Using Crash Costs in Safety Analysis

Paul F. Hanley
University of Iowa

DOI: https://doi.org/10.17077/o4qy-o4hi
Using Crash Costs in Safety Analysis
Using Crash Costs in Safety Analysis

Paul F. Hanley
Assistant Professor
Graduate Program in Urban and Regional Planning
Civil and Environmental Engineering
and the Public Policy Center

Public Policy Center
The University of Iowa
2004

This study was funded by the Iowa Department of Transportation. The conclusions are the independent products of university research and do not necessarily reflect the views of the funding agency.
PREFACE

There are three primary reasons state departments of transportation (DOTs) invest in road and highway upgrades—to promote economic development, to alleviate congestion, and to improve safety. This monograph focuses on the third of these key considerations. Because funds available to finance safety improvements are always quite limited, priority projects must be carefully selected in order to maximize the net safety improvement to society.

An important component of project selection is economic in nature. What are the dollar savings to society of preventing fatalities, injuries, and damage to personal property? For any given proposed project, how do these savings compare to the costs of making the particular investment? An earlier monograph published by the Public Policy Center (Forkenbrock, et al. 1994) proposed a methodology for estimating the safety cost savings of various road upgrades. That methodology and essentially all others depend upon reasonable dollar estimates for fatalities, personal injuries, and property-damage-only crashes. It is the objective of this monograph to suggest current and well-accepted parameter values for preventing each of these types of crashes.

Through telephone interviews of DOT staff in safety and design offices, we were able to obtain the crash values many states are currently using and to gain a sense of how they are applied in investment decisions. We also asked about the role of safety analysis in design exception reviews. The interviews revealed that the majority of DOTs use safety cost savings values recommended by the Federal Highway Administration (FHWA) either to prioritize or to qualify the potential value of proposed projects intended to improve safety.

We also compare how different states prioritize safety improvements. While many use the dollar values for fatality and injury crash costs in their processes, a number expressed concern that several types of analysis tend to skew the ranking of crash locations toward sites where a single fatality has occurred. Some states have attempted to solve this potential distortion by approaches such as weighting costs with criteria like average daily traffic, or by calculating crash costs by crash type or facility type rather than by injury severity. The interviews revealed that a majority of states use benefit-cost analysis to prioritize safety projects.

After analyzing both the values of key parameters used in assessing safety improvements and the methods applied to incorporate these improvements into the investment decision-making process, we offer several recommendations. Specifically, we recommend assigning updated dollar cost values to the three types of crashes, discounting the future benefits of avoided crashes, and discounting any future costs to their present values.
Our research was carried out at the University of Iowa Public Policy Center. Funding for this research was provided by the Iowa Department of Transportation.
ACKNOWLEDGMENTS

In the preface, we mentioned that this research was funded by the Iowa Department of Transportation. We are grateful for its support. Thomas Welch, State Transportation Safety Engineer, was highly instrumental in getting this research funded, and he provided us with important insights throughout the project.

In conducting the surveys of state departments of transportation, we spoke with numerous safety professionals who freely gave their time and provided us with a clear picture of national conventions in valuating safety benefits.

Jennifer Jones, a graduate student in the Graduate Program in Urban and Regional Planning, provided excellent research assistance, mainly by reviewing the crash cost literature. David Forkenbrock, Director of the Public Policy Center, helped frame the analysis, reviewed various drafts, and provided numerous suggestions for preparing this monograph.

Teresa Lopes, editor at the Public Policy Center, provided editorial assistance. Kathy Holeton, administrative assistant at the Center, helped in numerous ways to make the project proceed smoothly.

With real appreciation, we acknowledge the important and diverse contributions of these people.
CONTENTS

PREFACE ............................................................................................................................ i
ACKNOWLEDGMENTS ..................................................................................................... iii
FIGURES ........................................................................................................................... vii
TABLES ............................................................................................................................ ix
CHAPTER 1 INTRODUCTION ......................................................................................... 1
  Methods for estimating crash costs ............................................................................. 1
  Current practices .......................................................................................................... 2
  Interview methodology ............................................................................................... 2
  Structure of the report ................................................................................................. 3
CHAPTER 2 CRASH COST METHODOLOGIES .......................................................... 5
  Human capital costs .................................................................................................... 5
  Human capital cost estimates used by the states ....................................................... 7
  Comprehensive costs ................................................................................................. 7
  Sources of comprehensive costs for vehicle crashes .............................................. 10
  State approaches to assigning dollar values to crashes ......................................... 14
  Cost per injury or cost per crash .............................................................................. 16
  Conclusions .............................................................................................................. 16
CHAPTER 3 APPLICATION OF CRASH COSTS BY STATE DOTS ....................... 19
  Estimates of past economic loss .............................................................................. 19
  Prioritizing safety improvement projects ............................................................... 20
  Benefit-cost analysis approaches ........................................................................... 23
  State DOTs' use of benefit-cost analysis ............................................................... 23
  Forecasting benefits of crash reduction .................................................................. 25
  Role of safety analysis in design exception reviews .............................................. 27
  Cost per injury or cost per crash .............................................................................. 29
  Conclusions .............................................................................................................. 31
CHAPTER 4 RECOMMENDATIONS ........................................................................... 33
  Recommended values for reporting economic loss ................................................. 33
  Recommended values for safety improvement project evaluation ....................... 33
  Recommended use of values in ranking high-crash locations ............................... 34
  Recommended use of values in design exception reviews ..................................... 34
REFERENCES .............................................................................................................. 41
APPENDIX A ................................................................................................................. 47
APPENDIX B ................................................................................................................. 49
FIGURES

2-1. Dollar value sources ........................................................................................................7
2-2. Dollar values used for fatalities by state DOTs .......................................................... 16
3-1. Use of benefit-cost analysis by state DOTs ................................................................. 25
3-2. Use of reduction factors by state DOTs ...................................................................... 27
3-3. Safety reviews of design exception requests .............................................................. 30
C-1. Completed benefit-cost determination from I.M. 3.216 .............................................. 66
C-2. Commentary on the benefit-cost determination from I.M. 3.216 ......................... 67
C-3. Recommended change to the benefit-cost determination of I.M. 3.216 .......... 68
TABLES

2-1. Total cost per person for all injury levels—NHTSA ............................... 6
2-2. Total cost per person for all injury levels—NSC ........................................ 6
2-3. Dollar values used by DOTs ........................................................................ 8
2-4. Dollar values for a statistical life used by federal agencies ....................... 9
2-5. Dollar value for a statistical life in the literature .................................. 10
2-6. Ratios for estimating willingness-to-pay to avoid a non-fatal crash ......... 11
2-7. Comprehensive costs in police-reported crashes by AIS severity .......... 12
2-8. Comprehensive costs in police-reported crashes by K-A-B-C scale severity ................................................................. 12
2-9. Comprehensive costs of motor vehicle crashes—NHTSA ..................... 13
2-10. Comprehensive costs of motor vehicle crashes—NSC .......................... 13
2-11. Dollar values used by DOTs based on FHWA technical advisory ........... 15
3-1. State DOT modification of cost values ...................................................... 21
3-2. Partial listing of crash costs by facility type, New York DOT ............... 22
3-3. State DOTs that use benefit-cost analysis in safety improvement project evaluations .................................................................................. 24
4-1. Discount rates used by other agencies ...................................................... 38
CHAPTER 1
INTRODUCTION

State departments of transportation (DOTs) constantly seek to ensure that the funds available for safety projects are allocated in the most effective manner possible. Estimating the social costs of vehicle crashes is integral to this goal. There are different theories as to the best way to arrive at such estimations, as well as to how they should be used, and if other factors should also be considered in the analysis.

One major difficulty in using vehicle crash costs in the safety project decision-making process may be traced to the difference between fatal and injury crashes. Fatalities are naturally assigned a much higher valuation than injury crashes. However, when the valuations are then used to determine project ranking, the site of a single fatality might outweigh a site where numerous injury crashes have occurred.

The Iowa DOT currently assigns dollar costs to both fatality and injury crashes that are somewhat lower than those of most other states. It is also the only state to rank crash locations using two other indicators—crash frequency and crash rate. While the system works reasonably well, it is prudent to periodically compare one’s practices to those of other states in order to ensure that one is within the standard of practice.

The research reported in this monograph had four objectives. The first was to review the academic and professional literature for vehicle crash costs and the methods used by researchers to estimate such costs. The second was to assess current DOT practices across the country. To this end, we interviewed representatives from state DOTs to obtain existing values for fatal crashes, personal-injury crashes, and property-damage-only (PDO) crashes. We also gathered information on how the DOTs use these values in safety analysis and investment decisions and to evaluate new or existing design exceptions. The information gathered from the first two objectives was then used to complete the third and fourth, which were to provide the Iowa DOT with recommendations as to appropriate values for fatal, personal-injury, and PDO crashes costs, as well as to suggest modifications to the methods it currently uses when making safety investment decisions and evaluating design exceptions.

METHODS FOR ESTIMATING CRASH COSTS

Our literature review revealed two theoretical methods for estimating crash costs—the human cost method and the comprehensive crash cost method. The titles point to the way in which crash costs are derived in each method. Human cost values offer a way to estimate actual dollars spent on crashes and are therefore used to determine the impact of crashes that occurred in the past. Comprehensive cost values are derived for use in investment analyses and so produce an estimate
of the public’s willingness to pay to avoid future fatalities and injuries related to vehicle crashes. Thus, comprehensive costs measure the tradeoffs society is willing to make between safety and expense. Both methods have a place in safety analysis.

CURRENT PRACTICES

For this project, we contacted 48 state DOTs about their current state-of-practice for estimating crash cost values, prioritizing safety investments, and deciding on design exceptions. Through telephone interviews of DOT staff in safety and design offices, we were able to obtain crash values and to gain a sense of how they are used in investment decisions. We also asked about the role of safety analysis in design exception reviews. The interviews revealed that the majority of DOTs use the comprehensive costs for investment analysis recommended by the Federal Highway Administration (FHWA) either to prioritize or to qualify safety improvement projects.

Benefit-cost analysis is the most frequent economic analysis performed to evaluate the economic effectiveness of safety improvements. As part of the benefit-cost method, DOTs use crash reduction factors to estimate the number of crashes avoided as a result of the safety improvement. A number of DOTs frequently or always perform safety analysis when reviewing design exceptions, and a few perform economic analysis of design exception requests. None, however, use benefit-cost analysis as the sole deciding factor for approval of design exceptions.

INTERVIEW METHODOLOGY

Of the 48 DOTs contacted for this report, 39 completed full interviews, and partial interviews were conducted with seven others (including the Iowa DOT). We were unable to speak with representatives from Hawaii or Alaska, and two other states declined to participate in our survey. For the telephone interviews, initial contact was made with the office, division, or section of the DOT responsible for safety programs. Managers were identified from DOT web sites and telephoned directly. When we could not obtain a contact name or telephone number from the agency’s web site, we called the general number or the public information officer for assistance in locating the appropriate person.

Usually, the manager provided us with general information and then directed us to a safety analysis specialist so we could obtain specific details about the use of crash values in safety analysis and in the design exception process. If the contact in the safety office was not knowledgeable about the design exception process, we asked to be transferred to someone in the design office. With several of the state DOTs, we also contacted a third office that collects and maintains crash-related data to obtain the dollar values, source, and updating procedure for crash costs.

The interviews were informal and conversational. Although we were seeking specific information, question order was determined by the conversation flow—in other words, the order of the questions depended on individual responses. (See Appendix A for the interview questions.) We hoped that this method would elicit
more detailed responses than could be obtained from a structured interview format. In general, the insights gained from the open-ended questions were very helpful in casting light on how the DOTs use crash costs and their concerns about them. For example, several DOTs reported that they do not use the crash values to prioritize safety-related projects but rather to qualify projects for further evaluation. They then explained their qualification process. This information would have been lost if the question was posed with a yes/no response on a survey form.

STRUCTURE OF THE REPORT

Chapter 2 presents a theoretical framework for justifying, selecting, and using specific crash costs for safety analysis and investment decisions. It is much easier to select appropriate values when one understands the theoretical basis of data collection and crash cost estimation, as well as the final use of the values. Knowing how the values will be used—for example, for estimating the amount of funds spent on crashes or evaluating future investment in safety-related projects—helps determine which crash cost estimates are most appropriate. We also review the primary sources for comprehensive costs and the available guidance for using them.

In Chapter 3 we look at how state DOTs use the values for fatality and injury crash costs. We also compare how different states prioritize safety improvements. While many use the dollar values for fatality and injury crash costs in their processes, a number expressed concern that both the comprehensive and human capital values tend to skew the ranking of crash locations toward sites where a single fatality has occurred. A number of states have attempted to address this concern using approaches such as weighting costs with criteria like the annual average daily traffic (AADT), or by calculating crash costs by crash type or facility type rather than by injury severity. The interviews revealed that a majority of states use benefit-cost analysis to prioritize safety projects.

We conclude with a number of recommendations in Chapter 4. These include several revisions to the safety analysis methods currently used by the Iowa DOT. For estimating the past economic impacts of crashes, we suggest using the human cost values established by the National Safety Council (NSC) and updating these values annually. The NSC values should be used for ranking high-crash locations based on past economic loss, not for ranking locations for future improvements. For decisions about future investments in safety improvement projects, we suggest using the comprehensive costs recommended by the FHWA in Technical Advisory T 7570.2. These values should also be updated annually using the Gross Domestic Product Implicit Price Deflator (GDP-Deflator) as recommended by the FHWA.

We recommend that the Iowa DOT continue to use benefit-cost analysis, but propose that the method prescribed in Instructional Memorandum (I.M.) 2.316 be modified. Our suggested modification involves discounting the future benefits of avoided crashes, and discounting any future costs to their present values.
CHAPTER 2
CRASH COST METHODOLOGIES

There are two approaches to assigning a monetary cost to motor vehicle crashes. The first, called the human capital approach, is a methodology that was first used in the 1950s to place a dollar value on a fatality. Over the years it has been modified to include both the direct and indirect costs associated with a motor vehicle crash. Human capital costs, which of course are economic costs, are critical in estimating the dollar costs of motor vehicle crashes; however, these costs are only appropriate for estimating the economic losses of crashes that have already occurred. They do not reflect the total cost to society of crashes and should not be used in benefit-cost analysis. It is important to note that human capital costs do not include the intangible costs arising from loss of life or the reduction in quality of life. The second approach, called the comprehensive cost approach, is an estimate of the public’s willingness to pay to avoid future fatalities and injuries related to vehicle crashes. Comprehensive costs include both the direct and indirect costs plus a value to compensate for loss of life or the reduction in quality of life.

HUMAN CAPITAL COSTS

Human capital costs have two components—direct costs and indirect costs. Direct costs include those for medical and non-medical services directly attributable to an injury, as well as other costs related directly to the crash. Examples of direct medical costs include emergency room and inpatient care, physician visits, physical therapy, rehabilitation, prescriptions, and prosthetic devices (van Beeck and Mulder 1998; Blincoe et al. 2002). Direct non-medical costs refer to things such as emergency services, travel costs, occupational rehabilitation, insurance administration, workplace disruption, legal representation, and home adaptation. Generally, direct non-medical costs are paid by the injured parties, by relatives, or by other economic sectors. Property damage and travel delay constitute other direct costs. Indirect costs include the value of production losses due to a crash. In current indirect cost estimations, production losses include market wages, market benefit, and the value of non-market work, such as household work and childcare.

