTER 6. FHWA SAFETY BCA TOOL CRASH COSTS

NHTSA's *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*[11]—referred to as "NHTSA's report" throughout this chapter—is the most recent and comprehensive work on crash costs to date. Therefore, it is recommended that the crash cost data contained in NHTSA's report serve as the basis of default national crash unit costs for FHWA's Safety BCA Guide and Tool. NHTSA's report generated economic, QALY, and comprehensive costs for the MAIS injury scale using national crash database samples with AIS and KABCO designations for each crash record. The recommended methodology, presented in this chapter, draws upon the person-injury unit cost values and resources in NHTSA's report to develop KABCO crash unit costs for highway safety BCA.

6.1 DEVELOPING DEFAULT NATIONAL CRASH UNIT COSTS FOR THE FHWA SAFETY BCA GUIDE AND TOOL

Table 1-10 of NHTSA's report lists MAIS person-injury unit costs for 2010, which includes economic, QALY, and comprehensive costs.[11] These costs are synthesized in Table 28 below.

Table 28. MAIS person-injury unit costs (2010 dollars).[11]

Severity	Economic Person-Injury Unit Costs	QALY Person-Injury Unit Costs	Comprehensive Person-Injury Unit Cost
Fatal (MAIS 6)	$1,398,916	$7,747,082	$9,145,998
MAIS 5	$1,001,089	$4,578,525	$5,579,614
MAIS 4	$394,608	$2,037,483	$2,432,091
MAIS 3	$187,128	$805,697	$992,825
MAIS 2	$58,754	$340,872	$399,626
MAIS 1	$20,701	$23,241	$43,942
MAIS 0	$4,380	$0	$4,380
PDO Vehicle	$6,076	$0	$6,076

Since most safety analysis methods and tools—including FHWA's Safety BCA Tool—use KABCO crash frequency, the MAIS person-injury unit costs must first be converted into KABCO person-injury unit costs and then into KABCO crash unit costs for use in highway safety BCA. Figure 10 illustrates the process used in this chapter to develop national KABCO crash unit costs and the State-specific adjustment.

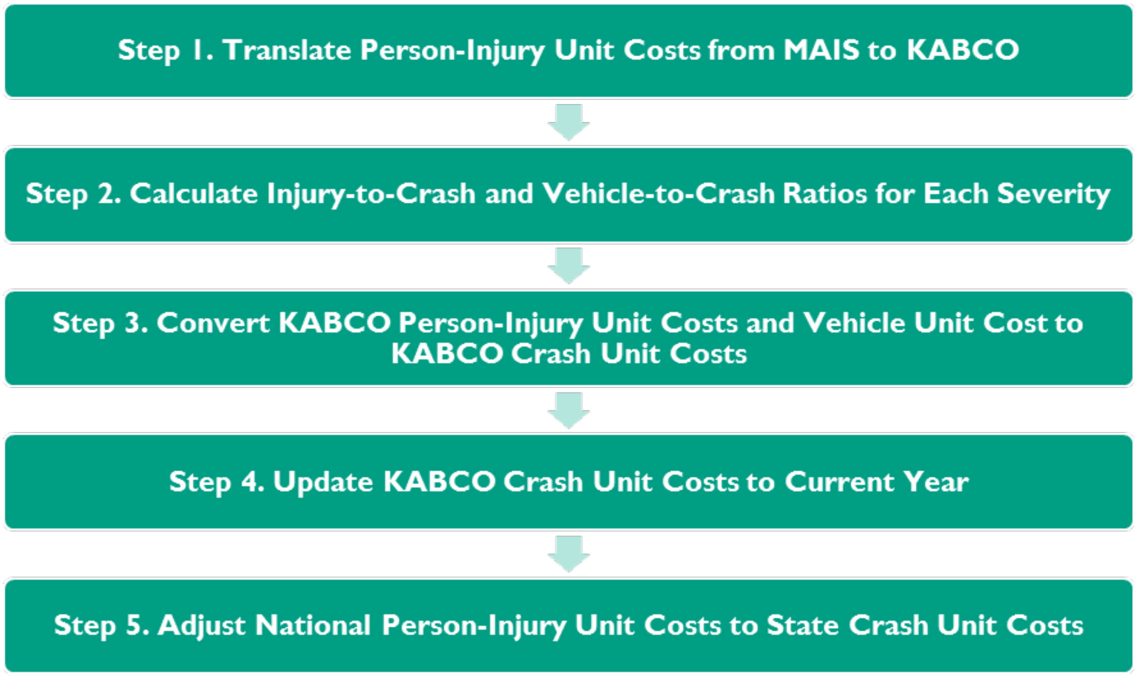

Figure 10. Chart. Process for developing and adjusting national KABCO crash unit costs.

6.1.1 Step 1: Translate Person-Injury Unit Costs from MAIS to KABCO

The first step is to translate the MAIS person-injury unit costs from Table 28 to KABCO using the translator table in Table 23 and the procedure presented in the example shown in Table 26. The resulting KABCO person-injury unit costs are shown in Table 29 (the KABCO level O values represent the small portion of people reported as O that actually sustained injuries). The PDO cost per vehicle in Table 28 is not translated (i.e., PDO cost is per vehicle and independent of persons involved, as none were injured).

Table 29. National KABCO person-injury unit costs (2010 dollars).

Severity	Economic Person-Injury Unit Costs	QALY Person-Injury Unit Costs	Comprehensive Person-Injury Unit Cost
K	$1,398,916	$7,747,082	$9,145,998
A	$84,507	$363,324	$447,832
B	$32,105	$97,974	$130,079
C	$21,749	$49,926	$71,675
O	$5,717	$2,563	$8,280

6.1.2 Step 2: Calculate Injury-to-Crash and Vehicle-to-Crash Ratios for Each Severity

The next steps involve converting the KABCO person-injury unit costs from Table 29 to crash unit costs. The authors estimated injury-to-crash ratios for each crash severity and a vehicle-to-crash ratio for PDOs using GES data from 2011 to 2015.[20] The injury-to-crash ratios are needed in the conversion of person-injury unit costs to crash unit costs on a national scale using the equation in Figure 6. The vehicle-to-crash ratio is needed to convert the cost per PDO vehicle to a cost per PDO crash. A five-year period provides a relatively long-term average for severity distributions. 2015 is the latest year available in the GES data, and there is no reason to suspect that the ratios would change significantly in 2016.

Table 30 shows the summary of crashes and corresponding injuries in those crashes over the five-year span, and Table 31 contains the resulting GES injury-to-crash ratios for the same period. Table 31 shows rounded ratios; however, calculations do not include intermediate rounding.

The GES data contained 115,451 PDO crashes with 205,541 vehicles from 2011 to 2015. The vehicle-to-crash ratio was calculated by dividing the number of vehicles by the number of PDO crashes, yielding a ratio of 1.78033. Again, intermediate rounding was not used in the calculations.

Table 30. 2010 MAIS to KABCO incidence translation (GES 2011-2015).

Crash Severity	Crash Incidence	K Person-Injuries	A Person-Injuries	B Person-Injuries	C Person-Injuries	O Person-Injuries
K	4,502	4,901	1,353	1,284	1,027	2,357
A	33,247	0	39,711	7,696	7,976	26,668
B	62,474	0	0	74,811	12,247	66,451
C	39,222	0	0	0	55,767	52,985
O	115,451	0	0	0	0	261,971
Total	254,896	4,901	41,064	83,791	77,017	410,432

Table 31. National injury-to-crash ratios (GES 2011-2015).

