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The Costs of Highway Crashes

Research and Development
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FOREWORD

This report summarizes the results of a research study on the comprehensive costs of highway crashes. The primary data bases used in the study come from the Fatal Accident Reporting System and the National Accident Sampling System of the National Highway Traffic Safety Administration of the U.S. Department of Transportation, and from the National Council on Compensation Insurance.

The report is intended to be used by highway engineers who are responsible for economic analyses of alternative highway safety improvements and/or new highway designs. The crash costs given in this report have many uses. These include: allocating scarce highway safety resources to maximize benefits, evaluating proposed safety regulations, and convincing policymakers and employers that safety programs pay. Chapter IX gives six examples of how the crash cost values can be used in engineering economic analyses.

The report is being distributed with two copies to each Region and six copies to each Division Office. Four of the Division copies should be sent to the State. The report is also being sent to the Transportation Research Information Service Network, Department of Transportation Library, and the National Technical Information Service (NTIS) in Springfield, Virginia, to be available for interested parties.

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16. Abstract

In 1988, an estimated 14.8 million motor vehicle crashes involved 47,000 deaths and almost 5,000,000 injuries. More than 4.8 million years of life and functioning were lost. Crash costs totalled $334 billion. They included $71 billion in out-of-pocket costs, $46 billion in wages and household production, and $217 billion in pain, suffering, and lost quality of life. Half of the out-of-pocket costs were property damage costs; the rest were medical, emergency services, workplace, travel delay, legal, and administrative costs. Employers paid 20 percent of the out-of-pocket and productivity costs. The general public paid 48 percent. People involved in crashes and their families paid the remainder and suffered the pain.

The comprehensive costs presented here are appropriate for use in benefit-cost analysis. The costs/police-reported crash are $2,723,000/K-fatal, $229,000/A-incapacitating injury, $48,000/B-nonincapacitating injury, $25,000/C-possible injury, $4,500/0-property damage only (these crashes include injuries missed by the police), and $4,300/unreported crash. The most costly kinds of crashes include motorcycle, pedestrian, pedalcycle, alcohol-involved, and heavy truck. Minor rural collectors, local rural streets, and urban arterials are the most dangerous/vehicle-mile of travel (vmt). Motorcycles have safety costs of $2.14/vmt, buses $.24/vmt, heavy trucks $.19/vmt, light trucks $.16/vmt, and cars $.12/vmt. In nonfatal collisions involving only occupants, the most harmful events with the highest cost/injury involve, in order: trees, overturns, other fixed objects, and utility poles.

17. Key Words
Crash costs, incidence, reporting rate, years lost, vehicle type, roadway class, drunk driving, most harmful event, who pays.

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I. INTRODUCTION

In 1 of every 11 American households, someone probably will die in a motor vehicle crash. Crashes are the fourth leading cause of death. They result in 125 deaths/day, 47,000/yr. Almost 5 million people are injured. Daily, 4.8 million days of life and functioning are lost.

This report tries to answer a hard, maybe even presumptuous question: How much should we invest to reduce the toll? Answering requires placing a dollar value on human life.

Is it morally offensive to reduce human life to dollars and cents? Perhaps, but how else can we make rational public investment decisions? As an example, suppose you were going to spend $100,000 on either concrete median barrier or transition guardrail at bridge ends. Suppose the median barrier would prevent roughly 1 death and 50 nonfatal injuries annually, the guardrail 2 deaths and 2 injuries. Which investment is better?

Whenever governments issue regulations or allocate resources that affect health and safety, implicitly or explicitly, they value peoples' lives and their safety. Explicit values allow the public to understand and possibly challenge the government's choices. They also promote consistency across decisions. Consistency, in turn, should make safety policy more rational.

Three Measures of Crash Costs

The easiest parts of crash costs to measure are the out-of-pocket costs of:

- Crash clean-up.
- Injury treatment.
- Property damage.
- Workplace disruption.
- Insurance claims processing, including legal proceedings, and public program administration.

These costs often are called direct costs.

In addition to the direct costs, crash costs must account for the effects of injury on individuals. Measuring those effects numerically is hard. When this study started in 1985, Federal agencies used one of three methods to measure them. This report calls the methods years lost plus direct costs, comprehensive (or willingness to pay), and human capital. Only the first two methods yield conceptually sound values for use in resource allocation.

Years Lost Plus Direct Costs. At its best, the years lost method estimates the years of life lost to fatal injuries and the years of functioning lost to nonfatal injuries. Because the medical costs for serious injury are much higher than for death, years lost are a misleading measure unless they are added to the direct costs.

The years lost method avoids placing a dollar value on lost life and functioning. That restricts its use. It generally is adequate for cost-effectiveness analysis of alternatives. It also can be used to analyze issues that involve tradeoffs between years of life and years of travel time. Examples are where to allow right turn on red and what speed limit to set.

The major problem with years lost plus direct costs is that its two benefit measures are not additive. All they can tell us is, for example, that straightening a hazardous curve on Winding Lane will save 1 year of life and functioning at a net cost of $50,000. Is that preferable to adding a lane on Ivy Lane with a benefit-cost ratio of 1.7 resulting from reduced travel time?

Another problem with the years lost method is that little work has been done on the values for nonfatal injury. Available estimates of years of functioning lost come from ratings by just a few doctors. Research by the National Highway Traffic Safety Administration (NHTSA) scheduled for completion late in 1991 should yield more defensible ratings.

Comprehensive. Like the years lost method, the comprehensive method includes the effects of injury on people's whole lives, not just the monetary effects. The method yields a comprehensive value that includes the dollar costs, the lost income, and the costs of pain, suffering, and lost quality of life.

Comprehensive life values are estimated by examining risk reduction values, the amount people pay for small decreases in safety and health risks. From the risk reduction values, the approach infers the market value of safety -- how much a large group of people would pay for an expected saving of one anonymous life. For example, suppose 10,000 people each spent $220 on an airbag that reduced their chance of dying prematurely by 1 in 10,000. Statistically, their $2,200,000 investment probably will save one life. Thus, the value of risk reduction would be $2,200,000/statistical life saved.

The economics literature named the comprehensive method **willingness to pay**. That name is misleading. Of the 47 sound empirical estimates identified in a literature review by Miller (1990), 41 are estimated from safety behavior or markets for safety products like safer cars or smoke detectors. They show how much people actually pay to reduce safety risks, not what they are willing to pay.

The comprehensive method's strength springs from its ability to explain behavior. People exchange money, time, comfort, and convenience for safety. To the extent they behave rationally, they have to decide what it is worth to reduce their risks of death and injury. That decision requires valuing all the likely effects of death and injury.

A further strength is that the benefits all are valued in dollars. Comprehensive costs allow us to estimate that a life year is worth roughly $90,000 more than direct costs. That means straightening the hazardous curve on Winding Lane would have a benefit-cost ratio of 1.8. It has a higher payoff than adding a lane on Ivy Lane.

The weakness of the comprehensive method is its assumption that people make rational decisions about health and safety. Although some decisions are reasoned, others clearly are not. This report pioneers a method to overcome another weakness, the difficulty of measuring consistent values for different injuries. The method relies on the estimates of functional years lost from the years lost approach.

Comprehensive life and injury values are the preferred valuation method for benefit-cost and regulatory analysis. Sources recommending the method include Federal Highway Administration -- FHwA (1988), Gillette and Hopkins (1988), Menzel (1986), National Safety Council (1989a), and U.S. Office of Management and Budget (1989). Since 1986, virtually every Federal regulatory analysis that monetized the benefits of saving lives has used willingness to pay values (Scodari and Fisher, 1988).

Comprehensive values show the maximum amount the public rationally should spend reducing health and safety risks. They do not show how much we should spend to save a known individual from immediate peril. Most Americans view life as sacred. They would find it morally offensive to stand by and watch someone die because saving them would cost too much.

Human Capital. The human capital method is more than 200 years old. The only effects of injury it counts are the out-of-pocket costs and the lost work and housework.

The human capital method has many drawbacks (Rice, MacKenzie, and Associates, 1989). It places very low values on children and old people. It values women less than men. It ignores pain, suffering, and lost quality of life. Its obvious imperfections make it a poor basis for policy analysis. Indeed, modern texts generally warn against using human capital costs in benefit-cost analyses of health and safety. (See Bailey, 1980; Hills and Jones-Lee, 1983; Mishan, 1988; Scodari and Fisher, 1988; Thompson, 1980.)

Nevertheless, human capital costs are useful. After the fact, they tell us the dollars lost to injury -- numbers safety advocates can trumpet. They also form the backbone of the methods courts use to decide appropriate compensation for injury.

Report Outline

Chapter II of this report describes the injury coding schemes used in our cost estimates and the main data bases analyzed. The cost estimates in the text use the coding scheme that police generally use in their crash reports. Data bases built from the police reports underlie most State analyses of highway safety issues. The appendixes provide costs in two other coding schemes: by body region and degree of threat to life, and by whether hospitalized. Previous efforts to estimate crash costs (Faigin, 1976; Hartunian, Smart, and Thompson, 1981; NHTSA, 1983) provided costs by degree of threat to life, so we use that coding scheme to compare our estimates with earlier estimates. We also compare selected estimates to aggregate estimates of the costs of crash injury in Rice et al. (1989).

Chapters III to V follow a common format. They present values, then summarize methods. Chapter III discusses how many crashes and injuries occur annually. Chapter IV presents the years lost values and explains the method in more detail. Chapter V presents the comprehensive, direct, and human capital costs, as well as the costs by component, in 1988 dollars. The report gives values per injury and for all injuries in a typical year. Chapter IV also explains how we discounted costs in future years to present values. All three costing methods used discounting.

Chapters VI and VII seek insight into safety priorities. Chapter VI compares the comprehensive benefits of avoiding different kinds of crashes. It examines variations by alcohol involvement, rural versus urban location, roadway type, and vehicle type, among others. Crashes that are both frequent and costly make attractive intervention targets. Chapter VII looks at the comprehensive benefits of preventing crashes classified by the causes of harm. It discusses both the first and most harmful events.

Chapter VIII examines who pays the crash costs. For the most part, society bears the human capital costs. The costs of pain, suffering, and lost quality of life largely fall on injured people and their families.

Chapter IX presents six examples. The examples illustrate how to use the crash costs. They also demonstrate the importance of choosing costs tailored to the problem at hand.

Four appendixes are included. Appendix A gives examples of injuries by threat-to-life severity. Appendix B provides details of the procedure for estimating crash incidence. Appendix C contains supplemental tables, including weights applied to the dimensions of impairment in order to compute years of functioning lost, costs in different injury coding systems, and the distribution of injury severity by crash severity. Appendix D explains how to inflate cost estimates in this report from 1988 to a later year.

This report describes methods briefly. Miller and Associates (1991) provides details of the methods, reviews the relevant literature, and discusses the costs in coding systems other than the system that police use.

II. INJURY CODING SCHEMES AND DATA BASES

Injury data are not collected uniformly. Almost every national data collection agency codes injury descriptions differently. The opening sections of this chapter describe two coding schemes used to record injury nature and severity. We estimated costs by severity level for these schemes.

The primary data bases used come from the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation and from the National Council on Compensation Insurance (NCCI). The last section of this chapter describes these data bases. They include:

- **NASS.** NHTSA's National Accident Sampling System.
- **FARS.** NHTSA's Fatal Accident Reporting System.
- **DCI.** NCCI's Detailed Claims Information data base.

KABCO: The Police Scheme for Injury Coding

The KABCO injury scheme is designed for police coding at the crash scene.[1] It is defined by the American National Standards Institute (ANSI) in standard D-16.1. Table 1 shows the scale.

KABCO coding does not require medical judgement. Rather, the police officer on the scene records whether the person was killed, suffered an incapacitating injury, suffered a less severe but evident injury, claimed to have an injury, or seemed uninjured.

KABCO coding does not consistently classify injuries. For example:

- Most police officers code any given injury as more serious if the victim is a woman.
- Bloody injuries tend to be coded as more severe.
- Officers who rarely see crashes generally code injuries as more severe than grizzled veterans do.

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[1] KABCO is not an acronym. Its name simply concatenates the codes used in the system--K, A, B, C, and O.

Table 1. The KABCO injury classification system.

KABCO Code	Injury Severity Level	Representative Injuries
K- or F-type	Killed/Fatal injury	Any injury that results in death within 30 days of occurrence.
A-type	Incapacitating injury	Any injury, other than a fatal injury, which prevents the injured person from walking, driving, or normally continuing the activities the person was capable of performing before the injury occurred.
	Inclusions:	Severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, unconscious at or when taken from the accident scene; unable to leave accident scene without assistance; and others.
	Exclusions	Momentary unconsciousness, and others.
B-type	Nonincapacitating/ Evident injury	Any injury, other than a fatal injury or an incapacitating injury, which is evident to observers at the scene of the accident in which the injury occurred.
	Inclusions:	Lump on head, abrasions, bruises, minor lacerations, and others.
	Exclusions:	Limping (the injury cannot be seen), and others.

Table 1. The KABCO injury classification system (continued).

KABCO Code	Injury Severity Level	Representative Injuries
C-type	Possible injury	Any injury reported or claimed which is not a fatal injury, incapacitating injury or nonincapacitating evident injury.
	Inclusions:	Momentary unconsciousness, claim of injuries not evident, limping, complaint of pain, nausea, hysteria, and others.
O-type	Property damage	Harm to property that reduces the monetary value of that property.
	Inclusions:	Harm to wild animals or birds that have monetary value, and others.
	Exclusions:	Harm to wild animals or birds that lack monetary value; harm to a snow bank unless, for example, additional snow removal costs are incurred because of the snow; mechanical failure during normal operation, such as tire blowout, broken fan belt, or broken axle; and others.

Source: Adapted from National Safety Council (1989b).

The KABCO scale also has been criticized because it does not relate to the threat the injury poses to the injured person's life. A broken arm and a severed spinal cord, for example, are considered of equal severity. A ruptured spleen may be coded as O, but will be fatal unless it is treated. In this report, we assume A, B, C, and O injuries are recoded to K if the victim dies. Not all States follow up on crash outcomes and revise their data bases on police-reported crashes in this manner. States that do not will need to add some fatal injury costs to the A, B, C, and O costs given in this report before using them. Vital statistics data are a possible source of data on how many crashes to reclassify.

Table 2 was computed from NASS data for 1982 through 1985. It gives some insight into the fraction of fatalities in each nonfatal KABCO category. It also shows the distribution of Maximum Abbreviated Injury Scale (MAIS) threat-to-life codes (defined below) by KABCO code. KABCO clearly does not sort injuries well by threat to life.

Table 2. Percentage distribution of police-reported KABCO severity by MAIS threat-to-life severity.

MAIS	O	C	B	A	K
0	92.7%	20.5%	5.2%	1.5%	0.0%
1	7.0%	70.9%	78.8%	48.6%	0.0%
2	.2%	7.0%	12.6%	28.0%	0.0%
3	.03%	1.5%	3.1%	16.9%	0.0%
4	.001%	.06%	.3%	2.8%	0.0%
5	0.0%	.01%	.1%	1.7%	0.0%
Fatal	.0001%	.013%	.026%	.5%	100.0%
All	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Special analysis of NASS data from 1982 through 1985.
Note: Categories for MAIS 1 to 5 include nonfatal injuries only. Fatal injuries were recoded as fatal, regardless of their MAIS severity. The table excludes fatalities ruled disease.

If KABCO codes are so imperfect, why are they the primary cost scheme in this report? Because they are widely used. Virtually every police crash report records the KABCO severity of injuries, possibly collapsing the KABCO codes into killed, injured, or no evident injury (O). Those crash reports are the backbone of the State data systems on crashes. They also are the starting point for construction of the NASS data. The NASS data include the KABCO code, an MAIS score, and a medical description of the injuries. For accuracy, we first computed the injury costs by MAIS and body region from the medical descriptions. To compute A, B, C, and O costs, we multiplied the percentage incidence by MAIS and body region for the A-B-C-O category times the cost distribution, then summed the products.

AIS: A Medical Scale for Injury Coding

The Abbreviated Injury Scale (AIS) was developed by the American Medical Association and the American Association for Automotive Medicine (AAAM). It was developed principally for measuring the severity of motor vehicle injuries. The AIS scale, shown in table 3, ranges from 0 (uninjured) to 1 (minor injury) to 6 (maximum injury--virtually unsurvivable). Appendix A gives further examples of the injuries in each AIS level.

The AIS indicates potential threat to life. The AIS scores began in 1971 as subjective assessments assigned by a group of experts. They have been revised roughly once every 5 years to reflect the findings of validation and medical outcome studies.

Table 3. The meaning of AIS scores.

AIS Score	Meaning	Examples
0	Uninjured	
1	Minor injury	Whiplash, bruise, broken tooth
2	Moderate injury	Closed leg fracture, finger crush
3	Serious injury	Open leg fracture, amputated arm, major nerve laceration
4	Severe injury	Partial spinal cord severance, concussion with neurological signs (unconscious less than 24 hours)
5	Critical injury	Complete spinal cord severance, concussion with neurological signs (unconscious more than 24 hours)
6	Maximum injury	Decapitation, crushed chest

Often an individual has multiple injuries or a crash injures several people. When this happens, the AIS score of the most life threatening injury (Maximum AIS, or MAIS) is often used to summarize the type and extent of injury.

AIS coding systematically classifies injuries. NHTSA also collects AIS data on a small, but nationally representative sample of crashes. Consequently, several prior studies designed to estimate total crash costs in the U.S. used injury incidence and consequences by MAIS as the basis for their estimates (Faigin, 1976; Hartunian, Smart, and Thompson, 1981; NHTSA, 1983). This choice is imperfect. The purpose of the AIS scale is to differentiate injuries by the threat they pose to life, not the cost, functional losses, or course of recovery they involve. For example:

- Loss of teeth is an AIS-1 injury that can involve substantial costs and lifetime pain and suffering.
- Timely, successful surgery often allows complete and rapid recovery from ruptured spleens and other potentially fatal internal injuries coded in AIS categories 3 through 5.

Three Injury Data Bases

NHTSA's FARS and NASS Cover Motor Vehicle Crashes. FARS is coded from State reports to NHTSA on fatal crashes. The FARS death count matches the crash-related count in vital statistics data. In this report, we use FARS to count deaths in different kinds of crashes. We make little other use of FARS because it only records the KABCO severity of nonfatal injuries.

The data on nonfatal crashes are less reliable than FARS data. NASS data from 1982 through 1985 offer the best national picture of nonfatal crash incidence and severity. In those years, NASS annually collected data on a nationally representative sample of roughly 10,000 police-reported crashes.[2] This report uses NASS data primarily to get injury distributions, not crash counts. The distributions probably did not vary much between the early and late 1980's.

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[2] In 1986, some sites stopped collecting data at mid-year. The weights did not adjust for the seasonal bias that resulted. Data representative of all crashes were not collected after 1986.

NASS codes much more information than FARS and is the principal crash data base for this report. Except in chapter VII, our NASS tables pool data for at least 3 years. The multi-year tables have more data on rare incidents, which makes the estimates more accurate.

The NASS sample is clustered geographically. Because many geographic areas are not sampled, the uncertainty in NASS estimates is large even after pooling. For MAIS-1 injuries, the 95-percent confidence limits are roughly ±16 percent; they rise to ±37 percent for nonfatal MAIS-5 injuries (NHTSA, 1985).

The uncertainty in NASS counts dictates using them sparingly. Therefore, we primarily used NASS to compute costs/injury. Per-injury costs are computed from NASS percentage distributions rather than national counts. That reduces the potential error. When one percentage estimate is too low, another must be too high. The offsetting nature of the errors reduces the error in computed sums. If each percentage is multiplied times a cost factor, the error in the sum of the products is a percentage of the difference in the cost factors rather than of their absolute values.

For example, suppose car crashes cost an average of $10,000 and light truck crashes cost $9,000. Suppose 2,000,000 ± 500,000 car crashes and 1,000,000 ± 400,000 truck crashes occurred last year. The average cost of car and light truck crashes combined would be $9,667, with an uncertainty range from $9,517 to $9,806 ($9,667 ±1.55 percent). In contrast, the total cost of car and light truck crashes would be $29 billion, with a range from $20.4 to $37.6 billion ($29 billion ±29.7 percent). The total cost, but not the average cost, is extremely sensitive to error in the incidence figures.

This report draws incidence data from more reliable sources than NASS. These include State crash reports, NHTSA's General Estimates System, insurance data bases, and State and National hospital discharge data. It also compares incidence estimates from different sources to test the reliability of the estimates.

The NASS data include a detailed description of the crash sequence, as well as the people and vehicles involved. For each injured person, NASS records:

- A medical description of the six most serious injuries.[3]
- The KABCO and MAIS codes.
- The medical treatment received.
- The length of stay if hospitalized.
- Employment status and days of work lost.

Data are recorded only on initial hospitalization and cover the first 60 days after the crash. The injury descriptions are coded from hospital records, including emergency room records, in about 35 percent of the cases. The remainder come from interviews with the crash victims.[4]

A limitation of both NASS and FARS is that they cover only police-reported crashes on public property. If a child is run over in a private driveway, these data sets will not record the incident. Deaths of farmers plowing fields and dune buggy riders on the beach also will be missed. Of necessity then, this report largely deals with the costs of crashes involving vehicles in transport on public roads.

The DCI Describes Workplace Injuries. This report uses DCI data about the paid medical charges for and long-term effects of workplace injury. DCI is the largest nationally representative data base that contains injury cost data. Even better, the data are longitudinal. DCI tracks the paid medical charges by year for individual injuries. Since 1979, DCI has tracked a simple random sample of workers' compensation lost workday claims in 16 States chosen as nationally representative. Lost workday claims involve at least 2 to 7 days of lost work, depending on the State. In most States, 3 days of work loss are needed. Among injuries involving this much work loss, we estimate Workers' Compensation claims include 30 percent of the total and 10 percent of motor vehicle injuries. The DCI file used for this

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[3] The coders record Occupant Injury Codes (OIC's), which state the body region, system, organ, lesion, and AIS score for each injury.

[4] Four contractors handled NASS data collection and had primary responsibility for training coders and assuring coding was consistent.

study contains data on almost 455,000 injuries for the period 1979 through 1988, including 135,000 with hospitalization.

DCI codes the person's most severe injury by body part and nature.[5] Other data reported are length of hospital stay if hospitalized, time lost from work, paid and expected future medical charges, paid and expected future hospital charges, paid non-medical rehabilitation charges, disability payments, and whether the injury resulted in permanent total, permanent partial, or only temporary disability.

When a claim enters the DCI sample, the Workers' Compensation Insurer involved reports the cumulative payments on the claim, by category, to NCCI 6 months after the claim occurs and every 12 months thereafter (months 18, 30, etc.) until the claim is closed. The amount the claims adjuster has reserved to meet future charges by category and any future income benefits that the insurer is committed to pay also are recorded. A case remains open until disability payments are scheduled and all reimbursable medical costs are paid or reserved. If complications arise, the case is reopened and the new paid medical payments/ reserves are reported. Work-related disability is recorded for a maximum of 200 weeks (with some variation between States).[6]

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[5] The injuries are coded using the ANSI Z-16.2 coding system. An instructor on AIS coding assisted us in establishing an equivalency table between groups of ANSI Z-16.2 codes and groups of OIC codes from NASS (Petrucelli, 1989).

[6] DCI data are extracted from claims forms by insurance company clerks who select the injury codes without NCCI training or quality control. Because the insurers fund DCI and use it to analyze rate-making and loss control issues, incentives exist to report accurately.

III. NUMBER OF CRASHES AND INJURIES

No one knows for sure how many crashes occur annually in the United States. We know how many were reported to the police. We can estimate reasonably well how many were reported to insurers. But what's the total? Excluding minor dents and scratches, perhaps 14.8 million crashes involving 25.5 million vehicles in 1988. With 181 million registered vehicles on the road, that means roughly 1 in 7 will be involved in a crash each year.

Figure 1 separates crashes into four groups:

- 6.35 million (43 percent) reported to both the police and insurers.
- 4.35 million (29 percent) reported only to insurers.
- 0.65 million (4.5 percent) reported only to the police.
- 3.45 million (23.5 percent) unreported.

Generally, vehicles in crashes that are reported to police but not insurers lack insurance. The completely unreported crashes probably are less severe. Few involve injuries or require towing.

Injury Incidence

Injury crashes are 21 percent of the total. Overall, in the late 1980's, we estimate 4.9 million people were injured annually in 3.15 million on-the-road crashes. Another 300,000, ranging from toddlers run over in driveways to dirt bike racers, were hurt on private property. FARS states 47,093 people were fatally injured in 42,119 crashes during 1988.

Although it is the best available source of data on the nature of injuries in crashes, NASS samples only crashes reported to the police. Legally, all on-the-road injury crashes should be reported, but in reality many are not. Although NASS follow-up interviews show 3.75 million are injured in reported crashes, the police reports identify only 3.1 million -- and not always the injured -- as injured. Unreported or unrecorded are roughly 18 percent of hospitalized injury and 45 percent of nonhospitalized.

Of necessity, we assumed the injuries in police-reported crashes, when broken down by hospitalization status, are

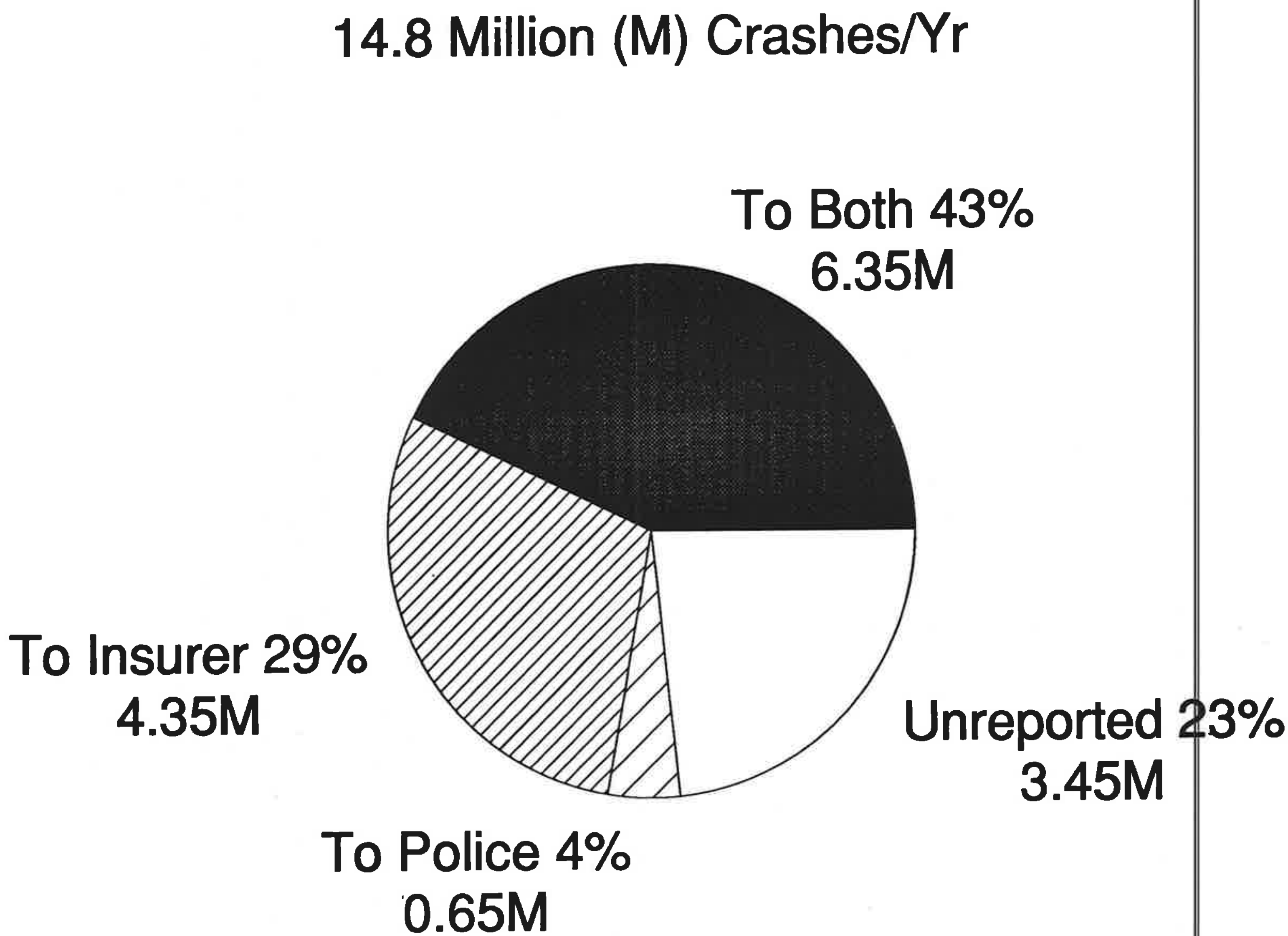

Figure 1. Crashes by reporting status.

representative. Rice et al. (1989) provide estimates for all crash-related injuries, on and off the road. Three cross-checks with their estimates support our assumption of representativeness. As discussed in chapter V:

- The medical cost/case, by hospitalization status, from the police-reported crashes matches Rice's estimate.
- The average wage loss/injury in police-reported crashes is within 8 percent of Rice's estimate.
- The estimated total cost/case, including medical and ancillary costs, wages, household production, vocational rehabilitation, and administration is within 2 percent of Rice's estimate.

Figure 2 breaks down nonfatal injuries in police-reported crashes by treatment received. Most injuries are medically treated. Approximately 11 percent are hospitalized; 38 percent are transported to the hospital, treated, and released; and 16 percent are treated at the scene or in a doctor's or chiropractor's office. Nevertheless, 35 percent of the injured are not treated.

As figure 3 shows, the majority of the untreated injuries are minor cuts and bruises. Almost 30 percent, however, are minor concussions or whiplash. More than 50,000 untreated injuries -- many of them in hit-and-run crashes -- pose a moderate to serious threat to life (Miller, Pindus, et al., 1990). Most alarming are 20,000 untreated moderate concussions. We estimate that 1 in 20 moderate concussions is so serious it permanently impairs the victim's ability to work.

Figure 4 shows the distribution by MAIS threat-to-life severity of people injured in police-reported crashes. About 6 percent of the injured find their lives seriously threatened. Of these, one in five dies.

Of those the police code as nonfatally injured (figure 5), roughly 45 percent are C (complaint of pain -- possible injury), 38 percent B (evident injury), and 17 percent A (incapacitating injury). Table 4 shows the number of crashes and injuries by severity. Roughly 7.75 million crashes involving 13.9 million people go unreported.

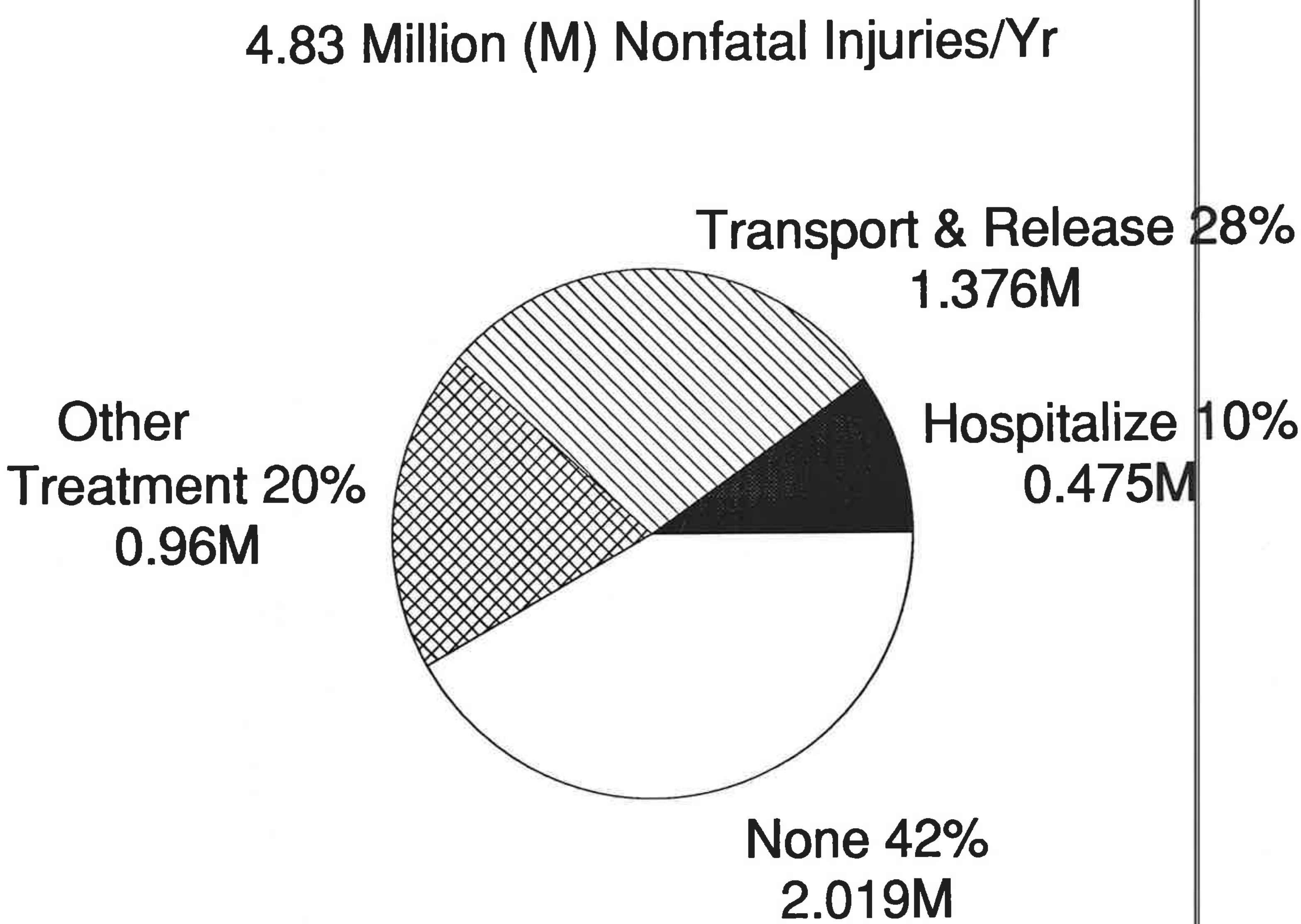

Figure 2. Injuries by treatment.

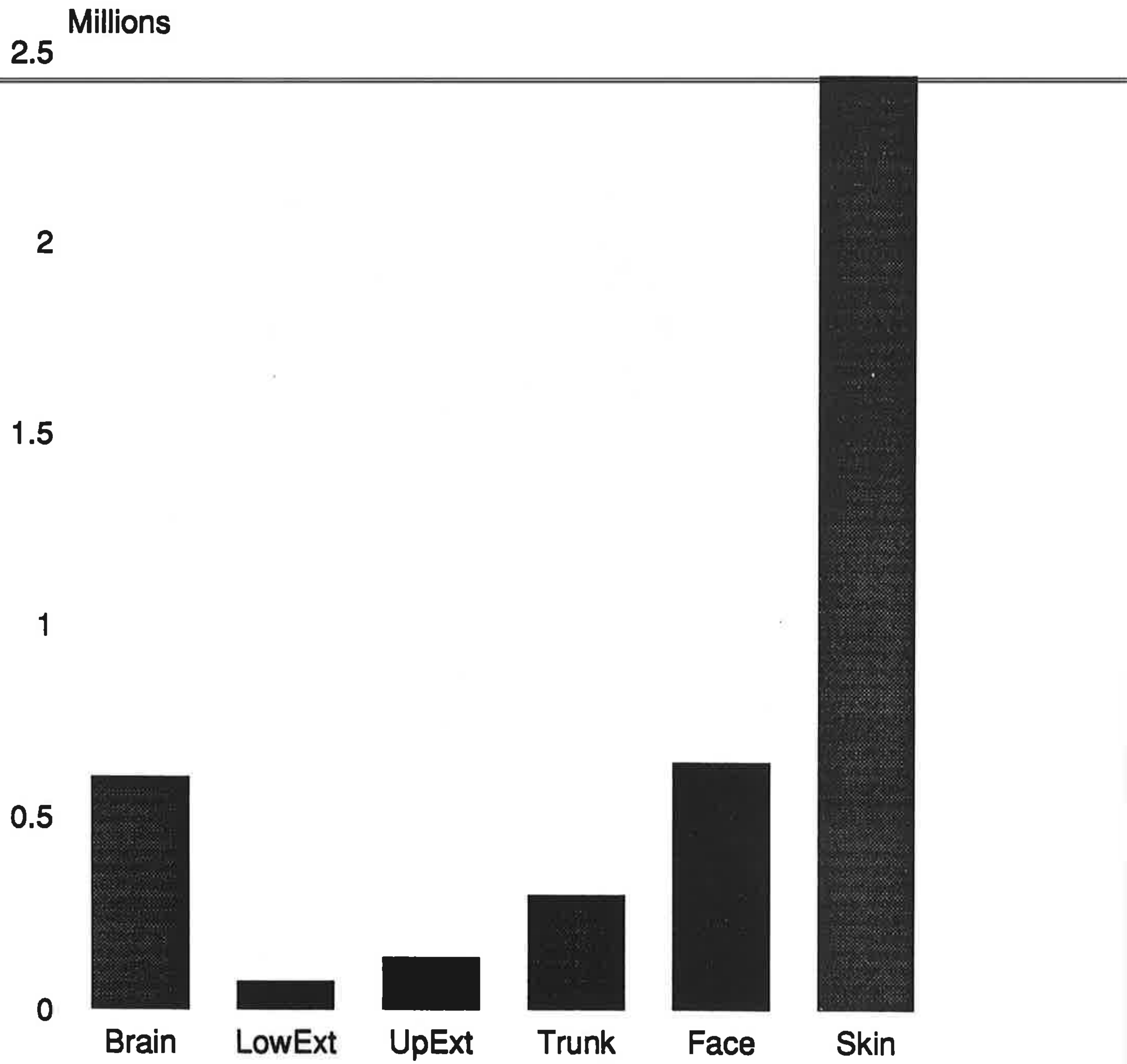

Figure 3. Untreated injuries by body region.

