

Chapter 4

Willingness to Pay

The willingness-to-pay method of estimating the cost of injury is conceptually different from the human capital approach presented in Chapter 3. Human capital refers to individual worth measured by the production over time of a stream of output estimated at market value. Willingness to pay, on the other hand, reflects the value placed on health and life by individuals. Willingness-to-pay research is an effort to derive social preferences regarding public policy and assess the burden of pain, suffering, and loss in quality of life associated with injury. Thus, the willingness-to-pay method attempts to value life comprehensively.

Societal cost, according to the willingness-to-pay approach, has two components: 1) individual willingness to pay defined as the value a typical person places on health and safety, and 2) the cost the rest of society saves by preventing or controlling an injury. This chapter focuses primarily on the first term, how much people are willing to pay, and actually do pay, for safer and healthier lives. The second term, the savings society gains through injury prevention and control, includes increased tax revenues; reduced transfer payments in Medicare, food stamps, unemployment compensation, etc.; reduced private insurance payments; and reduced costs for administering transfer payment and insurance programs (Miller, Brinkman, and Luchter, 1988; U.S. NHTSA, 1983).

To Reduce Fatal Injury Risk

The literature on individual willingness to pay as a measure of the value of human life has grown in recent years. Some works are theoretical (Cropper and Sussman, 1988; Mishan, 1988; Rosen, 1988; Smith, 1987); some are philosophical (Administrative Conference of the United States, 1988; Gillette and Hopkins, 1988; Menzel, 1986; Merkhofer, 1987; Miller, 1988; Robinson, 1986; Viscusi, 1986; Wenz, 1986); and others are empirical (Blomquist, 1988; Fisher, Chestnut, and Violette, 1989; Garen, 1988; Gerking, de Haan, and Schultze, 1988; Hammitt, 1988; Moore and Viscusi, 1988). Miller (1989) evaluates 49 studies on this issue and concludes that 29 are of reasonably good quality. The most common problems with the remaining studies are: 1) faulty surveys, such as asking about probabilities too small for people to understand, restricting respondents to a few students or professors, or ignoring responses of

zero; and 2) use of inaccurate risk variables, such as a variable on risk by industry that ascribes the same risk to the janitor, the secretary, and the machinery operator, or a variable on risk by occupation that was based on only one year of data and involved more occupations than deaths, thus causing most occupations to have equal risks of zero rather than varying, small levels of risk.

The 29 studies of good quality have estimated the values of a reduction in individual risk of fatal injury or illness based on four possible elements:

- Extra wages received for risky jobs;
- Price and demand for products that increase health and safety;
- Personal tradeoffs made between time, money, comfort, and safety; and
- Surveys about individual willingness to invest money to increase health and safety.

Miller converted the estimates from the 29 studies to 1985 after-tax dollars and recomputed those that involved a discount rate or value of time using consistent values for these parameters. Following the Blomquist method (1982), Miller also adjusted the values obtained to assure that behavior be interpreted in terms of perceived, rather than actual, risk levels. Table 24 shows the value of life by type of study.

Across the 29 studies, the individual willingness to pay to save one life ranges from \$1.0 million to \$3.1 million, with a mean of \$1.95 million and a standard deviation of \$0.5 million. This level of uncertainty is typical of the effectiveness estimates in most cost-benefit analyses. Furthermore, the emergence of values in a similar range from studies using many different approaches and data sets suggests that the methodological concerns raised by individual studies are not of central importance. For example, existing data appear to underestimate the risk of fatal workplace injury. A comparison across studies implicitly assumes that the willingness to pay to avoid death is the same for slow, painful death as for sudden death, and that the willingness to pay to reduce risk does not vary significantly between unavoidable risks like nuclear disaster and risks like auto crashes, over which the individual has some control. In addition, the choice for some workers may be between a risky job and unemployment rather than a less risky, but lower-paying, job.

To give a simple example of the estimation of the value of human life, a study might estimate that the average person spends \$200 on optional auto safety features that reduce the chance of dying prematurely by 1 in 10,000. Dividing \$200 by the 1 in 10,000 probability

Table 24
**Individual Willingness-to-Pay Estimates of Value of Life
 by Type of Study, 1985**

Type of Study and Sources	Amount (millions*)
Average of 29 Studies	\$ 1.95
Extra Wages for Risky Jobs (15 studies)	1 .00-3.00
Demand and Price	
Safer cars (Winston & Mannering, 1984)	1.90
Smoke detectors (Dardis, 1980)	1.00- 1.80
Houses in polluted areas (Smith & Gilbert, 1984)	2.30
Life insurance (Landefeld & Seskin, 1982)	1.10
Behavior	
Pedestrian tunnel use (Melinek, 1974)	1.80
Safety belt use (Blomquist, 1979; 1988)	1.30-3.10
Speed choice (Jondrow, Bowes, & Levy, 1983)	1.30-1.60
Driver's travel time (Miller, 1989)	1.00- 1.20
Surveys	
Cancer (Landefeld, 1979)	2.40
Safer bus (Jones-Lee, Hammerton, & Phillips, 1985)	2.60
Safer job (Gegax, 1984)	2.00
Auto safety (Viscusi, Magat, & Huber, 1989)	2.20

Source: All estimates from Miller, 1989a; references in parentheses show primary sources prior to adjustment or value extraction from behavioral models

* After-tax dollars

suggests that the average person is willing to spend \$2 million to assure a safe and healthy life. This value estimation does not imply that most people would actually be able to pay \$2 million to avoid dying

prematurely. The estimate is based on the small amounts people regularly pay – in dollars, time, discomfort, and inconvenience -- to reduce health risks. The aggregate expenditure of \$2 million on health and safety, by ten thousand people, prevents one anonymous, statistical individual from dying. That is the price average Americans pay for safety.

