UM-HSRI-80-28

THE ECONOMIC COST OF NONUSE OF OCCUPANT RESTRAINTS IN THE UNITED STATES: A PRELIMINARY ANALYSIS

Ralph K. Jones
Rex L. Franson
Kent B. Joscelyn

June 1980

The University of Michigan
Highway Safety Research Institute
Ann Arbor, Michigan 48109

ACKNOWLEDGMENT

Several of our colleagues at the Motor Vehicle Manufacturers Association (MVMA) and the Highway Safety Research Institute (HSRI) reviewed draft versions of this report and provided many useful suggestions. We are especially grateful to Mr. Nils Lofgren of MVMA and Dr. Robert Hess, Mr. James O'Day, and Mr. James Haney of HSRI for their comments.

SUMMARY

Preliminary estimates of the costs of nonuse of occupant restraints were developed as a result of the first phase of a two-phase effort. Using published injury and cost data, it was found that such costs are significant. The costs amount to some $500 in "direct" costs for every outboard front seat occupant who does not wear a lap-and-shoulder restraint in a passenger car that is damaged so severely that it must be towed from the scene of the crash. "Societal" costs (including the direct costs) are about $2,500 for each such occupant.

Summing these costs across all such occupants in all such crashes nationwide results in a total direct cost of about $1.6 billion per year and a total societal cost of about $8.4 billion per year. We view these estimates as conservative. Inclusion of other types of vehicles, crashes, and occupants in the calculations would also increase costs--probably by thirty percent or more. An estimate of $15 billion per year as the upper range of economic costs of nonuse of occupant restraints is a reasonable order-of-magnitude approximation.

The question of who pays these costs has not been adequately addressed in past studies. The implication of the studies on direct costs is that the crash victim or his family pay, but the manner in which such costs may be transferred to other sectors (for example, government) has not been analyzed. Similarly, studies identify "society" as the payor of the societal costs, but the specific sectors of society that bear given components of cost are not stated.

Two topics are singled out for emphasis during the second phase of this study. First, data will be collected for use in identifying sectors that bear significant portions of the cost of not using occupant restraints. Several past crashes will be examined to identify cost categories and who paid the costs in those categories. The second topic will be the continued examination of injury severity data. Existing data bases will be studied to see if presently available distributions of injury severity can be improved and/or extended to other populations (for example, small trucks and vans).

CONTENTS

1.0 INTRODUCTION

Almost all motor vehicles now in use on the nation's highways are equipped with some form of active occupant restraint. Use of these available occupant restraints can reduce injury and consequent economic losses for people involved in traffic crashes. While the safety benefit of occupant restraint use is well established, use rates remain low. The objective of this study is to examine the nature and estimated amount of economic costs resulting from the nonuse of occupant restraints, and to develop information that will support programs to increase their use.

The study is being conducted by the Policy Analysis Division of The University of Michigan Highway Safety Research Institute (HSRI). Funding for the study has been provided by an unrestricted gift by the Motor Vehicle Manufacturers Association.

The report is preliminary in nature. Interim findings are presented and future directions for the study are identified. The methods of analysis used and to be used are described. We recognize that the study topic is of interest to the highway safety community. We hope that by sharing our preliminary findings that comment can be obtained from colleagues and that others examining the topic will join with us in using common methodological approaches so that comparative data can be developed. Past studies have used different terminology, different data, different methods of analysis, and, not surprisingly, are difficult to compare.

The topic is large. No one study can hope to be definitive. Greater commonality in approaches will allow the topic to be addressed more rapidly and more definitively. Because of this, in our study we have emphasized the development of methods and specification of terminology. In later phases of the study, similar attention will be given to identifying data requirements and data collection methods. We seek comment and will welcome the opportunity to talk with other researchers and practitioners interested in the subject.

1.1 Objectives

The general objective of this report is to develop a preliminary estimate of the economic costs of not using occupant restraints. Specific objectives are to:

- specify an approach for analyzing the costs of traffic crash injuries due to the nonuse of restraints,
- develop data requirements for making cost estimates,
- identify currently available data from the published literature,
- develop preliminary cost estimates, and
- identify the research required to develop more detailed cost estimates.

1.2 Scope and Approach

The study has been divided into two phases. In the first phase, reported here, the focus was on the identification and evaluation of existing data and research approaches as found in the published literature. The most attention was given to the literature that directly addressed the topic. Indirect sources (e.g., relevant economic literature, trauma research findings) were cursorily examined as data requirements developed. Similarly, limited contacts were made with practitioners and researchers who had interest in the topic. In the second phase of the study, as data requirements are established in greater detail, the literature search will be broadened and more extensive contacts will be made to collect data.

The preliminary cost estimates presented in this report are the "global" costs of injuries resulting from nonuse of occupant restraints. The costs are those generated by entire populations of drivers in the vast variety of crash situations. The aim was to develop an estimate of the cost of nonuse of occupant restraints for the mythical "average" crash-involved occupant. This estimate is then used to obtain an order-of-magnitude estimate of the costs of nonuse nationwide. All identifiable, significant components of economic costs were sought, including both direct and indirect costs.

As our approach did not rely on disaggregate data, no attempt was made to build up the costs from basic data on trauma, hospitalization costs, disability costs, etc. Similarly, no attempt has been made to disaggregate the costs by specific subpopulations of occupants (e.g., older persons) in specific crash situations (e.g., rollover crashes). Data are not readily available to allow disaggregation.

A major concern has been to identify who pays the costs. We speculated that the present literature would not contain data that would support statements about who bears the ultimate costs. Regretably, we must report that our initial hypothesis appears to be correct. Thus, later phases of this study will address the question by specifying data requirements, identifying collection and analysis approaches, and to the extent funding permits—data collection and analysis will be undertaken.

We hope to be able to provide some insights on the question of who pays. More work will be required to develop definitive estimates and to refine the estimates so that they are applicable to specific subpopulations. We encourage other sponsors and researchers to also undertake such research. We note that conduct of such inquiry has been recommended by the National Academy of Sciences in a recent report to Congress (Transportation Research Board 1980).

1.3 Report Organization

Our analysis is presented in four parts. First, past methods are examined and classified. A basic approach is identified and the top-level variables needed for analysis are specified (Section 2.0). Next, past studies of these variables and their use in cost analysis are examined to determine their applicability to this study (Section 3.0). Values of these variables most appropriate to this study are then identified and are used in developing our preliminary cost estimates (Section 4.0). Conclusions and recommendations are presented in Section 5.0.

2.0 MODELS FOR ESTIMATING THE EFFECTIVENESS OF OCCUPANT RESTRAINTS

This section presents and discusses two fundamentally different models for estimating the effectiveness of occupant restraints. The first model uses reduction in injury severity as a measure of effectiveness, while the second model uses reduction in economic cost as a measure. The models have been widely used either implicitly or explicitly in past studies. The purpose of the discussion is to identify the top-level variables that are germane to this analysis, to place them in the context of prior studies, and to show how they interact to create applicable costs.

Only the cost reduction model can be used for cost analyses. The injury severity model is presented to provide background and perspective for understanding this cost model.

2.1 Reduction in Injury Severity

Most studies of the benefits of occupant restraints have used reduction in injury severity as a general measure of effectiveness. However, the studies differ widely in their specific definitions of this measure. They also differ in their use of accident data in developing values of the measure. Surprisingly, few studies make any explicit or rigorous statement of their measure of effectiveness at all, leaving it to the readers to develop their own statement from discussions and presentations in a research report.

The general measure of effectiveness used in such studies is either explicitly or implicitly of the form:

$$E = \frac{P_{\bar{R}} - P_R}{P_{\bar{R}}} = 1 - \frac{P_R}{P_{\bar{R}}} \qquad (2\text{-}1)$$

where

$P_{\bar{R}}$ = the probability that an occupant of a vehicle will sustain an injury of specified severity, given that the vehicle is involved in a crash and the occupant is not wearing a restraint.

P_R = the probability that an occupant of a vehicle will sustain an injury of specified severity given that the vehicle is involved in a crash and the occupant is wearing a restraint.

Studies vary considerably with respect to the specified severity considered. Some are concerned with a discrete level of severity, for example, fatal injuries (U.S. Department of Transportation 1979b; Huelke and O'Day 1979). Others deal with a range of severities, for example, all "serious" injuries (Huelke et al. 1979; Dalmotas and Keyl 1979).

For equation 2-1 to be a valid measure of the effect of restraint use on injury reduction, the two probabilities must be computed from crashes that are exactly the same in every respect, except that for P_R the occupants wore a restraint and for $P_{\bar{R}}$ the occupants did not wear a restraint. Otherwise it could not be said that any difference in the two probabilities was likely to be due to the restraint. Some studies (especially earlier ones) have not been careful in controlling for other variables that might influence P_R and $P_{\bar{R}}$. Other studies do not fully describe how such variables were accounted for, so the validity of their conclusions about the effects of restraints cannot be assessed. Studies by Reinfurt, Silva, and Seila (1976) and by Hochberg (1976) are examples of studies that took great care in attempting to account for such confounding effects as age, sex, type of car, damage severity, and others.

Other measures of restraint effectiveness can be defined, but have rarely been used in past studies. For example, Hochberg (1976) suggests two possible additional measures:

- the probability that a restrained occupant will be less severely injured than an unrestrained occupant, and
- the ratio (restrained/unrestrained) of the odds of an injury severity of less than a given amount to the odds of an injury severity of at least as severe as a given value.

A third measure suggested by Hochberg (and often used in analyzing the effects of other factors on traffic crashes) is relative risk. This is simply the ratio of P_R to $P_{\bar{R}}$ as used in equation 2-1.

2.2 Reduction in Economic Cost of Injury

This measure of effectiveness has been used in only a few studies, most recently by Reinfurt, Silva, and Seila (1976) in their analysis of towaway crashes. The general expression for this measure is:

$$E = \frac{C_{\bar{R}} - C_R}{C_{\bar{R}}} = 1 - \frac{C_R}{C_{\bar{R}}} \qquad (2\text{-}2)$$

where

C_R = cost of injuries when crash-involved occupants wear restraints, and

$C_{\bar{R}}$ = cost of injuries when crash-involved occupants do not wear restraints.

The term "cost" as used here is defined as the expected economic cost to a specified sector of a specified level of injury caused by traffic crashes during a specified time period. Again, it is assumed that the crashes involving the restrained occupants are exactly the same as the crashes involving the nonrestrained occupants, except for the use or nonuse of the restraints.

Clearly, then, this measure of effectiveness is dependent upon:

- The level or levels of injury severity of concern.
- The distribution of injury severity level(s) among the target population of occupants wearing and not wearing restraints.
- The number of crash-involved occupants wearing restraints and the number of crash-involved occupants not wearing restraints.
- The time period during which the crashes occur.
- The types and characteristics of crashes of concern (for example, highway environment, types of vehicles, types of drivers, direction of impact, etc.).
- The nature of the sectors that bear the costs of concern

(for example, occupants, occupants' families, employers, government agencies).

- The costs to those sectors of an injury of the severity level(s) of concern.

For discrete distributions of injury severity, the relationships between these factors can be expressed mathematically as:

$$E_k = 1 - \frac{C_{R_k}}{C_{\bar{R}_k}} \qquad (2\text{-}3)$$

$$C_{R_k} = N_R \sum_i \sum_j C_{ijk} P_R(i) \qquad (2\text{-}4)$$

$$C_{\bar{R}_k} = N_{\bar{R}} \sum_i \sum_j C_{ijk} P_{\bar{R}}(i) \qquad (2\text{-}5)$$

where

$P_R(i)$ = $\Pr\{i \mid A, \vec{x}, \bar{R}\}$

= the conditional probability of an injury of severity i to an occupant, given a crash A **and** a set of factors $\vec{x}$ **and** that the occupant is wearing a restraint.

$P_{\bar{R}}(i)$ = $\Pr\{i \mid A, \vec{x}, R\}$

= the conditional probability of an injury of severity i to an occupant, given a crash A **and** a set of factors $\vec{x}$ **and** that the occupant is not wearing a restraint.

N_R = the number of restrained occupants involved in crashes with factors $\vec{x}$ in time T

$N_{\bar{R}}$ = the number of unrestrained occupants involved in crashes with factors $\vec{x}$ in time T

C_{ijk} = the cost to sector k of the j^{th} component of cost of an injury of severity i incurred in a crash with factors $\vec{x}$

E_k = the effectiveness of restraints in reducing crash injury costs to sector k in crashes with factors $\vec{x}$.

Note that the vector $\vec{x}$ contains a subset of factors that describe the subject occupants (restrained and unrestrained).

To calculate E_k (and its primary components C_{R_K} and $C_{\bar{R}_K}$) one needs the data specified above. Unfortunately, these data can only be approximated since no practical experiment can completely control for all of the factors $\vec{x}$. Also, the cost factors C_{ijk} and the number of restrained and unrestrained occupants in crashes must be determined empirically from a wide variety of sources, including claims against insurance companies, accident reports, etc.

Thus, any real-world application of this cost model will only yield approximate values of the effect of occupant restraints on the economic cost of injuries sustained in traffic crashes. Also, the level of detail at which the costs of nonuse can be expressed will depend on the level of detail of the data used to calculate values of the independent variables in equations 2-4 and 2-5.

The cost elements C_{ijk} are explicitly related to the sector that pays the cost. This means that the value of a given cost element depends not only on the severity of the injury, but also on the sector that pays a given component of the cost of that injury. For example, the value of the element C_{321} might be defined as the **hospitalization** cost (j=2) for a **severe injury** (i=3) paid by the **injured party** (k=l). The cost of hospitalization for a severe injury paid by, say, an **employer** (k=2) would be denoted in this case by C_{322} and could have an entirely different value.

This distinction is critical to this study. It means that, as used here, a cost is not invariant but depends on the reference frame within which it is measured. It will be seen in Sections 3.0 and 4.0 that a major problem with existing cost analyses is that they do not specify this reference frame and, indeed, often mix reference frames implicitly within the same analysis. This severely limits the usefulness of the cost analysis for our purposes, especially when costs measured in different frames are added together.

Equations 2-3, 2-4, and 2-5 rigorously specify and relate the elements of analysis of this report. They are used throughout in organizing and in presenting the results of this preliminary study.

2.3 Summary and Conclusions

Two types of top-level models have been used in past studies of occupant restraint effectiveness. The first type defines effectiveness as the percentage decrease in an occupant's probability of incurring an injury of specified severity in a crash. The second type defines effectiveness as the percentage decrease in an occupant's cost of injuries incurred in a crash.

Clearly, the cost-based model is most appropriate for this study. Both the effectiveness measure and its components are of interest. The top-level costs in the model are expressed as functions of an injury severity distribution, unit costs of injuries of given severities, and number of occupants who wear and who do not wear restraints. The cost model and its major submodels are used for organizing the analysis contained in the remainder of this report.

3.0 REVIEW OF THE LITERATURE

This section contains a short review of the literature germane to determining the effect of occupant restraint use on the economic cost of injuries incurred in traffic crashes. The primary objective is to identify the published data that are best suited for developing a preliminary estimate of the amount and incidence of the costs of nonuse of occupant restraints. The term "incidence" is used by economists to describe the distribution of costs among the sectors that pay those costs. Our major concern is who bears the cost burden rather than who pays the out-of-pocket expense. A secondary objective is to provide background information on issues related to the development of such cost estimates. The review describes the relevant studies and briefly considers their deficiencies and limitations of their data for use in this study.

The review is presented in three parts. First, studies similar in purpose to this study are examined to see which, if any, of their findings are applicable to this study. These so-called full studies include those that have calculated the effects of restraints on the cost of injuries per occupant per crash. Also included among these full studies are those that attempt to estimate the total cost of nonuse of restraints among populations of drivers.

Next, literature on the critical components needed for calculating the costs of nonuse of restraints is discussed. Such components include:

- injury severity distributions as a function of restraint use,
- costs of injuries per occupant per crash as a function of restraint use, and
- number of occupants in crashes who use and who do not use restraints.

Finally, the results of our attempts to locate information on the incidence of the cost of restraint nonuse are reported.

3.1 Full Studies

Full studies of occupant restraint effectiveness based on cost reduction require three key types of data:

- cost data on sources of expense for accident victims and for society in general,
- incidence of payment of costs for each of the groups affected by accident costs, and
- restraint use data on injury severity that can be merged with the cost data.

No studies were found that had all three of these types of data, but three studies had cost data as a function of injury severity and restraint use. These data permit one to calculate effectiveness measures based on cost reduction, but do not permit analysis of who bears the burden of accident costs.

The first and most recent of these studies is reported in two different references (Snow 1979, and Ontario Ministry of Transportation and Communication 1978). At the 1979 International Symposium on Seat Belts in Tokyo, Japan, J. W. Snow, Minister of Transportation and Communications, Government of Ontario, Canada, noted, without reference to a data source:

> The most recent statistics concerning traffic accident victims showed that the average cost of active treatment for in-car victims wearing seat belts was $228. For those who were not wearing seat belts or wearing them improperly, the cost was $419—almost double. (Snow 1979, p. 201.)