Crash Severity	K Injury-to-Crash Ratio	A Injury-to-Crash Ratio	B Injury-to-Crash Ratio	C Injury-to-Crash Ratio	O Injury-to-Crash Ratio
K	1.08863	0.30053	0.28521	0.22812	0.52355
A	0.00000	1.19442	0.23148	0.23990	0.80212
B	0.00000	0.00000	1.19747	0.19603	1.06366
C	0.00000	0.00000	0.00000	1.42183	1.35090
O	0.00000	0.00000	0.00000	0.00000	2.26911

6.1.3 Step 3: Convert KABCO Person-Injury Unit Costs and Vehicle Unit Cost to KABCO Crash Unit Costs

The authors adapted the equation in Figure 6 to substitute the injury-to-crash ratio for the injury and crash counts, which is shown in Figure 11 for fatal crash costs.

$$\text{Cost}_{K,\text{crash}} = \sum\nolimits_{\alpha=\{K,A,B,C,O\}} \text{Injury-to-crash}_{\alpha,\text{person}} \times \text{Cost}_{\alpha,\text{person}}$$

Figure 11. Equation. Converting person-injury unit costs into a fatal crash unit cost using injury-to-crash ratio.

The authors used the equation in Figure 11 with injury-to-crash ratios from Table 31 to convert the 2010 national KABCO person-injury unit costs from Table 29 to national KABCO crash unit costs, shown in Table 32. The calculation of the 2010 comprehensive fatal crash unit cost is shown in Figure 12. Rounded ratios are shown in Figure 12, but intermediate rounding was not used in the calculations for the Table 32 costs.

$$\text{Cost}_{K,\text{crash}} = \left\{ \begin{array}{c} (1.08863 \times \$9{,}145{,}998)+ \\ (0.30053 \times \$447{,}832)+ \\ (0.28521 \times \$130{,}079)+ \\ (0.22812 \times \$71{,}675)+ \\ (0.52355 \times \$8{,}280) \end{array} \right\}$$

Figure 12. Equation. Calculation of comprehensive fatal crash unit cost from injury-to-crash ratios and person-injury unit costs.

The PDO (i.e., "O") crash cost was calculated by multiplying the PDO cost per vehicle from Table 28 (i.e., $6,076) by the vehicle-to-crash ratio, without rounding, determined in Step 2 (i.e., 1.78033). The resulting cost per PDO crash in 2010 dollars was $10,817. The PDO cost per vehicle is already accounted for in the economic costs in Table 28, so this vehicle-level cost does not need to be added to costs for other injury levels.

Table 32. National KABCO crash unit costs (2010 dollars).

Severity	Economic Crash Unit Costs	QALY Crash Unit Costs	Comprehensive Crash Unit Cost
K	$1,565,406	$8,583,550	$10,148,956
A	$118,172	$470,675	$588,847
B	$48,789	$129,835	$178,623
C	$38,645	$74,450	$113,095
O	$10,817	$0	$10,817

6.1.4 Step 4: Update KABCO Crash Unit Costs to the Current Year

Finally, the 2010 KABCO crash unit costs were updated to 2016 dollars (i.e., the last full year of economic indexes) using the CPIs and MUWEs for 2010 and 2016. The CPI adjustment ratio, which is applied to the economic cost portion, is calculated using the equation in Figure 8. The CPIs selected for the update are the CPI-U for "all items," annual average index, and unadjusted, which is consistent with the first edition of the HSM and other publications. The annual average CPI for 2010 is 218.1 and 240.0 for 2016, yielding a CPI ratio of 1.101.[8]

The MUWE adjustment ratio, which is applied to the QALY cost portion, is calculated using the equation in Figure 9. The MUWEs selected for the updates are the current dollar MUWE index, not seasonally adjusted for total workers (i.e., 16 years and older), as explained in Chapter 5. The annual average MUWE for 2010 is 746.5 and 832.5 for 2016, yielding an MUWE ratio of 1.115.[21]

The CPI and MUWE ratios were applied to the 2010 national KABCO crash unit costs in Table 32 to calculate the 2016 national KABCO crash unit costs in Table 33.

Table 33. National KABCO crash unit costs (2016 dollars).

Severity	Economic Crash Unit Costs	QALY Crash Unit Costs	Comprehensive Crash Unit Costs
K	$1,722,991	$9,572,411	$11,295,402
A	$130,068	$524,899	$654,967
B	$53,700	$144,792	$198,492
C	$42,536	$83,026	$125,562
O	$11,906	$0	$11,906

The cost values in Table 33 were rounded to the nearest $100 and presented in Table 34, which represent the default national comprehensive crash unit costs for use in the FHWA BCA Guide and Tool. These national crash unit costs could be considered for other uses, as well.

Table 34. Recommended national KABCO comprehensive crash unit costs for the FHWA BCA Guide and Tool (2016 dollars).

Severity	Comprehensive Crash Unit Costs
K	$11,295,400
A	$655,000
B	$198,500
C	$125,600
O	$11,900

States using observed crash frequency in safety BCA—or States seeking to align crash costs with program objectives—could develop weighted average comprehensive crash unit costs from these values using their severity distribution. Chapter 5 provides more information on the disadvantages of using observed crash frequency in BCA. The suggested sets of weighted costs are either K/A, B, C, and O or K/A/B/C and O.

6.1.5 Step 5: Adjust National Person-Injury Unit Costs to State Crash Unit Costs

The previous sections describe the process to establish national crash unit costs by applying national injury and crash incidence data to a set of KABCO person-injury unit costs. The same procedure used to develop the national crash unit costs can be used to develop State crash unit costs. The information needed to calculate injury-to-crash and vehicle-to-crash ratios is generally available in State crash and injury databases.

To adjust the national costs to a State, the analysts can follow the same procedure outlined in this chapter, substituting their data in Table 30 and Table 31. Then, the resulting costs should be adjusted by multiplying the PCI ratio. The following section demonstrates an example State-specific adjustment.

6.1.5.1 Example State-Specific Adjustment Calculations

Hypothetical example State-adjusted KABCO crash unit costs are presented in Table 35 using the data from the example shown in Table 27, the Figure 6 equation, KABCO person-injury unit costs from Table 29, and an assumed vehicle-to-crash ratio of 1.85. Table 35 is the result of the first three steps in this chapter for the example State. The equation in Figure 13 demonstrates the calculation of the comprehensive fatal crash unit cost in Table 35 (i.e., using the number of injuries directly rather than calculating average ratios, which provides the same result).

$$Cost_{K,crash} = \frac{\left\{\begin{array}{c}(202\text{ K injuries} \times \$9{,}145{,}998\text{ per K injury})+\\(33\text{ A injuries} \times \$447{,}832\text{ per A injury})+\\(50\text{ B injuries} \times \$130{,}079\text{ per B injury})+\\(30\text{ C injuries} \times \$71{,}675\text{ per C injury})+\\(162\text{ O injuries} \times \$8{,}280\text{ per O injury})\end{array}\right\}}{186\text{ K crashes}}$$

Figure 13. Equation. Example calculation of State-specific comprehensive fatal crash unit cost using crash and person-injury data from Table 27 in 2010 dollars.