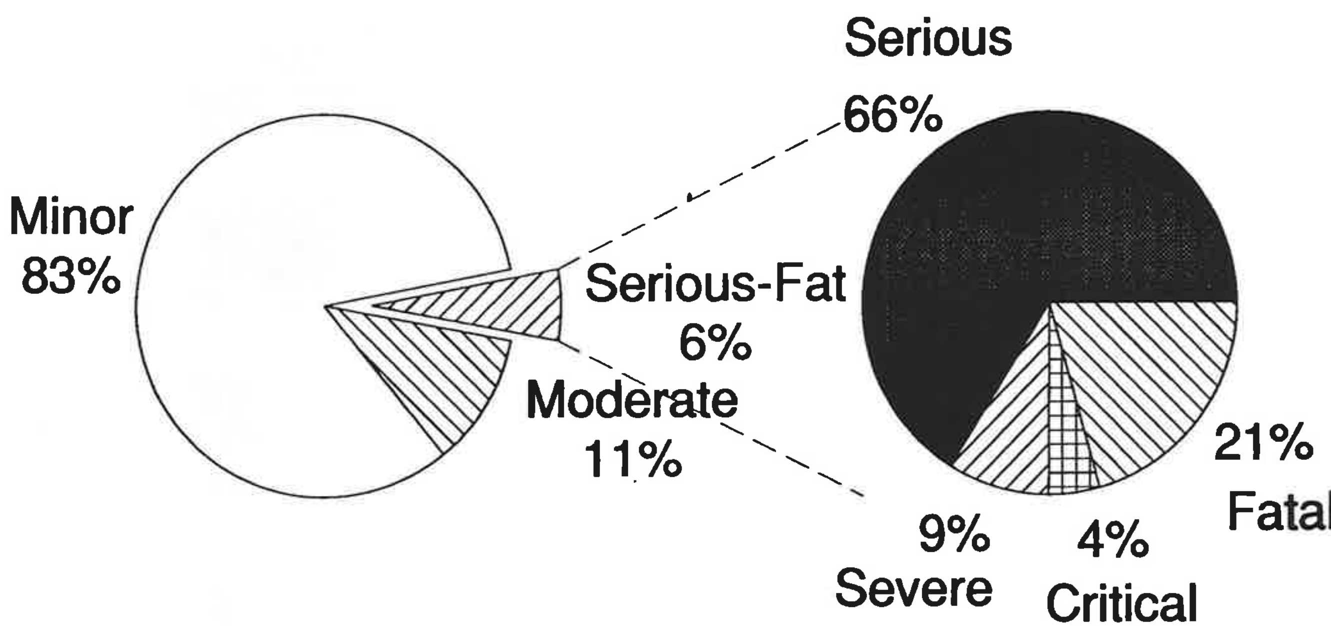

Figure 4. Injuries in police-reported crashes by threat to life.

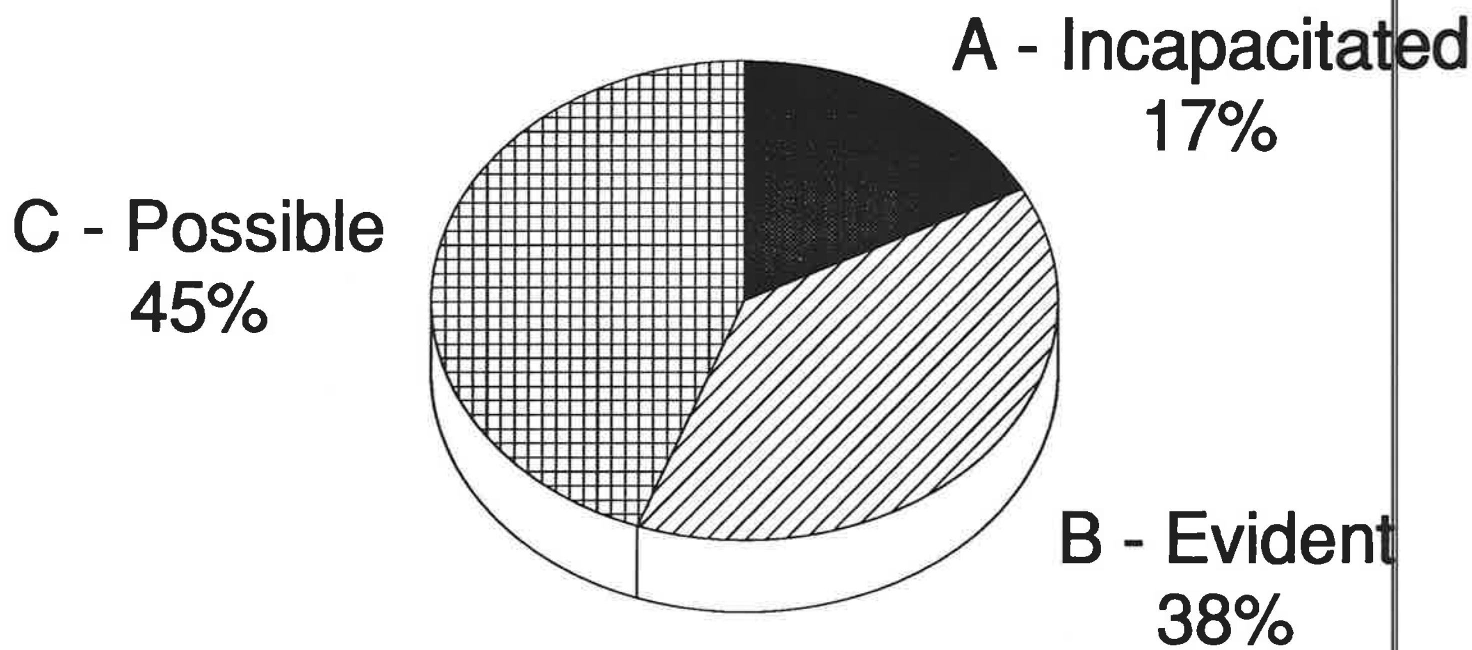

Figure 5. Nonfatal police-reported injuries by KABCO severity.

Table 4. Crashes and people involved by KABCO severity.

Severity	Crashes	%	People	%
K - Fatal	42,119	0.3%	47,093	0.1%
A - Incapacitating	425,479	2.9%	558,467	1.5%
B - Evident	821,202	5.6%	1,154,001	3.0%
C - Possible	1,131,141	7.6%	1,828,531	4.8%
O - Property damage	4,614,044	31.2%	13,791,181	36.2%
Unreported	7,766,000	52.4%	20,766,878	54.4%
Total	14,800,000	100.0%	38,146,151	100.0%

Police Miscode Many Injuries

Some police departments do no follow-up. Consequently, as table 5 shows, more than 10 percent of fatalities are coded A, B, or C rather than K. Within 60 days, 0.5 percent of those coded A die (table 2). In this report, all those who die within 60 days have been recoded as K (killed).

Police also miscode many injuries. Table 5 shows that they code 26 percent of the injured as O-uninjured. Conversely, averaged across A, B, and C, 12 percent of those coded as injured were not. C codes are the least accurate, with 20 percent uninjured. Even 5 percent of the B and 1.5 percent of the A codes are assigned to uninjured people.

Table 5. KABCO coding accuracy.

	Percentage Coded As					
	O	C	B	A	K	Total
Fatal	0.06%	0.6%	1.0%	8.5%	89.9%	100.0%
Actual nonfatal	26.4%	31.1%	29.2%	13.3%	--	100.0%
% Uninjured	92.7%	20.5%	5.2%	1.5%	--	

Source: Special analysis of NASS data from 1982 through 1985.
Note: Excludes fatalities ruled disease.

Incidence Estimation

To estimate the number of crash-involved vehicles, we relied heavily on insurance data. We divided total insurance reimbursement by property damage reimbursed/vehicle, then adjusted for uninsured vehicles. Finally, we multiplied by the ratio of total to reported crashes from NHTSA (1983). Appendix B fully describes the estimating procedure.

The total number of crashes and the number reimbursed by insurers were computed by dividing the number of vehicles by the NASS estimate (using data from 1982 through 1984) of 1.72 vehicles/crash. Data on police-reported crash incidence in 1988 came from NHTSA's General Estimates System (NHTSA, 1990a). The 95 percent confidence interval for GES estimates of incidence by KABCO severity is roughly ±15 percent. To reduce the error, we adjusted the overall counts of injuries and injury crashes to match the summed counts from complete State enumerations (FHwA, 1990). The estimated total injury crashes were 2.7 percent lower than the enumeration; the estimated total injuries were 3.9 percent lower.

FARS provided all fatality data.

The percentage distribution of nonfatal injuries by MAIS severity came from computer runs on NASS data for 1982 through 1985. We compared the NASS estimates of police-reported injuries with the summed State-level counts from Highway Statistics (FHwA, various years). This comparison showed that the States report about 1.12 times as many injuries as the NASS estimate. Similarly, a comparison with FARS data for 1982 through 1984 showed its average fatality count was 1.16 times the NASS estimate. Therefore, we multiplied the NASS incidence estimates times 1.12 to obtain estimates of total injuries reported to the police.

Of course, not all injuries are reported. Rice et al. (1989) uses the Health Interview Survey count of motor vehicle injuries and estimates hospitalized injuries from Hospital Discharge Survey data. We accepted these counts.

These counts include non-collision events -- carbon monoxide poisoning and falls while getting into the car. Rice et al. estimated hospitalized injuries by cause from Maryland data on injury causation during 1984 through 1986. They estimated 523,000 motor vehicle injuries with hospitalization/yr. A frequency count of the cause codes showed that 4 percent of the injuries were non-collision (MacKenzie, 1991). Thus, roughly 502,000 hospitalized injuries resulted from crashes.

Only roadway crashes are reported to the police. The cause codes indicated 5.5 percent of the injuries occurred on private property. So dirt bike crashes, children run over in driveways, and snowmobile mishaps cause roughly 27,000 hospitalizations annually. Injuries in road crashes caused 475,000. Only 82.5 percent of these injuries were in crashes reported to the police.

Rice et al. estimate motor vehicles caused 4,803,000 injuries not requiring hospitalization in 1985. Assuming the distribution of injuries by cause does not vary with hospitalization, 4,610,000 of these resulted from crashes. Of these, 255,000 occurred off the road.

Finally, to estimate the number of injury crashes, we divided the number of injuries by the average injuries/injury crash: 1.55 according to NASS data for 1982 through 1985.

Unreported Injuries

We checked the reasonableness of Rice's estimates by computing rates of police underreporting, then comparing them with published estimates. The adjusted NASS count was 392,000 hospitalized injuries. Dividing the adjusted NASS estimate by Rice's estimate suggests that 17.5 percent of hospitalized injuries are unreported. A literature review by Hauer and Hakkert (1988) yields a consistent estimate: roughly 20 percent.

For all injuries, dividing the complete count from State files (FHwA, 1990) by Rice's estimate suggests 41 percent of injuries are not reported to the police if we include people who the police incorrectly code as injured in the injury count, 45 percent if we do not. By comparison, Hauer and Hakkert estimate 50 percent of all injuries are not reported, and Miller, Whiting, et al. (1987) estimate 30 to 35 percent are not. Again, the estimates are consistent.

Finally, NASS records more injuries than the police in police-reported crashes. NASS counts 70 percent of all injuries, or after adjustment to the overall count of police-reported crashes, 79 percent. Consistent with this, Greenblatt et al. (1981) surveyed people about crash reporting and estimated prospectively that NASS would capture 74 percent of all injuries.

This study's incidence estimates yield injury reporting rates consistent with published estimates. That finding strengthens the incidence data's credibility.

IV. YEARS LOST TO DEATH AND INJURY

Valuing injuries requires measuring their relative severity. One appealing measure sums the years of life lost to fatal injury and the years of functional capacity lost to nonfatal injury. Years lost are a non-monetary measure. They do not mirror monetary costs. Therefore, the direct costs of injury and death generally should be accounted for separately when using years lost in a cost-effectiveness analysis.

This chapter estimates the years lost, then explains the estimating methods. Chapter V presents the direct costs.

A year of **functional capacity** covers 24 hrs/day, 365 days/yr. This report defines functional capacity loss as impairment along any of the following seven dimensions:

- Mobility.
- Cognitive.
- Self care.
- Sensory.
- Cosmetic.
- Pain.
- Ability to perform household responsibilities and wage work.

In addition to the years of functional capacity lost, this chapter estimates two of its components -- the years of household production and wage work lost. Chapter V estimates the dollar value of the years lost for these components.

Household production is defined as housework and other household chores including paying bills, yard work, child care, shopping, and home repair. A household production year contains 365 days. The number of hours in a household production day varies by age and sex (Douglass et al., 1990). For the age and sex profile of fatalities in motor vehicle crashes, we computed that household production days average 2.1 hours. For the age and sex profile of nonfatal crash injuries, the average is 2.45 hours.

A year of **wage work** averages 243 days that last 8 hours. People only lose work on days they would have been employed.

Years of Life and Functioning Lost to Crashes

Crashes can be terribly debilitating. On average, 1.54 years of life and functioning are lost in an injury crash.[7] The annual loss exceeds 4.85 million years (figure 6). Deaths obviously cost the most hrs/case. Table 6 presents the hours lost to all injuries and figure 6 the years lost. In aggregate, major nonfatal injuries (MAIS 3 to 5) cost slightly more functioning than deaths. Conversely, deaths cost more household production and wage work.

Table 6. Millions of hours of functioning, household production, and work lost to injury, by injury severity.

	Injury Severity			
	Modest	Major	Fatal	Total
Functioning				
Hours (M)	7,664	17,295	17,580	42,539
Percent	18.0	40.7	41.3	100
HH Production				
Hours (M)	740	649	1,546	2,935
Percent	25.2	22.1	52.7	100
Work				
Hours (M)	1,338	1,179	3,652	6,169
Percent	21.7	19.1	59.2	100

Note: Modest injuries are MAIS 1 and 2; major injuries are MAIS 3 to 5.

Nonfatal functional loss need not cause productivity loss. The seriously injured lose many more functional than productive years. Through courage and sweat, determined people overcome physical challenges. They adapt, returning to work and helping around the house. They rebuild their lives.

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[7] To compute this number, we divided the total years from figure 6 by the 3.15 million injury crashes from chapter III.

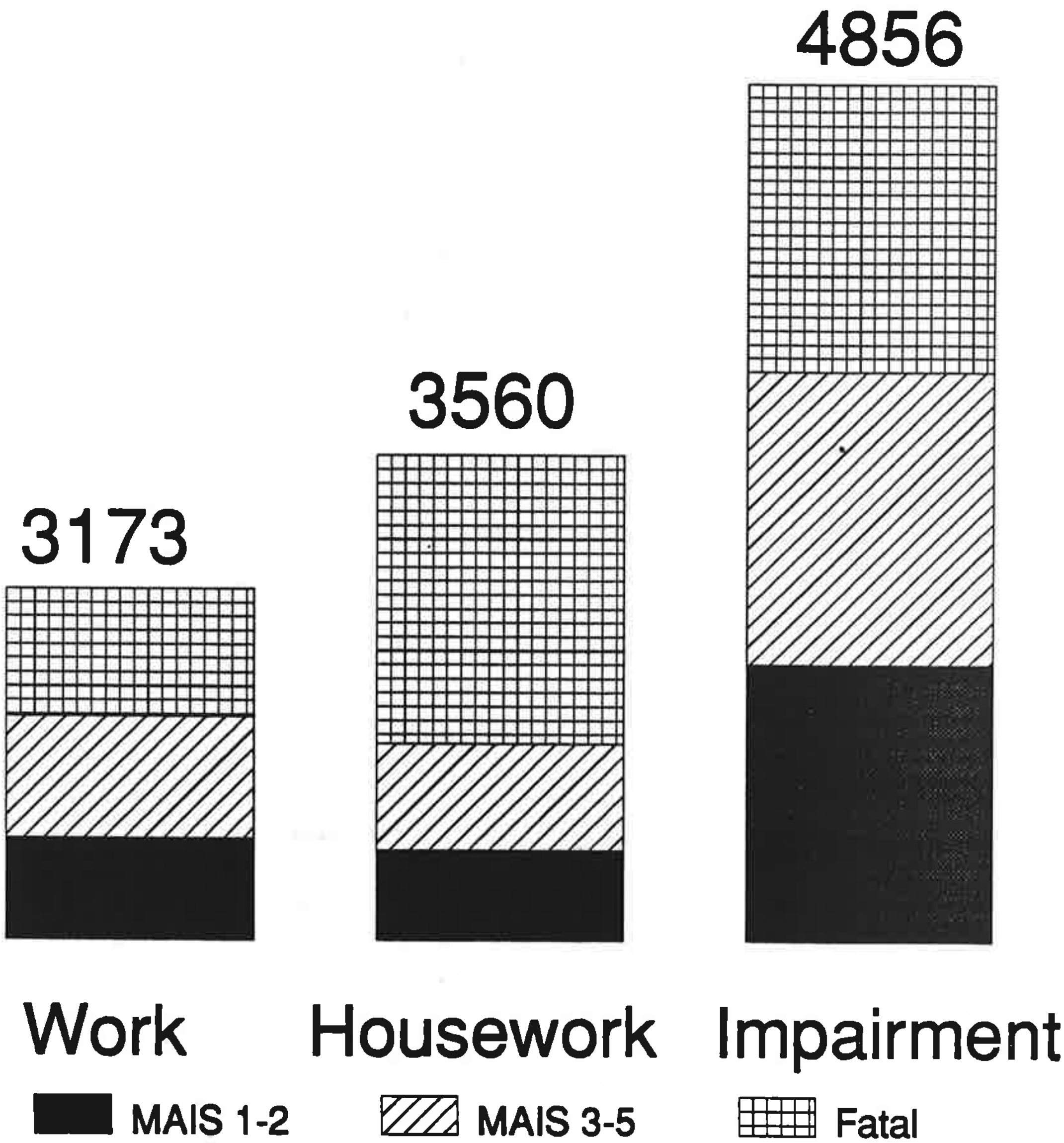


Figure 6. Thousands of years lost to crashes.

Nevertheless, figure 6 suggests that modest injuries (MAIS 1 and 2) lead to roughly proportional productive and functional losses. This finding may result from our estimating methods. Minor (MAIS 1) injuries typically cause little permanent loss of functioning. These injuries primarily cause permanent losses when recovery goes awry. We were able to estimate how often minor injuries reduce earning capacity, but lacked data about other aspects of atypical functional loss. Thus, the estimated years of functional loss for modest injury are a lower bound.

Years Lost/Case

The average person surviving injury in an auto crash had 47.2 years of lifespan remaining. For fatalities, the comparable figure was 42.7 years. Nonfatal injury can substantially shorten functional lifespan. Average years lost/injury, a modest .07 percent of the remaining lifespan for minor injuries, soar to 35 percent for severe injuries and 70 percent for critical ones. (See table 7.) The most debilitating injuries are primarily spinal cord injuries and brain injuries.

Seemingly benign moderate injuries -- deep cuts, concussions causing less than 1 hour of unconsciousness, amputated toes, closed leg fractures, and compound arm fractures -- cause an average of 1.1 years of impairment. The largest number of functional years, almost 1.2 million, is lost to serious (MAIS 3) injuries. These injuries include compound leg fracture, arm crush or amputation, foot crush or amputation, major nerve laceration, brain injury involving 1 to 6 hours of unconsciousness, and abdominal organ bruise. On average, they cost 6.5 years of functioning and 2.7 years of productivity.[8]

Decisionmaking Should Consider Present Value Years

So far, this chapter has treated days lost this year and days that will be lost in 2010 as equivalent. The total days lost call dramatic attention to the crash problem. They are ideal for publicizing it and testifying about it. For decisionmaking, however, both logic and empirical evidence suggest that a day lost in 2010 is of less concern than a day lost next week.

[8] Table 39 in appendix C provides details on the functional years lost by MAIS and body region.

Table 7. Functional years lost by MAIS.

MAIS	Per Injury	Percent of Lifespan	Per Year	Percent of Annual Total
Minor	0.07	0.15	316,600	10.7
Moderate	1.1	2.3	587,700	20.0
Serious	6.5	13.8	1,176,700	40.0
Severe	16.5	35.0	446,700	15.2
Critical	33.1	70.0	413,800	14.1
Avg nonfatal	0.7	1.5	2,941,500	100.0
Fatal	42.7	100.0	2,007,000	

Note: The expected lifespan for the nonfatally injured averages 47.2 years.

Logically, would you pay more today to reduce your chance of breaking your arm today than to reduce your chance of breaking it 4 years from now? You probably would. Rational reasons for placing a lower value on reducing the future risk include:

- You may die in less than 4 years.
- Technological change may make a broken arm heal faster 4 years hence than it does today or reduce the chance of permanently impairing complications.

Empirical evidence also suggests valuing present years more than future ones. Moore and Viscusi (1990) develops six models that estimate the discount rate implicit in job choices between lower fatality risk or higher wages. They find that workers use discount rates of 1 to 14 percent to convert future life years to present values. In a survey of students about airline safety, Horowitz and Carson (1990) obtain a median discount rate of 4.5 percent for life years. No other published studies offer empirical evidence on the discount rate to use in converting future years to present value years.

Miller, Whiting, et al. (1987) recommends using a 4-percent discount rate for highway safety decisionmaking that does not involve capital investment. Our report uses this discount rate to compute the present value of future monetary costs of injury. For consistency, we somewhat arbitrarily chose the same discount rate for computing present value years.

Fatal injuries cost an average of 19.4 present value years. Figure 7 shows the present value years lost/nonfatal injury by KABCO severity. A-injuries are the most debilitating, causing an average loss of 1.4 years of functioning. B-injuries typically cost about .25 years and C-injuries .1 years. People involved in crashes omitted in police statistics lose an average of .007 years, twice the .0035 years that people who police record as uninjured typically lose.

Fatal crashes cost an average of 22.05 present value years. Figure 8 shows the present value years lost/nonfatal crash. These range from 1.85 years for an A-crash to .02 years for an unreported crash and .01 years for an O-crash.

Computing Years Lost to Death: A Life Table Analysis

Years of life lost were computed by subtracting each person's age at death from their expected lifespan as shown in a life table. This computation overestimates the life years lost by people whose deaths resulted from habitual high-risk behavior. Taking extra risks raises a person's chance of dying; risk-takers have less years left than the life table suggests. Nevertheless, the error is probably not very large.

Those who die also lose all their remaining productivity. The section on productivity loss in chapter V describes how we estimated the dollars lost. The hours lost were derived by dividing the dollars lost by the average cost/hr.

Computing Years Lost to Nonfatal Injury Using Medical Judgement

To compute years of functional capacity lost to nonfatal injury, we:

- Estimated average health status over time, by injury, for the first six dimensions of functioning listed above.

- Estimated the average days of productivity loss by MAIS and body region.

- Developed weights and applied them to combine the ratings on the seven dimensions into a single rating of the percentage of functioning lost over time.

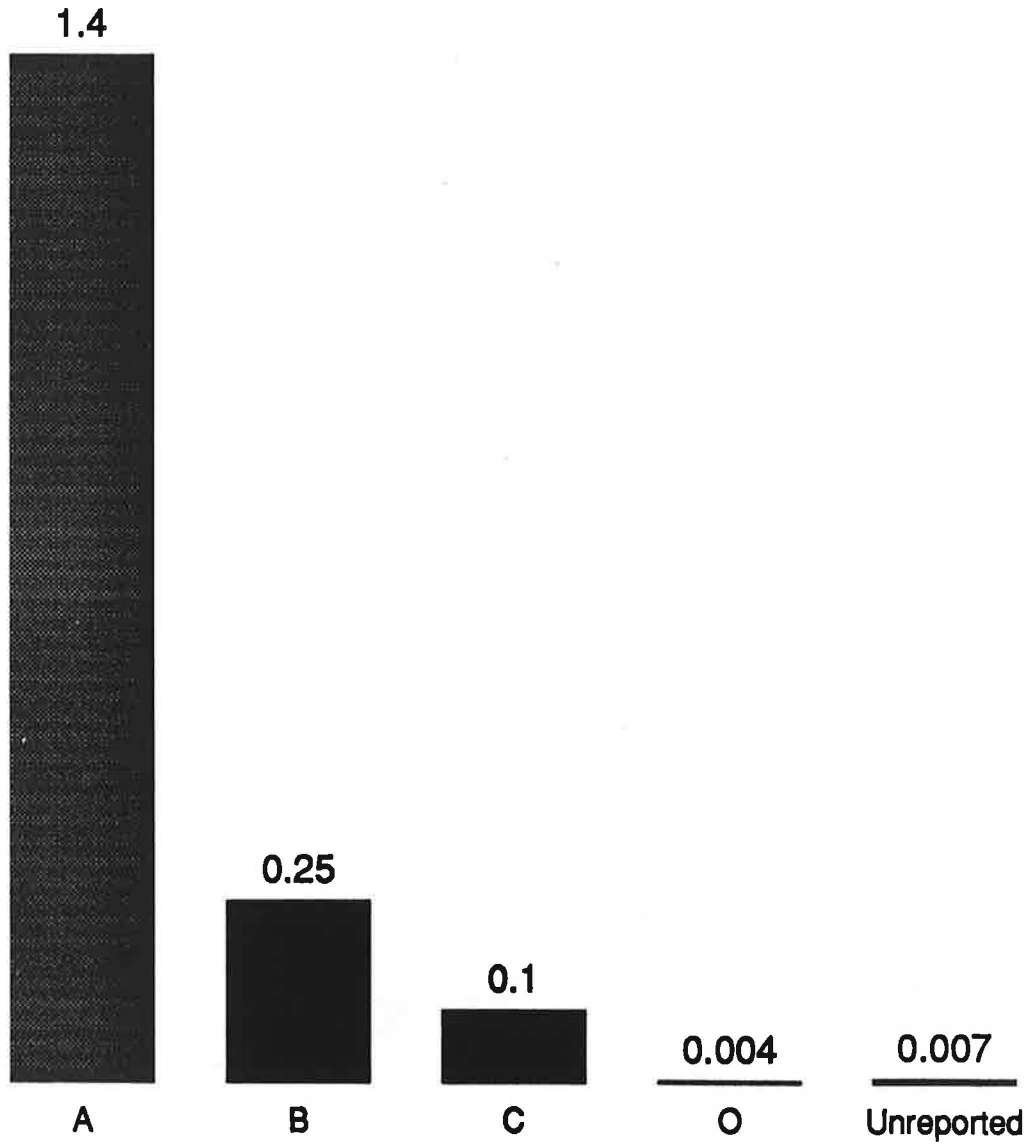


Figure 7. Years lost/nonfatal injury by KABCO severity.

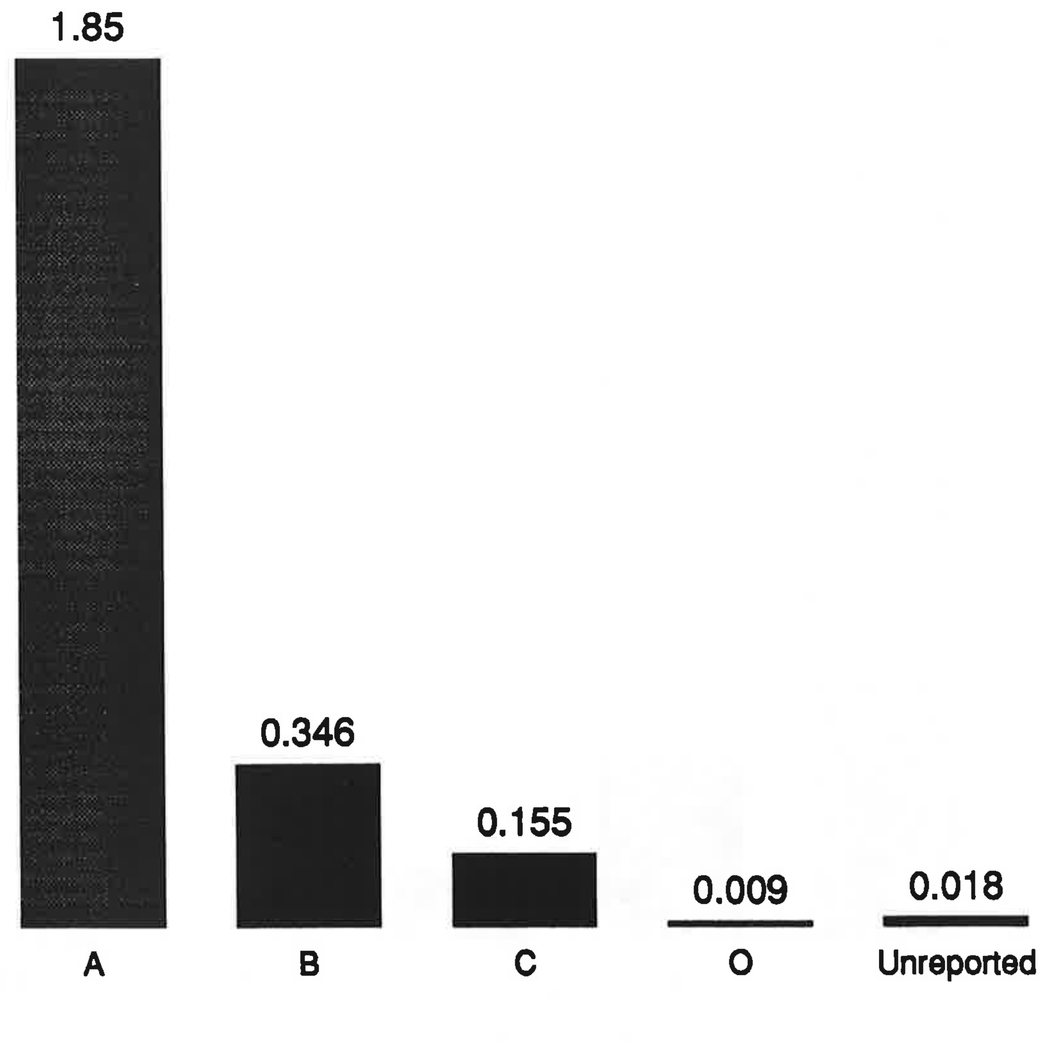


Figure 8. Years lost/nonfatal crash by KABCO severity.

- Computed the years lost from the percentage lost over time and the expected lifespan.

Estimating health status over time. For most injuries of MAIS 2 through 5, one or two cognizant medical specialists had estimated the typical course of recovery (Hirsch et al., 1983; Carsten, 1986). They estimated health status over time along the first six dimensions of functioning. For each dimension, they used a functional scale with levels ranging from 0 (no impairment) to 4 (maximum impairment). Table 8 contains the scales. The ratings showed the probable number of weeks of impairment at each level during the first year, and the probable impairment levels during the second through fifth year period and thereafter. The prognosis was rated separately for four age groups.

We added ratings for injuries omitted from the original ratings. In some cases, we assumed the impairment equalled the rated level for similar injuries; for example, we set the impairment for "knee fracture and dislocation" equal to the larger of the impairments for "knee fracture" and "knee dislocation."

For minor injuries and more serious lacerations, we assumed the percentage impairment in the first year equalled the percentage of work lost during that year. If a person with minor injuries permanently lost earning power, they obviously also lost some capacity to function physically. We assumed, conservatively, that they lost 5 percent. As table 9 shows, that equates to mild sensory or cognitive loss. Mild losses in mobility or self-care involve a larger percentage loss.

Estimating days of lost productivity. The work loss in the first 60 days following injury came from NASS. Data from NHTSA's National Crash Severity System, NASS's predecessor, were used to infer the length of work loss for those who lost more than 60 days but were not permanently disabled. Finally, using NASS and DCI data, we computed the probability of permanent work-related disability, then multiplied it times expected lifetime working hours. The productivity loss section in chapter V provides details about the estimating procedure. It also explains how we estimated household productivity losses from wage losses.

Combining the losses across dimensions. From Carsten (1986), Kaplan (1982), Kind et al. (1982), and Drummond et al. (1987), we selected importance weights for combining the seven dimensions. Miller and Associates (1991) describes the selection process. Table 9 shows the weights. Total and severe cognitive

Table 8. Scales for rating functional capacity.

Mobility

1. Impaired mobility with intact functional ability.

2. Impaired mobility with mildly abnormal function. Partially dependent on mechanical assistance. Unable to lift reasonable size objects (needs crutches, walker).

3. Severely impaired mobility with abnormal function. Dependent on mechanical assistance and wheelchair, occasionally needs attendant.

4. Entirely dependent on attendant or otherwise confined to bed.

Cognitive/Psychological

1. Mild inappropriate behavior, neurotic, depressed, increased irritability, intermittent confusion, occasional swings into elation-depression, increased errors in language and arithmetic.

2. Often disoriented, loss of ability to do simple arithmetic, slight impairment of language or memory, may be psychotic but not committable.

3. Severe memory impairment, severe impairment of language processing and/or psychotic/committable behavior.

4. Vegetative, total amnesia, no purposeful response to stimuli.

Self Care

1. Inability to do some normal nonessential activities.

2. Inability to do most nonessential and/or some essential activities.

3. Partially dependent on assistance for essential activities.

4. Totally dependent on assistance for most activities and functions

Table 8. Scales for rating functional capacity (continued).

Cosmetic

1. Normally covered, amenable to cosmetic cover-up. Readily covered orthosis.

2. Can be effectively covered by cosmetics and/or forces a change in dress habits. May require orthosis, but does not require prosthesis.

3. Prosthesis or cover-up required.

4. Readily observable; not amenable to cosmetic, prosthetic, or clothing cover-up.

Sensory

1. 10 to 25 percent loss to special senses or limbs.

2. 26 to 50 percent loss to special senses or limbs.

3. Greater than 50 percent loss to special senses or limbs.

4. Total loss to special senses or limbs.

Pain

1. Normal function with no or occasional non-narcotic drugs and/or other non-invasive therapy.

2. Normal function only with the use of non-narcotic drugs and/or other non-invasive therapy.

3. Can function normally only with narcotic drugs and/or invasive therapy.

4. Cannot function normally even with narcotic drugs and/or invasive therapy.

Ability to Work

1. Can work, but earning capacity reduced.

4. Complete loss of earning capacity.

Source: Hirsch et al. (1983). Ability to work, this report.

Table 9. Percentage loss in overall functional capacity resulting from loss on a single dimension of functioning.

SEVERITY	DIMENSION OF FUNCTIONING						
	Mobility	Cognitive	Self Care	Sensory	Cosmetic	Pain	Ability to Work
4-Total	68	95	71	37	10	60	33
3-Severe	55	90	36	24	6	10	
2-Moderate	28	20	33	15	3	3	
1-Mild	13	5	8	5	1	1	8
0-None	0	0	0	0	0	0	0

losses are the largest: 95 and 90 percent of the complete loss resulting from death. Losses in mobility and self care rank next in importance. Least important are cosmetic losses and mild to severe pain.

We used the formula in American Medical Association (1984) to combine the impairments across dimensions.[9] Carsten (1986) and Luchter (1987) used the same formula. We also used this formula to combine the impairments associated with multiple injuries.

Computing Years Lost. Following Luchter (1987), we computed the years of functioning lost as the percentage impaired times the person's expected lifespan. We computed the losses both undiscounted and at a 4-percent discount rate.

[9] The formula is 1 - (1 - i1) * (1 - i2) * ... * (1- i6) where i1 to i6 are the fractional impairments that are to be combined. This multiplicative formula assumes that the percentage impairment on the different dimensions is independent of initial functional level. For example, if mobility is impaired by 50 percent, 20-percent cognitive impairment would mean 20 percent of the residual functioning (10 percent of total functioning) was lost.

V. INJURY COSTS

Annually, the comprehensive cost of crashes exceeds $334 billion. This figure is the maximum rational highway safety investment beyond current expenditure levels. Per vehicle, the maximum is $1,618/yr on injury prevention plus $207 to reduce property damage. Per capita, the maximum is $1,233. Consider a driver with an average injury risk. If an airbag reduced this driver's risk by one third, it would be worth $420/yr -- $3,700 in present value over the car's 11-year lifespan. No wonder car advertising is stressing safety!

As figure 9 shows, the costs of pain, suffering, and lost quality of life dominate the comprehensive costs; they account for 65 percent. The remaining costs are split roughly equally between property damage, lost wages and household production, and other direct costs. The other direct costs include:

- Medical.
- Crash-related travel delay.
- Emergency services.
- Vocational rehabilitation.
- Workplace costs for replacing the disabled.
- Legal system.
- Insurance and public program administration.

This chapter presents the costs/injury and costs/crash, as well as the total costs. For many cost categories, it compares our estimates with prior ones. It also briefly describes how each cost was estimated. Details of the estimating procedures appear in Miller and Associates (1991).

Although comprehensive costs are the most useful, this chapter also presents direct costs and human capital costs. Table 10 lists the cost components by costing methodology. The components are quite similar. Comprehensive costs include all categories of costs. Direct costs replace lost earnings and the most tenuous monetary estimates -- the values for lost household production, pain, suffering, and lost quality of life -- with a nonmonetary measure, years lost. Human capital costs simply omit the pain, suffering, and lost quality of life.