Though Snow does not specify his source, it is likely that his data come from a study done by the Ontario Ministry of Transportation and Communications (1978).

The OMTC study was designed to determine the economic impact of mandatory safety belt laws and reduced speed limit laws implemented on 1 January 1976 in Ontario Province, Canada. The OMTC established a Monitoring System Committee to collect and analyze data for 1975 and

1976 to provide an accurate record of the effects of these two laws.

One result of the Monitoring System Committee's work is the data summarized in Table 3-1. The average cost figures are for "active" treatment costs only, supplied by sixteen Ontario hospitals. Lost wages are not included in these estimates.

The average cost of active treatment for occupants who used seat belts in cars when belts were available was calculated as $228 for 1976. For occupants in the four categories where occupants did not use seat belts (installed or not), or where seat belt use was unknown or not reported, Snow's estimate of the average cost was $419. For the two categories where nonuse was certain (installed and not used, and not installed), the weighted average cost was $396. (See Table 3-2 for numbers of occupants in each seat belt usage category to determine weights.)

Without knowing more about data collection procedures, it is not possible to examine the significance of possible systematic errors in the unknown and unreported categories. Because the usage rates in Table 3-2 depend on honest reporting of seat belt use by the victims to police, it can be expected that systematic errors contributing to biased data do exist in the known categories. Other studies have shown the existence of errors in police-reported data on restraint use (Hochberg 1976).

Data limitations that lead to systematic errors, a large proportion of unknown and unreported cases for restraint usage, and the inclusion of only active treatment costs severely limit the reliability and usefulness of the effectiveness estimates based on these data. Also, the applicability of these Canadian data to crashes in the United States is questionable. However, because it is one of only three studies that provide estimates based on cost reduction, its results are useful for comparative purposes. The estimate of effectiveness for known restraint use implies a forty-two percent cost reduction due to restraint use. The effectiveness estimate for unknown, unreported, and unused categories versus the used category is forty-six percent.

A second study of restraint effectiveness based on cost data was done at the University of North Carolina Highway Safety Research Center

TABLE 3-1

OMTC STUDY RESULTS:
AVERAGE COST OF "ACTIVE" TREATMENT OF TRAFFIC CRASH INJURIES WITH AND WITHOUT SEAT BELTS

Seat Belt Usage in the Vehicle	Average Cost of Active Treatment 1976 (at 1975 rates)
Installed, used	$228.00
Installed, not used*	381.00
Installed, use unknown*	396.00
Not installed*	445.00
Not reported*	501.00
All categories	301.00

*The weighted average of these four categories is $419.00

Source: Ontario Ministry of Transportation and Communication 1978, p.52.

TABLE 3-2

OMTC STUDY:
NUMBER OF OCCUPANTS IN
SEAT BELT USAGE CATEGORIES, 1976 VICTIMS

Seat Belt Usage Category	Number of Occupants	Percent of Total
Installed, used	3,191	61.7%
Installed, not used	1,134	21.9
Installed, use unknown	66	1.3
Not installed	357	6.9
Not reported	421	8.1
All occupants	5,169	100.0

Source: Ontario Ministry of Transportation and Communication 1978, p.50.

(HSRC) (Reinfurt, Silva, and Seila 1976). In that study, the researchers developed estimates of effectiveness that are surprisingly similar to those in the OMTC study, despite different data sources, different cost definitions, and different methods of control for interactive factors.

Injury data for the HSRC study are from the Restraint Systems Evaluation Program (RSEP) of the National Highway Traffic Safety Administration. The RSEP data combines police, occupant, witness, hospital, and vehicle investigation information for victims of accidents involving 1973-1975 model year cars that were towed from the scene of the accident. The data are from level-two files of accident investigations in five geographic areas--western New York state, Michigan, Miami, San Antonio, and Los Angeles--but are not necessarily representative of crashes nationwide.

Cost elements in the HSRC study include medical expenditures (hospital and professional charges), lost wages, and funeral costs. Approximately six thousand injury claim records from Blue Cross/Blue Shield of North Carolina were the basis for medical expenditures. These claims were matched with National Center for Health Statistics (NCHS) data on number of restricted days due to injury, NCHS tables of life expectancy, and inflation-adjusted U.S. Bureau of Census wage data for 1970 in order to estimate lost wage costs. Funeral costs are calculated as the difference between the cost of the funeral at the time of death and the present discounted value of the cost of the funeral at the expected age of death if no accident had occurred.

An important element that contributes to the validity of the HSRC study is the use of techniques for the analysis of complex categorical data. The purpose is to account for the effect of other, nonrestraint factors on injury costs. In effect, these techniques permit the researcher to "control" for complex interactons between variables, for example, between age and injury severity or sex and restraint use. Two techniques used in the HSRC study were generalized least squares (GENCAT) and Mantel-Haenszel (see Reinfurt, Silva, and Seila 1976, pp. 47-52). Only the Mantel-Haenszel procedure was used for cost data adjustments.

HSRC's average cost estimates for unrestrained, lap-belted, and lap-and-shoulder belted occupants are shown in Table 3-3. Effectiveness estimates based on Table 3-3 are shown in Table 3-4. These two tables show the apparent contradiction that the average cost of injuries for lap-and-shoulder belted occupants is greater than the average cost of injuries for lap-only belted occupants. The average cost is 19.8% higher unadjusted and 5.3% higher adjusted by the Mantel-Haenszel type estimation procedure. This contradiction is explained by data limitations listed below. The effectiveness estimates in Table 3-4 suggest about a fifty percent accident cost reduction for occupants who use restraints (54.6% for unbelted versus lap-belt-only and 52.2% for unbelted versus lap-and-shoulder belted).

The HSRC study appears sound methodologically. Data insufficiencies and sample anomalies contribute the only significant shortcoming of the study vis-a-vis our study. These problems can be summarized as follows:

- There are small numbers of injuries in some categories, e.g., only four fatalities in the lap-belted group, which makes statistical inference difficult and creates biases in estimates;
- The sample is limited to 1973-1975 model year cars;
- Because the sample contains only victims of accidents where at least one car was towed from the scene, the study may overestimate effectiveness due to underreporting of minor accidents and has sample definition problems due to inability to control perfectly for the sample-inclusion threshold;
- Special definition of the AIS scale peculiar to this study limits comparison with other studies (all fatalities are assigned AIS = 6, regardless of injury severity);
- No analysis of the incidence of costs means the study ignores an important dimension of the accident cost problem;
- Missing cost data, e.g., incidental and subjective elements, probably reduce the effectiveness estimate because these elements are most significant for severe and fatal injuries; and
- Neither cost nor injury severity data qualify as nationally representative samples.

TABLE 3-3

HSRC STUDY:
AVERAGE COST OF CRASHES BY RESTRAINT STATUS

Restraint Status	Unadjusted	Mantel-Haenszel
Unrestrained	$674	$588
Lap belt only	230	267
Lap and shoulder	276	281

Source: Reinfurt, Silva, and Seila 1976, vol. 1, p.89.

TABLE 3-4

HSRC STUDY: EFFECTIVENESS ESTIMATES
BASED ON COSTS FOR OCCUPANT RESTRAINT USE

Category	Unadjusted	Mantel-Haenszel
Unrestrained vs. lap belt	65.8%	54.6%
Unrestrained vs. lap and shoulder	59.1	52.2
Lap belt vs. lap and shoulder	(19.8)	(5.3)

Note: Parentheses denote negative effect.

Source: Reinfurt, Silva, and Seila 1976, vol. 1, p.89.

The HSRC researchers were severely limited by data unavailability. The other limitations noted above create uncertainties about their effectiveness estimate, although the net effect of all the limitations is not clear. The magnitude of overestimation and underestimation cannot be determined without further research.

Another "full" study with a reasonably sound approach also suffers from data limitations. The study was performed by the John Z. DeLorean Corporation (1975) for the Allstate Insurance Company. The study was a benefit/cost analysis of four restraint systems: the lap belt, the three-point lap-shoulder system, and air bags with and without the use of lap belts. The study used a computer model to estimate accident characteristics and calculated societal cost using the results of the computer model.

The computer model enabled the researchers to control for the mix of automobile types in operation--an important factor related to injury severity, but one that has not been examined in other studies. Inputs for the model were automobile sales projections; projected vehicle scrappage rates; injury rates as a function of vehicle class, occupant seat position, accident mode, and impact velocity; injury severity by accident mode and velocity; restraint system effectiveness; historical and projected restraint usage rates; restraint system costs; and consumer retail prices.

The societal cost calculation was based on cost definitions originally developed in a Department of Transportation study (U.S. Department of Transportation 1972). Cost elements included were hospital and professional charges, lost income from employment and lost value of home production, employer losses, funeral costs, legal fees, insurance administration costs, pain and suffering, and a category for losses to others. These costs were combined with accident characteristics and effectiveness estimates to derive a quantitative estimate of the potential societal benefit of the four restraint systems.

The DeLorean study reports lifetime benefits of the restraint system studied based on assumptions of restraint effectiveness and usage. These results (Table 3-5) show potential savings for all of the restraint systems

TABLE 3-5

DELOREAN STUDY:
LIFETIME SOCIETAL BENEFITS OF RESTRAINT SYSTEMS--1978

Restraint System	Discounted Benefit (Billion$)	System Cost (Billion$)	Net Benefit (Billion$)	Benefit/ Cost Ratio
Lap/Shoulder (Low usage)**	$2,170	$1,030	$1,140	2.1
Lap/Shoulder (High usage)**	4,290	1,030	3,260	4.1
Air Bag	8,860	2,000	6,860	4.4
Air Bag & Lap Belt (20% use)	9,220	2,380	6,830	3.9
Air Bag & Lap Belt for Driver and Lap/Shoulder for Right Front Passenger	6,970	1.780	5,190	3.9

*5% discount rate

**Low usage = 6% lap and 20% lap/shoulder usage
High usage = 12% lap and 40% lap/shoulder usage

Source: DeLorean 1975, p. 49.

studied with the greatest potential benefit for the air bag supplemented by the lap belt. The highest benefit/cost ratio is for the air-bag-only system.

The use of potential benefits as a measure of the effectiveness of restraint systems differs from most studies that use percentage reduction of injury severity or cost as a measure of effectiveness. However, the potential benefits in the DeLorean study were derived from assumptions made about restraint effectiveness in reducing injuries. The assumptions were based on data developed in other studies, mainly those done by General Motors and Ford.

Unfortunately, these data do not adequately account for the effects of other, nonrestraint factors on effectiveness. This methodological deficiency seriously limits the value of the DeLorean study for our purposes. Also, the rationale behind many of the key assumptions is not fully described, so the validity of the assumptions cannot be assessed. These shortcomings significantly reduce the usefulness of the study for estimating the "global" economic cost of not using occupant restraints. Nevertheless, the study is of interest because of its general approach, which could possibly be applied in future studies.

3.2 Component Studies

This subsection discusses studies that have examined the components that are needed for calculating the cost of not using occupant restraints. Injury severity distributions that include details on restraint use have received the most attention in the literature and are discussed first. A discussion of the few applicable studies of the cost of injuries follows. Costs as a function of injury severity are presented along with a discussion of the individual elements of costs that were used in the cost functions. This subsection closes with a brief discussion of factors identified in the literature as affecting restraint use, and a summary of studies that have estimated use.

3.2.1 Injury Severity Distributions. Many injury severity scales have been developed to aid in the analysis of all kinds of accidents. Two of these scales are in common use in highway safety studies: the police scale (KABCO) and the Abbreviated Injury Scale (AIS). Of these two, the AIS has been used most often recently by researchers and medical personnel, while the KABCO tends to be used more often by nonmedical personnel, primarily police.

The AIS was originally developed in 1969 by representatives from the American Medical Association, Society of Automotive Engineers, and the American Association for Automotive Medicine. Eight levels of severity are contained in the 1980 revision of the AIS (American Association for Autmotive Medicine 1980, p.6):

0	No injury
1	Minor
2	Moderate
3	Severe (not life-threatening)
4	Serious (life-threatening, survival probable)
5	Critical (survival uncertain)
6	Maximum (currently untreatable)
9	Unknown

Other scales have been developed and appear to be better in some respects for classifying injury severity (c.f., Baker et al. 1974; Reinfurt et al. 1978; Kirkpatrick and Youmans 1971; Krischer 1976; and Gibson 1976), yet the AIS persists as the most common classification scheme for motor vehicle accident victims. Reasons why the AIS continues to be used appear to be:

- long history of use has made it well known to many researchers and accident investigators;
- reasonably standardized application based on widespread, consistent documentation;
- easier to use in practice than more detailed scales;
- more reliable than the police scale; and
- the desire for results to be comparable to studies done in the past.

Recently, HSRC researchers have tried to construct and validate an injury scale based on the cost of trauma (Reinfurt et al. 1978). The scale is based on North Carolina Workman's Compensation files and on claim records from Blue Cross/Blue Shield of North Carolina. While this effort would remove the need to match injury severity data from traditional scales with cost data from these sources, the new scale has not been used enough to judge its validity or practicality.

Past and ongoing studies have found a large number of variables that are related to injury severity. Some of the most important and most commonly available in studies we examined are listed in Table 3-6. The variables most important to control for in such studies are in the occupant characteristics category and include age, weight, seating position, occupant role, restraint system use, and entrapment/ejection variables. All of these variables will affect the economic cost of injuries, and so data on them should be included in a study of such costs.

We emphasize that the relationships between these factors are very poorly known. Further, low correlations have been found between some of these factors (especially such physical descriptions as energy/mass and force/mass). Thus, there is a good chance that AIS is influenced by factors that we do not know about and are not included in the table.

Because of the large number of variables that affect injury severity, it is important to use techniques of data analysis that allow one to "control" for complex interactions among variables. Very few of the studies have accounted for such interactions in their analysis. Two exceptions are studies done at HSRC: Hochberg (1976) and Reinfurt, Silva, and Seila (1976). Both discuss the statistical inference made possible by categorical data analysis, limitations placed on various approaches by sample sizes and sample definition, and some applications of specific techniques.

Because most studies have not controlled for interactive factors, their results are not comparable, and it is not known whether restraints or other factors caused observed differences in injury severity. The most important factor making comparison difficult is differences in sample definition. These differences cause samples to exhibit different compositions with respect to almost all of the accident, vehicle, and occupant characteristics outlined in Table 3-6.

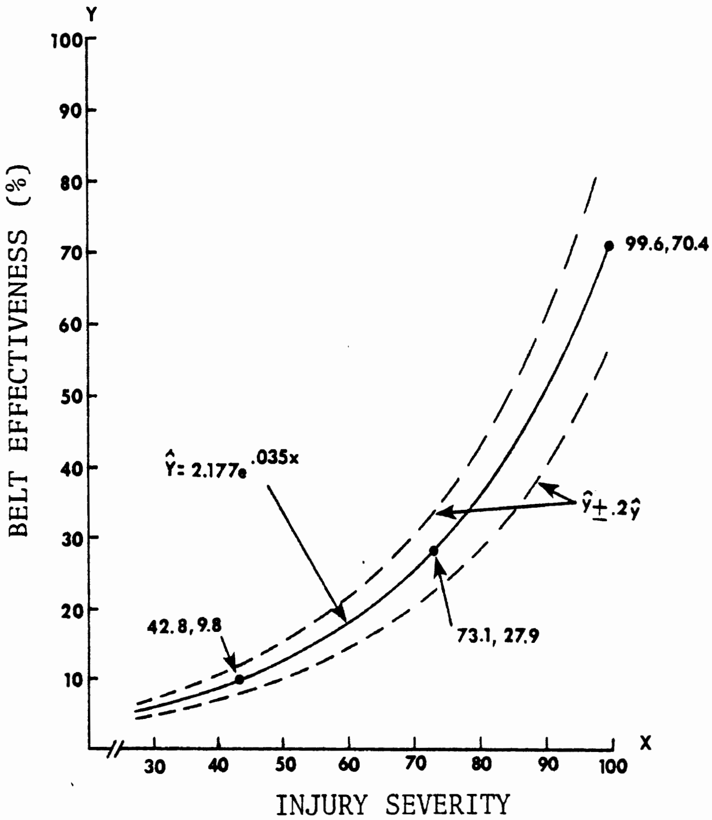
Table 3-7 presents a brief overview of studies done since 1975 that have contained injury severity distributions and estimates of restraint effectiveness. All of the studies in Table 3-7 are based on injury severity data, but all do not present data in its disaggregated form to permit comparison across studies. Table 3-8 presents cumulative injury distributions for eight of the studies. The distributions are for all occupants reported in each sample, with and without restraints. The percent of each sample who were injured (AIS $\geq$ 1) varies greatly, from 29.2% for NCSS (which was concerned with towaway crashes of passenger cars) to 94.2% for the Garrett study (which examined frontal impacts only). The percent of fatalities varies from a low of 0.1% for HUK/Verband to 1.9% for the Garrett study.