The same calculation was performed for A, B, and C crash severities. The assumed vehicle-to-crash ratio was applied to the cost per PDO vehicle to determine the O crash unit cost. This adjustment results in slightly different State-specific costs—shown in Table 35—than the national values shown in Table 32.

Table 35. Example State-specific KABCO crash unit costs (2010 dollars).

Severity	Economic Crash Unit Costs	QALY Crash Unit Costs	Comprehensive Crash Unit Costs
K	$1,551,363	$8,514,581	$10,065,944
A	$114,989	$447,159	$562,149
B	$43,240	$117,040	$160,280
C	$28,178	$53,057	$81,236
O	$11,241	$0	$11,241

The 2010 costs from Table 35 were updated to 2016 costs using the national CPI ratio of 1.101 and MUWE ratio of 1.115, calculated previously. The 2016 crash unit costs are shown in Table 36.

Table 36. Example State-specific KABCO crash unit costs (2016 dollars).

Severity	Economic Crash Unit Costs	QALY Crash Unit Costs	Comprehensive Crash Unit Costs
K	$1,707,534	$9,495,497	$11,203,031
A	$126,565	$498,674	$625,239
B	$47,593	$130,523	$178,117
C	$31,015	$59,170	$90,185
O	$12,372	$0	$12,372

After the crash unit costs were adjusted to the State-specific injury-to-crash and vehicle-to-crash ratios and updated to current dollars, the State-specific cost of living PCI adjustment factors were applied (found in *Appendix F: State Cost of Living Adjustment Factors*). Each cost in Table 36 was multiplied by a hypothetical State's PCI adjustment factor of 1.23456. The results are shown in Table 37.

Table 37. Example KABCO crash unit costs (2016 dollars).

Severity	Economic Crash Unit Costs	QALY Crash Unit Costs	Comprehensive Crash Unit Costs
K	$2,108,053	$11,722,761	$13,830,814
A	$156,252	$615,643	$771,895
B	$58,757	$161,139	$219,896
C	$38,290	$73,049	$111,339
O	$15,274	$0	$15,274

6.1.5.2 Example State-Adjusted KABCO Comprehensive Crash Unit Costs

The final example State-adjusted KABCO comprehensive crash unit costs, in 2016 dollars, rounded to the nearest $100 dollars, are shown in Table 38.

Table 38. Example State-adjusted KABCO comprehensive crash unit costs (2016 dollars).

Severity	Comprehensive Crash Unit Costs
K	$13,830,800
A	$771,900
B	$219,900
C	$111,300
O	$15,300

6.2 UPDATING NATIONAL CRASH UNIT COSTS

The procedures to update crash unit costs over time and adjust the national person-injury unit costs to States using the costs presented in this chapter are sufficient for regular updates in the future with CPI, MUWE, and PCI. National and State-specific crash unit costs should be updated annually, if possible, with these procedures.

The base costs in Step 1 should be replaced as new crash costs are available from NHTSA or other comparable research. Additionally, the injury-to-crash and vehicle-to-crash ratios in Step 2 may benefit from a revision roughly every five years with CRSS data or as new data are available that would improve the numbers (e.g., a larger, more comprehensive sample than is currently provided in GES). These ratios should remain fairly stable, and any annual changes would likely be due to random fluctuations rather than prevailing trends. Updating the ratios every five years, averaging over the five most recent years of data, should better account for new trends in vehicle fleet, ridership, and other travel characteristics that may affect injury-to-crash and vehicle-to-crash ratios.

CHAPTER 7. SUMMARY

This guide presents a synthesis of various sources of crash costs, crash cost estimation methodologies, current practice in selecting and applying crash costs, considerations in establishing and using crash costs in safety BCA, and advantages and disadvantages of establishing national crash costs. The following is a summary of salient points based on current practice and considerations for applying and updating crash costs.

7.1 CURRENT STATE PRACTICE

There is no universal recommended set of national crash cost values for safety BCA. States primarily use crash costs from one or more of four national sources of crash costs: USDOT, AASHTO, NSC, and NHTSA. Each State either uses those costs directly or adapts those costs to their needs. Most States update their crash costs regularly with economic adjustment factors or as new crash costs are published. A few States use multiple sets of crash costs for different purposes.

7.2 FEASIBILITY OF NATIONAL CRASH COSTS

An opportunity to establish a recommended set of national crash costs for safety BCA has arisen given the revitalized national discussion on the topic. Most States already use national estimates, but there is a wide range in the values they use. National crash costs would provide consistency in project decisions and research, while lessening the burden on States to adopt and maintain their own crash costs.

This guide proposes a set of national crash costs with State adjustment factors—based on NHTSA research that represents the most recent and comprehensive crash cost estimation—for default crash unit costs in the FHWA Safety BCA Guide and Tool. The guide also proposes a procedure to further adjust these national crash costs to States based on State-specific injury and vehicle distributions in crashes and cost of living adjustment factors.

7.3 CRASH COST CONSIDERATIONS

Actual crash costs differ in every crash due to the specific circumstances related to each crash event—the damage, injuries, response, and lasting effects. It is unlikely that future crashes, even at the same site, will bear the same economic or societal costs as previous crashes. Further, it is extremely difficult and costly to quantify the finite costs of each crash as it occurs. For these reasons, estimating average crash costs for certain circumstances provides a more practical, consistent, and reliable way to estimate the impact of past crashes and predict the impacts of future crashes (or the economic benefit of reducing crashes).

There are several methodologies available to estimate the average cost of crashes and injuries. While there are differences, there is not necessarily a preferred method for all purposes. Each provides distinct advantages and disadvantages. For example, comprehensive costs, measured with as many economic cost impacts as possible plus the impacts of QALYs, are suited for estimating the real impact of crashes in safety BCA and when calculating the full burden of crashes on the public. The VSL, which represents the value in risk reduction, is suited for use in evaluating the benefits of legislation and programs that will reduce risk. Regarding crash unit costs and person-injury unit costs, it is important that analysts account for the differences in available data.

Crash costs are most commonly developed and presented by severity for a specific injury scale, which can be a problem if the crash cost injury scale does not align with the severities reported by police officers in a State. A translator table is available to translate costs between MAIS and KABCO, although the conversion is not exact. Further, the use of two injury scales presents complications not only in comparing disaggregate crash costs, but also the total burden of certain injuries in projects or across a State, particularly when characterizing serious injuries. Consistency in injury scale between all State crash reports and crash costs, and more accurate injury assessment using hospital injury surveillance data, would alleviate the confusion and inconsistency created by two separate conventions.

Some States develop weighted crash costs to help account for situations where even a small number of observed fatal or serious injury crashes can seem to bias BCA. While weighted crash costs are one method to mitigate the impact of high severity crashes in estimating benefits, the underlying issue is the use of short-term average observed crash history in safety BCA. The recommended method is to estimate the long-term average crash frequency (e.g., predicted crash frequency or expected crash frequency with EB method) and apply unweighted crash costs, rather than applying weighted crash costs to observed crash frequency.