To Reduce Nonfatal Injury Risk

The \$1.95 million value per life is based on the behavior of people who have an average of roughly 40 years to live. If the net present value of 40 future life years is \$1.95 million, the implied value per life year is roughly \$120,000, based on a 6 percent discount rate. Willingness to pay to prevent a nonfatal injury can be estimated by multiplying this value times the years of functioning lost to injury, discounted to present value.

The percentage of functioning lost to different types of moderate and severe injuries has been estimated by a small number of physician experts (His et al., 1983). The ratings cover three time periods: the year after the injury, the second through fifth years, and thereafter. They examine six aspects of functioning: physical dependency, mobility, pain, and cognitive, cosmetic, and sensory functioning. Subsequently, the ratings were extended to a more comprehensive range of injuries (Carsten, 1986). Aided by the *Guides to the Evaluation of Permanent Impairment* (AMA, 1984), developed by physician panels of the American Medical Association, Carsten also developed a method for combining the ratings by functional aspect into a summary impairment rating. Luchter (1987) used the physician ratings to compute average impairment by injury severity, based on the relative incidence by severity of different injuries in auto crashes.

Table 25 shows estimates by injury severity of individual and societal willingness to pay to prevent nonfatal injuries. The societal amounts range from \$30,000 for prevention of an injury of moderate severity to \$1.5 million to prevent a critical injury. To prevent a fatal injury, the societal amount is estimated at \$2 million. Thus, the willingness-to-pay estimates for reduction in critical nonfatal injuries and fatal injuries are roughly 4.5 to 6 times the cost per death caused by injury -- \$317,187, estimated by the human capital approach.

To Avoid Specific and Minor Injuries

Arthur (1981) presents a theoretical model of willingness to pay that is readily extended to nonfatal events. The model indicates that willingness to pay to reduce the incidence of an injury equals willingness to pay for life times the relative loss associated with the injury and

filled with such phrases as "He'd be better off dead," or "I'd rather die." Mercy killing is a hotly debated issue. The suicide rate soars for people with central nervous system disorders or AIDS (Marzuk et al., 1988). The largest jury awards have been primarily for severe injury, rather than death. The question of whether death or paralysis from the neck down is worse generally yields split, but emphatic, opinions.

Guilt, regret, stress, loneliness, bereavement, and pain can be much worse than death. The stressful uncertainty faced by the loved ones of a permanently unconscious person can exact a terrible cost. Three studies outlined below provide adequate information to assess the loss associated with fates generally considered worse than death.

Through sample surveys in Canada, Torrance (1982) developed scores according to status on four dimensions of functioning (mobility and physical activity, self-care and role function, emotional well-being and social activity, and health problems). He obtained further insight into fates worse than death by asking parents whether it would be better to bear a disabled baby or experience a still birth. One weakness of the health problems scale used by Torrance is that it has only one moderate level each for pain and disfigurement. Green and Brown (1978) surveyed British students about the relative severity of death and a variety of injuries.

Kind, Rosser, and Williams (1982) estimated scores on a two-dimensional health status scale. One dimension measures disability, with 1 representing full mobility and 8, unconsciousness. The second dimension measures distress, with 1 being none and 4, severe. Median scores were computed from the noneconomic component of British jury awards, which follow an informal schedule.

The loss scores for quadriplegia and head injury resulting in long-term unconsciousness or total permanent disability were taken directly from the studies. Quadriplegia scores averaged about a 10 percent greater loss than death, while totally disabling head injury scores averaged about a 15 percent greater loss.

An important caution about these loss scores is that values vary widely among individuals. For example, Torrance (personal communication, 1988) found that partial and complete quadriplegics who adjust to their injury perceive their loss as 65 percent, while quadriplegics who sue for the right to starve to death clearly perceive a loss exceeding 100 percent. The 110 percent loss estimate for complete quadriplegia is an average loss score based on a survey of people with differing expectations about their ability to adjust.

The losses associated with severe burns were computed from the functional scales based on the impairment ratings reported by His and associates (1983). The physician ratings suggest that severely burned

people over 45 generally would need an attendant for the rest of their lives, be confined to bed, and experience some mental impairment, as well as substantial disfigurement and pain. Severe burns are essentially the worst fate possible, with a loss almost 40 percent greater than the loss associated with death. It is little wonder that the debate over death with dignity is becoming more heated as the survivability of persons with these injuries and other severe health conditions increases.

Severe Injuries Preferable to Death

Functional scales were applied to paraplegia and partially disabling head injury, as was a scale developed by Kaplan (1982). Based on sample surveys in the U.S., this scale assumes no fate is worse than death. The scale has three dimensions (mobility, physical activity, and social activity) and adjustments for a diversity of symptom-problem complexes. It includes adjustments for pain by body part (at a single severity level) and for information related to disfigurement.