Sources of human capital costs

Many researchers have estimated the human capital cost of crashes. One notable example is the National Highway Traffic Safety Administration (NHTSA) report entitled “The Economic Impact of Motor Vehicle Crashes 2000” (Blincoe et al. 2002). According to this report, the total economic cost of motor vehicle crashes in the U.S. in 2000 was $230.6 billion. The average cost of a fatality was estimated to be $977,000, which is lower than the value used in other reports. The other primary source of motor vehicle crash costs based on human capital costs is the National Safety Council (NSC), which publishes an annual bulletin called
“Estimating the Costs of Unintentional Injuries.” The NSC estimate of the value to society of preventing a motor vehicle fatality in 2001 was $1,040,000 (NSC 2003).

The cost estimates of NSC and NHTSA differ in terms of when the estimates are adjusted for inflation. The NSC estimates are updated and published each year, whereas the NHTSA crash cost reports are infrequent. Another difference between the NHTSA and NSC is the approach used to update the estimates. The NSC general approach is to adjust benchmark costs, which were derived from previous studies such as the NHTSA cost report, to the current year using an appropriate inflator for each cost component (NSC 2001). The NHTSA reports begin by estimating the costs from actual crash histories; in a sense these reports set the benchmarks for the NSC.

Tables 2-1 and 2-2 contain current cost estimates from NHTSA and NSC, respectively. However, the values for injuries are not directly comparable between the two because they use different reporting systems. NHTSA reports severity based on the Abbreviated Injury Scale (AIS) of the Association for the Advancement of Automotive Medicine, and the NSC reports severity using the American National Standards Institute (ANSI) Standard D16.1-1996 (NSC and ANSI 1996).

Table 2-1. Total cost per person for all injury levels—NHTSA

<table>
<thead>
<tr>
<th>Crash type</th>
<th>2000 dollars</th>
<th>2001 dollars*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>977,208</td>
<td>1,000,977</td>
</tr>
<tr>
<td>Critical AIS 5</td>
<td>1,096,161</td>
<td>1,122,824</td>
</tr>
<tr>
<td>Severe AIS 4</td>
<td>348,133</td>
<td>356,600</td>
</tr>
<tr>
<td>Serious AIS 3</td>
<td>186,097</td>
<td>190,624</td>
</tr>
<tr>
<td>Moderate AIS 2</td>
<td>66,820</td>
<td>68,445</td>
</tr>
<tr>
<td>Minor AIS 1</td>
<td>10,562</td>
<td>10,819</td>
</tr>
<tr>
<td>Property damage only</td>
<td>2,532</td>
<td>2,593</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.


Table 2-2. Total cost per person for all injury levels—NSC

<table>
<thead>
<tr>
<th>Crash type</th>
<th>2000 dollars</th>
<th>2001 dollars*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1,000,000</td>
<td>1,040,000</td>
</tr>
<tr>
<td>Incapacitating injury (A)</td>
<td>47,900</td>
<td>49,500</td>
</tr>
<tr>
<td>Non-incapacitating evident injury (B)</td>
<td>16,000</td>
<td>16,500</td>
</tr>
<tr>
<td>Possible injury (C)</td>
<td>9,100</td>
<td>9,400</td>
</tr>
<tr>
<td>Property damage only</td>
<td>6,500</td>
<td>6,500</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.

Human capital cost estimates used by the states

The DOT interviews revealed that one state DOT currently uses the NHTSA values and that six use the NSC values for safety analysis (see Figure 2-1). Table 2-3 gives a sense of the dollar values used by eight states; it presents the source of the values, how they are indexed each year, dollar amounts used, and if the values are applied per crash or per injury for the three general types of crashes.

**Figure 2-1. Dollar value sources**

**COMPREHENSIVE COSTS**

The term comprehensive costs refers to the sum of all of the human capital costs listed above plus the intangible consequences of crashes to individuals and families (Blincoe 2002). Unlike human capital costs, which are the goods and services people purchase plus productivity losses, comprehensive costs include the value of the resources that society dedicates to reducing the risk of loss of life, physical and mental suffering, diminished quality of life, and permanent cosmetic damage (van Beeck and Mulder 1998).

**Estimating comprehensive costs**

Three techniques have been used to estimate comprehensive costs. Two rely on the revealed preferences of consumers and wage earners, and the third is derived from people’s stated preferences. Revealed preference studies can either determine the dollar amount consumers actually spend on safety-related devices such as smoke detectors or investigate the difference in wage rates between high-risk and low-risk
occupations. This wage difference, called a wage premium, compensates workers for exposure to the risk of fatal work-place injuries. Stated preference studies, also called contingent valuation methods, in contrast estimate the dollar amount people say that they would be willing to pay to avoid a fatal or non-fatal injury. Such studies use survey methods to establish the dollar amount participants would be willing to pay to slightly reduce their risk of dying in a crash. From these responses, researchers can calculate the average value society places on risk reduction.

Table 2-3. Dollar values used by DOTs

<table>
<thead>
<tr>
<th>State</th>
<th>Source</th>
<th>Index</th>
<th>Update</th>
<th>Fatal</th>
<th>Injury</th>
<th>PDO</th>
<th>$ Per</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas</td>
<td>NSC</td>
<td></td>
<td>2002</td>
<td>1,191,887</td>
<td>69,199</td>
<td>1,969</td>
<td>Crash</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>NSC</td>
<td>CPI</td>
<td>2002</td>
<td>1,057,000</td>
<td>50,300</td>
<td>6,600</td>
<td>Injury</td>
</tr>
<tr>
<td>Illinois</td>
<td>NSC</td>
<td></td>
<td>2001</td>
<td>1,040,000</td>
<td>36,000</td>
<td>6,500</td>
<td>Injury</td>
</tr>
<tr>
<td>North Dakota</td>
<td>NSC</td>
<td>NSC web site</td>
<td>2001</td>
<td>1,040,000</td>
<td>36,500</td>
<td>6,500</td>
<td>Injury</td>
</tr>
<tr>
<td>South Dakota</td>
<td>NSC</td>
<td>NSC web site</td>
<td>2001</td>
<td>1,040,000</td>
<td>36,500</td>
<td>6,500</td>
<td>Injury</td>
</tr>
<tr>
<td>Connecticut</td>
<td>NSC</td>
<td>NSC web site</td>
<td>2001</td>
<td>1,040,000</td>
<td>36,500</td>
<td>6,500</td>
<td>Injury</td>
</tr>
<tr>
<td>Michigan</td>
<td>NSC</td>
<td>NSC web site</td>
<td>2000</td>
<td>1,000,000</td>
<td>35,300</td>
<td>6,500</td>
<td>Injury</td>
</tr>
<tr>
<td>Ohio</td>
<td>NHTSA</td>
<td>NSC web site</td>
<td>2002</td>
<td>987,977</td>
<td>39,258</td>
<td>6,480</td>
<td>Crash</td>
</tr>
</tbody>
</table>

Source: Telephone interviews

The revealed preference techniques have some shortcomings. Such studies rely on consumers and wage earners who may or may not be representative of the entire population. Consumer studies, for example, can only measure the behavior of people who purchase safety products, and such individuals may have higher risk aversion than the general public. Labor market studies tend to analyze the behavior of people who are more risk-seeking than the population as whole. The methods also assume that consumers and wage earners know the objective risks involved and consider those risks when making the decision to buy a product or take a job.

Unlike the revealed preference methods, the contingent valuation method controls for how representative the sample is. This method has other limitations, however. Researchers criticize the fact that the approach requires people to answer questions about hypothetical situations in which their decisions have no consequences. Technical problems have also arisen in applying the method; responses will sometimes show anchoring effects or participants may make irrational decisions in response to stated risks. Also, what people say they would do in the abstract may not exactly replicate their actions when faced with a real situation.
Despite these shortcomings, researchers use these methods to calculate comprehensive costs, which are also referred to as the value of a statistical life. Government agencies are understandably reluctant to attach an explicit value to a human life, and so they use the abstract concept value of statistical life. This removes the focus from any one “identified” life and directs it to the value society ascribes to reducing the statistical probability of one person’s dying (Viscusi 1992, 1993). Perhaps the best way to think about this is that it reflects the value to society of preventing one more fatality.

Applications of comprehensive costs

To gauge the range of proposed values for a statistical life we searched the literature and found that many federal agencies are required to perform economic analyses of their risk-reduction policies, rules, and regulations. In conducting these analyses, the agencies use different values for a statistical life. In 2002, the U.S. DOT published a memorandum guiding its administrations to use a value of $3.0 million in 2001 dollars (U.S.DOT 2002). To get a sense of how this compares to other federal agencies, in various reports the U.S. Environmental Protection Agency (EPA) used $4.8 million in 1990 dollars, the U.S. Department of Agriculture (USDA) used a high value of $721,418 in 1996 dollars, and the Food and Drug Administration (FDA) used $1.2 million in 1999 dollars (Kenkel 2001). Table 2-4 summarizes the original values used by these agencies, and the values adjusted to 2001 dollars.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Study Value</th>
<th>Value in 2001 dollars*</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA</td>
<td>$4,800,000 (1990 dollars)</td>
<td>$6,100,000</td>
</tr>
<tr>
<td>U.S.DOT</td>
<td>$3,000,000 (2001 dollars)</td>
<td>$3,000,000</td>
</tr>
<tr>
<td>FDA</td>
<td>$1,200,000 (1999 dollars)</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>USDA</td>
<td>$721,418 (1996 dollars)</td>
<td>$788,631</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.

A continued search of the literature produced numerous theoretical and empirical estimates. For example, Viscusi summarized several labor market studies and found the average value of a statistical life to be in the range of $3 to $7 million, using 1990 dollars (Viscusi 1995). Miller (2000) investigated the way value of statistical life varies between countries. He concluded that the average value of a statistical life was $3,472,000 in 1995 dollars. Mrozek (2001) pooled 40 existing labor market studies and using meta-analysis suggested a range of $1.5 to $2.5 million in 1998 dollars. We also found studies specific to transportation safety. One study that focused on automobile safety suggested a range of between $3 and $4 million in 1990 dollars (Viscusi 1995). Dionne and Lanoie (2002) reported from what they determined to be the best transportation studies an average value of $3,622,000 in 2000 dollars. If we exclude Viscusi’s general study results and focus on the transportation studies he reviewed, the 2001 adjusted values range from $1.6 to $5 million. This range encompasses most values used by state DOTs. Table 2-5 lists
the original values from these studies and the figures adjusted to 2001 dollars using the GDP-Deflator.

The range in statistical life values in Table 2-4 is noticeably larger than in Table 2-5. The difference can be partly explained by research that has shown people are willing to pay more to avoid especially dreaded risks, such as dying from cancer, than to avoid less-dreaded ones, such as dying in a plane crash (Savage 1993). Because Table 2-5 contains measures of risk to life from transportation crashes, which tend to be sudden and less dreaded, the values should be lower than those from risks to life from environmental pollution (Savage 1993).

Table 2-5. Dollar value for a statistical life in the literature

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Study value</th>
<th>Value in 2001 dollars*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscusi 1995</td>
<td>$3,000,000 to $7,000,000 (1990 dollars)</td>
<td>$4,000,000 to $9,000,000</td>
</tr>
<tr>
<td>Viscusi 1995 (Transportation studies only)</td>
<td>$3,000,000 to $4,000,000 (1990 dollars)</td>
<td>$4,000,000 to $5,000,000</td>
</tr>
<tr>
<td>Miller 2000</td>
<td>$3,472,000 (1995 dollars)</td>
<td>$3,871,000</td>
</tr>
<tr>
<td>Dionne and Lanoie 2002</td>
<td>$3,622,000 (2000 dollars)</td>
<td>$3,710,000</td>
</tr>
<tr>
<td>Mrozek 2001</td>
<td>$1,5000,000 to $2,500,000 (1998 dollars)</td>
<td>$1,600,000 to $2,600,000</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.

**SOURCES OF COMPREHENSIVE COSTS FOR VEHICLE CRASHES**

In addition to the NHTSA and NSC reports, there are two other sources for comprehensive costs for vehicle crashes. The U.S. DOT and the FHWA have published documents guiding the selection and use of values of a statistical life.

**U.S. Department of Transportation guidance**

In 1993, the U.S. DOT published a memorandum that endorsed the comprehensive cost approach in setting the value of a statistical life. The memorandum instructed the recipients of federal funds to use comprehensive costs to evaluate regulations and investments that improve transportation safety. It also set the U.S. DOT policy of using $2.5 million as the benefit of averting an accidental fatality. This recommendation was based on a study by Miller et al. (1991). The 1993 guide also instructed that the value be periodically updated using the GDP-Deflator. In 1995, the U.S. DOT adjusted the value to $2.7 million (U.S.DOT 2002).

In 2002, the U.S. DOT issued a revision of the 1993 guide. The conclusion of this revised report was as follows:

Recent years have seen a considerable expansion in the number of studies published and refinement in analytical techniques. However, it
does not appear that newer estimates converge on a consensus value or range that would justify modification of our established standard, and some significant estimates continue to lie well below it. Therefore, for the present, we will continue to use the procedure adopted in the 1993 guidance. Adjusting the value of life by the GDP implicit deflator for the third quarter of 2001, we now recommend the use of a value of $3.0 million in all DOT analysis (U.S.DOT 2002).

The 1993 and 2002 DOT memorandums also set costs for avoiding non-fatal injuries (see Appendix B). The policy is to estimate the values as a fraction of the cost for avoiding a fatality. Fractions are based on the Abbreviated Injury Scale (AIS; see Table 2-6 for a listing of the fractions). The 2002 guide states that the U.S. DOT decided again to retain the relative values published in the 1993 memorandum for injuries of varying severity (U.S.DOT 2002). Thus, when the comprehensive cost for fatalities is adjusted using the GDP-Deflator, the values for injuries should also be amended.

Table 2-6. Ratios for estimating willingness-to-pay to avoid a non-fatal crash

<table>
<thead>
<tr>
<th>AIS Level</th>
<th>Descriptor</th>
<th>Fraction of fatality cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 6</td>
<td>Fatal</td>
<td>1.0000</td>
</tr>
<tr>
<td>AIS 5</td>
<td>Critical</td>
<td>0.7625</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe</td>
<td>0.1875</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious</td>
<td>0.0575</td>
</tr>
<tr>
<td>AIS 2</td>
<td>Moderate</td>
<td>0.0155</td>
</tr>
<tr>
<td>AIS 1</td>
<td>Minor</td>
<td>0.0020</td>
</tr>
</tbody>
</table>


Federal Highway Administration technical advisory

In 1994, the FHWA released a technical advisory titled Motor Vehicle Accident Costs (T 7570.2), which replaced a 1988 technical advisory of the same name (T 7570.1). The advisory offered “updated information on the most current comprehensive costs of motor vehicle traffic accidents that are appropriate for use” (FHWA 1994). It restated the position the U.S. DOT had taken in its 1993 memorandum that comprehensive costs should be used for averting fatal and non-fatal crashes in benefit-cost evaluations of safety improvement projects. The advisory included two tables of values with different injury scales; Tables 2-7 and 2-8 reproduce these tables with additional columns containing the adjusted values in 2001 dollars. To show the practical difference between using the GDP-Deflator and the Consumer Price Index (CPI), we have adjusted the values using both.
Table 2-7. Comprehensive costs in police-reported crashes by AIS severity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 6</td>
<td>Fatal</td>
<td>2,600,000</td>
<td>2,964,840</td>
<td>3,001,915</td>
</tr>
<tr>
<td>AIS 5</td>
<td>Critical</td>
<td>1,980,000</td>
<td>2,257,840</td>
<td>2,286,074</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe</td>
<td>490,000</td>
<td>558,758</td>
<td>565,746</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious</td>
<td>150,000</td>
<td>171,049</td>
<td>173,187</td>
</tr>
<tr>
<td>AIS 2</td>
<td>Moderate</td>
<td>40,000</td>
<td>45,613</td>
<td>46,183</td>
</tr>
<tr>
<td>AIS 1</td>
<td>Minor</td>
<td>5,000</td>
<td>5,702</td>
<td>5,773</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.  
†Adjusted using the CPI.  