Using consistent crash costs (i.e., for the same crash type, crash severity, facility type, jurisdiction, and other factors) is important in safety BCA. For safety improvement programs, such as the HSIP, consistent crash costs promote fair and equitable stewardship of safety funding. If potential projects are analyzed with different crash costs, it may lead to one project artificially favored over the other (i.e., assuming actual differences in crash costs between project locations are appropriately accounted for or are not known). Agencies should consider adopting a standard set of crash costs values for use across their agency or within each funding program in which projects are competitively prioritized.

7.4 KNOWLEDGE GAPS AND FUTURE RESEARCH

Gaps in knowledge and potential for future research exist in the area of crash costs. The crash unit costs recommended in this guide are based solely on the body of available literature; the authors did not undertake new data analysis (e.g., to estimate crash cost components or VSL) in developing recommended crash costs for the FHWA Safety BCA Guide and Tool. Future research is needed to develop technical knowledge (i.e., fundamental and empirical) regarding a few of the crash cost considerations listed in Chapter 5:

- Understand the actual effects of using severity-weighted crash costs on decision-making and resulting implemented project effectiveness.
- With many still relying on observed crash frequency in safety BCA, there is an opportunity in the future to study the impacts of various crash cost-related practices when applying predicted or expected crash frequency in BCA.
- Reconcile the impact of injury scale on crash cost, including the unreliable nature of KABCO, for future crash unit cost estimates and for safety analysis in general.
- Determine the appropriate and recommended situations for applying crash unit costs by severity, by type, by severity and type, or neither.

Possibly the greatest limitation of the recommended procedure in Chapter 6 of this report is the translation from MAIS to KABCO. The translation table, based on well-sampled crash data and with accurate AIS representation of injuries, indicate that KABCO, as conveyed on police crash reports, generally does not reliably characterize true injury severities. While the recommended KABCO crash costs in this guide are averages and account for the differences between MAIS and KABCO to the extent possible, relying on the translation limits the accuracy of the resulting crash costs. There are potential research opportunities to improve upon the KABCO characterization of injuries or implement State-specific translations. Developing more comprehensive databases of the State and national crash attributes, and integrating with hospital AIS data for each injury and crash incidence, will enhance the accuracy of the cost estimates.

7.5 CONCLUSION

Crash costs are an essential consideration in highway safety analysis. This guide combines methodologies and procedures from over 10 years of research by various organizations and individuals regarding crash costs and their application. While there are currently no universally recommended national crash cost values, this guide presents new crash cost values and accompanying adjustment procedures for the FHWA Safety BCA Guide and Tool based on the comprehensive work documented in NHTSA's 2015 report.[11] These values should be updated annually using the procedures described herein. Nationally recommended crash costs would provide consistency in project decisions and research while lessening the burden on States to each adopt and maintain their own crash costs. There are procedures States and researchers can use to adjust the national crash cost values to better reflect State conditions.

APPENDIX A: SELECTED CRASH GEOMETRIES

The 2005 FHWA Report, entitled *Crash Cost Estimates by Maximum Police-Report Injury Severity Within Selected Crash Geometries* and summarized in Chapter 3 of this guide, categorizes the costs of the following 22 crash geometries within six levels.

1. Single-vehicle struck human, at intersection (sv, ped, int).
2. Single-vehicle struck human, not at intersection (sv, ped, n-int).
3. Single-vehicle struck animal (sv, animal).
4. Single-vehicle struck object (sv, object).
5. Single-vehicle struck parked vehicle (sv, prkveh).
6. Single-vehicle rolled over (sv, rollover).
7. Multiple vehicles cross paths at signal (mcp, sig).
8. Multiple vehicles cross paths at sign (mcp, sign).
9. Multiple vehicles cross paths no signage (mcp, nosgn).
10. Multiple vehicles cross paths unspecified (mcp, unk).
11. Multiple vehicles rear-end at all locations (re-all locations).
12. Multiple vehicles rear-end at intersection with no/unknown signage (re-unk int).
13. Multiple vehicles rear-end at signed intersection (re-signed int).
14. Multiple vehicles, rear-end at signalized intersection (re-signl int).
15. Multiple vehicles rear-end, no intersection (re-no int).
16. Multiple vehicles sideswipe (ss).
17. Multiple vehicles, opposite direction not at intersection (ho, n-int).
18. Multiple vehicles, opposite direction at signalized intersection (ho, sig).
19. Multiple vehicles, opposite direction at signed intersection (ho, sign).
20. Multiple vehicles, opposite direction no/unknown signage (ho, unksgn).
21. Multiple vehicles backing (backing).
22. Undefined crash type (undefined).

APPENDIX B: STATE CRASH COST QUESTIONNAIRE

Objective

The FHWA Office of Safety launched a task to synthesize the state of the practice on States' adopted crash cost values and related methodologies used to determine and apply these values. We are contacting each FHWA Safety Specialist for your help in providing this information for your State. The information needed is reflected in the few questions presented below. The results will be included as an appendix to [this guide] describing the various methods, and related strengths and limitations, for developing and applying crash costs.

Questionnaire

1. **Crash Cost Values**
   a. Please list (or provide link(s) to) the most recent crash costs by type and severity used by your State. If your State uses different crash cost values for different purposes (e.g., different crash costs for HSIP vs. non-HSIP projects, engineering vs. behavioral projects, State vs. local projects, planning vs. evaluation), please provide the crash cost values for the different purposes and indicate the reasons for this differentiation.

Purpose (check all that apply)	**Specific Crash Cost Values** (if different from HSIP crash costs)	**Reasons for Different Values**
☐ Crash costs for HSIP projects.		
☐ Crash costs for non-HSIP projects.		
☐ Crash costs for behavioral projects.		
☐ Crash costs for local projects.		
☐ Crash costs for evaluation.		
☐ Other (please specify)		

2. **Methodology**
   a. How does your State develop their crash cost values? If there is documentation, please provide.

      ☐ Conduct internal research.

      ☐ Use values directly from national or other State's manual, publication, or research (**please list sources**):
      ☐ Adapted/weighted values from external sources (**please list sources**):

      ☐ Other (please explain):

   b. Does your State use crash cost values at the person level or crash level (i.e. fatalities and injuries or fatal crashes and injury crashes)?

   c. Does your State regularly update their crash cost values? If so, how often?

   d. What economic indexes or growth factors are used for the updates?

e. Which of the following crash cost components are included in your crash cost values? (check all that apply and indicate source)

Crash Cost Components (check all that apply)	Source		
	Your State Data	Other State's Data	National Data
☐ Public assistance and social services (vocational rehab and State welfare / safety net)			
☐ Direct government crash costs as an employer (employee medical, taxes, legal, at-fault liability, employer costs, insurance administration, wage loss, and property damage)			
☐ Public revenue (State tax loss)			
☐ Property damage (roadside hardware)			
☐ Judicial (court operation-related)			
☐ Emergency services (EMS, police, fire, emergency incident management)			
☐ Medical (Medicaid and coroner)			
☐ Other (please specify)			

3. Current Applications of Crash Cost Values

a. Please explain or provide documentation on the methodology to apply crash costs in your economic analysis.

b. Which of the following crash cost measures are used in your State for economic analysis?

☐ Human capital crash costs (i.e., estimates of direct and indirect economic crash costs to individuals and society).
☐ Comprehensive crash costs (i.e., the human capital costs plus the monetized quality-adjusted life years (QALYs)).

c. Are there any special considerations or variations regarding the application of crash costs in your State? If yes, please explain.