On average, complete paraplegia is associated with about a 60 percent loss, incomplete paraplegia about a 50 percent loss, and incomplete quadriplegia about a 90 percent loss. Torrance (personal communication, March 1988) reports that paraplegics who have adjusted well to the condition rate their loss at about 45 percent. Partially disabling head injuries are associated with losses ranging from 15 to 62 percent, depending on the severity of long-term consequences.

Miller and associates (1988) used the loss scores for serious burns, head injuries, and spinal cord injuries to validate selected willingness-to-pay estimates. They estimated individual willingness to pay to avoid critical injury at 1.1 million, which is on the same order of magnitude as the 1.2 million computed in Table 25 from the Carsten (1986) estimates of impairment and life years lost. The estimated willingness to pay to avoid a severe injury is \$310,000, compared to the \$260,000 computed from the impairment estimates.

Table 26 shows the estimated societal willingness to pay to avoid selected injuries. The highest amounts result from severe nonfatal injuries, rather than fatalities. Included is an estimated \$3.6 million to avoid a severe burn, \$2.9 to \$3.2 million to avoid a totally disabling head injury, and \$2.2 to \$2.6 million to avoid injury resulting in quadriplegia. The estimate exceeds \$1.3 million to avert an injury resulting in complete or partial paraplegia.

Minor Injuries

Physician ratings of functional impairment were not available for minor injuries. Data from the National Highway Traffic Safety

Table 26
Societal Willingness-to-Pay Estimates to Avoid Selected Injuries
by Nature of Injury, 1985

Nature of Injury	Amount (thousands*)
Severe Head Injury	
Total impairment	\$2,900-3,200
Partial impairment	550-1,500
Quadriplegia	
Complete	2,600
Partial	2,200
Paraplegia	
Complete	1,800
Partial	1,350
Very Severe Burn	3,600
Minor Injury	4
Death	2,000

Source: Miller, Brinkman, and
Luchter, 1988
* After-tax dollars

Administrations National Accident Sampling System (NASS) indicated that an average of 2 days were spent in the hospital and another 2.8 days of ability to perform work or housework were lost (Miller et al., 1988) Perhaps another 4.8 days of progressively less severe activity limitation and mild pain might follow. The three impairment scales described above suggest an average functional loss of 37 percent for 9.6 days, or a total of .01 life years lost. The societal willingness-to-pay amount to avoid a minor injury is estimated at \$4,000.

Conclusion

Much of this report discusses the cost of injury to society. This chapter focuses on a methodology that combines individuals' assessment of the amount they are willing to spend on injury risk reduction with the potential savings to society. This assessment yields values of \$2 million to avoid death. To avoid moderate to critical injuries, the estimates range from \$30,000 to \$1.5 million. To avoid severe head injuries involving total impairment, quadriplegia, or very severe burns, willingness-to-pay estimates range from \$2.6 million to \$3.2 million.

There is support in the economics profession for employing the willingness-to-pay method rather than the human capital approach when a dollar value is placed on health and safety benefits in cost-benefit analyses or resource allocation models (Bailey, 1980; Menzel, 1986; Mishan, 1988; National Safety Council, 1987; Thompson, 1980). Regulatory analyses performed by several federal agencies have employed the willingness-to-pay approach. Included are the Consumer Product Safety Commission, Occupational Safety and Health Administration, Federal Highway Administration, Coast Guard, Federal Aviation Administration, Nuclear Regulatory Commission, and Environmental Protection Agency. The Department of Agriculture has also used the approach in cost-benefit analysis.

The American public would be willing to invest \$300 billion a year to prevent all injury deaths and \$800 billion to prevent all nonfatal injuries, for a total of \$1.1 trillion. It is clear that the human capital approach yields significantly lower estimated values of human life than does the willingness-to-pay method. Both sets of estimates are presented in this report to provide the reader with the best and most current estimates available employing each approach.

Chapter 5

Potential Savings from Injury Prevention

The premature deaths, disabilities, and costs resulting from injury, including large public sector expenditures, highlight the need to reduce the burden of injury in the United States. The application of current knowledge can substantially reduce the incidence or severity, and accompanying cost, of injury. This chapter provides examples of estimated savings to society of selected injury control interventions for which reasonable estimates of effectiveness and cost can be made. When effects of an intervention are known, but data are insufficient on cost or current extent of implementation, the missing data are noted.

The precision of the estimates varies depending on research design and the generalizability of research findings. Scientists often disagree on these issues. However, in cases with large effects, or small effects based on large samples, it is unlikely that additional research would reverse the conclusion that a given intervention did or did not produce savings. In many cases, better data would increase the precision of the estimates.

Background

Some progress has been made in reducing injuries in the United States. Automobile occupant fatalities per million miles driven were reduced about 40 percent by the Federal Motor Vehicle Safety Standards authorized by the Motor Vehicle Safety Act of 1966 (Robertson, 1984). In New York City, where most children's deaths from falls result from crawling out of windows in multistoried buildings, health department initiated programs and regulations helped reduce such fatal falls of children from about 50 per year in the 1960s (Bergner, Mayer, and Harris, 1971) to about 4 per year in the 1980s (Bergner, 1982).