Table 2-8. Comprehensive costs in police-reported crashes by K-A-B-C scale severity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Fatal</td>
<td>2,600,000</td>
<td>2,964,840</td>
<td>3,001,915</td>
</tr>
<tr>
<td>A</td>
<td>Incapacitating</td>
<td>180,000</td>
<td>205,258</td>
<td>207,825</td>
</tr>
<tr>
<td>B</td>
<td>Evident</td>
<td>36,000</td>
<td>41,052</td>
<td>41,565</td>
</tr>
<tr>
<td>C</td>
<td>Possible</td>
<td>19,000</td>
<td>21,666</td>
<td>21,937</td>
</tr>
<tr>
<td>PDO</td>
<td>Property damage only</td>
<td>2,000</td>
<td>2,281</td>
<td>2,309</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.  
†Adjusted using the CPI.  

National Highway Transportation Safety Administration and National Safety Council Estimates

Tables 2-9 and 2-10 contain the comprehensive costs of fatal and injury vehicle crashes as reported by NHTSA and the NSC. The NSC estimates for a fatality are about 10 percent higher than those of NHTSA. This difference is minor if you consider that the individual values approximate the dollar amounts people appear to be willing to pay to avoid a fatality.

Adjusting for inflation

When performing benefit-cost analyses, analysts must adjust values for benefits and costs to a common base year. The base year can be either the current year or a selected year in the past. To make the adjustments, one must use an appropriate index that measures inflation for goods or services over time. Crash cost literature contains recommendations on how to update the cost estimates from year to year using either the CPI or the GDP-Deflator. For example, Miller et al. recommend
using the CPI (Miller et al. 1991), whereas the U.S. DOT and the FHWA recommend using the GDP-Deflator (U.S. DOT 1993, 2002; FHWA 1994). Usually recommendations are based on the origin and precision of the estimates—if estimates are derived from precise consumer spending, then the CPI is appropriate. Before continuing the discussion of when to use the CPI or the GDP-Deflator, we will first define them.

**Table 2-9. Comprehensive costs of motor vehicle crashes—NHTSA**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 5</td>
<td>Critical</td>
<td>2,402,997</td>
<td>2,345,936</td>
<td>2,316,539</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe</td>
<td>731,580</td>
<td>714,208</td>
<td>705,258</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious</td>
<td>314,204</td>
<td>306,743</td>
<td>302,899</td>
</tr>
<tr>
<td>AIS 2</td>
<td>Moderate</td>
<td>157,017</td>
<td>153,288</td>
<td>151,368</td>
</tr>
<tr>
<td>AIS 1</td>
<td>Minor</td>
<td>15,017</td>
<td>14,660</td>
<td>14,477</td>
</tr>
<tr>
<td>PDO</td>
<td>Property damage only</td>
<td>2,532</td>
<td>2,472</td>
<td>2,441</td>
</tr>
</tbody>
</table>

*Adjusted using the GDP-Deflator.
†Adjusted using the CPI.

**SOURCE:** Blincoe 2002.

**Table 2-10. Comprehensive costs of motor vehicle crashes—NSC**

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Cost per injury (2000 dollars)</th>
<th>Cost per injury (2001 dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>3,214,290</td>
<td>3,340,000</td>
</tr>
<tr>
<td>Incapacitating</td>
<td>159,449</td>
<td>165,000</td>
</tr>
<tr>
<td>Non-incapacitating</td>
<td>41,027</td>
<td>42,500</td>
</tr>
<tr>
<td>Possible</td>
<td>19,528</td>
<td>20,200</td>
</tr>
<tr>
<td>No injury</td>
<td>1,861</td>
<td>1,900</td>
</tr>
</tbody>
</table>

**SOURCES:** NSC 2002 and 2003.

The CPI measures inflation experienced by consumers in their day-to-day living expenses (Bureau of Labor Statistics [BLS] 2003). The measure represents all goods and services purchased by urban consumers, urban wage earners, and clerical workers (87% of the U.S. population). Expenditure items are classified into more than 200 categories, arranged into eight major groups that include transportation and medical care (BLS 2003). The Bureau of Labor Statistics provides the CPI for downloading at http://www.bls.gov/cpi/.
The GDP-Deflator is a broad-based index combining the prices paid by federal, state, and local governments, businesses, and consumers (BLS 2003). It is a measure of inflation in the overall economy of the United States. The GDP-Deflator may be found on the Saint Louis Federal Reserve Bank website at http://research.stlouisfed.org/fred2/categories/21.

As stated previously, there are conflicting recommendations for selecting the appropriate index. The basis of the Miller et al. study (1991) was specifically identified consumer expenditures, such as medical costs. As a result, they recommended use of the CPI. They suggest that each cost estimate component be updated using the appropriate index from the CPI when available, and that the general CPI be used for all others. Their rationale is that the inflation rate for individual components can be drastically different than the broad-based GDP-Deflator.

On the other hand, the U.S. DOT and the FHWA recommend the GDP-Deflator, a general index. Both the 2002 U.S. DOT memorandum and the FHWA technical advisories stress that comprehensive costs are imprecise measures of people’s willingness-to-pay to avoid crashes. They recommend the general index so as not to imply great accuracy in the cost estimates.

Because the U.S. DOT, FHWA, and Miller et al. vary in their use of the two indexes, we updated the estimates using both to judge the practical difference. The last two columns in Tables 2-7, 2-8 and 2-10 contain adjusted dollar values. For the period between the early 1990s and 2001, the practical difference between the two is small. For example, the percent difference between the fatality values updated using the GDP-Deflator and CPI in Table 2-10 is 1.2 percent. Based on the results, over this period, there is no practical effect of selecting either index.

STATE APPROACHES TO ASSIGNING DOLLAR VALUES TO CRASHES

The interviews revealed that 26 DOTs currently use FHWA Technical Advisory T 7570.2 as the basis for specific dollar values. One DOT uses FHWA Technical Advisory T 7570.1, and another identified the U.S. DOT 2002 memorandum as the source of its values. Although 25 state DOTs use either T 7570.2 or T 7570.1, they do not all use the same values. This is because some DOTs elect to use the CPI rather than the GDP-Deflator to adjust the values recommended by the advisory. Some update the value of avoiding a fatality but not of avoiding an injury. Other differences occur because DOTs have different lag periods for reporting crash data (see Figure 2-1 for the spatial distribution of data sources). Table 2-11 lists the values used by states and whether they are based on a FHWA technical advisory or on the 2002 U.S. DOT memorandum.

Figure 2-2 is a graphical representation of dollar value of a fatality by state.
Table 2-11. Dollar values used by DOTs based on FHWA technical advisory

<table>
<thead>
<tr>
<th>State DOT</th>
<th>Index</th>
<th>Update</th>
<th>Fatality</th>
<th>Injury</th>
<th>PDO</th>
<th>$ Per</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD</td>
<td>CPI</td>
<td>2001</td>
<td>4,102,000</td>
<td>130,000</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CA</td>
<td></td>
<td>2002</td>
<td>3,700,000</td>
<td>587,000</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>NY</td>
<td></td>
<td>2002</td>
<td>3,636,493</td>
<td>99,938</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>MO</td>
<td>CPI</td>
<td>1999</td>
<td>3,600,000</td>
<td>47,000</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>OR</td>
<td>GDP-Def.</td>
<td>2001</td>
<td>3,600,000</td>
<td>300,000</td>
<td>65,000</td>
<td>35,000</td>
</tr>
<tr>
<td>WA</td>
<td>GDP-Def.</td>
<td>1999</td>
<td>3,570,000</td>
<td>300,000</td>
<td>65,000</td>
<td>35,000</td>
</tr>
<tr>
<td>MN</td>
<td>GDP-Def.</td>
<td>2002</td>
<td>3,400,000</td>
<td>270,000</td>
<td>58,000</td>
<td>29,000</td>
</tr>
<tr>
<td>NC</td>
<td>CPI</td>
<td>2000</td>
<td>3,300,000</td>
<td>200,000</td>
<td>57,000</td>
<td>27,000</td>
</tr>
<tr>
<td>KS</td>
<td>GDP-Def.</td>
<td>2001</td>
<td>3,113,950</td>
<td>43,100</td>
<td>22,750</td>
<td>2,400</td>
</tr>
<tr>
<td>DE</td>
<td></td>
<td></td>
<td>3,090,000</td>
<td>180,250</td>
<td>180,250</td>
<td>180,250</td>
</tr>
<tr>
<td>ID</td>
<td>GDP-Def.</td>
<td>Yearly</td>
<td>3,026,107</td>
<td>209,500</td>
<td>41,900</td>
<td>22,114</td>
</tr>
<tr>
<td>WI</td>
<td>GDP-Def.</td>
<td>2002</td>
<td>3,022,400</td>
<td>41,850</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>WY</td>
<td>GDP-Def.</td>
<td>2002</td>
<td>3,000,000</td>
<td>18,704</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>AL</td>
<td>GDP-Def.</td>
<td>2002</td>
<td>3,000,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>SC</td>
<td>GDP-Def.</td>
<td>2001</td>
<td>3,000,000</td>
<td>207,000</td>
<td>41,400</td>
<td>21,700</td>
</tr>
<tr>
<td>SD</td>
<td>CPI</td>
<td>Yearly</td>
<td>3,000,000</td>
<td>209,000</td>
<td>42,000</td>
<td>22,000</td>
</tr>
<tr>
<td>MT</td>
<td></td>
<td></td>
<td>3,000,000</td>
<td>170,000</td>
<td>43,000</td>
<td>17,000</td>
</tr>
<tr>
<td>PA</td>
<td>GDP-Def.</td>
<td>2000</td>
<td>2,882,516</td>
<td>1,043,826</td>
<td>69,990</td>
<td>5,543</td>
</tr>
<tr>
<td>UT</td>
<td>GDP-Def.</td>
<td>2000</td>
<td>2,722,548</td>
<td>228,568</td>
<td>48,333</td>
<td>25,228</td>
</tr>
<tr>
<td>WV</td>
<td></td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>NH</td>
<td>Not updated</td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>IN</td>
<td></td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>AZ</td>
<td>Not updated</td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>OK</td>
<td></td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>ME</td>
<td>Not updated</td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>FL</td>
<td>Not updated</td>
<td>1994</td>
<td>2,600,000</td>
<td>180,000</td>
<td>36,000</td>
<td>19,000</td>
</tr>
<tr>
<td>NV</td>
<td></td>
<td>2,400,000</td>
<td>209,000</td>
<td>*</td>
<td>*</td>
<td>3,300</td>
</tr>
<tr>
<td>NE</td>
<td>GDP-Def.</td>
<td>1998</td>
<td>1,700,000</td>
<td>69,600</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>IA</td>
<td></td>
<td>2001</td>
<td>1,000,000</td>
<td>150,000</td>
<td>10,000</td>
<td>2,500</td>
</tr>
<tr>
<td>AR</td>
<td>Not updated</td>
<td>1994</td>
<td>150,000</td>
<td>11,000</td>
<td>11,000</td>
<td>11,000</td>
</tr>
<tr>
<td>KY</td>
<td></td>
<td>100,000</td>
<td>100,000</td>
<td>*</td>
<td>*</td>
<td>3,000</td>
</tr>
</tbody>
</table>

*Indicates that the DOT uses only one value for all types of injuries.
*Per crash based on Cost per Injury supplied by Ted Miller and Rebecca Spicer
*Other source
COST PER INJURY OR COST PER CRASH

The comprehensive and human capital costs reported by the FHWA, NHTSA, and NSC are costs per fatality or injury, not per fatal or injury crash. Safety analysis requires that these values be converted into costs per crash. Therefore a method must be adopted to convert the costs to the appropriate units. The following method is typical among the DOTs. During the year 2000 in the state of North Carolina, 1,567 fatalities occurred in 1,415 crashes. In addition to the fatal injuries, there were 478 incapacitating, 617 evident, and 453 possible injuries that occurred as a direct result of fatal crashes. Using comprehensive costs of $2,925,100 for a fatal, $144,796 for an incapacitating, $37,486 for an evident, and $17,916 for a possible injury, one can calculate the total cost per fatal crash. North Carolina uses cost values obtained and updated by Children’s Safety Network Economics and Insurance Center (Troy 2001). For each class of injury, the state multiplies the frequency by its cost, sums the products, and divides the sum by the number of fatal crashes. In 2000, the total cost per fatal crash was $3,094,556, which they rounded to $3,300,000. This is the comprehensive cost that North Carolina assigns to fatal crashes (Troy 2001).

CONCLUSIONS

Attaching cost values to crashes that kill or injure people or damage their property is bound to be difficult. Over the years, two main methodologies have been
suggested for arriving at estimates of such costs. The human capital approach focuses on out-of-pocket costs associated with injuries and the loss of productivity such injuries cause. An alternative approach, the comprehensive cost approach, adds the costs of intangible consequences of crashes, including pain and suffering.

Whatever approach is used, for safety improvements to be evaluated for their cost-effectiveness, it is necessary to assign dollar values to fatalities and injuries. The literature is replete with theoretical and empirical assessments of what such values should be. The values various authors suggest vary quite widely. Likewise, various state and federal agencies apply differing dollar figures to fatalities and personal injuries. In recent years, the U.S. DOT has provided useful guidance regarding cost values that should be used when evaluating projects funded at least in part with federal dollars. These cost values are based on the comprehensive cost approach, which has become the most accepted approach.

Our survey of state DOTs indicates that most derive their values from the U.S. DOT and FHWA memorandum on cost values. Some states have developed innovative approaches to combining costs, recognizing that in many fatal crashes more than one person is killed or injured and property is damaged.
CHAPTER 3
APPLICATION OF CRASH COSTS BY STATE DOTS

State DOTs use the values for fatalities and injury crash costs in several ways. Most use specific values when reporting the costs of crashes within their state, and some use the values to identify high-crash locations. Several DOTs use crash costs to prioritize the funding of safety improvement investments once high-crash locations have been pinpointed. Others use them to estimate the benefits of proposed safety improvements and to eliminate those in which the costs exceed the benefits. Only a few DOTs use these values directly in reviewing design exception requests or the continuation of existing below-standard designs.

Knowing the source of the values assigned to fatalities and injuries is important for proper analysis and reporting. Both the NSC bulletins and the NHTSA report emphasize that human capital costs of crashes are different than comprehensive costs. Whether one chooses to use human capital or comprehensive costs will therefore depend on one’s objective. The following sections discuss the current roles of human capital and comprehensive costs in state-level safety analysis, reporting, and investment decisions.

