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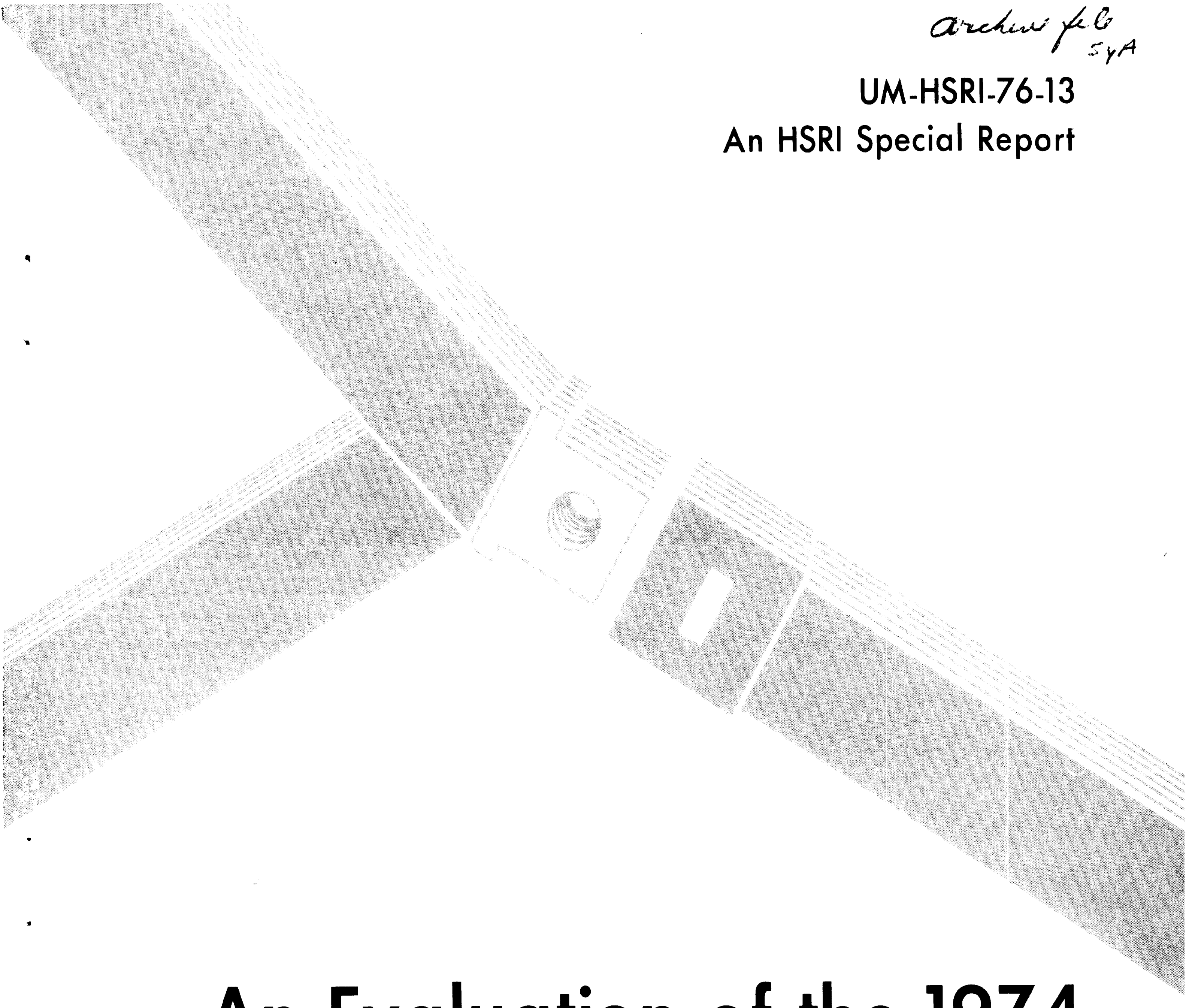
An HSRI Special Report



An Evaluation of the 1974 and 1975 Restraint Systems

Robert E. Scott
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Joseph C. Marsh IV

May 1976

Highway Safety Research Institute/University of Michigan

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Robert E. Scott
Jairus D. Flora
Joseph C. Marsh IV

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

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16. Abstract In-depth accident investigation programs were conducted specifically to collect data for evaluation of the efficacy of the 1974 and 1975 restraint systems. Stratified random sampling techniques were used to collect data on 1973-1975 American passenger cars in towaway accidents. After eighteen months of field investigation by teams at the Highway Safety Research Institute, Calspan Corporation, and Southwest Research Institute, data were available on 6,729 vehicles and 9,186 outboard-front-seat occupants. Occupants of 1974 cars used restraints substantially more frequently than occupants of 1973 cars. Use of full restraints by these occupants increased by a factor of eight over their use in 1973 cars. Use of the full restraint in 1975 cars was lower than in 1974's, but still more than seven times as great as in 1973 cars.

There was no measurable difference in the incidence of moderate or worse injuries in the three model years. Nevertheless, restraint systems in these cars demonstrated a substantial capability to reduce the incidence of moderate or worse injury when they were used. Lap belts alone reduce the probability 27% compared to no restraint. The lap and upper torso belts together reduce the probability 21%, compared to the lap belt alone, and 42%, compared to no restraint.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Description of Project

This is a report on an evaluation of the effectiveness of the occupant restraint system used in 1974 and 1975 American passenger cars. In early 1973, the objectives of the in-depth accident investigation programs at the Highway Safety Research Institute and CALSPAN Corporation were redefined to collect data for evaluation of the 1974 restraint systems. The data collection was designed to establish whether front-seat occupants were using the restraint system at the time of the crash, and what severities of injuries the occupants incurred.

The introduction of the sequential-ignition interlock in 1974 cars was expected to greatly increase the use of full restraints, i.e., both the lap and upper-torso belts, over their very small use in the past. This would provide the first opportunity to observe the benefits of the complete restraint system in a large number of real traffic accidents, and the net benefit in a specific model year. Since the beginning of data collection we have seen the elimination of the ignition-interlock in new cars, and the introduction of models with otherwise similar restraint systems (1975 cars). These changes were not anticipated at the start, but they have actually enhanced our ability to examine certain features of usage patterns, and have not detracted from our ability to assess restraint system efficacy.

To meet the objectives rapidly and at reasonable cost, the existing accident investigation programs of HSRI in Oakland and Washtenaw Counties, Michigan, and of CALSPAN in the eight western counties of New York were redirected to the task. The National

Highway Traffic Safety Administration (NHTSA) also requested the multidisciplinary accident investigation team at the Southwest Research Institute (SwRI) to collect compatible data in the seven counties from San Antonio to Austin, Texas. The data from all three teams were made available to HSRI for analysis and evaluation.

The specific goals and measures of performance for the evaluation were selected in close consultation with staff members and an Ad Hoc committee of the MVMA. The goals established were to compare the reduction of the rate of incidence of AIS$\geq$2 injuries to outboard-front-seat occupants of 1973 and 1974 cars, and to design the program so as to assure detection of an actual relative reduction of as low as twenty percent.* The study originally was to have been based on one year of accident data to minimize the introduction of seasonal biases. Following the legislative elimination of the interlock, the data collection was extended through eighteen months, providing more data and hence more precision in the measurement of restraint performance.

Because neither the case selection criteria nor the observations or documentation previously used were suitable for these objectives, extensive changes in the project were required. This, coupled with a well-defined mandate limited to a rather specific research question, provided a unique opportunity to develop a project based on the principles of experimental design.

The design adopted at HSRI, and which later became a model for other teams, was to investigate a sample of crashes drawn from the population of 1973 and 1974 cars towed from the scene of an accident. The sampling plan was designed to maximize the precision of the measurement of reduction of severe injury to occupants of 1974 cars, and to minimize the possibility of introducing bias errors from missing data under the constraints imposed

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* The Abbreviated Injury Scale (AIS) is described briefly in Section 5.2 and in detail in Reference 4.

by limitations of available resources. A stratified sampling plan was selected, with investigation of all accident vehicles from which an occupant was taken to a hospital. For vehicles from which an occupant was not taken to a hospital, a sampling rate of one-third was used for 1973 cars and a rate of one-half for 1974 and 1975 cars after the latter appeared in the accident population.

Data Collection

The procedures used for data collection in the field were examined and completely redefined for this project. After development of the experimental design, the variables necessary for analysis were identified and all possible sources of the necessary data which would be available to the investigators were considered. The emphasis on restraint usage and inclusion of minor crashes required that occupants from all crashes be interviewed, a substantial change from past programs. Great emphasis was also placed on the need to investigate all vehicles in the sample, regardless of the effort required to locate the occupants and vehicles. Our objective was to successfully investigate at least ninety percent of all cases and keep the missing data rate to less than ten percent. By choosing appropriate sampling procedures and rates, this objective was met. The field operation was monitored by a data management system to assure adherence to the sampling plan, evaluate the notification process, and thus assure the integrity of the sample and the credibility of the findings. The management system was implemented through inclusion of specific procedures in the field investigations, documentation, and data processing.

After a two-week pilot test of operating procedures and documentation, the actual data collection started on March 1, 1974, at HSRI. CALSPAN and SwRI started on April 1, 1974. The data collection was later extended through August 1975 for HSRI and longer for CALSPAN and SwRI. This report is based on eighteen months of data from each team.

After eighteen months, the number of cars of American manufacture investigated by HSRI was 1,814. An additional 2,668 American passenger cars were investigated by CALSPAN, while SwRI investigated 2,247. Thus, data on a total of 6,729 vehicles were available for the study, containing 9,186 outboard-front-seat occupants.

Analysis Methodology

The objective of the analysis presented in this report is to evaluate the relative reduction in injury of AIS≥2 to outboard-front-seat occupants of 1974 cars compared to 1973 cars. In addition to this primary goal, the changes in restraint usage rates following the introduction of the starter interlock are examined, and the benefits of the lap belt and of lap and upper torso restraints are evaluated.

Two analytic techniques were used to estimate a rate for the proportion of occupants using restraints and the proportion suffering overall injury severities of AIS level 2 or greater. The first technique used was a straightforward computation of crude rates, weighting cases in each strata appropriately to represent the target population of towaways. Confidence intervals and tests of statistical significance were obtained for rates derived from stratified samples.

A large number of variables could be defined from the data collected during the project. Several of these are known or suspected of influencing injury rate. Many, such as the Collision Deformation Classification (CDC), size of vehicle, occupant descriptors, etc., were collected for this very reason. Variation in these variables between compared populations can confound the comparisons. Any thorough evaluation must account for the effects of these variations or control for the effects. Many of the potentially confounding parameters are measured on ordinal or nominal scales (e.g., CDC extent, collision configuration, sex). The number of analytical tools for statistically controlling for these categorical variables is more limited than for interval variables.

A multivariate technique for generalized analysis of categorical data, using a weighted least squares linear model, was employed in this study to control for the effects of confounding variables. The program used also provides rates adjusted to a standard population (distribution) of the control variables. While several candidate control variables were examined, the model used in the final analyses controlled on a measure of damage severity. Control on a measure of crash severity would be more desirable. Such a variable, e.g., ΔV or energy was not available. In lieu of a true crash severity measure, a scale was developed using all elements of the Collision Deformation Classification. The resulting variable is a measure of damage severity rather than crash severity. However, it does have merit as a useful surrogate for crash severity, and incorporates considerably more information than is provided by the CDC extent code alone. While it has been used successfully in this study, the utility and applicability of this scale to other data sets has not been demonstrated. The standard population of damage severity used in the analysis is the aggregate distribution of the severity across all three teams and all three model years. This adjustment provides standardized rates for individual restraints, model years, and teams, computed for a common-baseline accident population.

The results presented here are in general given separately for each team. Strictly speaking, the results for each team faithfully represent only that area in which the data were collected. Certain descriptive statistics such as confidence intervals and standard errors are small because of the large number of cases available, and one is tempted to interpret the results as representative of a much larger population of accidents. The desire to have a national result makes this attractive. <u>However</u>, the small sampling errors resulting from the rigid sampling procedures that have been used in this program do not include a measure of any biases that the areas providing the data may have. Thus, there is no information included in the study that justifies an assumption that the three areas together represent the nation.

On the other hand, if results from the three teams were uniform and consistent, one would be tempted to interpret the stability as an indication that the results probably represent a much larger population. Differences between teams have been observed and, in general, the results should not be considered "national." Fortunately, the final result for restraint performance--the relative reduction in severe injury--is very similar for the three teams. This effectiveness measure has been combined for the teams and an average value is provided in the conclusions.

Findings and Conclusions

1. Restraint Usage. Use of the full restraint, i.e., both the lap and upper-torso belts, is much greater in 1974 cars than in 1973 cars--by a factor of eight to ten times.

The full restraint is used less frequently in 1975 cars than in the 1974 models, but still more than seven times as frequently as in 1973 models.

More occupants are restrained--by either the lap belt alone or fully restrained--in both 1974 and 1975 cars than in 1973 cars.

The use of restraints by crash victims in 1973-1975 model cars of American manufacture is shown in Table 1.

2. Decrease of Use of Full Restraints in 1974 Cars. Use of the full restraints in 1974 cars declined during the period of data collection. Early in the program 1974 full restraint usage was high--about fifty percent. From this level there was a gradual decline in usage, starting early in the program, even before Congressional action on the interlock, until, at the end, the usage was about the same as that shown for 1975 cars in Table 1. The inducement of the interlock largely disappeared by the end of the project.

Table 1

RESTRAINT USAGE
BY OUTBOARD-FRONT-SEAT OCCUPANTS

	Percent of Occupants		
	CALSPAN	HSRI	SwRI
1973 Models			
No Restraint	70	69	60
Lap Belt Only	26	27	37
Full Restraint	4	4	3
1974 Models			
No Restraint	59	56	50
Lap Belt Only	8	5	5
Full Restraint	33	39	45
1975 Models			
No Restraint	64	66	58
Lap Belt Only	5	4	2
Full Restraint	31	30	40

Occupants of cars with the integrated belt configuration of 1974 and 1975 cars, but without a sequential interlock, use *full* restraints with the same frequency that all restraints were used in 1973 cars. Evidently, people who would have used only the lap belt in the former models used the full restraint in cars with the latter configuration.

(Section 5.1)

3. *Comparison of Injury Rates in 1973 and 1974 Cars*. The overall injury rates--proportion of outboard-front-seat occupants with injuries of AIS$\geq$2--do not differ among the three model years Even though the use of restraints is quite different in the three model years, the proportions with moderate or worse injury are nearly the same for all three years for all three teams. The small differences that do exist are of little consequence and are not statistically significant.

(Sections 5.2.1 and 5.2.3)

4. Injury Rates for Restrained Occupants. When adjustments have been made for differences in the severity of the crashes, occupants using restraints are substantially less likely to have injuries of AIS≥2. Furthermore, fully restrained occupants fare better than those using only a lap belt. The rates of moderate and worse injury are shown in Table 2 for each team.

Table 2

PERCENT OF OUTBOARD-FRONT-SEAT OCCUPANTS
RECEIVING INJURIES OF AIS≥2,ADJUSTED FOR CRASH SEVERITY

Restraint	Team		
	CALSPAN	HSRI	SwRI
None	14.4	8.0	11.9
Lap Only	10.6	6.1	8.4
Full	7.9	4.5	7.5

Although there are differences between teams, all three show substantial and consistent reductions with restraints.

(Section 5.2.3)

5. Effectiveness of Restraints in Reducing Injury. The effectiveness of restraints--the relative reduction in the incidence of moderate and worse injury--is both substantial and consistent in all three teams. The average effectiveness figures for the three teams is shown in Table 3 along with the standard errors of the estimates.

The lap belt reduces the incidence of moderate and worse injuries about one-quarter, compared to unrestrained occupants.

Table 3

EFFECTIVENESS OF RESTRAINTS
IN REDUCING THE LIKELIHOOD OF
RECEIVING AN INJURY OF AIS≥2

-Averages for three teams-

Comparison	Effectiveness in Percent	Standard Error in Percent
Lap vs. None	26.7	9.7
Full vs. Lap	20.9	12.2
Full vs. None	42.1	6.8

The full restraint reduces the incidence one-fifth below that for the lap belt, for a total reduction of forty-two percent below the rate for unrestrained occupants.

(Section 5.2.3)

These benefits of restraints are available to occupants who are not ejected. They are not an artifact of containment. Nor are they restricted to a narrow range of collision types or configurations. Both restraints provide substantial protection--even in non-frontal impacts.

(Section 5.2.1)

6. Injury Patterns. Restrained occupants receive fewer specific injuries (per person) than unrestrained occupants, and fully restrained occupants receive fewer than those using only the lap belt.

Restraint systems are more effective in eliminating moderate or worse injuries than they are in preventing minor injuries.

The head, face, extremities, and chest regions of restrained occupants are injured less frequently, while their neck, abdominal, and pelvic regions sustain more minor injuries.

Full restraints reduce the frequency of occupants sustaining an injury from the steering assembly (wheel and column) and front interior, but do not eliminate them.

Moderate or worse injuries attributed to the restraint system are extremely rare.

1.0 INTRODUCTION

The question originally addressed in this investigation was "Are the ignition interlock restraint systems in the 1974 passenger cars reducing injury to occupants of those vehicles when they are involved in crashes, relative to the systems in 1973 passenger cars?" A corollary of this question, of course, is to find a quantitative measure of any observed reduction.

Secondary objectives were to measure the efficacy of the production restraint systems in reducing the severity of injuries. Since beginning this work we have seen, of course, the disappearance of the ignition interlock. Thus the original primary objective is considerably less relevant than it was early in the project, and some may take the view that the entire study has been more of an academic exercise than was originally intended. Interest in measuring the performance of the restraints on the road today has not lessened, however, and the importance of the secondary objectives has increased. The project provides considerable information on the efficacy of belt systems--knowledge we hope will be of value to both rulemakers and practitioners.

It would be desirable to answer such questions nationally--e.g., to be able to say that, for the U.S. as a whole, the introduction of a new system to enhance restraint usage reduced the likelihood of injury in some measurable way. The techniques developed over a period of years of in-depth accident investigation have provided the tools and scales for such a program--the Abbreviated Injury Scale is well defined, the Collision Deformation Classification can provide an independent measure of crash severity, and a cadre of investigators exists with the capability to report accurately on investigated crashes. But applying this capability to a population of accidents selected to reliably represent national experience is not done quickly.

The Motor Vehicle Manufacturers Association (MVMA) for a number of years has supported accident investigation activities both at The University of Michigan and at CALSPAN Corporation, and in lieu of a more national population the programs at these two locations were redirected to address the specific problems defined above. It is clear that these two areas do not necessarily represent the nation, but if similar results are found in both areas there should be some support for the sample being true of larger populations. Further, the NHTSA offered the data being collected by the Southwest Research Institute (SwRI) under a parallel DOT-sponsored program. Again, if the results are similar now in all three regions, one would be tempted to defend inferences drawn to a national population.

Fortunately, in this as in many experiments, information has been acquired which answers some interesting questions other than the primary one. For example, with the present data we can obtain more precise estimates of the value of restraint systems of various types (regardless of the model year of the car), and some statistics on the usage of restraint systems, the defeat of the mechanisms which were supposed to induce wearing, etc. Indeed, some of these questions can be answered with more assurance than the original problem and have actually become the principal focus.

This report is based on the eighteen months of data collected by each of the three teams. Field work at HSRI started on March 1, 1974, and on April 1, 1974, at CALSPAN and SwRI. Thus, while the same eighteen months were not covered by each team, they differ by only one month. While the project was initially to have been a one-year program, data collection was later extended through the end of August, 1975. Because of the extension of the field effort, 1975 cars were included after their introduction in late 1974. The 1975 cars provide additional data on the performance of full restraints, i.e., the upper-torso belt worn with a lap belt. In addition, they provide insight on the usage that can be expected with current belt systems.

In any real-world data-collection effort, many factors may affect the measure of effectiveness. In this experiment, we have attempted to take into account the principal ones. For example, we know past observations have indicated that older persons are more likely to incur injury in the same crash than younger persons--and if there is a substantial difference in the age of the various populations we wish to compare (e.g., belted vs. unbelted, 1973 car occupants vs. 1974, etc.) we must take this variation into account in the analysis (1,2). We know, too, that cars of different size offer differing degrees of protection, and that any variation here should be accounted for. The data collected include enough detail to do this.

The analytical technique which has been used to adjust for confounding factors such as the size of the car, type and severity of crash, and occupant age is based on multivariate analyses of contingency table data. These methods will be discussed in the section on analytical methods.

The report consists of five chapters. In addition to the Summary and Introduction they are (2) Project Design, (3) Implementation and Monitoring of Field Operations, (4) Data Processing and Analysis Methods, and (5) Results. The last section includes a discussion of the incidence of injury by model year and restraint, and an examination of injury patterns by number and location.

The project was not addressed to a measurement of fatality rates. Even by pooling the data from the three teams, the number of fatalities is far too small to permit many valid statistical inferences. Nevertheless, a number of fatalities did occur in vehicles investigated. While no statistical conclusions should be drawn from these cases, the subject is of such importance that they are summarized on a "case study" basis in Section 5.4.

The main body of the report is intended to be self-sufficient, yet some details which are not essential to the presentation have been omitted for simplicity and clarity. These non-essential but pertinent details are included in appendices.

2.0 PROJECT DESIGN

This chapter presents the development of the project design implemented at HSRI. The most important project questions now concern the efficacy of the various restraint configurations; most of the report is addressed to these questions. Nevertheless, the original goal to which the design was addressed was a comparison of results in 1973 and 1974 cars, and the project design can best be presented in the context of its original objective. It is not coincidental, hoerbrt, that the project so designed is also appropriate for evaluating restraints.

The goal of the sponsors was to obtain a meaningful measure of effectiveness of the 1974 systems, compared to that of the 1973 systems, using essentially the same level of field effort that had previously been allocated to in-depth accident investigation. The constraints on time and resources dictated the use of existing in-depth teams, i.e., those at CALSPAN and HSRI. These organizations are two of about 20 teams that have operated at one time or another since 1969 under support of either the MVMA or NHTSA. Although some of the teams have operated considerably longer, only since about 1969 have they been formalized by NHTSA and adopted similar reporting practices, using the Collision Performance and Injury Report, commonly known as the General Motors Long Form.

These teams have developed considerable experience and set some precedents for in-depth accident investigations suited to meeting the objectives of this project. However, all of the previous programs, including those of CALSPAN and HSRI, had certain characteristics not wholly suitable to the current objectives. Some of the teams were interested in a particular subject and concentrated on such cases. Many, including several at HSRI and CALSPAN, concentrated on vehicles in which occupants sustained substantial injury. Such programs were quite suitable for determining and monitoring the causes of injury--the original objective of many of the programs. Concentration on a specific subject or restriction to severe injury excludes the "successes" and thus does not allow measurement of rates of occurrence in the accident population. Such a measurement is fundamental to the goals of this project.

Because neither the case selection criteria nor the observations and documentation previously used were suitable for the new objectives, extensive changes in the project were required. Recognition of these problems, coupled with a well-defined mandate limited to a rather specific research question, provided an opportunity to develop a project based on the principles of experimental design. This has seldom been done for in-depth accident investigation projects.

The project plan presented here was developed and implemented at HSRI. Similar procedures are used by several other teams, although they differ in detail. The project design developed here is based in part on characteristics of the local area in which the HSRI teams operate and on the reporting protocol used by police in Michigan. Identical procedures are not necessarily appropriate or even possible in other regions.

The major differences in the field programs used at CALSPAN and SwRI will be described later. As stated earlier, the primary objective of this study was to measure the reduction in the incidence of severe injury among front-outboard-seat occupants of 1974 American passenger cars, compared with those of 1973 cars. The goal of the project design was to provide a reliable answer to this question within the region covered by the HSRI teams. The population of cars of interest was 1973 and 1974 passenger cars of American manufacture that were towed from the scene of the accident. Although the restriction to towaways was somewhat arbitrary, considerable justification can be given for eliminating the large number of vehicles driven from the scene without compromising the findings.