Numerous interventions to reduce the incidence and severity of injury have been identified (e.g., Haddon, 1970; Dietz and Baker, 1974; Robertson, 1983; Baker, O'Neill and Karpf, 1984; Waller, 1985), but many have yet to be implemented. Delay in the application of interventions known to be effective has a long history. In the 19th century, railroad workers had a very high injury mortality rate because of dependence on time tables to avoid the collision of trains on the same track, lack of uniform braking of all cars, and use of flexible chains to join cars. Despite the availability of automatic signaling systems, automatic braking systems, and automatic coupling systems in the 1870s (Adams,

1879), most railroads did not adopt the technology until it was required by Congress near the turn of the century (Robertson, 1983). Fatalities per thousand rail workers were reduced 80 percent from 1890 to 1920 (Swain, 1980).

In recent years, argument over the cost of applying interventions has been a major factor in delay of implementation. Determination of the net savings to society if any one intervention were implemented depends on estimates of level of incidence reduced, the cost of injury severity reduced, the estimated cost of implementing or increasing the intervention, and the extent to which the intervention would be applied. Unfortunately, for most interventions that have been suggested or implemented to some degree, data on all these elements are unavailable.

Savings Estimation Method

The current review of the literature on injury control interventions suggests that, most often, the cost of the intervention is not known or reported. Researchers who evaluate the effects of interventions seldom include cost estimates of the interventions.

It is also difficult to find data on the extent of implementation of many interventions. For example, a controlled experiment in which parents in an experimental group were counseled regarding infant falls from tables, beds, etc. suggests that these falls can be reduced about 41 percent by physician warnings and counseling (Kravitz, 1973). To estimate the savings that could be realized' from expanding such counseling, however, data is needed on the current extent of counseling by physicians. No survey of physicians to determine the extent of such counseling and its cost is known.

The following data are necessary to calculate savings:

- a. Number of injuries of given severity to which an intervention applies;
- b. Cost of injuries by severity;
- c. Proportion of each severity level reduced by the intervention;
- d. Reduced costs = Sum of $a_i \times b_i \times c_i$ where i = each severity level;
- e. Cost of applying or incrementing the intervention; and
- f. Net savings = d - e.

It should be noted that this is not cost-benefit analysis. Certain costs and benefits that are not translatable into dollars are not included. On the cost side, for example, some interventions include alteration in transportation of teenage children that changes the daily routine of

families. On the benefit side, for example, the human capital approach does not include reduced pain and suffering, and on the cost side, substitution of economic productivity with caregiving by family members. The willingness-to-pay approach includes the assumptions that people perceive risks accurately and evaluate them in economic terms. Even were the latter true, the public's assessment of many risks is at variance with reality (Slovic, Fischhoff, and Lichtenstein, 1987). Nevertheless, with assumptions explicit, application of a particular method to a variety of interventions sheds light on the relative merits of the interventions in economic terms.

Table 27 presents savings estimated for several interventions by the human capital and willingness-to-pay methods, separately, using data from Chapters 2 and 4. Although some of the uncertainties and ranges of estimates are discussed in this chapter, the literature cited should be consulted for a more complete view of the strengths and limitations of the studies relative to their use here. More detail on the methodology is found in Appendix B.

Table 27
Estimated Cost and Savings of Interventions
to Reduce Injury and Severity

Intervention	Cost (millions)			Savings (millions)	
	Willing-			Willing-	
	Human Capital	ness to Pay	Program	Human Capital	ness to Pay
Child pedestrian injury campaign	\$112	\$234	\$54	\$58	\$180
Bicycle helmet promotion	255	356	72	183	284
Driver education elimination	-700 *	-2,067 +	-163 *	863 **	2,230 **
License age 17	1,446	4,267	0	1,446 **	4,267 **
Motorcycle helmet use laws	393	1,500	296	97	1,200
Reduced ignition of cigarette paper	187	1,100	0	187 **	1,100 **
Air bags	8,650	23,491	4,000	4,650	19,491
Side crash protection	916	3,529	2,000	0	1,529
Automatic vehicle lights	391	1,154	620	0 **	534 **

* Represents reduced cost

** Excludes savings in property damage

Implementation Strategies

Implementation strategies can be categorized into four general approaches:

- Persuade individuals to reduce risky behavior or protect themselves and others;
- Require that people refrain from risky behaviors or increase protection by administrative rule or law;
- Change vehicles or environments to increase automatic protection (that is, the individual at immediate risk does not have to be changed to be protected); and
- Improve post-injury emergency and rehabilitative treatment services.

Generally, automatic protection is most successful and persuasion least successful, particularly if the persons at risk must take very frequent action for protection, such as the use of child restraints and safety belts in cars (Robertson, 1975). There seems to be a preference for education and other behavior-change approaches without resort to law, probably because they are thought to be less controversial or less costly, but such assumptions are subject to challenge by research. Laws may reduce risk if sufficiently enforced, but several nonlegal factors are related to both compliance with law and degree of enforcement (Robertson, 1983). The success of automatic approaches requires technical competence in design and quality control in implementation, after political, social, and economic barriers are overcome.

Persuaded Behavior Change

The research on three attempts at behavior change by persuasion is complete enough to allow a savings estimate – a campaign against child-pedestrian injuries tested in three cities, a bicycle helmet promotion tested on a large scale in Australia, and high school driver education, which has been the subject of numerous studies.