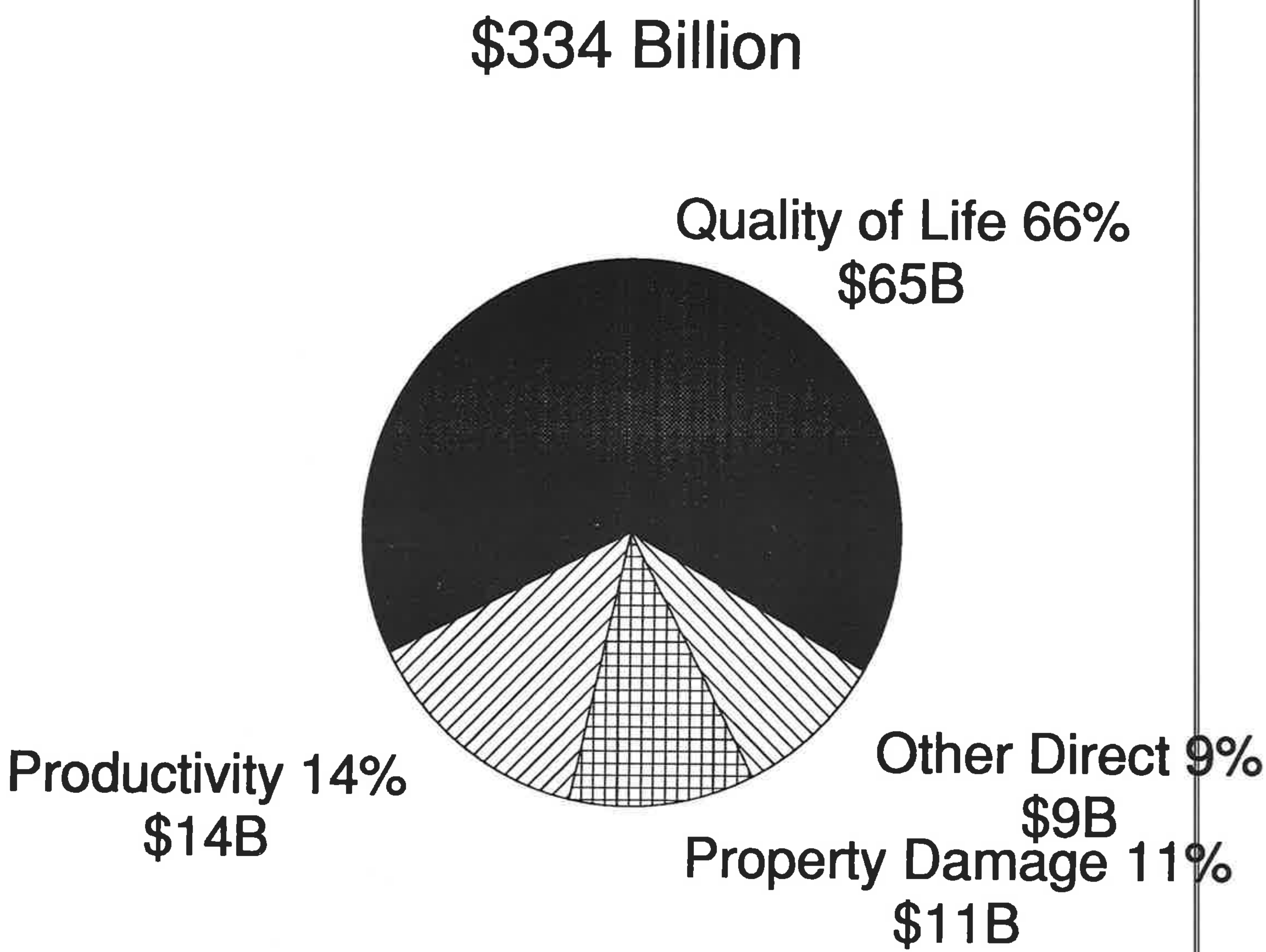


Figure 9. Annual cost of crashes.
(in 1988 dollars discounted at 4%)

Table 10. Cost components by costing methodology.

Component	Compre-hensive	Years Lost Plus Direct	Human Capital
Property damage	x	x	x
Lost earnings	x	non-monetary	x
Lost household production	x	non-monetary	x
Medical costs	x	x	x
Emergency services	x	x	x
Travel delay	x	x	x
Vocational rehabilitation	x	x	x
Workplace costs	x	x	x
Administrative	x	x	x
Legal	x	x	x
Pain & lost quality of life	x	non-monetary	

Comprehensive Costs: The Most Useful Numbers

Table 11 shows the comprehensive costs/person and costs/crash by severity. Fatal injuries cost an average of $2,392,742 each and fatal crashes $2,722,548. A-injuries, the next most costly, cost less than one tenth of fatalities.

Table 11. Comprehensive costs/person and costs/crash, by police-reported severity.

Severity	Per Person	Per Crash
K - Fatal	$2,392,742	$2,722,548
A - Incapacitating	169,506	228,568
B - Evident	33,227	48,333
C - Possible	17,029	25,228
O - Property damage	1,734	4,489
Unreported	1,601	4,144
A-B-C - Reported nonfatal	$46,355	$69,592
K-A-B-C - Reported injury	77,153	115,767

Note: In 1988 dollars at a 4-percent discount rate.

People coded as O have the lowest average costs in police-reported incidents, $1,734. People in unreported crashes have even lower average costs, $1,601. Some of these people are injured. The cost/uninjured person averages $1,123.

Figure 10 graphically illustrates that the percentage distribution of costs by injury severity is very similar to the percentage distribution by crash severity. Fatal incidents account for the largest share of the total costs by severity. A-crashes and injuries account for an almost equal share, followed by B-crashes and injuries. The smallest share of the costs, 6 to 7 percent, are attributable to incidents coded as Property Damage Only (PDO).

As the examples in chapter IX illustrate, comprehensive costs are widely applicable in highway engineering. They also are the appropriate numbers to use in benefit-cost analysis of safety programs and regulations.

Some safety improvements affect only a subset of the costs. For example, an air bag will not reduce property damage. Also, States may wish to use geographic price adjusters to refine our national average medical costs, wage losses, and property damage. Therefore, this chapter presents the costs by component.

Table 12 summarizes the costs by component. By KABCO severity, it presents:

- The costs/case.
- The percentage distribution of costs/case among cost categories.
- The total costs for all cases.
- The percentage distribution of total costs by cost category among severity levels.

Tables 40 and 41 in appendix C show cost estimates in other injury severity systems -- by body region and MAIS threat-to-life severity, and by medical treatment received. Miller and Associates (1991) discusses these costs. It also offers estimates at other discount rates and by body region, MAIS, and medical treatment.

To compute the costs by KABCO category in table 12, we first computed costs by body region and MAIS. These costs appear in table 40 in appendix C. We aggregated the costs by KABCO severity using NASS data on the mix of injuries in each KABCO category. To compute costs/crash, we used table 42 in appendix C, which shows the distribution of injury severity by crash severity.

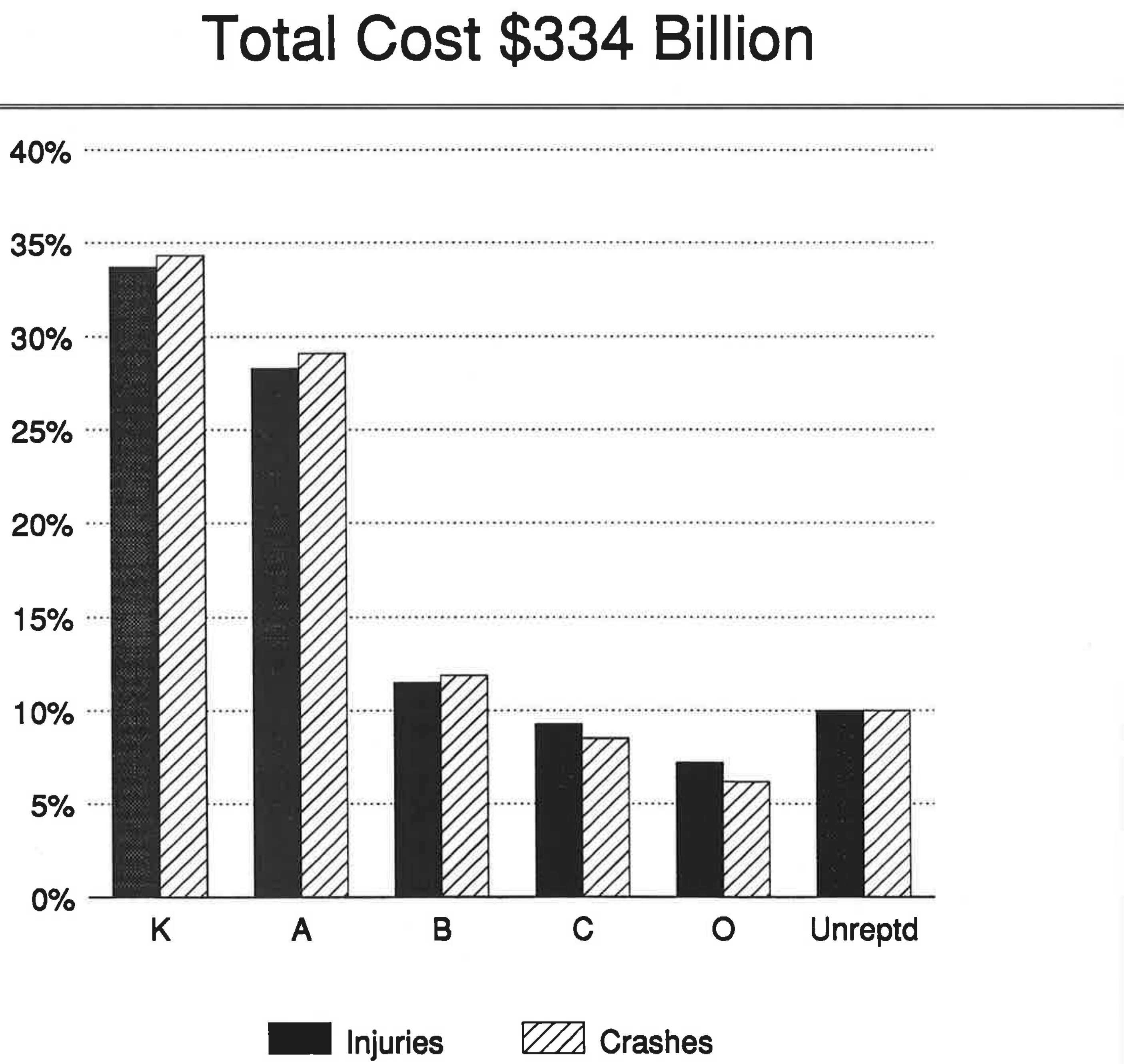


Figure 10. Percentage of total injury and crash costs by KABCO severity.

Table 12. Costs/injury and for all injuries by KABCO severity and cost component, in 1988 dollars.

Severity	Cases	Hosp/ Med	Voc Rehab	HH Prod	Wages	Insur Admin	Wkplc Cost	Emerg Svcs	Travl Delay	Legal/ Court	Prop Damag	Human Capital	Pain & Suffer	Compre- hensive	Direct Costs	Years Lost
		COSTS PER PERSON (1988 dollars at a 4% discount rate)														
K	47093	5859	0	92014	428316	43751	6186	842	358	64205	7294	648825	1743917	2392742	128495	19.39
A	558467	9660	69	3250	11728	2470	961	245	160	3920	3118	35581	133925	169506	20603	1.39
B	1154001	1742	24	845	2946	721	333	146	160	849	2603	10369	22858	33227	6578	0.25
C	1828531	1017	19	522	1782	484	223	114	160	486	2295	7102	9927	17029	4798	0.11
O	13791181	49	1	48	91	104	30	23	84	27	1029	1486	248	1734	1347	0.004
AllRptd	17379273	588	7	503	1993	379	117	50	100	429	1351	5517	11788	17305	3021	0.13
A-B-C	3540999	2616	29	1058	3730	874	375	145	160	1146	2525	12658	33697	46355	7870	0.36
K-A-B-C	3588092	2659	28	2251	9303	1437	452	154	163	1974	2588	21009	56144	77153	9455	0.61
Unreptd	20766878	41	0	40	93	55	19	1	12	22	714	997	604	1601	864	0.007
O-Vehicl	9270136	73	1	71	135	155	45	34	125	40	1531	2210	369	2579	2004	0.005
		PERCENTAGE DISTRIBUTION OF COSTS/PERSON BETWEEN COST CATEGORIES														
K		0.24	0.00	3.85	17.90	1.83	0.26	0.04	0.01	2.68	0.30	27.12	72.88	100.0	5.37	
A		5.70	0.04	1.92	6.92	1.46	0.57	0.14	0.09	2.31	1.84	20.99	79.01	100.0	12.15	
B		5.24	0.07	2.54	8.87	2.17	1.00	0.44	0.48	2.56	7.83	31.21	68.79	100.0	19.80	
C		5.97	0.11	3.07	10.46	2.84	1.31	0.67	0.94	2.85	13.48	41.71	58.29	100.0	28.18	
O		2.83	0.06	2.77	5.25	6.00	1.73	1.33	4.84	1.56	59.34	85.70	14.30	100.0	77.68	
Unreptd		2.51	0.04	2.51	5.82	3.46	1.18	0.04	0.75	1.41	44.56	62.28	37.72	100.0	53.95	
		COSTS FOR ALL PEOPLE (millions of 1988 dollars)														M of years
K		276	0	4333	20171	2060	291	40	17	3024	343	30555	82126	112681	6051	0.91
A		5395	39	1815	6550	1379	537	137	89	2189	1741	19871	74793	94664	11506	0.78
B		2010	28	975	3400	832	384	168	185	980	3004	11966	26378	38344	7591	0.29
C		1860	35	954	3258	885	408	208	293	889	4196	12986	18152	31138	8773	0.21
O		676	14	662	1255	1434	414	317	1158	372	14191	20494	3420	23914	18577	0.05
All Rptd		10216	115	8740	34634	6591	2034	871	1742	7454	23476	95872	204869	300741	52498	2.23
Unrptd		843	8	830	1939	1152	389	16	252	465	14830	20725	12545	33270	17956	0.14
Total	30451055	11059	123	9570	36573	7743	2423	887	1994	7919	38306	116597	217414	334011	70454	2.37
		PERCENTAGE DISTRIBUTION OF TOTAL COSTS WITHIN EACH COST CATEGORY														
K	0.15	2.5	0.0	45.3	55.2	26.6	12.0	4.5	0.9	38.2	0.9	26.2	37.8	33.7	8.6	38.5
A	1.8	48.8	31.3	19.0	17.9	17.8	22.2	15.4	4.5	27.6	4.6	17.0	34.4	28.3	16.3	32.8
B	3.8	18.2	22.5	10.2	9.3	10.8	15.9	19.0	9.3	12.4	7.8	10.3	12.1	11.5	10.8	12.1
C	6.0	16.8	28.3	10.0	8.9	11.4	16.8	23.5	14.7	11.2	11.0	11.1	8.4	9.3	12.5	8.7
O	45.3	6.1	11.2	6.9	3.4	18.5	17.1	35.8	58.1	4.7	37.1	17.6	1.6	7.2	26.4	2.1
Unrptd	42.9	7.6	6.7	8.7	5.3	14.9	16.1	1.9	12.6	5.9	38.7	17.8	5.8	10.0	25.5	5.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Direct Costs for Use with Years Lost

Table 13 and figure 11 show the crash-related direct costs including property damage. Direct cost savings should be treated as dollar benefits when using years saved as a cost-effectiveness measure. Although fatal costs are substantially higher than other costs, the cost differentials between severities are much smaller than for total costs. Unreported and O-incidents account for more than half the direct costs.

Table 13. Direct costs/person and costs/crash, by police-reported severity.

Severity	Per Person	Per Crash
K - Fatal	$128,495	$154,748
A - Incapacitating	20,603	30,156
B - Evident	6,578	11,089
C - Possible	4,798	8,458
O - Property damage	1,347	3,487
Unreported	864	2,237

Note: In 1988 dollars at a 4-percent discount rate.

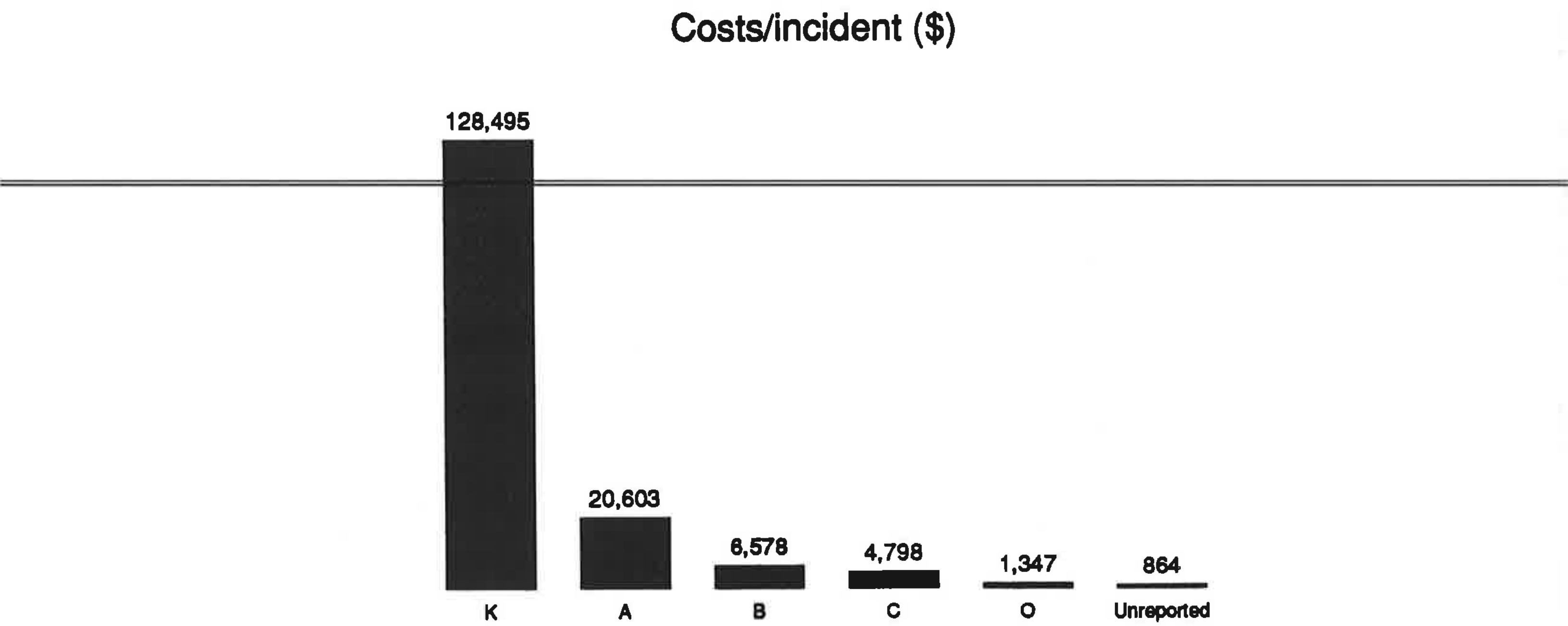
Human Capital Costs: The Monetary Impacts of Crashes

Human capital costs are used to measure the monetary costs of injuries. They equal the direct costs plus wage and household production losses. **Human capital costs should never be used in benefit-cost analysis.**

Human capital costs/fatality average $648,825. (See table 12.) They are more than 50 times larger than the average $11,757 cost/nonfatal injury or $12,658/police-reported injury. Figure 12 shows how the nonfatal human capital costs are distributed.

In 1988, crashes had monetary costs of $107 billion (excluding lost household production). They may have slowed the Nation's economic growth; the total growth in Gross National Product (GNP) in 1988 was only $350 billion (Bush, 1991).

Comparison with Prior Estimates. Several previous studies estimated the human capital costs of crashes. Rice et al. (1989) estimate the costs at $55.0 billion (inflated to 1988 dollars). The estimate used a 6-percent discount rate. It excludes property damage, travel delay, workplace costs, and legal system



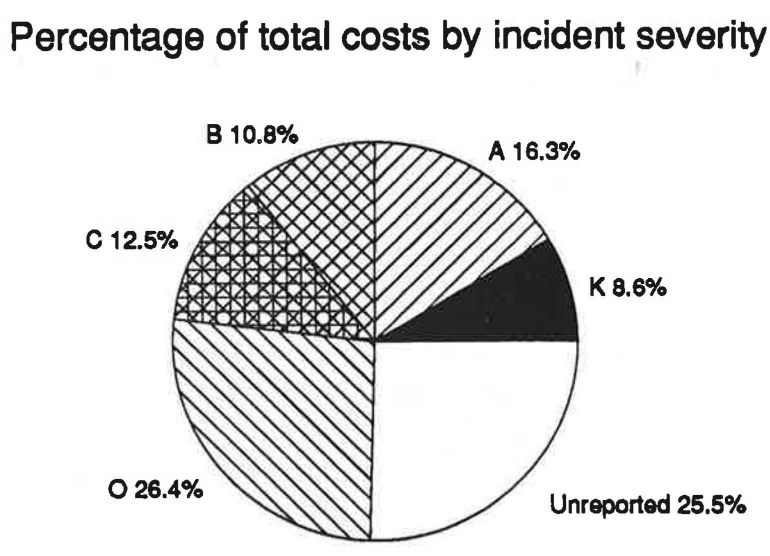
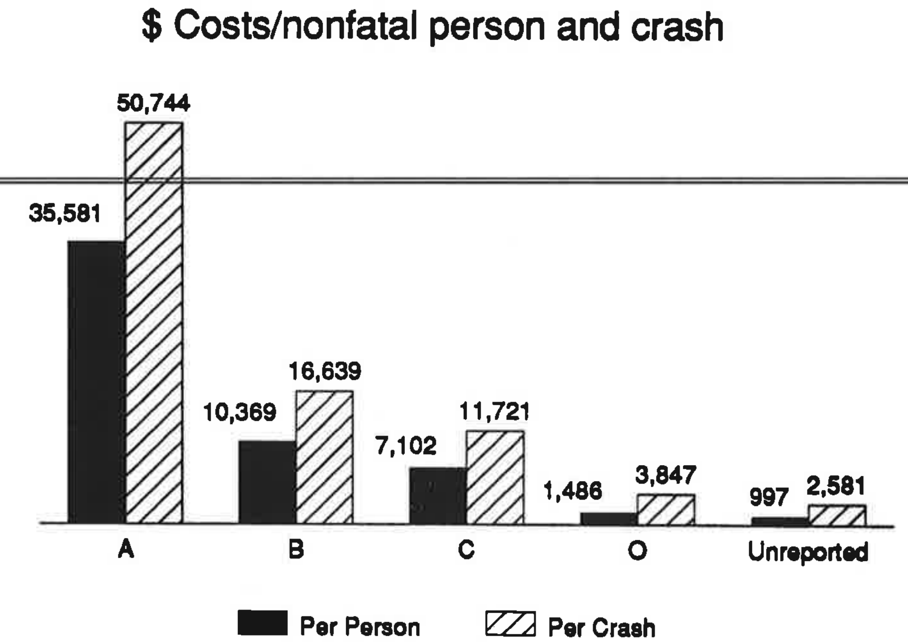


Figure 11. Crash-related direct costs by KABCO severity.



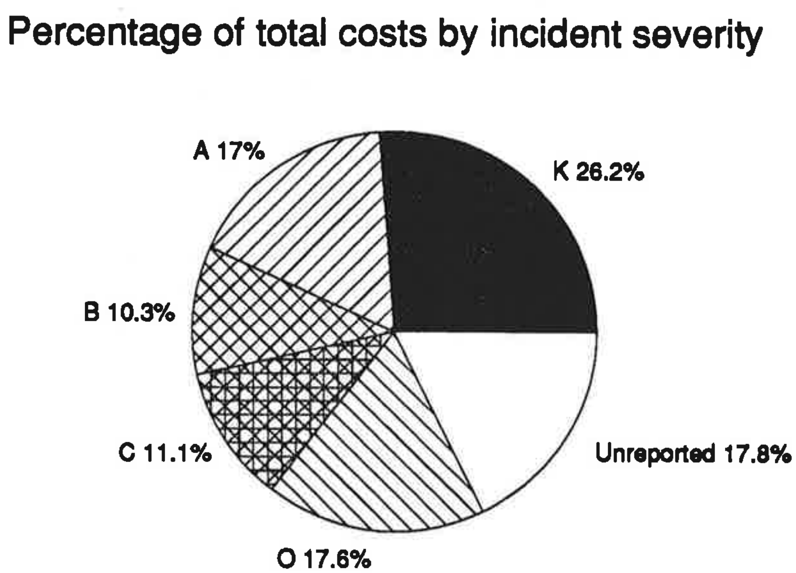


Figure 12. Human capital costs by KABCO severity.

costs. It includes injuries off-the-road, about 6 percent of the total. At that discount rate and with those exclusions, our study's estimate for on-the-road crashes would be $53.9 billion. The estimates match.

The National Safety Council's (1989a) cost estimate also matches our study's estimate. The Council estimates the costs of property damage reimbursed by insurers, wages lost, medical expenses, and insurance administration at $70.2 billion. With their 6-percent discount rate, our estimate would be $71.2 billion. The consistent totals, however, mask very discrepant costs by category. For example, our estimates of medical expenses is more than double the Council's.

The estimates in Hartunian, Smart, and Thompson (1981) are much lower than our study's or Rice et al.'s estimates. With the same discount rate and exclusions as Rice et al., their estimate is $32.6 billion (inflated to 1988 dollars).

NHTSA (1987) also obtained a lower estimate than we did -- $64.6 billion (inflated to 1988 dollars).[10] This estimate used a 7-percent discount rate. It includes all of our cost categories except workplace costs and travel delay. It is restricted to injuries in police-reported crashes, but covers the property damage in all crashes. With those exclusions and a 7-percent discount rate, our estimate would be substantially higher, $90.0 billion.

Why are the NHTSA estimates of crash costs so much lower? The next section shows that differing property damage estimates are one cause. Excluding property damage, the estimates are $35.1 billion by NHTSA versus our study's $51.4 billion. Hartunian et al. provided much of the data NHTSA used in estimating medical costs and the incidence and cost of permanent work disability. As discussed below, our study's cost estimates and Rice's are higher primarily because of these cost categories. This study's and Rice's data are more recent and more representative of U.S. experience than the older data.

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[10] Variable costs exclude the costs of having an insurance system and highway safety programs, which NHTSA suggests might be eliminated if the highways became completely safe.

Property Damage Costs

Figure 13 shows that aggregate costs of property damage rise as crash severity declines. O and unreported crashes account for more than three quarters of the total. Figure 13 also shows the property damage cost/vehicle by crash severity and cost/person by injury severity. This figure shows the damage/vehicle because some crash-reporting systems count the number of vehicles rather than the number of people in O crashes.

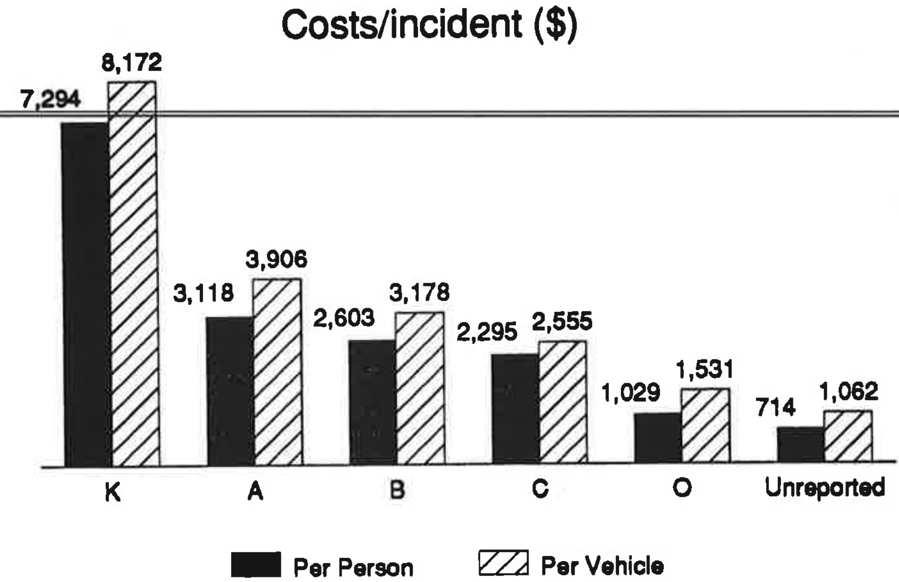
Comparison with Prior Estimates. Table 14 compares this study's property damage costs with NHTSA's. The costs differ considerably because:

- Insurance data indicate repair costs/vehicle rose 55 percent more than inflation between 1980 and 1988.
- Unlike NHTSA, we counted both repaired and unrepaired property damage. Unrepaired damage is a loss. It may not result in immediate out-of-pocket costs, but it reduces the vehicle's value. NHTSA's estimates of unrepaired damage are: for vehicles in minor crashes $649, in reported property damage only (PDO) crashes $305, and in unreported PDO crashes $120.
- NHTSA did not add the excess damage in crashes involving large trucks. The excess raises the average cost/vehicle $42 in a PDO crash, $152 in an injury crash, and $1,524 in a fatal crash.

Table 14. Costs/vehicle for property damage in this study and in NHTSA (1987).

MAIS	This Study	NHTSA
None	$1,352	$ 711
Minor	2,942	1,515
Moderate	3,466	2,527
Serious	5,280	3,948
Severe	7,069	5,355
Critical	7,103	5,398
Fatal	8,489	5,398

Note: In 1988 dollars.



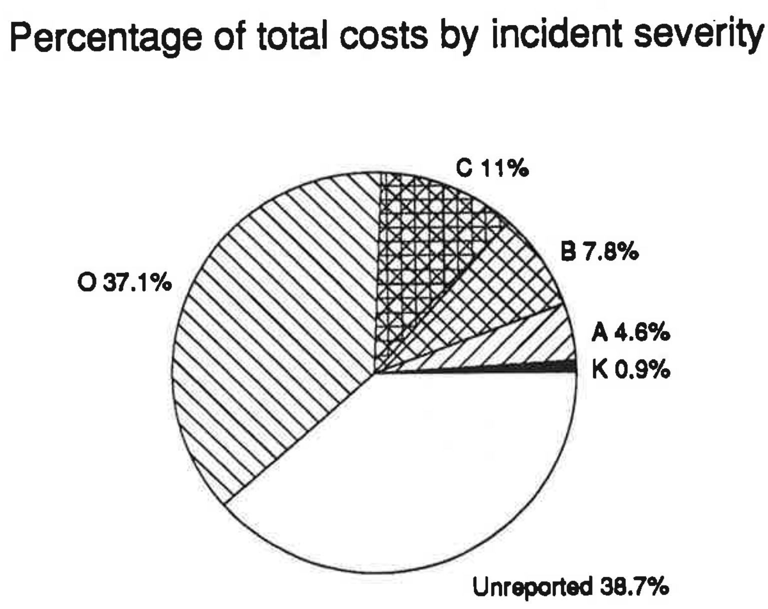


Figure 13. Property damage by KABCO severity.

Methods. To compute property damage costs, we adjusted data from Insurance Information Institute (1990) on the average property damage/passenger vehicle claim to account for deductibles. Following NHTSA (1983), we assumed crashes that insureds chose not to report to their insurers involved one tenth of the average property damage in reported crashes. We computed property damage/crash by crash severity with Faigin's (1976) ratios of cost by severity to average cost. We used Bureau of Motor Carrier Safety data to cost the damage in heavy truck crashes. These data cover both vehicle and cargo damage. Finally, we used data from Michigan (Andary et al., 1981) to cost unreported damage to bridges, guardrails, signs, and other roadside furniture.

Earnings Losses and Household Production Losses

Productivity losses include lost earnings and household production. Chapter III described the hours of productivity lost to crashes. Figure 14 shows the dollar losses/nonfatal injury. The losses decline with injury severity. A-injuries cost an average of $11,728 in earnings, including fringe benefits, and $3,250 in household production. At the other extreme, people who the police code as O-uninjured and people in unreported crashes lose less than $150 of productivity. One part of their loss is the household production time consumed in repairing a damaged vehicle and completing police and/or insurance paperwork. We assumed 4 hrs/vehicle were required.

Fatal productivity losses are far greater than injury losses. At $428,316 in earnings and fringe benefits and $92,014 in household production/death, they are almost 35 times the productivity losses per A-injury. They account for roughly half of the total loss (figure 15).

As table 6 in chapter III showed, injuries cost about three times as many hours of wage work as household production. Wages average $9.29/hr plus 19.5-percent fringe benefits in 1988 (Bush, 1991). Household production had a lower value -- $6.19/hr (Douglass et al., 1990). Consequently, earnings lost to injuries are roughly 3.5 times household production losses.

Comparison with Prior Estimates. This study estimated the average productivity loss/nonfatal injury at $3,603 for injuries in crashes reported to the police or $3,064 for all injuries (at a 6-percent discount rate). Both values are lower than Rice et al.'s estimate of $3,884 (inflated to 1988 dollars).

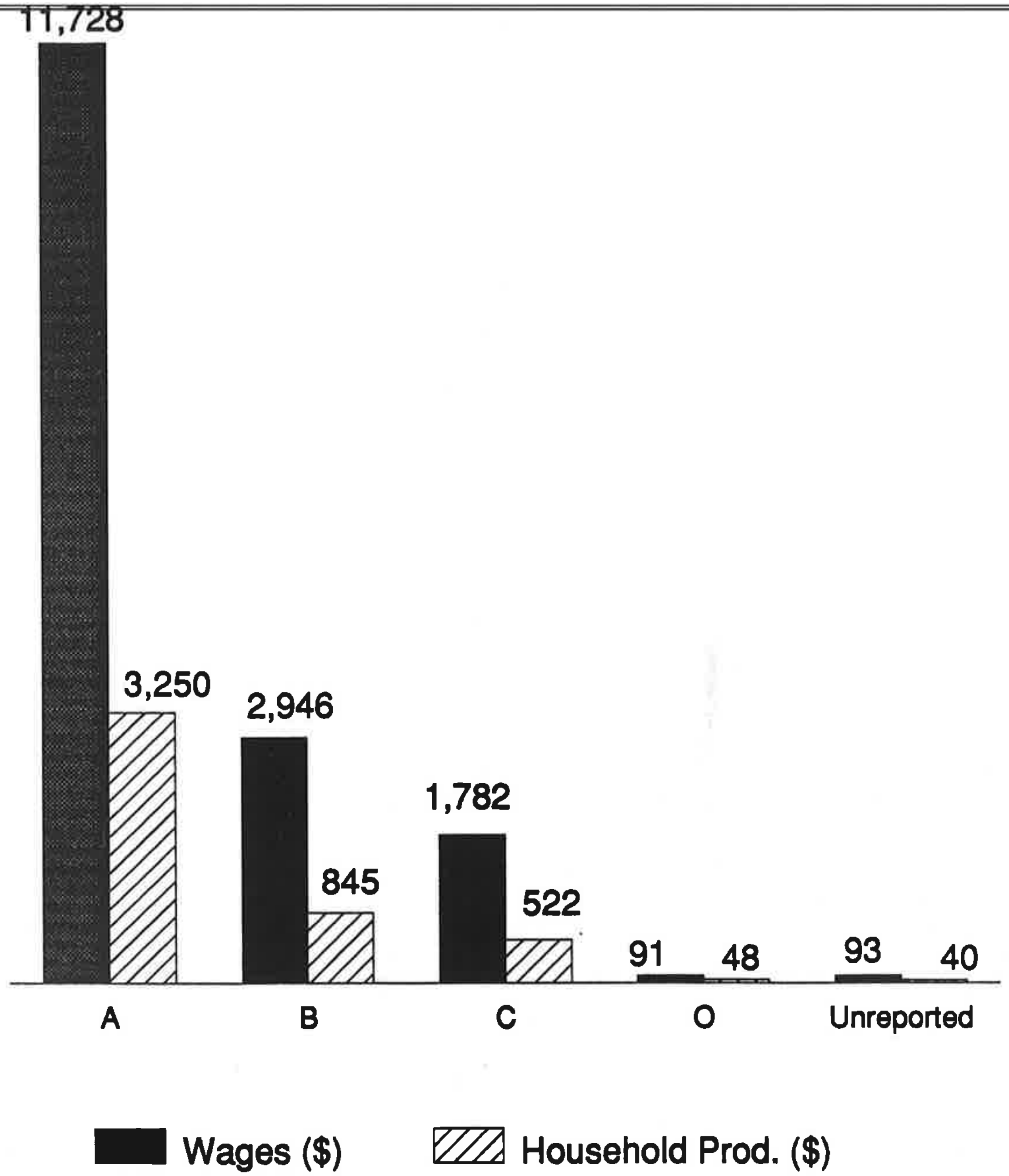


Figure 14. Productivity lost/nonfatal injury.