☐ Weighted fatal and injury costs (e.g., K+A, K+A+B, etc.):
☐ Counting some fatal crashes as injury crashes:
☐ Counting some injury crashes as fatal crashes:
☐ Estimating type and severity of unknown crashes:
☐ Other:

d. Has your State looked at the impact of crash costs on your State's operating budgets to justify projects or maintenance activities?

e. Does your State use a software tool or standard spreadsheet to apply crash costs in economic analysis? If yes, please identify.

4. Future Applications of Crash Cost Values

a. Would adopting a set of national crash costs be advantageous or disadvantageous to your State? Please explain why.

APPENDIX C: STATE CRASH COSTS BY SEVERITY

Table 39 presents the crash costs by severity used in safety BCA, including HSIP, from the questionnaire.

When responses did not list specific values, the authors used or calculated the latest values from the State's preferred source. In the case that the State did not respond to the questionnaire, the synthesis was supplemented with an online search for relevant reports and documentation. The authors of this guide converted costs per person or MAIS costs to KABCO crash costs, if possible, for a simpler comparison of values in a synthesized table. The authors did not similarly update costs to current year dollars. Therefore, the costs in Table 39 may not reflect the exact values that States apply in BCA.

The dollar year column represents the year in which the costs are expressed in, as reported in the questionnaire or literature, or as best determined by the authors otherwise. A value of "N/A" indicates that the State does not use crash costs, and a value of "UNK" indicates the authors were not able to discern the values' dollar year.

Table 39. State crash costs.

State	K	A/*Major**	B/*Minor**	C	O	Source	Dollar Year
AL	$190,200	$190,200	$190,200	$54,000	$8,900	Questionnaire	2015
AK	$2,003,000	*$1,001,000*	*$200,000*	N/A	$20,000	Questionnaire	2016
AZ	$5,800,000	$400,000	$0	$0	$0	Literature	2008
AR	$5,666,000	$302,000	$110,000	$63,000	$10,000	Questionnaire	2016
CA	$9,600,000	$459,120	$125,050	$63,854	$3,235	Questionnaire	2016
CO	$1,500,000	$80,700	$80,700	$80,700	$9,300	Questionnaire	2013
CT	$5,740,100	$304,400	$111,200	$62,700	$10,100	Questionnaire	2016
DE	$651,000	$651,000	$651,000	$651,000	$2,920	Questionnaire	UNK
DC	$1,542,000	$90,000	$26,000	$21,400	$11,400	Questionnaire	2015
FL	$10,100,000	$818,636	$163,254	$99,645	$6,500	Literature	2013
GA	$9,100,000	$955,500	$955,500	$955,500	$27,300	Questionnaire	2013
HI	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	UNK

State	K	A/*Major**	B/*Minor**	C	O	Source	Dollar Year
ID	$6,391,502	$318,302	$89,155	$59,097	$6,842	Literature	2013
IL	$6,245,736	$336,521	$123,079	$0	$0	Questionnaire	2016
IN	$373,000	$373,000	$35,200	$35,200	$6,300	Questionnaire	2009
IA	$4,500,000	$325,000	$65,000	$35,000	$7,400	Questionnaire	2014
KS	$4,733,650	$402,550	$80,500	$42,500	$3,250	Questionnaire	2016
KY	$257,890	$257,890	$257,890	$6,793	$6,793	Questionnaire	2015
LA	$1,712,721	$488,947	$173,599	$58,640	$24,982	Questionnaire	2015
ME	$5,740,100	$304,400	$111,200	$62,700	$10,100	Questionnaire	2016
MD	$9,200,000	$505,000	$121,400	$68,700	$12,480	Questionnaire	2014
MA	$5,740,100	$304,400	$111,200	$62,700	$10,100	Questionnaire	2016
MI	$1,512,000	$88,500	$25,600	$11,300	$11,300	Questionnaire	2014
MN	$1,140,000	$570,000	$170,000	$84,000	$7,600	Questionnaire	2015
MS	$9,145,998	$1,001,206	$276,010	$127,768	$42,298	Questionnaire	2010
MO	$9,200,000	*$313,869*	*$81,606*	N/A	$4,565	Questionnaire	2014
MT	$5,628,500	$298,700	$109,100	$61,600	$10,000	Questionnaire	UNK
NE	$1,500,000	$88,500	$25,600	$21,000	$4,200	Literature	2013
NV	$5,665,555	$301,035	$109,990	$62,076	$10,067	Questionnaire	2016
NH	$5,740,100	$304,400	$111,200	$62,700	$10,100	Literature	2016
NJ	$5,740,100	$304,400	$111,200	$62,700	$10,100	Questionnaire	2016
NM	N/A	N/A	N/A	N/A	N/A	Questionnaire	N/A
NY	$3,686,232	$91,316	$91,316	$91,316	$4,443	Literature	2015
NC	$10,133,000	$564,000	$176,000	$96,000	$6,700	Questionnaire	2013
ND	$10,082,000	$1,103,000	$304,000	$141,000	$46,600	Questionnaire	2014
OH	$336,145	$336,145	$56,146	$38,056	$8,576	Questionnaire	2014

State	K	A/*Major**	B/*Minor**	C	O	Source	Dollar Year
OK	$9,600,000	$2,553,600	$451,200	$28,800	$4,200	Questionnaire	2016
OR	$870,000	$870,000	$72,400	$72,400	$19,400	Questionnaire	2012
PA	$6,568,966	$1,429,846	$95,699	$7,620	$3,048	Literature	2008
PR	$4,002,800	$89,200	$89,200	$89,200	$0	Literature	UNK
RI	$1,322,600	$1,322,600	$112,600	$63,400	$10,200	Questionnaire	2016
SC	$9,600,000	$459,120	$125,050	$63,854	$3,235	Questionnaire	2016
SD	$374,724	$374,724	$374,724	$374,724	$17,528	Questionnaire	2013
TN	N/A	N/A	N/A	N/A	N/A	Questionnaire	N/A
TX	$3,300,000	$3,300,000	$475,000	$0	$0	Questionnaire	2014
UT	$2,064,800	$2,064,800	$128,900	$65,800	$3,300	Questionnaire	2015
VT	$338,272	$291,200	$106,400	$60,000	$9,700	Questionnaire	2016
VA	$4,008,885	$216,059	$56,272	$56,272	$7,428	Literature	2001
WA	$2,900,000	$2,900,000	$155,000	$60,000	$10,000	Questionnaire	2010
WV	$5,289,928	$285,022	$104,244	$59,248	$9,765	Questionnaire	2012
WI	$210,000	$210,000	$210,000	$60,000	$10,000	Questionnaire	UNK
WY	$2,237,000	$2,237,000	$98,000	$98,000	$39,000	Questionnaire	2013

* Two States, AK and MO, use Major Injury and Minor Injury classifications rather than A, B, and C in KABCO. For those States, the Major cost is listed in italics in the A cost column, the Minor cost is listed in italics in the B cost column, and N/A is listed in the C cost column.

APPENDIX D: PRACTICES IN DEVELOPING AND UPDATING CRASH COSTS

The following sections illustrate some of the different methods that States use to develop their crash costs. These sections list notable State practices from the crash cost questionnaire responses and online research to demonstrate some ways that States have established their own methods for developing and updating crash cost values.