Campaign Against Child-Pedestrian Injuries

Based on research regarding child ‘dart-out’ behavior resulting in pedestrian injuries, a campaign using an animated character, “Willy Whistle,” in schools and on television was studied in three cities. The researchers estimate a 20 percent reduction in dart-out injuries to pedestrians under age 15 and a 12 percent reduction in all child-pedestrian injuries. The one-time developmental and research cost of the campaign was \$472,000. The success of the campaign is dependent on

use in school classrooms and on television. The television time (e.g., 380 showings in Los Angeles valued at \$150,000) was contributed by local stations as a public service (Blomberg, Preusser, Hale, and Leaf, 1983).

Apparently only Miami, Florida has used the program consistently. The Miami schools spend \$95,000 per year to implement the program in 135 elementary schools, about \$704 per school. If that cost is generalizable to the 76,000 elementary schools in the U.S., the annual cost of full implementation would be about \$53.5 million per year, excluding any contributed television time. Limiting the use of the program to schools in neighborhoods that have a history of child-pedestrian injuries would reduce the cost. Since the effect of the program used only in schools without any television may be less than in the original experiment, the savings may be less with only school use.

There were 978 deaths to pedestrians under age 14 in 1985. Using ratios of deaths and hospitalizations to incidence of medically treated child-pedestrian injuries from a large regional study (Barancik, Chatterjee, Greene-Cradden, et al., 1986), investigators estimate the medically treated incidence and hospital admissions per fatality. A 12 percent reduction in child-pedestrian injuries would result in about 117 fewer fatal injuries, 1,413 fewer hospitalizations, and 2,289 fewer medically treated and released cases.

The cost of these injuries in human capital terms would be about \$112 million, and by willingness-to-pay estimates, \$234 million for fatal injuries alone. The human capital savings exceed the estimated cost of the program by about \$58 million. Savings employing willingness-to-pay estimates less the cost of the program, would be about \$180 million. The latter approach excludes nonfatal cases, for which the cost was not comparably calculated.

A film entitled "And Keep on Looking," dealing with a wider range of child-pedestrian situations for 9-12 year olds, has been field tested and a 20 percent reduction in injuries estimated (Pruesser and Lund, 1988). A videotape combining the "Willy Whistle" and the new film is being considered for distribution to urban and suburban schools by the National Highway Traffic Safety Administration. If these tapes are used, they may provide substantial results at less cost per school than the Miami program, but the cost per school has not been established.

Bicycle Helmet Promotion

Head injuries to bicyclists can be reduced substantially by helmet use (Thompson, Rivara, and Thompson, 1989). A promotional campaign to increase use of bicycle helmets in Victoria, Australia during 1982-85 resulted in a 20 percent reduction in head injury to bicyclists (Wood and Milne, 1988). The campaign included:

- 1,000 helmets sold through the schools at two-thirds retail cost;
- Required helmet wearing while cycling in school activities;
- Poster distribution to all schools, physicians, and helmet retail outlets;
- Distribution of promotional materials to cycling clubs;
- A television and radio campaign that cost \$A160,000 (Australian dollars); and
- Government rebates of \$A225,000 to purchasers of about 25,000 helmets.

Although the total cost of this effort is not calculable, a reasonable estimate of the program cost, given the identified cost, is \$A500,000. The cost to consumers of helmet purchases must be added to that amount. The helmets known to have been sold through the rebate program cost consumers about \$A900,000 after subtracting the rebates. The total cost, not counting unrebated helmet purchases, was about \$A1.4 million in a population of 3.9 million. To implement the program in the U.S. population of about 245 million, converting Australian dollars to U.S. dollars at the 1985 conversion rate, 1.208, would cost about \$72 million, assuming comparable rates of bicycle use.

The total incidence and severity of head injuries to bicyclists is unknown. Head injuries have ranged from 49 percent to 67 percent of hospital admissions of bicyclists in three studies (summarized in Friede, Azzara, Gallagher, and Guyer, 1985). Assuming that these estimates are reasonably accurate, and applying the ratios of hospitalizations and deaths to incidence from a large regional study (Barancik et al., 1986), a 20 percent reduction in bicyclist head injuries would result in 178 fewer fatalities, 2,463 fewer hospitalized injuries, and 16,602 fewer injuries treated and released. Deducting the \$72 million cost of the program, the savings of the Australian bicycle helmet program in the U.S. would be about \$183 million in human capital terms or at least \$284 million by willingness-to-pay estimates. The latter estimate is for fatality reduction alone since the nonfatal injury cost was not calculated in a way usable here. The validity of these estimates depends on the extent to which cultural differences affect public acceptance of such programs and on the extent to which the direct conversion of Australian and U.S. dollars distorts differential effects of incentives in countries with different wage structures.

Driver Education

One of the most widespread attempts to educate people to reduce injury by altering behavior is driver education in the public schools. According to the latest survey (1982-83), 998,363 students were enrolled. Costs per pupil varied widely among the states, but the median was \$163 (National Safety Council, 1985). Therefore, high school driver education cost approximately \$162.7 million in that year, not counting time diverted from academic subjects. The 1985 cost was probably not very different from the 1982-83 cost since any decline in numbers taking the course in the two years after the most recent survey would be at least partly offset by inflation in cost per pupil.