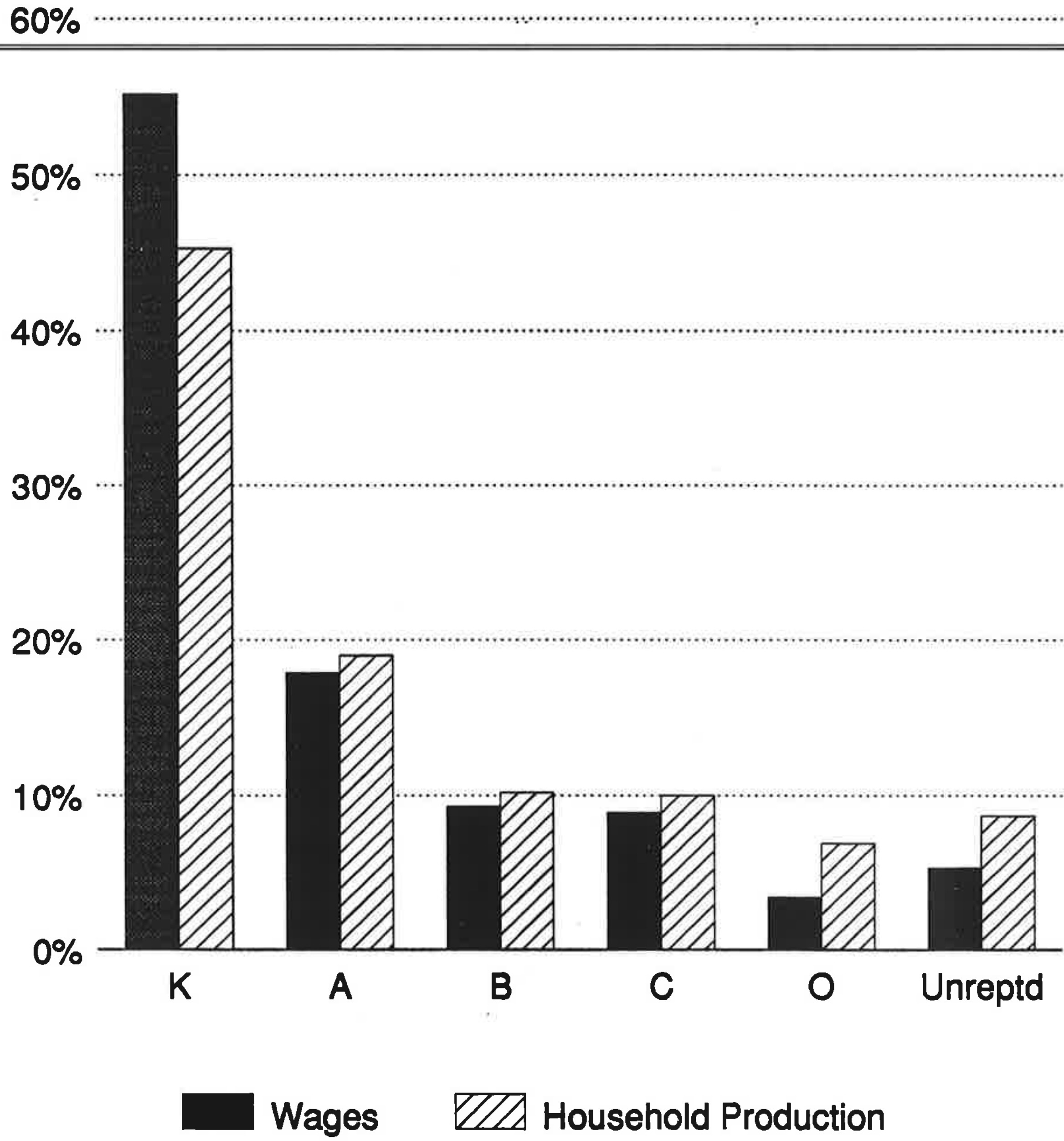


Figure 15. Percentage of productivity loss by KABCO severity.

We suspect the problem is with Rice et al.'s estimates for hospitalized injuries. These estimates derive from 1- and 4-year follow-up interviews with patients treated at the Johns Hopkins University (JHU) trauma center (MacKenzie et al., 1988). Figure 16 suggests these patients were more severely injured than typical patients. This figure is restricted to injuries posing a minor to moderate threat to life. In each of four body regions, the percentage of injured people who returned to work within 1 year in MacKenzie et al.'s study was lower than the percentage of hospitalized patients who NASS found returned to work within 60 days. For more severely life-threatening injuries, the percentage returning to work was comparable in the two sources. In almost all cases, the average time until return to work also was higher in MacKenzie et al. than in NASS data.

Rice's estimate for injuries that were not hospitalized should be quite reliable. It comes from the Health Interview Survey.

Table 15 compares our study's productivity loss estimates at a 7-percent discount rate with NHTSA's. Our study's costs are higher. The 7-percent difference in fatality costs results from our use of newer data on the value of household production. The largest difference for nonfatal injuries is that we included permanent work disability resulting from injury. NHTSA only included permanent disability for severe to critical head and spinal cord injuries.

Table 15. Productivity loss/person by injury severity in this study and NHTSA (1987).

MAIS	This Study	NHTSA
None	$ 22	$ 0
Minor	929	137
Moderate	8,096	774
Serious	25,966	2,186
Severe	36,633	18,033
Critical	125,580	96,266
Fatal	350,435	330,322

Note: In 1988 dollars at a 7-percent discount rate.

Methods: Analysis of NASS and DCI. We computed short-term productivity losses from NASS data on the days of work lost in the first 60 days after an injury. To monetize the wage loss,

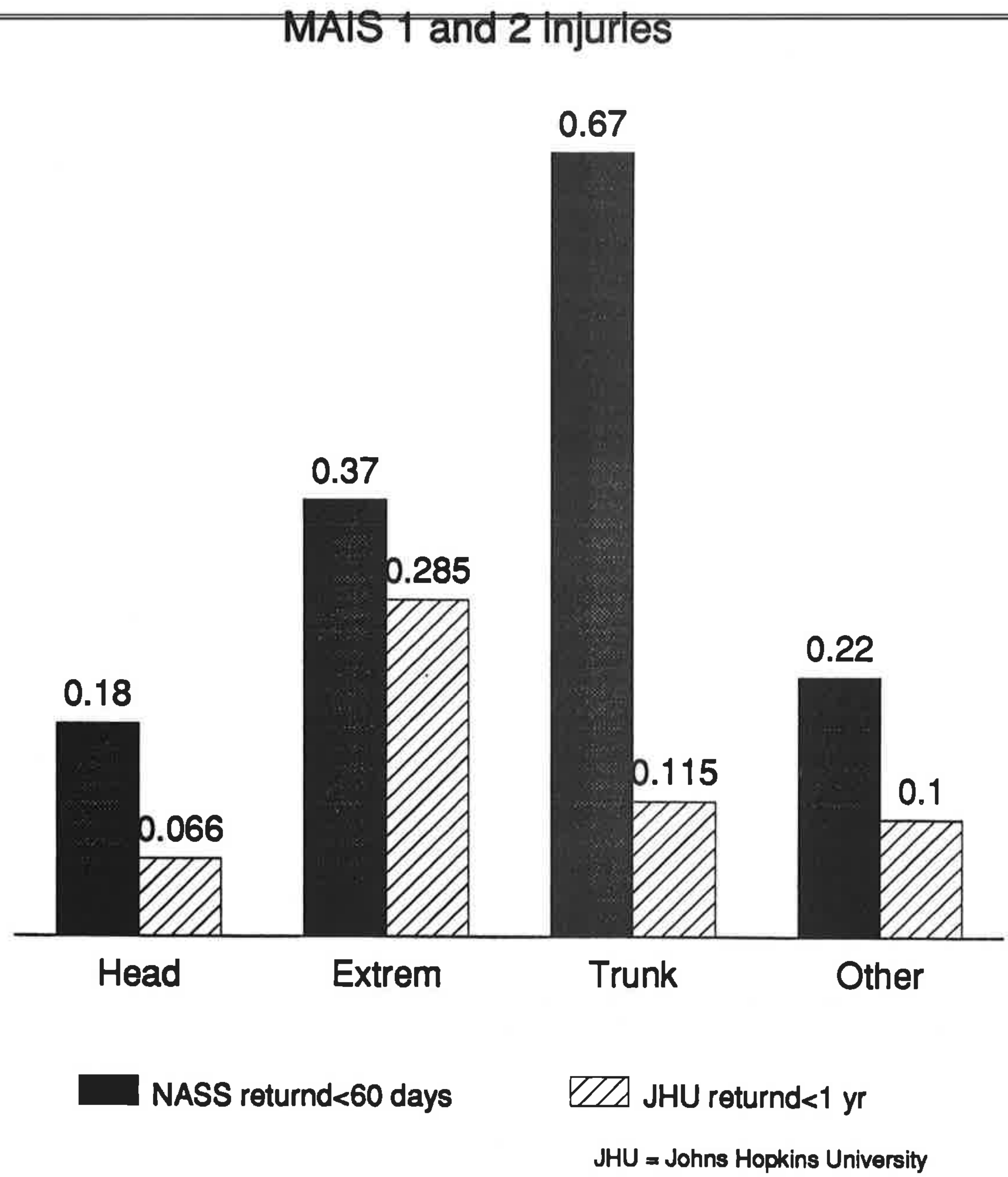


Figure 16. Fraction returning to work in two data sets.

we multiplied average hourly wages and fringe benefits from Rice et al. (1989) times the age and sex distribution of injured workers from NASS.

We assumed that the days of household production lost equalled the days of work lost times 365 days/yr divided by 243 work days/yr. Consistent with this assumption, Waller (1990) finds that workers suffering hand injuries generally return to work and housework on the same or successive days. We assumed those not working would lose the same number of days of household production as workers with the same injury. To monetize the lost household production, we used the values by age, sex, and work status in Douglass et al. (1990).

Some injuries result in permanent loss of earning power. Long-term earnings loss was computed as expected lifetime earnings times the probability of disability times the percentage of disability. We combined NASS data and Workers' Compensation data from the Detailed Claims Information (DCI) data base to estimate disability probabilities. We combined data clustered by body region, threat-to-life severity, and whether hospitalized. DCI distinguishes total from partial disability.[11]

Partial disability averages a 17 percent earnings loss (Berkowitz and Burton, 1987). For spinal cord injury, we instead used a 50 percent loss. We assumed those with multiple MAIS 4 and 5 head injuries were totally debilitated; they would not return to work. This raised the estimate of totally disabled, offset by a reduced partial disability estimate.

We computed the present value of lifetime earnings and household production from life table data and the cost data used in monetizing short-term wage loss. We assumed the 1-percent

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[11] The DCI codes often spanned several severity levels. In most States, DCI cases involve at least 3 days of work loss. We allocated the DCI cases among severity levels in proportion to NASS cases with at least 3 days lost from work. We allocated the DCI permanent disability cases in proportion to NASS cases who had not returned to work before the follow-up interview 60 days after the injury. We computed the disability probability as the NASS probability that an injured worker lost at least 3 days from work times the allocated DCI probability of permanent work loss. We substituted the probability of losing at least 61 days from work for the probability of disability if it was lower. Three substitutions were necessary, all for nonhospitalized injuries.

average productivity growth rate for wage work during the 1980's (computed from the output/hr in Bush, 1991) and the recent 0-percent productivity growth rate for household production (DeSeve, 1990) would continue.

Medical Costs

This study defines medical care costs quite broadly. They include:

- Paid and anticipated future hospital charges, including emergency room charges.
- Paid and anticipated future professional fees of doctors and other health care professionals.
- Institutional care.
- Attendant care and other personal assistance.
- Home modification.
- Equipment such as wheelchairs and canes.
- Pharmaceuticals.
- Coroner's costs and the costs of accelerated funeral purchase for fatalities.

Figure 17 shows the medical costs/injury and for all injuries by injury severity. Medical costs total $11.2 billion annually. Incapacitating injuries account for 49 percent of the costs. Severe brain and spinal cord injuries are the dominant factors here, accounting for 20 percent. These injuries require lifetime care. Some require institutionalization. The annual toll is at least 11,600 brain injuries, with an average medical cost of $153,000, and 550 spinal cord injuries with an average medical cost of $508,000.[12]

Our estimated medical costs largely exclude chiropractor costs. These costs appear to be sizable; $.5 to 1 billion annually. Studies of closed auto insurance claims document them. Nationally, roughly 18 percent of 1987 auto insurance claims

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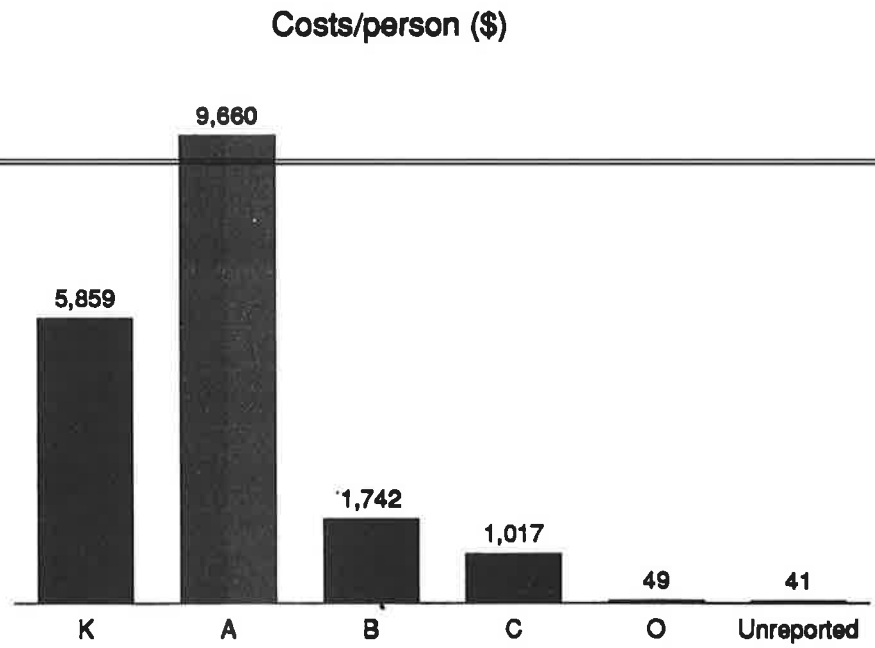
[12] These estimates were computed from table 40 in appendix C.



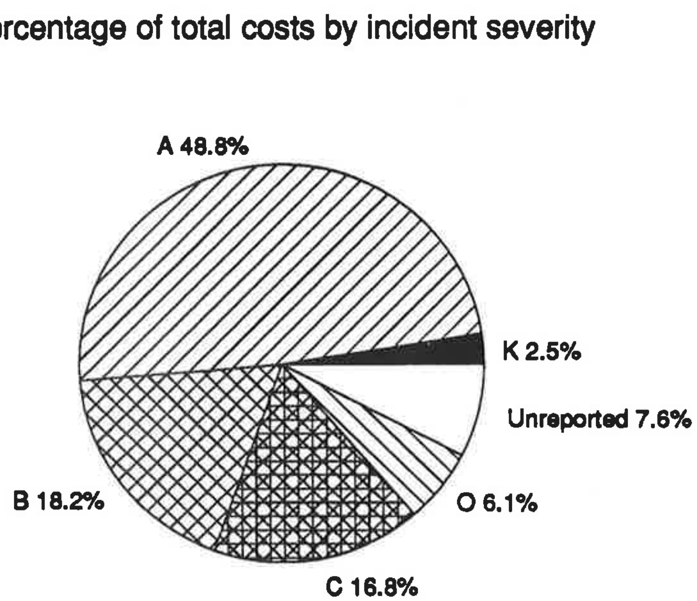


Figure 17. Medical costs by KABCO severity.

under injury coverages included chiropractor costs (Segraves et al., 1989). In California, auto insurers paid an average of $6 in chiropractor claims in 1989 for every $13 of hospital and doctor claims (Gillespie et al., 1990). No data are available on chiropractor costs of crash injuries by body region.[13]

Comparison with Prior Estimates. We compared our medical costs with Rice et al.'s (1989) estimated medical costs/person injured in a motor vehicle crash. Their costs are by hospitalization status. Figure 18 compares the costs. In figure 18, our costs are shown without nursing home costs for head injury, which were largely omitted in Rice's study. The average costs are quite similar.

The similarity is remarkable since Rice et al. used completely different data sources to compute acute care costs. For non-hospitalized injury, they used Health Interview Survey and National Medical Care Utilization and Expenditure Survey data. For hospitalized injury, they primarily used national, Maryland, and California Hospital Discharge Survey data. Like us, they used MacKenzie's data on rehospitalization and the DCI percentage of paid charges beyond the first year.

NHTSA estimated the medical costs of crashes at $4.7 billion.[14] For the injuries they covered, our estimate is $8.2 billion. Table 16 reveals that the differences are large for most injury severities. NHTSA based its costs on data collected at Massachusetts General Hospital in the early 1970's. Hartunian et al. (1981) also used those data to compute their medical costs. The data clearly are not representative of current national experience.

Methods: Analysis of NASS and DCI. Our medical cost computation methods are detailed in Miller et al. (1990). We used NASS data on the percentage of people requiring medical treatment, the percentage requiring hospitalization, and the average length of initial hospital stay. We used data by body region and severity from MacKenzie et al. (1989) to infer the total hospital days in the first year from the initial length of stay. We then multiplied times the hospital cost/day, ratio of

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[13] Shekelle and Brook (1991) and American Chiropractic Association (1990) show the distribution of all treated injuries.

[14] The costs were inflated to 1988 dollars using the medical component of the Consumer Price Index.

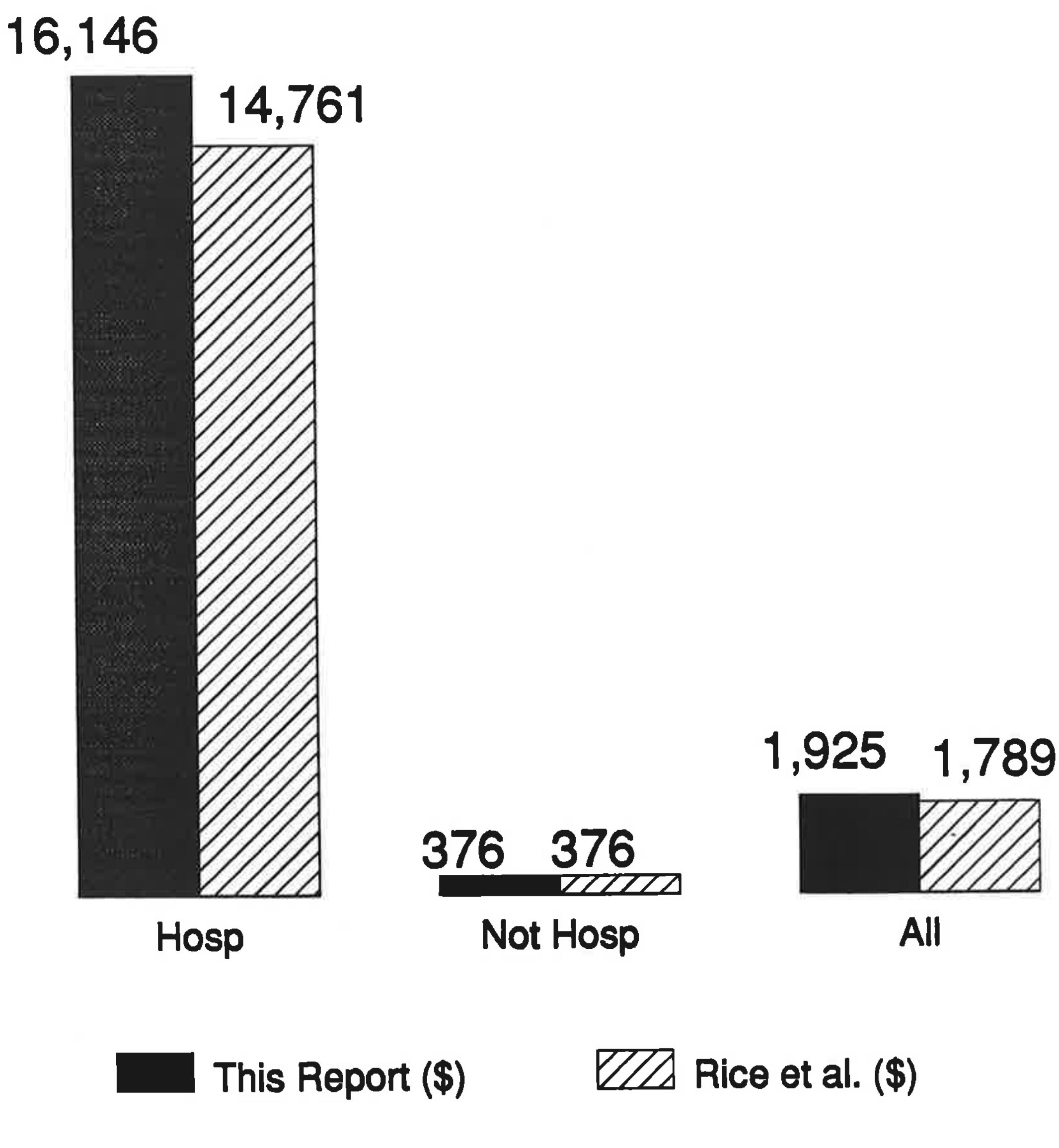


Figure 18. Medical costs in this report compared to Rice et al. (1989).

Table 16. Medical costs/person by MAIS in this report and in NHTSA (1987).

MAIS	This Report	NHTSA (1987)
Minor	$ 583	$ 308
Moderate	4,697	2,549
Serious	15,822	5,835
Severe	42,932	17,852
Critical	180,996	179,684
Fatal	3,154*	3,696

* Excludes the $2,705 cost of holding a funeral 43 years early.

Note: In 1988 dollars.

other costs to hospital costs, and ratio of first year to lifetime costs from the DCI. These factors were computed on an injury-specific basis or for groups of related injuries. We also used DCI data on the cost of medically treated nonhospitalized injury. NASS provided the incidence data.

Annual medical care inflation between 1980 and 1989 averaged 3.4 percent more than general inflation, meaning the inflation-free discount rate for medical care costs was close to 0. Much of the excess inflation resulted from technological change and other factors that seem likely to continue into the future. Therefore, we assumed the excess inflation rate for medical care costs would roughly match the 4-percent discount rate. This assumption eliminated the need to discount future medical costs to present values. We did discount future costs for nursing home and attendant care.

The DCI data include few spinal cord injuries. Instead of DCI, we used data on spinal cord injury costs from Berkowitz et al. (1990), which examines the full range of medically related and ancillary costs for a large cross-section of people with spinal cord injuries.

We added lifetime nursing home costs of $515,000 for the 1,800 people/yr with multiple severe or critical brain injuries. We assumed these injuries caused permanent total disability.

Finally, for fatalities, we added Rice et al.'s medical costs to coroners' costs from NHTSA (1983). We also added the difference in present value of the funeral cost in 1988 versus at the end of the expected remaining lifespan. Data on funeral costs came from cognizant trade associations.

Emergency Services Costs, Including Police, Fire Department, and Emergency Transport

Emergency services are a minor cost component. Figure 19 shows the costs/case and for all cases. The largest share of national emergency services costs are for police, followed by emergency transport. As figure 20 illustrates, fire department costs are the smallest.

Comparison with Prior Estimates. Table 17 compares our estimates of emergency services costs with the estimates in NHTSA (1983). Our ambulance costs replace many assumptions with nationally representative data. The main reason they differ from NHTSA's, however, is the addition of costs for helicopter transport of the severely injured.

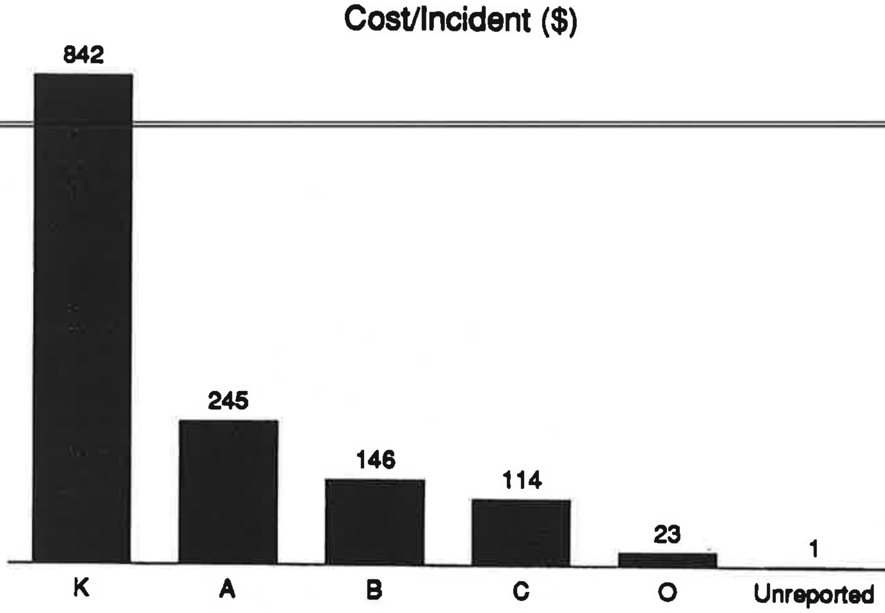
NHTSA's estimates of the police response costs for moderate to critical injuries may be more accurate than ours. NHTSA assumed time on the scene rose with severity; we assumed instead that the number of officers on the scene rose. The data sources we relied on did not deal with these injuries separately.

NHTSA's estimated fire department costs were built on arbitrary assumptions and Boston data about the cost of a fire run in 1974. This study's estimates are better.

Table 17. Emergency services costs/person by MAIS in this report and NHTSA (1983).

MAIS	Ambulance		Police		Fire	
	New	NHTSA	New	NHTSA	New	NHTSA
PDO	$ 0	$ 0	$ 9	$ 11	$ 5	$ 0
Minor	55	132	59	55	7	0
Moderate	124	184	74	77	71	0
Serious	153	181	81	111	170	0
Severe	353	181	88	154	478	63
Critical	354	181	94	185	487	63
Fatal	251	178	185	185	406	63

Note: In 1988 dollars.



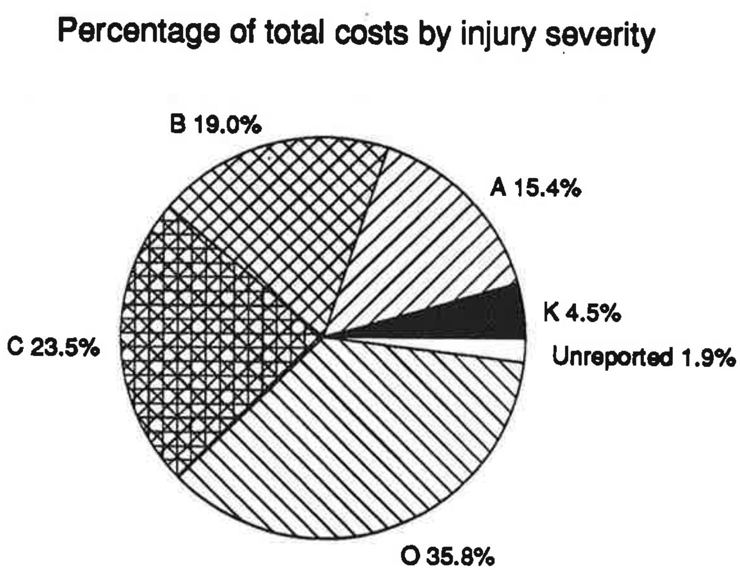


Figure 19. Emergency services costs by KABCO severity.

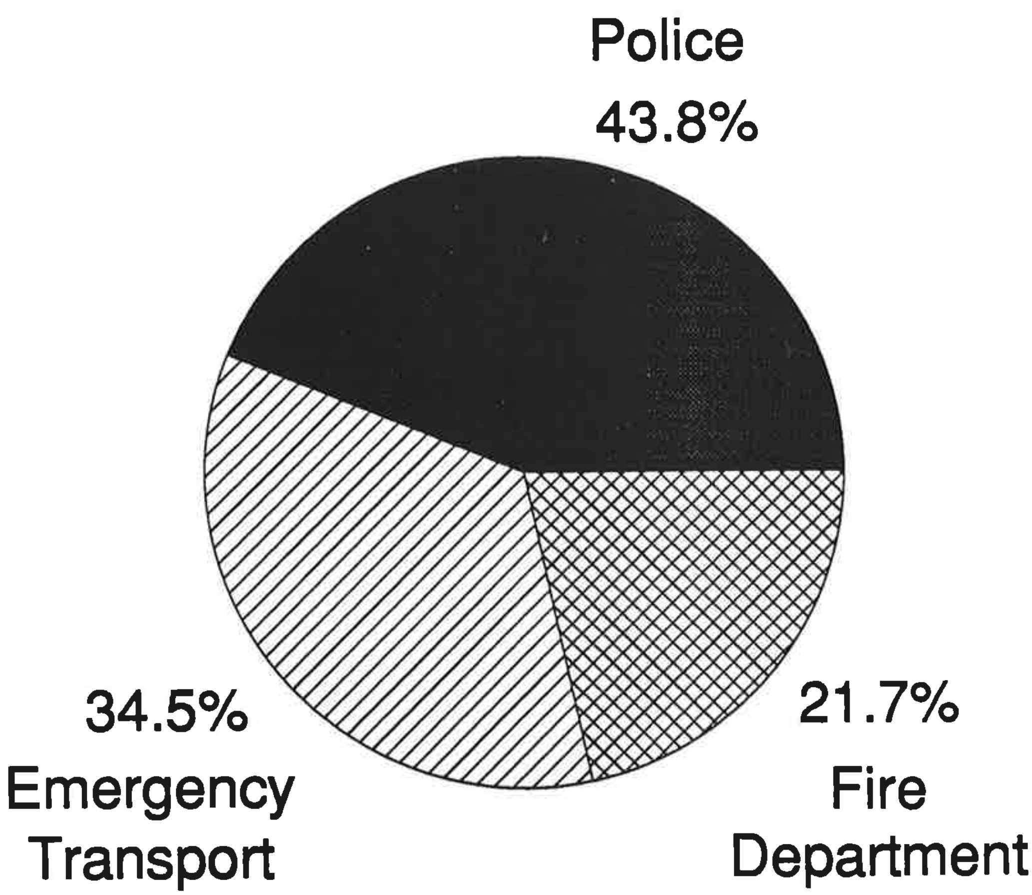


Figure 20. Distribution of emergency services costs by type of service.

Methods: National and Small-scale Surveys. To get police costs, we multiplied average wages from the 1982 Census of Governments and fringe benefits from Peterson et al. (1986) times average time on the scene. We surveyed five urban police departments and five State police departments about on-the-scene time by crash severity. These queries targeted departments with automated time tracking systems. We assumed one officer responded to a PDO crash and one officer/injury to other crashes.

Ambulance costs/transported case came from the National Medical Care Utilization and Expenditure Survey. Data on which cases were transported came from NASS. Rice et al. (1989) cite data from industry surveys on cost/helicopter transport ($722) and the number of helicopter transports for trauma victims. Surveying five helicopter transporters revealed that 62 percent of their trauma transports were highway crash victims. We allocated the transports by severity proportionately among critical and severe nonfatal injuries and the half of fatalities who are not clearly dead at the scene.

Surveying nine large fire departments suggested the average response cost is around $550. Karter (1985) indicates more than 400,000 fire responses a year relate to highway vehicles. We assumed 60 percent resulted from crashes. Calls might be for assistance with traffic control, extraction of trapped vehicle occupants, clean-up of fuel or hazardous materials spills, fire control, or other reasons. We allocated the 240,000 calls by assuming fire personnel (or other emergency personnel beyond the initial police response team) would respond to:

- 90 percent of fatal and severe injury crashes, and 95 percent of critical injury crashes.
- 35 percent of serious injury crashes and 15 percent of moderate injury crashes.
- 40 percent of heavy truck crashes involving minor injury and 1 percent of other minor injury crashes.
- 25 percent of police-reported heavy truck crashes involving only property damage.

Travel Delay Caused by Crashes

Crashes tie up traffic. The extent of traffic delay depends on how long the crash is on the scene, how badly the road is blocked, and how much traffic is on the road. Thus, travel delay costs differ by roadway type and urban vs. rural location. Figure 21 summarizes the delay costs by type of roadway and location. By far the greatest delay costs result from urban Interstate highway crashes. The costs of travel delay are roughly the same for any police-reported injury crash. PDO crashes reported to the police account for 58 percent of delay costs.

Comparison with Prior Estimates. Faigin (1976) provides the only prior national estimate of travel delay. Although the estimates are on the same order of magnitude as ours, they have a contrary pattern (figure 22). Delay costs fall as severity rises. This counter-intuitive result stems from the greater tendency for serious crashes to occur outside of peak hours. Whichever estimates are correct, delay clearly is a minor cost element except in PDO crashes.

Methods: Simulation. At our request, Lindley (1988) ran simulation models to compute the delay due to crashes on urban Interstate highways. We used police data about the time from call-in to clearance to estimate crash duration by crash severity. We allocated the delay among crashes by severity in proportion to crash duration. A review of available data on the duration and delay associated with heavy truck crashes led us to assume these crashes cause almost double the delay of other crashes, with minimal variation by injury severity.

For other types of roads, we assumed the delay/crash by severity would vary from urban Interstates in proportion to the difference in traffic volume. We assumed crashes did not delay traffic on local streets and caused only 1 hour of delay on urban collectors for PDO and injury crashes and 2 hours for fatal crashes. Longer delays probably result from crashes on downtown streets.

We used the values of travel time from FHwA's partially completed Highway Economic Requirements System (HERS), which updates the Highway Performance Management System (HPMS). HERS values travel time differently for trips taken as part of the work day versus other trips. The value of on-the-job travel delay equals wages plus fringe benefits, plus the costs of cargo delay and of equipment unavailability. The value for other travel delay is 1.5 times the value of travel time -- 90 percent of the wage rate for drivers and 67.5 percent for passengers. These values come from an extensive literature review (Miller, 1989a).

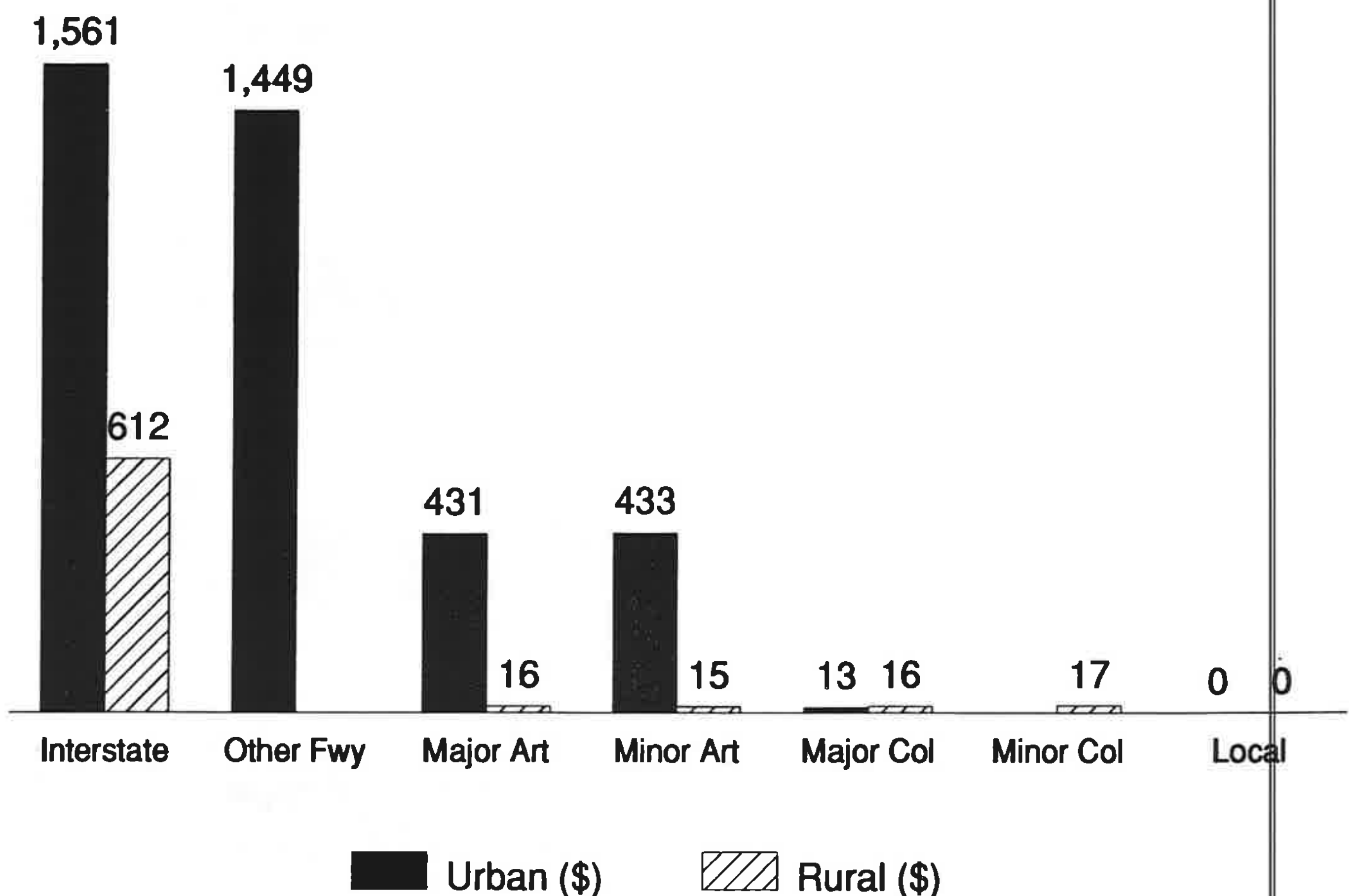


Figure 21. Delay costs/crash by roadway type.