An obvious method of meeting the objectives would have been to investigate a census of all vehicles in the target population. Conducting a census has two potential problems that are related. The first is cost. A true census, i.e., investigating every single case, can be very costly and may not be cost-effective. In the present project, we decided that at HSRI we could not accomplish such a census with the resources available. The second problem is that an attempted census may not in fact be complete. For a variety of reasons some of the cases may not be included or certain key variables may be missed on several cases. This results in missing data, which can lead to erroneous results. Conclusions regarding the apparent efficacy of restraints can be very sensitive to a relatively small amount of missing data. Obviously, if injury and restraint usage in the missing cases do not differ from those investigated, the results are not biased. However, the results can be defended only to the extent that lack of bias in the missing data can be bounded, and this is usually impossible to assess.

Past attempts to conduct in-depth investigations on a census of vehicles have resulted in substantial missing data. As an example, for several years we conducted investigations on "all" new-car involvements in Washtenaw County. Subsequent record checks have indicated that we missed nearly half of the cases. Sometimes the vehicles or occupants cannot be located without a great deal of effort, or a vehicle may disappear before we get to it. The result has been in fact a sample, but a sample of convenience. Such an uncontrolled sample is likely to be seriously biased.

The proportion of occupants with injury of AIS $\geq$ 2 estimated from the previous HSRI programs in Washtenaw County was 13 percent. The experience of the present program is 8 percent. This suggests that the earlier attempt to achieve a census produced biased data--by over-representation of moderate and more serious injury cases

An alternative to a census is the use of well-established sampling techniques. If a suitably drawn sample is used, of a size small enough to permit devoting enough effort to complete each case in the sample, biases from missing data can be kept arbitrarily small. The question then is to find if a sample can be drawn small enough to allow near-complete coverage, yet large enough to assure an acceptably small sampling error. The total error of a survey can be represented by

$$\text{rms error} = [(\text{sampling error})^2 + (\text{bias error})^2]^{1/2} \quad (1)$$

where the bias error in the measurement of a proportion P is

$$\text{bias error} = W\,(P_{sample} - P_{missing\ data}) \quad (2)$$

where W is the fraction of missing data in the sample, P_{sample} is the proportion in the sample group without missing data, and $P_{missing\ data}$ is the proportion in the sample group for which data are missing. Sampling error is reduced by increasing the size of the sample, and in a true census both terms become zero. In the incomplete censuses with uncontrolled missing data typical of past efforts, neither the proportion of missing cases (W) or the bias among the missing cases were controlled, and could lead to considerable error. If a sampling technique is used with an appropriately drawn sample, the sample properly represents the population from which it is drawn without bias. Bias from missing data is then introduced only by cases in the sample which are not completed.

This approach--sampling from the target population--was the method selected for measuring the efficacy of the restraint systems used in 1974 cars. There are many examples of successful measurements using sampling techniques with samples of very modest sizes. It is interesting to note that the U.S. Bureau of the Census continually conducts an evaluation of the most recent national census (3). By employing a composite of techniques, the Census Bureau estimates that the 1970 census undercounted the Negro population by 7.7 percent. Thus we have the interesting situation of a census being corrected by a random sample.

The measures of effectiveness for the study were selected by an Ad Hoc committee consisting of members of the staffs of MVMA, member companies, and the HSRI. The measure selected was the reduction of the incidence of injury of AIS $\geq$ 2 to the outboard-front-seat occupants of 1974 cars, compared to the occupants of 1973 cars (4). The ad hoc committee decided that only a reduction of at least 20 percent (relative to the incidence in 1973 cars) was sufficiently meaningful to warrant measurement, but that if such a reduction existed, it should be detected with a probability of 90 percent. Furthermore, if no differences between model years actually exist, the probability that the sample would indicate a change of at least 20 percent should be less than 10 percent. These requirements dictated a power of 0.9 (β = 0.1), an α of 0.1, and together with the primary measure of effectiveness, defined the objectives of the sample design.

A stratified probability sample was used because such a technique can increase the precision of the estimate, compared to that possible with a simple random sample of the same size, if an a priori stratification can be made with a substantial difference in p between strata. The Michigan accident report includes a notation on whether an occupant was conveyed to a hospital. Since there is considerably increased probability of severe injury among this group, an effective a priori stratification can be based on the hospital notation on the police report.

The theory of stratified random sampling for estimating proportions is covered in many standard references (5,6). Designing a sampling plan for estimating the difference between proportions can be a rather complex iterative task involving pilot surveys to estimate parameters of the target population. The availability of several years of accident data from police and in-depth investigation experience in Washtenaw and Oakland County simplified the task considerably. We estimated that with the resources available we could investigate about 1200 accidents per year in the two counties and yet be able to complete the investigations on over 90 percent of the sample. The design sequence, then, was to determine the appropriate size for each of the four strata (hospital and non-hospital for each of the two model years), with the total equal to 1200. The strata descriptions, together with estimates of the probability of a serious injury in each strata, and the expected total population of 1973 and 1974 towaways, were used to compute expected α and β rates. The total accident population for 1973 cars in 1974 was estimated from police records of 1971 cars in accidents in 1972. The population of 1974 cars was estimated to be 30 percent less than that of 1973 cars. Previous in-depth accident investigations in Washtenaw and Oakland County indicated that the probability of moderate or more serious injury ($AIS \leq 2$) among the 1973 cars would be about 13 percent.

These estimates allow a computation of an optimal allocation among strata--optimal in the sense that the variance in the estimate of the difference in proportions of serious injuries in the two model years is minimized for a given total sample. The optimal allocation is of approximately equal sample sizes for each strata, or about 300 each, a number larger than the expected number of cases in each hospital strata. The sampling plan adopted was to include 100 percent of all hospital cases, with the remainder divided evenly between the two non-hospital strata. Design estimates of the sample stratification are given in the first column of Table 4. The implied sampling fractions for the non-hospital cases of each model year are also given.

The sample includes a substantial portion of all the cases in the region from which the sample is drawn. Large sampling fractions lead to estimates that are more precise than those obtained from the same size sample from a larger population. This improvement factor is given by the finite population correction. Since the objective was to properly represent restraint efficacy in the Washtenaw and Oakland County populations, the expected α and β rates included the finite population correction. The precision of the difference of probability of injury of AIS$\geq$2 for the two model years

$$\Delta = \hat{P}_{1974} - \hat{P}_{1973} \tag{3}$$

is given by the sampling variance of Δ which is

$$V(\Delta) = \sum_{i=73}^{74} \sum_{j=1}^{2} \frac{N^2_{ij}}{N^2_i} \frac{f_{ij} \; P_{ij}(1-P_{ij})}{n_{ij}} \tag{4}$$

where the subscript i denotes the model year, j=1 is for non-hospital cases, and j=2 is for the hospital cases.

Table 4

HSRI SAMPLE STRATIFICATION

	Design Estimates[1] (12 mo.)	Twelve Month Results[1]	Eighteen Month Results
Population of 1973 Cars	1300	1162	1685
Population of 1974 Cars	910	1029	1523
Population of 1975 Cars[2]	----	----	320
Proportion of towaways[3] in hospital strata	0.216	0.238	0.246
Hospital Strata (sampled at 100%)			
1973	281	268	390
1974	197	254	400
1975	---	---	74
Non-Hospital Strata			
1973	361	293	434
1974	361	396	562
1975[4]	---	---	193
Total Sample	1200	1211	2053
Non-Hospital Sampling fraction			
1973	0.35	0.328	0.335
1974	0.51	0.511	0.500
1975[5]	----	-----	0.547

----

[1]The original plan for twelve months of data collection did not include 1975 cars. Therefore the design estimates, and twelve month results for comparison, are shown excluding 1975 cars.

[2]The figure for 1975 cars in the eighteen month period includes 101 which were investigated during the first twelve months.

[3]The proportions do not include 1975 cars. The corresponding figure for 1975's is 0.231.

[4]Until June 1, 1975, all 1975's were sampled at 100%. After June 1, 1975, the non-hospital cases were sampled at 50%.

[5]The sampling fraction given for 1975's is the fraction achieved while the non-hospital cases were sampled at 50%.

N_{ij} = number of vehicles of model year i in stratum j in the sample frame

N_i = total number of vehicles of model year i in the sampling frame

n_{ij} = size of sample of model year i in the stratum j

P_{ij} = observed probability of severe injury for occupants of vehicles of stratum j of model year i

f_{ij} = finite population correction.

The finite population correction is:

$$f_{ij} = \frac{(N_{ij} - n_{ij})}{(N_{ij} - 1)} \qquad (5)$$

Sampling 100 percent of the hospital cases has two important implications. The numerator of the finite population correction is zero for the hospital stratum of each model year. Thus the variance of the estimate has only two terms, one for each of the non-hospital strata, and is independent of the magnitude of the probability of injury in the hospital strata. Furthermore, P(1-P) for the non-hospital strata becomes small if the probability of severe injury in these strata is small. Thus, stratifying on a variable highly associated with the incidence of severe injury, and sampling 100 percent of the cases in the strata with a high likelihood of injury, considerably improves the precision of measurement; the variance estimates are a function of only the sample sizes and the probability of severe injury in the non-hospital strata.

With the design estimate given in Table 4, and assuming the incidence of severe injury in 1973 cars is 13 percent, a 20 percent reduction in 1974 cars can be detected with α = 0.05 and a power of 0.9 if the probability of severe injury among non-hospital cases is 4 percent or less.

Thus, a sampling plan including all the hospital cases and using the sampling rates shown in Table 4 for the non-hospital cases,and with injury experience in 1973 cars equivalent to that which has been observed previously in Washtenaw County, will provide a sample in which the bias from missing data can be held to an acceptable level, with a sampling error small enough to meet the primary objectives of the project.

For operational reasons, we adopted non-hospital sampling fractions of one-third and one-half for 1973 and 1974 cars, respectively, rather than the awkward design fractions given in Table 4. The sizes of each stratum after one year and after 18 months of data collection at HSRI are included in Table 4.

The actual number of cases investigated is very close to the original estimate. The actual percentage of the towaway population which is in the hospital strata is slightly higher than anticipated, but this has resulted in a more nearly optimal distribution of cases among the individual strata. While the design was based on an expected proportion of occupants with severe injury of 13 percent in 1973 cars, the observed proportion has been only 7.7 percent. The proportion of severe injuries in the 1973 non-hospital stratum is only 1.6 percent, thus providing a power of over 0.9 with $\alpha = 0.1$.

Several general comments regarding the experimental design should be made. The design provides reliable representation of the target population in the region covered by the HSRI teams. There is considerable interest in extrapolating the results to a much larger population, even to a national estimate. For this purpose, the finite population correction approaches 1 and should be neglected, thus increasing the variance of the estimated difference in the measured proportions. With other parameters unchanged, the power is reduced to approximately two-thirds--considerably lower than the level desired for this study. This problem would be largely offset by the inclusion of data collected by CALSPAN and SwRI if the data from all three teams could be combined. The expected total quantity would raise the power back to acceptable levels of between 0.85 and 0.9. It must be emphasized, however, that while the sampling error using all three teams may be acceptably low for national inferences, the data from the three specific local areas do not comprise a probability sample from the nation and do not necessarily provide an unbiased estimate. Simply increasing the size of the sample within each area does not reduce bias in a national estimate. Any confidence in a national extrapolation engendered by seemingly acceptable sample statistics may be illusory. Nevertheless, one might be tempted to draw a cautious inference regarding questions for which results from the three areas are uniform and consistent.

3.0 FIELD OPERATIONS

The field operations represented a redirection of two programs that have been conducting in-depth investigations in Washtenaw and Oakland Counties for several years. The geographic areas and total level of field effort have not changed. All investigations were done off-scene, usually within one or two days of the accident.

Notification was through daily contact with nine police departments in the two areas. The only change in the notification procedure of the earlier programs was expansion of the candidate vehicle criteria to include all towaways.

From the initial planning of the program the philosophy of collecting only the data required to meet the project objectives on a suitably selected sample was adopted. Thus the number of data elements was minimized so that the number of cases could be increased without compromising the integrity of the sample. The principal data collected were:

1) Vehicle Identification (VIN make and model)
2) Collision type and object struck
3) Vehicle Damage (Collision Deformation Classification and crush)
4) Injury description using the Occupant Injury Classifications(7)
5) Occupant description
6) Restraint usage
   - 6a) Restraint system defect or defeat mechanisms

The last item, restraint system defeat, was collected as material evidence regarding restraint usage and was of value in making a reliable assessment of usage. No detail on structural performance of the vehicle or occupant contact (except to assist in restraint usage assessment) was collected, nor was the scene of the accident visited. In general only a fraction of the information included in the General Motors Long Form was collected. This simplified the field effort considerably. On the other hand, considerable care and effort was devoted to assessment of restraint usage and injury. The large proportion of minor collisions meant that physical evidence on restraint usage through occupant contact and kinematics reconstruction was often not present. Therefore, an occupant interview was required in nearly every case. Such interviews were also the principal source of injury information for occupants who did not go to a hospital.

The documentation used in a large data-collection effort is important to the success of the project. This is particularly true if a rigorous formal sampling technique is used. A form for field use was developed specifically for this project. The form is intended to be simple and convenient for field use, and is structured for direct keypunching without a separate coding or transcription operation. Considerable detail was devoted to recording information relevant to the assessment of restraint usage, since this is one of the most important yet most difficult variables to assess reliably. In addition to the final conclusion on usage, information was provided on the investigator's confidence in the conclusions. Data were also included on the sources of information relevant to usage determination and the indications from each source. This detail was provided as much to structure the usage evaluation and assist the investigator as to provide data for analysis. Additional data were included in each report for purposes of data management and control. A copy of the form is included in Appendix A.

Rigorous conformity with the sampling plan was critical to the success of this restraint system evaluation. The results are credible only to the extent that the sample is a probability sample representing the target population without biases introduced through inappropriate sampling or incomplete coverage. Considerable effort was devoted to maintaining the integrity of the sampling procedures. The first requirement was to keep the sampling process from being influenced by the investigator's judgment. To keep the total process efficient and to provide pre-investigation stratification, we decided to select the sample solely on the basis of the police report. Stratification was based on the listing of where the injured were taken. This item is included in the police report. If any occupant of a candidate vehicle was taken to a hospital, the case was investigated and was denoted by an "H", indicting a unit of a hospital stratum. If a hospital was not listed, the case was included in the sample on the basis of the last two digits of the license plate as listed on the police report, accepting all 1974 cars with an odd digit and all 1973 cars whose last two digits are divisible by 3. Such cases were denoted by a "G", indicating units in the non-hospital strata. Vehicles which failed the latter check were denoted "N" and were not included in the sample.

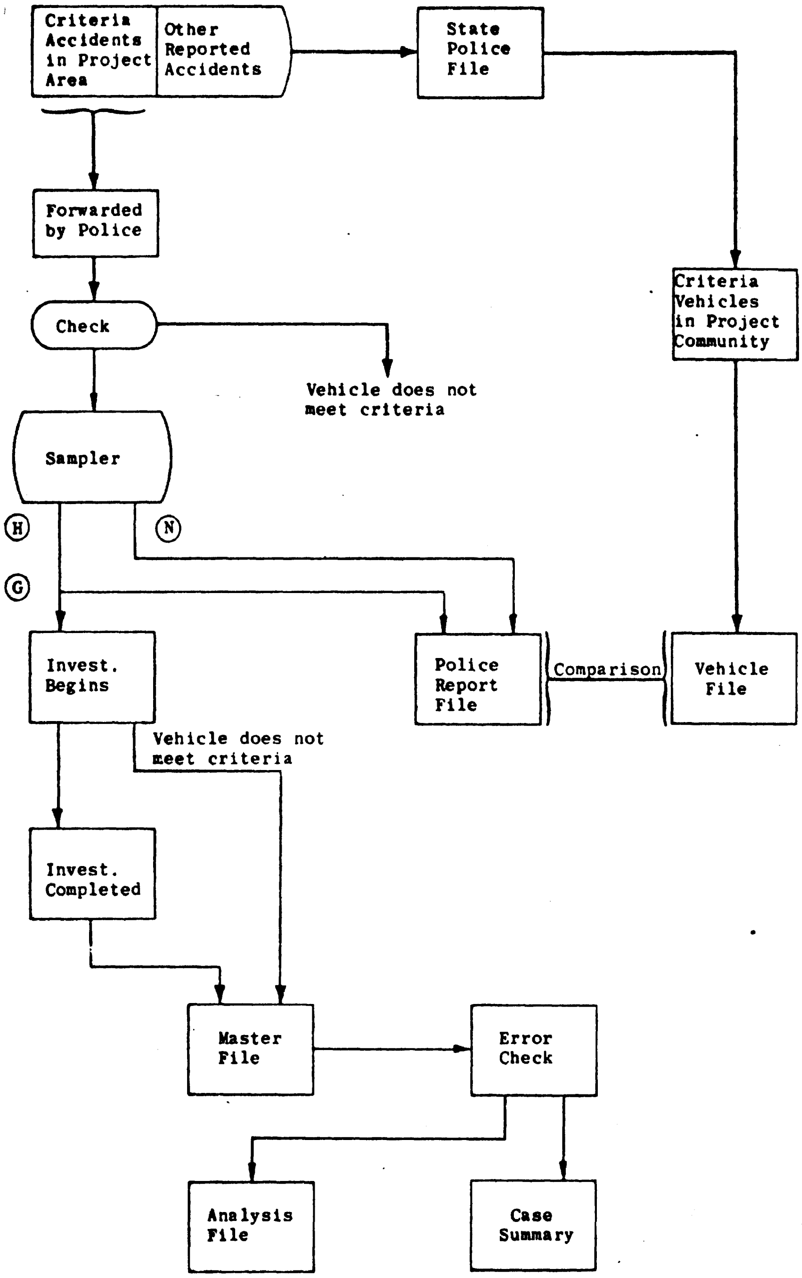
A rather complex procedure was established for handling the data, both police reports and field reports, to permit monitoring of the sampling procedure. The methods used to monitor and maintain quality control, and to assure adherence to the project design, were incorporated within the protocol used for data management and control. The specific objectives of the procedures used were to:

1) Eventually generate a file of case investigations for analysis.
2) Allow monitoring of the application of the sample selection techniques.
3) Allow checking the completeness of the sample frame (reports forwarded by police).
4) Allow measurement of actual strata sampling fractions.
5) Allow measurement of missing data within the sample frame.
6) Allow examination of characteristics of missing data cases and omissions from the sample frame based on police-report data.

The methods used to achieve these objectives can best be explained by reference to the flow chart for project data shown in Figure 1. All police reports forwarded to the project listing a vehicle which meets the acceptable criteria on the basis of the original report were used to create a "police report file." The entire report was not keypunched. Only those entries which relate to the vehicle acceptability criteria and those related to accident identification (date, time, location, etc.) and to sample selection were coded. In addition, the sample results (H, G, N) and case report number were included.

This file was later matched against a file of all candidate vehicles in the project areas derived from tapes provided monthly by the Michigan State Police. This match identifies candidate vehicles in the State files which were not forwarded to the project through the notification scheme. An attempt was made to find the police report for the "missing" cases, either from the local police department or from the State police files, and to investigate the cases even though they were old.

Occasionally errors are made on police reports, and some apparent candidate cases in fact did not meet our vehicle criteria. Examples are 1973 cars that turned out to be 1972



PROJECT DATA FLOW CHART

FIGURE 1

models. If these cases were not included in the police-report file, they would incorrectly be identified as missing data cases in the state file. On the other hand, they should be deleted from the final analysis. This is the reason they were carried as cases and identified on the report form. Other procedures for accomplishing the same objective are possible, but this was selected as convenient both in the field and for automatic data processing.

The sampling procedures used in the field were monitored by mechanized duplication of the process in the police report file and comparison of result with the coding of H, G, or N assigned by the investigators. The achieved sampling ratios were also available from the police report file.

The valid cases were used to construct the analysis file, after automated error checks are made.

The procedure described above may appear to be complex, but in fact is rather efficient and accomplishes all the listed objectives. This assisted greatly in providing good quality control and assuring that the results of the study would be credible.

The procedures that have been described above were used at HSRI. CALSPAN and SwRI used procedures which by necessity were somewhat different. CALSPAN investigated all cases that met the vehicle criteria, and thus provided a census of the eight western counties of New York. One result of the census is that the finite population correction for the area covered is zero. Thus the CALSPAN data represent the New York counties without sampling error, the only errors being observational errors and errors from missing data within the census. SwRI used a rather complex stratified sampling procedure. Eight strata were defined on the basis of whether the worst injury was of AIS=2 or greater, an occupant was conveyed to a hospital, and the highest police injury code on the accident report.

Inclusion of the AIS of the worst injury as a stratification variable considerably complicates statistical inference and could result in some bias since for these occupants the stratification is based on the dependent variable. Except for one stratum which included only 3.5 percent of the vehicles, the strata consist of subsets of cases which were "hospital" cases sampled at 100 percent and "non-hospital" cases sampled at 50 percent. The exception was a strata of AIS$\geq$2, no-hospital,and an injury indicated on the police report. These cases were sampled at 100 percent by SwRI but were infrequent because of the discrepancy between the AIS and "no hospital" requirement.

SwRI selected cases sampled at 50 percent by a license plate criteria similar to the method used at HSRI. The license plate test was applied to all cases and the results were included with the digital information sent to HSRI. We were thus able to sample this strata* by the same license plate test used at SwRI, and derive a post-experimental stratification which was 100 percent of all "hospital cases" and 50 percent of all others, similar to the method used at HSRI. This latter stratification avoids the use of the dependent variable and was used for the analysis reported here. Only 35 (1 percent) cases were dropped from the eighteen-month sample by using this procedure.

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*The strata with "non-hospital", AIS$\geq$2, and injury indicated on the police report.

4.0 DATA PROCESSING AND ANALYSIS

4.1 Data Processing

The data acquired in the field for this program represent a compromise from the usual in-depth accident investigation data reported on the Collision Performance and Injury Report (GM Long Form). This compromise resulted from the requirement for minimizing missing data, producing an adequate sample, and staying within a given budget.

The field form as used in Washtenaw and Oakland Counties was developed as a keypunching form--i.e., the information was recorded in such a way that a keypuncher could work directly from the form, rather than going through an intermediate step of transcribing. There was, however, a manual editing step to ensure that the data elements are consistently and properly coded, prior to keypunching. The punched cards were then read monthly by a pre-file build program that checked again for coding errors and composed one-page summaries in text form (Figure 2).

The field investigation data were then built into both vehicle and occupant analysis files, using the OSIRIS format. The final step of each monthly file update was the preparation of several dozen bivariate tables to check the file contents and recompute routine analysis results.

The file of sampled vehicles, then, contains all of the detailed information of the field report, e.g., the Collision Deformation Classification (CDC) for the vehicle, the injury codes for the occupants, and a variety of other information

HIGHWAY SAFETY RESEARCH INSTITUTE

MVMA Restraint Study

Case Summary

Case No. MS-1477

Date of Accident: 06/27/74

Time of Accident: 0147 hours

Case Vehicle: 1974 Oldsmobile Cutlass Supreme 2 Door Colonnade Hardtop Coupe

VDI		Crush	Collision Event	Collision Type	Object Contacted
Primary	12-FREE-4	43 in.	3rd	01 - Vehicle To Object	57 - Large Post/Tree
Secondary	12-FREN-3	25 in.	2nd	01 - Vehicle To Object	57 - Large Post/Tree
Tertiary	12-FCEN-2	13 in.	1st	01 - Vehicle To Object	57 - Large Post/Tree

Occupant		Restraint Usage	Injury	OIC
Driver	28 years Female 65 inches 125 pounds	Lap: +3 Shoulder: +3 Other: NA	AIS: 01 Minor Treatment: 01 First Aid	/SLCI1*//PRCI1*,PLCI1*/,
Right Front	43 years Male 66 inches 144 pounds	Lap: +3 Shoulder: +3 Other: NA	AIS: 00 None Treatment: 00 None	None
Left Rear	29 years Female 65 inches 125 pounds	Lap: +3 Shoulder: NA Other: NA	AIS: 01 Minor Treatment: 01 First Aid	/FCCI1 //PRCI1*,PLCI1*/,
Right Rear	42 years Male 72 inches 193 pounds	Lap: +3 Shoulder: NA Other: NA	AIS: 00 None Treatment: 00 None	None

Notes * = Injury is restraint caused NA = Not Applicable Number of photos available = 7
? = Unknown if injury is restraint caused

HSRI: MS-1477

Figure 2
Computer-Generated Case Summary

such as vehicle weight, number of vehicles in the accident, crash type, objects struck, age-weight-height-sex of occupants, belt usage information, etc. In addition to the information reported on the field form, several derived variables were created in this file for convenience in analysis. These include, for example, the Julian day of the collision, the sampling ratio used for this particular case, and bracketed age and weight information.