Unfortunately, the scientific evidence indicates that expenditures on driver education in the public schools had an adverse rather than an ameliorative effect on injury rates. Although carefully controlled experiments find that driver education has little or no effect on individual risk in the aggregate (Shaoul, 1975; Lund, Williams, and Zador, 1986), it results in a large increase in licensure in an age group that has a very high crash rate (Shaoul, 1975). An increase of 8 licensed 16- and 17-year-olds per 10 students was found in a 27-state study (Robertson and Zador, 1978). In Connecticut, when driver education was eliminated from the public schools in nine school districts, there was a 75 percent decline in licensure of 16 and 17-year-old drivers of those taking high school driver education compared to comparable districts that retained the course (Robertson, 1980).

A 75 percent reduction in licensure of the 998,363 students enrolled nationally in 1982-83 would reduce the number of fatal crashes by about 595 per year based on the national rate of 7.95 fatal crashes per 10,000 licensed drivers aged 16-17. There were 1.64 deaths per fatal crash of 16-year-old drivers, so about 976 deaths can be attributed to early licensure due to driver education.

Since 16-year-old drivers have a fatal crash rate per mile about 11.4 times that of drivers aged 35-39 (Robertson, 1983), near the average age of their parents, there would be about 91 percent fewer deaths if parents drove their children the same number of miles that the children drive themselves. Therefore, adjusted for substitution of parental driving, the reduction from eliminating driver education would be approximately $0.91 \times .75 \times 976$ or 666 deaths per year. If the distribution of nonfatal injury severity relative to deaths is similar to the distribution for all crashes, severity of injuries reduced would be distributed by the Abbreviation Injury Scale (AIS) as follows: AIS 1 - 69,657, AIS 2 - 5,974, AIS 3 - 1,325, AIS 4 - 213, AIS 5 - 71, fatal - 666.

The estimated savings of crash injuries prevented would be approximately \$700 million in human capital terms or \$2.1 billion by willingness-to-pay estimates had there been no driver education in public schools. Adding the savings from eliminating the program, the total savings would be about \$863 million per year in human capital terms or \$2.2 billion by willingness-to-pay estimates, not counting property damage.

Laws Addressing Individual Behavior

Estimates of savings from the effects of laws on individual behavior are not possible for many laws because the cost of enforcement is unknown. Estimates are attempted below for two cases -- legal driving age and motorcycle helmet use, for which the cost of enforcement is considered to be minimal.

Legal Driving Age

Driver education would have no adverse effect if the legal minimum driving age were raised to 18 (Robertson and Zador, 1978). Since no state has a minimum licensing age of 18, the exact effect of such a policy cannot be estimated. Research comparing fatal crash involvement of 16-year-old drivers in New Jersey with a licensing age of 17 (except for an agricultural license at age 16) and Connecticut with a licensing age of 16 indicates that about a 65-85 percent reduction in fatalities involving 16-year-old drivers would ensue from a minimum licensing age of 17 (Williams, Karpf, and Zador, 1983). Although the study found that the fatal crash rate involving 17-year-old drivers in New Jersey was slightly higher than in Connecticut, the fatal crash rate of drivers in the combined 17-29 age group was comparable among the states. Also, there were no offsetting rates of 16-year-olds killed as pedestrians or bicyclists.

In 1985, 2,014 people in the United States were killed in crashes involving 16-year-old drivers. Applying the same adjustments for parent substitution for 16-year-old drivers as in the case of driver education, about 1,375 deaths ($0.91 \times 0.75 \times 2,014$) would have been avoided if the legal driving age had been 17 in 1985. Assuming that the ratio of nonfatal to fatal injury distribution when these drivers are involved is similar to that for drivers in all age groups, the reduction in injury distribution of a 75 percent decrease in crashes by drivers less than 17 years old would be approximately as follows: AIS 1 - 143,808, AIS 2 - 12,344, AIS 3 - 2,736, AIS 4 - 440, AIS 5 - 146, fatal - 1,375. Since it is unlikely that every trip of a 16-year-old driver would be substituted by a parent or other adult, this is a conservative estimate.

A total savings of \$1.4 billion in human capital terms or \$4.3 billion by willingness-to-pay estimates would result from a minimum licensing

age of 17. This does not account for time spent by parents or others transporting teenagers under age 17 or the savings in property damage. A survey of teenagers in Michigan, New Jersey, and New York, with very different rates of licensure, found very little effect of licensure on lifestyle. The increase in percent of teenagers with jobs, comparing employment at age 15 and 16, was highest in New Jersey, where licensure at 16 was prohibited except in agriculture (Preusser, Williams, and Lund, 1985).

Law enforcement expenditure would probably not have to be increased much, if any, to achieve the reduction. Most law enforcement would be achieved by parents who are unlikely to allow unlicensed drivers to use family vehicles.

Motorcyclist Helmet Use Laws

Laws requiring motorcyclists to use helmets reduce motorcyclist deaths by about 24-30 percent (Robertson, 1976; Watson, Zador, and Wilks, 1980; Hartunian, Smart, Willemain, and Zador, 1983). Data on nonfatal head injuries are sparse, but one study indicates that the increase in such injuries after repeal of a helmet law paralleled the increase in deaths (McSwain and Lummis, 1980). The nonfatal head injury to death ratio was 3:1.