ESTIMATES OF PAST ECONOMIC LOSS

Many states use values derived from estimations of dollars spent and income not received—defined as human capital costs—for estimating the cost of crashes within the state. These cost estimates are an accounting of the actual economic transactions measured in dollars. The values represent the dollar amount that a person would need to compensate for financial losses related to a crash.

Minnesota, Indiana, and Wisconsin, for example, report that they use the NSC values in their annual crash facts reports. The following is an excerpt from Minnesota’s 2002 City County Crash Cost report prepared by the Department of Public Safety.

The cost estimates presented in this report are based on the National Safety Council’s estimates for 2001. The following tables are based on the economic impact of motor vehicle crash injuries and fatalities. They do not represent the more intangible consequences of motor vehicle crashes such as pain and suffering. Based on the National Safety Council’s cost estimates, total economic loss from traffic crash injuries and fatalities in Minnesota in 2002 was nearly 1.3 billion dollars (MOTS 2003, p. 10).

Compare this to an example of the improper use of fatality and injury costs in estimating economic loss due to crashes.
Economic Cost of Collisions. Table 4 gives estimated economic costs for Idaho motor vehicle collisions in 2001. Estimates in this table are based on 1994 Federal Highway Administration (FHWA) cost estimates for collisions. The cost estimates are updated to 2001 dollars using the Gross Domestic Product Implicit Price Deflator Ratio. The components of the cost estimates include productivity losses, property damage, medical costs, rehabilitation costs, travel delay, legal and court costs, emergency service costs, insurance administration costs, premature funeral costs and costs to employers. The estimated cost of Idaho collisions in 2001 was $1.5 billion. The total cost of collisions in 2001 was $45 million dollars less than the estimated cost of collisions in 2000 (IOHS 2003, p. 6).

While the preceding paragraph defines human capital costs, the values reported in the 1994 FHWA Technical Advisory are comprehensive costs. This renders the conclusion of Idaho’s Office of Highway Safety incorrect. The value they report is the total societal cost, which can be significantly greater than human capital cost.

The misuse of crash cost data in safety analysis is evident in education as well as in practice. For example, Garber and Hoel (1999, p. 154) recommend the use of NHTSA crash unit costs in benefit-cost analysis to establish project priorities if state values are not available. They make this recommendation without drawing the distinction between economic and comprehensive costs and the proper use of either. When discussing crash costs, they write, “Published data vary widely, and the most prudent course, if an economic value is desired, is to select a value that appears most appropriate for the given situation” (Garber and Hoel 1999, p. 564). They state that benefit-cost analysis should be used to show which investment will result in a benefit to society, although no mention is made of using values that measure societal costs.

PRIORITIZING SAFETY IMPROVEMENT PROJECTS

Twenty-two state DOTs use dollar values for fatalities and injury crash costs in prioritizing safety improvement projects. The driving force behind this approach is the Hazard Elimination Program that funds safety improvements. Many DOTs, however, expressed concern about the use of the recommended value for avoiding fatalities. Comments suggested that using a value for fatalities that is nearly 15 times larger than that for an incapacitating injury (in the case of the FHWA recommendation) leads to skewed results. The DOTs were concerned that using either the comprehensive or the human capital values skews the listing of high-crash locations towards sites that have fatalities, as opposed to those that have a much larger number of personal-injury crashes. They felt that the resulting ranking is essentially a listing of fatal crash sites, and could result in a misallocation of safety improvement dollars.

The impression of misallocated safety funds stems from the belief that the difference between a fatal crash and one with severe injuries is difficult to trace directly to geometric deficiencies in the roadway. Because the majority of safety improvement
funds are spent on upgrading geometric deficiencies, a site with a fatal crash will take priority over—and resources from—a site with many incapacitating injuries. As one respondent put it, “Fatal accidents are like lighting, they happen a lot but rarely in the same place.”

Several solutions to the perceived problem were presented. Six DOTs merge the fatal and incapacitating values into one and use that value in their analysis whenever a fatal or incapacitating injury crash occurs. To obtain the combined dollar value, they weight the fatal and incapacitating injury values using the statewide frequency of occurrence for each crash type. Four other DOTs weight costs with criteria such as average daily traffic or with assigned integer values. The representative of the DOT that uses integer values said that they reflect the impacts of each crash type, but did not know the source or derivation of the values. Four DOTs avoid the problem by calculating crash costs by type of crash rather than by injury severity. Finally, three DOTs calculate crash cost by facility type. Thus, a total of 17 state DOTs use modified values for crash analysis. Table 3-1 presents the methods used by state. The remaining DOTs reported that they use the values as listed in Tables 2-3, 2-9, and 2-10.

Table 3-1. State DOT modification of cost values

<table>
<thead>
<tr>
<th>State</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>By area type</td>
</tr>
<tr>
<td>Idaho</td>
<td>By crash type</td>
</tr>
<tr>
<td>Illinois</td>
<td>By crash type</td>
</tr>
<tr>
<td>Nebraska</td>
<td>By crash type</td>
</tr>
<tr>
<td>Oregon</td>
<td>By crash type</td>
</tr>
<tr>
<td>Florida</td>
<td>By facility and area type</td>
</tr>
<tr>
<td>New York</td>
<td>By facility and area type</td>
</tr>
<tr>
<td>Indiana</td>
<td>By facility type</td>
</tr>
<tr>
<td>Kansas</td>
<td>Merges fatalities with injuries using frequencies</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Merges fatalities with injuries using frequencies</td>
</tr>
<tr>
<td>Missouri</td>
<td>Merges fatalities with injuries using frequencies</td>
</tr>
<tr>
<td>Washington</td>
<td>Merges fatalities with injuries using frequencies</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Merges fatalities with injuries using frequencies</td>
</tr>
<tr>
<td>Michigan</td>
<td>Weights by ADT and number of crashes</td>
</tr>
<tr>
<td>Texas</td>
<td>Weights costs to develop a safety index</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>Weights fatalities with injuries using assigned integer values</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Weights with crash frequencies</td>
</tr>
</tbody>
</table>
For the purposes of illustration, we look at the method the Washington State DOT uses to merge fatal and disabling injuries costs into one value. Washington uses, in 1999 dollars, $3,570,000 per fatal crash and $300,000 per disabling injury crash. In 1999, there were 311 fatal and 1,178 disabling crashes in the state. The DOT multiplied the cost values by crash frequencies and divided by the sum of the crash frequencies to obtain a combined value of $982,989 per crash, which was rounded to $1,000,000. They use this value for the societal costs per fatal or disabling injury crash.

The California DOT (Caltrans) also merges the dollar values for fatal and personal injury crashes, and bases their values on the location of the crash. They distinguish between fatal and injury crashes that occur in urban areas and those in rural areas. In addition, they merge all personal injury crashes into one category of severity. The final values are $24,000 per urban fatal and injury crash and $61,000 per rural fatal and injury crash. These values are used for prioritizing projects submitted for funding through their Hazard Elimination Safety program.

The New York DOT calculates the cost of crashes based on facility type. Using crash frequency, severity, and location data, they developed 103 cost values for different facility types. Examples of these costs are shown in Table 3-2.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Fatal</th>
<th>Injury</th>
<th>Fatal/Injury</th>
<th>PDO</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full access, rural, divided, 4-lane</td>
<td>3,886,600</td>
<td>97,700</td>
<td>161,100</td>
<td>5,200</td>
<td>39,200</td>
</tr>
<tr>
<td>Full access, urban, divided, 4-lane</td>
<td>3,518,900</td>
<td>103,200</td>
<td>129,100</td>
<td>3,800</td>
<td>47,800</td>
</tr>
<tr>
<td>Partial access, rural, divided, 4-lane</td>
<td>3,411,900</td>
<td>89,800</td>
<td>107,600</td>
<td>5,200</td>
<td>25,200</td>
</tr>
<tr>
<td>Partial access, urban, divided, 4-lane</td>
<td>3,506,900</td>
<td>93,700</td>
<td>119,600</td>
<td>3,800</td>
<td>40,200</td>
</tr>
<tr>
<td>Free access, rural, undivided, 2-lane</td>
<td>3,708,700</td>
<td>95,900</td>
<td>189,100</td>
<td>5,200</td>
<td>49,000</td>
</tr>
<tr>
<td>Free access, urban, divided, 2-lane</td>
<td>3,426,500</td>
<td>97,500</td>
<td>123,400</td>
<td>3,800</td>
<td>44,200</td>
</tr>
<tr>
<td>On-ramp, rural, all cntls, merge w/1 lane</td>
<td>3,224,800</td>
<td>95,800</td>
<td>122,300</td>
<td>5,200</td>
<td>36,500</td>
</tr>
<tr>
<td>On-ramp, urban, all cntls, merge w/1 lane</td>
<td>3,575,900</td>
<td>103,300</td>
<td>123,500</td>
<td>3,800</td>
<td>40,700</td>
</tr>
<tr>
<td>Off-ramp, rural, all cntls, merge w/1 lane</td>
<td>3,224,800</td>
<td>95,800</td>
<td>122,300</td>
<td>5,200</td>
<td>36,500</td>
</tr>
<tr>
<td>Off-ramp, rural, all cntls, merge w/2&amp;&gt; lane</td>
<td>3,224,800</td>
<td>95,800</td>
<td>122,300</td>
<td>5,200</td>
<td>36,500</td>
</tr>
</tbody>
</table>

**Source:** New York State Department of Transportation Safety Information Management System, 2000.
The solutions presented in the preceding paragraphs are derivations of a method proposed by the FHWA in their Technical Advisory 7570.1, which states:

To avoid disproportionate attention to locations where a fatality occurred and thus improve decisions regarding safety improvements, States should use a combined fatal-plus-injury cost (also property damage only [PDO] if available). This may be done on a statewide basis, by functional system, by land use (rural/urban), by accident type, or some other combination depending upon the data available with the State’s accident records system. (FHWA 1988)

They provided the following formula for calculating the average cost for fatal and injury crashes.

$$\text{cost($)/ fatal + injury accident} = \frac{(\text{fatalities} \times \text{fatality cost}) + (\text{injuries} \times \text{injury cost})}{\text{fatal accidents} + \text{injury accidents}}$$

**BENEFIT-COST ANALYSIS APPROACHES**

The typical approach used by state DOTs to evaluate the economic value of a proposed project is benefit-cost analysis. Benefit-cost analysis relies on four principles from applied welfare economics: consumer sovereignty, welfare maximization, valuation of goods according to willingness-to-pay, and neutrality with respect to distributive outcomes (Elvik 2001). These principles require that consumers have the ability to place values on the choices they face. In the case of safety improvements, the choice is whether to make an improvement, and if so, which one. The principles call for consumers to communicate the value they place on their choices using willingness-to-pay methods. Welfare maximization is measured using consumers’ preferences based on willingness-to-pay. The last principle dictates that the results of the analysis should not be concerned with which groups in society benefit, but rather that society benefits as a whole.

If the goal is to maximize social welfare by minimizing loss to society, the cost values must be the total costs of crashes, including loss of life or quality of life. Because the human cost values do not account for intangible losses—those that are experienced by people but not seen as dollar transactions—it is inappropriate to use them in benefit-cost analysis because they do not measure total societal loss. Clearly, the requirements of benefit-cost analysis mean using comprehensive costs; otherwise, the theoretical foundation of benefit-cost would be compromised.

**STATE DOTS’ USE OF BENEFIT-COST ANALYSIS**

Thirty-four DOTs reported that they use benefit-cost analysis to prioritize or qualify safety-related projects. Nine of these states use it to qualify projects for funding but not as a means of prioritizing projects relative to one another. Safety-related projects qualify for funding if the benefit-to-cost ratio exceeds one; if the ratio is less than one, the project is rejected. Wisconsin allows intervening criteria to override this decision in certain situations. In states that use benefit-cost to qualify projects,
if the ratio exceeds one, the project is evaluated further. For example, the project might be accepted for funding if it could be programmed that year.

Four DOTs reported that they do not use benefit-cost analysis. These DOTs stated that they rely on experience, intuition, and engineering judgment to evaluate the merits of projects; some said that they do not use benefit-cost analysis because of staff limitations. DOTs that do use benefit-cost analysis to qualify or prioritize safety-related projects are listed in Table 3-3. Figure 3-1 illustrates the location of these DOTs.

Table 3-3. State DOTs that use benefit-cost analysis in safety improvement project evaluations

<table>
<thead>
<tr>
<th>Alabama</th>
<th>Kentucky</th>
<th>Oklahoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>Maine*</td>
<td>Oregon</td>
</tr>
<tr>
<td>California</td>
<td>Maryland*</td>
<td>Pennsylvania</td>
</tr>
<tr>
<td>Connecticut*</td>
<td>Michigan</td>
<td>South Carolina*</td>
</tr>
<tr>
<td>Delaware</td>
<td>Minnesota</td>
<td>South Dakota</td>
</tr>
<tr>
<td>Florida</td>
<td>Missouri</td>
<td>Texas</td>
</tr>
<tr>
<td>Idaho</td>
<td>Nebraska</td>
<td>Utah</td>
</tr>
<tr>
<td>Illinois</td>
<td>Nevada</td>
<td>Washington</td>
</tr>
<tr>
<td>Indiana</td>
<td>New York*</td>
<td>West Virginia*</td>
</tr>
<tr>
<td>Iowa</td>
<td>North Carolina*</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>Kansas</td>
<td>Ohio</td>
<td>Wyoming</td>
</tr>
</tbody>
</table>

*DOTs use benefit-cost analysis to qualify projects but not to prioritize them.

Several times in the interviews concerns were raised that “easy” projects are being completed based on benefit-cost ratios. The implication was that projects with high benefit-cost ratios (well over 10), which are projects with low capital cost requirements, are being funded. Other projects that have lower benefit-cost ratios often are larger in scale and therefore have large capital costs—so large that they may exceed safety improvement budgets. Most economists would suggest that these DOTs consider using the net present value (NPV) approach, whereby discounted costs are subtracted from discounted benefits, rather than dividing the later by the former. The NPV approach does not favor smaller projects with high ratios.

Minnesota’s DOT calculates a benefit-cost ratio only to prioritize its safety improvement projects. With their method, the number of crashes avoided is calculated using crash reduction factors. (Information about how the DOTs use crash reduction factors is presented in the next section.) The number and costs of avoided crashes allows calculation of the benefits of a safety improvement. Such benefits are then projected into the future using a constant growth factor. The growth factor is an estimate of traffic growth in the state, and is currently set at
three percent. The number of years projected depends on the service life of the safety improvement. A discount rate—currently 4.5 percent—is used to calculate the present value of future benefits. Finally, the ratio of the present value of benefits to the present value of costs is obtained, and the projects are ranked using their benefit-cost ratios.

The Michigan DOT uses a decision support tool for comprehensive project prioritization called the Transportation Management System (TMS). TMS has six components that evaluate bridge, pavement, congestion, public transportation, intermodal, and safety projects. Safety projects are evaluated in the Safety Management System (SMS) using benefit-cost analysis. To perform the analysis, a computer program named the “Time of Return Analysis Package” (TOR) is used to evaluate and develop priorities for proposed safety-funded construction improvements (Michigan DOT 2003). The TOR calculates the number of years it will take for the benefits of reduced crashes to equal the costs of the improvement. It uses crash reduction factors to forecast the number of avoided crashes, and crash costs from the NSC.