CALSPAN Corporation provided the Restraint System Evaluation Study data collected in the eight-county Buffalo, New York, area to HSRI in a format identical to the Oakland and Washtenaw County field form. Consequently, the data collected by CALSPAN were subject to the same code checks and file-build process as the data collected by HSRI. Both sets of data shared a common analysis file format. The data collected by SwRI in a seven-county area stretching fron San Antonio to Austin, Texas, was provided to HSRI in SwRI's own format. While the resultant file format differs, many of the data elements are common to the CALSPAN and HSRI data.

Two other files of police-reported data were constructed: police reports collected by HSRI in the notification process, and state-police-processed police reports. The first of these is the set of all candidate vehicles collected from participating police agencies. The information coded into the file was taken from the police report, and serves to identify the total population from which the sample is drawn--the sample frame. In this file we note the reporting agency, date and time, make and model, year of vehicle, whether or not the vehicle was towed, the license plate number, location to which the injured were taken, as well as several other factors. However, we did not include all the information on the police report. Since the basic selection and sampling was done using these data elements, there is enough information here to permit comparison with the sampled vehicle field data file described above for the confirmation of sampling procedures.

The second police file was one derived from Michigan State Police Department tapes. These were acquired on a regular periodic schedule approximately three months after the accident, and is the digital record prepared by the state police from forms forwarded to them by the various reporting police departments. For a variety of reasons, the state police files may contain reports of acceptable vehicles which were not obtained by the investigators, and the investigators may have obtained reports which the state police never receive. It would be ideal if there were no discrepancies between these two sets of data.

One cannot compare the data in the two files on the basis of an assigned accident report number, because the only identifying number in the state police file is assigned at the time it is encoded by that agency. A comparison was made between the files by matching on ten variables and following up on any cases that were originally omitted from the sample form.*

Note that the data processing is not an end in itself, but simply a procedure that makes the data ready for analysis. As a matter of convenience, numerous derived variables were added. The basic analysis file is a compilation of all of the fully investigated cases along with certain information about the sampling ratios, so that the entire population can be reconstructed analytically as required.

Although the entire data-taking program covered a period of 18 months, data files were built after the first six months on a monthly basis--permitting preliminary analytic activities to take place on a substantial portion of the full data.

*The ten variables were police codes for county, city, policing agency, date, hour, driver age, vehicle type-make-model year, and "towed from scene."

4.2 Summary of Data Collection

The total number of cases investigated and available for this report from the eighteen month period for each team is shown in Table 5. Not all of the cases shown were used for analysis, because a certain number from each team were missing data on a variable of interest.

Since missing data was a factor of great importance to the study, it is worthwhile to review the success of the teams in controlling and minimizing missing data.

At HSRI we have no measure of the completeness of the CALSPAN or SwRI sampling frames, i.e., we cannot detect accidents that were not included in the frame. The comparisons of the files of the Michigan State Police and the accident reports collected in Oakland and Washtenaw Counties permit a check as described earlier. The comparisons of the two police report files did present some difficulties, apparently because the coding and keypunching done by two separate organizations were not always identical. Using several variables compounded the problems, while using fewer produced an unacceptably large number of non-unique, ambiguous "matches." Computer matches for both counties indicated that we were missing about 18 percent of the accident reports that should have been in the sample frame. However, upon attempting to find and investigate the missing reports we found that many had been received but did not meet the case criteria based on the information on the original copy. There were a number of valid reports that were missed in the original notification procedure. In general we were successfully finding and investigating only a very small number of these cases, although the procedure did lead to modification of the notification method used at one police department. After accounting for the apparently missing cases that were known to be not within the sample frame, and those that were later investigated, the proportion of the

Table 5

NUMBER OF CASES INVESTIGATED

AMERICAN PASSENGER CARS

	Team			
	CAPSPAN	HSRI	SwRI	Total
Number of Vehicles				
1973	1245	711	1062	3018
1974	1203	857	910	2970
1975	220	246	275	741
Total	2668	1814	2247	6729
Number of Outboard Front Seat Occupants				
1973	1693	985	1441	4119
1974	1675	1163	1241	4079
1975	293	326	369	988
Total	3661	2474	3051	9186

target population of HSRI that was finally missing from the sample frame was about nine percent.

Missing data within the sample cases can be determined directly from the data files. The missing data rates on key variables are shown for each team in Table 6. The rates are low for HSRI and SwRI on all the variables shown, and particularly for the key CDC extent, AIS, and restraint usage variables. The CDC extent code for missing data is ambiguous. The scale is from zero to nine, with no provision for a code for missing data. CALSPAN and SwRI investigated only cars towed for damage. Therefore, all zero codes were interpreted as missing data, and this interpretation is consistent with the crush data. HSRI investigated cases that were indicated on the police report to have been towed. A number of these cars were not actually towed or were towed for reasons other than damage, e.g., the driver was apprehended for drinking. Consequently, the zero extent code for HSRI includes both missing data and no-damage cases. The two can be differentiated by examination of the variable for inches of crush. Thus, of the 3.3 percent that were zero extent, 2.9 percent were missing data and 0.4 percent (11 cases) were zero damage.

The high missing data rates for the CDC extent and occupant height/weight variables deserve explanation. The missing CDC extent data largely represent vehicles which were not examined by project investigators. In some of these cases other elements of the CDC were provided from police report data. The missing data on height and weight represent occupants who were not interviewed. The practice used by CALSPAN in the absence of an interview was to obtain injury data from medical records for occupants taken to a hospital. Apparently this was done for 578, or 15.8 percent of the total number of outboard-front-seat occupants. If the occupant did not go to a hospital, an AIS of 0 was assigned, if the police reported

Table 6

MISSING DATA RATES

	Missing Data in Percent*		
	CALSPAN	HSRI	SwRI
Vehicle Data:			
Case Vehicle Body Type	9.6	0.3	0.1
CDC-extent	33.5	2.9	6.7
Outboard Front Seat Occupants			
Age	2.3	0.6	0.9
Height/Weight	45.0	3.7	11.0
Overall AIS	1.0	2.1	3.3
Restraint Usage	5.7	0.6	0.7

no injury, and an AIS of 1 if the report indicated an injury. The procedure was evidently based on the assumption that people with an injury as severe as AIS=2 would have been taken to a hospital. The number of occupants with the AIS determined by this procedure was evidently 944, or 25.8 percent of all occupants.

The HSRI investigations include 14 occupants with an AIS≥2 who did not go to a hospital. This is 4.7 percent of those with AIS≥2. The SwRI data indicate that 9.2 percent (39) of the occupants with injuries of AIS≥2 did not go to a hospital. Thus the data of both HSRI and SwRI suggest that a modest bias in injury severity could result from using the CALSPAN rationale.

The restraint data for the 45 percent of the CALSPAN occupants who were not interviewed were obtained from the police report. Restraint usage is given on the New York state accident report form for each occupant.* In such cases the reliability of the assessment was never coded as definite. Occupant age was also obtained from the police report for these cases.

One other aspect of the data is worthy of note in this section. The design of the program in each area had to be based on estimates of the severity of injury taken from previous studies. No previously available data, however, have provided an unbiased distribution of injury on the AIS for a general population of crashes. This project, which represents vehicles towed from the scene, is the first to give this information.

The distribution of AIS for the reconstructed population is given for each team by model year in Table C-1 of Appendix C.**

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*Police Accident Report, State of New York, Department of Motor Vehicles, form MV-104A 1/74.

**The figures for the reconstructed population were derived by weighting each case by the inverse of the sample ratio.

The distribution for all three teams and both model years is shown in Figure 3. The results shown are for the reconstructed population with the three teams pooled. No weighting was applied to the individual teams other than that inherent in the number of occupants represented in each sample. The most surprising result is the low incidence of injury of AIS$\geq$2. Ninety percent of the occupants were either not injured (48 percent) or had injuries of AIS=1. There were differences between teams which will be discussed later, but the proportion of AIS=0-1 varied only from 87.4 percent for CALSPAN to 92.5 percent for HSRI. Correspondingly, the incidence of AIS$\geq$2 was only 10.1 percent, and only 2.7 percent for AIS$\geq$3. It should also be noted that the frequency of fatality (0.48 percent) is greater than the frequency of AIS 4 and 5 (0.33 percent).

This distribution is significant to the measure of effectiveness selected for the study. The dichotomy formed by splitting at AIS$\geq$2 was selected largely because it was desired to look at the reduction of non-trivial injuries, and an AIS-1 injury was considered a tolerable consequence even when restrained. It would be reasonable to increase the threshold to AIS=3, and originally we had planned to also look at this split. However, the lower-than-expected frequency of injuries of AIS$\geq$3 and greater prevents any meaningful inferences at levels higher than AIS$\geq$2. Clearly, when we are dealing with a broadly defined spectrum of accidents such as all towaways, severe injuries of AIS$\geq$3 are infrequent events. Figure 3 has been presented here because the distribution is significant to the experimental design. It is of general importance, however, because it is the first such data available and constitutes a noteworthy finding.

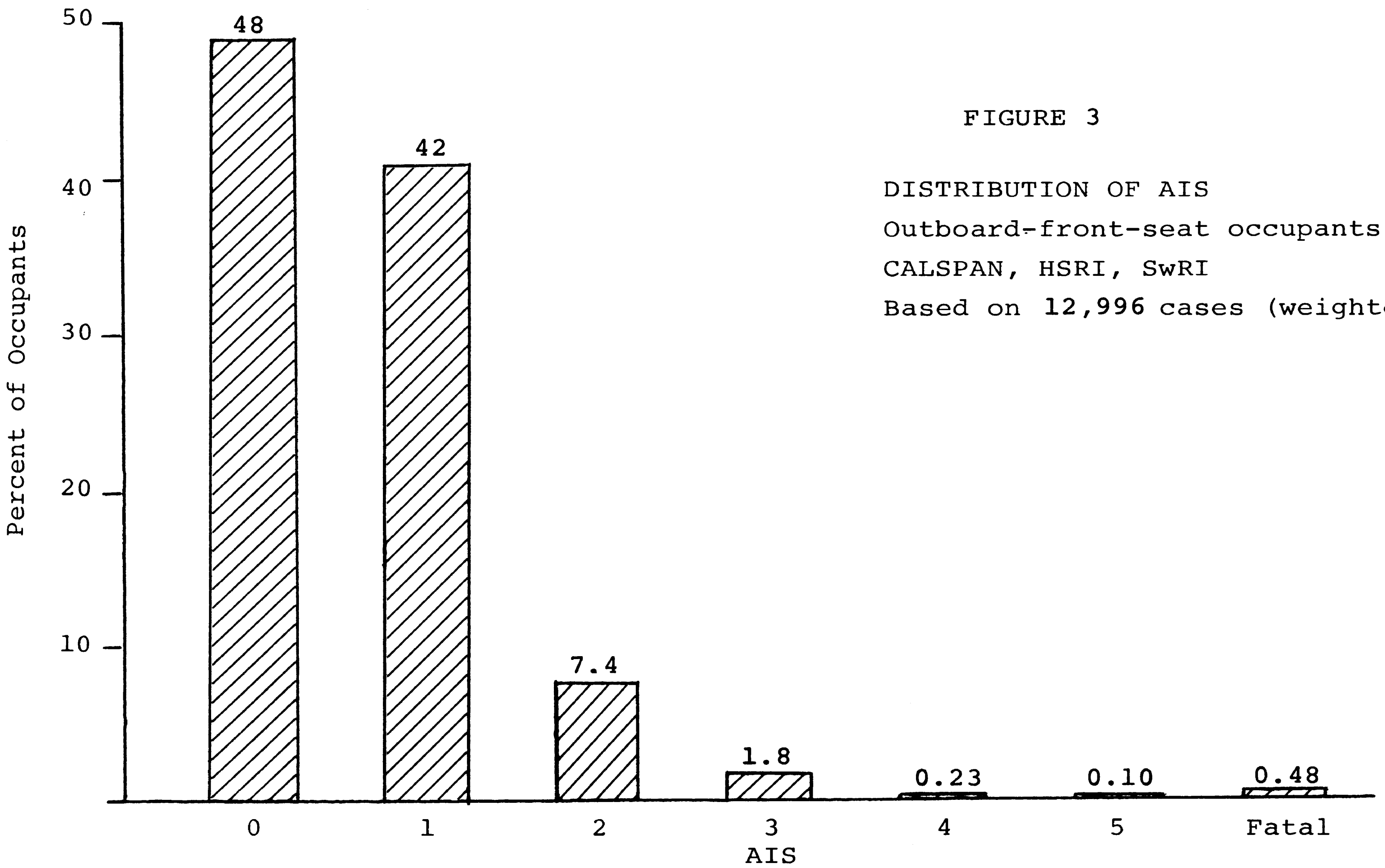

FIGURE 3

DISTRIBUTION OF AIS
Outboard-front-seat occupants
CALSPAN, HSRI, SwRI
Based on 12,996 cases (weighted)

4.3 Methods of Analysis

The analyses presented in this report are directed to three principal questions: (1) What is the frequency of restraint usage? (2) Are occupants of 1973 cars injured less severely than the occupants of 1974 or 1975 cars? (3) How does the relative frequency of severe injury vary with the restraint used? Since the primary interest is in the effect of restraints, only occupants with an option for using the full range of restraints are included. Thus the analysis is restricted to outboard-front-seat occupants sitting in a normal position. All statistics and tables are restricted to these occupants unless otherwise indicated. Attention is further restricted to those in American cars. For purposes of this study American cars include those manufactured by American corporations, and those sold in this country by American manufacturers. This includes the domestic models and cars such as Opels, Capris, and Colts.

As stated in the introduction, a desirable output of the entire study would be an estimate of the effectiveness of restraint systems in reducing injuries in automotive crashes in the nation. There are a number of problems in getting to that. First, while we have acquired very carefully defined samples of data (permitting the use of statistical methods in estimating the effect on a larger population), we do not have a truly random sample of collisions in the nation. The results are, strictly speaking, only applicable to the regions studied. Secondly, there may well be some interacting factors in the data which mask or enchance the expected change in injury production; and the data acquired are not extensive enough to take out all of those factors by post-experimental stratification. The analysis of the data, then, must account for such interactions and must provide a defensible conclusion in spite of such unwanted variations in the sample population.

Because of the first problem, lack of a nationally representative sample, the analyses were conducted separately for each team. The results show that there are differences between teams--differences which are not necessarily geographic. Because of these differences, the data from the three teams have not been combined. It would be possible to combine the data, or alternatively, to combine the results reported here. Such a combination could be done with a variety of strategies for weighting the contribution of each team. In this way one could conceptually produce a combined result that in some way optimally uses the three data sets to represent the nation. For example, they could be combined on the basis of population of the geographic areas covered by the teams, or on the basis of their relative urban-rural distribution compared to the nation, or by a variety of other approaches. In any case, their basic differences and the reasons for the differences would be lost and the larger total sample would infer a small sampling error and an accurate estimate. This would be misleading because the very real possibility of a bias still would exist and might be unrecognized. The differences between teams that are evident when the results are derived separately themselves provide a caution against unwarranted extrapolation to a much larger population.

The statistical analysis presented in the report is basically in four parts. These are (1) examination of restraint usage, (2) raw (crude) injury rates for AIS$\geq$2 by model year and restraint usage, (3) injury rates controlling for confounding variables using multivariate contingency table techniques, and (4) injury patterns.* Both the examination of restraint usage and raw injury rates are basically

*The results for these four parts are given in Sections 5.1, 5.2.1, 5.2.2,5.2.3, and 5.3, respectively.

bivariate analyses. The raw injury rates provide results that were observed in the field without adjusting on other variables. As such they provide a picture of what actually occurred. The objective of these analyses is the estimation of rates (proportion), i.e., the proportion of occupants with AIS$\geq$2, using full restraints, etc. Confidence intervals, and tests of significance of the difference between two proportions using the Z statistic, have been computed using the normal approximation to the binomial distribution. In the estimates of raw proportions of occupants with AIS$\geq$2 by model year, and of restraint usage by model year, the sample variances of the stratified samples were computed using the terms of Equation 4, page 21, representing the appropriate strata (5, p. 106). The variance thus computed includes the effect of stratification. For the proportions of restraint usage, the stratification does not necessarily reduce the variance, because usage is not positively associated with the sampling rates used. However, it may in fact affect the variances and thus should be included.

The variances, and in turn the test of significance and confidence intervals, have been computed both with the finite population correction (fpc) and without the correction (fpc=1). With the correction, the results describe the precision of representation of the areas from which the samples were drawn. The results without the fpc describe the sampling error of the sample as drawn from a much larger population. They do not, however, provide a measure of any biases that the sample might have as a representation of a larger or different population. In a strict sense, the results can be offered as representative of only the areas from which they were drawn, and for these areas the use of the fpc is appropriate.

In addition to analysis of the raw proportions in the reconstructed populations, statistical models were used to investigate the relationships between the proportion of occupants with an injury of AIS$\geq$2 and damage severity or demographic variables. Since different distributions of type of crash or of occupants involved in crashes would generally affect the injury rates, it was important to understand--and be able to control for--the influence of these potentially explanatory variables when drawing conclusions about injury rates by restaint use or by model year.

Two types of statistical models were considered. In the first, the proportion of persons with an injury of AIS$\geq$2 was expressed as a linear function of effects of controlling variable. For example,

$$\hat{P}_{ij} = \hat{\mu} + \hat{r}_i + \hat{s}_j \qquad (6)$$

would represent the predicted probability of an AIS$\geq$2 injury for an occupant using the i^{th} level of restraint, who was involved in a crash of severity type j. In this model, μ represents an estimate of the mean probability of an injury of AIS$\geq$2 if all other effects are zero. The parameters r_i and s_j represent the estimated effects of restraint usage and damage severity j. To cite a specific example, for this model, using the HSRI data, the parameters were estimated to be

μ = .1011	s_1 = -.0777
	s_2 = -.0728
r_1 = .0183	s_3 = -.0522
r_2 = -.0012	s_4 = -.0625
r_3 = -.0171	s_5 = .0811
	s_6 = .1841

Thus the model predicts that the probability that an unrestrained occupant in a crash of severity level 3 will have an AIS$\geq$2 injury is P = .1011 + .0183 - .0522 = 0.0672, while this same probability for a fully belted occupant is only 0.0318.

The second type of statistical model employed is similar in form except that the logarithm of the odds ratio is used as the dependent variable rather than the proportions themselves. That is,

$$\log \frac{P_{ij}}{1-P_{ij}} = \mu + r_i + s_j$$

would be the model corresponding to the previous one. This is equivalent to predicting the proportions by a logistic form:

$$\hat{P}_{ij} = \frac{1}{1 + \exp[\hat{\mu}+\hat{r}_i+\hat{s}_j]}$$

In general, these models did not provide a better description of the data than did the linear ones. They are also somewhat more difficult to interpret and explain. They were used primarily in early selection of variables to be included since it was possible to investigate a larger number of variables simultaneously using them. The final models used and presented in the analysis are linear ones (eq. 6). The parameters were estimated using the weighted least squares technique in the program CENCAT (9).

When the models fitted by this technique were obtained, the predicted values were combined with standard distributions of severity variables to calculate adjusted rates for comparison. There are several reasons for using this method of adjustment rather than one based directly on observed rates. The fitted or predicted injury rates are smoothed, so that some of the sampling variability is removed. This also provides a useful summarization of the data. If a particular configuration of variables happens to be missing in one sample, the model still provides an estimate of what that proportion would be. Without the model, such cases must be eliminated. The models do not estimate zero rates of injury for any configuration. That is, even though, say, no occupants out of twenty in a certain class received an AIS≥2 injury, one would be reluctant to estimate this probability to be zero. Finally, use of an additional model or one which includes only some of the interactions generally results in a smaller standard error for the predicted proportions than that based on the raw proportions. Consequently, the precision of resulting standard errors of the adjusted rates and the estimates of effectiveness are improved.

While the analysis of specific injury patterns was not originally an objective of the study, the specific injuries each occupant sustained were recorded by all teams using the Occupant Injury Classification (OIC) system (5). The OIC contains four letters, denoting Body Region, Aspect, Lesion/Diagnosis, and Body System/Organ, followed by the numeric Abbreviated Injury Scale (AIS). The OIC is used to record occupant trauma in a manner similar to the way the Collision Deformation Classification records vehicle damage. The computer file-building programs then created several occupant injury summary variables, such as the highest AIS sustained by the head.

The injury sources (usually vehicle contact points) were recorded uniquely for each OIC only in the SwRI data. Thus, for example, steering-wheel nose-fractures and windshield forehead-lacerations could be uniquely recorded as separate facial injury sources. SwRI recorded up to two injury sources for each of the first OIC reported. Specific contact points were not recorded by Calspan or HSRI. Consequently, data from all three teams were used in the analysis of body region patterns and the pattern of injury sources was analyzed in the SwRI data.

The analysis of injury patterns was performed in terms of the percentage of occupants in each restraint class who sustained an injury to a particular body region. The highest AIS for each body region was used as the overall AIS for that region.

Unless otherwise noted, all of the estimated proportions presented in the report have been computed to represent the populations from which the stratified sample was drawn, by weighting each observation by the inverse of the sampling ratio. The manner in which the weighting was mechanized results in an indicated number of cases which is similarly weighted and larger than the actual number of observations. The sample size, n, given in tables is also the weighted result unless otherwise indicated.

5.0 RESULTS

5.1 Restraint Usage

Determination of restraint usage was not one of the primary objectives of the study. Nevertheless, it is one of the principal factors of the basic hypothesis of the study, and as such is of considerable importance. Accident data are not necessarily the best and certainly not the most efficient source of information on restraint use in the general driving population. However, since the major benefits of restraints result from their role in impacts one might argue that measurement of their use in the accident population is as relevant as measurement in the general driving population.

Three changes were incorporated in the restraint systems in 1974 model cars. Probably most important was the introduction of the interlock which was intended to prevent starting unless the outboard-front-seat occupants are belted. Secondly, the inertial-locking retractor on the upper torso became a standard item on all cars. Thirdly, the integrated three-point system first came into general use in American cars in 1974.* Each of these changes could reasonably be expected to increase the use of the full restraint system.

Restraint usage, of all the variables fundamental to the study, is the most difficult to determine. All sources of evidence regarding usage were included in the investigations, and were considered by the investigators in reaching their final conclusion. Then they subjectively assigned a code from a three-level scale denoting their confidence in the assessment of usage. Many of the crashes are minor with little or no

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*The lap and upper-torso restraints are permanently joined at their inboard end.

physical evidence in the form of interior vehicle damage or injury patterns to indicate if restraints were used or not. For these cases, determination of restraint usage was obtained primarily from an interview with the occupant.

In contrast to these somewhat pessimistic concerns for determination of restraint usage, many occupants openly admitted they did not use restraints. Such statements were often taken at face value, and occurred frequently enough to give the investigators considerable confidence in their conclusions. The incidence of obvious or suspected false statements by respondents was less than had been anticipated.