The number of motorcyclist fatalities in states without helmet laws in 1985 was 2,714. Therefore, based on a 24 percent reduction from the law, it is estimated that 651 fewer deaths and 1,953 fewer head injuries would have occurred had these states had helmet use laws. The reduction in injuries and deaths multiplied times their cost, results in an estimated cost reduction of \$393 million in human capital terms or \$1.5 billion by willingness-to-pay estimates.

Such a reduction is particularly significant because it would disproportionately reduce public expenditures. A detailed analysis of the cost of treatment and rehabilitative care of motorcyclists in a major trauma center found that 63 percent of the costs were borne by the taxpayers, mainly through Medicaid (Rivara, Dicker, Bergman, Dacey, and Herman, 1988). This is in contrast to all motor vehicle injuries, for which about 19 percent of treatment and rehabilitative costs are paid by Medicare and Medicaid (U.S. National Highway Traffic Safety Administration, 1983).

Helmet use rates in states without laws range from 42 to 59 percent (Williams, Ginsburg, and Burchman, 1979). Assuming that about 50 percent of the owners of registered motorcycles in the states without laws would have to purchase a helmet, the cost of the helmets would be approximately \$296 million (based on a median price per helmet of \$170 in 1989, although some were available for less than \$100). Assuming that

the helmet would be used in subsequent years, the annualized cost would be a fraction of that amount. Since virtually all motorcyclists use helmets in states where there are laws, the increment in law enforcement cost is considered nil. Therefore, if motorcyclist helmet use were required in states without such laws, the savings, subtracting the cost of the helmets, would be about \$97 million in human capital terms or \$1.2 billion by willingness-to-pay estimates in the first year. Savings would increase in subsequent years because helmets would not have to be repurchased each year by most riders.

An earlier analysis of the net human capital losses from motorcycle helmet repeal, using more detailed age distributions but a lower estimate of helmet costs, put the net cost of repeal of helmet laws at \$160 million in 1980 (Hartunian et al., 1983).

Product Design and Environmental Changes

Numerous potential changes in product design and environments have been studied. For many, the cost and effectiveness varies by degree since various levels of protection are possible. The examples below -- cigarette design; automobile air bags, side crash protection, and automatic lights and head restraints; and offshore drilling equipment -- are analyzed briefly at one specified level of protection each.

Reduced Ignition Potential of Cigarettes

The most frequent cause of housefires is a cigarette dropped on bedding or upholstered furniture where it smolders and later produces a killing smoke or fire, often after occupants of the household are asleep. In response to The Cigarette Safety Act of 1984, a Technical Study Group on Cigarette and Little Cigar Safety produced a report on the feasibility and the cost of modifying cigarette design to reduce the likelihood of ignition by dropped cigarettes (Technical Study Group, 1987).

Experimental cigarettes manufactured on equipment now used by the industry were tested on fabric, standardized as to padding and geometry. The numbers of ignitions in 20 tests varied from 0 to 20 for cigarettes with 41 combinations of type of tobacco, tobacco density, paper porosity, citrate added, circumference, and second paper wrapping. Lower ignitions were associated with low tobacco density, lower circumference, lower paper porosity, and no citrate added.

Subsequent tests on commercially available furniture with fabric and substrate similar to the standardized mockup produced an exceptionally strong correlation ($r=0.86$) to results with the mockup. Although the Technical Study Group cautiously called for more work to establish performance criteria, the results of these studies indicate that

reliable tests of cigarettes for potential ignition are feasible and standards for cigarette manufacture could be based on performance in such tests.

Various costs and savings related to the modification of identified characteristics of cigarettes were estimated by a group at the National Bureau of Standards for the Technical Study Group (Ruegg, Weber, Lippiatt, and Fuller, 1987). A combination of modifications to cigarettes could achieve up to a 75 percent reduction in cigarette-related fire injuries, but several would result in increased cost of manufacture and lost revenues to farmers and in taxes. Reduced paper porosity, a modification that was assumed to generate no cost, produced a 30 percent reduction in ignitions. A 30 percent reduction in cigarette-ignited fires in 1985 would have avoided about 450 deaths and 2,100 injuries as well as millions of dollars in property damage. The cost of these deaths and injuries is estimated to be \$187 million in human capital terms or \$1.1 billion by willingness-to-pay estimates (excluding reduced property damage cost).

Air Bags

After 20 years of regulatory battles and court decisions, a federal standard now specifies limits for forces on the head, chest, and legs in frontal crashes of automobiles at 30 miles per hour into a barrier. The standard is being phased in during the 1987-1990 model years. Manufacturers have indicated that, to comply with the standard, some vehicles will have driver-side airbags and safety belts in the right-front seat. Others will have the automatic safety belts in driver and right-front passenger positions. Automatic safety belts vary in effectiveness depending on design and ease of detachability (Graham and Henrion, 1988; O'Neill, 1988).

Estimates of the effect and cost of various forms of compliance with an automatic restraint standard have been the subject of controversy for two decades. The official regulatory analysis indicates fatality reductions of 40-50 percent for fully used lap-shoulder belts, 35-50 percent for fully used automatic belts, and 45-55 percent for air bags with full lap shoulder belt use (U.S. National Highway Traffic Safety Administration, 1984). Since full belt use will not be accomplished, even with belt use laws and automatic belts, the actual effectiveness depends on projections of belt use generally and particularly among people at high risk. The effect on fatalities of increased use as the result of safety belt use laws is not nearly as high as predicted by estimated effectiveness of belts (Williams and Lund, 1988).