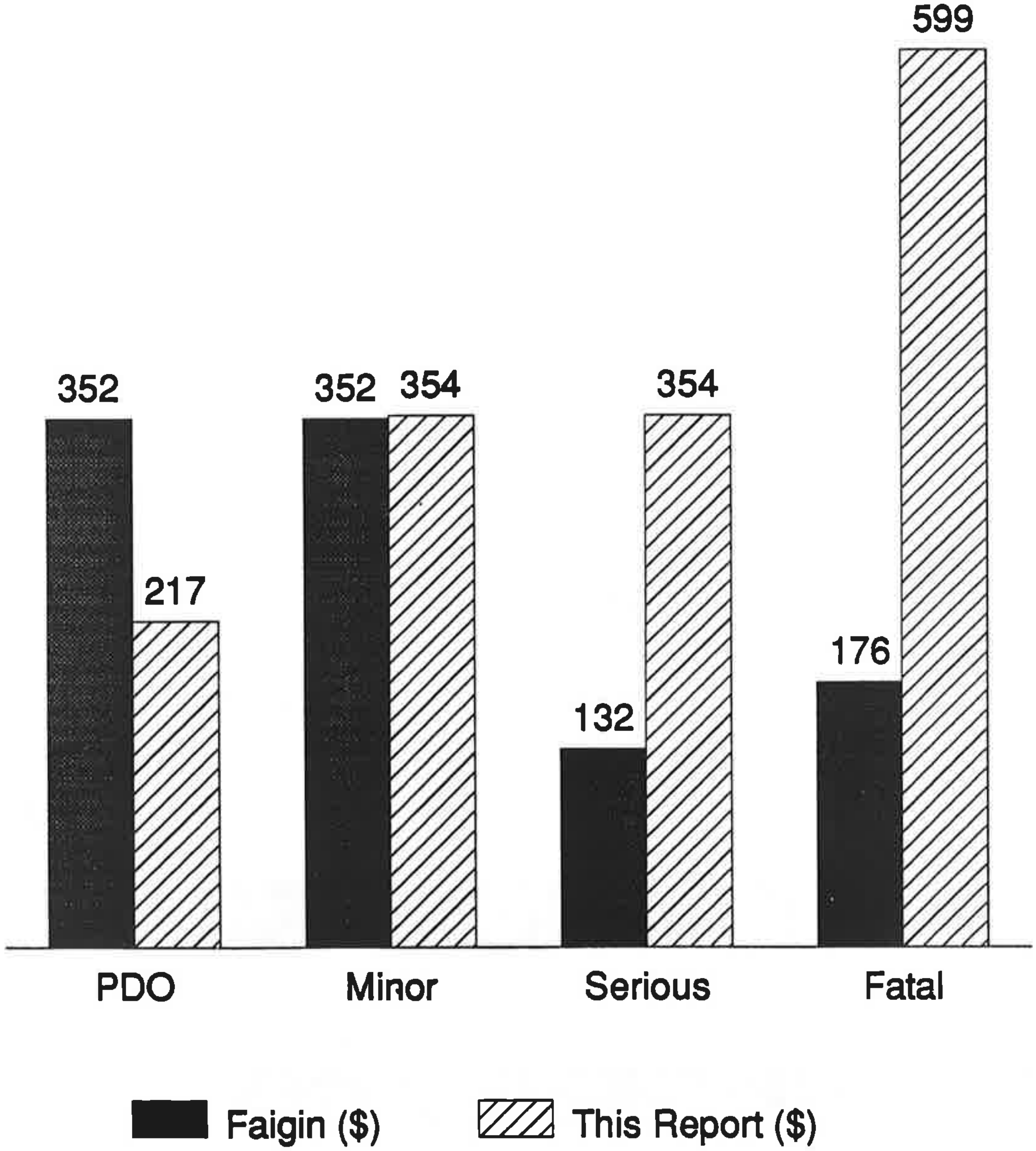


Figure 22. Delay costs/crash by crash severity.

Vocational Rehabilitation Costs

Vocational rehabilitation costs, which we took from the DCI, are a minor cost component. Figure 23 shows the costs/case and for all cases.

Rice et al. also used vocational rehabilitation costs from the DCI. No other estimates of vocational rehabilitation costs exist.

Figure 23 does not state actual vocational rehabilitation expenditures. Rather, it indicates how much non-medical rehabilitation would be cost-effective in terms of decreasing work disability. Our estimates of permanent work disability assume this rehabilitation is delivered to other injured people just as it is to those covered by Workers' Compensation. Without it, the wage losses would be larger.

Workplace Costs

Crashes can have costly consequences in the workplace. These include:

- Workers lose productivity talking about crashes involving themselves, their families, or their co-workers.
- Workers take leave to recuperate from injuries or care for a loved one. Overtime pay for co-workers, pay for temporary help, and production delays all may result.
- When injury requires replacing a worker, the firm pays to recruit and train a replacement. Unique skills and knowledge also may be lost. If the employee returns to a less demanding job, further retraining costs arise.

Workplace costs total $2.4 billion/yr. Figure 24 suggests that workplace costs/case are largest for fatalities, but the total costs are higher in each of the other categories. Workers chatting about O and unreported crashes account for a third of the losses.

Methods: Heavy on Assumptions. To estimate workplace costs, we assumed minor to moderate injuries to workers involved 2 days of disruption, serious injuries 1 month, and severe to fatal injuries 4 months. We assumed all injuries to nonworkers involved 2 days of worker productivity loss, with no loss for PDO

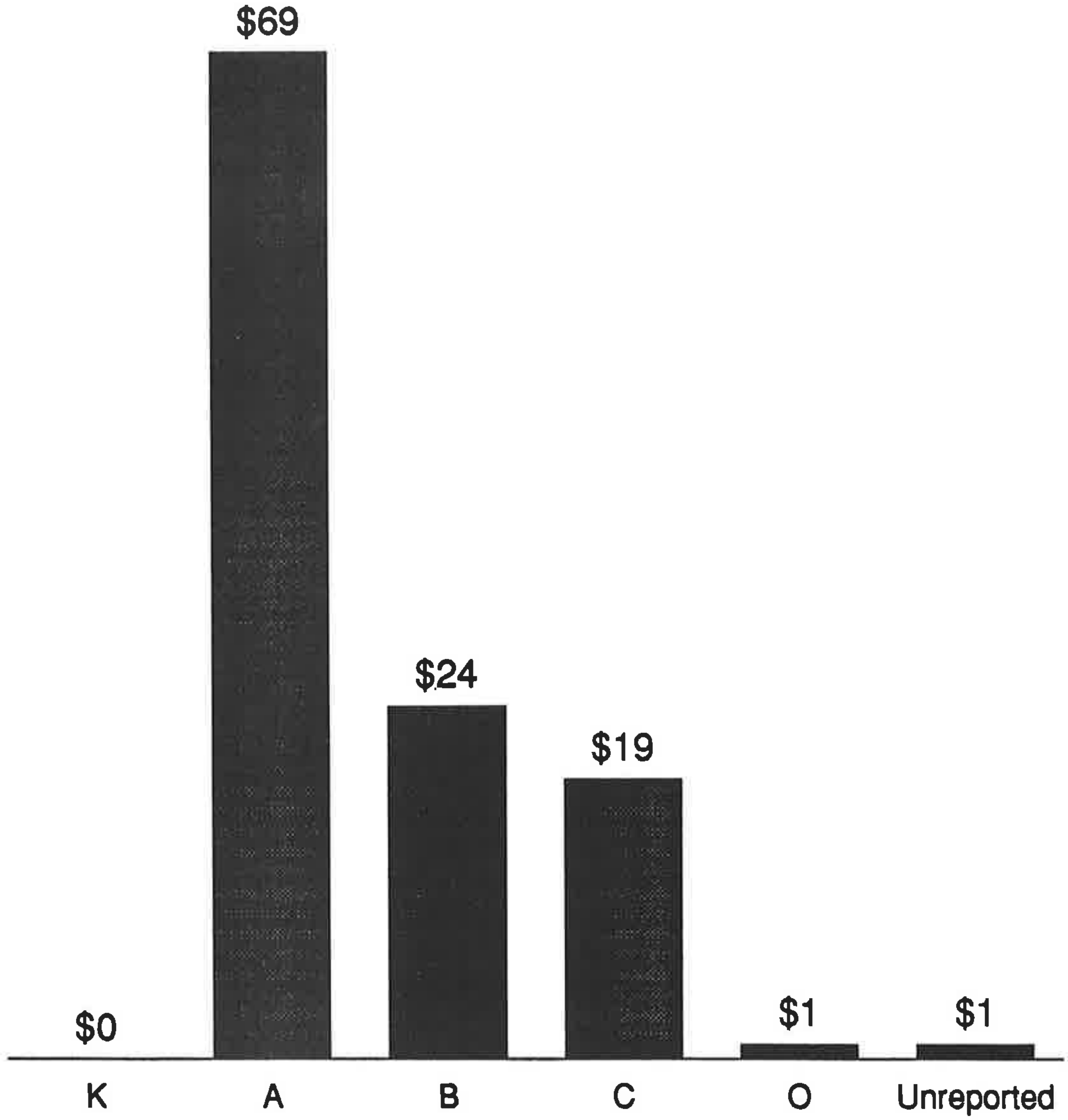
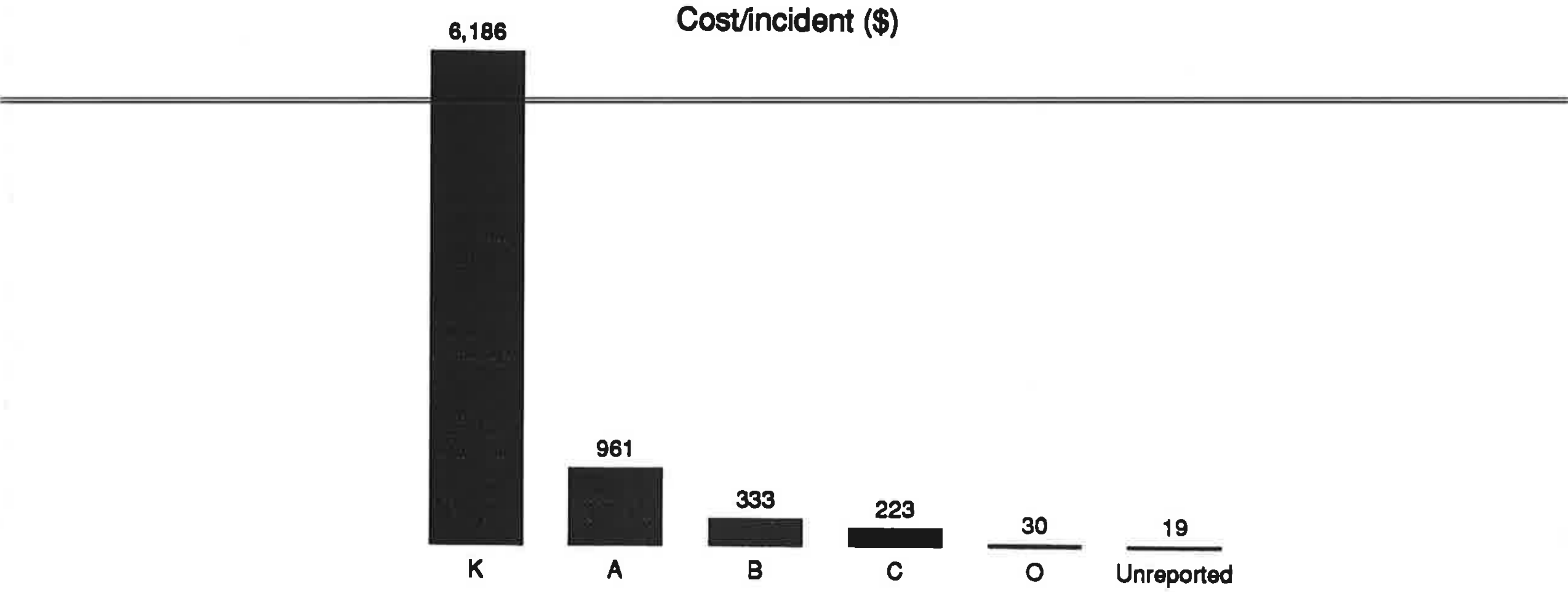


Figure 23. Vocational rehabilitation costs/person by injury severity.



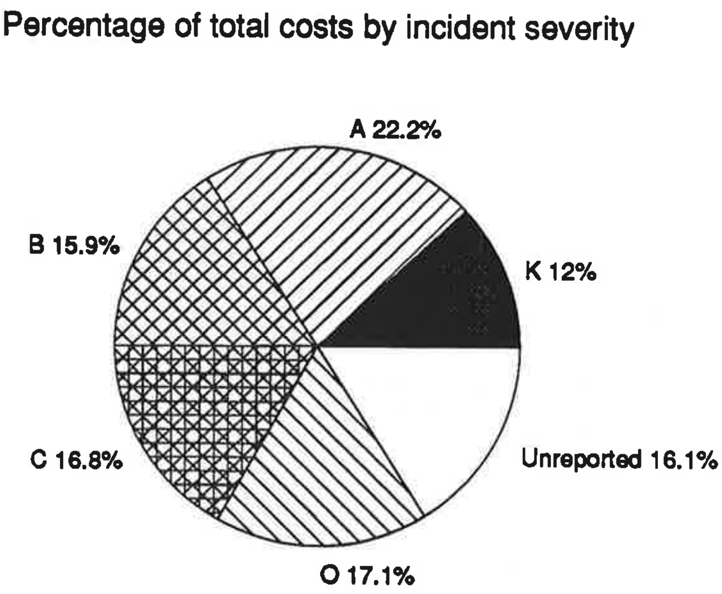


Figure 24. Workplace costs by KABCO severity.

crashes. We costed the losses at the average wage rate. This costing is conservative since supervisory time, temporary help, and overtime pay all are expensive.

This workplace cost estimate is the first of national scope. It is fairly crude. It also masks wide variation between firms. Some large firms employ people specifically to cover employee absences (Young, 1988). Conversely, loss of a key person in a small firm can bankrupt it.

Administrative and Legal Costs

Administrative activities resulting from crashes include:

- Investigating and paying insurance claims.

- Administering public financial assistance provided to crash victims and their families. Examples of public assistance include social security disability payments, rent subsidies, and food stamps.

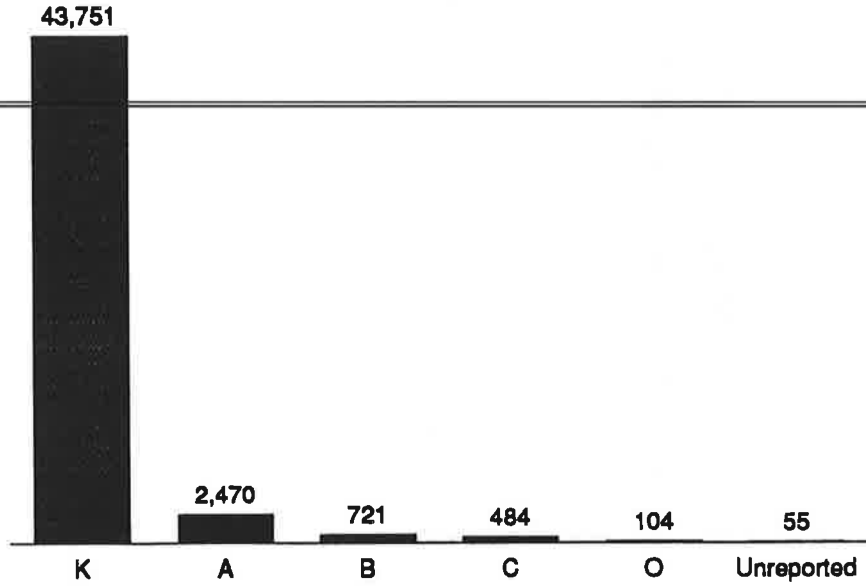
Figure 25 shows that fatal injuries have the highest administrative cost/case and in aggregate. A-injuries have the next highest cost/case. A-injuries and O-incidents have high aggregate costs.

Of households where someone is injured in a crash, 35 percent hire an attorney (Sprinkel, 1988). The resulting legal and court costs are substantial. They exceed the administrative costs for most fatal, A-, and B-injuries and roughly equal them for C-injuries. Figure 26 shows the legal costs/case and for all cases. The total is $7.75 billion/yr.

Comparison with Prior Estimates. Table 18 shows that our estimates of administrative and legal costs by MAIS differ markedly from NHTSA's. Our cost estimates are better.

To compute administrative costs, both studies started by determining who paid the costs. We determined administrative cost percentages by payer and cost category, then applied these to the costs by injury severity. NHTSA instead calculated aggregate administrative costs and used assumptions to allocate among incidents by severity. Notably, NHTSA's total administrative cost estimate for crashes reported to the police is $4.5 billion (at a 7-percent discount rate). This study's $4.8 billion matches.

Cost/Incident ($)



Percentage of total costs by incident severity.

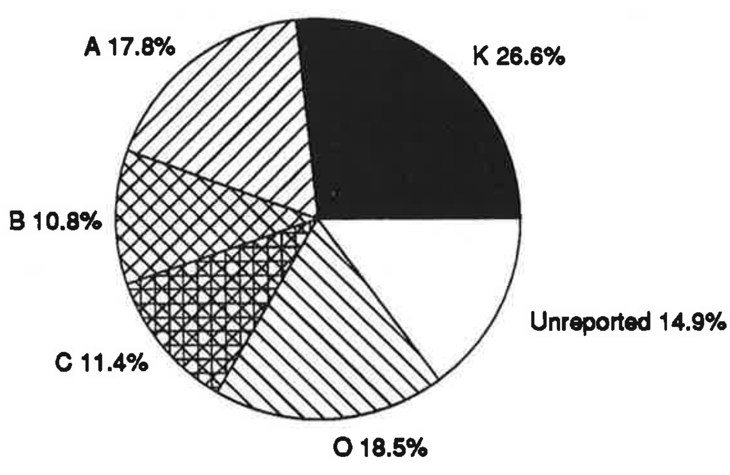
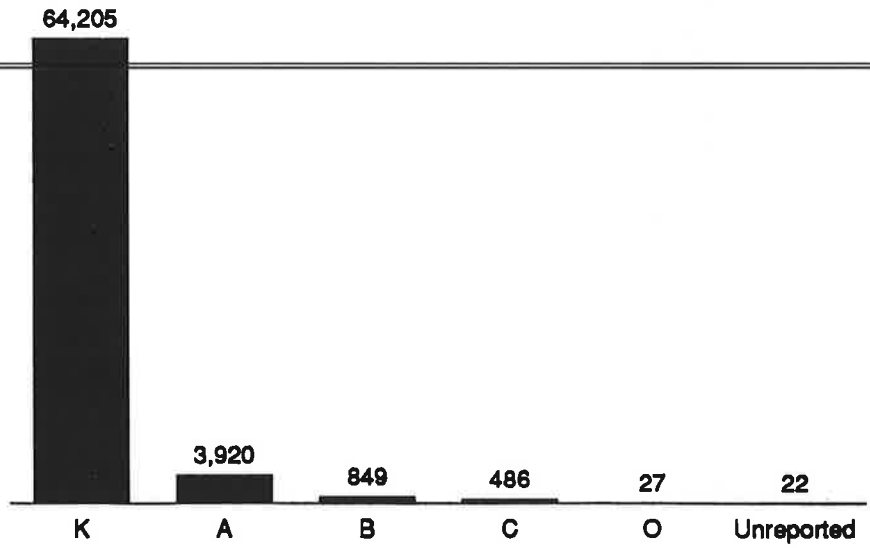


Figure 25. Administrative costs by KABCO severity.

Cost/incident ($)



Percentage of total costs by incident severity

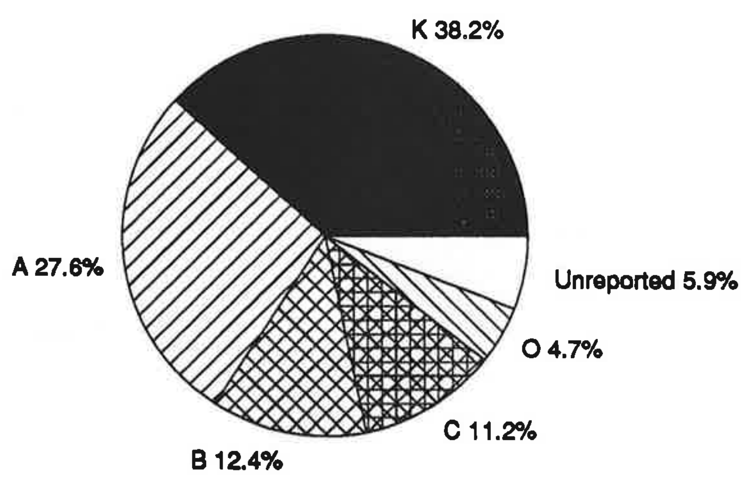


Figure 26. Legal costs by KABCO severity.

Skyrocketing legal expenses made our legal costs higher than NHTSA's. Auto insurance data suggest total legal costs rose from $4.8 billion (in 1988 dollars) in 1977 to $8.0 billion in 1988. Our computations largely paralleled NHTSA's.

Methods: Computed from Medical and Productivity Losses. To compute administrative and legal costs, we first had to estimate the costs eligible for compensation. The eligible costs are medical costs and the present value of lost wages and household production. The compensation system generally computes present values using a discount rate of 1 to 3 percent (U.S. Supreme Court, 1983); we chose 2.5 percent. Chapter VIII estimates the payments by source. We multiplied published administrative expense ratios by source times these payments.

Table 18. Administrative and legal costs/person by MAIS in this report and NHTSA (1983).

MAIS	Administrative		Legal	
	This Study	NHTSA	This Study	NHTSA
PDO	$ 77	$ 55	$ 0	$ 11
Minor	381	869	268	708
Moderate	1,556	869	1,936	776
Serious	5,087	869	9,151	3,833
Severe	10,426	22,169	18,198	7,395
Critical	40,121	22,169	68,835	11,298
Fatal	43,751	22,169	64,205	19,242

Note: In 1988 dollars at a 7-percent discount rate.

To compute the legal costs, we modelled the legal process. We used probabilities of reaching each stage in the process and costs/stage from Kakalik (1983) and NHTSA (1983).[15] We assumed that roughly half of the seriously injured and one third of surviving heirs and of those with modest injuries used lawyers in seeking compensation. Attorney fees were computed as 29.7 percent of expected compensation (Sprinkel, 1988). In a successful suit, we assumed medical, vocational rehabilitation, and productivity costs are compensated fully.

[15] The legal costs could be updated further using the probabilities of reaching each stage of the legal system from Sprinkel (1988). That effort was beyond the scope of this project.

Pain, Suffering, and Lost Quality of Life

More than 70 percent of the pain, suffering, and lost quality of life results from fatal and A-injuries. Figure 27 indicates that the cost/fatal injury is largest by an order of magnitude. The quality of life costs are the largest single injury cost component. They are 1.8 to 8.9 times the productivity loss (figure 28).

Methods: Years Lost Times the Value of a Year. To value quality of life, we started with the value people place on fatal risk reduction. We subtracted the monetary component of this value -- the after-tax wages and household production. The remainder is the value of pain, suffering, lost quality of life, and lost financial security. To value the quality of life associated with nonfatal risk reduction, we multiplied the value of fatal risk reduction times the ratio of the years of functional capacity at risk in a fatality versus the injury of interest. Miller, Calhoun, and Arthur (1990) provides a theoretical basis for this approach. Chapter 4 gives the years at risk.

Value of Fatal Risk Reduction

Valuing statistical lives is a well-practiced art. Miller (1990) critically reviews 67 valuations.[16] The values generally stem from estimates of how much people pay for small changes in their survival probabilities. The studies fall into four classes:

- Wage-risk studies, which analyze compensating wage differentials associated with risky jobs.

- Market studies, which analyze the market for products that affect health and safety. For example, Winston and Mannering (1984) estimates the value of risk reduction from the prices and sales figures for cars with differing safety records. Miller (1990) estimates the value from the increase that falling prices caused in the number of smoke detectors purchased to protect families from fire death.

[16] Other recent reviews of this literature include Fisher, Chestnut, and Violette (1989) and Jones-Lee (1989).

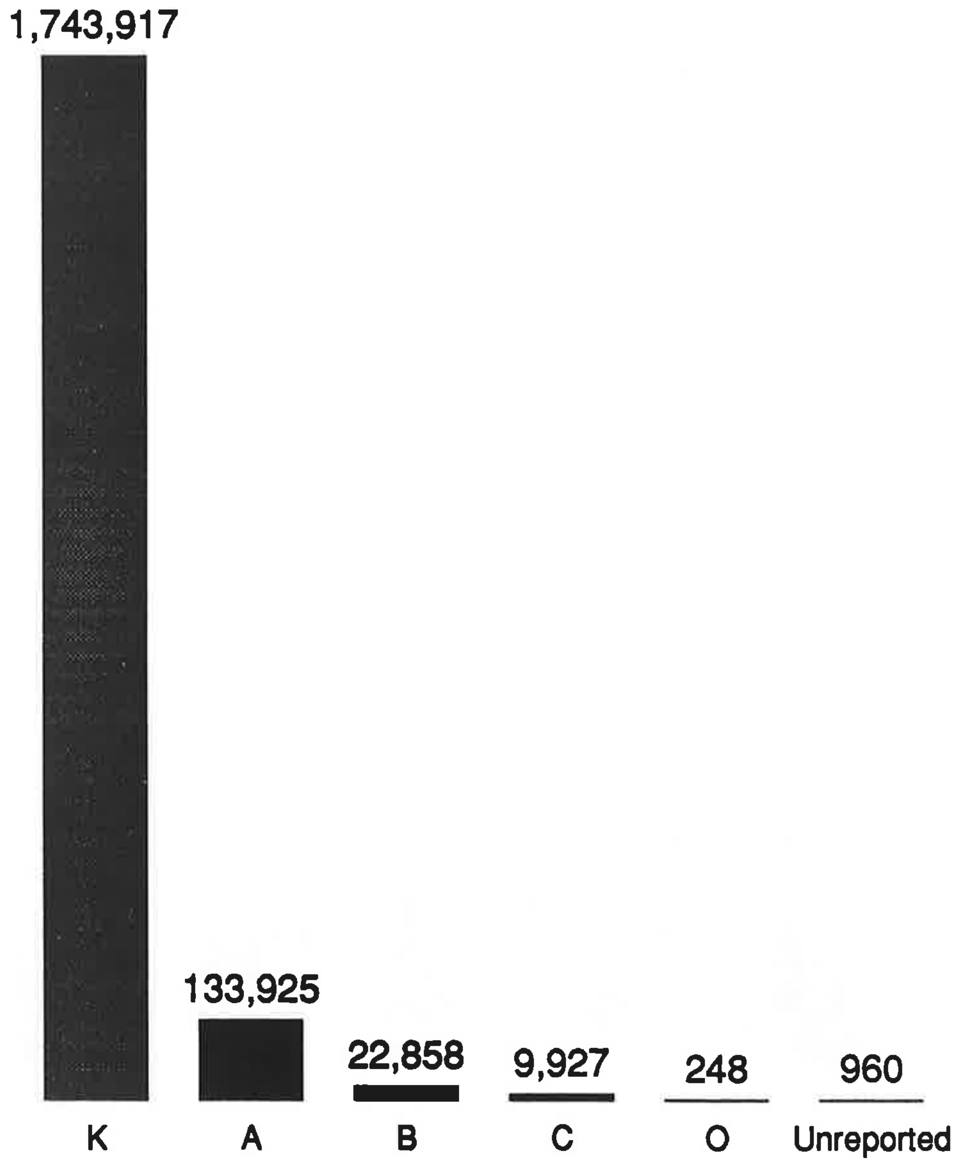


Figure 27. Quality of life costs/incident.
(in 1988 dollars at a 4% discount rate)

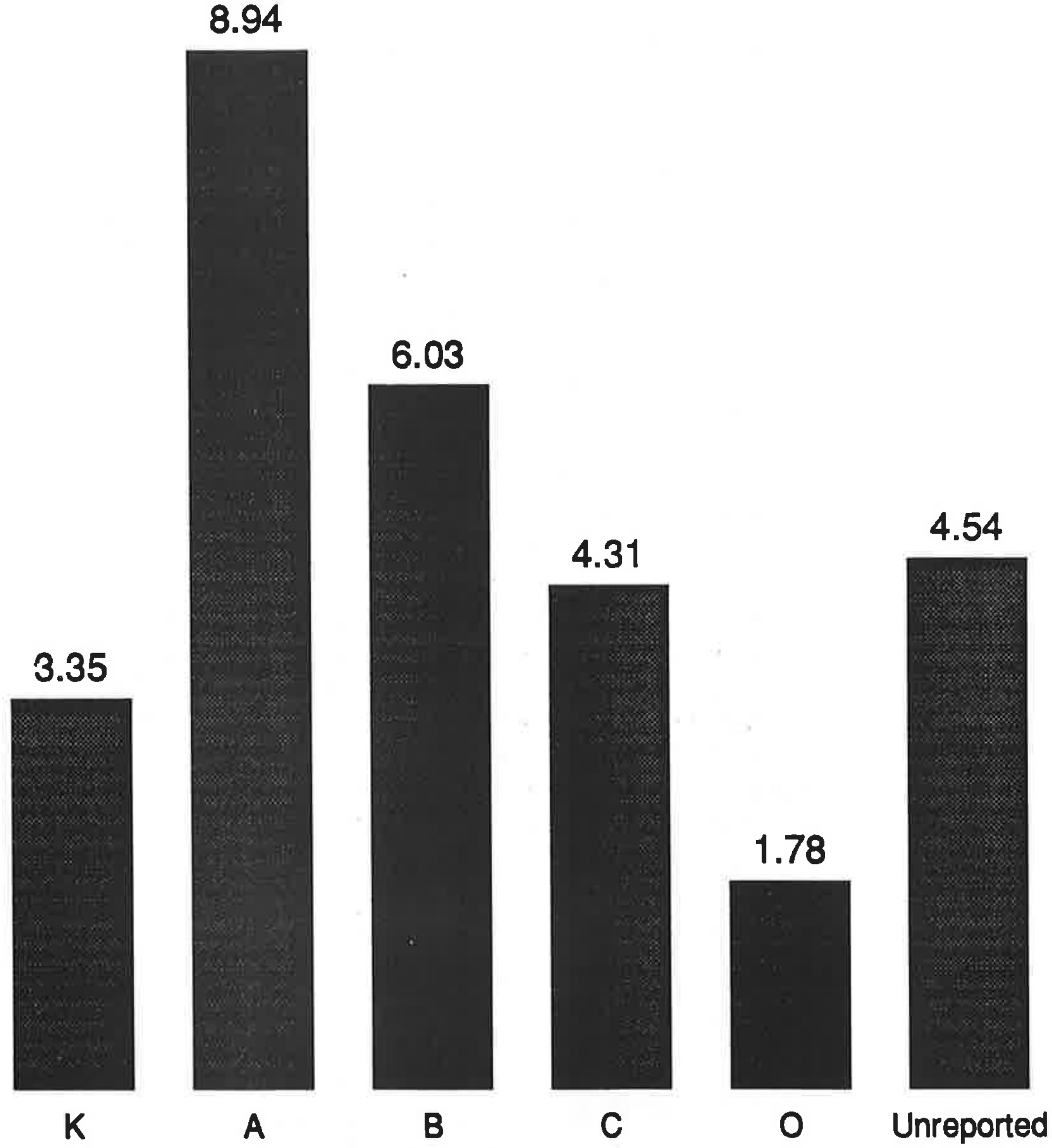


Figure 28. Ratio of quality of life loss to productivity loss.

- Behavioral studies, which examine risk-avoidance behavior in inherently risky situations. For example, Blomquist and Miller (1990) studied the values implied by decisions about using safety belts and motorcycle helmets. Ghosh, Lees, and Seal (1975) and Miller (1990) studied the values implied by speed choice. Melinek (1974) studied the value implied by a choice between using a pedestrian underpass or walking through a traffic circle. These situations involve trading time and convenience for safety.

- Surveys, which probe how much people are willing to pay for small changes in risk.

Normally, the value of fatal risk reduction is converted to a value/statistical life. For example, suppose a study estimated that the average car buyer spends $110 on optional auto safety features that reduce the chance of dying prematurely by 1 in 20,000. Dividing $110 by the 1 in 20,000 probability yields a $2.2 million value/statistical life.

Almost 50 Reliable Values Exist. Miller (1990) identified 67 values of a statistical life. He judged 47 technically sound. To compare the values from these studies, Miller made several adjustments. Using the Blomquist (1982) method, he recomputed selected values using the risk levels people perceive instead of actual risk levels. He converted wage-risk values to after-tax wages. Fifteen wage-risk estimates were adjusted to account for systematic biases resulting from their risk variable definition. He recomputed estimates involving a value of travel time using a value of 60 percent of the wage rate/passenger.[17] With data from Miller, Luchter, and Brinkman (1989), he introduced a uniform method for removing the benefits of nonfatal risk reduction from analyses of highway safety markets and behavior. Finally, he applied a uniform discount rate of 2.5 percent.[18]

We added recent surveys on willingness to pay for highway safety in Austria and New Zealand to Miller's 47 sound studies (Maier et al., 1989; Miller and Guria, 1991).

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[17] The values were 75 percent for drivers and 45 percent for other passengers. Our travel delay estimates use the same average.

[18] Using a higher discount rate would raise four values and lower one.

The mean of the 49 reliable values is $2.2 million. The standard deviation is $.6 million and the range from $1.0 to $3.6 million. This uncertainty level is typical of the uncertainty in the effectiveness and incidence estimates in most safety benefit-cost analyses. Furthermore, the emergence of values in a similar range from studies using many different approaches and data sets suggests that any methodological concerns about individual studies are not of central importance.[19] If they produce errors, the errors are not large enough to substantially skew the values.

Of the 49 values, 11 are specific to highway safety. Their mean is $2.136 million. The New Zealand survey may not be applicable to the U.S. where incomes are much higher. Without it, the average for the highway safety studies would be $2.233 million.

Table 19 summarizes the reliable values. It splits them into the four major types described above. Figure 29 shows that the mean values are similar across the four types.

These values do not imply that most people would actually be able to pay $2.2 million to avoid dying prematurely. They are based on the small amounts people regularly pay -- in dollars, time, discomfort, and inconvenience -- to reduce fatality risks. When tens of thousands of people, between them, spend $2.2 million on health and safety, on average, these expenditures prevent one individual from dying. That is the price Americans pay for safety.

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[19] The principal methodological concerns include: a comparison across studies implicitly assumes willingness to pay to avoid death is the same for sudden and slow, painful death, and that willingness to pay to reduce risk does not vary significantly between unavoidable risks like nuclear disaster and risks like car crash where the individual has some control; existing data appear to underestimate the risk of fatal workplace injury; and the choice for some workers may be between a risky job and unemployment rather than a less risky, but lower-paying job.

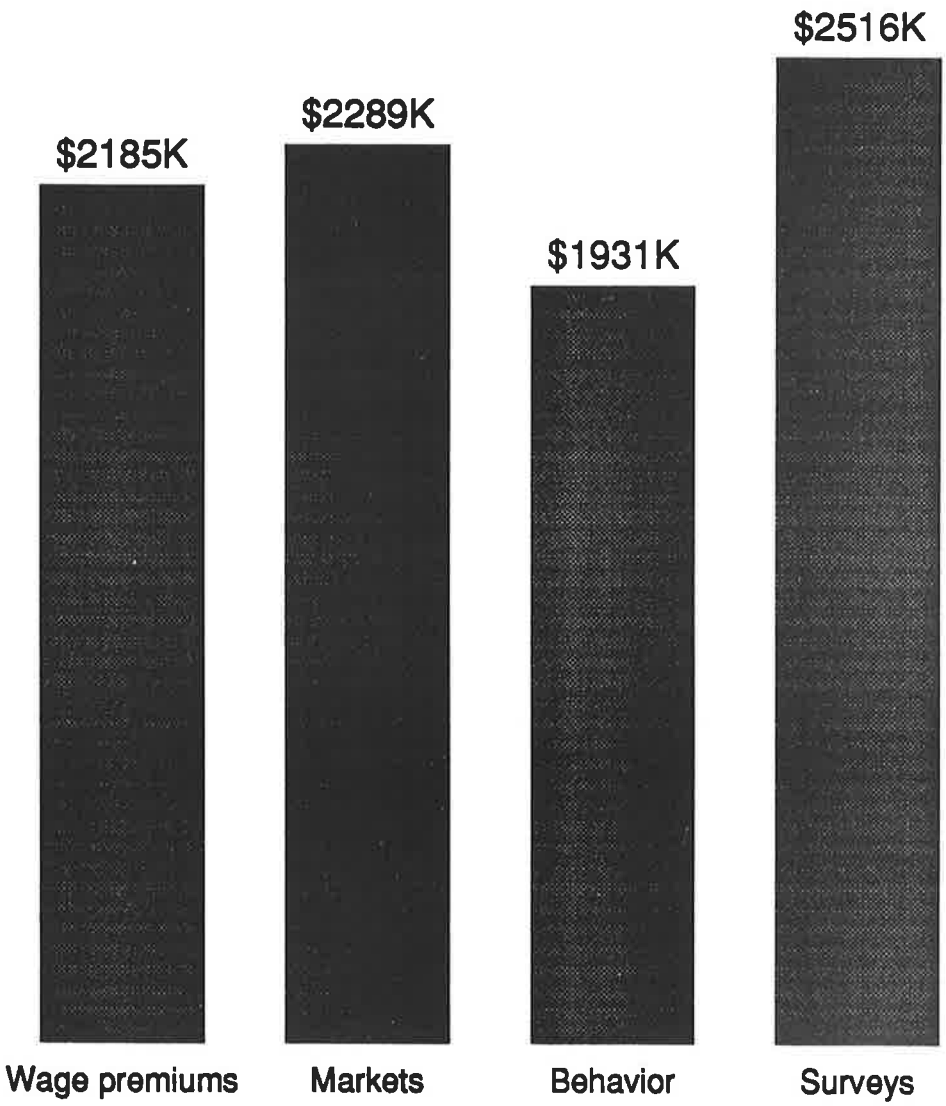

Figure 29. Value of fatal risk reduction by type of study.

Table 19. Estimated values of life by type of study.

Average of 49 studies	$2.2M
Average of 11 auto safety studies	2.1M
<u>Study Type</u>	
Extra wages for risky jobs (30 studies)	1.9M-3.4M
Market demand versus price	
safer cars	2.6M
Smoke detectors	1.2M
Houses in less polluted areas	2.6M
Life insurance	3.0M
Wages	2.1M
Safety behavior	
Pedestrian tunnel use	2.1M
Safety belt use (2 studies)	2.0M-3.1M
Speed choice (2 studies)	1.3M-2.2M
Smoking	1.0M
Surveys	
Auto safety (5 studies)	1.2M-2.8M
Cancer	2.6M
Safer job	2.2M
Fire safety	3.6M

Source: Miller (1990).