Alaska Method

Alaska DOT's HSIP Handbook presents their method for developing crash unit costs, which are based on the 2014 USDOT guidance.[24,12] The USDOT crash cost values are first converted into the KABCO scale and then into Alaska's injury scale categories—Fatality, Major Injury, Minor Injury, and PDO—before inflating to current year by gross domestic product (GDP) implicit price deflator measure, as an annual four-quarter average. These costs, shown in Table 40 as the base 2016 costs, present a fatality as 1,300 times the cost of a PDO, which Alaska indicates will result in a "misallocation of highway safety funds" when using crash history as the basis for economic analysis.

Table 40. Alaska DOT base crash costs.

Severity	Base 2016 Crash Costs	Base EPDO Weights	Average Annual Crashes
Fatality	$10,635,263	1300	56
Major Injury	$715,846	90	351
Minor Injury	$109,365	13.75	3,231
PDO	$7,954	1	9,000

Based on the five-year average number crashes by severity, indicated as Average Annual Crashes in Table 40 and Table 41, Alaska DOT determines the total cost of all crashes by multiplying the crash costs by severity by the number of crashes of each severity. This annual average cost of crashes in Alaska (i.e., $1,291,090,265) is then redistributed using subjective EPDO weights of 100, 50, 10, and 1 to determine new costs by severity as listed in Table 41 as HSIP Crash Costs. The result is the same annual average cost of crashes in the State (i.e., in both cases the crash costs multiplied by the number crashes of each severity equals the same total cost) with less disparate crash costs by severity.

Table 41. Alaska DOT HSIP crash costs and EPDO weights for BCA (2016 dollars).

Severity	Average Annual Crashes	New EPDO Weights	HSIP Crash Unit Costs
Fatality	56	100	$2,003,000
Major Injury	351	50	$1,001,000
Minor Injury	3,231	10	$200,000
PDO	9,000	1	$20,000

Arizona Method

Arizona DOT uses the original default crash unit costs in AASHTOWare Safety Analyst from 2010, which are based on the FHWA crash unit costs from 2008. Arizona ignores B, C, and O crashes in their BCA spreadsheet, with their crash costs shown in Table 42.

Table 42. Arizona DOT crash unit costs for BCA (2008 dollars).

Severity	Comprehensive Crash Unit Cost
K	$5,800,000
A	$400,000
B	$0
C	$0
O	$0

Colorado Method

Colorado uses economic person-injury unit costs from NSC 2013 for injury crashes and an economic crash unit cost for PDOs. For all A, B, and C crashes, they apply a consistent value that represents a nonfatal disabling injury, which is roughly the economic cost of an A injury. Colorado noted they will be updating to NSC's 2015 crash costs soon. Table 43 lists Colorado's crash costs.

Table 43. Colorado DOT economic crash unit costs for BCA (2013 dollars).

Severity	Economic Crash Unit Cost
K	$1,500,000
A	$80,700
B	$80,700
C	$80,700
O	$9,300

Florida Method

Florida uses two sets of crash unit costs when calculating BCRs per a Florida DOT memo in 2014.[25] Both sets are based on 1994 and 2013 USDOT guidance with State-specific adaptations.[17,1] When quantifying expected crash frequency with SPFs for BCA, Florida uses one set of crash unit costs in which they convert USDOT MAIS person-injury unit costs into comprehensive KABCO crash unit costs. Table 44 lists Florida's crash costs for predictive BCA.

Table 44. Florida DOT crash unit costs for predictive BCA (2013 dollars).

Severity	Comprehensive Crash Unit Cost
K	$10,100,000
A	$818,636
B	$163,254
C	$99,645
O	$6,500

For sites where Florida uses observed crash frequency in BCA (e.g., when no SPF is available for the facility type), they use a weighted average K/A/B/C/O crash unit cost (i.e., not further categorized by injury level). The Florida DOT memo provides one average crash unit cost for all State roads (i.e., $195,791) as well as several average crash unit costs by facility type, which is disaggregated by number of lanes, median type, and area type. Florida DOT uses five-year crash and injury severity data to develop weighted averages.[25]

Georgia Method

Georgia uses the person-injury unit costs from the USDOT VSL guidance in safety BCA. Rather than converting from MAIS to KABCO, Georgia uses the AIS 3 person-injury unit cost (i.e., severe injury) from the 2013 USDOT guidance as a weighted crash unit cost for all KABCO A, B, and C crash unit costs.(1) Table 45 lists Georgia's crash costs.

Table 45. Georgia DOT comprehensive crash unit costs for BCA (2013 dollars).

Severity	Comprehensive Crash Unit Cost
K	$9,100,000
A/B/C	$955,500
O	$27,300

Illinois Method

Illinois uses comprehensive costs from the HSM updated with a three-percent annual adjustment factor, rather than using the CPI and ECI adjustments. The three-percent annual adjustment is consistent with Illinois's practice for estimating construction costs and other life-cycle analysis.

Illinois counts KABCO level C crashes (i.e., possible injury) as PDO, and assigns a unit cost of $0 to C crashes and PDO crashes in HSIP BCA analysis. Table 46 lists Illinois's crash unit costs.

Table 46. Illinois DOT comprehensive crash unit costs for BCA (2016 dollars).

Severity	Comprehensive Crash Unit Cost
K	$6,245,736
A	$336,521
B	$123,079
C	$0
O	$0

Iowa Method

Iowa DOT uses crash costs in analyzing safety improvements under their State-funded Traffic Safety Improvement Program. During BCA, Iowa considers the first fatality in the analysis at each site as a major injury (and applies crash costs as such) to reduce the emphasis on single fatal crash events.

Minnesota Method

Minnesota DOT adapts the 2015 USDOT VSL guidance costs for BCA.(12) After converting the VSL costs into comprehensive crash unit costs, based on three-year crash history and USDOT conversion procedures, Minnesota sets their fatal crash cost equal to two times the A-level crash cost to reduce the impact of fatal crash cost on BCA when using observed crash frequency. Table 47 lists Minnesota's HSIP crash costs.

Table 47. Minnesota DOT comprehensive crash unit costs for HSIP BCA (2015 dollars).

Severity	Comprehensive Crash Unit Cost
K	$1,140,000
A	$570,000
B	$170,000
C	$84,000
O	$7,600

Nevada Method

Nevada DOT uses crash costs from the HSM, updated as recommended in the HSM with CPI and ECI indexes. Nevada noted that in some analyses, they consider the first fatal crash as an injury crash in BCA.(26)

North Carolina Method

Based on an internal memo dated 2014, North Carolina DOT calculates comprehensive crash unit costs based on the USDOT VSL guidance.(27) North Carolina first develops an average number of injuries per crash by crash severity category, as shown in Table 48.

Table 48. North Carolina DOT injury-to-crash ratios.

Crash Severity	K Injury-to-Crash Ratio	A Injury-to-Crash Ratio	B Injury-to-Crash Ratio	C Injury-to-Crash Ratio	O Injury-to-Crash Ratio
K	1.09	0.13	0.34	0.29	0.40
A	0.00	1.15	0.34	0.30	0.57
B	0.00	0.00	1.23	0.42	0.75
C	0.00	0.00	0.00	1.50	1.37

Then, North Carolina translates the VSL costs, using disutility MAIS factors for injury costs, into KABCO person-injury unit costs. This translation is done using a translator table, as discussed in Chapter 5. The person-injury unit costs are multiplied by the respective injury-to-crash ratios and then summed for all injury severities to determine the crash unit cost for the given crash severity.