The interlock in all cars can be defeated with some effort. It might be expected that restraint usage would increase sharply in 1974 cars when they were first introduced, and then gradually decrease as owners became more familiar with the systems and learned how they might be defeated. Since the data collection did not start until about six months after the introduction of the 1974 models, the early part of the learning curve--if it existed--was not observed.

The use of an interlock to encourage restraint use was eliminated by legislative action during the project.[1] Subsequently, on October 29, 1974, NHTSA amended Motor Vehicle Safety Standard 208 to remove the requirement for interlocks.[2] These changes were enacted too late to directly affect the 1974 cars included in the study. This action, through the

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[1] "Motor Vehicle and School Bus Safety Amendments of 1974" Public Law 93-492 Section 109, 93rd Congress, S. 355, October 27, 1974.

[2] Federal Register, Vol. 39, No. 211, Oct. 31, 1974, p. 38380.

attendant publicity, may have provided an aura of "social acceptability" to defeating the interlock. If this phenomenon occurred, it could have resulted in a further decline in usage after about the eighth month of study.

These statements describe factors which may have affected usage during the period of data collection. They do not represent findings. Attitudes or social factors relating to the use of occupant restraints were not addressed in the program.

Restraint usage as measured in the study is shown in Table 7. Several observations are apparent. The use of full restraints (both the lap and upper-torso belts) is greatly increased in 1974 cars for all three teams, by a factor of eight or more. Furthermore, there are more fully restrained occupants in 1974 cars than restrained occupants (lap or lap and upper torso belt) in 1973 cars. The use of full restraints in the 1975 cars is somewhat lower than in 1974 cars for each team, about the same as the use of restraints of either type in 1973 cars. The proportion of occupants using only the lap belt in 1974 or 1975 cars is small, 5 percent or less, and the proportion of 1973 occupants using full restraints is even smaller.

There are differences between teams, but they are not large. The CALSPAN and HSRI results are similar, while SwRI shows somewhat greater usage, both of lap belts only in 1973 cars and full restraints in 1974 and 1975 cars.

The 95 percent confidence intervals for each of the measured usage rates of Table 7 are given in Table 8. The tabulated values are one-half the 95% confidence intervals based on the variance of a stratified sample, and are given both with and without the finite population correction.

The commonly used restraints were the lap belt only in 1973's and the lap and upper torso in 1974's and 1975's. The usage of these restraints is shown in Figure 4 for each team along with the 95 percent confidence interval computed without the finite-population correction. The 95 percent confidence interval with the finite population correction is indicated by the broken lines. The increase of fully belted occupants

Table 7

RESTRAINT USAGE

(Data weighted on inverse of sampling fraction; occupants with other and unknown restraint usage are omitted from the table)

Team		None	Lap Only	Lap and Shoulder	Total
CALSPAN					
1973	N	1272	466	64	1802
	%	70.6	25.9	3.5	
1974	N	1052	138	581	1771
	%	59.4	7.8	32.8	
1975	N	215	17	105	337
	%	63.8	5.0	31.2	
HSRI					
1973	N	1337	519	78	1934
	%	69.1	26.8	4.0	
1974	N	1006	92	712	1810
	%	55.6	5.1	39.3	
1975	N	254	16	118	388
	%	65.5	4.1	30.4	
SwRI					
1973	N	1434	879	74	2387
	%	60.1	36.8	3.1	
1974	N	1059	99	953	2111
	%	50.2	4.7	45.1	
1975	N	359	15	245	619
	%	58.0	2.4	39.6	

Table 8

Restraint Usage
Confidence Intervals

The tabulated values are one-half the 95% confidence intervals in percent usage, for the usage rates given in Table 7.

Restraint	Team CALSPAN	HSRI	SwRI
With finite population correction			
1973 None	1.2	3.0	2.2
Lap	1.9	5.0	3.1
Full	2.5	6.4	4.0
1974 None	1.4	2.8	2.7
Lap	3.3	3.8	4.1
Full	1.5	3.2	3.0
1975 None	3.8	2.6	4.5
Lap	4.6	6.9	7.3
Full	7.0	4.6	5.7
Without finite population correction			
1973 None	2.8	3.9	3.3
Lap	4.4	6.3	4.4
Full	5.1	7.8	5.6
1974 None	3.3	4.4	4.0
Lap	5.6	5.9	5.8
Full	4.1	4.8	4.3
1975 None	7.3	5.8	6.7
Lap	11.5	11.7	10.5
Full	11.3	9.3	8.4

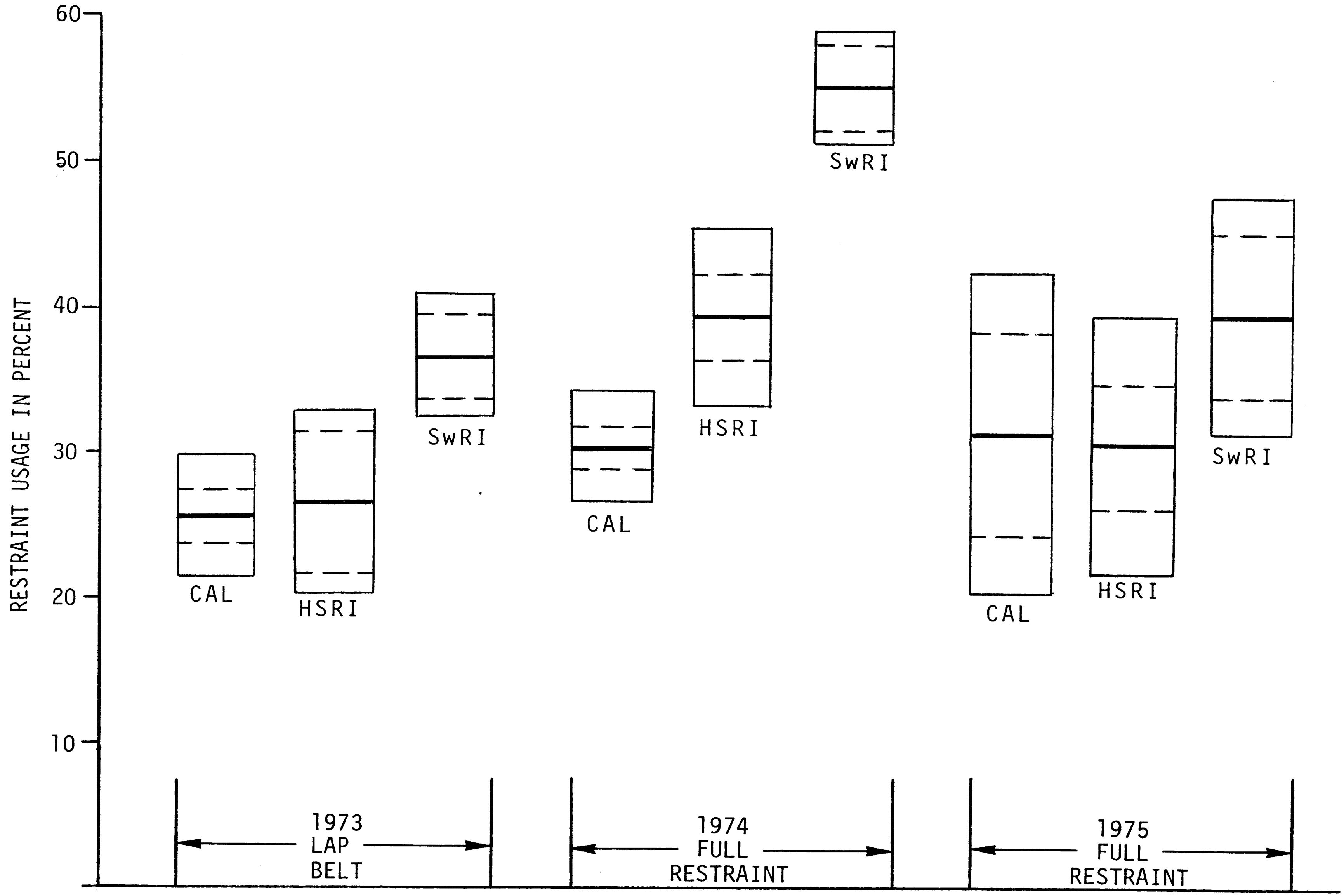

FIGURE 4

RESTRAINTS USED AND 95 PERCENT CONFIDENCE INTERVALS in 1974 and 1975 cars over those with lap belt only in 1973 cars is readily apparent from the figure. Chi-square tests indicate that within each team the differences in usage rates by model year are significant, with significant levels (p values) of 0.01 or less. The only exception is the comparison of 1974 and 1975 occupants for CALSPAN.* In particular, the use of full restraints in both 1974 and 1975 cars was significantly greater than in 1973 cars. However, both HSRI and SwRI data show lower use of full restraints in 1975 cars than in 1974's with significance levels of 0.01 or less.

Although the data of all three teams exhibit similar patterns of usage, there are differences among teams. Comparisons of restraint usage between pairs of teams for individual model years indicate that the differences are all statistically significant at the one percent level except for CALPSAN 73 versus HSRI 73, and CALSPAN 75 versus HSRI 75. Lap belt use in 73's and full restraint use in 75's is higher in the SwRI data. Restraint use in 74's is different for all three teams, with CALSPAN having the lowest (32.8%) and SwRI the highest (45.1%). Reasons for the differences among teams are not apparent. While CALSPAN did depend on police-reported information rather than in-depth investigations for a substantial portion of their subjects, their results are not consistently different from those of HSRI.

The 1974 restraint usage results given above are from data collections that started approximately half way through the 1974 model run. While we might expect to observe some gradual

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*The Chi-square tests do not include effects of stratification but are convenient to use. The p values were either large (e.g., 0.8) or small (e.g., 0.01). The effect of stratification would not change the results, so checks including the effects of stratification were not considered necessary.

decrease in the use of full restraints in the interlock cars as people learned how to defeat the system, the observation period did not include their introduction or use while they were "new" to the general public. Nevertheless, there is evidence of reduction in usage with time, as shown in Figure 5.

All three curves exhibit fluctuations which may well be sampling error. The 95 percent confidence intervals for each month are approximately $\pm$ 10 percent (in usage) for HSRI, $\pm$ 11 percent for CALSPAN, and $\pm$ 9 percent for SwRI; all are generally greater than the month-to-month fluctuation. These confidence intervals were computed from $\overline{V(p)} = \frac{P(1-P)}{n}$ where n is the total size of the reconstructed population and are only approximate. They do not include consideration of the stratified samples. This method was used for convenience. Comparison of values from Table 5 for stratified samples with the method used here indicates the above method gives values which are low by about 1/3 for 1973's and about 1/4 for 1974's. Inclusion of the effects of stratification give greater variances for estimates of full restraint usage because stratification was not on a variable closely associated with restraint use. Furthermore, the higher sampling fraction was used for those more likely to be unrestrained, thus reducing the precision of estimates of the proportion unrestrained.

Linear regressions of percent usage against month (Figure 5) provide measures of the statistical significance of the apparent trends. This method is justified only because approximately equal numbers of observations are available for each month, giving nearly uniform weighting and variance. The regression for the HSRI data indicates a slope of -2.3 percent usage per month. SwRI data has a slope of -1.8 percent usage per month, and -1.5 for the CALSPAN data. All three slopes are significantly different from zero at a level of less than 1 percent.

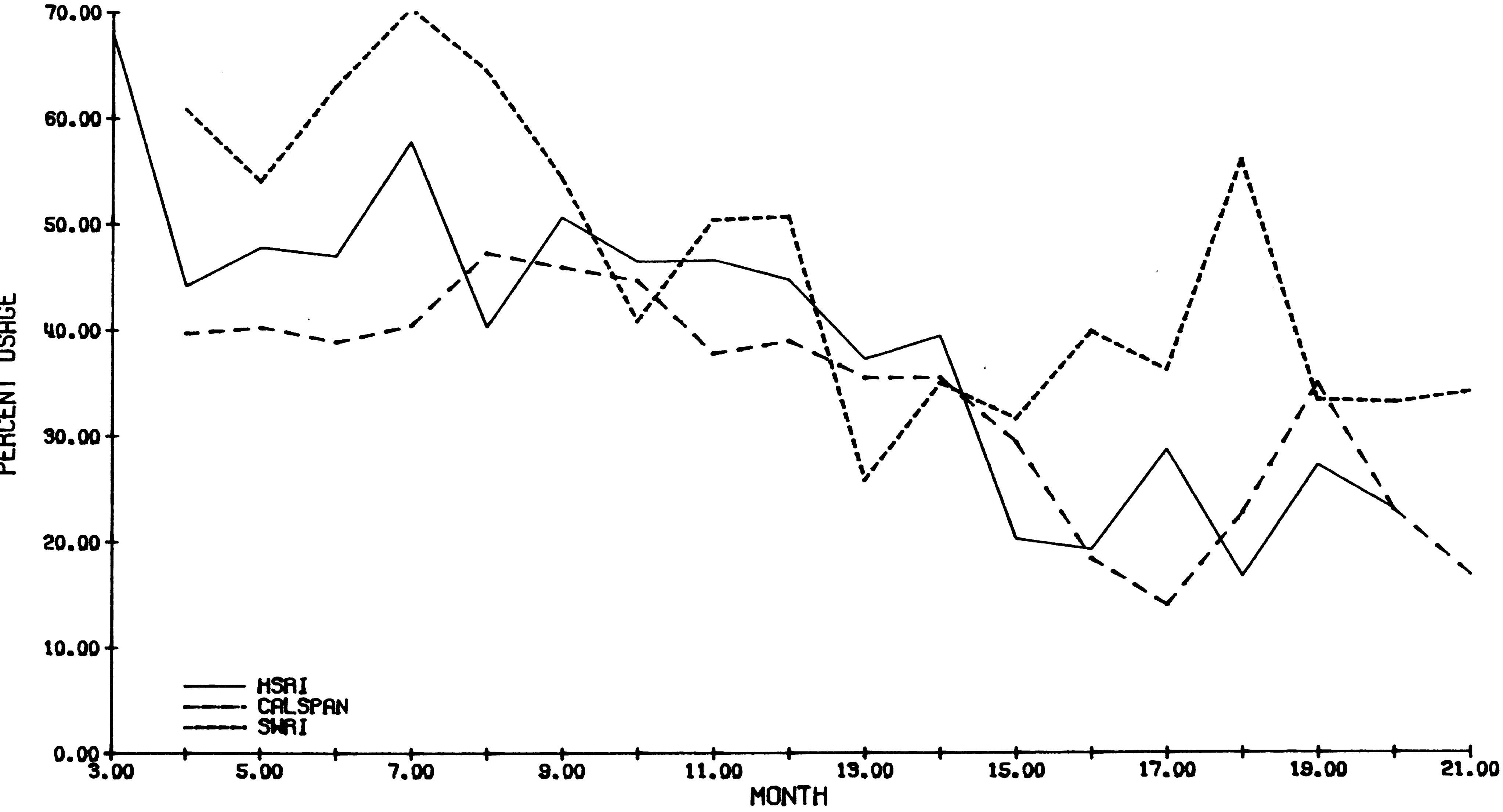

FIGURE 5
1974 FULL RESTRAINT
RESTRAINT USAGE BY MONTH

For comparison the use of the lap belt only in 1973 cars is shown in Figure 6. No trend is immediately obvious in any of the three and indeed linear regressions of the data show none of the three curves has a statistically significant slope. This would suggest that any reduction in usage in 1974 cars is related to those particular cars and not to a social factor affecting the general driving population.

The gradual reduction in the use of full restraints in 1974 cars indicates that people learned how to defeat the interlock system. The incidence of defeat is shown by month for each team in Figure 7. The average values over eighteen months of data are 35.2 percent for CALSPAN, 53.8 percent for HSRI, and 32.4 percent for SwRI. These values are the percents of outboard-front-seat occupants for whom the system had been defeated. In some cases the defeat applied to both seat positions, e.g., disabling the logic module, while in others the individual seat positions are affected, as by disconnecting the seat sensors.

The data from CALSPAN and SwRI are similar, both for the twelve-month average and in the monthly pattern. The incidence of defeat is greater for HSRI. Differences between teams could be a consequence of both the methods of data collection and of recording. At HSRI the measurement of system defeats was not a project objective per se, but was included to provide the investigators additional evidence regarding restraint use. As a result, the recording of information on defeat was in a binary form that does not allow distinction between "no defeat" and "unknown" or "missing data." This may have been true for other teams as well. Including "missing data" with "no defeat" would lead to an underestimation of the incidence of system defeats (although HSRI had the highest rate). The CALSPAN data include a substantial amount of missing data on elements obtained by vehicle inspection (about 28 percent). These missing data are also included with "no defeat" and lead to a low estimate. All teams show a trend of defeat increasing with time.

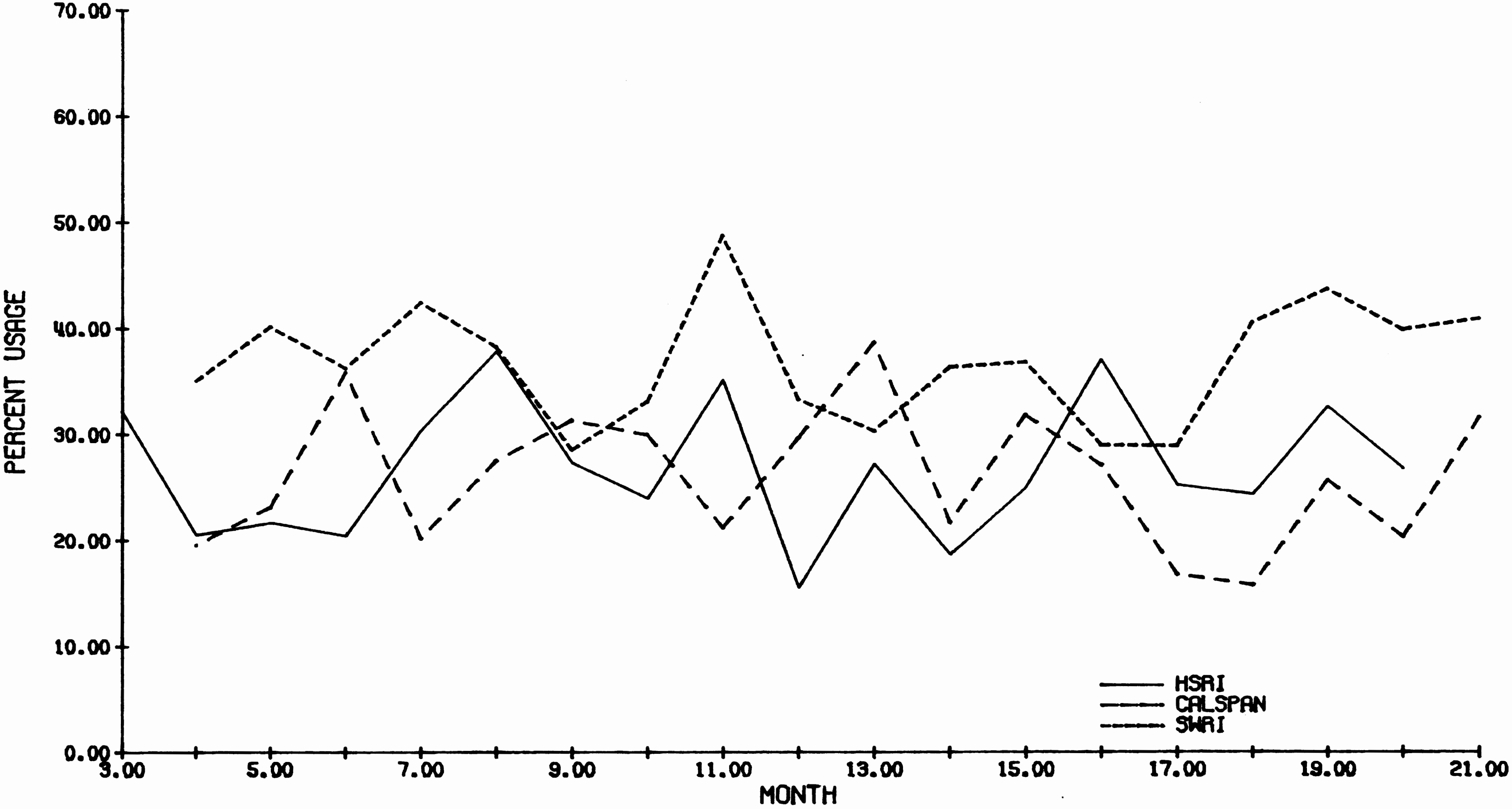

FIGURE 6
1973 LAP BELT ONLY
RESTRAINT USAGE BY MONTH

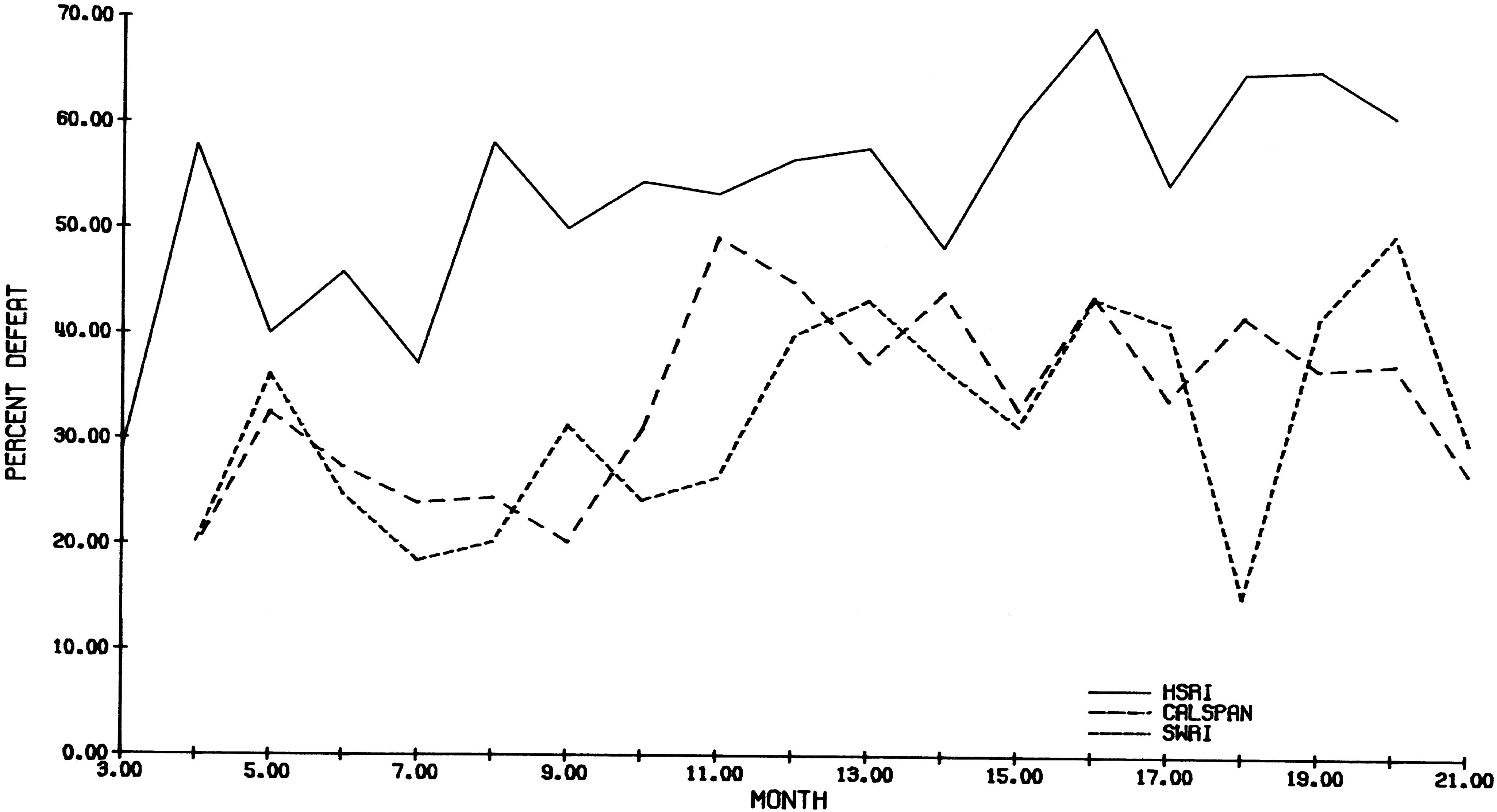

FIGURE 7
1974 INTERLOCK DEFEAT IN PERCENT OF
OUTBOARD-FRONT-SEAT OCCUPANTS, BY MONTH

Use of full restraints in 1974 cars is shown in Figure 8 by the mileage on the car. The points on the abscissa are odometer readings in 3,000 mile increments. Thus point 1 represents 0-3,000 miles, and point 8 represents 22,000-24,000 miles. The last point includes all cases greater than 24,000 miles. Missing data on mileage are excluded. The ordinate is again the percent of outboard-front-seat occupants wearing full restraints at the time of the accident. All three teams exhibit a dramatic reduction with mileage. The odometer reading of a current-model-year car at the time of the accident could be a measure of the intensity of use of the car, or a surrogate for the age of the car. Thus Figure 8 might indicate that people who drive many miles are more inclined to defeat the interlock and not use their restraints, or that people wear the restraints initially, but defeat the system some time later. Figures 7 and 8 have similar patterns, with both figures showing comparable usage at the right. This suggests that people used the restraints initially, but not after they later learned how to defeat the system. In any case the definite trend of all three curves of Figure 8, and their general agreement, are among the more consistent observations to come from the study.