The injury distributions clearly show that occupant restraints have been much more effective in reducing serious and fatal injuries than minor injuries. Thus, restraint effectiveness estimates will be severely affected by these obvious sample differences if no control is made for the interaction. Summary studies of occupant safety literature have indeed shown large differences in restraint effectiveness estimates (Griffin 1973; Huelke and O'Day 1979; and Mela 1974).

Campbell and Reinfurt (1979) found that sample differences do account for a significant part of the differences in restraint effectiveness found in the literature. They suggest a method to reconcile different effectiveness estimates based on standardizing injury categories. Because the injury scale is broken into discrete categories, sampling techniques, reporting thresholds, occupants included, and other definitional factors cause wide variations in the proportion of injured in any single category. If one assumes the difference in proportions is due to different samples and not different populations (not a good assumption when the data are localized regionally), corrections can be made that remove most of the inconsistencies of the estimates. The Campbell and Reinfurt study contains the best evidence that restraint effectiveness increases with injury severity (see Figure 3-1).

FIGURE 3-1

RESTRAINT EFFECTIVENESS AS A FUNCTION OF INJURY SCALE DIVISION



Source: Campbell and Reinfurt 1979, p.5.

Note: The equation $y = 2.177e^{.035x}$ is the weighted least squares categorical regression equation fit to a cross-section of effectiveness estimates, y. x is the point on the cumulative percentage scale where the injury reduction is examined. Dashed lines show the 20% confidence interval.

TABLE 3-6

VARIABLES RELATED TO INJURY SEVERITY

Accident Characteristics	Vehicle Characteristics	Occupant Characteristics
Hour of day	Model year	Number of occupants
Day of week	Model type	Age
Light conditions	Object contacted	Sex
Rural/urban	Direction of force	Weight
Roadway type	Delta-V	Height
Speed limit	Fire occurrence	Restraint system use
Road surface condition	Vehicle weight	Occupant role
Number of vehicles involved	Type of impact	Seating position
Accident type		Entrapment/ejection
		Body region injured

TABLE 3-7

SUMMARY OF POST-1975 LITERATURE

	Author	Year Published	Occupants Studies	Vehicles Studies	Sample Size	Injury Scale Used [1]	Restraint Classification [2]	Data Source
1.	HUK Verband	1975	All	Passenger cars	28,936 accidents 47,306 vehicles 50,464 occupants	AIS	N,R	West German auto insurers
2.	R.J. Cromack, et al.	1976	All	1973-76 model towed cars	5,747 vehicles [3] 8,995 occupants	AIS	N,L,L/S	RSEP
3.	Y. Hochberg	1976	Drivers	Passenger cars	49,835 accidents	AIS	N,L	North Carolina
4.	D.W. Reinfurt, et al.	1976	Front outboard	1973-75 model towed cars	15,818 occupants [3]	AIS	N,L,L/S	RSEP
5.	R.E. Scott, et al.	1976	Front outboard	1973-75 model towed cars	6,729 vehicles 9,186 occupants	OASIS	N,L,L/S	RSEP
6.	Baird, J. et al.	1977	All	1973-75 model towed cars	2,853 accidents 6,066 vehicles 4,913 occupants	AIS	N,R,	RSEP
7.	R.J. Court	1977	N/A	Passenger cars	25,948 accidents 67,687 occupants	Inj.,uninj., fatal	N,R	Australian police
8.	J.W. Garrett, et al.	1977	Drivers	Late model passenger cars--frontal impacts	647 drivers	AIS	N,L,L/S	Calspan Tri-Level
9.	D.F. Huelke, et al.	1977	Front seat outboard occupants in frontal and rollover crashes	Passenger cars	5,997 occupants	AIS	N,L,L/S	CPIR &RSEP (partial)
10.	H. Norin	1977	Front seat occupants	Volvo	4,995 accidents 6,944 occupants	AIS	Before and after mandatory use law	Volvo
11.	Ontario Ministry of Transportation and Communications	1977	N/A	N/A	14,859 occupants	AIS	Before and after mandatory use law	Province of Ontario

TABLE 3-7

SUMMARY OF POST-1975 LITERATURE (CONTINUED)

	Author	Year Published	Occupants Studies	Vehicles Studies	Sample Size	Injury Scale Used [1]	Restraint [2] Classification	Data Source
12.	C.A. Hobbs	1978	All	All	1,126 accidents 1,664 vehicles 2,879 occupants	AIS	N,R	United Kingdom
13.	T.A. Ranney	1978	All	Light trucks	364 trucks	AIS	N,L,L/S	Western New York State
14.	B. Chen	1979	All	All	1,715 accidents 4,126 occupants	KABC	N,R	California Highway Patrol
15.	P.M. Keyl D.J. Dalmotas	1979	Occupants with AIS 2 or greater injury	Passenger cars	94 occupants	AIS	N,R	Transport Canada
16.	D.F. Huelke, et al.	1979	Fatalities	Passenger cars	70 injured occupants 101 fatalities	--	N,L,L/S,AB,PB	Washtenaw County, Michigan
17.	S.C. Partyka	1979	NCSS	NCSS	NCSS	AIS	N,L,L/S	NCSS
18.	L. Ricci	1979	All	Towed Passenger cars	39,867 accidents [3] 39,444 vehicles 62,026 occupants	AIS	N,L,L/S,PB	NCSS
19.	U.S. Dot	1979	NCSS fatalities	NCSS	442 fatalities	--	N,L,L/S	NCSS
20.	U.S. Dot	1979	All	All	2,080 accidents 3,158 occupants	AIS	N,L,L/S	NASS

Notes:

1. AIS = Abbreviated Injury Scale
   OAIS = Overall AIS (composite index for all injuries one victim sustains)
   KABC = Police reporting system

2. N,R = Not restrained, restrained
   N,L,L/S = Not restrained, lap belt only, lap and shoulder belt
   AB = Air bag
   PB = Passive belt

3. Sample size numbers are weighted by various methods. Actual numbers are smaller.

TABLE 3-8

CUMULATIVE RELATIVE SAMPLE PROPORTIONS FOR AIS-INJURY CATEGORIES

AIS	DATA SOURCE							
	NASS	NCSS	Reinfurt (RSEP)	Dalmotas	Hobbs	Garrett	Baird (RSEP)	HUK/Vernand
0+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	--
1+	.389	.292	N/A	N/A	.675	.942	.677	.774
2+	.101	.082	.094	N/A	.274	.424	.115	.162
3+	.053	.037	.024	.404	.079	.143	.028	.036
4+	.023	.014	N/A	.170	.022	.043	N/A	.077
5+	.013	.008	N/A	.096	.017	.021	N/A	N/A
6	.007	.003	.005	.011	.009	.019	N/A	.001

3.2.2 Unit Cost of Injuries. To estimate the cost of a given injury one must build up the costs from their components. This subsection discusses alternative definitions of cost components that appear in the literature and identifies problems in using these definitions in this study. Four studies that have developed cost components as a function of injury are then discussed and compared.

3.2.2.1 Components of Accident Cost. Sherwin and Jackson (1978) have divided accident cost into five groups:

- property damage;
- loss of productive output due to fatality or injury;
- medical and hospital costs;
- incidental costs for items such as provision of emergency services; administration of insurance claims; legal, court, and coroner's costs; loss of use of vehicles, etc.; and
- subjective, nonquantifiable elements such as grief, pain, suffering, etc.

Past cost studies have variously used some subset of these cost components (Joksch 1975; Faigin 1976; Reinfurt, Silva, and Seila 1976; Ontario Ministry of Transportation and Communication 1978; Wohl 1969; Marsh, Kaplan, and Kornfield 1977; DeLorean 1975; and National Safety Council 1979).

While property damage is a significant component in accident costs, one would not expect it to vary significantly with occupant restraint use. Only if drivers change behavior when using restraints compared to not using restraints and somehow become more or less cautious would property damage be correlated with restraint use. This would appear to be a higher order effect that would not be of concern in our study.

Two controversies surround the second component of accident cost:

- the appropriateness of placing a dollar value on human life; and
- the lack of a single, most-preferred method to estimate

the dollar value of human life.

Placing a dollar value on human life could imply that expenditures above that amount are not justified in order to save a life. Though such an implication is seldom explicitly stated, nor necessarily a conclusion of placing an economic, as opposed to social, value on human life, it may lead to misunderstandings about the outcome of cost/benefit studies (Hapgood 1979).

The two most common approaches are the "human capital" approach and the "willingness to pay" approach.

The human capital approach has been used most often in past studies (Faigin 1976; DeLorean 1975; Reinfurt, Silva, and Seila 1976; Marsh, Kaplan, and Kornfield 1977). It is based on lost potential earnings and is calculated using wage and life expectancy data, discounted for time preference. Wage and life expectancy data are available in abundance. Discount rates are arbitrarily determined, but can give a range by choice of several reasonable alternatives.

A drawback of the human capital approach is a net negative potential income for some individuals, for example, young children and retirees. Depending on assumptions made about the timing of labor market entry and exit, and the level of "maintenance and upkeep costs," the present discounted value of future income can be less than consumption expenditures necessary to maintain the human capital. For most individuals, potential future income peaks in the years between 25 and 35. This outcome again makes an uncomfortable implication—society should be willing to pay more to reduce the risk of individuals in the 25 to 35 year age groups than for children or for retirees.

The "willingness to pay" approach is more firmly founded on economic theory (see Linnerooth 1979), but is more difficult to use. This approach requires wage and risk data for a cross-section of occupations. Presumably, a worker must be compensated with a higher wage for taking a riskier job. Estimating this compensating differential provides the basis for placing a value on human life.

Because there is no reason to expect the two approaches to provide the same estimate, the choice of one or the other will influence the values of the costs. In the case of motor vehicle crashes, the immediate choice must be made on the basis of data availability.

The theoretical basis of the willingness to pay approach makes it more appealing. Implications of the human capital approach are counterintuitive and clearly not consistent with behavior in our culture. Yet the lack of appropriate wage and risk data for drivers makes the human capital approach the choice by default.

The elements grouped in medical and hospital costs include professional charges of doctors, nurses, therapists, etc.; hospital, nursing home, and other institutional charges for inpatient care; charges of outpatient care facilities during convalescence; and other costs incurred for medicine, prosthetic devices, etc. While these elements are diverse and come from many sources, they create few problems compared to other cost elements. Insurance companies collect large amounts of data for claims on various medical and life insurance policies. These data often contain enough treatment information to permit matching with existing accident data files for such variables as injury type, injured body area, and injury severity (All-Industry Research Advisory Committee 1979).

Small amounts from many sources makes the fourth cost component, incidental costs, very difficult to handle (Faigin 1976, DeLorean 1975). The combined amount of all incidental costs has been relatively insignificant in past studies, but because each individual element is relatively small and very difficult to estimate, estimation and allocation of these costs on a per-crash basis is one of the weakest parts of many cost studies. One result, which is clearly not satisfactory, is that many studies have not included elements of incidental costs (Ontario Ministry of Transportation and Communication 1976; Reinfurt, Silva, and Seila 1976). Even though the expected value of incidental costs is relatively small for all crashes, incidental costs constitute a significant portion of total costs for the most severe accidents.

The last cost component, subjective elements, does not seem to be quantifiable. If the willingness-to-pay approach could be used, some subjective elements would appear in the valuation of life. Risk avoidance is surely in part motivated by a desire to eliminate pain, grief, and suffering from our lives. Yet it is unclear how well individuals can place a value on the pain and suffering accompanying accidental injury without having had the experience.

Rather than attempt to quantify subjective cost elements, many cost/benefit analysts have opted for a "contingency calculation" approach (Mishan 1971b; Sherwin and Jackson 1978). After calculating the costs and benefits of a proposed project, the cost/benefit analyst calculates the critical value that would have to be placed on subjective costs or benefits in order to just offset the dollar value of items on the other side. This critical value is the "contingency calculation," and it enables policymakers to weigh all the merits of a proposed project.

A simple example will help illustrate this approach. Assume that a state legislature is considering a law designed to save lives and reduce injury and that analysts have estimated that project costs exceed project benefits by $2 million. If there are no subjective costs of the law, a contingency calculation can be made to account for potential reduction of pain and suffering on the benefit side. If the law were expected to save 1,000 lives and reduce serious injuries for another 9,000 individuals, the contingency calculation could be expressed as $2,000 per life saved or $200 per individual affected. The legislator would then have to decide whether such a cost for pain and suffering were reasonable.

In practice, if subjective elements appear on both sides as benefits and costs, this approach is limited. With regard to proposals to increase the use of occupant restraints, most analyses can be structured not to include subjective cost components.

Because of problems such as those outlined above for accident cost components, many criticisms have been directed at the use of cost/benefit analysis for selecting highway safety measures. The concensus seems to be that cost/benefit analysis provides valuable insights to decisionmakers, but that it is not wise to base decisions solely on the results of the analyses (see Joksch 1975, p. 151). As in the example above, decisionmakers need to know what subjective elements are important, how they are incorporated in the analysis, how much uncertainty is involved in the estimates, and from what point of view the analysis is done. In short, decision-makers should be well schooled in the shortcomings of cost/benefit analysis and must thoroughly understand the analysis to determine its sensitivity to various assumptions.

3.2.2.2 Studies of Traffic Crash Cost and Injury Severity. Four studies that have published distributions of crash costs as a function of injury severity are examined in this subsection. Other studies have estimated the amount of such costs, but either have not published an injury severity scale, have used only part of the severity scale, or are outdated and of limited use here (see Lawson 1978; Marsh, Kaplan, and Kornfield 1977; Heaton 1971; Joksch 1975; Wohl 1969; Sherwin and Jackson 1978; U.S. Department of Transportation 1970; U.S. Department of Transportation 1972; Morris and Paul 1968; and Wuerdemann and Joksch 1973).

Three of the studies were discussed in Section 3.1 as "full" studies of the cost of not using restraints. In this section, only the cost elements and distributions of those studies are reviewed.

The study done by the Ontario Ministry of Transportation and Communication (1977) contains an estimate of only the medical and hospital care component for accident injury victims treated in sixteen hospitals in Ontario Province, Canada. Elements of cost included were outpatient emergency treatment, inpatient acute hospital care, and medical and therapy treatment. Only accident victims treated at one of the sixteen hospitals were included; victims who were treated in doctors' offices were excluded from the study. The period of treatment was assumed to be the time of inpatient or outpatient care plus one month after hospital discharge or release from emergency treatment. Data collection was done for 1975 and 1976, the years before and after introduction of compulsory seat belt legislation and the reduced speed limit law.

The next step up from the OMTC study is the HSRC study (Reinfurt, Silva, and Seila 1976), which included hospital costs and professional fees, lost wages, and funeral expense.

Hospital costs and professional fees for each injured victim in the study were estimated based on nearly 600,000 claims records from Blue Cross/Blue Shield of North Carolina. Individual estimates were affected by degree of injury, type of treatment, place of treatment, length of hospital stay, age, and sex for each victim.

Lost wages were calculated using U.S. Bureau of the Census wage data for North Carolina from the 1970 Census (updated to 1974 dollars) and National Center for Health Statistics life expectancy tables. For nonfatal cases, lost wages were calculated as the product of the mean daily wage and the number of days of disability or restricted activity or both for each age, sex, and injury class. For fatalities, lost wages were computed as the sum of discounted yearly wages for the expected number of years of life remaining, adjusted for each victim's age and sex.

Funeral costs were also included for fatalities. Because death is certain, funeral costs were calculated as the difference between $2,000 (the cost of a funeral in 1974) and the present discounted value of the funeral at the expected age of death if no accident had occurred. The discount rate used was ten percent.

The DeLorean study was commissioned by the Allstate Insurance Company to analyze the impact of proposed standard FMVSS 208, which required that cars sold in the U.S. be equipped with front seat passive restraint systems. Cost elements from all five cost components discussed in subsection 3.2.2.1 were included. An attempt was also made to place a dollar value on subjective cost elements—pain and suffering.

Different procedures were used for estimating the costs of fatal and nonfatal injuries in the DeLorean study. For nonfatal injuries (AIS 1-5), costs were calculated for hospital and physician charges, lost earnings, rehabilitation, insurance, and legal factors. Cost estimates for all but insurance and legal factors were based on data from the Commission on Professional and Hospital Activities (CPHA), Ann Arbor, Michigan. Injury frequency data were obtained from HSRI accident data files. The procedure used to calculate the cost for each injury level was complex and required bits and pieces of data from a large number of sources that were not necessarily compatible. Insurance and legal costs were obtained from the 1972 U.S. Department of Transportation study and updated for inflation.

For fatalities, cost elements included in the DeLorean study were hospital, medical, lost earnings, suffering, home and family duties, employer losses for retraining, losses to others, funeral, legal, and insurance administration. Except for the lost earnings component, these costs were also obtained by updating data from the 1972 U.S. Department of Transportation study. Again, computation of individual elements requires data from a large number of disparate sources. The usual human capital approach was used to calculate lost earnings.