Table 49 provides an example computation for average fatal crash cost. The values in the second and third column for each row are multiplied to calculate the fourth column. The values in the fourth column are summed to determine the average fatal crash unit cost of approximately $10,133,000.

Table 49. North Carolina DOT computation of fatal crash unit cost (2013 dollars).

Severity	Injury-to-Crash Ratio	Comprehensive Person-Injury Unit Cost	Comprehensive Crash Unit Cost Portion
K	1.09	$9,200,000	$10,016,380
A	0.13	$439,990	$56,313
B	0.34	$119,839	$40,901
C	0.29	$61,194	$17,857
O	0.40	$3,100	$1,254

Oklahoma Method

Oklahoma develops crash unit costs based on the USDOT guidance. However, rather than using a translator table, Oklahoma sets various MAIS severity levels directly equal to KABCO severities and uses the MAIS person-injury unit costs as KABCO crash unit costs, as shown in Table 50.

Table 50. Oklahoma DOT MAIS to KABCO direct conversion and comprehensive crash unit costs (2016 dollars).

MAIS	KABCO	Comprehensive Crash Unit Cost
MAIS 6	K	$9,600,000
MAIS 4	A	$2,553,600
MAIS 2	B	$451,200
MAIS 1	C	$28,800
MAIS 0	O	$4,200

Puerto Rico Method

Based on the Puerto Rico Department of Transportation and Public Works' High Crash Location Report Summary, Puerto Rico uses comprehensive crash unit costs adapted from the HSM comprehensive crash unit costs.[28] They use a comprehensive fatal crash unit cost and a weighted injury crash unit cost, as shown in Table 51. Puerto Rico ignores PDOs in their economic analysis.

Table 51. Puerto Rico comprehensive crash unit costs.

Severity	Comprehensive Crash Unit Cost
K	$4,002,800
A/B/C	$89,200
O	$0

Texas Method

Texas DOT uses the NSC comprehensive injury cost values to develop a weighted K/A crash unit cost value and B crash unit cost value, as shown in Table 52. These are based on 2014 NSC data. Texas DOT does not consider C and O crashes in economic analysis, so these crash unit costs are considered $0. These values are updated annually as new NSC data are published.

Table 52. Texas DOT comprehensive crash unit costs (2014 dollars).

Severity	Crash Cost
K/A	$3,300,000
B	$475,000
C/O	$0

Texas DOT's weighted crash unit cost values are calculated as outlined below.

1. Determine the total number of fatal crashes in the most recent three years.
2. Determine the total number of injuries of all severities (i.e., including non-injured) in those fatal crashes.
3. Multiply the comprehensive person-injury unit cost for each injury type by the total number of each corresponding injury in fatal crashes.
4. Sum the costs of all injuries and non-injured persons in fatal crashes and divide by the total number of fatalities to determine the average fatal crash unit cost.
5. Repeat steps 1-4 for incapacitating injury crashes to determine the average incapacitating injury crash unit cost.
6. Calculate the weighted average fatal and incapacitating injury crash unit cost value by multiplying each average crash unit cost by the ratio of fatal crashes among all fatal and incapacitating injury crashes, and the same for incapacitating injury crashes, and summing the result.
7. Repeat steps 1-4 for non-incapacitating injury crashes to determine the average non-incapacitating injury crash unit cost.

Wyoming Method

Wyoming DOT uses the USDOT VSL fatal injury cost as a base value, and then applies weighting factors to create severity-weighted K/A, B/C, and O/U crash unit cost values, as shown in Table 53. These are based on 2012 USDOT costs.(1) These values are updated as new VSL numbers are published, or updated (from the 2012 VSL) annually based on a 1.0107% growth factor.

Table 53. Wyoming DOT comprehensive crash unit costs (2013 dollars).

Severity	Comprehensive Crash Unit Cost
K/A	$2,237,000
B/C	$98,000
O	$39,000

Wyoming DOT's weighted crash unit cost values are calculated as outlined below.

1. Convert VSL AIS person-injury unit costs to KABCO crash unit costs using the translator table from TIGER BCA Resource Guide, as shown in Table 15.
2. Combine KABCO crash unit costs into severity-weighted Critical (i.e., fatal and incapacitating injury), Serious (i.e., non-incapacitating injury and possible injury), and Damage (i.e., no injury and unknown) crash unit cost values.
3. Adjust the severity-weighted crash unit costs for inflation by multiplying the values by a factor of 1.0107^N, where N is the number of years after 2012 (or since the newest VSL values used in the calculations).

APPENDIX E: QUESTIONNAIRE RESPONSES TO THE FEASIBILITY OF RECOMMENDING NATIONAL CRASH COSTS

The following are quotes from the questionnaire responses regarding question 4: **"Would adopting a set of national crash costs be advantageous or disadvantageous to your State? Please explain why."** When a State was named in the responses, they have been scrubbed for anonymity.

- Indicated "advantageous" or answer appears advantageous (19 responses):
    - Yes, a national crash cost would be advantageous so we wouldn't have to develop one ourselves. In the past, we have used Federal crash costs.
    - Yes, if it could be adjusted based on state or region.
    - Yes, it would be advantageous if the injury severity levels were more consistent with KABCO (i.e., better distinguish between minor and serious injuries and other levels of severity).
    - May be advantageous, but have NSC that is adequate for use today.
    - Advantageous. [Jurisdiction] has no preference as we refer to national guidance.
    - It will be advantageous, as long as it considers different socio-economical costs and provides an average value for the nation. This will make all the States' analyses consistent with each other and project prioritization will be consistent.
    - This would be advantageous because the process [to update crash costs] is tedious and ideally should be updated each month when the CPI is updated monthly and the ECI is updated quarterly.
    - It would be advantageous as a starting point if [Jurisdiction] were to consider modifying their current methodology regarding using crash costs.
    - Better quantifies the message to the public if everyone uses similar costs.
    - We do not feel real comfortable with the way we are determining our crash costs now, but it is the best method we have. Since BCRs are a big part of prioritizing our safety projects, the more accurate we can be the better our decisions will be.

- Adopting a set of national crash costs would be very advantageous for all States using the same methodology to estimate crash costs (with adjustments being made annually).
- Would be advantageous, but must have flexibility of adjustment to reflect local conditions.
- A common crash cost may be helpful to standardize, especially if this is updated every year. However, the way [Jurisdiction] is [adapting the crash costs], they would likely still do that to make the data more [Jurisdiction]-specific.
- I don't know. I assume so. It is important that we are using the same values that other aspects of project evaluation are using (pollution costs, delays, etc.) so that safety is compared at the same level as the other analysis.
- [Jurisdiction] likes the two options included in the Highway Safety Manual (Human Capital Cost and Comprehensive Crash Cost). [Jurisdiction] thinks a national standard is needed and will be able to adjust [Jurisdiction]'s program accordingly.
- I consider the values provided in the HSM once updated using the HSM methodology to be kind of national crash costs. Having national crash costs at the crash-level would be useful. It would be the official source.
- Depends on the business area. [Traffic and safety engineering staff] would like to see consistency, not only across the nation, but amongst the various programs within the [Jurisdiction]. The managers of the various programs may not agree with that assessment.
- We are already using national VSL/QALY numbers. We do not have the expertise to calculate the economic impact costs nor the knowledge to keep them up to date.
- It would be acceptable if the crash costs were updated annually. If values were given with no ability to account for inflation, it would be less advantageous to us.