As stated earlier, two aspects of the 1974 systems may have modified the use patterns of earlier models. These are the integrated lap and upper-torso belts, as well as the interlock. It is impossible to determine the relative contribution of each of these changes from the data collected in this study. Nevertheless, some insight can be gained by examining two subjects. One is the relationship between restraint usage and interlock defeat in 1974 cars. The other is the usage in 1975 cars which have essentially the same belt configuration but not the interlock. Each of these subjects will be examined below, first the 1974 interlock defeat, then usage in 1975's.

If the integrated belt configuration were an important (positive) factor, we might expect that some of the people who

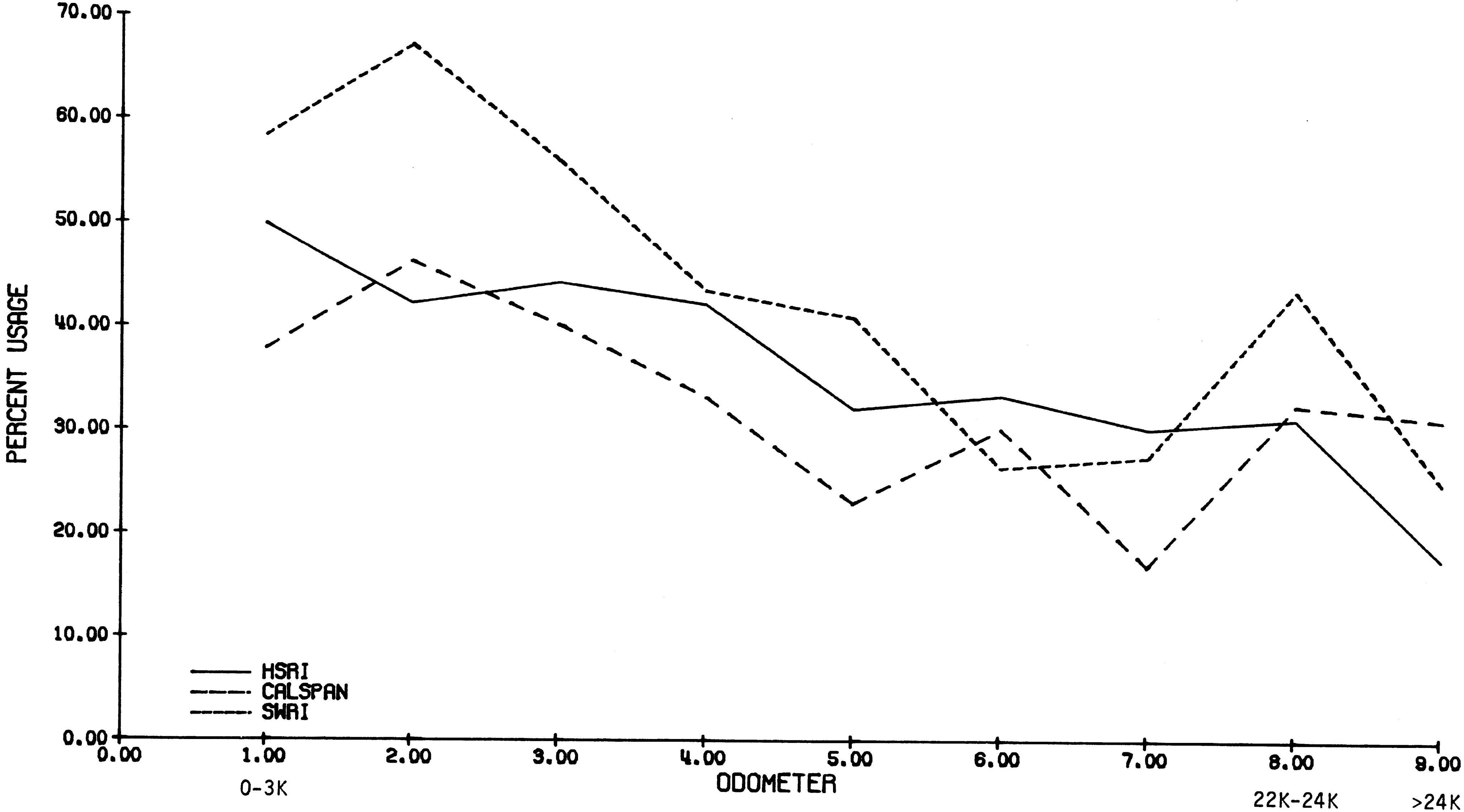

FIGURE 8
1974 FULL RESTRAINT
USAGE BY ODOMETER READING

found the interlock restrictive or objectionable might have disabled the system, while continuing to wear the full restraint. This is examined in Table 9. The proportion of all outboard-front-seat occupants who were in seats for which the interlock was defeated is given for each team. The HSRI and SwRI data both indicate that about 50 percent were in defeated positions. The lower defeat rate for CALSPAN (35 percent) is again likely a consequence of missing data on variables obtained from vehicle inspection or occupant interview. This suggests that the CALSPAN data on "defeat" probably are much less reliable than either HSRI or SwRI.

The incidence of defeat among the unrestrained is about 90 percent in the HSRI and SwRI data. It is difficult to imagine how people could be unrestrained in an interlock car without defeating the system. The HSRI and SwRI data are very consistent on this point, however. The remaining 10-15 percent may have been cases of failure or inability to detect the defeat. Among the restrained occupants (restrained by either lap belt or lap and upper torso) the incidence of defeat was low: 15 percent.

Table 9 also gives the incidence of restraint (by either lap or full) by defeat status. Among those occupants in positions for which the interlock was not defeated, usage was over 80 percent, while only 12 percent of the occupants in defeated positions were using restraints. This latter figure is disappointingly low and suggests that much of the increased usage in 1974 cars was a consequence of the interlock. We might also conclude that those individuals who were inclined to use their restraints did not bother to disable the interlock simply to avoid any inconvenience it might provide.

The methods used to defeat the interlock system were noted by the investigators in determining the status of the system, but the digital data files constructed at HSRI included the information only for SwRI. The methods used to defeat the interlock detected by SwRI are shown in Table 10. The most common

Table 9

RESTRAINT USAGE IN 1974 CARS
BY INTERLOCK STATUS

	Team		
	CALSPAN	HSRI	SwRI
1. Proportion of Occupants with defeated interlock in percent:			
All occupants	34.6	53.8	56.6
Unrestrained	47.2	85.3	91.3
Restrained	17.2	14.9	15.1
2. Proportion of occupants using restraints in percent among those in seats with interlock:			
Not defeated	47.9	83.2	89.1
Defeated	18.9	12.3	12.1

Table 10

METHODS USED TO DEFEAT THE
1974 INTERLOCK SYSTEM

SwRI Data

Method	Percent of Identified Methods	
Seat sensor wires cut or disconnected	71.4	
Buzzer or warning light module disconnected	19.9	
Logic module altered	3.1	
Underhood emergency start module altered	1.8	
Defeated by other means	3.9	
Total	100.1	(N=675)
No defeat, unknown if defeated, defeat method not known	N=1464	

method is to disconnect or sever the wires to the seat sensor. This latter method would not actually defeat the starter interlock but could have been used by people who wear or pull out the lap belt for starting, then do not wear the belts afterward. Other methods used only add to 9 percent of the techniques identified by SwRI.

The methods listed in the table are those techniques detected by the investigator from examination of the vehicle. Defeat by methods which were not physically or electrically detectable on inspection would constitute missing data and are not included in the distribution.

The data for 1975 cars provide additional insight, although interpretation of the data for 1975 cars could be complicated somewhat by the timing of the legislature removal of the interlock. The interlock was mandatory on new cars sold up until the end of October 1974, and illegal afterwards. Since this was about two months after the introduction of the model line, the 75's sold early may have had the interlock. The field investigators were not able to determine if a '75 was an early sale with the interlock defeated by the owner, or if the defeat was by the manufacturer or dealer for sale after the end of October. Most of the 75's investigations were in the last few months of data collection, and were probably cars sold without a functioning interlock. This being the case, the data are not seriously confounded.

Figure 9 shows use of the full restraint by month. The variance of the estimate for each month is high because of the small number of 1975 cars investigated. Hence the plots exhibit large fluctuations from sampling error, and trends cannot be established reliably. Nevertheless, the usage is considerably lower than was observed in 1974 cars early in the project.

It is interesting to note that even with the gradual reduction in full restraint use in 74's, the average use shown in Table 7 is greater for both HSRI and SwRI than in 1975 cars.

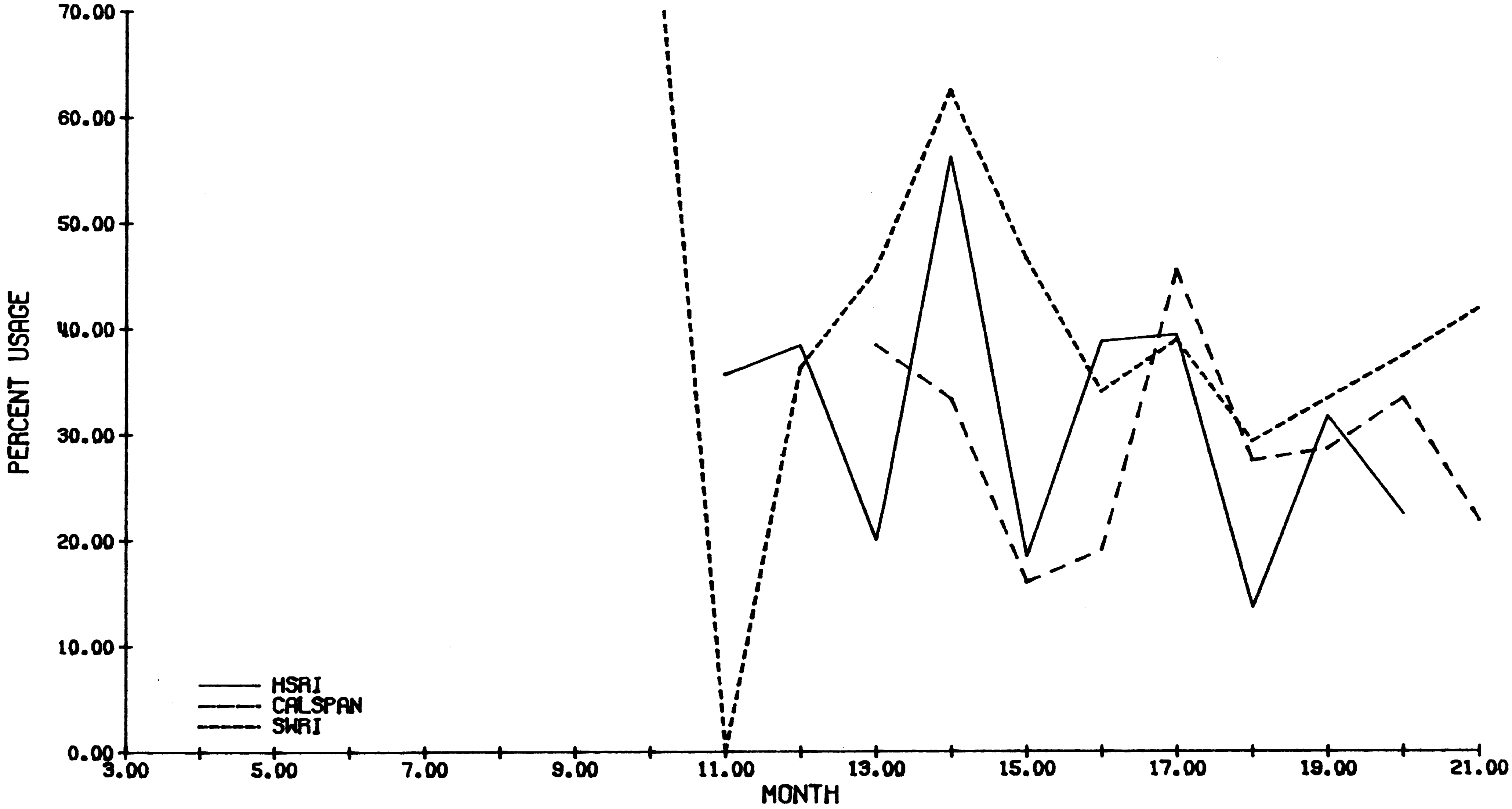

FIGURE 9
1975 FULL RESTRAINT
RESTRAINT USAGE BY MONTH

Furthermore, the use of full restraints in 75's differs from the use of restraints (either lap only or full) in 73's by less than one percent for all three teams.

The evidence available from both the association of defeat with restraint usage in 74's and comparison of usage in 74's and 75's does not provide a conclusive finding, but certainly suggests a very plausible inference. It appears that the integrated three point restraint did not increase the overall use of restraints, but that those occupants who formerly used only the lap belt now use the full restraint. In addition, it appears that the sequential interlock increases restraint use among new owners, but that after a "learning" period, its benefits are largely circumvented by overt defeat of the system.

5.2 Injury Rates

This section deals with the rates of injury by model year and by restraint, the principal objectives of the study. The scale of injury severity used is the overall occupant severity on the Abbreviated Injury Scale (AIS) (2). The scale was intended to be applied to each individual injury an occupant may sustain. It is also used by most investigators to describe the overall severity to the victim. The AIS as it was applied to the overall severity has eleven levels, including five levels for fatalities. The levels of non-fatal injury are:

- 0 No Injury
- 1 Minor
- 2 Moderate
- 3 Severe (not life-threatening)
- 4 Serious (life-threatening, survival probable)
- 5 Critical (survival uncertain)

Levels 6 through 10 cover fatalities, categorizing the time to death and number of individual injuries. The AIS has been revised by the Joint Committee on Injury Scaling of the Society of Automotive Engineers, American Medical Association, and the American Association for Automotive Medicine but the scale defined in Reference 2 was used by the teams contributing to this study (8).

The ad hoc committee selected the rate of injury above a specific level of the AIS as the measure of performance for the study. The dichotomy of injury that was chosen is AIS=0,1 and AIS≥2. This cut point was not an arbitrary decision. The fatality rate is a measure of great interest, but the project was not expected to provide sufficient data to study fatalities, and has not done so. Injuries of AIS 4 and 5 occur even less frequently than fatalities, as shown in Figure 3, and together with fatalities provide insufficient data in the samples that have been collected.

It would be feasible to study the incidence of no injury (AIS=0) versus any injury. Such a dichotomy has been used in the past, particularly in studies using injury data provided by police investigations. AIS 1 contains injuries that are indeed minor. On this scale, <u>any</u> injury is assigned a non-zero value, including minor contusions, abrasions, and tenderness. Many of these are trivial injuries similar to those we often consider an acceptable part of everyday living. Including such injuries would seem to be inappropriate, if not irrelevant.

The remaining possible cut points are AIS≥2 and AIS≥3. Both of these are of interest and will be addressed, but even those of level three and above occur so infrequently that the data analyzed here are insufficient for more than a superficial examination. The levels originally selected for study, AIS≥2, (moderate or worse) are appropriate for both philosophic and pragmatic reasons, and the results to follow are based largely on this measure.

The results for the incidence of moderate or worse injury as a function of model year and by restraint used are given in two parts. The first deals with unadjusted or crude rates, i.e., rates derived without considering the effects of confounding variables. The primary objective of the program was a comparison of such rates for 1973 and 1974 cars and this is indicated, although since the removal of the interlock, evaluation of restraint effectiveness is much more important.

The second part gives the results of using a generalized program for analysis of multivariate categorical data. This analysis is used to control for the effects of confounding variables, and results in injury rates which are adjusted to a standardized population of the independent (confounding) variables.

The results in both sections have been obtained by omitting cases with missing data on essential variables. Thus, for each table, cases with missing data on one of the tabulated variables have been deleted.

5.2.1 Unadjusted Injury Rates. The proportions of outboard-front-seat occupants receiving injuries of AIS=2 or greater by model year are shown in Table 11. The results for the three teams are all quite different.

CALSPAN and HSRI both show a slight increase in the incidence of moderate or worse injury in 1974 cars, and a substantial increase in 1975 cars. The figures for SwRI indicate similar results in 1974 and 1975 cars, both reduced over 1973 cars.

The reductions relative to 1973 results, shown in parentheses, are the relative reductions used here and elsewhere in the report and are given by

$$\text{relative reduction} = (P_1 - P_2)/P_1 \qquad (7)$$

and are expressed in percent.

Tests of significance were conducted using variances for stratified samples computed from equation 4, page 21 . One-

Table 11

PROPORTION OF OCCUPANTS
RECEIVING INJURIES OF AIS≥2 BY MODEL YEAR

Team	AIS≥2 in Percent	Reduction in Percent[1]	Total N (weighted)
CALSPAN			
1973	11.8		1893
1974	11.9	(-1)	1885
1975	14.2	(-20)[2]	367
HSRI			
1973	7.4		1917
1974	7.7	(-4)	1787
1975	9.5	(-29)[2]	377
SwRI			
1973	11.4		2349
1974	8.9	(21)[2]	2050
1975	9.2	(19)[2]	598

[1]Relative to 1973

[2]Significant at 0.1 w/o fpc

sided tests for 1975 compared to 1973 are significant at the 0.1 level for all three teams, while the 1974-1973 comparisons are significant at 0.1 only for SwRI. The above tests are without the finite population correction. Including the finite population corrections leads to significance at the 0.1 level for all comparisons except HSRI 1974.

Comparisons of 1975 and 1974 are not shown, and are not significant at the 0.1 level for any team without the finite population correction. With the correction included, they are significant for CALSPAN and HSRI, but not for SwRI.

Thus we may conclude that the raw unadjusted rates do not indicate a reduction of the incidence of moderate or worse injury in 1974 and 1975 cars except in the SwRI data, where the reduction is about 20 percent. CALSPAN and HSRI both show an increase of injury in 1975 cars.

The 95% confidence intervals for the injury rates shown in Table 11 are given in Table 12 both with and without the finite population correction. They are based on the variance of a stratified sample and are equal to $1.96(V)^{\frac{1}{2}}$.

Although the results for CALSPAN and HSRI both show an increase of similar relative magnitude in the later years the average rate (for all years) is lower for HSRI than for either of the other teams--only 64 percent of that for CALSPAN and 77 percent of that for SwRI. An apparent reason for the lower rate for HSRI is the policy each team uses for coding the severity of lacerations. This will be discussed in more detail in Section 5.3.3.

The increased incidence of injury among occupants of 1974 and 1975 cars for CALSPAN and HSRI data is disappointing in view of the greatly increased use of full restraints in the later model years. The injury rate by restraint is shown in Table 13 for the aggregate of all three model years. Also shown is the relative reduction for each restraint compared to unrestrained occupants. All three teams show a substantial

Table 12

CONFIDENCE INTERVALS OF ESTIMATED PROPORTIONS OF INJURY OF AIS≥2 BY MODEL YEAR

The tabulated values are the half-widths of the 95 percent confidence intervals in percent of occupants with AIS≥2.

	Team		
	CALSPAN	HSRI	SwRI
1973 w fpc*	0	0.55	0.74
w/o fpc	1.43	1.20	1.37
1974 w fpc	0	0.43	0.71
w/o fpc	1.43	1.22	1.31
1975 w fpc	0	0.73	1.36
w/o fpc	3.35	3.00	2.53

*finite population correction

Table 13

PROPORTION OF OCCUPANTS RECEIVING INJURIES OF AIS$\geq$2 BY RESTRAINT

Team	AIS$\geq$2 in Percent	(Reduction in Percent)[1]	Total N (weighted)
CALSPAN			
None	15.6		2513
Lap Only	7.8	(50)[2]	618
Full	6.6	(58)[2]	748
HSRI			
None	9.2		2551
Lap Only	4.9	(47)[2]	615
Full	5.5	(41)[2]	897
SwRI			
None	13.8		2737
Lap Only	6.4	(54)[2]	985
Full	5.0	(64)[2]	1242

[1]Relative to "None"

[2]Significant at 0.001 w/o fpc

reduction in the rate for lap-belted occupants, compared to those unrestrained. CALSPAN and SwRI show an even greater reduction for those using both the lap and upper-torso restraint, while HSRI shows a greater reduction for the lap belt only. However, the advantage of full restraints compared to lap-belt only is not as great as for the lap-belt over no restraint for any of the three teams.

The reductions in moderate and worse injury among lap belted and fully restrained occupants compared to the unrestrained are significant at 0.001 with or without the finite population correction. The differences between lap belted and fully restrained occupants are significant without the finite population correction only in the case of SwRI (p=0.098). Confidence intervals for the proportions of moderate and worse injuries for the three restraint configurations are given in Table 14.

The results shown in Tables 11 and 13 for CALSPAN and HSRI are paradoxical, in that both teams found increased use of full restraints in 1974 cars (as shown in Table 7), substantially fewer severe injuries among the fully restrained, and yet an increased injury rate in 1974's. Both teams also showed an increase in injury in 1975's compared to 1974's, but this may have resulted in part from the decreased use of full restraints in 1975's. One reason for the paradox in 1973's and 74's is the substantial benefit of lap-belts, which were worn primarily in 1973 cars, as shown in Table 15. The injury rates with the lap belt--with substantial usage in 1973's--are nearly as low as for full restraints in the CALSPAN and HSRI data. This appears to cancel much of the net benefits that were anticipated with the introduction of the 1974 cars.

A second phenomenon confounds the issue and contributes to the paradox. The injury rates by restraint shown in Table 9 were obtained by pooling (aggregating) the data for all three model years. As shown in Table 15, however, the data for individual restraint configurations are not distributed similarly across the three model years. Data on unrestrained occupants

Table 14

CONFIDENCE INTERVALS OF ESTIMATED PROPORTION OF INJURY OF AIS≥2 BY RESTRAINT

The tabulated values are the half-width of the 95 percent confidence intervals in percent of occupants with AIS≥2.