**FORECASTING BENEFITS OF CRASH REDUCTION**

In order to proceed with an economic evaluation of safety-related projects, DOTs must be able to forecast the number of crashes that would be avoided due to a given safety improvement. The need to forecast the avoided crashes, or benefits, is part of safety improvement planning. Steps include identifying hazardous locations, design problems, safety improvements, and the benefits and costs of those improvements, as well as selecting the improvements that have the highest net benefits and doing before-and-after studies of them (Davis 2000).
DOTs often use reduction factors to forecast the benefits of safety improvement projects. However, those that use crash reduction factors developed outside of their state run the risk of undermining the benefit-cost procedures (Strathman et al. 2001). Strathman et al. applied a system-level framework and found statistically significant relationships between crashes and the number of lanes, curve characteristics, vertical grade, surface type, median type, turning lanes, shoulder width, and lane width. They concluded that due to the low number of system-level studies, it is unlikely the current widespread use of reduction factors will be replaced. Strathman et al. suggest, however, using the system-level approach to test the validity of critical reduction factors.

States’ approaches to forecasting benefits

The DOTs identified three methods for forecasting the benefits of safety improvements. The first was a predictive model based on mathematical formulas contained in the crash prediction module of the FHWA’s Interactive Highway Safety Design Model (IHSDM) (FHWA 2004). No state DOT, however, reported using predictive mathematical models to forecast crashes. The second forecasting method was based on intuition, past experience and engineering judgment developed from years of experience. Five DOTs stated that they base their evaluation of safety improvement benefits on experience. The third method was derived from crash reduction factors. Thirty DOTs reported using reduction factors to forecast the number of crashes that would be avoided due to safety improvements. Thirteen of those 30 have either developed new or modified previously published reduction factors. Among these DOTs, the Kentucky Transportation Center Report 96-13 was the most frequently mentioned source for reduction factors. The other 17 DOTs rely solely on previously published reduction factors. Five DOTs are currently updating their reduction factors in-house or externally. Figure 3-2 shows the geographic distribution of the use of reduction factors.

The California Department of Transportation (Caltrans) prioritizes safety projects submitted to them for funding from the Hazard Elimination Safety Program. It requires that local agencies compete for funding based on the effectiveness of their projects in eliminating or reducing the number and severity of crashes. Caltrans bases its evaluation on a safety index that is calculated using estimated benefits from avoided crashes over the life of the safety improvement and the cost of the improvement. Benefits are estimated using reduction factors.

Caltrans presents its method for combining reduction factors when a project has multiple types of improvements in Exhibit 9-B of its Safety Index Calculation Form (Caltrans 2001). As an example, it looks at a situation in which a left-turn lane and safety lighting are added to an unsignalized intersection. According to the reduction factors, left-turn lanes reduce crashes by 35 percent and lighting by 15 percent. Assuming a rate of 20 crashes per year, 12 of which occur at night, the lighting would reduce crashes by 1.8 \((12 \times 0.15 = 1.8)\). Adding the left-turn lane would reduce the remaining 18.2 crashes \((20 - 1.8 = 18.2)\) by 6.4 crashes \((18.2 \times 0.35 = 6.4)\). The total number of reduced crashes equals 8.2, from which
you can calculate the combined reduction factor of 41 percent (8.2\times 20 = 0.41 or 41 percent).

Figure 3-2. Use of reduction factors by state DOTs

ROLE OF SAFETY ANALYSIS IN DESIGN EXCEPTION REVIEWS

DOTs in states that are urbanizing quickly are finding that existing roads built to previous standards may be considered substandard today, based on road use. As one state DOT representative put it, “Essentially, we built the urban roads and we built the rural roads. What has happened is our city limits have expanded and we have rural designs in urban areas.” These DOTs face the decision of whether to upgrade existing roads to standards that meet current conditions. The rule, according to Turner and Blaschke (1995, p.25), is as follows: “If a road was designed and constructed according to the accepted standards of its day, then it did not have to be upgraded if the standard later changed. However, if the condition of the road changed (such as a large increase in traffic volume), then it might be necessary to upgrade the road.”

The cost of reconstructing existing roads to current standards can become unacceptably high. This problem has been evident since at least 1970, when emphasis began to be placed on maintaining and extending service life for existing facilities and improving safety (Turner and Blaschke 1995). As a result, the FHWA classified some work as 3R projects (resurfacing, restoration, and rehabilitation). 3R projects include pavement structural and joint repair, minor lane and shoulder widening, minor alterations to vertical grades and horizontal curves, bridge repair, and removal or protection of roadside obstacles. The rationale was that 3R projects would exempt designers from meeting current design standards for all geometric features of the roadway and thus avoid large expenditures. Projects could focus, for example, on a safety improvement such as widening the shoulder without
upgrading all other substandard features. The American Association of State Highway and Transportation Officials (AASHTO) written policy is that existing roads that do not meet the guidelines for geometric design are not necessarily unsafe and do not necessarily have to be upgraded to meet design criteria. The policy states, “The fact that new design values are presented herein does not imply that existing streets and highways are unsafe, nor does it mandate the initiation of improvement projects” (AASHTO 1994, p. xliii).

As things stand today, new construction, reconstruction, and some 3R projects must meet current design standards. New construction is defined as the construction of a highway facility where nothing of its type currently exists. Reconstruction is a major change to an existing highway within the same general right-of-way corridor. It may also signify substantial modifications to an older highway’s horizontal and vertical alignment in order to eliminate safety problems (FHWA 1997). There are situations where new or reconstruction projects cannot be made to meet existing standards, such as when it is not possible to obtain adequate right-of-way. One DOT provided an example of a project that could not obtain the right-of-way because it would have involved demolition of an historic monument. Preserving the monument was judged to be more important than meeting the design standards, so a design exception was granted.

A design exception allows for the use of criteria lower than the minimum acceptable values specified in state-adopted design standards such as those presented in A Policy on the Geometric Design of Highways and Streets (AASHTO 1994), commonly referred to as “The Green Book.” Exceptions are generally sought to avoid unacceptably high project costs or major impacts on the adjacent environment (FHWA 1997). Design exceptions can be actively sought in current roadway projects or may arise when accepted standards change. Whether they are seeking a new design exception or the continuance of an existing exception, many DOTs stated, without being asked, that they never compromise safety.

Prior to performing the telephone interviews, we learned that a complementary NCHRP synthesis on this issue, Design Exception Practices (Mason and Mahoney 2003), was in its final stage of completion. The purpose of the synthesis was in part to identify the conditions that require a design exception, data collection and analysis techniques, and agencies’ roles in preparing, reviewing, and approving design exceptions. We contacted the authors and found that they had already completed data collection using a mail-back survey. They shared as much of their findings with us as they could prior to having their work approved for release. We incorporated this information into our interview questions dealing with design exceptions, hoping to gather information not included in the synthesis, and focusing on state DOTs’ use of crash costs. Design Exception Practices was published as we were preparing this document and we cite it frequently, as we believe our work extends the findings of the synthesis.
VARIATION IN DESIGN EXCEPTION PRACTICES BY STATE

The DOTs have varying policies for what is included and reviewed in design exception requests. Twenty-four DOTs reported that some form of safety analysis is always performed in a design exception review. All 24 of these DOTs review crash history to identify high-crash locations and clusters or patterns of crashes related to the engineering portion of the project. In cases of new construction, many DOTs that review design exception requests suggest safety mitigation measures. One DOT, for example, “would suggest the installation of guardrail in areas where the proper clear zone is not available.” Eleven DOTs acknowledged that they never or rarely review design exceptions for safety. Mason and Mahoney (2003), after reviewing design exception documentation, found 26 of 30 DOTs require the collection of crash data, and 29 of 30 require an assessment of how the design exception may affect safety.

Ten of the 24 DOTs that review design exceptions for safety also perform economic analysis in the form of a cost-effectiveness analysis. None of the ten, however, use cost effectiveness as the sole criteria for granting or rejecting a design exception request. When asked to what degree benefits and cost of crashes determine design exception, one DOT responded, “It is one of a series of humps you have to get over in order to get an exception. There is no fixed rule as to when cost wins over the others.”

Mason and Mahoney asked DOTs about the type of analysis tools they use in evaluating design exceptions. Responses included accident information, accident trends, before/after studies, classical statistical methods, collision/condition diagrams, and benefit-cost analysis. Based on the data contained their report, 16 of the 46 DOTs responding routinely use benefit-cost analysis in design exception evaluations. Of those 16, Iowa and West Virginia are the only ones that use benefit-cost analysis as the predominate evaluation method, with other methods occasionally or never used. The other 14 DOTs routinely use at least one other analysis tool in their evaluation (Mason and Mahoney 2003, Appendix D Table D8).

The Florida DOT has a detailed policy on the use of benefit-cost analysis for evaluating design exceptions. It requires that the analysis be performed to assess the cost-effectiveness of correcting or mitigating a substandard design feature. Analysts may use either a manual crash history method or a computer program to calculate the benefit-cost ratio. The two methods differ in their use of crash costs. The crash history method uses crash costs based on facility and area types derived from the FHWA 1994 Technical Advisory. The computer program, on the other hand, uses crash costs based on severity straight from the FHWA 1994 Technical Advisory.

Regardless of the method used, the Florida policy clearly states that benefit-cost ratios are only one of several criteria used to evaluate design exceptions. The policy regarding the use of benefit-cost ratios is: “A benefit/cost ratio indicates the cost effectiveness of implementing a particular design. However, the final decision is a management decision that considers all factors important to the successful
implementation of the Department’s mission” (Florida DOT 2000, pp. 23-25). Figure 3-3 indicates the states that do and do not perform safety reviews of design exception requests.

We were interested in documenting the role of safety offices in the design exception review and decision process. Our interviews revealed that the role of such offices is limited. Twenty-two of the 24 DOTs that perform some type of safety analysis for design exceptions indicated that the safety office only supplied data for the design exception review. There were two exceptions; Utah and Pennsylvania reported that their safety offices perform safety reviews independently from their design offices. In general, however, it appears that the offices responsible for reviewing design exceptions use safety offices as a data resource and estimate the impacts on safety themselves.

Mason and Mahoney (2003) addressed the question of who reviews design exception requests and who grants the final approval for design exceptions. They found that 22 DOTs have an office or committee other than the office preparing the design exception review design exception requests whereas, 24 do not require independent review. They also found that 12 DOTs allow the office that prepares the design exception request to review and approve design exceptions without independent oversight. The Iowa DOT is one of the 12 DOTs that review and approve design exceptions within the same office (Mason and Mahoney 2003).

Figure 3-3. Safety reviews of design exception requests
CONCLUSIONS

The way state DOTs apply safety cost savings that may result from highway improvements varies quite widely, and some practices are more defensible than others. It appears that a growing number of states are using comprehensive costs, as recommended by the U.S. DOT, FHWA, NHTSA, and NSC. These values, of course, will result in higher cost estimates than would costs derived by applying the human capital approach.

A dilemma often exists in terms of how to combine the costs of fatal and personal-injury crash rates. Because of the values assigned to them, a fatal crash site is likely to be accorded a higher priority than sites with multiple personal-injury crashes, even if these injuries are serious or even incapacitating. Various states have developed weighting schemes to address this dilemma, such as taking into account the relative frequency of occurrence of the different types of crashes.

Use of crash cost values in project evaluation can take several forms, one of which is benefit-cost analysis. Currently, 31 states apply benefit-cost analysis in some form to prioritize safety projects. Some states have expressed concern that the benefit-cost ratio inherently tends to favor smaller projects with high benefit-to-cost ratios. Subtracting discounted costs from discounted benefits to yield the net present value is one way to avoid this bias.

An important application of safety cost analysis is to evaluate design exceptions. Design exceptions frequently arise in areas that are developing rapidly, where roads that met rural standards may not conform to standards for urban areas. One approach is to evaluate a road’s crash history and to compare the costs of crashes to the cost of upgrading it. Several states have developed rather sophisticated means for carrying out analyses to determine when a design exception compromises safety to a point where an upgrade is called for.
CHAPTER 4
RECOMMENDATIONS

Our review of other state DOT’s practices indicates that the Iowa DOT’s safety analysis methods generally conform to the current standard of practice. From the information we gathered through our review of the literature and survey, we do, however, suggest a number of revisions to the approaches used.

RECOMMENDED VALUES FOR REPORTING ECONOMIC LOSS

The cost values of NHTSA and NSC differ in terms of who needs to adjust the values for inflation and how. While NSC values are updated and published each year, NHTSA crash cost reports are infrequent. The NSC general approach is to adjust benchmark costs to the current year using an appropriate inflator for each component (NSC 2001). The NSC benchmarks are limited, however, in that they are not as current as those of NHTSA. In fact, some of the NSC benchmarks are drawn from the most recent NHTSA costs report.

In the latest NHTSA report, significant improvements were made in how costs are developed (Blincoe 2002). This is one advantage of using the NHTSA values. However, if you want values in current-year dollars rather than 2000 dollars, you should update the figures using specific indices related to the cost components or a general inflation index such as the GDP-Deflator.

NSC and NHTSA use different injury severity scales to report their costs. NSC uses the KABC scale, whereas NHTSA employs the AIS categories. Conversions between the two scales cannot be completed using only the final reported costs. Therefore, choosing between the NHTSA or NSC costs can be as simple as selecting the values based on the categories used in your state.

The human capital costs reported by both the NHTSA and the NSC are appropriate for reporting economic losses within the state. There are no major theoretical differences between the two sources, and you can overcome the practical differences between them easily. Therefore, we do not recommend either set of values over the other. We do, however, advise you to choose the source that matches how your state reports crash severity, to convert the costs from dollars per injury to dollars per crash, and to adjust the costs for inflation yearly.

RECOMMENDED VALUES FOR SAFETY IMPROVEMENT PROJECT EVALUATION

We recommend the use of comprehensive cost values derived from the consumer behavior, labor market, and willingness-to-pay methods for evaluating investments in safety projects. Our recommendation is based on the fact that researchers derive comprehensive costs in accordance with the same welfare economic principles that
analysts use to justify benefit-cost analyses of future investments. There is, however, no strong theoretical basis for selecting between the comprehensive cost values published by the NSC, NHTSA, the FHWA, or more generally, the U.S. DOT. These values all have sound economic basis, and are similar in magnitude. See Tables 2-8, 2-9, and 2-10 for the specific values.

While there are no compelling theoretical grounds for selecting between sources of comprehensive costs, there are practical reasons. The DOT has recently recommended that all their administrations continue to use the comprehensive costs and adjustment procedures contained in the U.S. DOT 1993 guidance memorandum (U.S.DOT 2002). As mentioned, these costs and adjustment procedures are identical to those contained in the FHWA 1994 Technical Advisory. We therefore recommend use of the FHWA inflation-adjusted comprehensive costs in investment evaluations. As additional support for the practicality of this recommendation, the majority of state DOTs currently base their cost values on the FHWA-recommended values. It is noteworthy that the values of other organizations lack significant theoretical differences from the FHWA values, and that the FHWA values are reported in the two common injury severity scales.