Eventually, as the relative effectiveness of the various technologies in actual use becomes known, the use of air bags will likely increase. Use of full front-seat air bags, assuming no belt use, is estimated to reduce

deaths by about 6,190 (range -- 3,780-8,630); AIS 1 injuries, by about 255,770 (no range indicated); and AIS 2-5 injuries, by about 110,360 (range -- 73,660-147,560) (U.S. NHTSA, 1984). Since the midpoint of the range is the best estimate, it is used to estimate savings of approximately \$8.7 billion in human capital terms or \$23.5 billion by willingness-to-pay estimates.

Increased belt use would reduce these estimates to the extent that there is overlap in the injuries reduced by air bags and those reduced by belts. Belt use laws have increased belt use from 10-20 percent to 40-60 percent with an accompanying reduction in deaths of 5-15 percent (Williams and Lund, 1988). Some of that reduction is in side crashes and ejections that would not overlap with the effect of airbags.

Since about 10 percent of the U.S. fleet is replaced with new vehicles each year, the savings from a modification of vehicles over their average lo-year use is about the same as the cost of injuries in a given year minus the cost of modifying a cohort of new vehicles of a given model year. The charges for air bags by manufacturers have varied from \$300 per car for full-front-seat air bags as an option by General Motors in the mid 1970s to \$800 per car for driver-side air bags in certain recent models of several manufacturers. Like all vehicle components, the cost per unit is greatly reduced as a function of the number manufactured. The National Highway Traffic Safety Administration estimated \$364 per car for full-front air bags, including lifetime energy costs of the added weight of the vehicle (U.S. NHTSA, 1984). Multiplied times the number of new cars sold in 1985 (11.04 million), the cost of full-front air bags on all cars would be about \$4 billion. Thus, subtracting the cost of the air bags, full-front airbags in each model year would save about \$4.7 billion in human capital terms or more than \$19.5 billion by willingness-to-pay estimates.

Side Crash Protection

The National Highway Traffic Safety Administration is presently receiving comments on a proposed rule to increase protection to occupants of passenger cars hit from the side, which accounted for 32 percent of car occupant fatalities in 1985 (U.S. NHTSA, 1988d). The NHTSA analysis presents effects and costs of various degrees of protection. At the highest level of proposed protection, estimated injury reduction would be approximately: AIS 3-5 - 4,735, fatal - 1,200.

Since NHTSA did not estimate any benefits for reduction in AIS 1 and AIS 2 injuries, the savings of \$916 million in human capital terms or \$3.5 billion by willingness-to-pay estimates are conservative. The 'worst case' cost estimate of the proposed side protection is \$185 per car, including lifetime fuel costs, or a total cost, if applied to new cars sold in

1985, of about \$2 billion. Therefore, while it seems there would be no net savings in human capital terms at that level of protection, the savings by willingness-to-pay estimates, less the cost of increased side protection at the specified level, would be approximately \$1.5 billion.

Automatic Vehicle Lights

Increased conspicuity of motor vehicles has been found an important factor in multiple-vehicle crash rates. Evaluations of the effects of the daytime use of headlamps, parking lamps, or redesigned systems have produced estimates of reductions in daytime, multiple-vehicle crashes of 7-38 percent (Stein, 1985). Sweden experienced a 11-13 percent reduction in such crashes when daytime headlamp use was required by law, despite the fact that 50 percent of drivers were using headlamps in daytime before the law (Transport Canada, 1986).

While crash reductions can be largely accomplished by requiring the driver to turn the lights on by law as was done in Sweden, there is substantial potential for adverse reaction from people whose batteries die when they forget to turn the lights off at the end of a trip. An automatic relay that turns the lights off when the ignition is turned off would alleviate this problem.

Although the current use of headlamps in daylight in the U.S. is unknown, it is unlikely to exceed 5 percent. Therefore, even considering the differences in weather and hours of daylight year-round between Sweden and the United States, the 11-13 percent reduction in crashes in Sweden, given a 50 percent prelaw headlamp use, seems a minimum to expect from automatic use were such a policy adopted in the United States.

Assuming that the nonfatal severity to death ratio in daytime multiple-vehicle crashes is similar to all crashes, a 12 percent reduction in daytime multiple-vehicle collisions in 1985 would reduce injuries approximately as follows: AIS 1 - 38,907, AIS 2 - 3,337, AIS 3 - 740, AIS 4 - 119, AIS 5 - 40, fatal - 372. This amounts to \$391 million in human capital terms or \$1.2 billion by willingness-to-pay estimates, excluding property damage and pedestrian injuries that might be avoided by greater vehicle conspicuity.

Transport Canada estimates the lifetime cost per vehicle of automatic reduced intensity highbeams at \$40 for cars and light trucks, including increased fuel use. Applied to the 15.5 million cars, light trucks, and vans sold in 1985, the lifetime cost of the lights would be about \$620 million. Since the lifetime use of a given model year is about equal to that of the full fleet in one year, automatic lights on all new vehicles in a given model year, if only 12 percent effective, would produce no savings in human capital terms but would save about \$534