The Faigin study (1976) used basically the same cost analysis methodology as the DeLorean estimates. Faigin adapted the 1972 U.S. DOT study to include some elements DeLorean did not and excluded pain and suffering from her calculations. Elements included in the Faigin study were lost income from both market and nonmarket production; medical care costs for hospital, physician, coroner-medical examiner, and rehabilitation; funeral; legal and court; insurance administration; accident investigation; losses to others; vehicle damage; and traffic delay. As with DeLorean, the estimation procedures require data from a large number of sources (see the Faigin report for a detailed description).

The procedure used for estimating legal and court costs (a relatively minor component of total costs) illustrates the large number of data sources required. The procedure required three references to DOT studies, four to NHTSA studies, four to Accident Facts of the National Safety Council, six to a study by Wuerdemann and Joksch (1973), three to Census data, and one to Bureau of Labor Statistics data.

Elements included in the OMTC, HSRC, DeLorean, and Faigin studies are summarized in Table 3-9 for comparison purposes. Faigin's study includes the most elements, but because elements included are not well defined and require many data sources to estimate, the validity of the results is unknown. Biases certainly exist, but the net effect cannot be determined without extensive study.

The same is true of the DeLorean study. An additional caveat is the use of the quantification of pain and suffering costs from the 1972 U.S.

TABLE 3-9

COST ELEMENTS INCLUDED IN FOUR STUDIES OF TRAFFIC CRASH COSTS

Category	Faigin	DeLorean	HSRC	OMTC
Property damage	Vehicle damage	None	None	None
Lost production	Market and non-market activities--earnings, home production, community service	Market and non-market activities--earnings, home production	Market activities only--earnings	None
Medical and hospital care	Institutional charges Professional fees Coroner-medical examiner Rehabilitation	Institutional charges Professional fees Rehabilitation	Institutional charges Professional fees	Institutional charges Professional fees
Incidental	Funeral Legal and court Insurance administration Accident investigation Losses to others Traffic delay	Funeral Legal and court Insurance administration Losses to others Employer losses	Funeral	None
Subjective	None	Pain and suffering	None	None

DOT study.

The HSRC components are much more concrete than those of DeLorean or Faigin. HSRC's use of a large insurance claims file appears to be a positive feature, but several questions about those data and their use need to be explored.

Table 3-10 presents the cost distributions from all four studies. The table shows that there are large differences between the costs calculated by HSRC and those calculated by DeLorean and Faigin. All of the figures were updated to May 1979 dollars by applying the consumer price index (U.S. Bureau of the Census 1979, p.483).

The extra elements included in DeLorean and Faigin are not large enough to account for all of the differences. Methodology and sample characteristics are not reported in sufficient detail to permit examination of the source of the differences.

A second result of the HSRC study that is inconsistent with the other studies is the extremely large jump in cost between levels 5 and 6 of the AIS scale. Again, the reasons for this apparent anomaly are not readily determinable from the HSRC report.

Another interesting question about the HSRC figures is the extent of reporting bias in the insurance claims data and its effect on the magnitude of costs at various AIS levels. The effect of deductible amounts on health care insurance, the extent of health care coverage, percent of the population covered, and many other things will bias cost estimates. More research is needed to determine the magnitude of these biases.

The OMTC study is by far the simplest, yet is of the least value to our study because of the large number of missing cost elements, particularly lost earnings. Note that this study does not include costs of treatment rendered at doctor's offices. One would expect the persons who received such treatment to be less severely injured than hospital-treated victims. Thus, the average cost of injury at lower levels of injury could be overestimated. Both the OMTC and HSRC studies are regionally specific and cannot be generalized to crashes nationwide.

TABLE 3-10

AVERAGE COST OF INJURY BY INJURY LEVEL IN FOUR COST STUDIES
MAY 1979 DOLLARS

AIS Level	OMTC	HSRC	DeLorean	Faigin
1	$ 80	$ 205	$ 2,447	$ 808
2	1,467	861	8,694	3,412
3	2,944	2,104	32,475	7,143
4	4,473	2,652	101,934	111,139
5	5,205	4,543	249,175	252,216
6	1,465	107,578	324,172	376,169

Note: Dollar figures cited in the studies are updated to May 1979 dollars by the consumer price index (CPI) (U.S. Bureau of the Census 1979, p.483).

The CPI for all items was used for OMTC, HSRC, and DeLorean. The CPI by budget category was used for Faigin where individual elements are presented.

3.2.3 Occupant Restraint Use. The total cost of injuries due to the nonuse of occupant restraints is clearly a function of the number of occupants who use restraints and the number who do not use restraints. In the "model" outlined in section 2.2 of this report, these two numbers appeared explicitly as a ratio.

A number of studies of the use rates of various types of restraints have been conducted over the past several years (Robertson, O'Neill, and Wixon 1972; Robertson and Haddon 1974; Cooke 1976b; Robertson 1976; Aiken 1976; and Nilsson 1976). The studies indicate use rates of available restraints of from less than twenty percent to as high as sixty-five percent in the United States, depending on the type of car, type of restraint, occupant seating location, time period (use rates were highest about six months after the interlock system), and many other factors. Use estimates, circa 1976, were in the twenty-five to thirty-five percent range for lap belts or lap-and-shoulder belts.

Later studies indicate restraint use has decreased. In the most recent of these, Partyka (1979) compared estimates of restraint use from the NCSS file for the accident-involved population and from a study by the Opinion Research Corporation (1978) for the nonaccident-involved population. An update of the ORC study shows a further decline in usage for 1979 (Opinion Research Corporation, p.3). The NCSS file has data collected on occupants of cars involved in accidents where at least one vehicle was towed from the scene. The ORC study was based on data collected by stopping and interviewing drivers at intersections in nineteen cities.

From comparing the two studies and data collection procedures employed in them, Partyka found:

> . . . that if a similar portion of the NCSS file is considered (drivers of 1964 through 1978 model year passenger cars in urban areas) and is then adjusted to the distributions of model years observed by ORC, the estimate of usage for NCSS is 13.8 percent versus 14.1 percent for ORC. This does not support the widely-held view that the accident-involved population differs significantly from the overall driving population in their rates of seat belt usage. (Partyka 1979, p. 2.)

Adjusted NCSS and ORC estimates of restraint usage are given in Table 3-11.

One researcher has attempted to develop a predictive model of restraint use. In an economic study of the safety behavior of drivers, Blomquist (1977) developed an econometric model based on probit analysis to predict seat belt use on the basis of factors in three broad areas:

- Factors affecting seat belt productivity: speed of travel, type of roadway, age, sex, car size, etc.;
- Factors affecting the cost and disutility of seat belt use: convenience of the restraint system, length of trip, frequency of stops, time cost for the individual, etc.; and
- Factors affecting the subjective value of life and good health: education, wealth, potential future earnings, family status, etc.

His model permits fairly accurate prediction of seat belt use for drivers in the general population. His estimate of overall restraint use by drivers is about twenty percent, which is close to the figure arrived at in the Partyka and ORC studies. Partyka's finding of high rates of use for certain groups (e.g., females, older people, occupants of smaller cars in urban crashes, occupants of newer cars, and occupants who received minor injuries in crashes) is also roughly consistent with Blomquist's findings.

3.3 Incidence of Traffic Crash Injury Costs

As noted at the beginning of this section, the distribution of costs among the various sectors that pay those costs is called the incidence of costs by economists. For our study the incidence-of-cost problem is to determine who bears the cost burden as opposed to who pays the out-of-pocket expense. For example, insurance companies pay compensation for damage and injury, but the costs are borne by individuals who pay the premiums. The insurance company in this case is merely a mechanism that "passes on" the cost of accidents to those who actually bear it.

As defined by Wohl:

TABLE 3-11

RESTRAINT USAGE
ORC AND ADJUSTED NCSS DATA

	NCSS Adjusted	ORC
All restraints	13.8%	14.1%
Lap and shoulder	9.2	9.2
Lap only	4.3	4.9
Other types	0.3	--

Source: Partyka 1979, p. 8.

> . . . the traffic safety problem is to determine (a) the aggregate levels of benefit and cost associated with the adoption of one safety measure or another, (b) who will benefit and how much, and (c) who will pay and how much. It is simply not good enough to say that "society as a whole will benefit," or that "safety will improve," if we adopt a certain safety measure. (Wohl 1969, p. 77.)

The later two elements in Wohl's definition of the traffic safety problem are concerned with the incidence of the costs and benefits of safety programs. Despite the caution against using society's viewpoint as the basis for benefit-cost studies, most studies seem to have taken just that viewpoint by estimating total societal cost (Faigin 1976; Cooke 1976a; Dawson 1976; Heaton 1971; Japan Research Center for Transport Policy 1978) or some part of societal cost (Lawson 1978; Ontario Ministry of Transportation and Communication 1977; Reinfurt, Silva, and Seila 1976).

In addition to Wohl, other researchers have emphasized the need to carefully examine the questions of who pays and who benefits. The Transportation Research Board (1980) has recognized the need for more attention to incidence of crash cost questions in order to increase seat belt use and recommended:

> The economic costs of not using safety belts should be identified and publicized among the groups that mainly bear those costs: The federal government should conduct studies that would specify the costs of nonuse of safety belts; such studies should begin within units of federal agencies, and their results should be used to educate the public on how personal economic interests would be served by increasing the rate of safety belt use. (Transportation Research Board 1980, p.3.)

Others have also stressed the importance of incidence of injury cost analyses without conducting empirical research (Joksch 1975; Sherwin and Jackson 1978).

Empirical studies that have estimated part or all of societal cost have not estimated the incidence of payment for those costs between various sectors of the economy. A more fundamental problem is that the aggregate societal cost figures ignore efficiency and market value changes that occur when resources are transferred between economic sectors. In estimating the economic cost to society of motor vehicle occupants not using restraints, one must be careful to net out efficiency and market value changes that would occur if resources devoted to care of injured victims, payment of lost wages, etc., were shifted to alternative uses through injury avoidance by restraint use. Reducing accident injury will transfer income from some sectors, notably the medical and insurance industries, to others where the dollar value (as measured by markets) of those resources may decrease, specifically, home production and leisure activities. Paradoxically, it is possible that societal economic welfare as measured in dollars by gross national product would decrease if injury attributable to the nonuse of occupant restraints decreased. This would lead to the conclusion that "society" is better off "in dollar terms" with accident injuries and deaths than without.

A similar problem occurs when one looks at the cost of traffic crash injury from an employer's viewpoint. Some or all of cost increases for a business are "passed on" to consumers of the product or service sold by the business. Likewise governmental units can pass on some of the cost to taxpayers, employers, or users of that unit's services. The incidence of injury cost question is exactly like questions associated with the net impact of public policies such as tariffs, taxation, industry regulation, price controls, and many others. To develop a methodology to determine the actual cost borne by individual sectors, net of amounts passed on and with corrections for efficiency changes, would solve problems that welfare and industrial organization economists deal with very frequently.

Empirical studies that seem to have estimated the incidence of injury costs from the individual victim's viewpoint have limited use in this study. They are either outdated (Conard et al. 1964; U.S. Department of Transportation 1970), do not have variables needed to estimate the cost of nonuse of occupant restraints or to match up with existing accident data bases that contain restraint and injury information (All-Industry Research Advisory Committee 1979), or like the societal cost studies, do not analyze the source and extent of payment for accident injury by sector (Callaway and Drucker 1979; Marsh, Kaplan, and Kornfield 1977).

Studies done before the implementation of "no-fault" auto insurance laws, beginning in the U.S. with Massachusetts on 1 January 1971, are outdated because of the impact of no-fault systems on payment for injury costs. The All-Industry Research Advisory Committee's (AIRAC) analysis (Table 3-12) shows the effect of no-fault insurance on the incidence of injury costs for states classified as relying on "no-fault," "add-on," or tort liability insurance systems. For no-fault states a greater share of reparations for injury costs are paid by auto insurance sources than in tort liability states: 75.5% compared to 63.5%. In no-fault states, the burden is shifted from government and health insurance sources to auto insurance sources relative to tort liability states.

Table 3-13 lists states classed as "no-fault" and "add-on" in the AIRAC study. "No-fault" states are those where each "driver/owner accepts financial responsibiltiy for some or all losses sustained by himself, pedestrians hit by him and occupants of his own vehicle in return for which he enjoys immunity from liability for losses to third party persons"; "add-on" states are "those states with legislation adding no-fault coverage to tort liability law, with no restriction on tort liability"; and tort liability states are those where the insured person is legally liable "for acts of negligence resulting in injury to third parties," wherein the insured commits "an infringement (tort) on the civil rights of the individuals injured" (All-Industry Research Advisory Committee 1979, volume I, p.9).

The states with complete or partial reliance on a no-fault auto insurance system have major differences in their systems which involve:

> . . . dollar limits on medical and hospital expenses (unlimited in some states), funeral and burial expenses, lost income and the amount to be paid a person hired to perform essential services that an injured non-income producer such as a housewife is unable to perform; also, conditions governing the right to sue which usually include death, serious injury, and a point at which medical expenses reach a stipulated amount. (Insurance Information Institute 1980, p.68)

As a result of these differences, even states that are grouped together as having no-fault systems will have different distributions of reparations for accident costs.

The AIRAC study aggregated the data it acquired in a consumer panel

TABLE 3-12

PERCENT OF ECONOMIC LOSS PAID BY REIMBURSEMENT SOURCES BY STATE GROUPINGS (1)

State Grouping	Group Health	Workers Compensation	Auto Insurance	Government Sources	Other Insurance
Tort	22.5%	4.1%	63.3%	8.8%	1.3%
No-fault	19.5	3.4	75.5	.5	1.1
Add-on	30.0	.2	67.8	1.8	.1
TOTAL	22.3%	3.5%	67.5%	5.6%	1.1%

(1) Source: All-Industry Research Advisory Committee 1979, volume I, p.128.

Note: See text for definitions of state groupings.

TABLE 3-13

AIRAC CLASSIFICATION OF STATES BY TYPE
OF AUTO INSURANCE SYSTEM (1)

No-Fault States:

Colorado	Hawaii	Michigan	New York
Connecticut	Kansas	Minnesota	North Dakota
Florida	Kentucky	Nevada	Pennsylvania
Georgia	Massachusetts	New Jersey	Utah

Add-On States:

Arkansas	Maryland	South Carolina	Texas
Deleware	Oregon	South Dakota	Virginia

(1) Source: All-Industry Research Advisory Committee 1979, volume I, p.9.

Note: See text for definition of no-fault and add-on systems.

study by amount of economic loss and by amount of reparations. Injury data on severity and body region injured were apparently collected, but not reported in the consumer panel portion of the published study. The economic loss measure is the only variable in their study that could be used as a measure of severity, but economic loss shows little correlation with injury severity scales (AIS, ISS, KABCO, etc.) used in data bases that have restraint information needed to make cost savings estimates for this study. This lack of correlation is illustrated in Table 3-14 with twelve AIS = 4 and thirteen AIS = 5 injuries reported in an HSRI study (Marsh, Kaplan, and Kornfield 1977). The wide ranges, large discrepancy between means and medians, and size of the standard deviations relative to the means emphasizes the need to collect more than just injury severity data. Knowledge of the vicitim's demographic cohort, injury type, and body region affected are also needed to accurately estimate economic costs for an individual victim (See also Reinfurt et al. 1978; Callaway and Drucker 1979; Stiffman 1978).

Although one cannot estimate the distribution of the cost of nonuse of restraints from data in the AIRAC consumer panel study, those data do give the best information available on the incidence of the payment for injury costs. Table 3-15 shows the incidence by amount of economic loss. Automobile insurance bears 97.6% of the burden for injuries with no economic loss where some form of payment was received by the injured. Auto insurance bears the majority of payment for all levels of injury severity except the most serious (economic loss greater than $10,000), where group health insurance provides a larger share of payment. Overall, group health insurance paid 22.3% of the total reparations paid to individuals in the AIRAC study, workers compensation paid 3.5%, auto insurance paid 67.5%, government sources paid 5.6%, and other insurance sources contributed 1.1% to the total reparations paid.

An earlier study by the U.S. Department of Transportation (1970) estimated incidence of accident costs using medical insurance, life insurance, auto medical insurance, collision insurance, net tort, and wage replacement (sick leave, workers compensation, social security, etc.) as the sources of reimbursement for seriously injured and fatal victims of

TABLE 3-14

RANGE, MEAN, MEDIAN, AND STANDARD DEVIATION
OF AIS 4 AND 5 INJURIES (1)

AIS	LOW	HIGH	MEAN	MEDIAN	STANDARD DEVIATION	N
4	$4,457	$217,979	$46,924	$18,121	$64,494	12
5	4,730	364,693	68,134	19,110	97,006	13

(1) Source: Marsh, Kaplan, and Kornfield 1977, p.26.