**RECOMMENDED USE OF VALUES IN RANKING HIGH-CRASH LOCATIONS**

The Iowa DOT recently revised its method for valuating losses. The current Iowa process, summarized by Pawlovich (2002), combines a rank for crash frequency, crash rate, and crash severity into one final score. The value of losses due to crashes is a surrogate for crash severity and is the sum of the dollar values for fatalities, major-, minor-, and possible-injury crashes, and PDO crashes. A dollar value of $1,000,000 is assigned to a fatality, $150,000 for a major injury, $10,000 for a minor injury, and $2,500 for possible injury and PDOs (Pawlovich 2002). This represents a major revision of the value loss process. Previously, dollar values for fatal, major and minor injury, and PDO were multiples of a possible injury (Hallmark 2001).

We recommend that the Iowa DOT set and annually update the costs for fatalities, personal injury, and PDO crashes according to the inflation-adjusted values reported by NSC. Human capital costs are appropriate for use in ranking crash locations because one is evaluating economic loss due to crashes that have occurred. We recommend the NSC values because the Iowa DOT crash severity data matches that of NSC, not of NHTSA. The NSC costs provide a sound economic justification for comparing severity of injuries. In addition, the human capital costs reflect the actual economic costs of different types of crash injuries.

Following the practice of other DOTs, we recommend using the high-crash location list as a starting point for the selection of safety improvement projects.

**RECOMMENDED USE OF VALUES IN DESIGN EXCEPTION REVIEWS**

The DOTs we interviewed indicated that safety analysis is an important part of the design exception evaluation process. Most reported, without prompting, that they
would not compromise safety when seeking new or continuing existing design exceptions. There is evidence for this in the fact that many DOTs frequently if not always perform a safety analysis in the form of analyzing crash histories.

Although safety analysis is common, economic evaluation of design exceptions that includes the benefit of avoided crashes is not. The four DOTs that frequently or always perform this type of analysis report that it is only one of several criteria used in the approval decision.

The Office of Local Systems (OLS) describes the Iowa DOT design exception process in Instructional Memorandum (I.M.) 3.218 (OLS 2001). I.M. 3.218 defines an eight-step process for use by county engineers. These steps are:

1) Determine the type of improvement.
2) Determine if the proposed improvement meets current design guides.
3) Analyze the crash data.
4) Prepare a cost estimate to bring the deficiencies up to current guidelines.
5) Calculate benefit to cost ratio.
6) Prepare a cover letter to the Iowa DOT requesting the exception.
7) Document the design exception in the project file.
8) Obtain approval/disapproval by the Iowa DOT.

According to the memorandum, county engineers should calculate the benefit-cost ratio by following the steps established in I.M. 3.216 (OLS 2002). The memorandum includes worksheets to calculate this ratio. The OLS also provides downloadable electronic worksheets at http://www.dot.state.ia.us/local_systems/publications/publications.htm. The worksheets attached to I.M. 3.218 and the electronic worksheets differ slightly. For example, the electronic version allows engineers to enter yearly operation and maintenance costs as “other annual costs,” while the I.M. 3.218 worksheets do not have that option.

I.M. 3.218 contains statements that reflect the uncertainty of the costs and benefits used in design exception reviews. This uncertainty is partially caused by the fact that the benefit-cost ratio is required when the project is in the preliminary design stage; uncertainty in terms of benefits is partly due to the crash reduction estimation process. It is common for agencies to acknowledge these uncertainties. For example, the U.S. DOT 2002 memorandum states: “It is important to emphasize that these values are imprecise and should be treated neither as an automatic justification for action or as a rigid barrier, but as a guide to thoughtful decision-making” (U.S.DOT 2002). The NSC also cautions users that their cost values are only approximations and not exact figures.

Because of the uncertainty, the Iowa DOT uses a range of benefit-cost ratios in their approval process for new or to continue existing design exceptions. According to
the memorandums, if the benefit-cost ratio is less than 0.8, the improvement is not cost-effective and therefore should not be pursued. If the ratio is greater than 1.20, the improvement is cost-effective and should be accomplished as part of the project or programmed in the near future. For projects where the ratio falls between 0.8 and 1.20, the county engineer must document other mitigating factors to assist the Iowa DOT in deciding if the new or existing design exception should be allowed. I.M. 3.216 lists six mitigating factors county engineers can consider when the benefit-cost ratio is between these values. The six factors are:

1) The crash rate determined in the forms should be reviewed against the statewide average for all secondary roads.

2) Type of crashes should be reviewed against the type of improvement. If the majority of the crashes within the project termini occurred at intersections, then flattening foreslopes may not have much of an effect.

3) The severity of the crashes should be reviewed with respect to location. If most of the crashes along the route were PDOs and one location had a number of injury or fatality crashes then a review of that particular "spot" location may be in order.

4) The cost of the improvement being considered should be compared with the project cost without the improvement. If a proposed resurfacing project is estimated to cost $200,000 and the estimated cost to widen shoulders or flatten foreslopes is $500,000, it may be desirable to program the improvement at some future time. If the project is estimated at $750,000 and the improvement at $50,000, it may be wise to include the improvement.

5) The environmental or social effects of the improvement should always be considered. These might include: farmland being taken out of production, relocation of families, adverse effect on wetlands or parks, and disturbance of historical or archaeological areas. The context-sensitive design process may be appropriate.

6) In some cases, other alternatives are available that may result in a similar benefit, or lower cost partial improvements may be used to mitigate the existing condition if a total improvement is not cost effective or feasible. If the reconstruction of a horizontal curve requires taking a farmstead or relocating a bridge and is not economically feasible, installing chevrons and advisory speed plates may be used to mitigate the situation.

After reviewing I.M. 3.216 and the electronic worksheets, we conclude that the method may be biased. (For commentary on the I.M. 3.216 method, see Appendix C.) The method overestimates the benefits of crash-reduction improvements because the time value of money is not taken into account. The future values of avoided crashes and yearly operation and maintenance costs are not discounted to present values for comparison. By calculating the benefit-cost ratio as prescribed in I.M. 3.216, county engineers will ignore the fact that dollar values change from year to year and cannot be directly compared unless they are adjusted to a common base year (Boardman et al. 1996; Brent 1996). Not to do so makes it more likely
that projects with high initial costs but benefits far off in the future will pass the benefit-cost test, as the ratio in such cases is generally greater than 1.0 (Weisbrod and Weisbrod 1997).

We recommend that the benefit cost-method prescribed in I.M. 3.216 and the electronic worksheets be modified. First, we suggest that the “other annual costs” be treated as a uniform series of payments over the life of the project and discounted back to the present. The present value of the “other annual costs” should then be added to the estimated project cost—assuming all project capital costs occur in the first year—to obtain the total project cost. If the project capital costs do not all occur in the first year, then those occurring beyond the first year should be discounted to the present. Our second recommendation involves forecasting the vehicle miles traveled for each year of the project’s life. The dollar value of avoided crashes can then be calculated for each year and discounted back to the present. After the present values of the benefits and costs are obtained, the benefit-cost ratio can be calculated. The use of present values in the benefit-cost ratio will remove the existing bias in the prescribed method. See Appendix C for a comparison of our recommended modification with the existing method.

Our recommended modifications to I.M. 3.216 require the use of a discount rate. What discount rate to use, however, is a controversial policy issue that reflects political values (Weisbrod and Weisbrod 1997; Brent 1996; Boardman et al. 1996). People who view government spending as being in direct competition with private investment will argue for high discount rates (meaning that project benefits occurring in the future are valued at a relatively lower rate). People who view government spending as a catalyst for private investment, on the other hand, will argue for low discount rates (Boardman et al. 1996). Thus, “When costs precede benefits, as is the case for most projects, those who favor such projects may argue for a low rate while those who oppose them may argue for a high rate (Boardman et al. 1996, p. 175).”

According to Weisbrod and Weisbrod (1997), the discount rates used for benefit-cost analysis of transportation investments are typically in the range of four to eight percent. A survey of state DOTs found that, of 34 responding departments, all but six use discount rates of between three and five percent, with nearly half using four percent (Cambridge Systematics, Inc. 1998). Examples of discount rates used in transportation investment analysis are listed in Table 4-1.

Based on the discount rates reported in the literature and obtained from current reports, we recommend the use of a discount rate of between three and five percent. To illustrate our recommended modifications to I.M. 3.216, we have generated benefits and costs for a widening and resurfacing project and discounted future values using a four percent discount rate. In the example contained in Appendix C, discounting future benefits and annual operation and maintenance costs changes the resulting benefit-cost ratio. The ratio from the modified method is 0.99, compared to 1.46 using the original method. If the modification to I.M. 3.216 were applied, the decision based on the benefit-cost ratio would indicate that the project falls within the range of 0.8 and 1.20 that, according to the I.M. 3.216,
would allow for possible justification using the six mitigating factors contained in I.M. 3.218.

### Table 4-1. Discount rates used by other agencies

<table>
<thead>
<tr>
<th>Agency</th>
<th>Discount Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missouri Department of Transportation(^a)</td>
<td>3</td>
</tr>
<tr>
<td>Kansas Department of Transportation(^b)</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Nebraska Department of Transportation(^c)</td>
<td>3 to 7</td>
</tr>
<tr>
<td>Army Corps of Engineers</td>
<td>4</td>
</tr>
<tr>
<td>National Traffic Safety Administration(^d)</td>
<td>4</td>
</tr>
<tr>
<td>Minnesota Department of Transportation(^e)</td>
<td>4.5</td>
</tr>
<tr>
<td>State of Wisconsin</td>
<td>5</td>
</tr>
<tr>
<td>Maine Department of Transportation(^f)</td>
<td>6</td>
</tr>
<tr>
<td>Office of Management and Budget</td>
<td>7</td>
</tr>
<tr>
<td>State of Massachusetts</td>
<td>7</td>
</tr>
<tr>
<td>UK Department of Transportation</td>
<td>7</td>
</tr>
<tr>
<td>Federal Highway Administration(^g)</td>
<td>7</td>
</tr>
<tr>
<td>B.C. Ministry of Transportation and Highways</td>
<td>8</td>
</tr>
</tbody>
</table>

**SOURCE:** Weisbrod and Weisbrod 1997 unless otherwise noted.  
\(^a\)MoDot, \(^b\)Cross and Parsons 2002, \(^c\)Cambridge Systematics, Inc. 1998, \(^d\)Blincoe 2002, \(^e\)MDOT 2003, \(^f\)MeDOT, \(^g\)FHWA 1994.

**CONCLUSION**

Our review of other state DOT practices indicates that the Iowa DOT’s safety analysis methods generally conform to the current standard of practice. One notable exception is that the dollar values per injury assigned to fatal and injury crashes are relatively low, ranking above only one other DOT. To put the Iowa DOT in parity with other states, for decisions about future safety investments we recommend using crash costs based on the K-A-B-C scale and published in FHWA Technical Advisory T 7570.2. These values should be updated each year using the GDP deflator. They are appropriate for use in economic analysis of future investments because they include the total cost to society due to crashes, which is necessary for analyses such as benefit-cost.

We recommend use of the crash costs published yearly by the NSC for calculating the actual dollar loss due to crashes that occurred in the past. These dollar values account for direct and indirect costs resulting from crashes. They should be used to estimate past losses so as to be consistent with how they were estimated and with economic theory.
Our research revealed that beyond the policy that design exceptions should not compromise safety, design exception review practices vary significantly between states. We found that the Iowa DOT design exception practice is generally in accordance with standard practice, although it relies more heavily on benefit-cost analysis than most. We recommend continued use of benefit-cost analysis for design exceptions, but in a modified form. The comprehensive crash costs published in the FHWA memorandum should be used in benefit-cost analyses and updated yearly using the GDP-Deflator. Also, we suggest that the Iowa DOT modify their benefit-cost analyses to include discounting future costs and benefits to their present value equivalent. Not discounting future values biases the benefit-cost ratio in favor of projects in which costs occur in the first year and benefits occur throughout the life of the project. Not discounting future values greatly exaggerates the benefits of safety projects. Although there is not universal agreement on the appropriate discount rate, we recommend a value within the range of three to five percent based on other state DOT standard practice. These modifications can be easily incorporated into the existing computer spreadsheet for I.M. 3.216 and distributed to the county engineers by the OLS.
REFERENCES


U.S. DOT. 1993. “Fatality and Injury Risk Reduction: Departmental Guidance in the Conduct of Economic Evaluations.” Attachment to *Treatment of Value of...


APPENDIX A
INTERVIEW QUESTIONS

The following questions were asked of DOT staff contacted for telephone interviews between May and June of 2003. The interviews were informal and conversational. Although we number the questions here for ease of reference, question order in the interview was determined by the conversation flow—i.e., the order of the questions depended on individual responses.

1) Does your office use specific dollar values for crash analysis? If you do:
   - What are the specific values you use?
   - What is the source of the values?

2) Do you or does anyone in your office update these values? If you do:
   - How do you update the values?
   - How frequently do you update the values?

3) Do you use these values to help prioritize safety-related projects? If you do:
   - What methods do you use?

4) Are you using benefit-cost analysis to evaluate safety projects? If you do:
   - How do you forecast the benefits of the safety improvement?

5) Are you using crash reduction factors? If you are:
   - What is the source of the reduction factors?

6) Have you attempted to modify existing reduction factors to reflect conditions in your state? If you have:
   - How are you doing it?

7) Are you familiar with the design exception process in your DOT? If you are:
   - What safety analysis is performed in evaluating design exception requests?

8) Are crash cost values used in evaluating design exception requests? If yes:
   - How are they used?
APPENDIX B
U.S. DOT AND FHWA GUIDANCE DOCUMENTS
Treatment of Value of Life and Injuries in Preparing Economic Evaluations

Walter B. McCormick, Jr.
General Counsel

Jeffrey N. Shane
Assistant Secretary for Policy
and International Affairs

To:
Assistant Secretaries
Modal Administrators

Departmental guidance on the use of economic values for undertaking regulatory and investment analysis was contained in a memorandum jointly signed by General Counsel and the Assistant Secretary for Policy and International Affairs dated June 22, 1990. That guidance contained the following recommendation:

"For the interim, those agencies that use a dollar value of life in economic analyses should use $1.5 million."

It was noted that upon completion of research work in progress, a revision to this interim value would be promulgated. That work has been completed and, in summary, the revised economic values and procedural guidance are as follows:

- There is widespread agreement that the collective willingness to pay (WTP) by society for reduced risks of fatalities and injuries should be the measure used by the Department to evaluate regulations and investments that improve transportation safety.

- The WTP number should be treated as a "threshold" by assigning monetary values to as many of each proposal's other benefits and costs as is practical, and then computing the net cost per fatality averted. If the calculated cost per life saved lies below the WTP threshold, then the proposal would pass the appropriate benefit-cost test or cost-effectiveness test as far as costs and benefits can be quantified.

- Under limited circumstances, computational procedures in investment analyses may require insertion of an explicit value for fatalities averted. In such limited cases, the WTP value can be used, but the accompanying text should avoid implying that the Department has set a dollar price on lives or injuries.
Through 1993, we recommend using $2.5 million as the WTP value of a fatality averted. This value is based on a 1988 estimate updated using the latest available GDP deflator (3rd quarter, 1992). We expect to issue a memorandum early in each subsequent year, beginning in 1994, that will contain an updated recommended WTP value for use during the year.

While the guidelines formulated in the attached memo should be followed as closely as possible, it is recognized that mitigating circumstances such as statutory, congressional or policy concerns may arise requiring some adjustments.