Note: In millions (M) of 1988 after-tax dollars. The text describes each type of study.

VI. COSTS BY NATURE OF CRASH

This chapter looks at the **comprehensive costs** of different types of crashes. It describes crash costs by:

- Alcohol use.
- Location.
- The nature and number of vehicles and nonoccupants involved.

The costs presented in this chapter are for fatal crashes and crashes reported to the police. Those crashes account for 79 percent of all crash costs.

We computed the costs from NASS counts by crash type. The counts showed the distribution of injuries and vehicles/crash by MAIS severity in 1982 through 1984. These distributions were multiplied times the unit costs in chapter V. Where possible, we used FARS data on fatalities.

Alcohol-involved Crashes

Drinking and driving mix badly. Drunk drivers are much more likely than most to crash. More than 46 percent of driver fatalities have alcohol in their blood (NHTSA, 1989). Almost 40 percent of adult pedestrian and pedalcycle fatalities also test positive for blood alcohol (NHTSA, 1989). When a crash occurs, alcohol raises the chance of serious injury and reduces the chance of survival (Fell, 1990). Because of their greater severity, the average cost of crashes involving alcohol is almost five times the cost of other crashes.

Figure 30 compares the costs of crashes by alcohol involvement and severity.[20] Both fatal and injury crashes are more costly when alcohol is involved. FARS estimates alcohol involvement for all fatal crashes. Nonfatal crashes where alcohol involvement is unknown are comparable in cost to those without alcohol involvement. Notably, alcohol involvement is unknown more often in injury crashes than PDO crashes.[21]

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[20] The costs/nonfatal injury are $62,368 for alcohol-involved, $30,547 for uninvolved, and $36,693 for involvement unknown.

[21] It may be worth researching why.

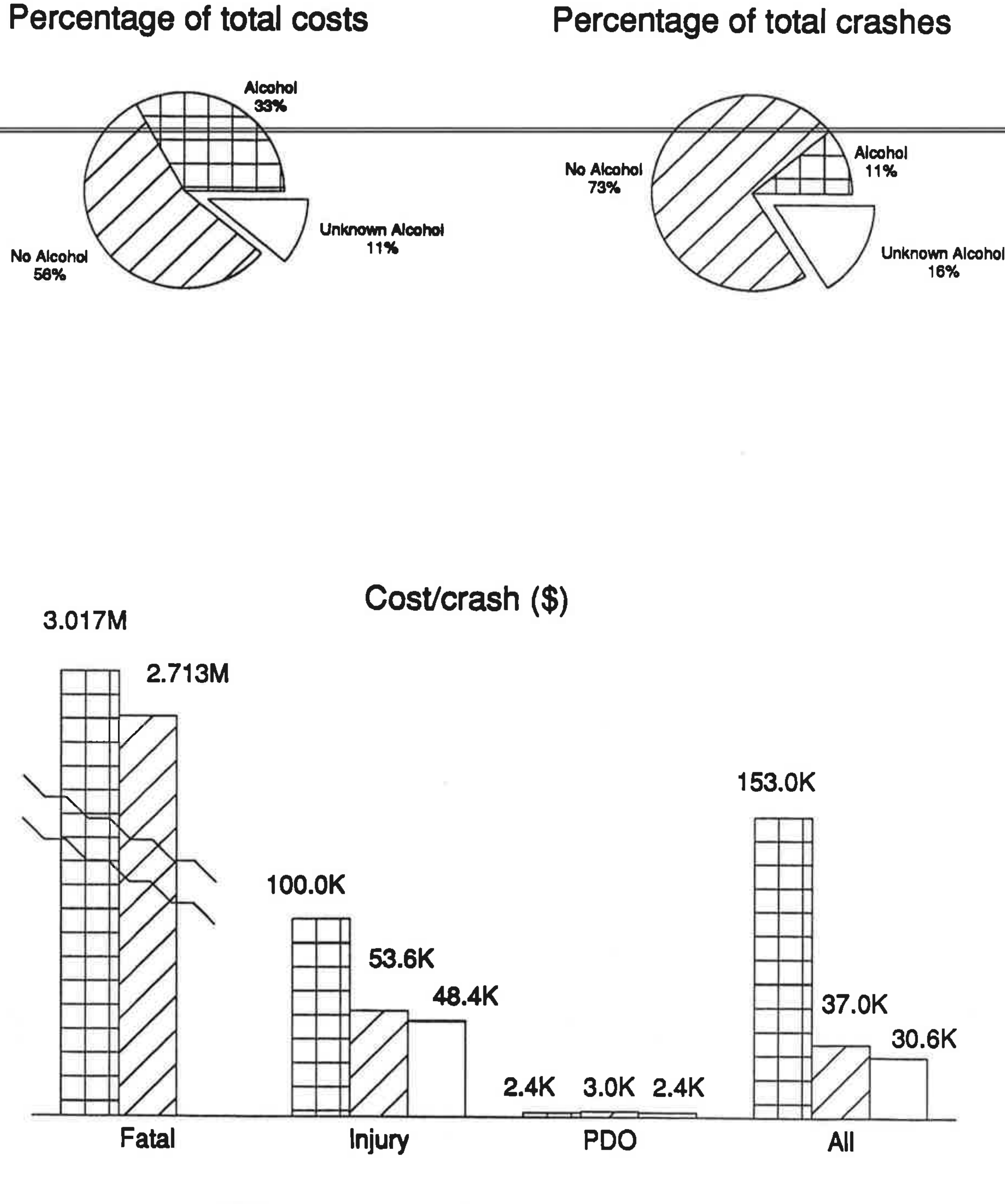

Figure 30. Comprehensive crash costs by alcohol involvement.

Overall, crashes that the police indicate involved alcohol cost almost $100 billion/yr. As figure 30 shows, they account for at least 33 percent of crash costs, but only 11 percent of the police-reported crashes.

Costs by Rural-Urban Location and Roadway Type

Figure 31 shows that the average rural crash costs $85,614 compared to $32,324 for the average urban crash. Rural crashes are 22 percent of the total, but account for 43 percent of the costs. They are almost five times as likely to involve a fatality as urban crashes and twice as likely to involve a serious nonfatal injury.

Table 20 breaks these costs down by functional class of roadway. Urban crashes on Interstate highways and other freeways are more severe than most urban crashes, ones on local streets less. Rural crashes follow a similar pattern, with crashes on other principal arterials also severe. The reasons that the average crash on high-speed roads is more costly include the higher fatality rate on these roads and the lower frequency of fender benders.

Table 20. Comprehensive cost/crash and for all crashes by roadway class and land use.

	URBAN		RURAL	
Class	$/Crash	Total	$/Crash	Total
Interstate	$53,579	$10.8 B	$92,436	$ 9.3 B
Other freeway	57,246	5.8 B	None	None
Princpl arterial	34,390	51.5 B	98,909	20.4 B
Minor arterial	34,238	37.1 B	86,242	20.4 B
Major collector	33,231	15.2 B	83,155	26.8 B
Minor collector	None	None	85,516	12.9 B
Local street	23,157	28.1 B	69,295	20.3 B
Average	$32,324	$148.5 B	$85,614	$110.4 B

Note: B = billion. In 1988 dollars at a 4-percent discount rate.

The $51.5 billion cost on other principal arterials in urban areas is the largest contributor to total crash costs. Minor urban arterials are a distant second at $37 billion.

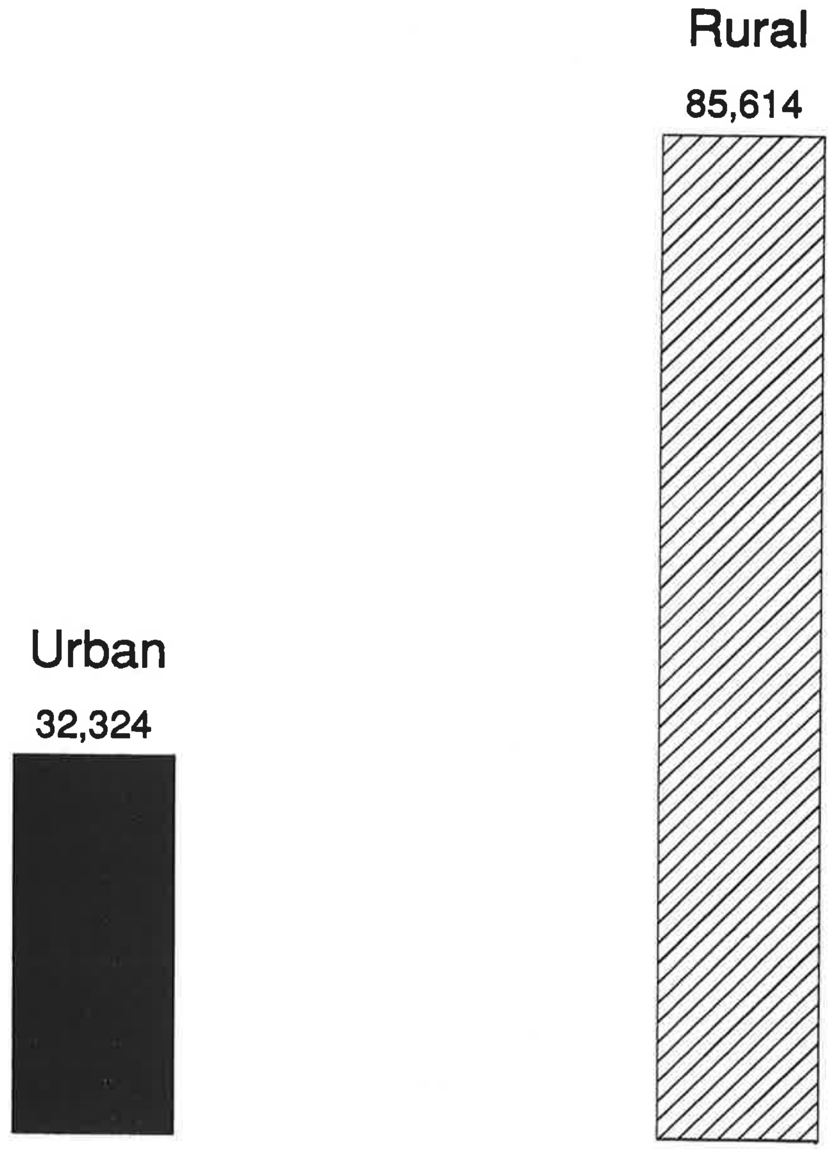

Figure 31. Comprehensive costs/crash by land use.
(in 1988 dollars at a 4% discount rate)

Which of the Nation's roads have the highest crash costs? Minor rural collectors. As figure 32 shows, the $299 cost/1000 vehicle-miles of travel (vmt) on these roads ($186/1000 km) is substantially more than any other. The roads with the second highest crash costs are local rural streets. In urban areas, arterials are most costly, $185/1000 vmt ($115/1000 km). The safest roads are Interstate highways and other freeways.

Some components of crash cost differ by location. Table 21 summarizes them. Longer distances cause police costs to average $77/rural crash compared to $31/urban. Fire department and property damage costs are higher in crashes involving medium to heavy trucks. These crashes are a larger percentage of the rural than urban total. Delay costs rise with traffic volume, meaning urban costs predominate.

Table 21. Comprehensive costs/crash that differ by land use.

Item	Urban	Rural
Police	$ 31	$ 77
Fire	23	40
Property damage	3,606	4,038
Travel delay	347	57

Note: In 1988 dollars at a 4-percent discount rate. Property damage cost includes 4 hours of household labor spent on vehicle repair and crash reporting.

Costs by Nature and Number of Vehicles and Nonoccupants Involved

This section breaks down crash costs in several ways. They include by:

- Non-occupant involvement.
- Vehicle type.
- Vehicle count.
- Extent of vehicle damage.

The most costly crashes occur when vehicles strike unprotected people. Pedestrian crashes cost an average of $287,838. (See figure 33). Almost 7 percent of these crashes

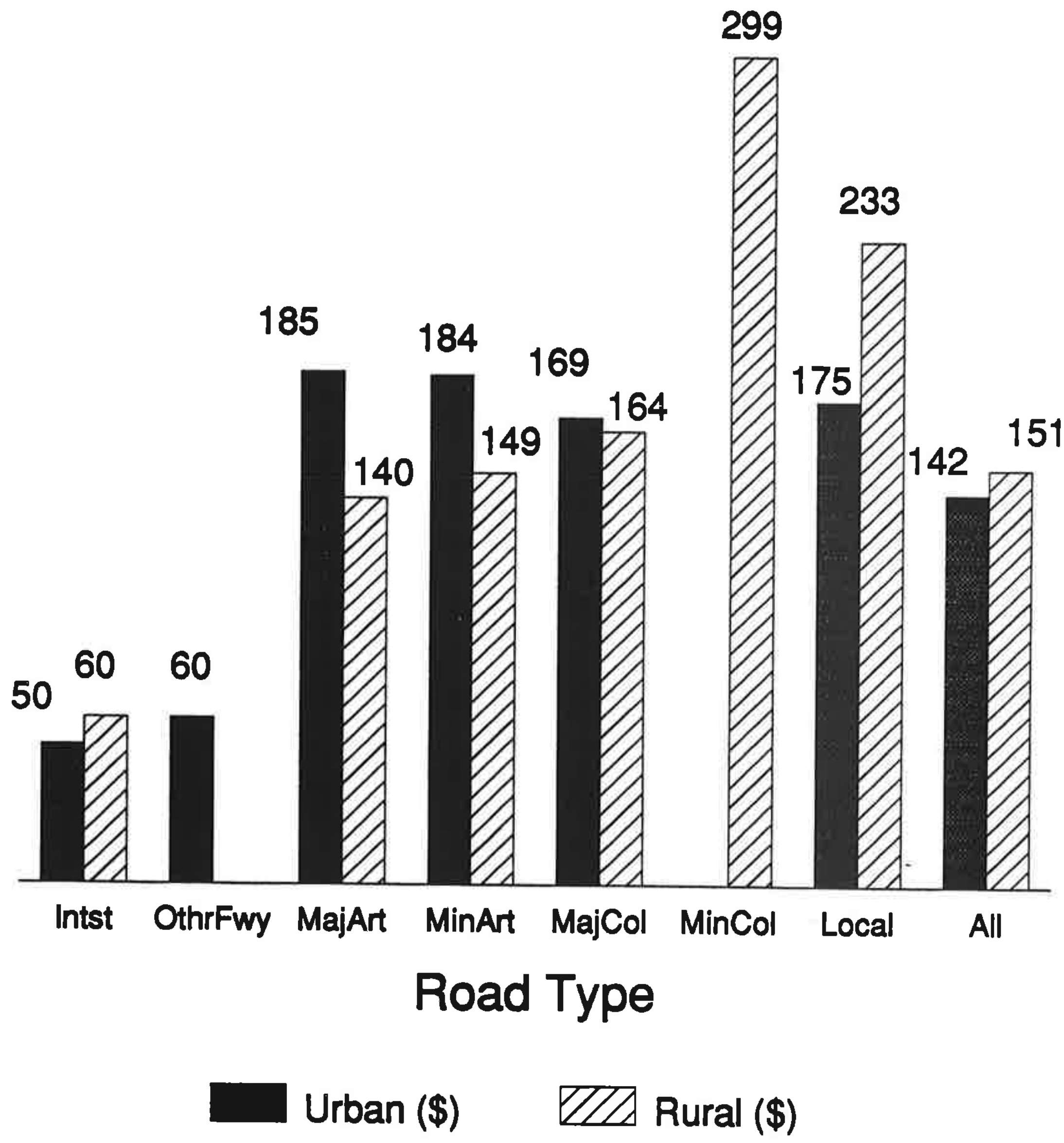

Figure 32. Cost/1000 VMT by road type.
Note: 1 mi = 1.6 km; comprehensive cost

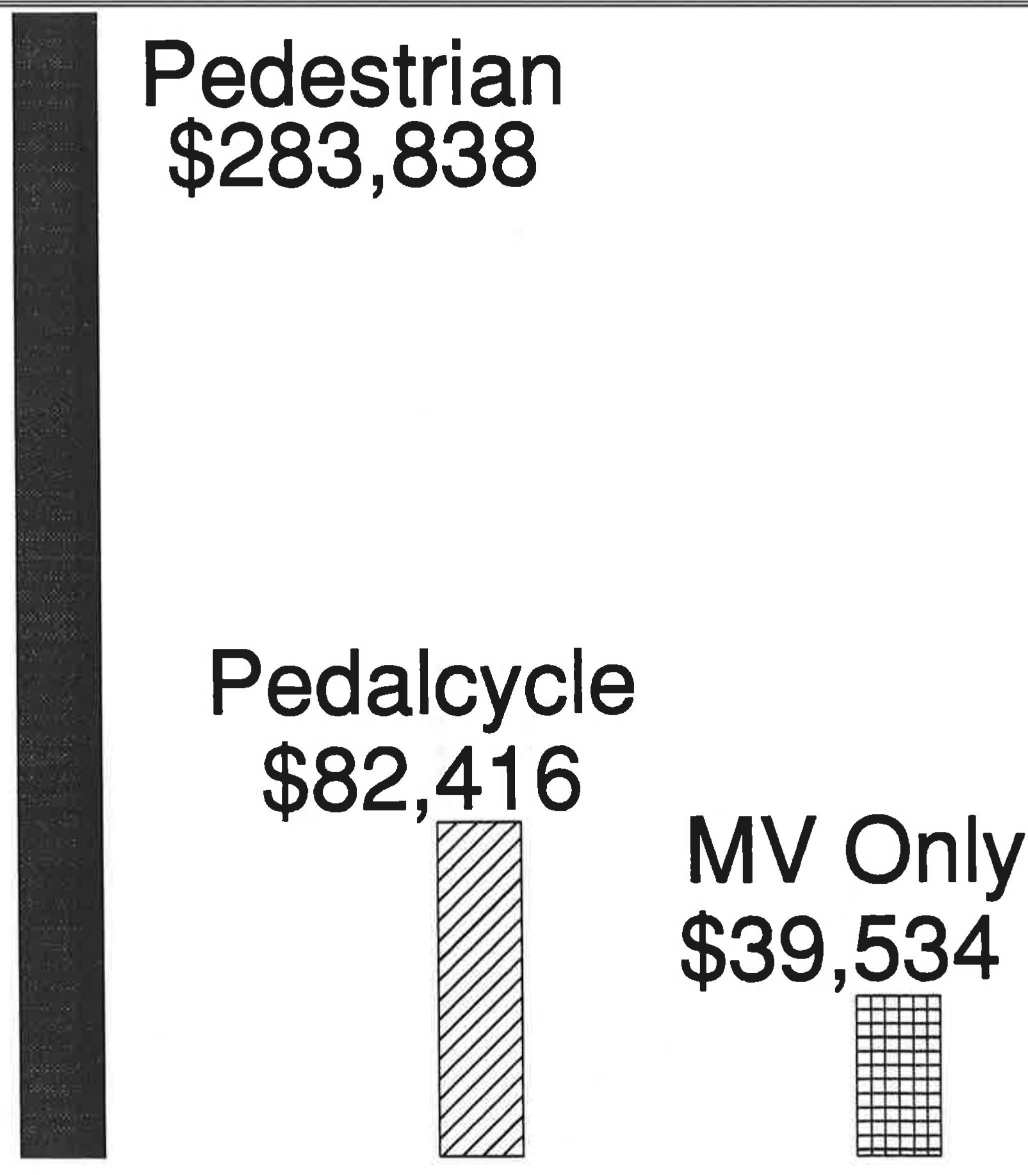

Figure 33. Comprehensive costs/crash by nonmotorist involvement.

are fatal. Pedestrian crashes are less than 2 percent of the total, but account for more than 11 percent of the crash costs.

Pedalcycle crashes cost an average of $82,416. By comparison, crashes involving only vehicle occupants average $39,534.[22]

Figure 34 shows the comprehensive crash costs by vehicle type. In terms of cost/crash, motorcycle crashes are strikingly high. Their costs average $165,974.[23] That is more than twice the cost of a pedalcycle crash or the next highest cost, $80,274/combination tractor-trailer truck crash.

Combination truck crashes cost twice as much as crashes involving only autos, vans, or buses. Other trucks have intermediate costs -- $42,512 for pick-ups and other light trucks, $51,247 for medium and heavy straight trucks (weight over 10,000 lb = 4,540 kg). Our computation methods may exaggerate the differential cost of truck crashes; we classified freeway pile-ups and other crashes as truck crashes if even one truck was involved.[24]

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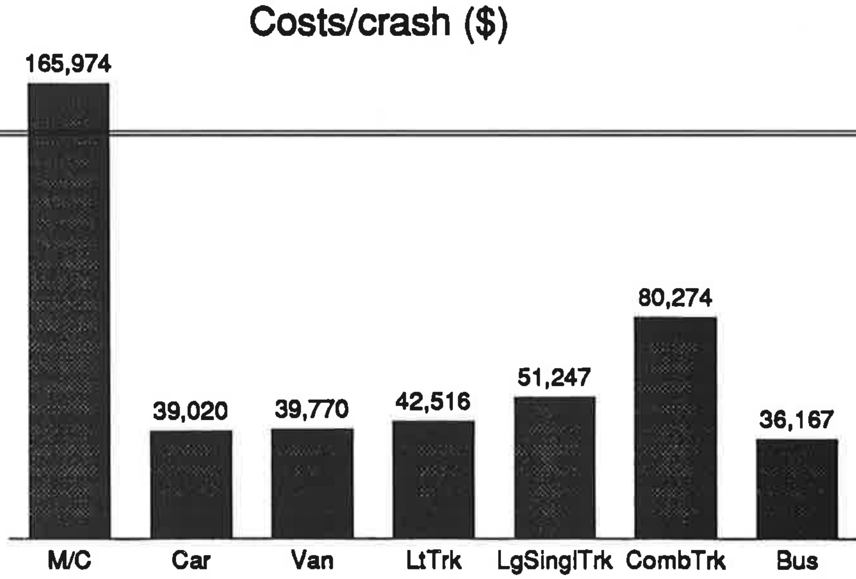
[22] These estimates do not ascribe a lower property damage cost/vehicle to crashes involving pedestrians or pedalcycles. That may exaggerate the cost of those crashes by perhaps $2,000 to $3,000.

[23] The cost/motorcycle crash may be an underestimate. We assumed the costs, for example, of broken legs or deep lacerations did not vary by crash type. In reality, wounds in motorcycle crashes tend to be dirtier and more infection-prone than others. Those characteristics can raise treatment costs and hamper functional recovery.

[24] The full classification hierarchy was combination truck (highest rank), medium to heavy straight truck, light truck, van, bus, motorcycle, and passenger auto. Crashes were classified by the vehicle with the highest rank that was involved in the crash. Sensitivity analysis showed that the cost ranking by crash type was unchanged when crashes (excluding motorcycle crashes) were very roughly classified by at-fault vehicle type. The effect on ranking by cost/vmt was not analyzed. Future research should probe costs/vehicle by vehicle role in the crash and costs to vehicle occupants by direction of impact.



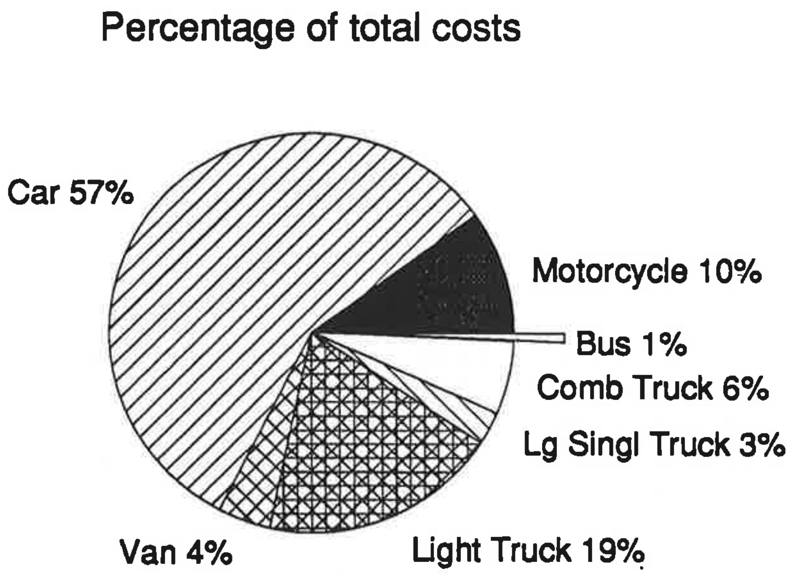


Figure 34. Comprehensive costs by vehicle type.

Truck crashes are more costly because of their excess fatality rate. Conversely, excluding fatalities, the average costs/motorcycle crash still exceed $100,000. In terms of total costs, autos and light trucks dominate.

Table 22 gives the costs/vehicle-mile of travel (vmt) and costs/vehicle/yr. In this context, motorcycles again are the most costly vehicles. Riders on these vehicles are very vulnerable. Their expected crash costs are staggering -- $2.14/mi ($1.35/km) of motorcycle travel. Their monetary costs, measured as human capital costs, average $.55/mi ($.34/km). The cost/ vehicle/yr is $4,719.[25] The human capital cost/yr is $1,210.[26]

Table 22. Comprehensive and human capital costs/unit of exposure by vehicle type.

Vehicle Type	Human Capital		Comprehensive	
	$/vmt	$/yr	$/vmt	$/yr
Auto/Passenger van	$.04	$ 401	$ .12	$ 1,193
Motorcycle	.55	1,210	2.14	4,719
Bus	.09	1,040	.24	2,851
Light truck	.05	551	.16	1,647
Med/Hvy single truck	.04	364	.11	863
Combination truck	.07	4,227	.19	11,617
All	.05	484	.15	1,457

Note: In 1988 dollars at a 4-percent discount rate. Vmt = vehicle-miles of travel. 1 mi = 1.61 km.

From the context of exposure, bus crashes may be intervention targets. Although these crashes are not typically

[25] Some might question if the average value of a statistical life can be applied fairly to motorcycle costs. To test if it could, from motorcycle helmet usage choices, Blomquist and Miller (1990) estimated the value specifically for cycle riders. The estimated value was $1.8 million, less than one standard deviation below the 49-value mean. Blomquist (1991) describes the methodology.

[26] This number was computed by multiplying the cost/mi times the average miles travelled/yr.

very costly, they are frequent. Buses have the second highest cost/vmt, $.24 ($.15/km). They also have the third highest cost/vehicle/yr, $2,851, and human capital cost, $1,040. Two contributory reasons for the high costs of bus crashes may be:

- The frequent operation of these bulky vehicles in congested areas.

- More complete crash reporting than for most vehicles.

Combination trucks have the highest cost/vehicle/yr, $11,617, and the highest human capital cost, $4,227. The costs are so high both because the vehicles are driven so much and because the cost/crash is high. Per vmt, the $.19 crash costs for combination trucks are not much higher the $.16 for light trucks. Both are higher than the $.12 costs for passenger cars and vans.

The excess cost for light passenger trucks over cars and vans underlines the possible need to extend more Federal motor vehicle safety standards to light trucks. NHTSA currently is considering action in this area.

Medium and heavy straight trucks contrast markedly with other trucks. They have the lowest cost/vmt ($.105) and cost/vehicle.

Property damage and clean-up costs/crash obviously vary by vehicle type. Little information exists about the differences. We were able to estimate the costs for large-truck crashes. Table 23 shows the costs.[27]

Single-vehicle crashes reported to the police are much more likely to involve death or injury than multivehicle crashes. Single-vehicle crashes are 35 percent of the total. As figure 35 shows, they account for half the costs. Possible reasons why single vehicle crashes are more costly include:

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[27] The cost estimates for motorcycle crashes may be slightly high because the property value/vehicle is below average. Conversely, the costs/bus crash may be low. Because light trucks, passenger vans, and cars have comparable purchase prices, the property damage costs for these crashes should be reasonably accurate.

- 86 percent of pedestrian and pedalcycle crashes involve a single vehicle. The average costs excluding these crashes are $53,752 single-vehicle versus $31,769 multivehicle.

- Drunk driving crashes often involve a single vehicle.

- Rollovers and run-off-the-road crashes often involve a single vehicle.

Table 23. Costs/crash that differ for medium and heavy trucks.

Item	Med/Hvy Truck	Other Vehicle
Fire	$ 192	$ 14
Property damage	10,092	3,463
Travel delay	640	258

Note: In 1988 dollars. Property damage cost includes 4 hours of household labor spent on vehicle repair and crash-related paperwork.

Not surprisingly, towaway crashes are the most costly. Crashes where vehicles were drivable but had to be towed because no one was available to drive them have intermediate costs. Figure 36 shows that non-towaway crashes are 61 percent of the total but account for only 21 percent of the costs.

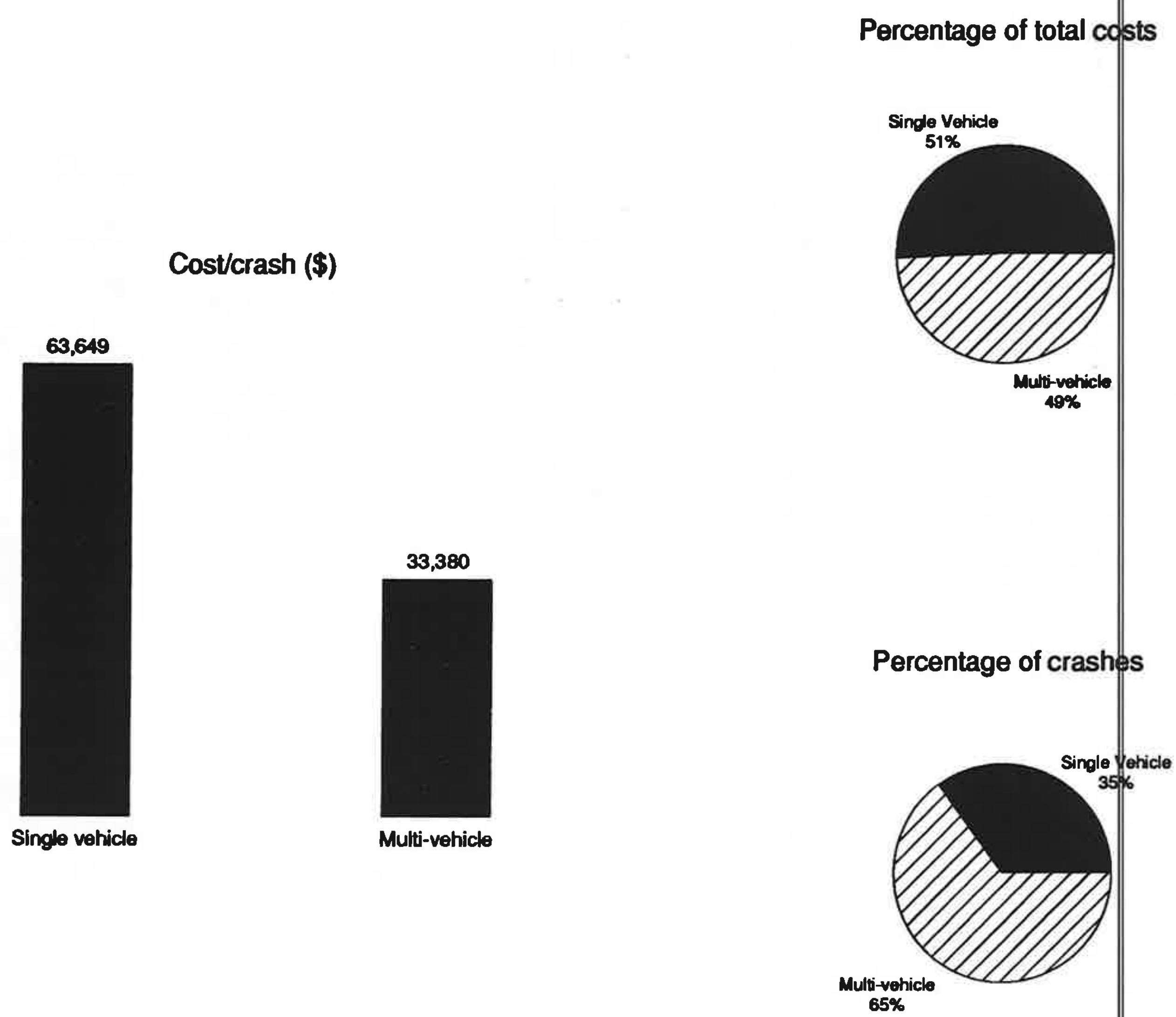

Figure 35. Comprehensive costs by number of vehicles.

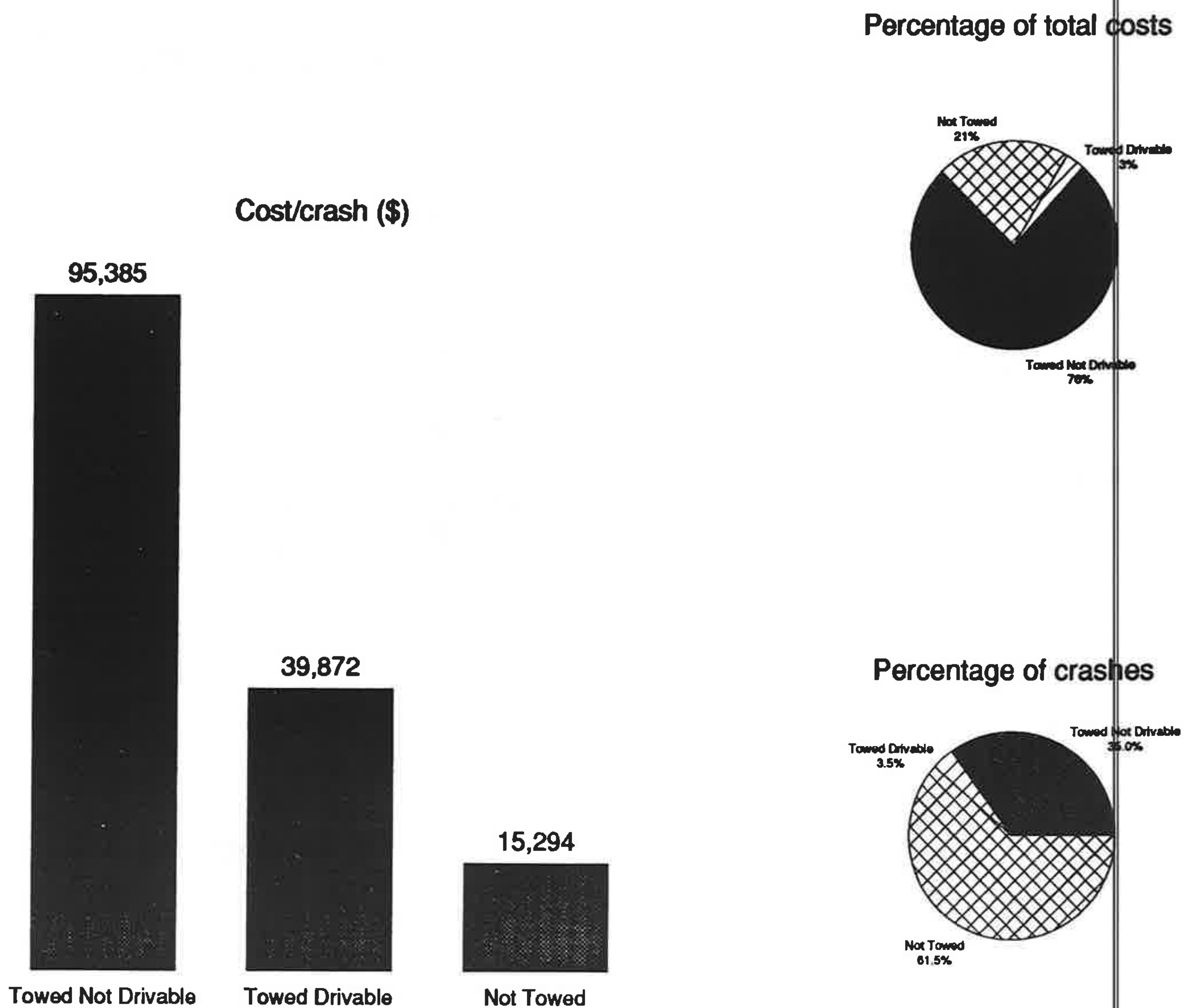

Figure 36. Comprehensive costs by towaway status.

VII. HARMFUL EVENTS IN CRASHES

A crash is a sequence of events or impacts. Three events are of primary interest. The **first precipitating event** is the underlying cause of the crash. Unfortunately, this event can be hard to pinpoint. For example, how would we know that the dead driver took his eyes off the road to change the radio station?

Events that directly cause property damage or injury -- harmful events -- are more reliably measurable. The **first harmful event** in the crash usually is readily determined. Crash investigators also can reconstruct the **most harmful event** -- the one that causes the most severe injury or property damage -- for each vehicle.

For example, the driver changing the radio station may have veered into another car. The collision between the cars was the first harmful event in the crash. If the collision threw the driver's car into a utility pole, killing him, the impact with the utility pole was the most harmful event for his vehicle. If the other vehicle escaped further impacts, the initial collision was its most harmful event.

Police generally record the first harmful event in a crash. In some States, they also code the most harmful event. NASS crash reconstruction teams code most harmful events for selected crashes after inspecting the vehicles.[28] FARS coders either code the most harmful event or validate the police coding. This chapter uses NASS and FARS data from 1985.[29]

The first and most harmful events have different uses. The first harmful event gives insight into crash causes and prevention strategies. The most harmful event is useful for analyzing how to lower crash severity.

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[28] NASS does not record the most harmful event for nontowaway crashes of severities B, C, or O that involve only passenger cars, vans, light trucks, and nonoccupants (pedestrians and pedalcyclists).

[29] Limitations in sample size forced us to group the event categories. We computed and costed counts in four categories: vehicles with property damage only, minor to moderate (MAIS 1 to 2) injuries, serious to critical (MAIS 3 to 5) injuries, and fatal injuries.