	Team		
	CALSPAN	HSRI	SwRI
Unrestrained			
w fpc*	0	0.46	0.74
w/o fpc	1.38	1.13	1.38
Lap belt only			
w fpc	0	0.45	0.92
w/o fpc	2.08	1.62	1.67
Full restraint			
w fpc	0	0.69	0.73
w/o fpc	2.26	1.58	1.33

*finite population correction

Table 15

PROPORTION OF OCCUPANTS WITH AIS ≥ 2

(Data weighted on inverse of sampling ratio; occupants with unknown injuries are omitted from the table)

	AIS ≥ 2 %	AIS ≥ 2 Total N
CALSPAN		
1973 No Restraint	14.5	1256
1974 No Restraint	15.7	1044
1975 No Restraint	21.1	213
1973 Lap Only	7.1	464
1974 Lap Only	10.2	137
1975 Lap Only	5.9	17
1973 Lap & Shoulder	1.6	64
1974 Lap & Shoulder	7.2	529
1975 Lap & Shoulder	5.7	105
HSRI		
1973 No Restraint	8.6	1320
1974 No Restraint	8.9	985
1975 No Restraint	13.4	246
1973 Lap Only	4.3	507
1974 Lap Only	8.7	92
1975 Lap Only	0.0	16
1973 Lap & Shoulder	5.1	78
1974 Lap & Shoulder	6.0	705
1975 Lap & Shoulder	2.6	114
SwRI		
1973 No Restraint	14.4	1391
1974 No Restraint	13.6	1001
1975 No Restraint	12.5	345
1973 Lap Only	7.1	875
1974 Lap Only	1.1	95
1975 Lap Only	0.0	15
1973 Lap & Shoulder	5.7	70
1974 Lap & Shoulder	4.9	934
1975 Lap & Shoulder	5.0	238

are provided about equally by 1973 and 1974 cars, with a small amount from 1975's. Lap belt data, however, are nearly all from 1973's. The full-restraint data are primarily from 1974's and 1975's. Conversely, the contributions to lap-belt data from 1974's are very small and almost none of the full-restraint data are from 1973's. Thus, the effect of pooling is greater on the data for unrestrained occupants than for either of the restrained categories. Furthermore, the injury rates for the unrestrained vary by model year.

When the lap belt rates (1973's) are compared with the unrestrained in Table13, they are compared not with just 1973 unrestrained, but with injury rates higher than for just the 1973's. This magnifies the apparent protection afforded lap belted occupants. Similarly, the apparent benefits of full restraints are decreased by the same pooling of unrestrained occupants. The net effect is an inflation of the relative benefits of lap belts compared to full restraints.

The phenomena described above could be avoided by evaluating the benefit of both restraints within individual model years. However, there are not enough data on full restraints in 1973 cars to compare them with lap belts, nor enough data on lap-belted occupants in 1974 or 1975 cars to compare them with full restraints. An alternative procedure is to measure the benefits of lap belts over no restraints in 1973's, and of full restraints over no restraints in 74's and 75's. The relative reductions in the incidence of moderate or worse injury (AIS$\geq$2) obtained in this latter manner are shown in Table 16. The Z statistic and the corresponding one-sided significance levels for the differences in the injury rates for the two restraint usages indicated are also given, based on the variance of a stratified sample.

The results for CALSPAN are almost identical to those given in Table 13, where the three model years are pooled. The benefits of the lap and full restraints are almost identical

Table 16

COMPARISONS OF INJURY OF AIS$\geq$2 ; REDUCTION AND SIGNIFICANCE LEVELS FOR RESTRAINTS WITHIN MODEL YEARS

Contrast	Team					
	CALSPAN		HSRI		SwRI	
	w fpc	w/o fpc	w fpc	w/o fpc	w fpc	w/o fpc
Lap vs. None						
1973						
Reduction (%)	50.9		49.8		50.7	
Z	∞	4.83	0.43	3.73	9.72	5.30
Prob.*	0	0.000	0.000	0.000	0.000	0.000
Full vs. None						
1974 and 1975						
Reduction (%)	57.8		47.8		62.8	
Z	∞	6.86	10.89	2.95	12.65	6.90
Prob.*	0	0.000	0.000	0.002	0.000	0.000

*one-sided significance level

for HSRI whereas the lap belt appeared somewhat better than the full restraint in Table 13. The results for SwRI show an increased benefit of the full compared to lap restraint.

The proportion of occupants injured with AIS$\geq$2 and the confidence intervals on the proportions are given in Table 17 for each of the sub-populations used in Table 16.

We may conclude that both restraints reduce the probability of severe injury, and that full restraints are more effective than lap-belts alone. However, both the CALSPAN and HSRI data indicate that the lap belts in the 1973 cars are nearly as effective as the lap and upper-torso combinations of 1974 cars in reducing the injury rates, compared to unrestrained occupants in the respective model years.

There are several possible explanations of the apparent similarity of lap and upper-torso restraint performance that can be examined. The upper-torso restraint may be more beneficial at higher accident and injury severities. Users of the full restraint may still receive moderate (AIS=2) but tolerable injuries, while being protected against more severe consequences. If much of the benefit of restraints were from prevention of ejection, the two configurations might demonstrate similar results. An important consideration might also be the reliability of the data on usage. The comparison of model years is independent of the investigator's determination of usage, and was selected as the original objective partly for this reason. Measurements of the performance of the individual restraint configurations are obviously sensitive to observational errors in usage. An additional explanation is the impact configurations encountered in the set of towaway accidents. Restraints might be expected to provide their greatest benefit in frontal impacts, yet not all impacts are frontal. The presence of a substantial number of non-frontal impacts conceivably could mask benefits in frontal impacts. These four factors--severity level, ejections, usage reliability, and frontal impacts--will be discussed individually.

Table 17

PROPORTION OF OCCUPANTS RECEIVING INJURIES OF AIS≥2 AND THE CONFIDENCE INTERVALS FOR SPECIFIC RESTRAINT AND MODEL YEAR

The half-widths of the 95% confidence intervals are given in percent injured (AIS≥2)

Restraint and Model Year	Team: CALSPAN	Team: HSRI	Team: SwRI
1973 None p (%)	14.5	8.6	14.4
C.I. w fpc	0	0.81	1.04
w/o fpc	1.90	1.61	1.96
1973 Lap p (%)	7.1	4.3	7.1
C.I. w fpc	0	0	1.04
w/o fpc	2.31	1.58	1.85
1974 and 1975			
None p (%)	16.6	9.8	13.3
C.I. w fpc	0	0.39	1.06
w/o fpc	1.99	2.63	1.95
Full p (%)	5.1	7.0	4.9
C.I. w fpc	0	0.75	0.74
w/o fpc	1.89	1.68	1.35

Table 18 gives the proportion of occupants with injury severity of AIS≥3 by model year and by restraint. The table corresponds to Tables 11 and 13 but with the injury dichotomy defined at the more severe level. The reduction patterns displayed in Table 18 are different than those of Tables 11 and 13. The CALSPAN results by year are changed from a slight increase (1%) for AIS≥2 to a decrease (11%) in 1974 cars and from an increase of 20% to an increase of only 1% for 1975 cars. The HSRI results by year change little. SwRI has similar reductions in AIS≥2 in 1974 and 1975 cars, but a lower reduction for AIS≥3 in 1974's and a much greater reduction in 1975's. The reductions by restraint for AIS≥3 are very similar to those for AIS≥2, and the greater incidence in later model years for HSRI, and in full restraints compared to lap belt only, is still present. In general, the small number of occupants with injuries of AIS≥3 precludes the use of inferential statistics.

The proportions of injuries of AIS≥2 for occupants not ejected are shown in Table 19, corresponding to those given for all occupants in Tables 11 and 13. Here, too, the results for model years combine all restraint usages, and the results for restraints combine both model years. The total number of actual ejections was not large. Including both partial, complete, or unknown ejections of an occupant, CALSPAN had 18, HSRI 52, and SwRI 19, for a total of 89 cases in which it was not established that the occupant remained fully within the car. Consequently, the results shown in Table 19 are almost identical to those for all occupants shown in Tables 11 and 13. Therefore, the benefits of restraints observed earlier were not restricted to prevention of ejection, but were applicable to contained occupants. Thus the similarity in reductions for both restraint types in the three data sets is not an artifact of containment.

Table 18

PROPORTION OF OCCUPANTS WITH AIS≥3
(Data weighted on inverse of sampling fraction;
occupants with unknown injuries or restraints
are omitted from table)

	AIS≥3 N	AIS≥3 %	(Reduction in Percent)[1]	Total N
CALSPAN				
1973	66	3.49		1893
1974	58	3.08	(11)	1885
1975	13	3.54	(-1)	367
None	103	4.10		2513
Lap	13	2.10	(49)	618
Full	14	1.87	(54)	748
HSRI				
1973	55	2.87		1917
1974	52	2.91	(-1)	1787
1975	13	3.45	(-20)	377
None	93	3.65		2551
Lap	7	1.14	(69)	615
Full	18	2.01	(45)	897
SwRI				
1973	47	2.00		2349
1974	37	1.80	(10)	2050
1975	7	1.17	(42)	598
None	74	2.70		2737
Lap	6	0.61	(77)	985
Full	11	0.89	(67)	1242

[1] Relative to 1973 or to None

Table 19

PROPORTION OF OCCUPANTS WITH AIS≥2
NON-EJECTED OCCUPANTS

(Data weighted on inverse of sampling fraction; occupants with unknown injuries or restraints are omitted from table)

	AIS>2 N	AIS>2 %	Total N
CALSPAN			
1973	215	11.38	1890
1974	217	11.57	1875
1975	47	12.98	362
No Restraint	371	14.91	2488
Lap Only	48	7.77	618
Lap & Shoulder	49	6.56	747
HSRI			
1973	135	7.15	1889
1974	129	7.30	1768
1975	33	8.87	372
No Restraint	219	8.67	2525
Lap Only	30	4.93	609
Lap & Shoulder	48	5.36	895
SwRI			
1973	246	10.66	2307
1974	175	8.72	2006
1975	52	8.80	591
No Restraint	351	13.11	2678
Lap Only	59	6.04	977
Lap & Shoulder	62	5.07	1224

Each team documented not only their final judgment of the restraint used, but also provided an assessment of their confidence of that conclusion. The reliability assessment was on a three point scale. The terms used for each level differed between teams. Those used at HSRI were "possible," "probable," and "definite." SwRI used "unreliable," "reliable," and "certain These are very subjective estimates in themselves, and should not be interpreted with too much attention to semantics. It is probably more appropriate, certainly in the case of the HSRI data, to consider them simply as a three-point scale, with "definite" or "certain" indicating those cases in which the investigator or investigators are the most confident in their conclusion. The percentage of occupants (weighted) for which the level of greatest confidence (definite) was used was 51 percent by CALSPAN, 81 percent by HSRI, and 51 percent by SwRI.

If the results shown in Table 13 for restraints do contain errors because of unreliable usage determination, we would expect different results for those cases in which usage was listed as "definite." The proportions for these cases are given in Table 20. The differences between "lap only" and "lap and upper torso" are somewhat greater for CALSPAN and SwRI, but not for HSRI.

The same general patterns exist in Table 20 as in Table 13, but there are some noteworthy differences. The greater benefits of the lap belt than for full restraints in the HSRI data of Table 13 are magnified in Table 20--by both an increase in the benefits of lap belts and a decrease in those of full restraints. The relative benefit of full restraints over lap belt for SwRI is increased, but the benefit of each compared to no restraint is substantially lower. These differences (for "definite" usage) do not all represent a uniform increase in the measured benefits of restraints, nor are they consistent.

Injury ($AIS \geq 2$) rates by restraint, and the reductions for restrained relative to unrestrained occupants, are given in

Table 20

PROPORTION OF OCCUPANTS WITH AIS≥2
RESTRAINT USE CODED "DEFINITE"
(Data weighted on inverse of sampling ratio;
occupants with unknown injuries are omitted
from the table)

	AIS≥2		(Reduction in Percent)[1]	Table N
	N	%		
CALSPAN				
No Restraint	273	18.02		1515
Lap Only	28	9.40	(48)	298
Lap & Shoulder	11	6.51	(64)	169
HSRI				
No Restraint	216	9.66		2235
Lap Only	26	4.68	(52)	555
Lap & Shoulder	31	6.13	(37)	506
SwRI				
No Restraint	310	14.72		2106
Lap Only	28	12.28	(17)	228
Lap & Shoulder	19	8.92	(39)	213

[1]Relative to "None"

Table 21 for frontal impacts. Frontal impacts are defined here as those with contact to the front of the car with force vectors of 11, 12, and 01 O'clock. The results in general differ little from the results for all crashes (Table 13). The impacts included in the table represent 47 percent of all CALSPAN data, 46 percent for HSRI, and 35 percent for SwRI. Rates of injury of AIS$\geq$2 are slightly higher in frontals for CALSPAN and SwRI, but about the same for HSRI. Injury reduction for lap belts is slightly lower for frontals than for all crashes, indicating that lap belts may provide slightly more benefit in non-frontals. The reductions provided by full restraints--compared to no restraints--are almost identical to the reductions observed in all impacts. Thus full restraints are evidently as effective in reducing the incidence of injury of AIS$\geq$2 in non-frontal impacts as in frontal impacts.

The material that has been presented in this section indicates that lap belts reduce the incidence of severe injury in towaway crashes by from 47 to 54 percent. Lap and upper torso restraints provide more protection--41 to 64 percent reduction, compared to unrestrained. However, the marginal benefit of the full restraint over lap belts is not as great as for lap belts over no restraint. The additional benefits of the full restraint, even when combined with their increased use in 1974 and 1975 cars, were not great enough compared to lap belts alone to substantially and consistently reduce the incidence of severe injury in 1974 and 1975 cars. These statements do not appear sensitive to the confidence of the teams in restraint usage, and are not limited to frontal impacts or the prevention of ejection.

These results, however, do not consider any differences in distributions in the sub-populations of other variables that are also factors in injury severity. Such factors and their effects are treated in the following section.

Table 21

FRONTAL IMPACTS

Impact to front of car with force vectors of 11, 12, 01 O'clock

	AIS≥2 N	AIS≥2 %	(Reduction in Percent)[1]	Total N
CALSPAN				
None	201	17.01		1182
Lap	27	9.25	(46)	292
Full	26	7.16	(58)	363
HSRI				
None	103	8.47		1216
Lap	16	5.80	(32)	276
Full	19	5.07	(40)	378
SwRI				
None	151	15.06		1003
Lap	29	8.53	(43)	340
Full	20	5.32	(65)	376

[1]Relative to "None"

5.2.2 Statistical Modeling of the Multivariate Contingency Tables. In selecting a multivariate statistical model to summarize the data and aid in estimating and interpreting the findings, several considerations come into play. Basically these are the determination of how many variables to include, which particular variables to include, and which interactions are important.

In considering the number of variables, the size and configuration of the data set must be kept in mind. Although one might be tempted to include a large number of variables in an initial model, the data may not permit this. The number of cells or sub-populations in a contingency table is the product of the number of levels of all the variables and thus becomes large quite rapidly. For example, if one considered three levels of restraint, five age categories, five levels of crash severity, and two model years, the result is a table with 3 x 5 x 5 x 2 = 150 cells, which must again be multiplied by two since there are two levels of response (injury). Even though the number of occupants is fairly large, the data thin out, leaving many empty cells and many cells with either only a few uninjured or one or two injured occupants in them. Thus, the number of variables and levels must be kept fairly small.

In many cases a choice of variables to include had to be made between two or more similar variables. For example, one measure of damage severity might be inches of crush, suitably categorized, while another would be the CDC extent code. These two are highly related and only one would generally prove useful. Another example would be body type and vehicle weight.

In addition to crush or CDC extent code, there are other aspects of a crash which may be important in determining severity in terms of its potential to produce injuries. These may include the direction of the impact vector, whether the impact was over a wide or narrow area, the nature of the object struck, etc. However, incorporation of all of these soon leads to a model which has too many cells to be used. A derived variable of damage severity was obtained using all components of the CDC and considering only unrestrained occupants. This is described in Appendix B. The hope was to obtain a variable with relatively few levels which would incorporate all components of the crash without having to treat these as individual variables.

This derived damage severity variable was compared with the CDC extent code to see which variable appeared to offer the best control. The models incorporated a dichotomy of collision type, three levels of restraint, four levels of crash severity (or CDC), and three age groups. Overall, both models gave about the same fit for the data. However, the derived damage severity variable explained much more of the variability than did the CDC extent code. Also, the other crash variables were much less significant when the derived severity variable was used than when the CDC extent code was used. As a result, the derived severity variable was selected as the variable for controlling on crash severity.

There are some drawbacks to this. First, the severity variable may be specific to this data set. Further work is needed to refine it and see if it is generally applicable as a measure of crash severity. Further, it incorporates all aspects of the CDC. It also appears to indirectly control for collision type and car size. If it is desired to estimate these effects separately from the energy dissipation component of the crash, the derived variable is not appropriate.

The derived severity variable was used in a variety of models with other variables such as occupant age or sex, seated position, car body type, etc., to see which, if any, of these other variables should be adjusted for when comparing injury rates for the different model years or restraints. A restriction was that in any final models, either restraint type or car model year would be included, since these were the variables of primary interest in the study. In general, after including the derived damage severity variable and either the restraint used or model year, the effects of the other variables were not significant. Occasionally a variable was found to have a significant effect in only one team. Tables of the proportions of AIS≥2 injuries for several of these variables are presented in Appendix D. It is evident there that most of the differences are small. From the modeling efforts, it appears that most of these differences are further reduced when the derived severity variable is taken into account.

With the limitations of the data in mind, the final decision was to use only the six-level damage severity variable derived from the complete CDC as a controlling variable for adjusted rates. Three final models were fit to the data: (1) main effects of model year and damage severity, (2) main effects of restraints and crash severity, and (3) a model incorporating the effects of restraints within model years (interaction) and damage severity.

These models were fitted to data from each team separately. The predicted proportions were then used with the severity distribution from the combined data to calculate adjusted rates for a standard accident population. It should be noted that even with these models there were a few cells in which no injuries were observed. When zeros occurred in the contingency tables they were replaced by 0.1 to avoid singularities in the resulting covariance matrices. This adjustment was necessary for, at most, three cells in one team.

In the model including the interaction, it was necessary to add 0.1 to four or five numbers in each team. In addition, two teams each had one cell with no data (different cells in the two teams). This was remedied by removing the appropriate row from the design matrix, reducing the total degrees of freedom by one. As a point of interest the model was also fitted inserting 0.1 for both the number of AIS≤1 and AIS≥2 categories of that cell, and virtually identical results were obtained.

The estimated parameters for each team are presented in Appendix E. The findings and results are presented in Section 5.2.3.

5.2.3 Adjusted Injury Rates. The result of the modeling process described in Section 5.2.2 is a selection of variables to be controlled in comparing injury rates for the different model years and different restraints. The injury rates estimated from the linear models have less sampling variability than do the raw injury rates. Further, the model permits injury rates to be estimated for combinations of restraint usage, severity, and model year for which no cases were observed or for which very few cases were observed resulting in no injuries. As described before, one of the efforts in modeling was to reduce the number of levels to the extent that there should be very few, if any, empty cells. Nevertheless, some accidents with certain combinations of variables were not present in all three teams. There is never more than one completely empty cell in any of the first models and also never more than six cells with either the injured (AIS≥2) or uninjured category empty.

The predicted cell proportions from the statistical models are combined with a standard distribution to obtain adjusted rates of AIS≥2 injuries. In general, a standard population may be quite arbitrary, since its function is to enable the standardized or adjusted rates to be directly compared without the confusing influence of the other variables. For the adjustments in this study the same standard population has been used for all three teams. The standard population chosen is that obtained by considering the damage severity distribution found from the combined experience of all three teams for all three model years. Thus, one interpretation of the adjusted rates is that these are the injury rates that would have been observed in each locality had a common damage severity distribution prevailed. To the extent that this distribution is representative of a larger population of accidents, these rates could be considered predictive of injury rates to be expected in a population of towaway accidents. Table 22 gives the distribution of the population by the severity classes.

Table 22

STANDARD POPULATION DAMAGE SEVERITY DISTRIBUTION

Severity of Classes	1	2	3	4	5	6
Percent of Population	13.02	36.47	17.39	18.37	8.52	6.22

5.2.3.1 Adjusted Injury Rates by Model Year. The original primary objective of the study was to estimate the expected reduction in moderate or worse injuries from 1973-model passenger cars to 1974-model passenger cars. The project was expanded to include 1975-model cars as these were introduced into the population. The statistical model finally chosen is one which includes the six-level severity variables derived from the Collision Deformation Classification (see Appendix B for a description) and the three model years as well as the injury variable. Table 23 summarizes the performance of the model in the three teams. In two of the teams the error chi square was clearly non-significant. In the SwRI data the error--or lack of fit of the linear model--is significant at P=.02. This indicates that there is some remaining systematic variation among the cell proportions. However, the linear model does account for over ninety percent of the variation among the cell proportions of AIS$\geq$2 injuries in each of the cases, so the model is judged acceptable and is used for all three teams. The estimated parameters of the model are reported in Appendix D.

Table 23

RESULTS OF THE LINEAR MODEL RELATING PROPORTION OF INJURIES OF AIS≥2 TO DAMAGE SEVERITY AND MODEL YEAR

Team:	CALSPAN	HSRI	SwRI
Error χ^2 (10df)	12.0 (NS)	3.9 (NS)	21.1 (.02)
R^2 (% variation explained)	94.0%	97.8%	93.6%
χ^2 for severity (5 df)	190.0 (0)	170.7 (0)	306.8 (0)
χ^2 for model year (2 df)	.92 (NS)	.23 (NS)	10.9 (.004)

Under each chi squared value is the associated significance. If the significance was greater than .05, "non significant" (NS) is indicated. Otherwise, the exact level is quoted. For CALSPAN and HSRI, there were no significant differences among the model year. For SwRI there is an indication of a statistically significant difference. This must be interpreted cautiously, since there is some question about the adequacy of the model in this team and the test is only exact if the model fits. The difference observed was a lower proportion of AIS≥2 injuries in the 1975 model cars--the 1973 and 1974 models having nearly the same rate. Since relatively few 1975 cars were involved in crashes in this study it is probably safe to conclude that there were no differences in the proportions of injuries by model year. This finding was consistent across three teams.

The overall proportions of persons injured moderately or worse differed among the teams. This has been discussed elsewhere and is probably due to a combination of different types of crashes and different coding procedures. Table 24 gives the adjusted percent of outboard-front-seat occupants who were injured moderately or worse by team and model year of vehicle. Ninety-five percent confidence intervals for these are also presented. These proportions have been adjusted for damage severity, using the standard distribution given in Table 22, so the percents can be compared among teams and model years directly. The adjusted rate for HSRI is about eight percent of front-seat-outboard occupants in towaway crashes; for CALSPAN it is about twelve percent, and about ten percent for SwRI. Within each team the rates are consistent across model years. Thus the general conclusion is that there are no differences in proportions of moderate or more severe injuries to outboard-front-seat occupants of 1973, 1974, or 1975 model passenger cars.

Table 24

ADJUSTED PROPORTION OF MODERATE AND WORSE INJURY
BY TEAM AND MODEL YEAR IN PERCENT
AND THE NINETY-FIVE PERCENT CONFIDENCE INTERVALS

		Team	
Model Year	CALSPAN	HSRI	SwRI
1973 P	11.81	8.03	10.94
C.I.	(10.12, 13.50)	(6.93, 9.13)	(9.78, 12.10)
1974 P	12.96	7.90	10.54
C.I.	(11.24, 14.68)	(6.80, 9.00)	(9.32, 11.76)
1975 P	12.56	8.48	8.45
C.I.	(9.29, 15.83	(5.40, 11.56)	(7.02, 9.88)

5.2.3.2 Adjusted Injury Rates by Restraint Used. A secondary but important objective of this project was to estimate the effectiveness of the different levels of restraints used--none, lap belt only, or lap belt plus shoulder restraint. The model selected was the additive model expressing the proportion of moderate or worse injury as a sum of an overall mean plus an effect due to crash severity plus an effect due to restraint used. The chi-squared statistic for lack of fit proved to be significant for this model in all three teams. Thus, there remains some systematic variation among the proportions of AIS$\geq$2 injuries. This is most likely an interaction in which restraints are more effective in some crash severities than in others. It was not possible to identify one or two such interactions which were consistent across the three teams. The additive models were used in spite of the indication of some lack of fit for several reasons. First, the models did explain a large proportion of the variability in the cell proportions--at least 73%--even though a portion remained unexplained. Secondly, the models provided a useful smoothing and summarizing of the data. Thirdly, the precision of the estimated proportions was improved using the models. And finally, the tests of significance for the effects of severity and of restraints appeared so strong that their inexactness due to the lack of fit seemed unlikely to change the conclusions. Table 25 summarizes the performance of the model in the three teams. All three teams are consistent in that the effects of severity and of restraints are highly significant.