The same set of values for fatality and injury reductions should be used throughout the Department. Although it is recognized that average income levels vary by transportation mode and that the concept of varying willingness to pay with income has been advanced, it is more appropriate public policy that the value of saving a life or preventing injury be independent of income.

The best current estimates for the willingness to pay to avoid injury are shown below relative to the WTP value of a fatality averted. These estimates are derived from Miller, Brinkman, and Luchter, "Crash Costs and Safety Investment," 1988:

<table>
<thead>
<tr>
<th>AIS Level</th>
<th>Severity Descriptor</th>
<th>Fraction of WTP Value of a Fatality Averted</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 1</td>
<td>Minor</td>
<td>0.0020</td>
</tr>
<tr>
<td>AIS 2</td>
<td>Moderate</td>
<td>0.0155</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious</td>
<td>0.0575</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe</td>
<td>0.1875</td>
</tr>
<tr>
<td>AIS 5</td>
<td>Critical</td>
<td>0.7625</td>
</tr>
<tr>
<td>AIS 6</td>
<td>Fatal</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

The above relationships to the full life WTP should be used with the understanding that values may change as the result of further research.

In addition to a traveler's own valuations of reduced risks, reducing the number of accidental deaths and injuries would reduce a variety of other costs incurred by society in connection with fatalities and injuries. These include costs for emergency services, medical care, and property damage resulting from transportation accidents. Such savings may vary significantly among travel modes and circumstances of particular accidents. Thus, the savings in these costs likely to result from particular safety measures under consideration should be estimated and reported as a separate benefit, additional to the willingness to pay to avoid fatality and injury. Average or representative direct cost estimates may be used for different types or patterns of accidents and used in the economic analyses of regulations or investments.
OMB requires the discounting of future costs and benefits to their present value to account for the fact that they are worth less in the future than they are today. Such analysis must use the discount rate specified by Circular A-94, currently 7 percent for constant dollar benefit-cost analysis of proposed investments and regulations, but may include a sensitivity analysis using higher and lower rates.

The attached document discusses in greater detail the revised economic values and procedural guidance for undertaking economic analysis, and presents the rationale for the recommendations based on recent research. The values and procedures presented should be used by Departmental organizations in the conduct of regulatory or investment analyses except in exceptional circumstances (e.g., statutory requirements). Deviations from this guidance should be fully explained and justified.
FATALITY AND INJURY RISK REDUCTION: 
DEPARTMENTAL GUIDANCE IN THE CONDUCT 
OF ECONOMIC EVALUATIONS

Reductions in fatalities and injuries are a major benefit of many of the Department's regulations and investments. The purpose of these guidelines is to provide more consistency within the Department on how the reduction in fatalities and injuries should be treated in the cost-benefit or cost effectiveness analyses of regulatory or public investment proposals. These guidelines are based on a careful review of the literature and recent research. In the absence of extenuating circumstances, these guidelines should be applied in the review of economic evaluations accompanying regulatory and investment proposals.

The Value of Improved Transportation Safety

There is widespread agreement that the collective willingness of society to pay for reduced risks of fatalities and injuries should be the measure used by the Department to evaluate regulations and investments that improve transportation safety. Society's valuation of safer transportation includes individual travelers' own willingness to pay (WTP) to reduce the risk of accidental death and injury they face in using the transportation system. It also includes any savings in medical, legal, and related expenses borne by the remainder of society that results when travelers' exposure to these risks is reduced.

Researchers have inferred estimates of individual travelers' willingness to pay for safety transportation from a variety of sources, including the additional compensation workers demand to accept more risky jobs, consumers' purchases and use of safety-enhancing devices (such as seat belts and smoke detectors), and structured interview techniques designed to elicit directly participants' willingness to pay for safer travel. In addition, detailed empirical estimates of medical, legal, and other accident-related costs have recently been developed, and can be used to assess the savings likely to be experienced by the remainder of society when accident risks are reduced. This guidance document outlines the use of these estimates to evaluate the potential benefits from regulations and investments that affect the safety performance of the nation's transportation system.

Willingness to Pay for Reduced Risks. Although the range of credible estimates of the value of preventing accidental fatalities is wide, those recommended in recent studies done by Miller and others at the Urban Institute for the FAA\(^1\) and FHWA\(^2\)

\(^1\) Federal Aviation Administration, Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, June 1989.

establish a reasonable range for the value that should be used by the Department to evaluate regulations or investments that enhance transportation safety. The estimates of willingness to pay per accidental fatality averted reported in these two studies are $1.6 million and $2.2 million, when expressed in terms of 1988 dollars. More specifically, these amounts represent estimates of what users of the nation's transportation system would themselves collectively pay to reduce by one the number of fatalities expected to occur in transportation accidents during a given time period. WTP is based on observed willingness to pay modest amounts for small reductions in risk. For example, if 10 million passengers on an already safe mode were willing to pay an extra 20 cents in their fare to reduce the risk of accidental death per trip by .0000001, over the 10 million trips $2 million would be collected and one less life would be lost. The WTP would be $2 million per life, although no one would have directly expressed a willingness to pay that sum to save his/her life.

Some researchers -- most notably Professor Viscusi in a recent survey of his own and others' research on the subject prepared for FAA -- argue that the various studies establish a range of demonstrated willingness to pay values and that values well above the $2.2 million per accidental death prevented might be more appropriate for use in benefit-cost or cost-effectiveness analyses of proposed Department regulations and projects.

DOT "Threshold" Value. The figure of $2.2 million (in 1988 dollars) per accidental death averted recommended in the more recent study conducted by Miller for FHWA is the result of a more comprehensive review of available research than encompassed by the earlier study for FAA. The higher figure also reflects more systematic efforts by Miller to express estimates of willingness to pay to prevent accidental deaths reported in the research on a comparable basis. Although the adjusted WTP values still display considerably wider range of uncertainty than the $1.6-2.2 million range of the central values from the two reports cited earlier, the uncertainty extends much farther above the upper end of the $1.6-2.2 million range than below its lower end.

Recognizing this situation and the practical difficulty of using a range of WTP values in analyses, we recommend the Department use the higher figure of $2.2 million (in 1988 dollars) per accidental death prevented as the threshold value in evaluation of proposed regulations and investment projects.

Should Taxes be Included? Some of the studies cited recommend that the income and other taxes that victims of transportation accidents would have been expected to pay over their remaining lifetimes be included as part of society's willingness to pay to prevent their deaths. Including tax payments that accident victims would have made is intended to measure society's pecuniary interest in their continued survival, and thus to represent another benefit of reducing the number of transportation fatalities. However, each of the levels of government to which accident victims would have
remitted taxes over their remaining lifetimes would also have made corresponding expenditures on their behalf, which would have reduced society's purely financial interest in prolonging their lives. The difference between lost taxes and avoided governmental expenditures is likely to be small, could possibly be negative and is certain to be controversial. We recommend that DOT analyses not include taxes saved as part of the benefits of saving lives.

Updating the Value of Saving Lives

The primary purpose for updating the recommended WTP value from 1988 dollars is to compensate for the declining value of the dollar caused by economy-wide price inflation. For this purpose, a broad-based index of price movements encompassing the entire U.S. economy, such as the implicit price deflator for the Gross Domestic Product (GDP), appears most suitable (the Consumer Price Index is widely thought to be excessively sensitive to fluctuations in housing prices for use as a measure of general inflation in prices for consumption goods and services). The GDP implicit price deflator rose about 14% from its average value during 1988 through the third quarter of 1992; hence, when expressed in approximately today's dollars, the recommended unit value per fatality prevented would be 14% higher than the $2.2 million recommended previously, or approximately $2.5 million.

Annual updating of this WTP value should be sufficiently frequent to capture the effects of current price escalation on transportation system users' willingness to pay for reduced fatality risks, and should avoid the confusion of differing values appearing in different analyses in the same year. We currently recommend using $2.5 million as the WTP value of a fatality averted. This value is derived from a 1988 estimate adjusted by the increase in the GDP price deflator through the third quarter of 1992. We will prepare and issue an updated memo early in each subsequent year recommending a WTP value to be used for that year.

Reduced Direct Costs of Accidents. In addition to travelers' own valuations of reduced risks of transportation fatalities, reducing the number of accidental deaths and injuries would lower a variety of other costs incurred by society. These include costs for emergency services, medical care, and property damage resulting from transportation accidents. While reducing these costs represents one of the benefits of regulations or investment projects that result in safer travel, the resulting savings may vary significantly among travel modes and circumstances surrounding the accidents that these measures are expected to prevent. Thus the savings in these costs likely to result from particular safety measures under consideration should be estimated and reported as a separate benefit, rather than including their average value per fatality or injury as part of society's total willingness to pay for averting each accidental death or injury, as recommended in the studies conducted for FAA and FHWA.
Analysis Using a Threshold Value

Because no single WTP value can reliably be established as the "true" or "correct" one, analysts should avoid if possible treating the value of saving a life as a hard and fast single number like the price of a piece of equipment. If possible, the WTP number should be treated as a "threshold" by assigning monetary values to as many of each proposal's other benefits and costs as is practical, and then computing the net cost per fatality averted. If the calculated cost per life saved lies below the WTP threshold, then the proposal would pass the appropriate benefit-cost test or cost-effectiveness test as far as costs and benefits can be quantified. For example, the simplified result of benefit-cost analysis might be:

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Expected Cost of Proposal</td>
<td>$57.4 million</td>
</tr>
<tr>
<td>Less Property Damage &amp; Other Direct Savings</td>
<td>$5.8 million</td>
</tr>
<tr>
<td>Net Cost of Proposal</td>
<td>$51.6 million</td>
</tr>
<tr>
<td>Number of Lives Saved by the Proposal</td>
<td>30</td>
</tr>
<tr>
<td>Net Cost per Fatality Averted</td>
<td>$1.7 million</td>
</tr>
</tbody>
</table>

The net cost per fatality averted in the example lies below the threshold, so the proposal passes the benefit-cost test without ever explicitly using WTP in the computations. The text accompanying such analyses should be something like, "The proposal satisfies the benefit-cost test because the net cost per fatality averted is less than the reasonable estimate of people's willingness to pay value of $2.5 million indicated by economic research."

Under limited circumstances, computational procedures in investment analysis may require insertion of an explicit value for fatalities averted. In such cases, the WTP value can be used, but the accompanying text should avoid implying that the Department has set a dollar price on lives or injuries. Rather than saying something like, "The Office of the Secretary has set the value of life at $2.5 million dollars ...," the preferable language would be more like, "Economic research indicates that $2.5 million per statistical life saved is a reasonable estimate of people's willingness to pay for safety."

The result of a benefit-cost analysis using an explicit WTP will typically be the net benefit of the proposal. For the above example, the result might be:

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits (in losses averted)</td>
<td></td>
</tr>
<tr>
<td>30 lives saved at $2.5 million WTP</td>
<td>$75.0 million</td>
</tr>
<tr>
<td>Property Damage &amp; Other Direct Costs</td>
<td>$5.8 million</td>
</tr>
<tr>
<td>Total Benefit of the Proposal</td>
<td>$80.8 million</td>
</tr>
<tr>
<td>Cost of the Proposal</td>
<td>$57.4 million</td>
</tr>
<tr>
<td>Net Benefit of the Proposal</td>
<td>$23.4 million</td>
</tr>
</tbody>
</table>
With a substantial positive net benefit, the proposal passes the benefit-cost test. In reviewing the benefit-cost analysis, OST would not question the use of a WTP value below the threshold. Despite its computational neatness the explicit inclusion of WTP can cause difficulties as discussed below.

What if Costs Exceed the Threshold? Cases may arise in which estimated costs exceed estimated benefits based on WTP figures for the current year. While such proposals would appear to fail the threshold, it is recognized that extraordinary circumstances such as legislative mandates or significant public concerns may override a strict cost-benefit test.

Restrictions on Raising or Lowering the WTP Threshold. The same set of values for fatalities and injury reductions should be used throughout the Department. Although it is recognized that average income levels vary by transportation mode and that the concept of varying willingness to pay with income has been advanced, it is more appropriate public policy that the value of saving a life or preventing injury be independent of income.

Generally no change in values should be made for groups affected that are younger or older than the average on which these estimates were based i.e., span of remaining life 39 years. Although there may be some conceptual basis for differentiating, making distinctions for different age groups implies a false degree of precision in the WTP numbers and extends them beyond the data on which they are based.

Value of Reducing Injuries

Virtually all measures that are expected to reduce the number of transportation fatalities -- whether they are regulations or investments in public infrastructure -- also reduce the expected incidence of injuries suffered by those involved in transportation mishaps. As with fatalities themselves, the value to society of reducing the incidence of injuries is represented by its collective willingness to pay for their less frequent occurrence. Unfortunately, however, reliable empirical estimates of individuals' willingness to pay to reduce their exposure to injury risks have proven considerably more difficult to develop than have comparable estimates of the value of reduced fatality risk. In their absence, Miller and others have recommended converting injuries of varying severity levels to their "fatality equivalent," based on such measures as the duration of time for which an injury victim is incapacitated relative to that resulting from premature death. A number of studies have used the Abbreviated Injury Scale (AIS), which categorizes injuries into levels ranging from AIS 1 -- minor, to AIS 5 -- critical. (There is also an AIS 6, called "maximum" that refers to injury that is almost always fatal and rarely used as an injury descriptor.)

Current research attempting to determine willingness to pay for the prevention of injuries is described in reports, by Miller, Brinkman
and Luchter\textsuperscript{3} and by Rice, MacKenzie & Associates\textsuperscript{4} as well as the two reports already cited. The research technique on willingness to pay to avoid injury relies on a panel of experienced physicians to relate injuries in each AIS level to the loss of quality and quantity of life involved. Avoiding a minor injury involving only a few days of discomfort equates to only a tiny fraction of a WTP for saving a life, while preventing a severe injury with permanent disability could be deemed nearly equivalent to preventing death.

The best current estimates for the willingness to pay to avoid injury are shown below in respect to WTP. These are derived from Miller, Brinkman, and Luchter, "Crash Costs and Safety Investment," 1988:

<table>
<thead>
<tr>
<th>AIS Level</th>
<th>Severity Descriptor</th>
<th>Fraction of WTP Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 1</td>
<td>Minor</td>
<td>0.0020</td>
</tr>
<tr>
<td>AIS 2</td>
<td>Moderate</td>
<td>0.0155</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious</td>
<td>0.0575</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe</td>
<td>0.1875</td>
</tr>
<tr>
<td>AIS 5</td>
<td>Critical</td>
<td>0.7625</td>
</tr>
<tr>
<td>AIS 6</td>
<td>Fatal</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

As noted earlier, reducing the number of injuries in accidents will also lower a number of other costs associated with accidents. These include the costs for emergency services, medical care and property damage. The savings in these costs resulting from particular safety measures under consideration should be estimated and reported as a separate benefit, rather than included in the average value of society's willingness to pay to avert an injury. The direct costs of accidents will vary according to the pattern and severity of injuries associated with the accident. Average or representative direct cost estimates may be used for different types or patterns of accidents and used in the economic analyses of regulations or investments.

The above relationships to the full life WTP should be used with the understanding that values may change as the result of further research. If it is determined that certain numbers of injuries in the various AIS levels will be prevented by a proposed safety measure, those numbers can be multiplied by the appropriate

\textsuperscript{3} Miller, Ted R., C. Philip Brinkman, and Stephen Luchter; Crash Costs and Safety Investment; Proceedings of the 32nd Annual Conference, Association for the Advancement of Automotive Medicine, Des Plaines, IL, 1988.

fraction to convert them into "equivalent lives saved." Thus the fatality and injury prevention benefits of a proposal can be treated as a single number, either implicitly as a threshold or multiplied by WTP and inserted explicitly.