TABLE 3-15

AIRAC ESTIMATES OF THE PERCENT PAID BY PRINCIPAL REIMBURSEMENT SOURCES FOR ALL INJURIES*, 1975-1977 DATA (1)

SIZE OF ECONOMIC LOSS	GROUP HEALTH	WORKERS COMPENSATION	AUTO INSURANCE	GOVERNMENT SOURCES	OTHER INSURANCE	TOTAL
$ 0	2.2%	0.0%	97.6%	.2%	0.0%	100.0%
1-100	12.6	1.2	81.4	3.3	1.5	100.0
101-300	11.2	.2	86.5	1.3	0.8	100.0
301-500	9.0	.9	88.6	.1	1.3	100.0
501-1,000	8.4	.4	90.6	.5	.2	100.0
1,001-2,500	9.2	1.6	86.5	2.2	.5	100.0
2,501-5,000	21.8	8.2	63.3	4.5	2.2	100.0
5,001-10,000	24.0	9.3	63.6	2.0	.9	100.0
10,001-25,000	26.9	3.2	46.8	20.9	2.1	100.0
over 25,000	76.3	0.0	23.2	.5	0.0	100.0
All Victims	22.3%	3.5%	67.5%	5.6%	1.1%	100.0%

(1) Source: All-Industry Research Advisory Committee 1979, volume I, p.126.

* To qualify for inclusion in the consumer panel study, which formed the data base, an individual had to have reported an economic loss or payment as a result of an auto crash injury.

crashes sampled in the 1967 to 1969 period. Table 3-16 shows the incidence of cost estimates from this study after deducting collision insurance and net tort in order to make the results more comparable to the AIRAC study results.

Unlike the AIRAC study, the U.S. DOT study shows no consistent pattern for the payment of reparations to crash victims. Sample differences may account for much of the difference in results, but there is a more fundamental problem with the U.S. DOT data. The data from which Table 3-16 was calculated (U.S. Department of Transportation 1979, volume I, p.45, Table 3.15) are reproduced in Table 3-17 exactly as they appear in the U.S. DOT study. The table suggests that row elements sum to 100% for each row, yet that is far from accurate when compared to the actual row sums in the column labeled "Actual Total." The discrepancies are too large for rounding errors and no mention is made of missing data or unknown classifications. These errors make it difficult to interpret the data available in this study.

The AIRAC and U.S. DOT studies have provided data on the incidence or payment for injury costs on the basis of the individual victim's viewpoint. Other viewpoints--employers, insurance premium payers, automobile owners, etc.—are less well represented.

The National Safety Council (NSC) has done some work to estimate the incidence of injury costs from the employer's viewpoint. In Accident Facts (National Safety Council 1979, pp.24, 25), NSC has estimated total time lost, injury costs, and the number of victims for **all** work-related accidents. In 1978, total time lost was 245 million person days (45 million for injured workers and 200 million for other workers) with 120 million person days lost in future years as a result of 1978 accidents. The total accident cost for all types of accidents was $23 billion in 1978. Of that total $10.6 billion was for "visible costs" ($4.2 billion for wage losses, $3.9 billion for insurance administration, and $2.5 billion for medical costs), $10.6 billion was for other related costs (value of time lost by other workers, accident investigations, etc.), and $1.8 billion was for fire losses.

A rough idea of the amount of these costs that is attributable to

TABLE 3-16

U.S. DOT ESTIMATES OF THE PERCENT PAID BY PRINCIPAL REIMBURSEMENT SOURCES FOR SERIOUS AND FATAL INJURIES*, 1967-1969 DATA (1)

SIZE OF ECONOMIC LOSS	MEDICAL INSURANCE	LIFE INSURANCE	AUTO MEDICAL INSURANCE	WAGE REPLACEMENT SOURCES**	TOTAL
$ 0-499	17.2%	49.6%	15.1%	18.1%	100.0%
500-999	27.3	19.7	15.8	37.2	100.0
1,000-1,499	32.8	18.4	31.0	17.8	100.0
1,500-2,499	19.7	44.1	11.6	24.6	100.0
2,500-4,999	39.0	15.1	15.9	30.0	100.0
5,000-9,999	39.7	1.8	21.3	37.2	100.0
10,000-24,999	40.3	12.6	6.9	40.3	100.1
over 25,000	6.9	29.9	1.1	62.0	99.9
All Victims	19.5%	24.8%	7.6%	48.2%	100.1%

(1) Source: U.S. Department of Transportation 1970, volume I, p.45.

* Sample includes injuries with: medical costs (excluding hospital) of $500 or more, <u>or</u> two weeks or more of hospitalization, <u>or</u>, if working, three weeks or more of missed work, <u>or</u>, if not working, six weeks or more of missed normal activity.

** Sick leave, workers compensation, social security, and similar sources.

TABLE 3-17

PERCENT OF REPARATIONS RECEIVED FROM PRINCIPAL SOURCES AS COMPENSATION FOR SERIOUS INJURY OR FATALITY, BY AMOUNT OF ECONOMIC LOSS AND ACTUAL ROW TOTALS (1)

Total Economic Loss (1)	Total (2)	Medical Insurance (3)	Life Insurance (4)	Auto Medical Insurance (5)	Collision Insurance (6)	Net Tort (7)	Wage replace-ment* (8)	Actual Totals
$ 1-499	100	4.1	11.8	3.6	-	74.4	4.3	98.2
500-999	100	9.7	7.0	5.6	3.6	59.6	13.2	98.7
1,000-1,499	100	10.9	6.1	10.3	5.6	56.6	5.9	95.4
1,500-2,499	100	10.4	23.3	6.1	9.5	38.4	13.0	100.7
2,500-4,999	100	15.2	5.9	6.2	11.4	40.0	11.7	90.4
5,000-9,999	100	17.7	0.8	9.5	10.6	39.1	16.6	94.3
10,000-24,999	100	19.9	6.2	3.4	3.8	42.5	19.9	95.7
25,000 & over	100	5.5	23.7	0.9	1.2	17.3	49.2	97.8
Total	100	11.1	14.1	4.3	5.5	32.1	27.4	94.5

(1) Source: U.S. Department of Transportation 1970, Volume *, Table 3.15, p. 45.

* Sick leave, workmen's compensation, Social Security, and similar sources.

motor vehicle crashes can be estimated by noting the number of work-related deaths and injuries involving motor vehicles. Of 54,800 accidental, work-related deaths in 1978, 25,000 involved motor vehicles, and of 5.4 million disabling injuries, 1 million involved motor vehicles (National Safety Council 1978, p.25). These figures are translated into dollars in a publication of the Transportation Research Board (1980, p.6):

> On average, each such death [work-related fatalities] cost the victim's employer $120,000. When on-the-job injuries are added to deaths, motor vehicle crashes directly and indirectly cost employers a total of about $1.5 billion in 1978. The employer cost of vehicle crashes off the job is estimated by the National Safety Council to be an additional $1.9 billion.

One fundamental problem that has not been addressed in the studies reviewed in this section is that of developing an adequate definition of the incidence of injury cost that accounts for reparations that are sometimes greater than the economic loss estimates. Data from the AIRAC consumer panel study (Table 3-18) show that those who suffered least in economic terms received more reparations per dollar of loss than those who suffered greatest. On average, each of the four individuals with economic loss greater than $25,000 was not compensated for about $11,000 of economic loss while those who suffered no economic loss (forty-three persons) received an average of $1,294 above the amount of economic loss. Even more surprising is the indication that **all** forty-three who had zero economic loss received some compensation while one of the four with the greatest economic loss received **no** payment (All-Industry Research Advisory Committee 1979, volume I, p.125, Table 12.4). Evidence from the much larger AIRAC insurer study of auto injury (All-Industry Research Advisory Committee 1979, volume II, pp.54-77) and from the U.S. DOT study (U.S. Department of Transportation 1970, volume I, p.41) corroborate this uneven distribution of compensation shown by the ratio of reparations to economic loss as a function of economic loss.

Incidence of injury cost estimates based on these data could lead to the conclusion that victims with "expensive" injuries bear almost half of the expense of their crashes while those with "inexpensive" injuries

TABLE 3-18

EXTENT OF REIMBURSEMENT BY SIZE OF LOSS--ALL INSURANCE AND GOVERNMENT SOURCES COMBINED (1)

Size of Economic Loss	Number of Persons	Average Amount of Loss	Average Payment Received	Payment for Each $1 of Economic Loss
$ 0	43	$ 0	$ 1,294	$ -
1-100	410	55	160	2.90
101-300	246	186	384	2.07
301-500	108	417	750	1.80
501-1,000	91	751	1,641	2.18
1,001-2,500	100	1,675	3,647	2.18
2,501-5,000	55	3,615	4,736	1.31
5,001-10,000	28	6,918	8,748	1.26
10,001-25,000	22	16,131	15,632	.97
over 25,000	4	52,025	40,926	.79
All Victims	1,107	$1,179	$1,648	$1.40

(1) Source: All-Industry Research Advisory Committee 1979, p.131.

"make" money as a result of being involved in a traffic crash. Individuals with inexpensive, minor injuries may profit economically because of overlapping insurance coverage, dishonest claims, etc., but some reparations are undoubtedly intended to cover intangible, noneconomic losses (e.g., pain, suffering, disability, inconvenience, etc.) that are **not** included in the economic loss figures. Because of the reparations paid for these intangibles, it would be inappropriate to use economic loss as a base for incidence of cost estimates from these data. To use such insurance data correctly, one needs a definition and quantification of a dollar value for items usually judged nonquantifiable (see Section 3.2.2.1), or a means for subtracting reparations paid only for intangible losses. Both of these needs would be very difficult to meet.

Though use of an appropriate base would remove the difficulty in interpreting data like that in Table 3-18, it would not eliminate the uneven distribution of reparations. The uneven distribution is due to such factors as limits on insurer liability, inadequate compensation for wage loss due to death or disability, and other problems with the injury compensation system not related to compensation paid for intangible cost components.

In summary, existing data on the incidence of injury costs are inadequate for estimating the cost of nonuse of economic restraints by sector. Only aggregate, "top-level" estimates such as those in Section 4.0 are possible until work is done to:

- Better define the role of intangible, noneconomic losses in incidence of injury cost estimates, i.e., specify an appropriate incidence-of-cost estimate through inclusion of intangible cost items in the base or exclusion of reparations paid exclusively for intangibles;

- Identify the causes and extent of redistribution of income and resources between sectors through passing on, taxation, insurance premiums, and income redistribution;

- Develop consistent data for all sectors--society, victim, employer, insurance company, etc.; and

- Define more exactly the impact of the various state auto insurance and workers compensation systems.

3.4 Summary and Conclusions

Published studies relevant to this study tend to fall into two broad categories:

- full studies that have developed estimates of the effectiveness and/or benefits of occupant restraints in reducing injury costs; and
- component studies that have developed estimates of the factors that are needed to calculate effectiveness or benefits. Such factors include injury severity distributions, unit costs of injuries, and restraint use rates.

A third area of significant concern to this study, the matter of who pays these costs (i.e., incidence of costs), has been neglected almost entirely. No study was found to have data elements necessary to allocate the cost of nonuse of restraints by sector.

Three recent full studies of the effects of restraints and the economic costs of injuries in North America have been conducted. One of these was in Canada and used cost elements that were too incomplete for adoption in this study. Of the other two, only one (the study by HSRC researchers) actually developed the data used in its effectiveness and benefits estimation. The main drawbacks of the HSRC study vis-a-vis this study are its restrictions to certain classes of crashes and its limitation of the cost components considered. Also, the HSRC study developed only the unit cost per occupant per crash of nonuse of restraints and made no attempt to estimate any nationwide cost of nonuse. Its estimate of this unit cost (called "direct" costs by the authors) was about $321 in 1974 dollars. This figure is for lap-and-shoulder belts.

The second full study (by the DeLorean Company) was more comprehensive than the HSRC study, but used severity reduction data from other studies. It is not clear whether any attempts were made to account for the confounding effects of other variables on injury severity reductions due to restraint use. The DeLorean study estimated nationwide societal benefits of from $1 billion to $9 billion, depending on the type and use rate of the restraint.

Many studies have examined various parts of the problem of economic costs of restraint nonuse. Most of these studies have been concerned only with the effects of restraint use on injury severity. Only a few are applicable to this study because most studies do not attempt to account for the possible confounding effects of nonrestraint factors, are limited in the populations they treat, or are now out of date. The most careful of the applicable studies is the HSRC study, while the most recent published injury **data** (unadjusted for interactions) come from the first fifteen months of the NCSS effort (January 1977 through March 1978).

Very few published studies have analyzed traffic crash costs as a function of injury severity. The data in these studies are difficult to apply to this study because of

- the lack of common definitions of individual cost components,
- the higher level of aggregation of cost components, and
- the lack of information about the samples used.

The result is that these studies can only be used to get a rough idea of the range of injury costs. The studies by HSRC and Faigin of NHTSA appear the most appropriate for this purpose.

4.0 COST ESTIMATES

This section uses published data selected from the literature reviewed in the preceding section to estimate the costs of not using occupant restraints. Because of the paucity of data on restraint use among occupants of crashed vehicles in general, the estimates are for a particular subpopulation of such occupants. The subpopulation is composed of occupants of passenger cars involved in crashes so severe that the vehicles had to be towed from the crash scene.

The use of these towaway crashes of passenger cars as the major target of the analysis is contrary to our original intent, but is less restrictive than it may seem at first. The greater severity of the crashes makes it more likely that the full injury-reducing potential of the restraints will be underscored and not be masked by other factors. Further, there are far more passenger cars than other types of vehicles in crashes. (The National Safety Council [1979, p.56] estimates passenger cars comprise 78.1% of the vehicles involved in all crashes and 65.1% of the vehicles involved in fatal crashes in 1978.)

The type of restraints considered in the cost calculations are lap-and-shoulder belts. This is necessary because the most reliable published data for analyzing costs are most applicable to this type of restraint.

Both unit costs and nationwide costs are considered. Some rough extrapolations of the costs for the restricted crash population to the more general population of crashes are presented at the end of this section.

4.1 Towed Passenger Cars

This subsection develops a first estimate of the nationwide costs of not using occupant restraints in passenger cars that are towed from the scene of a crash. As noted in previous sections, three major categories of ingredients are needed to compute such costs:

- frequency distributions of injury severity for occupants with and without restraints;
- expected unit costs of injuries of various severities; and
- numbers of crash-involved occupants with and without restraints.

The sources of data used to derive these three ingredients and the assumptions made in our analysis of their use are discussed first. The nationwide costs are then computed and discussed.

4.1.1 Injury Distributions. The published literature contains three possible sources of relevant injury distribution data that are recent enough for this analysis. The sources are:

- the report on the National Crash Severity Study (NCSS) statistics edited by Ricci (1979);
- the HSRC study of Level 2 accident investigation data from five geographic regions (Reinfurt, Silva, and Seila 1976); and
- the USC study of Level 2 accident investigation data from California (Baird et al. 1977).

Other studies of Level 2 data (e.g., Cromack et al. 1976; Scott, Flora, and Marsh 1976) are not readily applicable to this analysis because the injury distributions used are not presented in the reports.

The NCSS data cover all occupants in applicable crashes. The data are also very recent, having been collected during the period January 1977 through March 1978. Cars of all model years in applicable crashes are represented. However, the data are not representative of towaway passenger car crashes nationwide, although the source states that the "aggregate of the seven geographical areas used has an urbanization close to that of the entire United States" (Ricci 1979, p. iv). Perhaps an even more serious problem in using the NCSS data in this analysis is that the data as presented are raw data. No attempt has been made to "control" for confounding effects through post hoc manipulations of the data. Thus, it cannot be said that the observed differences in injury distributions with and without restraints are actually due to the restraints.

The HSRC study is the only one of the three that has attempted to remove differences in the distributions caused by other factors. Also, while its data are not truly "representative" of applicable crashes nationwide, the five locations chosen (western New York, Michigan, Miami, San Antonio, and Los Angeles) provide a wide range of geographical attributes. On the other hand, the study was deliberately limited to 1973-1975 model cars and thus does not apply to the present mix of passenger cars in the vehicle fleet. However, such a limitation has the advantage that the restraint systems and other safety features were similar for all cars in the sample.

Finally, the HSRC study was limited to occupants of outboard front seats. This limitation is inconsequential when analyzing lap-and-shoulder belts or when comparing lap-and-shoulder belts with other restraints, since such belts were available only at these positions.