As has been observed previously, the proportion of AIS$\geq$2 injuries varied among the three teams. However, the same pattern of restraint effectiveness is observed. Lap belts reduce the proportion of AIS$\geq$2 injuries, and full restraints reduce it still further.

The adjusted proportions of AIS$\geq$2 injuries for the three levels of restraint use, together with 95% confidence intervals, are given in Table 26. All three teams show a consistently

Table 25

RESULTS OF THE STATISTICAL MODELS FOR RESTRAINTS IN EACH TEAM

	Team		
	CALSPAN	HSRI	SwRI
Error χ^2 (10 df)	17.6 (.062)	48.6 (0)	87.9 (0)
R^2 (% variation explained	90.2%	73.7%	74.3%
Severities χ^2 (5 df)	161.3 (0)	136.6 (0)	254.4 (0)
Restraints χ^2 (2 df)	27.6 (0)	24.7 (0)	36.7 (0)

Table 26

PERCENT OF AIS≥2 INJURIES BY RESTRAINT USED FOR THREE TEAMS ADJUSTED FOR DAMAGE SEVERITY

	Team		
Restraint	CALSPAN	HSRI	SwRI
None P	14.44	8.04	11.93
C.I.	(12.87, 16.01)	(7.04, 9.04)	(10.77, 13.09)
Lap Only P	10.62	6.10	8.43
C.I.	(7.64, 13.59)	(4.53, 7.67)	(6.94, 9.92)
Full P	7.94	4.52	7.47
C.I.	(6.04, 9.84)	(3.42, 5.62)	(6.24, 8.70)

increasing benefit as the level of restraint increases. That is, the proportion of AIS≥2 injuries is highest among unrestrained occupants, is less among lap belted occupants, and is reduced still further for fully belted occupants.

A somewhat more direct measure of the effectiveness of restraints is provided by the proportional reduction in moderate or worse (AIS≥2) injuries achieved by restraints. For example, in comparing lap belted occupants to unrestrained occupants, this measure is:

$$\text{Effectiveness} = \frac{\text{Prop. AIS}\geq 2\text{ Unrestrained} \ - \ \text{Pro. AIS}\geq 2\text{ Lap Belted}}{\text{Proportion AIS}\geq 2\text{ Unrestrained}}$$

Table 27 presents this measure together with the associated 95% confidence intervals. The effectiveness of restraints is seen to be quite substantial and quite consistent over the three teams. An exception to this general consistency is in SwRI, where full restraints are estimated to be only half as effective (relative to lap belts) as in the other two teams. A partial explanation for this is the fact that lap belts' effectiveness relative to no restraint was highest in this data set, while full restraints were least effective relative to unrestrained occupants. These two results--lap belts being most effective and full restraints being least effective--combined to make full restraints appear rather ineffective relative to lap belts in the SwRI data.

Table 27

PERCENT EFFECTIVENESS OF VARIOUS RESTRAINTS BY TEAM

	Team		
	CALSPAN	HSRI	SwRI
Lap to None	26.4%	24.2%	29.4%
C.I.	(4.4, 48.4)	(3.8, 44.6)	(16.2, 42.6)
Full to None	45.0%	43.9%	37.4%
C.I.	(30.6, 59.4)	(29.4, 58.4)	(26.5, 48.3)
Full to Lap	25.3%	25.9%	11.4%
C.I.	(-2.1, 52.7)	(2.0, 49.8)	(-8.2, 31)

5.2.3.3 Interaction Between Restraints and Model Year. The results in Section 5.2.3.2 indicate very strong benefits (in terms of reduced percent of injured occupants) to be derived from use of restraints when damage severity is adjusted for. The results on restraint usage presented in Section 5.1 indicate that restraint usage was higher among occupants of 1974-and 1975-model cars. In particular, use of full restraints was increased. After controlling for crash severity one would have expected a resulting decrease in the proportion of injuries for occupants in 1974 and 1975 model cars, but the results of Section 5.2.3.1 do not show this. Instead, the percent of (AIS≥2) injuries (after adjusting for severity) is quite constant. As discussed in Section 2.2.2, other possible explanatory variables (such as occupant age, sex, etc.) were not significant. As a result, one is faced with the paradox that restraints appear effective and use of restraints is increased, but no overall benefit is observed even after controlling for damage severity

This led to the consideration of a statistical model with a restraint-by-model-year interaction in it. That is, could the effects of restraints be different in 1973-model cars than in 1974- and 1975- model cars. The interaction was incorporated by fitting the main effects for restraints separately for occupants of 1973 models and for occupants of 1974-and 1975-model cars. (There were not enough 1975-model cars to treat them separately, so they were combined with the 1974 model, since the restraint systems in those two model years were quite similar and differed from those in the 1973-model cars.)

The results indicated that there were indeed differential effects of restraints in the three different model years, but that the pattern of these differences was not completely consistent across all three teams. In SwRI and HSRI data the main effect of model year was not significant with the inclusion of severity and the restraint-by-model year interaction, but this main effect persisted in the CALSPAN data--with the later models appearing worse. Crash severity and restraints within model year were significant in all three teams. The chi-squared values and the R^2 for the model are given in Table 28, while Table 29 gives adjusted percents of moderate or worse injuries by team and model year, together with the associated 95% confidence intervals. Referring to this latter table, some general conclusions appear consistent across all three teams.

The adjusted percent of AIS$\geq$2 injuries for lap-belted occupants of 1973-model cars was virtually the same as the adjusted percent of AIS$\geq$2 injuries for fully belted occupants of 1974 and 1975-model cars. This occurred in all three teams. The difference was not statistically significant in any of the teams and the magnitude of the difference was quite small. The largest difference was from 8.3% to 6.8% in the SwRI data. Although one cannot conclude that the performance of the lap belt in 1973 cars was as good as the performance of full restraints in the 1974 and 1975 cars, the sample sizes were large enough so that difference of practical importance should have been detected.

Although there were relatively few fully belted occupants of 1973 cars, the percent of AIS$\geq$2 injuries among this group was consistently lower than for either the lap-belted occupants of 1973 cars or the fully belted occupants of 1974 or 1975 cars. Thus, a general conclusion seems to be that the restraint system in 1973 cars performed better--when used--than that in the 1974 and 1975 cars.

An anomaly in that data is the fact that lap-belted occupants in 1974 and 1975 cars had a lower percent of AIS$\geq$2 injuries than the fully belted occupants of these models in the HSRI and SwRI data. This difference was statistically significant in the SwRI data. On the other hand, full restraints were significantly better in the CALSPAN data and the difference was not statistically significant in the HSRI data. The relative rarity of this group may be responsible for the inconsistent results, but it seems likely that these are a

Table 28

RESULTS OF THE INTERACTING MODEL

	Team		
	CALSPAN	HSRI	SwRI
Error χ^2 (25 df)	48.7	80.5	145.8
R^2	81.2%	68.2%	68.1%
Severity χ^2 (5 df)	155.7	122.4	214.2
Model Year χ^2 (1 df)	10.5	0.003	0.45
Restraints in 1973 χ^2 (2 df)	20.8	20.2	12.5
Restraints in 1974 and 1975 (2 df)	25.5	15.7	69.0

Table 29

ADJUSTED PERCENT OF AIS$\geq$2 INJURIES BY TEAM, RESTRAINT, AND MODEL YEAR

Restraint	Team: CALSPAN 1973	CALSPAN 1974 & 1975	HSRI 1973	HSRI 1974 & 1975	SwRI 1973	SwRI 1974 & 1975
None P	12.3	15.7	8.0	7.5	10.8	11.9
C.I.	(10.3, 14.3)	(13.4, 18.0)	(6.6, 9.3)	(6.2, 8.8)	(9.3, 12.3)	(10.3, 13.5)
Lap Only P	7.9	13.5	4.3	4.0	8.3	3.2
C.I.	(4.9, 10.9)	(6.7, 20.3)	(3.0, 5.6)	(0, 8.5)	(6.7, 9.9)	(1.7, 4.7)
Lap Plus Shoulder P	1.3	8.0	3.6	4.2	4.6	6.8
C.I.	(0, 5.9)	(6.0, 10.0)	(0.7, 6.5)	(3.1, 5.3)	(1.1, 8.1)	(5.5, 8.1)
Model Years Adjusted to Equal Restraint Use P	9.1	13.6	6.4	6.2	9.0	9.3
C.I.	(7.4, 10.8)	(11.7, 15.5)	(5.3, 7.5)	(5.1, 7.3)	(7.8, 10.2)	(8.2, 10.4)

particular kind of occupant or accident, since it is usually necessary to cut the shoulder belt off in order to wear only the lap belt in these cars.

In summary, three findings appear to be consistent across all three teams and hence may apply to a broader population of accidents. First, there are no significant differences in the percent of AIS$\geq$2 injuries for occupants of the different model years (1973, 1974, 1975) after adjustment for damage severity Secondly, lap belts are quite effective (when worn) in reducing the percent of AIS$\geq$2 injuries, and lap and shoulder belts both are even more effective. Thirdly, the restraints in 1973 models seem to be somewhat more effective than those in the 1974 and 1975 models.

The most consistent finding is the effectiveness of restraints in reducing the percent of AIS$\geq$2 injuries. The results for the three teams are so consistent that one is tempted to combine them and view the result as being generalizable to a more general population of crashes. There are a number of difficulties in doing this, however. Although the standard distribution of damage severity used here may not be the adjusted rates seems the most logical one, there is nothing to guarantee that it represents any larger population. In addition, the measure of crash severity used here may not be appropriate in more general populations. Finally, although the standard errors may seem acceptably small, these represent sampling errors only--these data can in no way be considered a probability sample of the U.S. crash population. As a result, the actual errors also include a bias term, but there is no way of determining the magnitude of the bias. If one does combine the effectiveness measures of the three teams, with all the reservations, then the results estimate that lap belts alone--when used--reduce the number of AIS$\geq$2 injuries by about 26.7% (with a standard deviation of 9.7%). Lap and shoulder belts both--when used--would reduce the number of AIS$\geq$2 injuries (compared to unrestrained occupants) by about 42.1% (with a standard deviation of 6.8%). And the addition of a shoulder belt to the lap belt would reduce the number of AIS$\geq$2 injuries by 20.9% (standard deviation 12.2%). However, as noted above, it is not clear to what, if any, accident population these results would apply.

5.3 Injury Patterns

The analysis of injury patterns was performed on the specific Occupant Injury Classification (OIC) data recorded by the field teams. Individual OIC's were recorded for each specific injury sustained by an occupant. The individual OIC's were stored in a computer file along with automatically derived injury summary information for each body region of each occupant, e.g., highest AIS sustained by the "head." Both the total number of OIC's (injuries) each occupant sustained and the percentage of occupants who sustained an injury to a particular body region are reported in this section. The injury sources (e.g., vehicle contact points) recorded in the SwRI data were also analyzed--particularly the steering-assembly, front-interior, and restraint injuries. The contents of this section are organized as follows:

- 5.3.1 Number of Injuries per Occupant
- 5.3.2 Body Regions Injured
- 5.3.3 Laceration Severity Coding
- 5.3.4 Sources of Injury

In summary, occupants who use a lap belt reduce the expected number of specific injuries (incidence of OIC's of AIS≥1) by one-third. The lap belt provides some protection from injuries of all severities in all body regions with the possible exception of minor neck and abdomen injuries. However, the lap belt is about twice as effective in reducing the occurrance of moderate or worse (AIS≥2) injuries than in reducing AIS≥1 injuries, to all of the body regions with the exception of the face and lower extremities. Even in these regions the lap belt is more effective in reducing the AIS≥2 injuries than in increasing the rate of "no injury."

If an upper-torso belt is added to the lap belt, some face injuries may be traded for head injuries and a small increase in the percentage of minor injuries (AIS=1) will be experienced in the neck, torso, and lower extremities. On the other hand, relative to the unrestrained occupants the fully restrained occupants have cut in half the expected number of injuries worse than a minor (AIS≥2). A few minor injuries are a small price to pay for improved effectiveness in preventing significant injuries.

5.3.1 Number of Injuries per Occupant. The number of injuries (i.e., specific OIC's) sustained by an occupant is a possible alternative measure of restraint system effectiveness. Table 30 displays the number of occupants in each restraint class, the number of OIC's they sustained, and the rate of occurrence for each occupant class. All levels of AIS are included, i.e., any OIC with an AIS of 1 or more is counted. For each team, the incidence of OIC's (rate of OIC's per exposed occupant) was less for restrained occupants than for unrestrained occupants. Both CALSPAN and HSRI data demonstrated a one-third drop in OIC incidence with the use of restraint systems, with no notable differences between lap and full restraints. SwRI demonstrated little difference between no-restraint and lap-belt-only, yet displayed a 40 percent drop when full restraints were compared with lap-belt-only. The incidence of specific OIC's with an AIS of 2 or more was reduced 50 percent for restrained occupants (Table 31).

Note that the number of occupants in each of the three restraint classes is displayed as the second line of data for each team in Table 30. This is the set of numbers used for "exposed occupants" in all subsequent percentage computations. For clarity, the specific N's have not been included in most of the remaining figures and tables, but these can be estimated by multiplying the percentages by the number of exposed occupants.

Table 30

NUMBER OF AIS≥1 OIC's PER OCCUPANT

Restraints Used:	None	Lap	Full	Total
CALSPAN				
OIC's	3838	624	820	5282
Exposed Occupants	2539	621	750	3910
OIC's/Occupant	1.5	1.0	1.1	1.4
HSRI				
OIC's	4308	757	1061	6126
Exposed Occupants	2597	627	908	4132
OIC's/Occupant	1.7	1.2	1.2	1.5
SwRI				
OIC's	3271	976	808	5055
Exposed Occupants	2852	993	1272	5117
OIC's/Occupant	1.1	1.0	0.6	1.0

Table 31

NUMBER OF OIC's of AIS$\geq$2 PER OCCUPANT

Restraints Used:	None	Lap	Full	Total
CALSPAN				
OIC's	770	87	104	961
Exposed Occupants	2539	621	750	3910
OIC's/Occupant	.30	.14	.14	.25
HSRI				
OIC's	525	61	91	677
Exposed Occupants	2597	627	908	4132
OIC's/Occupant	.20	.10	.10	.16
SwRI				
OIC's	689	115	56	860
Exposed Occupants	2852	993	1272	5117
OIC's/Occupant	.24	.12	.04	.17

5.3.2 Body Regions Injured. The pattern of injury by body region for each restraint class is tabulated in Table 32. All the percentages are in terms of the percentage of exposed occupants in each restraint class who sustained an injury to a particular body region. For example, 21.1 percent of the unrestrained occupants in the CALSPAN data sustained a head injury (i.e., an AIS of at least 1). In order to consider injury severity in a manner parallel to earlier sections of the report, the percentages of occupants injured at AIS 2 or more were also included,* e.g., 4.3 percent of the unrestrained CALSPAN investigated occupants sustained a head injury of AIS 2 or greater.

The percentage of occupants with head and face injuries (AIS≥1) is lower for restrained occupants. All the chi-square tests for no-restraint vs. lap-only and vs. full restraint were statistically significant (at 0.05 level). Furthermore the percentages of face injuries for the full restraint are almost fifty percent less than the lap-belt-only percentages (all significant). Coincidentally, the CALSPAN data showed a non-significant increase in head injuries with full restraints, compared to lap-belt-only. The addition of upper-torso belt to the lap belt may have caused a slight shift from face to head injuries.

The percentage of occupants with AIS 2 and greater injuries to the head and face is also reduced with the use of restraint systems. The lap belt effectiveness in reducing AIS≥2 injuries is twice that of the AIS≥1 injury reduction. For HSRI and SwRI there is also both a significant drop in the percentage of face AIS≥2 injuries with the addition of the upper-torso belt to the lap belt and possibly a complementary increase in the percentage of AIS 2 or more head injuries (not statistically significant).

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*The injury severity for each occupant's body regions was set equal to the highest AIS code for each region.

Table 32 - PERCENT OF BODY REGIONS INJURED BY RESTRAINT SYSTEM USAGE

	Calspan		HSRI		SwRI	
	AIS2+	AIS1+	AIS2+	AIS1+	AIS2+	AIS1+
HEAD						
None	4.3	21.1	3.4	17.0	2.9	11.5
Lap	1.6	13.2	0.6	9.5	1.1	8.3
Full	2.1	14.7	0.9	7.5	0.9	6.6
FACE						
None	5.7	22.5	3.2	26.6	7.5	20.4
Lap	3.5	16.1	3.3	22.1	4.6	14.4
Full	2.7	10.3	1.3	10.6	2.2	8.2
NECK						
None	0.7	10.2	0.5	10.5	0.6	9.4
Lap	0.0	9.0	0.0	10.7	0.0	11.0
Full	0.7	13.5	0.0	14.3	0.5	12.6
UPPER EXTREMITY						
None	2.4	13.6	1.2	16.5	1.4	11.4
Lap	1.4	9.5	0.5	14.4	0.2	9.4
Full	0.9	11.0	1.2	12.3	0.3	8.4
CHEST						
None	3.7	14.6	2.9	13.6	2.2	12.1
Lap	1.4	9.5	0.8	8.5	1.0	7.2
Full	1.1	11.2	1.4	10.8	0.9	9.3
ABDOMEN + PELVIS						
None	1.3	5.0	0.8	7.1	0.9	4.0
Lap	1.1	5.4	0.0	5.6	0.2	5.5
Full	0.7	4.7	1.0	7.1	0.4	5.7
BACK						
None	0.8	6.9	0.3	6.8	0.4	6.0
Lap	0.3	4.3	0.2	6.1	0.0	6.2
Full	0.5	7.8	0.1	7.8	0.1	6.4
LOWER EXTREMITY						
None	3.2	18.3	1.2	26.7	1.6	20.1
Lap	1.1	12.1	0.3	14.3	0.3	10.0
Full	0.9	15.0	1.4	17.6	0.4	11.8

The only pattern of neck injuries that is consistent for all three teams is the increase when full restraints were used (significant for CALSPAN and HSRI). It should be noted that the amount of the increase is small and that, effectively, all neck injuries were minor (AIS-1).

The percentage of occupants with upper and lower extremity injuries was lower for both full and lap-only restraint systems when compared with unrestrained occupants (HSRI lap-only and CALSPAN full restraints not significant). Interestingly there is a slightly higher (not significant) percentage of lower extremity injuries (AIS$\geq$1) for fully restrained over lap-belt-only restrained occupants. Although both CALSPAN and SwRI data demonstrated an effectiveness for restrained occupants of fifty percent or better when compared with unrestrained occupants, none of the comparisons for AIS$\geq$2 extremity injuries are statistically significant.

The torso has been divided into three separate regions: chest, abdomen plus pelvis, and back (spine, excluding neck). The percentage of occupants sustaining chest injuries of AIS$\geq$1 or AIS$\geq$2 is reduced for all restrained occupants when compared with the unrestrained. Generally the restraint systems were twice as effective in reducing AIS$\geq$2 injuries to the chest than they were in lowering AIS$\geq$1 injuries. While all three sets of data show an increase in AIS$\geq$1 chest injuries for full restraints over the lap-belt-only restraints, the results are not statistically significant. Any increase is restricted to minor injuries (AIS-1) as almost no increase is observed for AIS$\geq$2 injuries.

The abdomen and back regions were injured less frequently than any of the other regions considered--between four and seven percent. There is no consistent pattern of abdomen injuries, except for a non-significant increase in AIS$\geq$1 and AIS$\geq$2 injuries for fully restrained occupants in the HSRI and SwRI data.

While fully restrained occupants receive the largest percentage of AIS≥1 back region injuries, the increase is generally restricted to minor injuries (AIS 1). In contrast, the percentage of AIS≥2 back injuries is lower for all restraint systems when compared with no restraint usage. None of the back injury comparisons were statistically significant.

5.3.3 Laceration Severity Coding. As noted earlier (Section 5.2.1, Table 11) the HSRI data demonstrated a lower rate of moderate and worse injuries (AIS≥2). One reason for this difference between teams appears to be in the assignment of AIS codes for lacerations, particularly in the choice of AIS 1 or 2 -- right at the cut point used in the analysis of overall effectiveness. Evidence of this is provided in the details of the specific OIC's for lacerations.

The rate of specific lacerations coded AIS 2 or more is similar for CALSPAN and SwRI, while the HSRI rate is roughly a third of the other teams (Table 33). This difference could be due to fewer HSRI-recorded lacerations or to a lower AIS rating of the lacerations recorded. The last column of Table 33 demonstrates that lacerations are reported at a similar rate by all three teams, with HSRI falling between the other two teams. Consequently the difference in the rate of severe lacerations is due to a lower AIS assignment for lacerations by HSRI.

To assess the importance of this difference, the proportion of all severe (AIS≥2) lesions that were lacerations is displayed in Table 34. As expected, the percentage of all severe lesions that are lacerations is higher for CALSPAN and SwRI. The frequency of severe lacerations is similar to that of severe fractures. In fact the two lesions together account for about two-thirds of the severe lesions. Consequently differences in AIS coding of other lesion types (e.g., concussions) would have a minor impact on the rate of severe injuries because of their relatively infrequent occurrence.

Table 33

PERCENT OF LACERATIONS OF AIS>2 AND INCIDENCE OF LACERATION PER OCCUPANT

	Laceration AIS				Number		Laceration
	AIS 1		AIS 2+		Total	Occu.	Incidence
	%	(N)	%	(N)	N	N	(Lac/Occ)
HSRI	88.8	(834)	11.2	(105)	939	4122	.227
CALSPAN	64.0	(654)	36.0	(368)	1022	3910	.261
SwRI	57.2	(452)	42.8	(338)	790	5117	.154

Table 34

PERCENT OF LESIONS OF AIS$\geq$2 WHICH ARE LACERATIONS

		AIS $\geq$2	
		%	N
HSRI	Lacerations	15.3	105
	Fractures	42.2	290
	Else	42.5	292
		100.0	687
CALSPAN			
	Lacerations	37.0	368
	Fractures	31.8	316
	Else	31.2	310
		100.0	994
SwRI	Lacerations	37.6	338
	Fractures	23.2	208
	Else	39.2	352
		100.0	898

Apparently there is a major difference in the AIS coding of specific lacerations between teams and, further, this difference has a major impact on the overall rate of severe injuries (i.e., many severe injuries are lacerations). These differences arise from variation in the interpretation of the AIS documentation. This analysis only detected the existence and impact of the different interpretations; we cannot say which is the correct one.

5.3.4 Sources of Injury. In summary, the potential for injury from the steering assembly and front interior is reduced by approximately 50 percent when full restraints are used. While there were fewer steering assembly and front interior injuries, the use of full restraints did not eliminate them. About 10 percent of the fully restrained occupants struck steering assembly or front-interior components.

The recording of specific injury sources (occupant contact points) was not part of the MVMA-sponsored field investigations performed by CALSPAN or HSRI. SwRI, on the other hand, did record up to two specific injury sources for each of the first six reported OIC's. Consequently, the following discussions of injuries by source are based upon the SwRI data. Table 35 gives the percentages of exposed occupants in each restraint class who sustained any injury from each particular injury source. For example, 15.5 percent of the unrestrained SwRI occupants sustained a steering wheel injury.