First Harmful Events

Crashes that start when vehicles collide account for 53 percent of crash costs. In another 12 percent, the first harmful event is a collision with a pedestrian (10 percent) or pedalcyclist (2 percent). The shaded bars in figure 37 show the percentage of cost attributable to these and nine other categories of first (and most) harmful events.[30] The leaders are other fixed objects at 10 percent, overturn at 7 percent, and tree at 5 percent. Each of the other categories account for less than 3 percent of total crash costs. The "other noncollision" category in this figure includes vehicle fires and immersions.

Five of the first harmful events are impacts with roadside objects. When these events are grouped, four broad categories account for 96 percent of the crash costs. (See table 24.) The roadside-object group accounts for 23 percent. NASS data indicate that 76 percent of overturns also occur outside the shoulder. These two crash groups are the targets for improved roadside safety design.

Table 24. Harmful events that dominate crash costs.

Harmful Event	First	Most
Vehicle	53.2%	48.7%
Roadside object	23.1%	22.2%
Pedestrian/pedalcycle	12.2%	12.3%
Overturn	7.4%	11.2%
Total	95.9%	94.4%

Table 25 presents the comprehensive cost/injury by first (and most) harmful event.[31] The cost/injury includes both fatal

[30] Data are unavailable about the split between pedestrians and pedalcyclists as most harmful events.

[31] Because most harmful events are not coded for modest crashes, the codes often are missing. Comparing costs by first and most harmful events requires assuming the crashes with missing data are distributed proportionally across events. That is unreasonable for nonoccupant crashes, where the number of single-impact crashes greatly exceeds the number of crashes with nonoccupant coded as the most harmful event. We used the number of single impact nonoccupant crashes in compiling table 25; that reduced the average cost of nonoccupant crashes by $31,597.

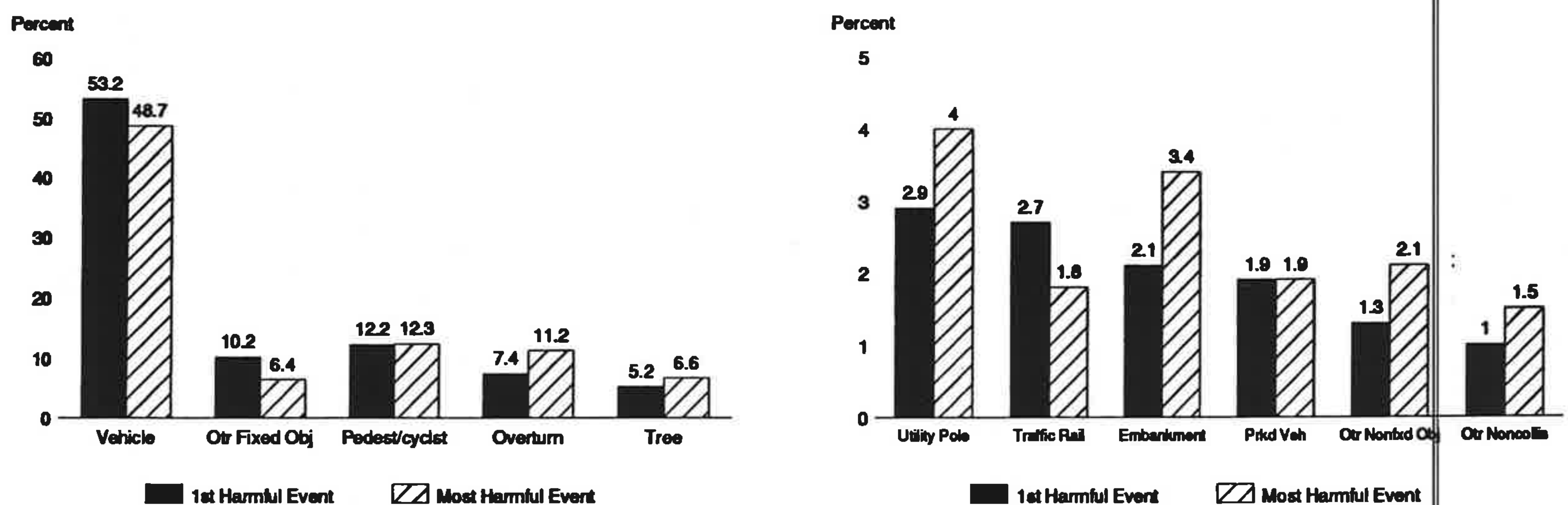

Figure 37. Percent of comprehensive costs by event type.

and nonfatal injuries. Table 25 also presents the cost/incident (including PDO incidents) for first harmful events.[32] Collisions between vehicles rank very differently from a unit cost perspective. Although they dominate total crash costs, they have low costs/injury, only 76 percent of the average. Their cost/incident also is low, only 69 percent of the average.

Table 25. Comprehensive cost/injury by first and most harmful events, and cost/incident by first harmful event.

Harmful Event	Cost/injury First	Cost/injury Most	Cost/Incident First
Pedestrian/pedalcycle	$165,561	$198,570	$156,454
Tree	132,363	163,885	100,813
Embankment	120,925	80,017	81,275
Overturn	109,557	131,416	91,849
Traffic rail/barrier	104,512	80,710	53,071
Other nonfixed object	98,031	79,148	19,457
Other fixed object	96,667	87,929	45,025
Utility pole	87,083	81,585	56,361
Collision of vehicles	55,768	62,720	19,069
Parked vehicle	52,289	68,922	12,320
Average for known event	$73,474	$83,519	$27,637
Unknown	$35,126	$33,471	$3,506
Percent unknown	1%	21%	1%

Note: In 1988 dollars at a 4-percent discount rate.

Table 25 shows that injuries where the first harmful event is an overturn or collision with a nonoccupant, tree, or embankment have the highest average costs. Injuries that start when vehicles hit traffic rails or barriers (guardrails, bridge rails, or median barriers) also are costly. Probing revealed this resulted from a high fatality rate. One of the lowest costs/nonfatal injury occurs when barrier or rail contact is the first harmful event.

[32] Data are missing about too many PDO crashes for us to compute accurate costs/incident for most harmful event.

Most Harmful Events

The black bars in figure 37 show the percentage of costs by most harmful event. Vehicle collisions still dominate. Pedestrian or pedalcyclist crashes again come next. Thereafter, the pattern shifts. Crashes where overturn is the most harmful event account for 11 percent of the costs. Trees and other fixed objects each are the most harmful impacts for 6.5 percent of the costs, utility poles 4 percent, and embankments 3.5 percent. Roadside features, taken together, account for 22 percent of the costs by most harmful event (table 24).

The importance of collisions between vehicles and other vehicles or pedestrians is not a surprise. For example:

- The test conditions used to develop occupant restraint systems and improve vehicle crashworthiness are largely two-car collision scenarios.
- Traffic signals and stop signs are intended to reduce vehicle collisions.
- Both NHTSA and FHWA have community grant programs to promote pedestrian safety.

Comparing the costs by first and most harmful event is fruitful. Notably, due to fatalities alone, at least one third of the cost of crashes where the first harmful event was a traffic barrier/rail impact occurred when another event was the most harmful. This finding suggests that traffic rails and barriers are effective despite the high average cost/crash when they are the first harmful event.

When a vehicle breaches rail or barrier protection, subsequent events often are deadly. FARS data show that barrier/rail collisions were the most harmful event in less than half of the 1,898 fatal incidents where they were the first harmful event. The major culprit was overturns. They accounted for 31 percent of the 1,100 deaths in collisions with guardrails "outside the shoulder." Research is needed to see how often the problem is impact with a guardrail end, location, misinstallation, or other factors. Traffic rails attenuate crash forces, but improvements in design and location may be desirable.

As figure 37 showed, trees and utility poles are the leading roadside features that cause crash loss. Together, they account for more than 10 percent of the costs by most harmful event. In fatal crashes, initial impacts with trees or poles generally are most harmful impacts. Proven countermeasures can reduce this toll. Utility poles can be relocated, converted to breakaways, or eliminated by burying the wires. For trees, selected removal or shielding with guardrail are possibilities.

Secondary events that often are especially harmful include overturns, collisions with embankments, vehicle fire or immersion, and collisions with trees and utility poles. For fatalities, overturn also frequently is the most harmful event when the first harmful event involves an embankment, culvert, or ditch. These problems may warrant flattening embankment slopes and ditch profiles, and adding flush inlet grates to culverts.

VIII. WHO PAYS THE CRASH COSTS?

Some costs of crashes are paid by the involved individuals, others by society. In compensating injury, the courts are most comfortable with a discount rate between 1 and 3 percent (e.g., U.S. Supreme Court, 1983; U.S. Second Circuit Court of Appeals, 1987). Impartial economists prefer the upper part of this range (e.g., King and Smith, 1988; Miller, Whiting, et al., 1987).

To correctly compute the legal and administrative costs that compensation generates, we need to compute costs as the compensation system does. Therefore, this chapter uses human capital costs at a 2.5-percent discount rate rather than the 4-percent rate used elsewhere in this report. That means the costs shown here exceed the costs in chapter V. Table 26 compares the cost estimates.[33]

Table 26. Crash costs at discount rates of 2.5- and 4-percent.

	DISCOUNT RATE	
Cost Category	2.5 Percent	4 Percent
Medical	$12.6B	$11.2B
Emergency services	0.9B	0.9B
Productivity	58.1B	46.1B
Workplace costs	2.4B	2.4B
Legal and court	7.9B	7.9B
Administrative	7.8B	7.8B
Travel delay	2.0B	2.0B
Property damage	38.3B	38.3B
Total human capital	$130.0B	$116.6B
Pain and suffering	228.5B	217.4B
Total comprehensive	$358.5B	$334.0B

Note: In billions (B) of 1988 dollars.

[33] The medical cost estimate at a 2.5-percent discount rate in table 26 has been raised by $1 million to reflect medical costs that our detailed data did not account for. These costs include chiropractor charges, bandages, knee braces, canes, and other items that health insurance rarely covers. From data about who pays, we can estimate their total amount, but their distribution among severities is unknown.

People injured in crashes and their families receive minimal compensation for their lost quality of life. As figure 38 (and tables 27 and 28, which are discussed below) show, they also bear about 31 percent of the economic burden, $40 billion annually. The largest share of the economic costs, 56 percent ($73 billion), are paid by insurers. Government pays 8 percent of the costs ($11 billion) and others 5 percent ($6 billion).[34]

Ultimately, individuals and businesses pay both the insurance costs and the government costs. Figure 39 tells who ultimately pays. Employers pay $27 billion annually and the public $63 billion. These totals exclude the costs of government highway safety programs (including traffic enforcement) and of maintaining an auto insurance system.

Annually, the public bill is $258/person. Employers pay $335/employee. If the company earns a 10 percent profit, sales receipts would have to be increased by $3,350/employee to achieve the same level of profitability that could be realized through prevention. Thus, programs aimed at promoting safer use of motor vehicles offer a way for employers to improve profitability. It may be less expensive and more productive to focus on reducing crash frequency and severity than on increasing sales.

Tables 27 and 28 break down the dollar and percentage reimbursement by nature and payer. The largest government cost is for income taxes lost when people die or are permanently disabled. These losses really are part of productivity losses; we counted them separately to highlight them. Auto insurers pay almost all of the administrative and legal costs, as well as huge bills for property damage and productivity loss. Health insurers pay most of the medical expenses. Life, health, and disability insurance also cover some medical costs and wage losses. Costs borne by others are varied. They include:

- Employers pay sick leave costs and the costs of recruitment, retraining, and worker distraction.

- Hospitals provide charity care.

- Traffic delay costs fall directly on the public.

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[34] The government total omits care in Veteran's Administration hospitals. Overall, these hospitals probably deliver more than $1 billion/yr in injury care.

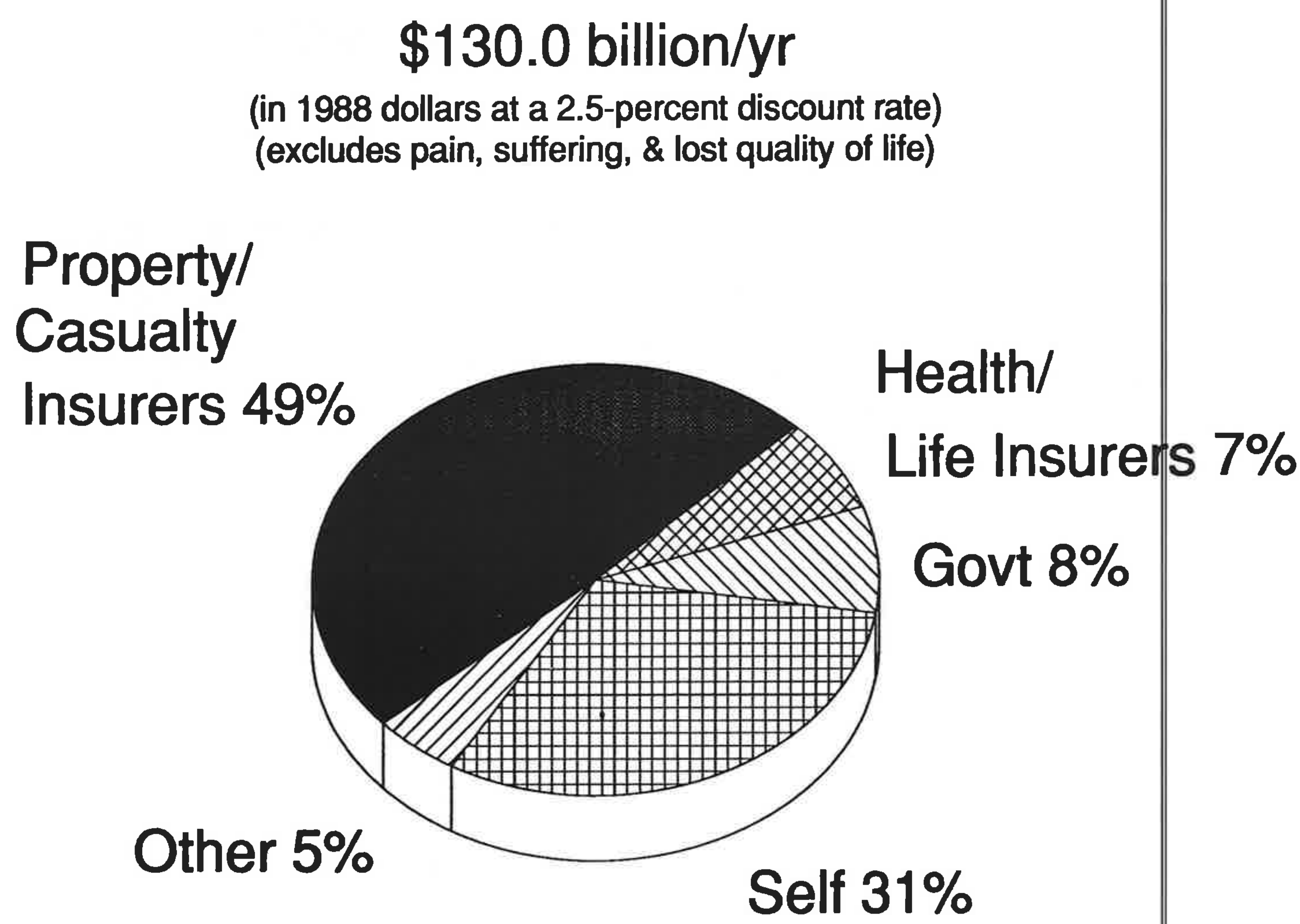

Figure 38. Who pays?

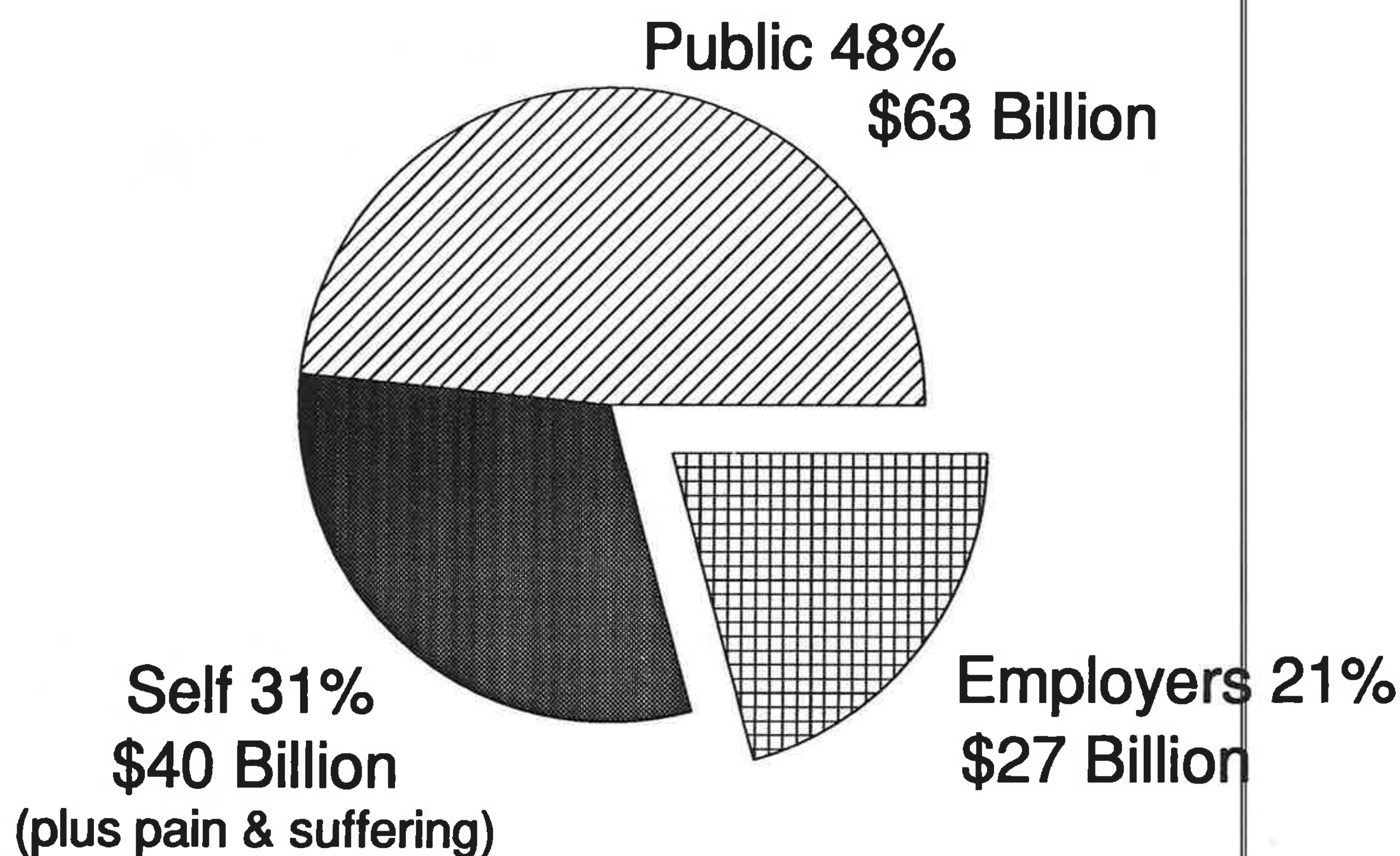

Figure 39. Who ultimately pays?

Finally, those involved in crashes and their families do not get reimbursed for substantial portions of the medical costs, lost wages and household production, and property damage.

Table 27. Who pays the crash costs.

Cost Category	All Sources	BILLIONS OF DOLLARS PAID BY Fed	State	Auto Ins	Hlth Ins	Wkrs Comp	Life Ins	Disab Ins	Other &Sick	Self
Medical	12.6	0.7	0.4	2.2	6.1	0.4			0.8	2.0
Emergncy svc	0.9		0.9							
Productivity	51.1	1.6	0.2	21.0		0.85	1.2	0.8	0.9	24.5
Income tax	7.0	5.8	1.2							
Workplace	2.4								2.4	
Legal/Court	7.9			7.9		0.02				DK
Admin	7.8	0.07	0.04	6.83	0.51	0.17	0.11	0.07		
Travel delay	2.0								2.0	
Prop damage	38.3			24.9						13.4
Total	130.0	8.17	2.74	62.83	6.61	1.44	1.31	0.87	6.1	39.9

Note: In 1988 dollars at the 2.5-percent discount rate used in the courts. Excludes costs of pain and suffering. DK = unknown.

Table 28. Percentage of crash costs paid by group paying.

Cost Category	$ Cost (Bill.)	$ Reimb (Bill.)	% Reimb	PERCENT OF COST BORNE BY Govt	Insurer	Other	Self
Medical	12.6	10.6	84.1	8.7	69.0	6.3	15.9
Emergncy svc	0.9	0.9	100.0	100.0	0.0	0.0	0.0
Productivity	51.1	26.55	52.0	3.5	46.7	1.8	47.9
Income tax	7.0	7.0	100.0	100.0	0.0	0.0	0.0
Workplace	2.4	2.4	100.0	0.0	0.0	100.0	0.0
Legal/Court	7.9	7.9	100.0	0.0	100.0	0.0	0.0
Admin	7.8	7.8	100.0	1.4	98.6	0.0	0.0
Travel delay	2.0	2.0	100.0	0.0	0.0	100.0	0.0
Prop damage	38.3	24.9	65.0	0.0	65.0	0.0	35.0
Total	130.0	90.1	69.3	8.4	56.2	4.7	30.7

Note: In 1988 dollars at a 2.5-percent discount rate. The percentage reimbursed equals the sum of the percentages of costs borne by government, insurers, and other sources. Excludes costs of pain and suffering.

Seven percent of injuries in motor vehicle crashes occur on the job (figure 40). These injuries are disproportionately serious. They account for 8.5 percent of the fatalities and 10 percent of the lost workday injuries. From another perspective, 33 percent of all workplace fatalities and 5.5 percent of lost-work-day injuries on the job result from motor vehicle crashes.

Table 29 details the employer costs/employee. These costs are high and make a strong case for employer-based driver safety programs. Many employers provide insurance for employees and their dependents. They help pay the costs of injuries both on and off the job; 68 percent of their costs are for work-related injury. In addition to insurance premiums and injury compensation, employers pay extra wages to induce people to take jobs that involve motor vehicle crash risks. The payments essentially insure these workers against the potential loss in quality of life that would occur if they were injured.

Table 29. Crash costs/employee paid by employers.

Cost Category	On-the-Job Crashes	Other Crashes
Workers' Compensation		
Medical	$4	$0
Disability	9	0
Life/disability insurance	1	7
Social Security disabil/surviv.	-	5
Health insurance	-	46
Sick leave	-	10
Motor vehicle insurance		
Liability	91	-
Property damage	34	-
Retraining, distraction	2	20
Income taxes to support public services	2	19
Sub-total	$143	$107
Wage premium	85	0
Total/employee/yr	$228	$107

Note: In 1988 dollars.

Motor vehicle crash costs are roughly 26 percent of the total employer costs of injuries (figure 41). They account for 9 percent of the total costs and 4 percent of the fringe benefit costs for illness and injury combined (Miller and Rossman, 1990).

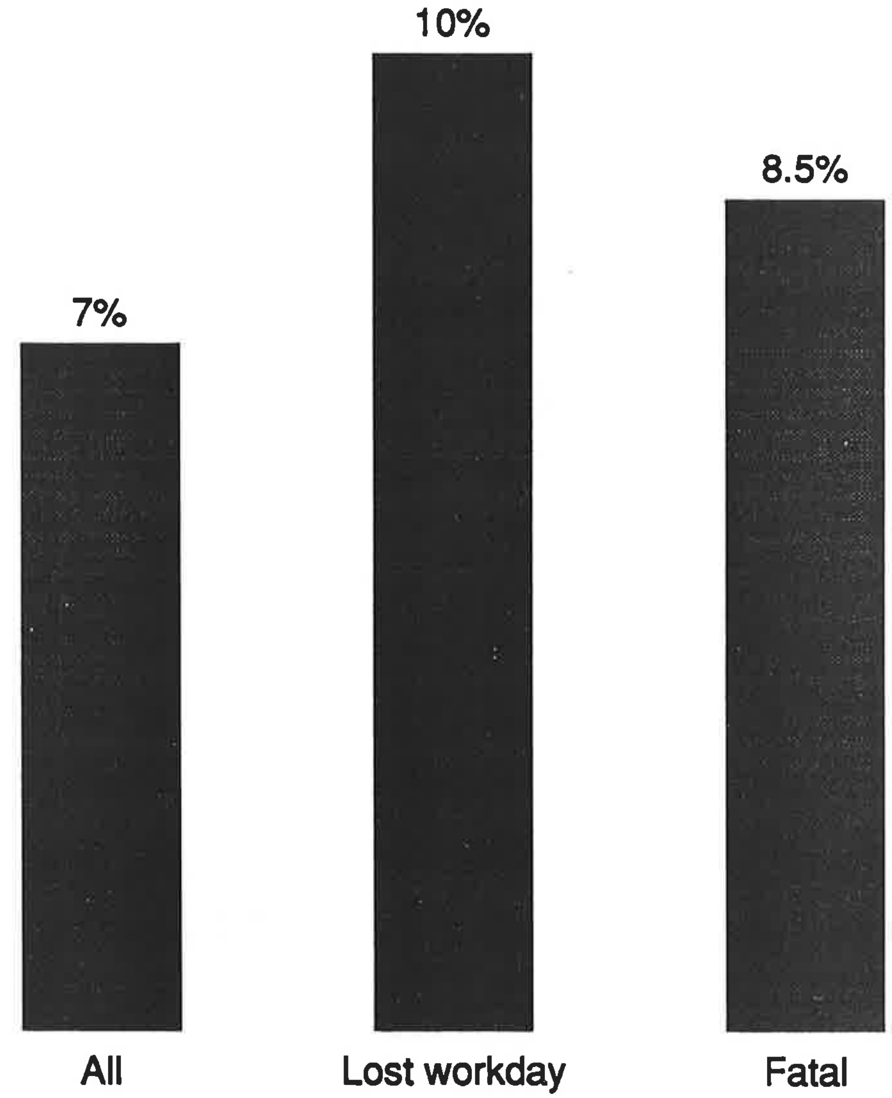

Figure 40. Percentage of motor vehicle injuries that happen on the job.

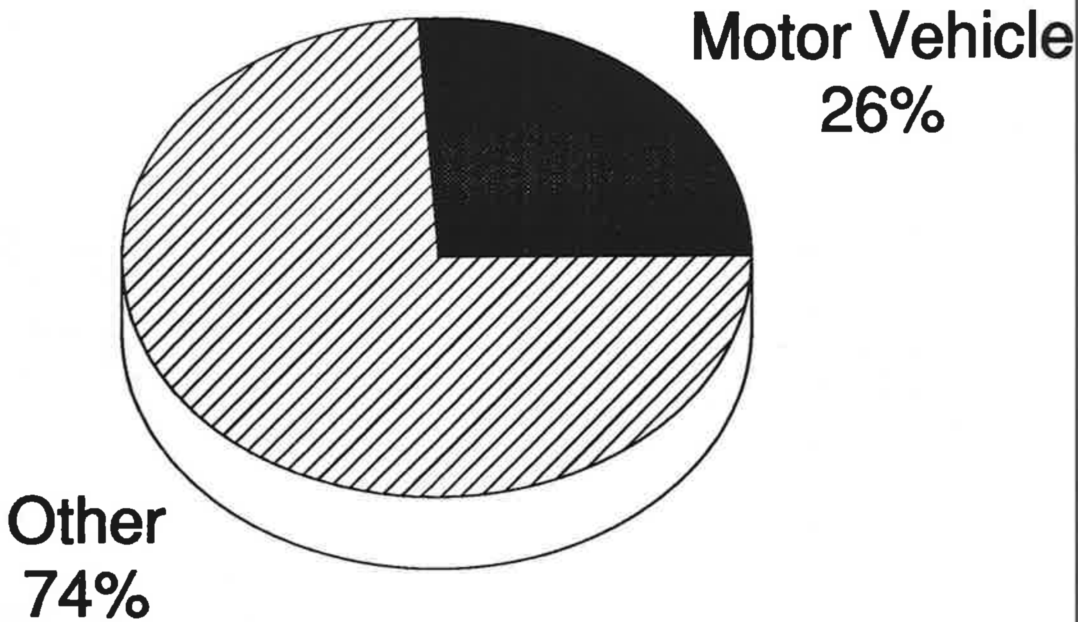

Figure 41. Motor vehicle injury costs as a percentage of all employer injury costs.

Miller (1989b) describes our methods for estimating who pays. We started with survey data (Sprinkel, 1988) showing the percentage distribution of injury compensation.[35] Because the dollar amount of auto insurance compensation is known, the other dollar amounts can be calculated. Life insurance losses were computed from life insurance industry data on the percentage of the population covered and the average policy amount. Tax losses were computed by multiplying short-term wage losses times the marginal tax rate and long-term wage losses times the average tax rate. We used Hensler et al.'s (1991) survey-based estimate that 16 percent of the medical costs of injuries are self-paid. Hensler et al. estimated total self-pay for nonfatal injuries in motor vehicle crashes at 30.5 percent, which matches our 30.4 percent estimate for all injuries (excluding workplace, travel delay, and property damage costs).

Once the payment profile was known, we were able to estimate employer costs from the percentage that employers pay of each type of insurance premium. Employer contributions to the public costs were computed using data from Bureau of the Census (1989) on the percentage of income taxes paid by corporations.

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[35] Our reliance on survey data may cause us to underestimate the costs of public and charity medical care. Both Sprinkel (1988) and Hensler et al. (1991) only interview people who speak English and have telephones. They undersample low-income people. We also have not accounted for care in Veteran's Administration hospitals.

IX. HOW TO USE THE COSTS

This chapter illustrates selected uses for the costs. Through examples, it also shows that accurate benefits analysis requires choosing values suited to the situation. Incorrect choices can yield misleading results. The examples are:

- Selecting the best way to treat a hazardous curve.
- Allocating a State's highway safety resources.
- Evaluating the effects of a highway safety improvement project.
- Determining where sobriety checkpoints are cost-beneficial.
- Estimating airbag cost-effectiveness.
- Assessing the size of a local or national safety problem.

Selecting the Best Way to Treat a Hazardous Horizontal Curve

Zegeer et al. (1990) analyze three types of improvements for a hazardous horizontal curve on a rural two-lane highway. Their analysis illustrates a typical application of crash costs in highway engineering.

Zegeer et al.'s geometric, roadway, traffic, and crash information for the curve and their assumptions (with some slight modifications for our purposes) were:

- Degree of curve (how sharply the road curves) = 10 degrees.
- Central angle (the angle formed by extending the straight sections at the start and end of the curve) = 30 degrees.
- No spirals (a gradually sharpening curved section used to help drivers transition into and out of the curve).
- Roadway width = 20 ft = 6.1 m (i.e., two 10-ft lanes with no shoulders).
- Rolling terrain.
- Sideslope (steepness of the terrain outside the shoulder) = 2:1.
- Roadside recovery distance (distance the driver has available to get back on the road safely after running off) = 5 ft (1.5 m) with trees on the roadside.
- No traffic growth expected.

- Crash experience = three total crashes in the past 5 years (one overturn, two collisions with trees).
- A 20-year service life on all improvements (meaning the annualized cost is .0736 times the total cost at a 4-percent discount rate).
- No additional right-of-way required for any of the proposed improvements.

The improvements that Zegeer et al. analyze are:

- Flatten the 10-degree curve to 5 degrees and add a spiral of 300 ft (92 m) to each end.
- Widen the lanes:
  - To 11 ft (3.4 m) and add an 8-ft (2.4-m) unpaved shoulder.
  - To 12 ft (3.7 m) and add a 6-ft (1.8-m) paved shoulder.
  - To 12 ft (3.7 m) and add an 8-ft (2.4-m) paved shoulder.
- Increase roadside recovery distance
  - To 20 ft (6.1 m) by removing 50 trees located between 20 and 54 ft (6.1 to 16.5 m) from the road and flattening the sideslope on the inside and outside of the curve to 4:1 (4 ft = 1.2 m height of fill).
  - To 25 ft (7.6 m) by removing 70 trees and flattening the sideslope on the inside and outside of the curve to 6:1 (8 ft = 2.4 m height of fill).

Table 30 summarizes the costs and percentage reduction in crashes (accident reduction factors -- ARF's) that Zegeer et al. estimated would result from each improvement. Curve flattening (reconstructing the roadway to reduce the curve's sharpness) is by far the most costly alternative.

Table 30. Costs and percentage accident reduction factors (ARF's) by proposed improvement.

Improvement	Costs	ARF's
Flatten curve	$212,900	50.6%
11 ft lanes	17,720	27.8%
12 ft lanes, 6-ft shoulder	21,550	30.5%
12 ft lanes, 8-ft shoulder	32,940	36.6%
20-ft recovery distance	19,660	23.0%
25-ft recovery distance	32,460	29.0%

In addition to these data, computing the benefit-cost ratio requires crash costs. With only three crashes, we cannot get a valid crash cost by multiplying the severity distribution from the crashes on the segment times the costs/crash from table 11. Accurately estimating the percentage of fatalities, which generally are rare events, might require data on hundreds of crashes.

Often the soundest way to compute the costs/crash is from the crash-severity distribution for road segments with similar characteristics and travel patterns. Table 31 computes the costs using a severity distribution for curved sections of two-lane rural roads. This distribution was computed from police reports in Washington State. The comprehensive costs average $110,194/ crash.

Table 31. Computing crash costs for curved sections of rural two-lane roads from Washington State's crash severity data.

Severity	% of Crashes	Cost/Crash	% Times Cost/Crash
K	2.55%	$2,722,548	$69,425
A	11.0%	228,568	25,143
B	20.5%	48,333	9,908
C	13.3%	25,228	3,355
O	52.65%	4,489	2,363
Total	100.0%		$110,194

Source: Severity distribution, Zegeer et al. (1990), p. 36; cost/crash, table 11.

A second-best way to compute the costs/crash is from the distribution of first harmful events (an overturn and two trees in this example) and the costs/incident in table 25. This method would work better with 20 or 30 crashes on the section. It yields a comprehensive cost/crash of $97,825 for this example.

To compute the benefit-cost ratio for a treatment, we first compute the benefits by multiplying 0.6 crashes/yr times the cost/crash times the ARF. Next, we compute the costs by multiplying the treatment cost times the annualization factor given above (.0736). Finally, the benefit-cost ratio equals the benefits divided by the costs.

Zegeer et al. suggest using incremental benefit-cost analysis to select the most cost-effective treatments. This method computes the benefit-cost ratio if the least costly alternative were chosen, then the ratio of the incremental benefits and costs of choosing the next most costly treatment, and so on. Only treatments with positive incremental benefit-cost ratios are candidates for implementation.

Table 32 summarizes the incremental benefit-cost analysis for the curve.

Table 32. Incremental benefit-cost analysis of treatments for the curve.

Treatment	Incremental Benefits	Incremental Costs	Ratio
11 ft lanes	$18,380	$1,304	14.09
20-ft recovery distance	10,979	1,447	7.59
12 ft lanes, 6-ft shoulder	1,375	282	4.88
12 ft lanes, 8-ft shoulder	3,105	838	3.70
25-ft recovery distance	2,515	942	2.67
Flatten curve	15,059	15,669	0.96

Upgrading the curve to 12-ft (3.6-m) lanes with 8-ft (2.4-m) paved shoulders and a 25-ft (7.6-m) recovery distance would be cost-effective. Also flattening the curve would not. Flattening would have a benefit-cost ratio of 2.14 if it were the only treatment applied, but its ratio is below 1.00 after less costly fixes are applied.

Allocating a State's Highway Safety Resources

States annually consider ways to treat hundreds of hazardous locations like the one in the first example. Many use benefit-cost models to allocate their highway safety resources among projects where benefits exceed costs. The INCBEN model, for example, selects the set of treatments that will yield the highest expected return for a fixed State budget (McFarland and Rollins, 1984). The model's inputs include:

- Average annual crash frequency and severity at hazardous locations.

- The estimated location-specific percentage reduction in crashes achievable using alternative treatments.

- The estimated location-specific cost of installing and maintaining each countermeasure.

INCBEN uses crash costs to convert the expected reductions in fatal, injury, and property damage crashes to a common metric.

Miller, Whiting, et al. (1987) tested whether the projects that INCBEN selected depended on the crash costs used. For 216 hazardous locations in Alabama, they input actual crash incidence and State estimates of the nature, cost, and effectiveness of feasible treatments.

Roughly 10 percent more of Alabama's possible treatments had positive benefit-cost ratios with an earlier version of comprehensive costs than with human capital costs. With a $1.5 million budget, the optimal treatments to implement varied with the crash costing method. When human capital costs were used erroneously instead of comprehensive costs, 3 of the 49 treatments in the optimal set were not selected. Ten other treatments were selected instead. The optimal treatments offered 30.9 percent more benefits, almost $630,000, for the same cost. With a $300,000 budget, the type of costs used did not affect the optimal set of treatments.

This analysis illustrates the value of using comprehensive costs. FHwA (1988) mandates their use in safety program analyses. To make safety decisions about highway design, however, some States continue to use human capital costs (McFarland, 1988). By doing so, they reduce the return on their highway investments.

Evaluating a Safety Project's Effectiveness

After the State treats a hazardous location, it generally will evaluate the actual safety benefits. Bailey (1988) provides a before-and-after evaluation of a project in a northeastern State's annual highway safety improvement report. Table 33 shows crash frequency data before and after the project was undertaken.

To analyze the project's effects, we can multiply the change in crash incidence by severity times the comprehensive crash costs by severity in table 11. The middle column in table 34 summarizes the results. The safety project apparently made the road segment more dangerous, costing $791,953. This conclusion is surprising, and probably wrong, since the project more than halved both injury and PDO crashes.

Table 33. Crashes on a road segment during 36 months before and 35 months after a safety project.