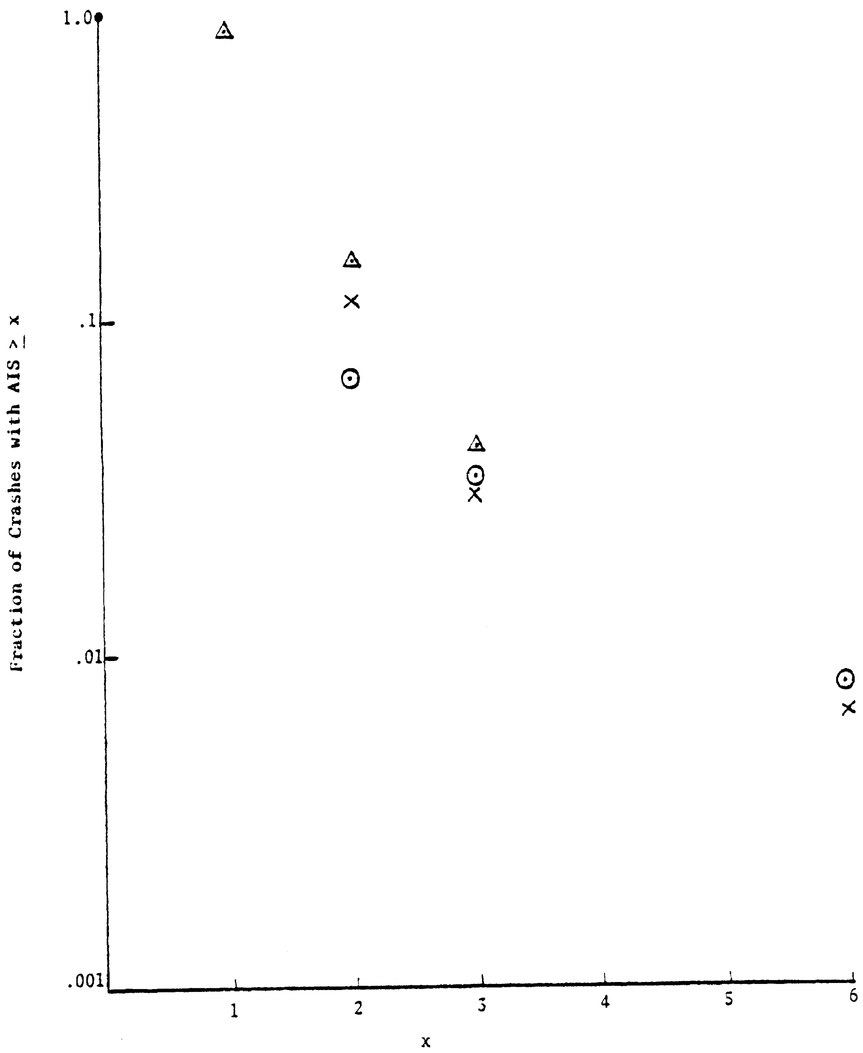
The USC study has most of the limitations of the HSRC study, but did not attempt to account for the effect of nonoccupant restraint factors on injury severity. It also had a smaller sample size (about half as many vehicles) and included crashes only from the Los Angeles area.

It is interesting that, despite the differences in these three data bases, the injury severity distributions are fairly close. Plotted on a semilogarithmic scale (see Figures 4-1, 4-2, and 4-3), the differences appear as "normal" scatter throughout most of the AIS range. Particularly, the NCSS and the HSRC data are quite close together at the higher AISs, except for the lap-belts category, where large differences exist at AIS = 6. This could be due to the very small number of fatally injured drivers who wore lap belts (13 in NCSS and 4 in the HSRC study). Large differences also exist at AIS = 2 for all categories of restraint use, but these differences will have a smaller effect on cost than an equal difference at higher AISs would have. There is no obvious explanation for the observed difference at AIS = 2.

On balance, it appears that the HSRC injury data offer the fewest pitfalls in arriving at a first estimate of the effect of occupant restraints

FIGURE 4-1

INJURY SEVERITY DISTRIBUTIONS FOR OCCUPANTS OF OUTBOARD FRONT SEATS OF TOWED PASSENGER CARS IN TOWAWAY CRASHES--NO RESTRAINTS USED



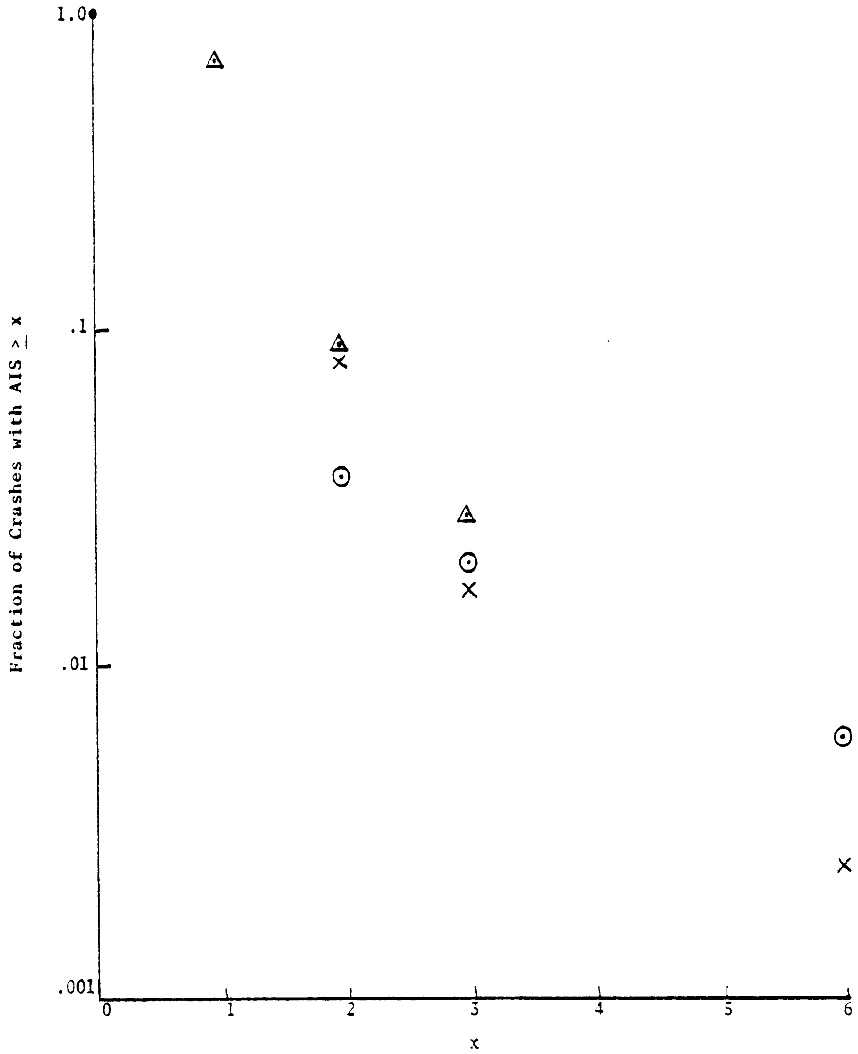
ʘ NCSS (Ricci 1979)

X HSRC, Adjusted, Mantel-Haenszel (Reinfurt, Silva, and Seila 1976)

Δ USC (Baird et al. 1977)

FIGURE 4-2

INJURY SEVERITY DISTRIBUTIONS FOR OCCUPANTS OF OUTBOARD FRONT SEATS OF TOWED PASSENGER CARS IN TOWAWAY CRASHES--LAP BELTS USED



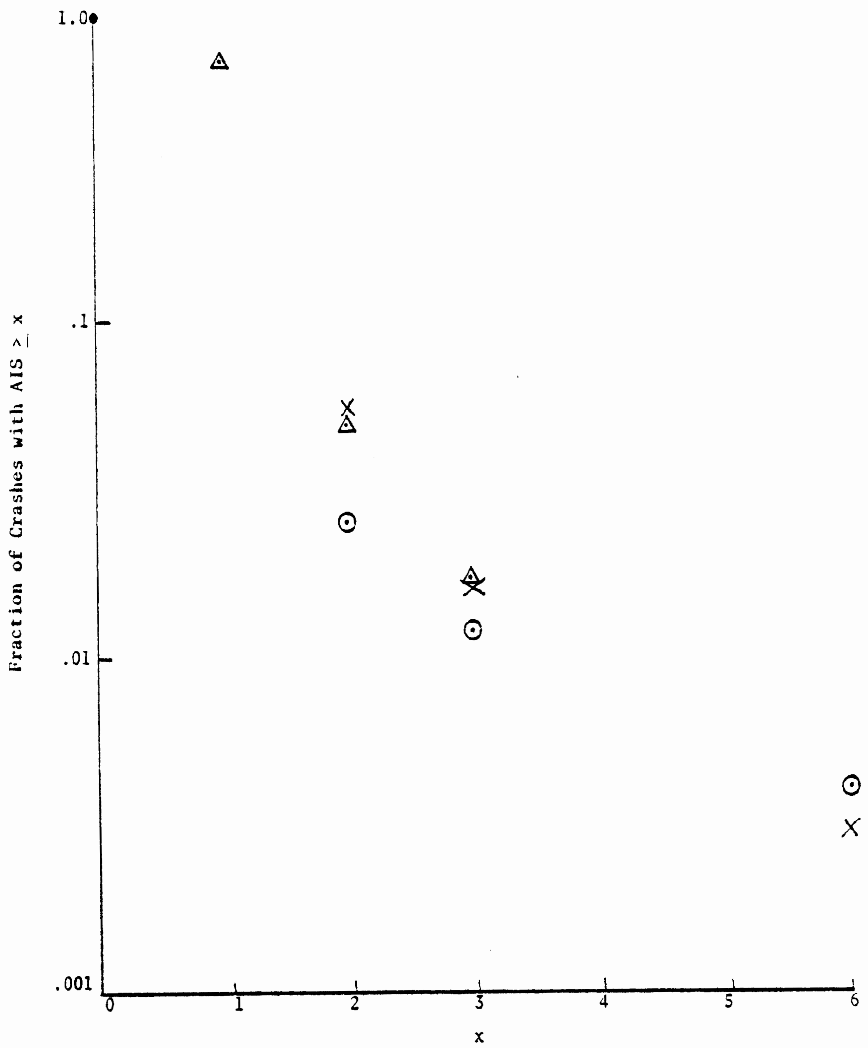
ʘ NCSS (Ricci 1979)

X HSRC, Adjusted Mantel-Haenszel (Reinfurt, Silva, and Seila 1976)

Δ USC (Baird et al. 1977)

FIGURE 4-3

INJURY SEVERITY DISTRIBUTIONS FOR OCCUPANTS OF OUTBOARD FRONT SEATS OF PASSENGER CARS IN TOWAWAY CRASHES--LAP-AND-SHOULDER BELTS USED



⊙ NCSS (Ricci 1979)

X HSRC, Adjusted Mantel-Haenszel (Reinfurt, Silva, and Seila 1976)

△ USC (Baird et al. 1977)

on the cost of injuries incurred in towaway crashes of passenger cars. Clearly, the HSRC data are better suited to our purposes than the USC data. However, because of uncertainties in the quantitative effects of the differences between the HSRC data and the NCSS data, we will retain both sets at this juncture and calculate costs using both sets. Differences in cost estimates can be then viewed as being due to uncertainties about the injury distributions with and without restraints. Table 4-1 shows the injury distributions from the HSRC and NCSS studies for the no-restraint and lap-and-shoulder belt categories. The numbers are based on data plotted in Figures 4-1 and 4-3. The last columns in the table list the differences between the probability of a given injury with no restraint and the probability of a given injury with a lap-and-shoulder belt restraint. The numbers shown for AIS = 1, 4, and 5 were derived through a log-linear interpolation of the data in Figures 4-1 and 4-3.

4.1.2 Unit Cost Functions. Only two sources were found to have documented cost data in a form suitable for this analysis. The first (and most widely used source in the highway safety field) is the NHTSA societal cost study by Faigin (1976). The second is the HSRC study by Reinfurt, Silva, and Seila (1976). The two studies differ widely in their purpose and approach, as noted in Section 3.0. Faigin's study sought to:

> . . . derive cost estimates that adequately reflect certain losses to society. Some losses are to individuals as a part of society and others are to society external to the individual. The two basic citeria for identifying loss components are (1) resources consumed in the repair of damage to people and vehicles that could be shifted in the long run to welfare-producing activities and (2) the consumption losses of individuals and society at large caused by losses in production and the ability to produce. (Faigin 1976, p. 1.)

The HSRC cost analysis had much more modest objectives, seeking merely to estimate what its authors defined as the "direct costs" of injury.

Some of the lower-level components of costs used in building up the costs in the two studies are sufficiently similar to allow direct

TABLE 4-1

INJURY SEVERITY DISTRIBUTIONS

FROM THE NCSS[1] AND HSRC[2] STUDIES

AIS (=i)	$P_{\bar{R}}(i)$[3]		$P_R(i)$[4]		$\Delta P(i)$[5]	
	HSRC	NCSS	HSRC	NCSS	HSRC	NCSS
0	.660	.745	.766	.842	-.085	-.076
1	.226	.188	.179	.133	.047	.055
2	.0840	.034	.0390	.0130	.045	.021
3	.0120	.0125	.0070	.0038	.0050	.0087
4	.0071	.0075	.0040	.0025	.0031	.0050
5	.0042	.0050	.0020	.0017	.0022	.0033
6	.0067	.0080	.0030	.0040	.0037	.0040

1. National Crash Severity Study (Ricci 1979).
2. Highway Safety Research Center (Reinfurt, Silva, and Seila 1976).
3. Probability that occupant will incur an injury of severity i, given a crash <u>and</u> no restraint.
4. Probability that an occupant will incur an injury of severity i, given a crash <u>and</u> a lap-and-shoulder belt restraint.
5. $\Delta P(i) = P_{\bar{R}}(i) - P_R(i)$

comparison were their values known. For example, HSRC's costs were calculated as the sum of hospital costs, professional fees, lost wages, and funeral expenses. Faigin's costs contain these components plus others. Unfortunately, the **values** of HSRC's components are not presented in its study report so it is not possible to compare them with the cost components presented in Faigin's report.

Nevertheless, costs from both reports are of interest to this study, if for no other reason than they provide a benchmark for further comparisons later in our project. Some adjustments in the costs are needed, though, to place them in the context of the present economic environment. The rationale behind the adjustments is discussed in section 3.2.

Tables 4-2 and 4-3 present the resulting calculations. Applicable unit costs of not wearing restraints are presented in Table 4-4. The unit costs are stated in terms of dollars per occupant of an outboard front seat of passenger cars towed from the crash scene. The unit costs were calculated by multiplying each injury cost component in Tables 4-2 and 4-3 by the probability differences from Table 4-1 and summing the resulting products over all injury severities.

The results show surprisingly small differences between costs computed using the HSRC and the NCSS injury severity distributions. The societal costs based on NCSS injury data are about twenty-two percent higher than the societal costs based on HSRC injury data. However, the so-called direct costs based on NCSS injury data are only about seven percent higher than the direct costs based on HSRC injury data. The reason that this latter figure is so low is that "direct" costs are relatively insensitive to percentage of injuries at the lower AISs. The differences between the NCSS and the HSRC injury distributions occurred at these lower AISs.

The unit "societal" cost savings from wearing lap-and-shoulder belts is about $2,500 to $3,100, or about five to six times the "direct" cost savings. The two major factors contributing to the large difference between societal and direct cost appear to be a large component of lost-productivity cost and a "home, family, and community" component in

TABLE 4-2

"DIRECT" COST OF INJURIES AS A FUNCTION OF AIS [1]

AIS	1974 Dollars Avg. Cost	May 1979 Dollars Avg. Cost	N
1	$ 130.56	$ 204.99	8100
2	548.30	860.89	1317
3	1,340.18	2,104.22	273
4	1,688.79	2,651.57	48
5	2,893.23	4,542.66	13
6	68,516.68	107,578.04	96
			9,847

(1) Source: Reinfurt, Silva, and Seila 1976, adjusted by the consumer price index for all items (U.S. Bureau of the Census 1979, p.483).

TABLE 4-3

"SOCIETAL" COSTS OF INJURIES AS A FUNCTION OF AIS[1]
(May 1979 Dollars)

	AIS					
Cost Component	6	5	4	3	2	1
Production/ Consumption						
Market	281,339	168,217	73,782	2,185	1,149	86
Nonmarket	84,400	60,465	22,128	564	412	27
Medical						
Hospital	424	8,862	3,468	1,688	694	69
Physician & other	227	7,843	3,069	746	234	78
Coroner-medical examiner	143	--	--	--	--	--
Rehabilitation	--	8,514	4,261	--	--	--
Funeral	1,229	--	--	--	--	--
Legal & Court	2,909	2,185	1,448	1,023	199	186
Insurance Administration	392	392	379	319	292	69
Accident Investigation	106	106	93	60	46	37
Losses to others	4,894	5,552	2,431	345	173	43
Traffic Delay	106	80	80	213	213	213
TOTAL	376,169	252,216	111,139	7,143	3,412	808

(1) Source: Faigin 1976, adjusted by the consumer price index for applicable budget categories (U.S. Bureau of the Census 1979).

TABLE 4-4

UNIT COSTS OF NOT WEARING LAP-AND-SHOULDER BELTS IN PASSENGER CARS TOWED FROM THE SCENE OF A CRASH

(May 1979 dollars)

COST COMPONENT	HSRC[4] INJURY DISTRIBUTIONS	NCSS[5] INJURY DISTRIBUTIONS
"SOCIETAL COSTS"[1]		
Market	1,706	2,097
Home, Family, Community	537	663
Medical[2]	153	189
Funeral	5	5
Legal/Court	43	49
Insurance Administration	21	17
Accident Investigation	5	5
Losses to Others	49	59
Traffic Delay	21	19
TOTAL	2,540	3,103
"DIRECT COSTS"[3]	475	506

1. From Faigin (1976), adjusted (see Table 4-3).

2. Includes hospital, physician, coroner/medical examiner, rehabilitation.

3. From Reinfurt, Silva, and Seila (1976), adjusted (see Table 4-2); includes hospital, professional fees, lost wages, and funeral costs.