With either technique, there are complications in dealing with injuries that should be recognized:

- Different accident types in different modes tend to have different patterns of associated injuries. In most cases the less severe injury levels tend to be more numerous, but the pattern may vary. (For the first few decades of flight, aviation crashes tended to be "all or nothing." People either were killed or walked away. Only in the last decade or two have improvements in overall safety and in aircraft crashworthiness reduced fatalities and changed the pattern to include significant numbers of injuries.)

- Different safety measures may prevent different patterns of injuries. Accident prevention measures will, of course, prevent injuries in the pattern associated with the type of accident, but crashworthiness or occupant protection measures may affect one injury level more greatly than others. It would be possible for a measure to reduce fatalities and the more serious injuries, but do little to reduce less serious injuries. In fact, a safety measure could have the effect of shifting casualties down to less serious levels and actually increase the numbers in lower AIS categories. (Advances in emergency services and trauma medicine have saved lives, but increased the number of survivors with long-term serious disabilities.)

- Injury data are often spotty and rarely reported in AIS levels. There is no injury equivalent to the complete NHTSA Fatal Accident Recording System (FARS) data on highway fatalities. Injuries are often reported as whether there was time lost, whether the victims were carried from the scene, whether they required subsequent hospitalization, etc. Minor injuries may not be reported at all. Virtually every economic analysis of the value of reducing injuries will have to make assumptions and approximations to convert available accident statistics into AIS levels and then to equivalent lives.

These complications mean that there can be no simple "cost of injury" number usable for transportation as a whole or for any mode. Each analysis that takes into account the benefit of injury prevention will have to establish on a case-by-case basis what patterns of injuries are occurring and what patterns of injuries will be prevented by the measure in question.
Discounting Future Safety Benefits

Discounting Future Lives Saved. As with the other benefits resulting from transportation investment projects or regulations, the value of preventing accidental deaths and injuries during future years should be discounted to reflect the fact that expected future benefits are valued less highly by society than immediate benefits. The usual technique for dealing with this in evaluation is to apply a discount rate that measures the percent per year the future valuation decreases. Dollar benefit values should be assigned to lives saved and injuries prevented but these values should then be discounted to "present values" using the appropriate discount rate.

Costs are likewise subject to the same discounting. A cost expected several years in the future takes on less importance than one that must be paid today. In cases where benefits are completely paid for at the time they are enjoyed, the anticipated costs of a proposed regulation or investment project can be converted to an equivalent annual installment and compared to the expected annual reduction in fatalities without the need for discounting. Nevertheless, many safety measures involve near-term expenditures that lead to longer-term benefits, often a stream of benefits spread out over many years. Comparisons of the cost and benefits are needed to make sound regulatory decisions and any valid comparison of dissimilar cost and benefit streams requires collapsing them to present values using a discount rate. The same is true if costs and benefits would be discounted at a different rate.

Discount Rates. The Office of Management and Budget revised Circular A-94 provides guidance on the discount rate to be used for cost benefit analyses of Federal programs and regulation impact analyses. The Circular specifies a discount value of 7 percent for constant dollar benefit-cost analyses of proposed investments and regulations. The analyses should also show the sensitivity of the discounted net present value to variations in the discount rate.
On January 8, 1993, to promote consistency among the policies of the several operating administrations, DOT published a guidance memorandum, "Treatment of Value of Life and Injuries in Preparing Economic Evaluations." That memorandum recommended the use of $2.5 million as the benefit of averting an accidental fatality in departmental regulatory and investment analyses. This figure has been periodically adjusted for inflation by the GDP implicit price deflator. The current value of $2.7 million was adopted in 1996.

Recent years have seen a considerable expansion in the number of studies published and refinement in analytical techniques. However, it does not appear that newer estimates converge on a consensus value or range that would justify modification of our established standard, and some significant estimates continue to lie well below it. Therefore, for the present, we will continue to use the procedure adopted in the 1993 guidance. Adjusting the value of life by the GDP implicit deflator for the third quarter of 2001, we now recommend the use of a value of $3.0 million in all DOT analyses. We will continue to review available research and may recommend changes to the value of life if warranted. The relative values of injuries of varying severity are unchanged from those published in the 1993 memorandum.

It is important to emphasize that these values are imprecise and should be treated neither as an automatic justification for action nor as a rigid barrier, but as a guide to thoughtful decision-making. Where the estimated benefits of an action are close to the estimated costs, governmental decision-makers should pay particular attention to the accuracy of all other factors in the cost-benefit analysis.

To deepen understanding of the empirical basis for these values among analysts who use them and to facilitate evaluation of current studies, we are initiating a process of consultation within the department. Before proposing major revisions, we intend to invite experts in this field of research to meet informally with DOT staff and share insights into the state of the art and the issues that must be considered in developing policy. We will announce meetings as they are scheduled.

1 The original guidance memorandum and background information on relevant sources may be found at http://ostpweb.dot.gov/VSU_background.htm
APPENDIX C
COMMENTARY ON I.M 3.216

After reviewing I.M. 3.216 and the electronic worksheet, we conclude that the method may be biased towards favoring some projects. Figure C-1 is a completed spreadsheet that illustrates the existing benefit-cost determination from I.M. 3.216 for a design exception. The benefit-cost ratio is calculated as 1.47, thereby indicating that the proposed road improvement, although it does not meet design standards, would reduce the number of crashes to off-set the costs of the improvement. We believe that this analysis would be greatly improved if the time value of money were taken into account. Considering the time value of money is important because a dollar given to you next year will not be equal in value to a dollar today. Therefore, the future values of avoided crashes, improvement costs that extend beyond the initial year, and yearly operation and maintenance costs should be discounted to present values for comparison. Ignoring the time value of money will likely favor projects with high initial costs and benefits accruing far off in the future (Weisbrod and Weisbrod 1997). Figure C-2 contains comments on where changes are suggested in I.M. 3.216.

We recommend that the benefit cost-method prescribed in I.M. 3.216 and the electronic worksheets be modified. To illustrate our recommended modifications we have included Figure C-3 that uses the same cost and crash values as the example in Figure C-1, but discounts future benefits with a discount rate of four percent. The benefit cost ratio from the modified method is 0.99 compared to 1.46 from the original method. The ratio of .99 falls within the range of 0.8 and 1.20, thereby allowing the project be justified using the six mitigating factors given in I.M. 3.218. For this example, the internal rate of return, which is the discount rate that makes the net present values of benefits and costs equal to zero, is 3.86. We included the equations for calculating the present value of safety benefits and costs and, when possible, used the terms and variable names from I.M. 3.216.
**Benefit Cost method of I.M. 3.216**

---

**Proposed Improvement:**

- **Estimated Improvement Cost (EC):** $1,280,000
- **Estimated Improvement Life (Y):** 20 Years
- **Estimated Accident Loss Reduction (LR):** 36%

**Traffic Data**

- **Average Daily Vehicle Miles (VM):** 4,104
- **Projected Average Annual Vehicle Miles (PM):** 0.01862 HMVM

**Accident Data**

- **Time Period (T):** 7.00 Years
- **Fatal Accidents:** 1, $1,000,000
- **Injury Accidents:**
  - Major: 2, $300,000
  - Minor: 10, $100,000
  - Possible: 5, $12,500
- **Property Damage Only:** Total $ Loss to Property: $57,645

**Benefit / Cost Analysis**

- **Projected Total Vehicle Miles (TM):** (PM)(Y) 0.37238 MEV
- **Projected Total Accident Loss (P$):** (SA)(AR)(TM) $2,211,994
- **Projected Total Benefit (PB):** (P$)(LR) $1,879,562
- **Projected Annual Accident Benefit (AB):** $93,978
- **Projected Annual Benefit (B):** $93,978

**Benefit / Cost Ratio**

$B / C = 1.47:1

---

Figure C-1. Completed benefit-cost determination from I.M. 3.216
Commentary on the Benefit Cost method of I.M. 3.216

The benefit cost procedure as outlined in this spreadsheet and in I.M. 3.216 incorrectly estimates the costs and benefits because it does not discount future dollar values to their present values.

Figure C-2. Commentary on the benefit-cost determination from I.M. 3.216
**Recommended change to calculating the number of avoided crashes and present value of loss.**

<table>
<thead>
<tr>
<th>Project Year</th>
<th>Daily Vehicle Miles Traveled (DVMT&lt;sub&gt;y&lt;/sub&gt;)</th>
<th>Hundred Million Vehicle Miles (HMVM&lt;sub&gt;y&lt;/sub&gt;)</th>
<th>Number of Crashes&lt;sub&gt;y&lt;/sub&gt;</th>
<th>Number of Avoided Crashes&lt;sub&gt;y&lt;/sub&gt;</th>
<th>Benefit of Reduced Crashes&lt;sub&gt;y&lt;/sub&gt;</th>
<th>Present Value of Benefit of Reduced Crashes&lt;sub&gt;y&lt;/sub&gt;</th>
<th>Project Costs</th>
<th>Other Annual Costs</th>
<th>Present Value of Total Project Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4,104</td>
<td>0.01498</td>
<td>4.86</td>
<td>1.75</td>
<td>$75,607.46</td>
<td>$75,607.46</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>1</td>
<td>4,186</td>
<td>0.01528</td>
<td>4.95</td>
<td>1.78</td>
<td>$77,119.61</td>
<td>$74,153.47</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>2</td>
<td>4,270</td>
<td>0.01558</td>
<td>5.05</td>
<td>1.82</td>
<td>$78,662.00</td>
<td>$72,727.34</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>3</td>
<td>4,355</td>
<td>0.01590</td>
<td>5.15</td>
<td>1.86</td>
<td>$80,235.24</td>
<td>$71,328.83</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>4</td>
<td>4,442</td>
<td>0.01621</td>
<td>5.26</td>
<td>1.89</td>
<td>$81,839.94</td>
<td>$69,957.13</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>5</td>
<td>4,531</td>
<td>0.01654</td>
<td>5.36</td>
<td>1.93</td>
<td>$83,476.74</td>
<td>$68,611.80</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>6</td>
<td>4,622</td>
<td>0.01687</td>
<td>5.47</td>
<td>1.97</td>
<td>$85,146.28</td>
<td>$67,292.34</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>7</td>
<td>4,714</td>
<td>0.01721</td>
<td>5.58</td>
<td>2.01</td>
<td>$86,849.20</td>
<td>$65,958.36</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>8</td>
<td>4,808</td>
<td>0.01755</td>
<td>5.69</td>
<td>2.05</td>
<td>$88,586.19</td>
<td>$64,729.06</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>9</td>
<td>4,905</td>
<td>0.01790</td>
<td>5.80</td>
<td>2.09</td>
<td>$90,357.91</td>
<td>$63,484.27</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>10</td>
<td>5,003</td>
<td>0.01826</td>
<td>5.92</td>
<td>2.13</td>
<td>$92,165.07</td>
<td>$62,263.42</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>11</td>
<td>5,103</td>
<td>0.01863</td>
<td>6.04</td>
<td>2.17</td>
<td>$93,908.37</td>
<td>$61,066.04</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>12</td>
<td>5,205</td>
<td>0.01900</td>
<td>6.16</td>
<td>2.22</td>
<td>$95,888.54</td>
<td>$59,911.70</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>13</td>
<td>5,309</td>
<td>0.01938</td>
<td>6.28</td>
<td>2.26</td>
<td>$97,806.31</td>
<td>$58,739.93</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>14</td>
<td>5,415</td>
<td>0.01977</td>
<td>6.41</td>
<td>2.31</td>
<td>$99,762.43</td>
<td>$57,610.32</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>15</td>
<td>5,523</td>
<td>0.02016</td>
<td>6.54</td>
<td>2.35</td>
<td>$101,757.68</td>
<td>$56,502.43</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>16</td>
<td>5,634</td>
<td>0.02056</td>
<td>6.67</td>
<td>2.40</td>
<td>$103,792.84</td>
<td>$55,415.84</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>17</td>
<td>5,747</td>
<td>0.02098</td>
<td>6.80</td>
<td>2.45</td>
<td>$105,868.69</td>
<td>$54,350.15</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>18</td>
<td>5,862</td>
<td>0.02139</td>
<td>6.94</td>
<td>2.50</td>
<td>$107,986.07</td>
<td>$53,304.96</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td>19</td>
<td>5,979</td>
<td>0.02182</td>
<td>7.08</td>
<td>2.55</td>
<td>$110,145.79</td>
<td>$52,279.86</td>
<td>$1,265,314.71</td>
<td>$1,280,000.00</td>
<td>$1,280,000.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99,716</strong></td>
<td><strong>0.36396</strong></td>
<td><strong>119.02</strong></td>
<td><strong>4.29</strong></td>
<td><strong>$1,287,062.35</strong></td>
<td><strong>$1,265,314.71</strong></td>
<td><strong>$1,280,000.00</strong></td>
<td><strong>$1,280,000.00</strong></td>
<td><strong>$1,280,000.00</strong></td>
</tr>
</tbody>
</table>

Present Value of Total Project Cost = $1,280,000.00
Present Value of Total Benefit = $1,265,314.71
Benefit to Cost Ratio = 0.99

**Figure C-3. Recommended change to the benefit-cost determination of I.M. 3.216**

**Equation C-1. Daily vehicle miles traveled**

\[ DVMT_y = VM \times \left(1 + \frac{G}{100}\right) \]

Where:

- \( VM \) = Current average daily vehicle miles
- \( G \) = Projected annual growth
- \( y \) = Project year

**Equation C-2. Hundred million vehicle miles**

\[ HMVM_y = \left(\frac{DVMT_y \times 356}{100,000,000}\right) \]

Where:

- \( DVMT_y \) = Daily vehicle miles traveled in year \( y \)
Equation C-3. Number of crashes per year

\[ A_y = HMVM_y \times \left( \frac{TA}{AM \times T} \right) \]

Where:
- \( HMVM_y \) = Hundred million vehicle miles
- \( TA \) = Total number of crashes from crash history
- \( AM \) = Present average annual miles traveled
- \( T \) = Number of years in crash history

Equation C-4. Number of avoided crashes

\[ AV_y = A_y \times LR \]

Where:
- \( A_y \) = Number of crashes
- \( LR \) = Estimated crash loss reduction

Equation C-5. Benefits of avoided crashes

\[ B_y = AV_y \times \$A \]

Where:
- \( AV_y \) = Number of avoided crashes in year \( y \)
- \( \$A \) = Average dollar loss per crash

Equation C-6. Present Value of benefits of avoided crashes

\[ pv(B_y) = B_y \times \left( 1 + \frac{DR}{100} \right)^{-y} \]

Where:
- \( B_y \) = Benefit of reduced crashes
- \( DR \) = Discount rate
- \( y \) = Year

Equation C-7. Present value of improvement project costs

\[ pv(C_y) = (EC_y + OC_y) \times \left( 1 + \frac{DR}{100} \right)^{-y} \]

Where:
- \( EC_y \) = Estimated improvement cost that occurs in year \( y \)
- \( OC_y \) = Other annual costs that occur in year \( y \)
- \( DR \) = Discount rate
- \( y \) = Year