Severity	Before	After	Change
Fatal	0	1	-1
Nonfatal Injury	46	20	+26
PDO	43	16	+27
Total	89	37	+52

Table 34. Benefits of the safety project on the road segment.

	Fatalities Costed	
Severity	Separately	With Injuries
Fatal	-$2,722,548	-$115,767
Nonfatal Injury	1,809,392	3,009,942
PDO	121,203	121,203
Total	-$791,953	$3,015,378

Our mistake was costing fatalities and injuries separately. The intersection had one fatality in 6 years. Since data were only collected for 6 years, it is unclear whether the fatality rate changed between the before and after periods. Combining the fatal and nonfatal injuries into a single category and using the cost/K-A-B-C crash from table 11 is a better approach. The right column in table 34 shows the results of costing with this approach. They make sense. The safety project was effective, yielding $3,015,378 in benefits over 3 years.

Determining Where Sobriety Checkpoints Are Cost-beneficial

Like highway engineers, the police can use crash costs to design and evaluate programs. A typical application is sobriety-checkpoint design. Sobriety checkpoints are roadblocks that police use to detect drunk drivers. Following Miller et al. (1985), we consider unannounced checkpoints that operate near bars from midnight to 4 a.m. (or 11 p.m. to 3 a.m.).

The costs of checkpoints include police costs and delays for sober drivers. The checkpoints apprehend drunk drivers. They prevent imminent crashes. The effective treatment or sanctioning of those apprehended adds long-term safety benefits. Finally, checkpoints may serve as general deterrents, reducing drunk driving through fear of apprehension. Our analysis is conservative because it ignores this aspect of effectiveness.

Costs. Operating costs/checkpoint total $2,974. During a 1982 pilot program in Maryland, 4-hour checkpoints required an average of 72 person-hours of police time (Maryland State Police, 1983). We assume the checkpoints would be largely an overtime activity. With the $26.15 cost/hr on straight time that we used for State police wages and fringe benefits in chapter V, the personnel costs would be $1,883/checkpoint; with overtime at time and one half, the personnel costs would be $2,824. Other costs cited in Miller et al. (1985) totalled $150/checkpoint (inflated to 1988 dollars using the Consumer Price Index-All Items). Included are the costs of flares and the costs/use for reusable signs, markers, and reflective vests.

Maryland found that checkpoints typically delayed 400 to 600 sober drivers by 5 minutes. Assume no commercial vehicles are delayed and that average vehicle occupancy is 1.5 at midnight. From chapter V, the average delay cost/vehicle/hr would be $11.50/hr ($9.29 wages/hr * (.9 of wage rate * 1 driver + .675 of wage rate * .5 passengers)). That means the average delay cost/checkpoint is $479 (5 minutes/60 minutes * $11.50/hr * 500 vehicles/checkpoint).

Assume drunk drivers apprehended will face automatic administrative license suspension for 1 year and receive probationary hardship licenses. Miller et al. (1985) concluded from a literature review that sanctioning would cost $118/drunk driver apprehended (inflated to 1988 dollars using the Consumer Price Index (CPI) for all items).

Drunk drivers also would lose roughly 60 percent of their mobility because of restrictions on their hardship license. Miller et al. (1985) suggest valuing mobility using the estimated cost of $.382/mi ($.239/km) of owning and operating a motor vehicle in 1988 (MVMA, 1990). This cost measures a driver's willingness to pay for mobility. The average personal vehicle is driven 10,246 mi/yr (16,394 km/yr) (MVMA, 1990). Thus, mobility is valued at $3,914/yr and the mobility loss at $2,348 ($3,914 * .6). This estimate is an upper bound because people will reduce their mobility loss by using other means of transport.

Benefits. A comprehensive literature review by Higgins and Stuart (1982) concludes that license suspension clearly reduces crashes. Hagen et al. (1979) estimated the effectiveness of a 1-year suspension. For 1,501 matched pairs of multiple drunk driving offenders in California, they looked at the time until first crash after possible license action. They found that suspension would reduce a drunk driver's alcohol-related crash involvement by 32 percent over a 3-year period.

Kaestner and Speight (1974) found that Oregon drivers receiving hardship licenses experienced 25 percent fewer crashes than suspended drivers without hardship licenses (a total reduction of 40 percent); they drove more carefully to reduce the chance of a further violation that would suspend the hardship license. Epperson et al. (1975) found that the percentage reductions in crashes resulting from license suspension are similar when fatal, injury, and PDO crashes are considered separately.

Miller et al. (1985) estimate that 87 percent of the drunk drivers apprehended at sobriety checkpoints would not be apprehended otherwise. They also estimate that in the early 1980's, 8.5 percent of fatalities, 3.8 percent of injuries, and 1.5 percent of PDO crashes were excessive involvements beyond the population average by drivers with a DWI conviction in the prior 3 years. These percentages resulted from 1.3 million convictions/yr. Assuming that these drivers did not face serious sanctions, the reduction in crashes of a given severity from apprehending and sanctioning a drunk driver would equal:

> (40 percent effectiveness) * (number of incidents of this severity) * (the percentage of excessive involvements) * (1 apprehension) * (.87 of apprehensions not otherwise apprehended) / (1.3 million apprehensions/yr).[36]

Applying this formula yields the expected crash reductions/ drunk driver apprehended, as shown in the second column of table

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[36] If those apprehended previously were sanctioned, the impact would be 1/.6 times the stated impact. For example, the 8.5-percent excessive involvement in fatalities would be 60 percent of the expected involvement absent effective sanctions. Because only five States had mandatory suspension laws before 1981, assuming the statistics reflect the modest sanctions should yield a conservative, but not overly conservative, result.

35. The third column of table 35 shows the product of the expected reductions and the crash costs from table 11. The average apprehension saves $2,727, net of the costs of sanctioning drivers who otherwise would not be apprehended. According to figure 30, injuries in alcohol-involved crashes are more severe than in other crashes. The last column in table 35 shows the costs if the cost/nonfatal injury is multiplied by the ratio of costs for crashes that do and do not involve alcohol. With these more precise costs, the net benefits of apprehending a drunk driver are $4,691.

Table 35. Computing the net benefits of apprehending a drunk driver.

Crash Severity	Crashes Prevented/ Apprehension	# Prevented Times Cost/Crash	Adjusted for Severity of Nonfatal Alcohol Crashes
Fatal	.001	$2,393	$2,393
Injury	.049	2,269	4,234
PDO	.047	211	211
Total benefits	.097	$4,873	$6,838
Less sanctioning costs		(2,146)	(2,146)
Net benefits/apprehension		$2,727	$4,691

Note: In 1988 dollars at a 4-percent discount rate. Both crash reductions and sanctioning costs were multiplied by .87 to exclude drivers who would be apprehended and sanctioned without a sobriety checkpoint.

Computing the Benefit-Cost Ratio. To compute net benefits, in table 35, we subtract the $2,146 in costs of drunk driver sanctioning (($118 + $2,348) * .87 not otherwise apprehended) from the benefits of apprehension. Dividing the $3,453 in costs/checkpoint ($2,824 + $150 + $479) by the net benefits of apprehension yields the minimum number of drunk drivers that must be apprehended to make a sobriety checkpoint cost-beneficial. With the costs from table 11, 1.25 apprehensions are needed ($3,453/$2,727). With the more precise costs adjusted to reflect the severity of alcohol-related crashes, only 0.75 apprehensions are needed at a 4-hour checkpoint ($3,453/$4,691). To put these numbers in perspective, Maryland's unannounced checkpoints yielded an average of six drunk drivers (Maryland State Police, 1983). In addition to their specific deterrence effect, sobriety checkpoints may serve as a general deterrent, inducing people not to drive drunk for fear of losing their licenses.

Estimating Airbag Cost-effectiveness

Auto manufacturers, insurers, and regulators also can use crash costs. Airbags illustrate these applications. This section analyzes how much users and nonusers of safety belts would be willing to pay for a driver-side airbag. It also examines the likely savings to insurers when the driver has airbag protection.

NHTSA (1984, 1990b) estimates that driver-side airbags cost $267 and add $12 in fuel costs over the vehicle's lifetime (deflated to 1988 dollars using the implicit GNP deflator).

Computing airbag benefits requires multiplying the percentage reduction in injuries times the number of injuries/driver that would occur without an airbag times the expected cost savings/injury prevented. We estimated each of these factors.

For drivers wearing manual lap-shoulder belts, NHTSA (1984, 1990b) estimates airbags will reduce fatalities by 5 percent of the unbelted fatality rate. This example arbitrarily assumes injuries would be reduced proportionally.[37] Without belt use, NHTSA estimates airbags will reduce:

- Fatalities by 20 to 40 percent.
- Moderate to critical injuries (which this example arbitrarily assumes are A-injuries) by 25 to 45 percent.
- Minor injuries (which this example arbitrarily assumes are B- and C-injuries) by 10 percent.

Police reports probably overestimate belt use because mandatory usage laws encouraged drivers to falsely claim belts were in use. They also contain many unknowns. For these

[37] NHTSA's regulatory analysis estimates the effectiveness for the manual lap-shoulder belts. With their estimates, the fractional effectiveness of airbags would be .05/(1-.45) = .0909 for fatalities, .05/(1-.5) = .1 against moderate to critical injuries, and .05/(1-.1) = .0556 against minor injuries.

reasons, we used the average number of injuries/driver rather than separate averages for belt users and non-users.

The injury risk equals the number of driver injuries divided by the number of licensed drivers. By police-reported belt use, the top panel in table 36 estimates the number of injuries by severity that drivers experienced in 1988. Because disaggregated data were not readily available, the counts and computations include truck and bus drivers. They exclude motorcycle drivers.[38] Drivers experienced 2,036,305 injuries in 1988 (summing the totals in table 36). Dividing by the number of licensed drivers (162,853,255 from FHwA, 1989) yields a risk of .0125 injuries/licensed driver/yr.

Table 36. Number of driver injuries by severity and safety belt use, and number of injuries prevented by airbag use.

Severity	Belted	Unbelted	Unknown
Injuries			
Fatal	4,198	17,112	2,577
A-Incapacitating	130,802	109,575	35,923
B-Evident or C-Possible	1,125,500	363,620	247,000
Total	1,260,500	490,307	285,500
Injuries prevented by airbags			
Fatal	382	5,134	
A-Incapacitating	13,080	38,351	
B-Evident or C-Possible	62,528	36,362	
Total	75,990	79,847	

Source: Injuries from FARS data for 1988 and an average of GES data for 1988 and 1989. Excludes motorcycle drivers.

We used the injury distribution in table 36 to compute the cost savings/injury that would accrue with airbags. The computation steps were:

[38] To remove motorcycle drivers from the GES data, we assumed the FARS ratio of drivers to passengers in fatal motorcycle crashes applied to nonfatal crashes.

- Compute the injuries prevented. The bottom panel in table 36 shows the results of this step. For unbelted drivers, by severity, the injuries prevented equal the number of injuries (from the appropriate column in the top panel of table 36) times the corresponding percentage injury reduction. We used the midpoint where NHTSA gave an effectiveness range.

  For belted injuries, airbag effectiveness is stated as a percentage of the injuries that would have occurred without belts. The computation involves an extra step to compute how many injuries would have occurred. This step involves dividing the number of injuries by 1 minus the effectiveness of manual lap-shoulder belts (by .55 for fatalities, .5 for A-injuries, and .9 for B- and C-injuries, according to NHTSA, 1984).

- Compute the cost/injury by severity. These computations exclude property damage, which an airbag cannot prevent. We computed injury-related costs from several perspectives. Analyzing airbag regulations requires society's costs. Analyzing how much people will pay for airbags, however, should consider only costs that people pay themselves. And analyzing how much subsidy a rational insurer might provide for airbag purchase requires just costs to insurers. To compute these costs, we multiplied the costs in table 12 times the ratio of the costs at discount rates of 2.5 and 4 percent (from table 26) times the percentages in table 28. For example, the medical and vocational rehabilitation costs to self for A-injuries would be ($9,660 + $69) * $13,800/$11,399 * .232 = $2,733. The top panel in table 37 shows the comprehensive costs by perspective.

- Multiply the injuries prevented by severity times the corresponding costs/injury. Sum the cost savings across severities.

- Divide by the total number of injuries prevented to get the cost savings/injury prevented. The center panel of table 37 shows the savings.

To get from the cost savings/injury prevented to the cost savings/vehicle over the vehicle's lifespan, we multiply the crash cost times the annual injury risk (.0125 from above) times a present value factor of 8.89 for a 4-percent discount rate and an 11-year expected vehicle life. The bottom panel of table 37 presents the cost savings/vehicle. These estimates are imprecise; they inappropriately include the injury risk to heavy truck and bus drivers.

Table 37. Costs/injury by severity, perspective, and occupant protection.

	Comprehensive Costs (in 1988 dollars at a 4-percent discount rate)		
	to Society	to Insurers	to Self
Costs/injury by severity			
Fatal	$2,385,448	$374,422	$2,025,374
A-Incapacitating	166,388	21,335	144,712
B-Evident or C-Possible	20,882	4,083	20,001
Savings/injury prevented			
Belted	$ 3,485	$ 537	$ 3,107
Unbelted	27,496	4,108	22,222
Savings over vehicle's lifespan			
Belted	$ 387	$ 60	$ 345
Unbelted	3,057	457	2,636

From the regulator's perspective, mandatory airbags appear likely to yield societal benefits exceeding their $277 cost.[39] From an insurer's perspective, a $300 rebate for buying a vehicle equipped with an airbag probably would be profitable only if less than 39.5 percent of drivers wore safety belts ($457*.395 + $60*.605 = $300).[40] From an automaker's perspective, people who do not wear belts are likely to buy airbags even if they substantially underestimate their risks. Conversely, people who routinely wear belts only are likely to buy airbags if they value their lives more than average drivers or perceive their risks reasonably well.[41]

[39] This estimate ignores mobility lost by people who cannot afford cars because airbags raise their price.

[40] This calculation assumes that belt users and nonusers would be equally likely to buy airbags.

[41] This is particularly true for optional airbags that cost $500 to $900. Belt users often might not buy those airbags without insurer incentives.

Assessing the Size of a Local or National Safety Problem

Safety advocates can use crash costs to identify safety problems or sell safety. For example, they might testify about the societal benefits of mandatory airbags or the differential costs between combination truck and car crashes.

Our final example probes an issue that concerns researchers as well as advocates: how to compare crash experience across States. Traditionally, this question has been addressed by considering the fatality and injury rates/million vehicle-miles (1.61 million km) of travel. Table 38 ranks the crash rates from largest (1) to smallest (50). The rankings for fatalities and injuries/million vmt differ markedly.

Clearly, a combined risk measure is needed. To combine the risk measures, we multiplied the fatal crashes/million vmt and injury crashes/million vmt in 1988 times the comprehensive costs/crash in table 11. For example, the cost/million vmt in Alabama is 232 * $2,722,548 + 7,558 * $69,592 = $11,576,074. Table 38 shows the combined risks.

The cost rankings reveal that one group of high-cost States are heavily urbanized -- Connecticut, Illinois, Maryland, Massachusetts, Michigan, New Jersey, New York, Ohio, Pennsylvania, and Rhode Island. These States generally have low fatality rates and high injury rates. Their high cost may be an artifact -- a misleading result of using injury costs computed with the national distribution of nonfatal crashes by severity. Actually, as chapter VI showed, urban areas have injuries of lower average severity than rural areas. We suspect these States would drop in rank if their A-B-C severity distribution was used in computing their crash costs/million vmt.

The second group of high-cost States may have safety problems. They include Arizona, Florida, Louisiana, Nevada, New Mexico, and West Virginia. Kentucky, South Carolina, and Tennessee also have higher safety costs than average.

The fatality and injury rates in Arkansas, Mississippi, and North Carolina seem incongruous. The mid-range cost ranks for these States may result from underreporting of injury crashes.

The costs/million vmt in table 38 also are useful for research. For example, they could be used in regressions examining the factors that make some States safer than others.

Table 38. Ranking of States by crashes and comprehensive costs/million vmt.

State	Fatals/M Vmt	Inj/M Vmt	Cost/M Vmt	Fatal Rank	Injury Rank	Cost Rank
Alabama	232	7558	$11,576,074	14	42	39
Alaska	224	9112	12,439,730	20	33	27
~~Arizona~~	~~246~~	~~11282~~	~~14,548,837~~	~~10~~	~~17~~	~~15~~
Arkansas	277	5828	11,597,279	7	49	38
California	202	9748	12,283,375	27	28	31
Colorado	163	9261	10,882,668	46	32	42
Connecticut	171	12690	13,486,781	41	11	21
Delaware	223	8976	12,317,859	21	35	28
Florida	262	13510	16,534,954	8	8	4
Georgia	239	10178	13,589,963	12	24	20
Hawaii	173	11739	12,879,412	39	14	24
Idaho	281	8778	13,759,145	6	36	18
Illinois	212	15669	16,676,172	24	3	3
Indiana	188	9717	11,880,644	37	29	36
Iowa	225	8729	12,200,418	18.5	38	32
Kansas	192	10142	12,285,312	33.5	25	30
Kentucky	227	10807	13,700,991	16	22	19
Louisiana	237	11315	14,326,773	13	15	16
Maine	202	11110	13,231,218	27	19	22
Maryland	190	13712	14,715,296	36	7	11
Massachusetts	155	15333	14,890,490	49	5	10
Michigan	195	13488	14,695,537	30.5	9	12
Minnesota	149	8435	9,926,681	50	40	47
Mississippi	286	5894	11,888,239	3	48	35
Missouri	215	9750	12,638,698	23	27	26
Montana	225	6752	10,824,584	18.5	42	43
Nebraska	175	11108	12,494,738	38	20	29
Nevada	285	11310	15,630,117	4	16	8
New Hampshire	159	8142	9,995,031	48	41	46
New Jersey	165	16395	15,901,812	45	2	6
New Mexico	283	11210	15,506,074	5	18	9
New York	199	18971	18,620,168	29	1	1
N. Carolina	242	5503	10,418,213	11	50	44
N. Dakota	160	5927	8,480,794	47	47	50
Ohio	193	15428	15,991,171	32	4	5
Oklahoma	172	6216	9,008,621	40	44	49
Oregon	226	8561	12,110,729	17	39	33
Pennsylvania	218	12339	14,522,111	22	12	14
Rhode Island	202	14577	15,643,972	27	6	7
S. Carolina	287	9781	14,620,506	2	26	13
S. Dakota	191	6715	9,873,169	35	43	48

Table 38. Ranking of States by crashes and comprehensive costs/million vmt (continued).

State	Fatals/M Vmt	Inj/M Vmt	Cost/M Vmt	Fatal Rank	Injury Rank	Cost Rank
Tennessee	253	10503	14,197,294	9	23	17
Texas	192	9715	$11,988,154	33.5	30	34
~~Utah~~	~~195~~	~~11052~~	~~13,000,276~~	~~30.5~~	~~21~~	~~23~~
Vermont	211	8768	11,846,402	25	37	37
Virginia	169	9046	10,896,398	42	34	41
Washington	167	11834	12,782,172	43	13	25
W. Virginia	292	13281	17,192,353	1	10	2
Wisconsin	166	9602	11,201,653	44	31	40
Wyoming	228	5917	10,325,168	15	46	45

Note: In 1988 dollars at a 4-percent discount rate. Rates are incidents/million vehicle-miles of travel, where 1 mi = 1.61 km.

Source: Rates, FHwA (1990); costs, computed from rates and comprehensive costs in table 11.

Conclusion

In 1988, an estimated 14.8 million motor vehicle crashes involved 47,000 deaths and almost 5 million injuries. More than 4.8 million years of life and functioning were lost (figure 6). Comprehensive crash costs and their components can help us to understand and reduce the toll. Their uses include:

- Highway engineering applications in selecting and evaluating safety projects.
- Safety regulatory analyses.
- Market analyses of the demand for safety products.
- Insurer decisions about offering safety incentives.
- Informed policy debate and safety advocacy.
- Safety research that analyzes outcomes comprehensively or requires a single risk measure that appropriately combines crash or injury risks by severity.

In 1988, crash costs totalled $334 billion. They included $71 billion in out-of-pocket costs, $46 billion in wages and household production, and $217 billion in pain, suffering, and lost quality of life (figure 9). More than half the out-of-pocket costs were property damage costs; the rest were medical, emergency services, workplace, travel delay, legal, and administrative costs.

Employers paid 20 percent of the out-of-pocket and productivity costs. The general public paid 48 percent. People involved in crashes and their families paid the remainder and suffered the pain (figure 39).

Data systems count crashes and injuries in varied categories. Table 11 shows the comprehensive cost/crash and cost/person by police-reported crash severity. Nonfatal crashes cost an average of $70,000, fatal crashes $2,722,000. In other units, towaway crash costs averaged $94,000 (figure 36); property damage crash costs averaged $1,682/vehicle (table 12).

The costs are useful for choosing among alternatives. For example, a median barrier that annually prevented 2 incapacitating injuries and 4 possible injuries would yield roughly the same benefits as a section of guardrail that prevented 22 possible injuries. Similarly, preventing one hospitalized injury yields more benefits than 20 lesser injuries (table 41).

The most costly kinds of crashes include motorcycle, pedestrian, pedalcycle, alcohol-involved, and combination truck (figures 30, 33, and 34). In terms of exposure, minor rural collectors, local rural streets, and urban arterials have the highest costs/vehicle-mile of travel (vmt) (figure 32). Motorcycles have safety costs of $2.14/vmt, buses $.24/vmt, combination trucks $.19/vmt, light trucks $.16/vmt, and cars $.12/vmt (table 22). In collisions involving only occupants, the most harmful events with the highest cost/injury involve, in order: trees, overturns, other fixed objects, and utility poles (table 25).

Motor vehicle crashes are a costly societal problem -- a killer and maimer. Hopefully, this report will help policymakers, analysts, and advocates to cut the crash toll.

A. EXAMPLES OF INJURIES BY AIS LEVEL

AIS Code	Injury Severity Level	Representative Injuries
1	Minor injury	Superficial abrasion or laceration of skin, digit sprain, first-degree burn, head trauma with headache or dizziness (no other neurological signs).
2	Moderate injury	Major abrasion or laceration of skin, cerebral concussion (unconscious less than 15 minutes), finger or toe crush/amputation, closed pelvic fracture with or without dislocation.
3	Serious injury	Major nerve laceration; multiple rib fracture (but without flail chest); abdominal organ contusion; hand, foot, or arm crush/ amputation.
4	Severe injury	Spleen rupture, leg crush, chest-wall perforation, cerebral concussion with other neurological signs (unconscious less than 24 hours).
5	Critical injury	Spinal cord injury (with cord transection), extensive second- or third-degree burns, cerebral concussion with severe neurological signs (unconscious more than 24 hours).
6	Maximum injury (currently untreatable, immediately fatal)	Decapitation, torso transection, massively crushed chest.

Source: Hartunian et al. (1981).

B. METHODS FOR ESTIMATING CRASH AND INJURY INCIDENCE

Estimating the crash count was complex. We relied primarily on published and unpublished insurance data. From Wish (1990), we learned that premiums paid for liability coverage totalled $52.6 billion in 1988; 90.4 percent of the premium dollars paid for losses and loss adjustment expenses (LAE). The comparable figures for collision and comprehensive coverage were $34.3 billion and 66.7 percent. Data we obtained from insurers writing more than 30 percent of all insurance premiums indicate that 65 percent of comprehensive and collision claims costs in 1987 were under the collision coverage.

According to the Insurance Information Institute (1990), the average loss plus LAE for a 1988 collision claim was $1,535 and for a liability claim was $8,736. Dividing total claims costs by cost/claim yields the number of claims. For collision, 9.7 million; for liability, 5.4 million. Liability claims include both at-fault property damage and bodily injury.

Dockets 74-14-32-6106 and 6126 (1984) and our insurance data indicate about 70 percent of auto insurance buyers carry collision coverage. AIRAC (1987) indicates 93 percent of drivers buy insurance. Dividing collision claims by the percentage with collision coverage suggests 14.9 million collision claims would have been filed if everyone had collision coverage. Adding the 5.4 million liability claims yields 20.3 million crash-involved vehicles. NASS indicates an average crash involves 1.72 vehicles, meaning roughly 11.8 million crashes were serious enough to be reported to insurers. In roughly 9.6 percent of these collisions ((5.2 million uninsured vehicles /20.3 million vehicles) ** 1.72), neither vehicle would have been insured.

The General Estimates System or GES (NHTSA, 1990a) estimates 6.877 million crashes were reported to the police in 1988. Assuming the probability of reporting to police and insurers is independent, 4.0 percent of the 11.8 million crashes -- about 475,000 -- were not reported.[42] Reported, about 11.3 million crashes.

NHTSA (1983) estimates 3 unreported crashes for every 10 reported. That implies 14.8 million crashes annually. One every 2 seconds, morning, noon, and night.

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42 .065*(1-(6877/11818))

Chapter III describes how we estimated the number of injuries and injury crashes. One detail it omits is how we allocated unknowns in the NASS computer runs. We allocated them in stages. For the distribution by MAIS, for example, we allocated unknowns with known treatment status proportionally to the distribution by MAIS for each treatment status. For the remaining unknowns, if KABCO was known, we allocated using the distribution by MAIS for each KABCO category. Finally, residual unknowns were allocated proportionally to the distribution of known or allocated nonfatal injuries by MAIS. Sensitivity analysis showed that allocating only among MAIS 1 through 3 in the final step did not affect the distribution when rounded to the nearest thousand.

C. SUPPLEMENTAL TABLES

Table 39. Impairment by time period and lifetime, by MAIS and body region.

Body Region & MAIS		Probability of Permanent Work Disability Total	Partial	MD Ratings Of Fraction Impaired Year 1	Years 2-5	Years 6+	Impairment Years Discounted? No	At 4%
Spinal Cord		0.2948	0.1538	0.697	0.504	0.325	22.2	9.28
	1	--	--	--	--	--	--	--
	2	--	--	--	--	--	--	--
	3	0.0714	0.1429	0.518	0.252	0.033	4.19	2.49
	4	0.3136	0.1788	0.558	0.173	0.053	16.48	6.47
	5	0.4952	0.1575	0.897	0.821	0.664	40.24	16.25
Brain		0.0060	0.0284	0.201	0.055	0.016	1.28	0.71
	1	0.0013	0.0103	0.014	0.0006	0.0006	0.09	0.05
	2	0.0054	0.0433	0.715	0.167	0.006	1.81	1.48
	3	0.0284	0.1730	0.858	0.267	0.078	5.95	3.38
	4	0.0696	0.1919	0.964	0.471	0.415	27.37	10.51
	5	0.2708	0.5869	0.979	0.830	0.890	43.59	18.79
Lower Extremity		0.0048	0.1171	0.166	0.027	0.047	2.59	1.17
	1	0.0002	0.0035	0.019	0.0005	0.0005	0.05	0.03
	2	0.0037	0.0929	0.146	0.0045	0.006	0.69	0.38
	3	0.0115	0.2821	0.363	0.089	0.161	8.22	3.6
	4	0.0258	0.3350	0.311	0.121	0.141	7.75	3.47
	5	--	--	--	--	--	--	--
Upper Extremity		0.0031	0.0839	0.086	0.015	0.012	0.9	0.44
	1	0.0005	0.0121	0.019	0.0013	0.0013	0.11	0.06
	2	0.0048	0.1276	0.112	0.0085	0.008	0.85	0.43
	3	0.0109	0.2990	0.333	0.103	0.076	4.75	2.28
	4	--	--	--	--	--	--	--
	5	--	--	--	--	--	--	--
Trunk/Abdomen		0.0021	0.0205	0.057	0.011	0.014	0.77	0.36
	1	0.0005	0.0039	0.02	0.0003	0.0003	0.05	0.03
	2	0.0041	0.0411	0.112	0.0007	0.00009	0.28	0.18
	3	0.0125	0.1264	0.295	0.098	0.108	5.67	2.58
	4	0.0171	0.1799	0.432	0.172	0.251	12.22	5.34
	5	0.0230	0.2420	0.364	0.154	0.225	11.18	4.87
OthrHd/Face/Neck		0.0010	0.0216	0.027	0.005	0.003	0.24	0.12
	1	0.0005	0.0120	0.015	0.0012	0.0012	0.11	0.05
	2	0.0038	0.0814	0.107	0.021	0.0044	0.62	0.36
	3	0.0242	0.3464	0.374	0.144	0.065	4.78	2.41
	4	0.0203	0.3103	0.645	0.354	0.316	16.1	7.33
	5	0.0606	0.8788	0.497	0.431	0.500	24.83	10.81
Minor External		0.0002	0.0053	0.010	0.0005	0.0005	0.05	0.03
	1	0.0002	0.0053	0.010	0.0005	0.0005	0.05	0.03
All NonFatal		0.0023	0.0257	0.073	0.0166	0.0093	0.72	0.32
Fatality		1.0000	--	1.000	1.000	1.000	42.71	19.39

Table 40. Costs/injury in police-reported crashes, by body region and MAIS (in 1988 dollars at a 4-percent discount rate).

	Cases	Hosp/ Med@	Voc Rehab	HH Prod	Wages	Insur Admin#	Wkplc Cost	Emerg Svcs*	Travl Delay	Legal/ Court	Prop Damag	Human Capital	Pain & Suffer	Compre- hensive	Direct
Spinal Cord															
All	939	302048	2262	39510	163034	50715	3627	709	160	84956	5674	652695	739474	1392169	444477
MAIS 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MAIS 2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MAIS 3	397	20425	165	12870	46777	7531	2540	404	160	14080	4607	109559	211101	320660	45305
MAIS 4	111	437470	2567	68259	200080	71271	3831	919	160	118837	6668	910062	446659	1356721	635055
MAIS 5	431	526579	4116	56645	260578	85198	4575	935	160	141516	6400	1086702	1442268	2528970	763079
Brain															
All	585688	4766	31	1517	5418	1319	484	175	160	1841	2752	18463	69041	87504	8776
MAIS 1	436683	774	10	477	1624	462	178	121	160	385	2605	6796	2923	9719	2090
MAIS 2	121774	3729	78	1829	6483	1237	1017	269	160	1489	2679	18970	149449	168419	7979
MAIS 3	15608	14016	153	7901	28645	4928	2330	404	160	8943	4607	72087	325671	397758	30934
MAIS 4	6693	72166	183	13771	50569	14324	2692	919	160	24465	6668	185917	1055950	1241867	114909
MAIS 5	4930	263147	159	49089	180322	50120	5526	935	160	85634	6400	641492	1786954	2428446	405681
Lower Extremity															
All	162290	9672	84	3787	13450	2630	1280	262	160	4091	3190	38606	107074	145680	18179
MAIS 1	50321	704	8	219	646	357	142	121	160	224	2605	5186	2789	7975	1716
MAIS 2	67505	7803	78	3059	10708	2021	1155	269	160	2497	2679	30429	28019	58448	13983
MAIS 3	43985	22552	180	8886	31927	6095	2747	404	160	10824	4607	88382	345466	433848	42962
MAIS 4	479	32391	157	13049	48170	8982	3578	919	160	16560	6668	130634	313324	443958	62747
MAIS 5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Upper Extremity															
All	153371	3049	35	2471	8816	1447	823	203	160	2077	2855	21936	36414	58350	7794
MAIS 1	83611	598	18	416	1392	423	175	121	160	332	2605	6240	4803	11043	1827
MAIS 2	52541	4638	45	3760	13407	1992	1301	269	160	2626	2679	30877	30879	61756	11031
MAIS 3	17219	10105	90	8519	30860	4759	2511	404	160	8873	4607	70888	206797	277685	26902
MAIS 4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MAIS 5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trunk, Abdomen															
All	354343	2098	43	925	3214	792	390	173	160	1009	2849	11653	33480	45133	4665
MAIS 1	288278	689	7	240	743	366	150	121	160	239	2605	5320	2607	7927	1732
MAIS 2	32293	3242	168	1932	6628	1198	877	269	160	1449	2679	18602	11994	30596	7363
MAIS 3	25571	9928	219	5091	18267	3382	1786	404	160	5907	4607	49751	252857	302608	21786
MAIS 4	6084	19325	252	7340	27043	5501	2455	919	160	10015	6668	79678	535001	614679	38627
MAIS 5	2117	32503	287	10090	37231	7854	2776	935	160	14159	6400	112395	474268	586663	58674

@ Includes hospital, medical, prescription, attendant, and nursing home services.
# Includes insurer's legal costs.
* Includes emergency transport, fire, and police services.

Table 40. Costs/injury in police-reported crashes, by body region and MAIS (continued).

Severity	Cases	Hosp/ Med	Voc Rehab	HH Prod	Wages	Insur Admin	Wkplc Cost	Emerg Svcs	Travl Delay	Legal/ Court	Prop Damag	Human Capital	Pain & Suffer	Compre- hensive	Direct
Face, Other Head, Other Neck															
All	424997	1446	43	699	2432	620	314	136	160	647	2645	9142	9951	19093	3366
MAIS 1	391716	1112	41	393	1323	468	214	121	160	374	2605	6811	4226	11037	2490
MAIS 2	26574	3123	46	2482	8843	1407	1119	269	160	1790	2679	21918	28293	50211	7914
MAIS 3	5900	12340	162	11635	42098	6182	2933	404	160	11771	4607	92292	207783	300075	33952
MAIS 4	791	28769	35	10404	38267	7662	3080	919	160	13991	6668	109955	733320	843275	54616
MAIS 5	16	22134	195	29431	108306	14421	5905	935	160	29098	6400	216985	1023144	1240129	72848
Minor External															
All	1076966.	278	3	200	630	318	100	121	160	186	2605	4601	2114	6715	1166
MAIS 1	1076966.	278	3	200	630	318	100	121	160	186	2605	4601	2114	6715	1166
All Regions															
MAIS 0	11958000	1	0	22	0	77	19	15	66	0	905	1105	0	1105	178
MAIS 1	2813000	583	12	298	975	387	144	121	160	268	2605	5553	2793	8346	1675
MAIS 2	378000	4697	79	2511	8866	1615	1092	269	160	1936	2679	23904	75999	99903	9848
MAIS 3	134000	15822	170	7957	28679	5280	2433	404	160	9151	4607	74663	290898	365561	33420
MAIS 4	17000	48553	222	11222	40863	10700	2651	919	160	18198	6668	140156	784160	924316	81403
MAIS 5	9000	212628	423	38465	144362	41095	4695	935	160	68835	6400	517998	1394675	1912673	328771
Fatal	46000	5859	0	92014	428316	46540	6186	842	280	64205	7294	651536	1743917	2395453	123912
Nonfatal	3351000	2469	28	1012	3560	883	367	155	160	1086	2724	12446	30274	42720	5150
MAIS 1-2	3191000	1070	20	560	1910	532	256	139	160	466	2614	7727	11465	19192	2643
MAIS 3-5	160000	30370	190	10020	36481	7870	2583	489	160	13469	4927	106559	405395	511954	55131
PerPDOVehicl		1	0	33	0	115	28	22	99	0	1356	1655	0	1655	267

@ Includes hospital, medical, prescription, attendant, and nursing home services.
# Includes insurer's legal costs.
* Includes emergency transport, fire, and police services.

Table 41. Costs/case by medical treatment.

Severity	Cases	Hosp/ Med	Voc Rehab	HH Prod	Wages	Insur Admin	Wkplc Cost	Emerg Svcs	Travl Delay	Legal	Prop Damag	Human Cap	Pain & Suffer	Compre- hensive	Years Lost	Direct
HOSPITALIZED																
All	475000	19196	177	6030	21720	4565	2005	312	160	7277	3465	64907	192744	257651	2.05	33692
NOT HOSPITALIZED																
All	4355000	376	9	417	1404	407	159	104	97	331	2631	5935	9861	15801	0.11	1483
Med Treated	2336000	656	10	510	1739	466	183	119	103	397	2649	6832	14210	21049	0.15	1934
Not Treated	2019000	0	8	291	954	327	126	87	89	242	2607	4731	2180	6911	0.03	879

In 1988 dollars at a 4-percent discount rate.

Table 42. People/crash by crash severity.

Crash Severity	Number of People by Injury Severity K	A	B	C	O
K - Fatal	1.10	0.48	0.36	0.14	0.58
A - Incapacitating	0.00	1.26	0.26	0.23	0.96
B - Evident	0.00	0.00	1.25	0.28	1.12
C - Possible	0.00	0.00	0.00	1.32	1.57
O - Property damage	0.00	0.00	0.00	0.00	2.59
Unreported	0.00	0.00	0.00	0.00	2.59

Source: Tabulated from NASS data for 1982 through 1985.

D. HOW TO CONVERT THE COST ESTIMATES TO ANOTHER YEAR'S DOLLARS

The cost estimates are in 1988 dollars. This appendix describes how to convert them to another year's dollars. The inflators required are published in February of each year in an appendix to the Economic Report of the President, available from the U.S. Government Printing Office.

Most cost elements should be inflated by multiplying them times the Consumer Price Index (CPI) for All Items for the year of interest divided by the CPI-All Items for 1988. For example, in the 1991 Economic Report, the values are in table B-58, "Consumer price indexes, major expenditure classes." The value for 1988 is 118.3 and for 1990 is 130.7. To convert the costs to 1990 dollars, multiply times 130.7/118.3.

Some cost elements require other inflators. For medical costs, use the CPI-Medical Care, which had a value of 138.6 in 1988 and 162.8 in 1990. For wages, household production, and employer costs, use average hourly earnings in current dollars. In 1991, this value appeared in table B-44, "Average weekly hours and hourly and weekly earnings in private nonagricultural industries." For 1988, the value was $9.29, for 1990, $10.03.

For property damage, either use the CPI-All Items or the auto repair costs/claim published with a one year lag in Property/Casualty Insurance Facts (Insurance Information Institute, New York, NY). We do not recommend using the CPI-Automobile Maintenance and Repairs, which is based on only four maintenance and repair items.

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