4. Distributions from Reinfurt, Silva, and Seila (1976).

5. Distributions from Ricci (1979).

the societal costs. The only comparable component in the direct costs is a lost wage cost, which appears to be small compared to these two factors.

4.1.3 Nationwide Cost of Nonuse. The maximum possible nationwide cost of not wearing lap-and-shoulder belts in towaway crashes of passenger cars towed from the scene of a crash can be computed by multiplying the unit costs listed in Table 4-4 by the number of occupants in outboard front seats of all such vehicles in applicable crashes nationwide. Algebraically,

$$\Delta C_{N_{max}} = N_O \Delta c_R ,$$

where

$\Delta C_{N_{max}}$ = maximum nationwide cost of not using lap-and-shoulder belts in outboard front seats of towed passenger cars in applicable crashes

N_O = number of occupants in outboard front seats of towed passenger cars in applicable crashes

Δc_R = unit costs of not using lap-and-shoulder belts in outboard front seats of towed passenger cars in applicable crashes (from Table 4-4).

We estimate N_O from the following expression:

$$N_O = k_1 \; k_2 \; N_T ,$$

where

k_1 = ratio of number of outboard front seat occupants of towed passenger cars in applicable crashes to number of all occupants of towed passenger cars of applicable crashes

k_2 = ratio of number of all occupants of towed passenger cars in applicable crashes to number of applicable crashes

N_T = number of applicable crashes per year.

From Ricci (1979),

$$k_1 = .636 + .209 = .845 \qquad \text{(p. 56)}$$

$$k_2 = \frac{62026}{31867} = 1.946 \qquad \text{(p. 2)}$$

An analysis by Gimotty (1980) suggests that some 2.4 to 2.7 million towaway crashes involving passenger cars occurred during the first fifteen months of the NCSS data collection effort. We will assume a number of 2.5 million here. Thus,

$$N_T = \frac{12}{15} \times 2.5 \times 10^6 = 2.0 \times 10^6, \text{ and}$$

$$N_0 = .845 \times 1.946 \times 2.0 \times 10^6$$

$$= 3.29 \times 10^6$$

Applying this multiplier to the unit cost data in Table 4-4 yields the maximum nationwide costs per year of not using lap-and-shoulder belts in towaway crashes of passenger cars. These cost savings are presented in Table 4-5.

The societal costs are about \$8.4 billion to \$10.2 billion per year, depending on the injury distribution data used. Medical costs alone make up about \$0.5 billion of this amount. So-called "market" costs due to loss of productivity are by far the largest component of societal costs, amounting to some \$5.6 to \$6.9 billion per year. The direct cost components as defined by Reinfurt, Silva, and Seila (1976) also add up to a significant amount, about \$1.6 to \$1.7 billion per year.

Of course, these figures are maximum amounts for the conditions analyzed and thus are greater than could be saved through any actual countermeasure program. They are also slightly higher than the current cost of nonuse, since some four percent of all occupants of towaway crashes of passenger cars do wear lap-and-shoulder belts (Ricci 1979, p. 58). Nearly all of the lap-and-shoulder belt wearers and a few of the lap-belt wearers could be expected to be occupants of outboard front seats.

As was noted in Section 3.0, the question of who pays these costs has not been analyzed in any depth in published studies. Faigin's cost components are viewed from the perspective of all society, with no explicit discussion of which segments of society pay which costs. The cost components presented in the HSRC study appear to be viewed from the perspective of the accident victim and his family, but again there is no discussion of how portions of these costs may be transferred to other sectors of society (for example, government agencies and private business organizations).

4.2 Extensions of the Data on Towaway Crashes of Passenger Cars

Injuries to occupants of outboard front seats of passenger cars involved in towaway crashes can be expected to be a significant and probably major contributor to the total economic cost of not using occupant restraints. This is because:

- the more serious, and thus the most costly injuries occur more frequently to front seat occupants;
- most occupants sit in the front seat;
- towaway crashes are more likely to result in more serious injuries; and
- there are far more passenger cars than other vehicles in the vehicle fleet.

Unfortunately, no accurate estimates of the effects of these factors on the cost of restraint nonuse are possible from published estimates. Certainly, including other passenger car occupants in the calculations would not raise the cost estimate in the preceding subsection by any more than that obtained by using the number of all occupants instead of the number of outboard, front-seat occupants in the calculations. This would increase the costs in Table 4-5 by about twenty percent.

Including nontowaway crashes of all types in the calculations would have the effect of moving the distributions in Figures 4-1, 4-2, and 4-3 to the left. A rough idea of the magnitude of this shift on the cost of nonuse of restraints can be gained by assuming that the ΔP's in Table 4-1 go to zero for AIS = 3, 4, 5, and 6 but remain the same at AIS = 1 and 2. The number of outboard occupants in these nontowaway crashes could

TABLE 4-5

MAXIMUM ANNUAL NATIONWIDE COST OF NOT WEARING
LAP-AND-SHOULDER BELTS IN TOWAWAY CRASHES OF PASSENGER CARS

(Millions of May 1979 dollars)

COST COMPONENT	HSRC INJURY DISTRIBUTION	NCSS INJURY DISTRIBUTION
"SOCIETAL" COSTS[1]		
Market	5,613	6,899
Home, Family, Community	1,767	2,181
Medical	503	622
Funeral	16	16
Legal/Court	141	161
Insurance Administration	69	56
Accident Investigation	16	16
Losses to Others	161	194
Traffic Delay	69	63
TOTAL	8,358	10,208
"DIRECT" COSTS[2]	1,563	1,665

1. From Faigin (1976), adjusted.

2. From Reinfurt, Silva, and Seila (1976), adjusted.

be "guestimated" by assuming:

- there are 4.0×10^6 - 2.0×10^6 nontowaway, personal injury crashes per year (the first figure is from [Faigin 1976]), and
- the factors k_1 and k_2 are the same as for towaway crashes.

The resulting calculations show an additional "societal" cost of about $0.6 billion and an additional "direct" cost of about $0.1 billion. For societal costs, this amounts to an increase of some six percent over the costs calculated for towaway crashes. Not using lap-and-shoulder belts in the nontowed vehicles in towaway crashes could account for another two percent. Combining this factor with the twenty percent factor calculated above would increase the societal costs in Table 4-5 by about thirty percent. The direct costs would increase by a slightly larger percentage.

4.3 Summary and Conclusions

Published data on towaway crashes of passenger cars indicate that lap-and-shoulder belts reduce the risk of injury to occupants of outboard front seats of the cars involved in towaway crashes. The largest percentage reductions in risk occur at the higher injury severities, but significant reductions occur even at the lowest levels of severity. It appears that the incidence of fatal injuries among such occupants can be reduced by about one half by the use of lap-and-shoulder belts. The incidence of severe to critical injuries in this population can be reduced some forty to fifty percent, and minor to moderate injuries can be reduced about twenty percent and fifty percent, respectively.

These reductions in injury severity result in corresponding reductions in economic costs due to injury. Viewed another way, the expected cost of injuries incurred when lap-and-shoulder belts are **not** worn are higher than the expected cost of injuries incurred when such restraints **are** worn.

Based on the HSRC and Faigin studies, the average economic loss for an occupant of a passenger vehicle towed from a crash scene who did not use an available lap-and-shoulder restraint is estimated at about $500 in "direct" costs and $2,500 for "societal" costs that include direct costs. An average societal cost estimate of $3,100 may be obtained if NCSS data are used to calculate the average economic loss due to nonuse of available occupant restraints.

A nationwide estimate for occupants of cars towed from crashes who do not use lap-and-shoulder restraints is about $1.6 billion in direct costs. Total cost estimates for this population are about $8.4 billion. These cost estimates are in 1979 dollars and are annual costs for the population that formed the basis for the estimate (outboard front seat occupants of cars towed from the scene of a crash who did not use available lap-and-shoulder restraints). Inclusion of other types of occupants, vehicles, and crashes would increase estimates of economic costs by thirty percent or more.

5.0 CONCLUSIONS AND RECOMMENDATIONS

A three-part analysis is required to estimate the economic costs of nonuse of occupant restraints. These three parts are concerned with:

- the effects of nonuse on the severity of injuries incurred in crashes,
- the economic costs of such injuries, and
- the number of individuals in crashes who wear and who do not wear restraints.

Most of the published literature addresses the first and third of these parts. Very few studies have attempted to estimate the cost of traffic crash injuries as a function of injury severity. The studies that contain data on the effects of restraints on injury severity are concerned mainly with the effectiveness of various kinds of restraints in reducing injury severity. The effectiveness is usually defined (either explicitly or implicitly) as the percent reduction in injuries of a given severity when restraints are worn.

A serious problem in using data from most of these studies for our analyses is that they do not account for other factors that could have influenced injury severity among the populations studied. Thus, it is not known whether not using the restraints or some other factor caused the reduction in injury severity. The few studies that do attempt to account for these other factors either (1) have other methodological problems, (2) are restricted to specific subpopulations of drivers and vehicles, or (3) both.

The most careful, applicable study of restraint use and injury severity in this country was performed by researchers from the University of North Carolina Highway Research Center (HSRC). The study population was outboard front-seat occupants of passenger vehicles that were towed from the scene of a crash. They reported that shoulder-and-lap belts:

- reduced fatalities by 55%,
- reduced injuries of Abbreviated Injury Scale (AIS) three and higher by 46%, and
- reduced injuries of AIS two and higher by 52%.

Similar reductions in serious injuries have also been reported by other studies of similarly constituted populations of drivers (for example, data from the first fifteen months of data collection in the National Crash Severity Study [NCSS]).

Only two U.S. studies were found to have cost data in a form suitable for use in this study. The first was the HSRC study, which estimated "direct" costs, and the second was the NHTSA study (Faigin 1976), which estimated "societal" costs. Both studies presented their costs as a function of AIS. Direct costs included hospital costs, cost of professional fees, lost wages, and funeral costs. The societal costs included market costs (i.e., cost of losses in productivity); home, family, and community costs; medical costs; funeral costs; legal and court costs; the cost of insurance administration; the cost of investigating accidents; the costs of losses to others; and traffic delay costs.

5.1 Estimated Cost of Nonuse

These studies provide the best available data for developing preliminary cost estimates. For the population studied, we estimate that the direct cost of nonuse of a lap-and-shoulder restraint is about $500 per occupant per crash in 1979 dollars. This number is based on injury severity data and cost data developed by HSRC. The societal cost, which includes direct costs, is about $2,500 per occupant per crash in 1979 dollars. This number is based on injury data developed by HSRC and cost data developed by Faigin of NHTSA. These costs are for a crash-involved occupant of outboard front seats who did not use a lap-and-shoulder restraint in a passenger vehicle that was towed from the scene of a crash.

These estimates can be used to develop estimates of the total cost among the population nationwide involved in similar crashes. We estimate the nationwide direct costs to be of the order of $1.6 billion per year and the societal costs to be of the order of $8.4 billion per year for the nonuse of lap-and-shoulder restraints by crash-involved occupants of passenger vehicles that were towed from crashes.

We view these estimates as conservative. Use of severity data from the NCSS study would increase our cost estimate. Inclusion of other types of vehicles, crashes, and occupants in the calculations would also increase costs—probably by thirty percent or more. An estimate of $15 billion per year as the upper range of economic costs of nonuse of occupant restraints is a reasonable order-of-magnitude approximation.

5.2 Who Pays?

The important question of who pays these costs (i.e., the incidence of costs) could not adequately be addressed in the first phase of the study because of a lack of data in the published literature.

The language used in past studies implies that direct costs are paid by the victim or the family. Medical insurance is widespread. Many victims will have transferred the risk of injury loss through insurance—insurance that they have bought or that is provided for them by employers. Other victims will qualify for taxpayer-supported programs (e.g., Medicaid). Who actually pays the direct costs has not been established and needs to be addressed.

Similarly, the language of past studies implies that "societal" costs are paid by society rather than the victim. Clearly, there are important cost elements that are not paid by the victim that society does pay. What element of society bears which cost is not known. Thus, the question of who pays remains largely unanswered by research to date.

5.3 Future Directions

Two topics will be explored in the second phase of the study. The first, and most critical, is to develop methods for identifying the incidence of costs among various sectors of society. At this juncture, the sectors and the individual cost components themselves have not been identified with sufficient precision to warrant an in-depth analysis of a specific sector (e.g., industrial employers) to see what sectors pay what cost components. Similarly, an analysis of a given cost component (e.g., medical costs) to see what sectors pay that cost would be inappropriate, since the sectors that pay might not pay portions of other, perhaps more important, cost components (e.g., lost wages) that have not been clearly identified.

Thus, our approach will be to undertake data collection and analysis that will support the **identification** of sectors that bear significant portions of the important components of the cost of nonuse of occupant restraints. A case approach will be used. We will examine several past crashes to document the costs and who paid the costs. The possibility of using cases examined in two previous HSRI studies of traffic crash costs in Washtenaw County will be explored (Flora, Bailey, and O'Day 1975; Marsh, Kaplan, and Kornfield 1977). As these studies collected information on only nonfatal injuries, other cases would have to be included to develop fatal injury cost data.

This inquiry should lead to the preliminary identification of those sectors that appear to bear significant portions of the costs of nonuse of occupant restraints. This will support subsequent analysis of the sectors to determine the cost elements actually incurred. Such analyses will allow preliminary estimates of who pays what.

A second priority topic for the second phase of the study will be the continued examination of the data on injury severity. Existing data need to be expanded and associated with cost data. Much data on the effect of restraint use on injury severity exist in present accident investigation files but have not been published. We expect to undertake a limited effort to "mine" existing data. We recommend that more intensive efforts be funded to examine both the NCSS and early NASS (National Accident Sampling System) data files to see if presently available data on the distribution of injury severity can be improved or extended to other populations (e.g., small trucks and vans). The feasibility of using HSRC's analysis program for accounting for the effects of other factors on severity distribution should also be examined.

As this is an interim report of work in progress, we urge that a reader study it carefully to undertand the assumptions that were used in developing the estimates. We welcome comments. Refinement of the methods, the assumptions, and the estimates can be expected as the study progresses.

BIBLIOGRAPHY

Acton, J.P. 1976. Measuring the monetary value of life savings programs. Santa Monica, California: The Rand Corporation series A P-5675.

Aiken, H.J. 1976. Ontario seat belt law. Paper presented at National Motor Vehicle Safety Advisory Council meeting, 12-14 July 1976, Washington, D.C.

All-Industry Research Advisory Committee. 1979. Automobile injuries and their compensation in the United States. Volumes I and II. Chicago, Illinois: Alliance of American Insurers.

American Association for Automotive Medicine. 1980. The abbreviated injury scale: 1980 revision. Morton Grove, Illinois: American Association of Automotive Medicine.

Anderson, T.E. 1972. Final report: Analysis of vehicle injury sources. Buffalo, New York: Cornell Aeronautical Laboratory.

Andreassend, D.C. 1972. The effects of compulsory seat belt wearing legislation in Victoria. In National Road Safety Symposium. Canberra, Australia: Australian Department of Shipping and Transport.

Baird, J.; Sublett, F.; Hughes, R.; Didion, J.; Stoddard, J.; Wheatley, D.; Averett, V.; Clark, D.; and Zapiain, J. 1977. Restraint systems evaluation program. Final report. National Highway Traffic Safety Administration report no. DOT-HS-802-286.

Baker, S.P.; O'Neill, B.; Haddon, J., Jr.; and Long, W.B. 1974. The injury severity score: A method of describing patients with multiple injuries and evaluating emergency care. The Journal of Trauma 14(3):187-196.

Blomquist, G. 1977. Economics of safety and seat belt use. Journal of Safety Research 9(4):179-189.

Bodily, S.E. 1980. Analysis of risks to life and limb. Operations Research 28(1):165-175.

Bohlin, N.I. 1967. A statistical analysis of 28,000 accident cases with emphasis on occupant restraint value. In Proceedings of the 11th Stapp Car Crash Conference. New York: Society of Automotive Engineers.

Brennan, P. 1979. Monetary compensations of death. Society 17(1):62-69.

Brock, H.W. 1980. The problem of "utility weights" in group preference aggregation. Operations Research 28(1):176-187.

Calabresi, G. 1970. The costs of accidents: A legal and economic approach. New Haven: Yale University Press.

Callaway, D., and Drucker, C. 1979. Social consequences of accidents. National Highway Traffic Safety Administration report no. DOT-HS-805-214.

Campbell, G.J., and Reinfurt, D.W. 1979. The degree of benefit of belts in reducing injury - An attempt to explain study discrepancies. Warrendale, Pennsylvania: Society of Automotive Engineers technical paper series no. 790684.

Chen, B. 1979. Motor vehicle occupant restraint systems study. California: California Highway Patrol.