- Response indicated "no preference" or answer did not indicate a preference (11 responses):
  - Already adopted national numbers.
  - We are currently using the provided crash costs per the memo – 9.1M for fatal, etc.

- Neutral, [Jurisdiction] already uses HSM to help us develop crash costs.

- Depends on if the National crash costs are higher than what we have developed for [Jurisdiction]. If the national crash costs are higher, it may improve our ability to show increased value in safety improvements.

- Since [Jurisdiction] uses the NSC numbers for our [economic analysis], adopting national crash cost would be neither advantageous nor disadvantageous. The national crash costs would be entered in our form and the [economic analysis threshold] would be reevaluated depending on how the national crash costs were developed, human capital or comprehensive.

- [Jurisdiction] already uses NSC average comprehensive crash costs as the main source of setting costs for economic analysis. A change to another source would not be necessarily advantageous or disadvantageous.

- Since [Jurisdiction] already uses national published crash costs, I'm not sure, under the current funding construct there is any advantage of one value across all States. If States begin to have to compete for a single pot of infrastructure dollars, it would be a benefit to operate from the same starting spot, but it would be disadvantageous in locations where certain inputs are much greater than others – i.e., EMS costs in rural [Jurisdictions] would well outpace EMS costs in highly urban States, like in the Northeast corridor.

- The Blincoe study already provides some guideline, but they must be adjusted in any case for State-specific situations. The most difficult part is to translate MAIS-specific costs to KABCO costs. Unfortunately, each State may have different distributions of KABCO depending on how police officers assess injury.

- Advantage would be level comparisons of countermeasure effectiveness. This will provide a standard in which countermeasures can be assessed by at a nationwide level instead State by State. A disadvantage would be a decreased flexibility in how each State would be able to evaluate the effectiveness of their own projects on a scale of their choosing. [Jurisdiction]'s crash costs tend to be more on the conservative side which yields lower [BCRs] than some other states.

- Not sure that it would matter. [Jurisdiction] likes [an older FHWA advisory] and the breakdown into Fatality, A, B, C, & PDO crashes. Previously, just the cost of fatality has been updated but not the [advisory]. [Many years later they evaluated an updated fatality cost.] I believe at the time they were evaluating [a countermeasure] and felt the much higher cost per fatality would skew analysis.

  - More beneficial would be an internal assessment of use of benefit-cost analysis more widely on all Department projects; though safety projects, by benefit of their exclusive funding, do not compete against other projects. That said, the use of non-safety funds often supports safety projects or safety improvements and the inclusion of more direct means to tally costs and benefits over the project would be beneficial to a more complete reckoning of investment choices. The use of national crash statistics has some advantages but the greater questions are separating severities or combining them (to not "overweigh"), and use of crashes as the counting unit or individuals.

- Response indicated "disadvantageous" or answer appears disadvantageous (5 responses):
  - We use the same [weighted] value for fatal and serious injury crashes to align our project outcomes with [our SHSP, which aims to reduce fatal and serious injury crashes]. The national values have always had a very different value for fatal and serious injury crashes – application of these values is more likely not prioritize projects that are also driving down serious injuries per our plan.
  - No, one size does not fit all. [Jurisdiction] has a few random fatalities that are spread across a wide range. We would not want to be in a position of chasing random fatalities.
  - I believe it would be disadvantageous for our State. Costs are only used when evaluating an alternative versus the expected crash reduction and using our approach we are assuming that a fatal crash (and costs) could be saved over the life cycle of the proposed solution. It is my belief that this is an incorrect assumption (so if you have a fatal crash in a 5-year period you will get credit for reducing 4 fatal crashes over a 20-year life period) and this is further multiplied by a large fiscal number. A recommended methodology for using crash data to develop a per crash cost (similar to [Jurisdiction]'s methodology) might be useful to other States.
  - It is perceived that a lot of things cost higher in [Jurisdiction] compared to the national averages. Perhaps a calibration factor can be used (just like in the SPF [safety performance function] calibration) to this set of national crash costs to reflect the differing costs between national and local settings.
  - Adopting national crash costs may not necessarily reflect local costs and thereby the true cost of crashes in the [Jurisdiction]. A study, using the methodology by NSC will need to be conducted to obtain the crash costs for the [Jurisdiction].

APPENDIX F: STATE COST OF LIVING ADJUSTMENT FACTORS

Table 54 lists the PCI ratio adjustment factors that adapt national mean crash costs to State-specific crash unit costs. To adjust the costs, multiply all crash unit costs (i.e., by severity and type) by the PCI ratio value. This procedure is also applicable to person-injury unit costs. The United States average is shown at the top of Table 54.

Table 54. State crash cost PCI ratio adjustment factors.[20]

State	PCI (2016 dollars)	PCI Ratio
United States (average)	$49,571	1.00000
Alabama	$39,231	0.79141
Alaska	$55,307	1.11571
Arizona	$40,243	0.81183
Arkansas	$39,345	0.79371
California	$55,987	1.12943
Colorado	$52,059	1.05019
Connecticut	$71,033	1.43295
Delaware	$48,697	0.98237
District of Columbia	$75,596	1.52500
Florida	$45,819	0.92431
Georgia	$41,835	0.84394
Hawaii	$50,551	1.01977
Idaho	$39,107	0.78891
Illinois	$52,098	1.05098
Indiana	$43,492	0.87737
Iowa	$46,794	0.94398
Kansas	$48,537	0.97914
Kentucky	$39,499	0.79682
Louisiana	$43,487	0.87727

Maine	$44,316	0.89399
Maryland	$57,936	1.16875
Massachusetts	$65,137	1.31401
Michigan	$44,347	0.89462
Minnesota	$52,117	1.05136
Mississippi	$35,936	0.72494
Missouri	$43,723	0.88203
Montana	$42,386	0.85506
Nebraska	$49,636	1.00131
Nevada	$43,637	0.88029
New Hampshire	$58,322	1.17653
New Jersey	$61,968	1.25009
New Mexico	$38,807	0.78286
New York	$60,534	1.22116
North Carolina	$42,002	0.84731
North Dakota	$55,038	1.11029
Ohio	$44,876	0.90529
Oklahoma	$45,682	0.92155
Oregon	$45,049	0.90878
Pennsylvania	$51,275	1.03437
Rhode Island	$51,576	1.04045
South Carolina	$39,465	0.79613
South Dakota	$48,049	0.96930
Tennessee	$43,380	0.87511
Texas	$47,636	0.96097
Utah	$40,744	0.82193

Vermont	$50,321	1.01513
Virginia	$53,723	1.08376
Washington	$53,493	1.07912
West Virginia	$37,386	0.75419
Wisconsin	$47,275	0.95368
Wyoming	$55,212	1.11380

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FHWA, Office of Safety

Karen Scurry
karen.scurry@dot.gov
609-637-4207

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