Conard, A.F.; Morgan, J.N.; Pratt, R.W., Jr.; Voltz, C.E.; and Bombaugh, R.L. 1964. Automobile accident costs and payments: Studies in the economics of injury reparation. Ann Arbor, Michigan: The University of Michigan Press.

Cooke, C. 1976a. Passenger car occupant injuries and their economic impact. In Societal costs of motor vehicle accidents, 1975. Final draft. Washington, D.C.: National Highway Traffic Safety Administration.

Cooke, C. 1976b. Usage of occupant crash protection systems. Unpublished manuscript, National Highway Traffic Safety Administration.

Cooke, C. 1979. Injury and fatality rates, with and without air bags. National Highway Traffic Safety Administration public docket no. 74-14.

Council, F.M., and Hunter, W.L. 1974. Seat belt usage and benefits in North Carolina accidents. Chapel Hill, North Carolina: University of North Carolina Highway Safety Research Center.

Court, R.J. 1977. Compulsory seat belt wearing in western Australia. In Proceedings of the sixth international conference of the International Association for Accident and Traffic Medicine. Melbourne, Australia.

Cromack, J.R.; Mason, R.L.; Pryor, J.W.; Schreyer, G.W.; Scofield, M.A.; and Swiercinsky, T.H. Multidisciplinary accident investigations—Special study of active and passive restraint systems in 1973-1976 model year vehicles. Volume I. Restraint systems effectiveness program. Final report. National Highway Traffic Safety Administration report no. DOT-HS-801-973.

Dalmotas, D.J., and Keyl, P.M. 1979. An investigation into the level of protection afforded to fully restrained passenger vehicle occupants. In

American Association for Automotive Medicine Quarterly Journal VI(2):25-29.

Dawson, R.F.F. 1967. Costs of road accidents in Great Britain. London: Department of the Environment RRL report LR79.

Dutt, K., and Reinfurt, D.W. 1977. Accident involvement and crash injury rates by make, model, and year of car: A follow-up. Final report: December 1, 1975-June 30, 1977. National Highway Traffic Safety Administration report no. DOT-HS-802-428.

Faigin, B.M. 1976. 1975 Societal costs of motor vehicle accidents. Washington, D.C.: U.S. Department of Transportation.

Filkins, L.D.; Scott, R.E.; O'Day, J.; and Kubacki, M. 1978. Multilevel study of accident causation and avoidance: Phase IA planning report. Interim report. National Highway Traffic Safety Administration report no. DOT-HS-805-177.

Flora, J.D.; Bailey, J.; and O'Day, J. 1975. The financial consequences of auto accidents. Hit Lab Reports 5(10):1-7.

Garrett, J.W.; McHenry, R.R.; Hendricks, D.L.; and Perchonok, K. 1977. Tri-level accident research study, final report: January 1, 1975-December 31, 1975. National Highway Traffic Safety Administration report no. DOT-HS-802-473.

Gimotty, P.A. 1980. National projections from NCSS statistics. Warrendale, Pennsylvania: Society of Automotive Engineers, Inc. technical paper series no. 800097.

Griffin, L.I. 1973. Analysis of the benefits derived from certain presently existing motor vehicle safety devices: A review of the literature. Chapel Hill, North Carolina: University of North Carolina Highway Safety Research Center.

Hall, R.G. 1976. Fact book: A summary of information about towaway accidents involving 1973-1975 model cars. Volume II. Final report. National Highway Traffic Safety Administration report no. DOT-HS-802-036.

Hapgood, F. 1979. Risk-benefit analysis: Putting a price on life. Atlantic Monthly 1979:33-38.

Heaton, C.J. 1971. A comparison of motor vehicle accident cost data. Federal Highway Administration highway planning technical report no. 21.

Hedlund, J.H. 1979. Preliminary findings from the National Crash Severity Study (NCSS). Washington, D.C.: National Highway Traffic Safety Administration, National Center for Statistics and Analysis.

Hobbs, C.A. 1978. The effectiveness of seat belts in reducing injuries to car occupants. Crowthorne, Berkshire, U.K.: Transportation and Road Research Laboratory report no. TRRL LR 811.

Hochberg, Y. 1975a. An investigation of the joint injury distribution of belted and unbelted drivers in automobile accidents. National Highway Traffic Safety Administration report no. DOT-HS-801-630.

Hochberg, Y. 1975b. On the variance estimate of a Mann-Whitney statistic for ordered grouped data. National Highway Traffic Safety Administration contract no. DOT-HS-4-00897.

Hochberg, Y. 1976. Problems of inference in studies of seat belt effectiveness. National Highway Traffic Safety Administration report no. DOT-HS-801-805.

Hochberg, Y. 1977. A methodology for analyzing general categorical data with misclassification errors with an application in studying seat belt effectiveness. National Highway Traffic Safety Administration report no. DOT-HS-802-425.

Hochberg, Y., and Reinfurt, D.W. 1975. An investigation of safety belt usage and effectiveness. Interim report. National Highway Traffic Safety Administration report no. DOT-HS-801-427.

Hochberg, Y.; Stutts, J.C.; and Reinfurt, D.W. 1977. The randomized response technique: A review and application. National Highway Traffic Safety Administration report no. DOT-HS-802-175.

Huelke, D.F.; Lawson, T.E.; Scott, R.; and Marsh, J.C., IV. 1977. The effectiveness of belt systems in frontal and rollover crashes. Warrendale, Pennsylvania: Society of Automotive Engineers paper no. 770148.

Huelke, D.F., and O'Day, J. 1979. Passive restraint systems—A scientist's viewpoint. Paper presented at Brookings Institution Conference on the Scientific Basis of Health and Safety Regulations, 8-9 November 1979, Washington, D.C.

Huelke, D.F.; Sherman, H.W.; Murphy, M.J.; Kaplan, R.J.; and Flora, J.D. 1979. Effectiveness of current and future restraint systems in fatal and serious injury automobile crashes. Warrendale, Pennsylvania: Society of Automotive Engineers paper series no. 790323.

HUK Verband. 1975. Interior safety of automobiles: Road traffic accidents and their consequences. Hamburg, West Germany: German Association of Third-Party Liability Accident and Motor Traffic Insurers.

Insurance Information Institute. 1980. Insurance facts 1979. New York: Insurance Information Institute.

Jago, K.W.D., ed. 1978. Review of car seat belt research. Loughborough, Leicestershire, England: Institute for Consumer Ergonomics.

The Japan Research Center for Transport Policy. 1978. Social losses from accidents. Tokyo, Japan: The Japan Research Center for Transport Policy.

Joksch, H.C. 1975. A critical appraisal of the applicability of benefit-cost analysis to highway traffic safety. Accident Analysis and Prevention 7:133-153.

Jones-Lee, M.W. 1969. Valuation of reduction in probability of death by road accident. Journal of Transport Economics and Policy 3(1):37-47.

Kahane, C.J. 1974. Usage and effectiveness of seat and shoulder belts in rural Pennsylvania accidents. National Highway Traffic Safety Administration report no. DOT-HS-801-398, technical note N43-31-5.

Keeney, R.L. 1980. Evaluating alternatives involving potential fatalities. Operations Research 28(1): 188-205.

Kirkpatrick, J.R., and Youmans, R.L. 1971. Trauma index: An aide in the evaluation of injury victims. Journal of Trauma 11(8):711-714.

Krischer, J.P. 1976. Indexes of severity: Underlying concepts. Health Services Research 1976:143-157.

Lawson, J.J. 1978. The costs of road accidents and their application in economic evaluation of safety programmes. Paper presented at the Annual Conference of the Road and Transportation Association of Canada, 18-21 September 1978, Ottawa, Ontario.

Linnerooth, J. 1979. The value of human life: A review of the models. Economic Inquiry 17:52-74.

MacKenzie, E.J.; Gorthe, E.R.; and Gibson, G. 1978. Evaluating the abbreviated injury scale. In Proceedings, American Association for Automotive Medicine 22nd conference. Morton Grove, Illinois: American Association for Automotive Medicine.

Marsh, J.C., IV; Campbell, K.L.; and Shah, U. 1977. A review and investigation of better crash severity measures: An annotated bibliography. Ann Arbor, Michigan: The Univesity of Michigan Highway Safety Research Institute report no. UM-HSRI-77-22.

Marsh, J.C., IV; Kaplan, R.J.; and Kornfield, S.M. 1977. Financial consequences of serious injury. Final report. Ann Arbor, Michigan: The University of Michigan Highway Safety Research Institute report no. UM-HSRI-77-27.

Marzoni, P., Jr. 1971. Motivating factors in the use of restraint systems. Philadelphia: National Analysts, Inc.

Mela, D.F. 1974. Review of safety belt usage and effectiveness in accidents. Unpublished report. National Highway Traffic Safety Administration.

Mishan, E.J. 1971a. Cost-benefit analysis. An introduction. New York: Praeger.

Mishan, E.J. 1971b. Evaluation of life and limb: A theoretical approach. Journal of Political Economy 79(4):687-705.

Morris, P., and Paul, J.C.N. 1968. The financial impact of automobile accidents. In Dollars, delay, and the automobile victim. New York: The Bobbs-Merrill Company, Inc.

National Center for Health Statistics. 1969. Types of injuries: Incidence and associated disability. Series 10, No. 57. Washington, D.C.: U.S. Department of Health, Education, and Welfare.

National Center for Health Statistics. 1971. Vital statistics of the United States, Volume II, section 5: Life tables. Washington, D.C.: U.S. Government Printing Office.

National Safety Council. 1979. Accident Facts. Chicago, Illinois: National Safety Council.

Nilsson, L.E. 1976. Swedish government and industry studies of belt usage law effectiveness. Trollhatton, Sweden: Saab-Scania AB Report 1976-07-05.

Norin, H. 1977. The seat belt wearing law in Sweden and its effect on occupant injuries in Volvo cars. Traffic Accident Research report no. 77/2A. Goteberg, Sweden: AB Volvo.

O'Day, J.; Carlson, W.L.; Douglass, R.; and Kaplan, R.J. 1974. Statistical inference from multidisciplinary accident investigation. National Highway Traffic Safety Administration report no. DOT-HS-801-111.

O'Day, J.; Gimotty, P.A.; Kaplan, R.; Huang, L.; Bertram, B.; and Campbell, K. 1978. Analysis of the national crash severity study, Interim report. Ann Arbor, Michigan: The University of Michigan, Highway Safety Research Institute report no. UM-HSRI-78-63.

O'Neill, B., and Kelley, A.B. 1974. Cost, benefits, effectiveness and safety: Setting the record straight. Warrendale, Pennsylvania: Society of Automotive Engineers, Inc. report no. SAE 740 988.

O'Neill, B., and Robertson, L.S. 1976. A critique of the benefit/cost analysis accompanying the announcement of the August 3, 1976 DOT public hearing on motor vehicle occupant crash protection. In a letter to Secretary William T. Coleman, dated 17 September 1976.

Office of Science and Technology. 1972. Cumulative regulatory effects on the cost of automotive transportation (RECAT). Final report. Washington, D.C.: Office of Science and Technology.

Ontario Ministry of Transportation and Communications. 1977. Changes in the number and cost of motor vehicle injury victims in Ontario following the introduction of seat belt legislation and highway speed limit reductions, 1975-1976. Ontario, Canada: Ontario Ministry of Transportation and Communications.

Opinion Research Corporation. 1978. Safety belt usage: Survey of cars in the traffic population--November 1977-June 1978. National Highway Traffic Safety Administration contract no. DOT-HS-7-01736.

Opinion Research Corporation. 1980. Highlights of four research studies: I. Safety belt usage among drivers. II. Use of child restraint devices, passenger safety belts, and seat position data. III. Motorcycle helmet usage. IV. Automatic safety belt systems. Princeton, New Jersey: Opinion Research Corporation.

Partyka, S.C. 1979. Restraint usage and effectiveness on the National Crash Severity Study. National Highway Traffic Safety Administration report no. DOT-HS-805-151.

Patrick, L.M. 1975. Passive and active restraint systems-performance and benefit/cost comparison. Warrendale, Pennsylvania: Society of Automotive Engineers paper no. 750389.

Prentice, H.A.J. 1979. Seat belt effectiveness: Possible benefits and advertising. In International symposium on seat belts in Tokyo, '79. Reports. Tokyo, Japan: Japanese Council of Traffic Science.

Preston, F.R., and Shortridge, R.M. 1973. A study of restraint use and effectiveness. Ann Arbor, Michigan: The University of Michigan, Highway Safety Research Institute report no. UM-HSRI-SA-73-10.

Ranney, T.A. 1978. Analysis of accident data involving light trucks. Buffalo, New York: Calspan Field Services, Inc. report no. 6303-Y-1.

Reinfurt, D.W.; Silva, C.Z.; and Seila, A.F. 1976. A statistical analysis of seat belt effectiveness in 1973-1975 model cars involved in towaway crashes. Volume I. Final report. National Highway Traffic Safety Administration report no. DOT-HS-802-035.

Reinfurt, D.W.; Stewart, J.R.; Hall, R.G.; Dutt, A.K.; Stutts, J.C.; Li, L.K.; and Markley, J.B. 1978. Injury scaling research. Final report.

National Highway Traffic Safety Administration report no. DOT-HS-803-452.

Ricci, L., ed. 1979. NCSS statistics. Ann Arbor, Michigan: The University of Michgigan Highway Safety Research Institute report no. UM-HSRI-79-80.

Robertson, L.S. 1976a. Automobile seat belt use after the interlock. Washington, D.C.: Insurance Institute for Highway Safety.

Robertson, L.S. 1976b. Estimates of motor vehicle seat belt effectiveness and use: Implication for occupant crash protection. American Journal of Public Health 66(9):859-864.

Robertson, L.S., and Haddon, W., Jr. 1974. The buzzer-light reminder system and safety belt use. American Journal of Public Health 64:814-815.

Robertson, L.S.; O'Neill, B.; and Wixon, C.W. 1972. Factors associated with observed safety belt use. Journal of Health and Social Behavior 13:18-24.

Roy Jorgensen Associates. 1975. Methods for evaluating highway safety improvements. Washington, D.C.: Transportation Research Board, National Cooperative Highway Research Program report 162.

Schelling, T.C. 1968. The life you save may be your own. In Problems in public expenditure analysis, ed. B. Chase. Washington, D.C.: Brookings Institution.

Schwing, R.C. 1979. Longevity benefits and costs of reducing various risks. Technological Forecasting and Social Change 13:333-45.

Scott, R.E.; Flora, J.D.; and Marsh, J.C. 1976. An evaluation of the 1974 and 1975 restraint systems. Ann Arbor, Michigan: The University of Michigan, Highway Safety Research Institute report no. UM-HSRI-76-13.

Sherwin, M.A., and Jackson, L.F. 1978. Cost of road accidents. Road Research Unit Bulletin 38. Wellington, New Zealand: National Roads Board.

Snow, J.W. 1979. Seat belt legislation in Ontario, Canada: Its history and effects. In International symposium on seat belts in Tokyo '79. Reports. Tokyo, Japan: Japanese Council of Traffic Science.

Stiffman, L.H. 1978. Regional environmental health planning and analysis for highway injury control. The University of Michigan unpublished Ph.D. dissertation.

Thaler, R., and Rosen, S. 1976. The value of saving a life: Evidence from the labor market. In Household Production and Consumption, ed. N. E. Terlekyi. New York: National Bureau of Economic Research.

Transportation Research Board. 1980. Methods for increasing safety belt use: Proceedings of a workshop. Transportation Research Board report no. UR-17.

U.S. Bureau of the Census. 1973. Census of population: 1970. Volume 1, characteristics of the population. Washington, D.C.: U.S. Government Printing Office.

U.S. Bureau of the Census. 1979. Statistical abstract of the United States: 1979. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Transportation. 1970. Economic consequences of automobile accident injuries. Volumes I and II. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Transportation. 1972. Societal costs of motor vehicle accidents. Preliminary report. National Highway Traffic Safety Administration report no. DOT-HS-820-185.

U.S. Department of Transportation. 1979a. National accident sampling system. Pilot study. Final report. National Highway Traffic Safety Administration report no. DOT-HS-804-909.

U.S. Department of Transportation. 1979b. Preliminary analysis of the national crash severity study: Factors in fatal accidents. National Highway Traffic Safety Administration report no. DOT-HS-802-773.

Waller, R.F.; Li, L.K.; Campbell, B.J.; and Herman, M.L. 1977. Safety belts: The uncollected dividends. A manual for use by state legislators and state officials on techniques to increase safety belt usage. National Highway Traffic Safety Administration report no. DOT-HS-802-598.

Warder, J. 1980. Possible influences on people and their use of occupant restraints. Lansing, Michigan: Michigan State Police, Traffic Services Division.

Wohl, M. 1969. Putting the analysis and evaluation of traffic safety measures into perspective. Accident Analysis and Prevention 1:77-99.

Wuerdemann, H., and Joksch, H. 1973. National indirect costs of motor vehicle accidents. Hartford, Connecticut: Center for the Environment and Man report no. 4114-494-B.