Table 35

INJURY SOURCE VS. RESTRAINT USAGE
(PERCENTAGE OF EXPOSED OCCUPANTS, SwRI)

	None	Lap	Full
Steering Assembly	15.5	15.3	8.5
Front Interior	29.6	12.6	11.6
Side Interior	8.7	7.4	9.6
Restraint System	0.0	7.3	12.8
Other Sources	14.4	8.5	9.7

Table 36

SEVERITY OF RESTRAINT-
CAUSED INJURIES (SwRI)

	Lap		Full	
AIS	%	(N)	%	(N)
1	100%	(76)	99.9	(205)
≥2	0	(0)	5.1	(11)
	100%	(76)	100%	(216)
OIC's/Occupant	.08 (76/993)		0.17 (216/1272)	

All of the possible injury sources have been grouped into five broad categories in Table 35--steering assembly, front interior, side interior, restraint system, and other. The "steering assembly" includes both the steering wheel and column. The "front interior" excludes the steering assembly, but includes, for example, the windshield, header, A-pillars, and instrument panel. The "side interior" includes the doors, side windows, B- and C-pillars and roof rail. The "restraint system" includes the belts and hardware. "Other" sources include roof, floor, seats, external objects, and "impact forces."

The occurrence of injury from the steering assembly was significantly reduced for full restraints but not for lap-belt-only restraints when compared with no restraints. On the other hand, injuries from the front interior (e.g., instrument panel) for each restraint system were equally lower (significant) than the percentage for no restraint system.

Note that while the frequency of body regions injured for fully restrained occupants from each source is reduced, the frequency is not zero. While performing better than lap-belts-only, full restraints still do permit some injuries caused by contact on the steering assembly and front interior.

The usage of restraint systems produced no significant differences in the occurrence of injuries from side-interior contacts. Injuries related to the belts or hardware were significantly higher for fully restrained occupants than for lap-belt-only occupants, possibly because of the exposure of the upper torso to the shoulder belt of the former. It is important to note that almost all of the specific restraint-caused injuries (OIC's) are minor (AIS=1) and the expected occurrence is relative rare: 0.13 (292/2265) restraint injuries per restrained occupant (Table 36). These infrequent and minor injuries are a minor penalty compared to the benefits of the overall reduction of OIC incidence (Table 30 and overall reduction in moderate and above (AIS$\geq$2) injuries (Table 13) gained through the wearing of restraints.

5.4 Fatalities

The project was not expected to adequately measure fatality rates, and indeed the numbers of these rare events in the data sets are not sufficient to allow any firm conclusions. Because of their great importance, and for the sake of completeness, it seems appropriate to include some information on the fatalities that were investigated. If nothing else, it illustrates the difficulty of obtaining valid fatality rates. All three teams investigated all cases of a fatality in a candidate vehicle, i.e., they were sampled at 100 percent.

Before proceeding further, it should be cautioned that the fatality rates given here should **not be construed as adequate** predictions.

The number of fatalities by team and restraint is given in Table 37. All the accidents investigated by all three teams included a total of only 70, about equally divided between teams. Only 14 of these were restrained victims. The observed fatality rates by restraint are also shown. Tests of significance using Fisher's exact probability indicate that the rate for each restraint configuration is significantly ($p < 0.01$) lower than for the unrestrained.* The two rates for restrained occupants are not significantly different, however ($p = 0.4$). Because of this lack of significance, and the low cell size, we cannot draw any inferences about the relative rates for the two restraints.

Pooling the data for both lap and full restraints indicates that restraints reduce the incidence of fatalities about 62 percent.

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*The test is applicable to 2x2 contingency tables with small cells.

Obviously the fatalities for the restrained occupants are so low in this study that addition or subtraction of only a few would significantly alter the percentage findings. However, the findings have been presented here so that they may be considered, along with those from other studies, as indirect evidence of the efficacy of restraint systems.

A case summary of each of the 14 restrained fatalities is given in Table 38. Each was in a different vehicle. There were no cases of multiple restrained fatalities in a single vehicle. Six of the crashes were frontal impacts, one with 24 inches of crush and four with over 58 inches. Seven were side impacts, six of which had over 20 inches of crush. One was a rollover with 27 inches of crush. Eleven were apparently catastrophic collisions.

Table 39 lists the Collision Deformation Classifications of the 56 unrestrained fatalities. The case numbers are also given for the CALSPAN and HSRI cases. The distribution of extent codes for the same cases is shown in Table 40.

Table 37

FATALITIES BY RESTRAINT USAGE

Number of Fatalities	Restraint Usage None	Lap-Belt	Full
CALSPAN	21	3	3
HSRI	16	0	3
SwRI	19	2	3
Total	56	5	9
Number of Occupants Represented by Samples From all 3 Teams	7801	2218	2887
Fatality Rate (Fatalities/100 Occupants)	0.718	0.225	0.312

Table 38

CASE SUMMARIES OF RESTRAINED FATALITIES

I. Lap Belted Fatalities

1. Case No-407016 (CALSPAN) Model-74 Pontiac intermediate
   Collision: head-on with a full size car
   Fatal CDC: 12FYEW5 crush - 58 in.
   Occupant: 29 yr., Male, AIS=6, Fatal within 24 hrs.
   Injuries: laceration of liver and spleen

2. Case No-410050 (CALSPAN) Model-74 Chevrolet full size
   Collision: head-on with a van
   Fatal CDC: 12FLMW5 crush - 61 in.
   Occupant: 34 yr., Male, AIS=8, Fatal within 24 hours.
   Injuries: concussion

3. Case No-412187 (CALSPAN) Model-74 Chevrolet unknown body
   Collision: head-on into semi
   Fatal CDC: 11FDEW0 (unknown extent) crush - unknown
   Occupant: 73 yr., Female, AIS=8, Fatal within 24 hrs.
   Injuries: hemorrhage of head and arteries

4. Case No-00308 (SwRI) Model-73 Oldsmobile full size
   Collision: angle with a locomotive
   Fatal CDC: 09LDAW5 crush - 36 in.
   Occupant: 42 yr., Female driver, AIS=8, Dead-on-arrival
   Injuries: crushed chest (AIS=6), fractured skull (AIS=6), bilateral fracture of both lower legs (AIS=4), contact with interior side surfaces of case vehicle and exterior surfaces of the locomotive

5. Case No-07270 (SwRI) Model-73 Dodge intermediate
   Collision: angle into a pillar
   Fatal CDC: 12FLEW9 crush - 98 in.
   Occupant: 25 yr. Female right front, ejected, AIS=7, Dead-on-arrival
   Injuries: avulsion of brain (AIS=6), amputation of left arm (AIS=4), amputation of left foot (AIS=4), bilateral fracture of both legs (AIS=4) contact with unknown area exterior to car

II. Fully Restrained Fatalities

1. Case No OK-1234 (HSRI) Model-74 Pinto
   Collision: intersection type L with a semi
   Fatal CDC: 02RYAW5 crush - 30 in.
   Occupant: 18 yr. Female driver, AIS = 5, Fatal within 24 hrs.
   Injuries: fatal head injuries, loss of tooth (AIS=1), laceration of lip (AIS=1), fracture of left wrist (AIS=2), fracture of pelvis (AIS=2) from restraint

2. Case No OK-1388 (HSRI) Model-74 Opel MantaLuxus
   Collision: head-on with an intermediate
   Fatal CDC: 10LYAW4 crush - 25 in.
   Occupant: 17 yr. Male driver, AIS=6, DOA
   Injuries: hemorrhage of left lung

3. Case No UM-962 (HSRI) Model-74 Pontiac Firebird
   Collision: lateral/top (45 degrees) impact into large post
   Fatal CDC: 00TPA09 crush - 27 in.
   Occupant: 19 yr. Male right front, AIS=6, Fatal within 24 hrs.
   Injuries: laceration of brain, right side

4. Case No 408082 (CALSPAN) Model-74 Ford subcompact
   Collision: fixed object (large tree or post)
   Fatal CDC: 10LPAW4 crush - 22 in.
   Occupant: 19 yr. Female, AIS=7, time to fat. unknown
   Injuries: brain hemorrhage

5. Case No 7637 (SwRI) Model-74 Buick luxury
   Collision: angle impact with train
   Fatal CDC: 9LFEW6 or 00TPA03 crush - 46 in.
   Occupant: 9 yr. Male right front, AIS=10
   Injuries: fractured skull, left contact other

6. Case No-502030 (CALSPAN) Model-75 Ford Full Size
   Collision: head-on with a car of unknown type
   Fatal CDC: 12FDAW9 crush - 98 or more inches
   Occupant: 63 yr. Male driver, AIS=8, Dead at scene
   Injuries: brain concussion (AIS=6), fractured skull (AIS=4), crushed chest (AIS=6), unknown bilateral injuries to upper extremities (AIS=unk).

7. Case No-510059 (CALSPAN) Model-74 Buick compact
   Collision: head-on with a full-size Chevrolet
   Fatal CDC: 01FYEW2 crush - 24 in.
   Occupant: 69 yr. Male driver, AIS=10, Dead-on-arrival
   Injuries: unknown fatal injury (AIS=6), unknown injuries of abdomen (AIS=unk), unknown injuries of pelvis (AIS=unk.)

8. Case No-01027 (SwRI) Model-74 Plymouth compact
   Collision: angle with intermediate (specialty)
   Fatal CDC; 10LDEW4 crush - 34 in.
   Occupant: 34 yr. Male driver, AIS=6, Dead-on-arrival
   Injuries: rupture of the heart (AIS=6), bilateral fracture of chest (ribs) (AIS=4), bilateral laceration of lungs (AIS=4), laceration of spleen (AIS=4) contact with side interiors

9. Case No-08996 (SwRI) Model-74 Opel
   Collision: into a pole or tree
   Fatal CDC: 10LFEN2 crush - 5 in.
   Occupant: 64 yr. Female right front, AIS=6, Fatal after 24 yrs.
   Injuries: brain (concussion) (AIS=6), contusion of left skull (AIS=1) contact with roof top, laceration of right skull (AIS=1) flying glass

Table 39

PRIMARY COLLISION DAMAGE CLASSIFICATION
FOR EACH FATALLY INJURED
UNRESTRAINED OCCUPANT

Team	Case Number	CDC
CALSPAN	404070	01FREE4
	406128	00TPGW6
	406148	02RYAW4
	408041	12FZEW3
	408081	12FYEW6
	408081	12FYEW6
	411102	11LYAW3
	412083	02RPAW4
	412083	02RPAW4
	502052	12FYEW3
	502115	00TDH04
	503101	00TPHN6
	504022	00TDH03
	504029	00LDAW7
	506044	12FREW3
	506065	12FDEW6
	507150	00BDEW3
	508045	12FREN3
	508066	12FDEW4
	508066	12FDEW4
	509094	12FDLW2
HSRI	HS1534	09LPEW4
	HS1597	11FLEW8
	HS1597	11FLEW8
	OK1063	12FDEW2
	OK1299	10LPEW6
	OK1308	12FDEW4
	OK1371	11FYAW6
	OK1466	12FCEN3
	OK1682	02RPAW4
	OK1748	12FDEW2
	OK2129	10LYEW3
	OK2133	03RZAW4
	UM0927	01FZAW6
	UM0950	11FREE5
	UM1032	03RYEW3
	UM1137	00TDH04

SwRI	12FDEW4
	10LPEW5
	08LDEW5
	03RPEN8
	03RDAW8
	01FDEW3
	03RYEW9
	07LYHA6
	12FCEW3
	12FCEW3
	00TDA03
	00RDA02
	09LDHA9
	10LYAW4
	12FLES5
	12FCEW4
	02RYEW3
	02RYEW3
	12FREN2

Table 40

DISTRIBUTION OF CDC EXTENT CODES FOR UNRESTRAINED FATALLY INJURED OCCUPANTS

CDC Extent	Number of Cases	Percent
1	0	0
2	5	8.9
3	16	28.6
4	15	26.8
5	4	7.1
6	9	16.1
7	1	1.8
8	4	7.1
9	2	3.6
Total	56	100.0

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1. J. O'Day and R. Kaplan, "How Much Safer are You in a Large Car," Paper 750116 presented at SAE meeting February 24-28, 1975.

2. F. Preston, "Interactions of Occupant Age, Vehicle Weight, and the Probability of Dying in a Two-Vehicle Crash," HIT Lab Reports, Vol. 5, No. 12, Highway Safety Research Institute, The University of Michigan, Ann Arbor, Michigan, August 1975

3. U.S. Bureau of the Census, Census of Population and Housing: 1970, Evaluation and Research Program, PHC(E)-4, "Estimate of Coverage of Population by Sex, Race and Age: Demographic Analysis," February 1974.

4. The overall severity to the victim on the Abbreviated Injury Scale (AIS) is used. The scale is described in "Rating the Severity of Tissue Damage," Committee on Medical Aspects of Automotive Safety, Journal of the American Medical Association, Vol. 215, No. 2, January 11, 1971.

5. W. G. Cochran, "Sampling Techniques," Wiley and Sons, N.Y., 1963.

6. L. Kish, "Survey Sampling," Wiley and Sons, N.Y., 1967.

7. A detailed description of the OIC (which incorporates the AIS) and its use is given in "Multi-disciplinary Accident Investigation Report Automation and Utilization- 1973 Editing Manual and Reference Information," Highway Safety Research Institute, The University of Michigan, Ann Arbor, Michigan.

8. J. States, D. Huelke, L. Hames, "1974 AMA-SAE-AAAM Revision of the Abbreviated Injury Scale (AIS)," Proceedings of the Eighteenth Conference of the American Association for Automotive Medicine, Toronto, Canada, September, 1974.

9. J. Richard Landis, William M. Standish, and Gary G. Koch, "A Computer Program for the Generalized Chi-square Analysis of Categorical Data Using Weighted Least Squares to Compute Wald Statistics (GENCAT)," Biostatistics Report No. 8, Department of Biostatistics, The University of Michigan, Ann Arbor, Michigan, and Department of Biostatistics, University of North Carolina, Chapel Hill, North Carolina, February, 1976.

APPENDIX A

HSRI FIELD DATA FORM

HIGHWAY SAFETY RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN

FORM 7/74-1

RESTRAINT SYSTEM USAGE -- INJURY REDUCTION STUDY

CARD 0 1 (1 2)

* *

TEAM ________________

INVESTIGATOR __ __ (9 10)

CASE NO. __ __ - __ __ __ __ (3 4 5 6 7 8)

INVESTIGATION DATE __ __ / __ __ / __ __ (11 12 13 14 15 16) mo day yr

* *

REPORTING POLICE DEPARTMENT __ (17)

P. R. REPORT NO. __ __ __ __ __ (18 19 20 21 22)

DATE OF ACCIDENT __ __ / __ __ / __ __ (23 24 25 26 27 28) mo day yr

TIME OF ACCIDENT *24 Hour Clock* __ __ __ __ (29 30 31 32)

* *

Case Vehicle actually towed?

33
1( ) YES ⟶ to: ________________
3( ) NO reason: ________________

SELECTION CODE
34 ( )1 H Hospital
( )2 G Good Case

* *
* *

I. Investigation Complete:

35
1 a( ) Data Complete
2 b( ) Data Incomplete

NOTE: TO BE COMPLETED WHEN CASE SUBMITTED.

INVESTIGATION TERMINATED

II. Investigation Incomplete:

3 c( ) No Data--case could not be investigated.
Reason: ________________

4 d( ) Case Did Not Meet Criteria
Reason: ________________

* *

SAMPLE RULE/PERIOD
36 ( ) 1 ( )3
( ) 2 ( )4

KP (37-42)

CASE VEHICLE SLIDES __ __ (43 44)

SUPPLEMENTARY DATA (7/74)

(1:45-53)

CASE VEHICLE DATA

ACRS	Cylinders	Automatic Transmission	Air Conditioning	Vehicle Loading
45( )1 Yes	1( ) Rotary	47( ) 1 Yes	48( ) 1 Yes	49( )4 Below
( )2 No	2( ) 2-Cyl	( ) 2 No	( ) 2 No	( )5 Near
( )9 Unk	4( ) 4-Cyl	( ) 9 Unk	( ) 9 Unk	( )6 Above
	6( ) 6-Cyl			( )9 Unk
	8( ) 8-Cyl			
	7( ) Other			
	9( ) Unknown			

Road Paved	Front Seat	MOST SEVERE INJURY CRASH EVENT NUMBER
50( ) 1 Yes	51,52( )19 Bench	0-7 = actual
( ) 2 No	( )29 Bucket	8 = 8th +
( ) 3 Not App	( )99 Unknown	___ 53 9 = unknown
( ) 9 Unk		

****
****

MICHIGAN STATE POLICE CODES

VEHICLE MAKE

TRUCKS

20 Chevrolet
21 Diamond T
22 Dodge
23 Federal
24 Ford
25 GMC
26 International
27 Mack
28 Peterbilt
29 Reo
30 White
31 Willys
32 thru 33 not assigned
39 Other Trucks
40 Motorcycles
41 School Bus
42 Commerical Bus
43 Farm Equipment
44 Construction Equip.
45 Fire Equipment
46 Ambulance, Hearse
47 Police Equipment
48 Snowmobile
49 Other or not known
50 Dune Buggy

PASSENGER CARS

00 American Motors
01 Buick
02 Cadillac
03 Chevrolet
04 Chrysler
05 Dodge
06 Ford
07 Imperial
08 Jeep
09 Lincoln
10 Mercury
11 Oldsmobile
12 Plymouth
13 Pontiac
14 Volkswagen
15 Not assigned
16 Not assigned
17 Not assigned
18 Other foreign
19 Other domestic

VEHICLE TYPE

0 Full size
1 Intermediate
2 Compact
3 Sports car
4 Station Bus, Carryall
5 Jeep type
6 Pickup or panel
7 Straight Truck, Dump, Van, Flat Bed, Etc.
8 Truck Tractor (small)
9 Other or not known

TRAILERS

1 Car & Other Trailer
2 Not assigned
3 Not assigned
4 Not assigned
5 Single Bottom Semi
6 Double Bottom Semi
7 House Trailer

CARD 0 2 -
1 2
Dup col 3-8

CASE VEHICLE:

MAKE ______________________ Make-Model Code ___ ___ ___ ___ ___ (9 10 11 12 13)

MODEL ______________________

MODEL YEAR 19 __ __ (14 15) ODOMETER __ __ __ __ __ (16 17 18 19 20)

VIN __ __ __ __ __ __ __ __ __ __ __ __ __ (21 22 23 24 25 26 27 28 29 30 31 32 33)

BODY STYLE (34)
1 ( ) Sedan or Coupe
2 ( ) Hardtop--No upper B pillar
3 ( ) Station Wagon
4 ( ) Convertible
5 ( ) Hatchback
9 ( ) Unknown

NO. OF DOORS (35)
( ) 2
( ) 3
( ) 4
( ) 9 Unknown

Shipping Weight __ __ 00# (36 37)

CASE VEHICLE

UPPER B PILLAR (38)
2 ( ) NO
1 ( ) YES
9 ( ) Unknown

TRAILER BEING TOWED AT TIME OF COLLISION (39)
2 ( ) NO
9 ( ) Unknown
1 ( ) YES: ______________
Type

Police Report Vehicle No. ___ (40)

* *

Other Vehicle Case No. __ __ - __ __ __ __ (41 42 43 44 45 46)

Third Vehicle Case No. __ __ - __ __ __ __ (47 48 49 50 51 52)

* * * CARD 0 3 *
1 2
Dup col 3-8

OTHER VEHICLE: Police Report Vehicle No. ___ (9)

MAKE ______________________

MODEL ______________________

MODEL YEAR 19 __ __ (10 11)

Make-Model Code ___ ___ ___ ___ ___ (12 13 14 15 16)

VEHICLE TYPE

Police Code / Body Style (17,18)
( ) 00 Full size
( ) 01 Intermediate
( ) 02 Compact
( ) 03 Sports car
( ) 04 Carryall
( ) 05 Jeep type
( ) 06 Pickup/panel
( ) 07 Straight truck, Van
( ) 08 Truck-tractor Doubles
( ) 09 Other:________, Not known
( ) 10 Pedestrian
( ) 11 Motorcycle

Estimated Weight __ __ __ __ 00# (19 20 21 22)

THIRD VEHICLE: Police Report Vehicle No. ___ (23)

MAKE ______________________

MODEL ______________________

MODEL YEAR 19 __ __ (24 25)

Make-Model Code ___ ___ ___ ___ ___ (26 27 28 29 30)

VEHICLE TYPE

Police Code / Body Style (31,32)
( ) 00 Full size
( ) 01 Intermediate
( ) 02 Compact
( ) 03 Sports car
( ) 04 Carryall
( ) 05 Jeep type
( ) 06 Pickup/panel
( ) 07 Straight truck, Van
( ) 08 Truck-tractor Doubles
( ) 09 Other:________, Not known
( ) 10 Pedestrian
( ) 11 Motorcycle

Estimated Weight __ __ __ __ 00# (33 34 35 36)

OBJECT CONTACTED

NOTE: A vehicle may contact an object more than once.

01 No object or vehicle--None

CARS:

11 Full size, Standard
12 Intermediate
13 Compact and Mini
14 Sports Car
15 Jeep type
19 Unknown automobile

TRUCKS & BUS:

21 Pick-up/Panel
22 Van (Econoline type)
23 Van (Step Van type)
24 Straight Truck (Dump, Van/Box)
25 Semi Tractor-Trailer
26 Double Bottom
27 Bus (Passenger)
28 Bus (School)
29 Unknown Truck

OTHER VEHICLE:

30 Bicycle
31 Motorcycle
32 Snowmobile
33 ATV
34 Farm Vehicle (Tractor, etc.)
35 Construction Vehicle
36 Train (cars)
37 Locomotive (engine)
38 Trailer: ________________
41 Pedestrian
42 Pedestrian Conveyance
39 Unknown other vehicle

40 Other car, truck or vehicle:
____

49 Unknown motor vehicle

OBJECTS

54 Fallen Objects
55 Traffic Cones, Barrels, Construction Barriers
56 Construction or Emergency Equip.
57 Large Posts/Trees, Utility Pole, Large Sign Posts
58 Ditch--Embankment, Snowbank
60 Ground (Rollover only)
61 Curb (Damage Producing Impacts Only)
62 Culvert
63 Fence
64 Hydrants, Stumps, Etc.
65 Small Posts/Trees, Rural Mail Boxes, Delineators
66 Building
67 Pier, Pillar
68 Abutment, Retaining Wall
70 Bridge Rail
71 Guard Rail
72 Cable, Fence Barrier
73 Concrete Barrier (Median)
74 Impact Attenuator
75 Breakaway Fixtures
78 Other: ____________________

79 Unknown Object

99 Unknown vehicle or object

* *

COLLISION TYPE -- CASE VEHICLE

See also the scene schematic.

VEHICLE TO OTHER

01 Vehicle to Object
02 Rollover
03 Other: ________________

99 Unknown

VEHICLE TO VEHICLE (Moving or Parked)

11 Head on (F to F
12 Rear end (F to R)
13 Side swipe--same direction
14 Side swipe--opposite direction
15 Intersection Type L
16 Intersection Type T
17 Intersection Type Unknown
18 Other: ____________________

19 Configuration Unknown

VEHICLE DAMAGE INDEX--VDI

(FOR THE CASE VEHICLE)

LIST IN ORDER OF DAMAGE SEVERITY.

PRIMARY

__ __ - __ __ __ __ - __ (37 38 39 40 41 42 43) COLLISION TYPE __ __ (44 45) OBJECT CONTACTED __ __ (46 47)

CRUSH __ __ (48 49) in. COLLISION EVENT: 50:( ) 1 First; ( ) 2 Second; ( ) 3 Third

SECONDARY

__ __ - __ __ __ __ - __ (51 52 53 54 55 56 57) COLLISION TYPE __ __ (58 59) OBJECT CONTACTED __ __ (60 61)

CRUSH __ __ (62 63) in. COLLISION EVENT: 64:( ) 1 First; ( ) 2 Second; ( ) 3 Third

TERTIARY

__ __ - __ __ __ __ - __ (65 66 67 68 69 70 71) COLLISION TYPE __ __ (72 73) OBJECT CONTACTED __ __ (74 75)

CRUSH __ __ (76 77) in. COLLISION EVENT: 78:( ) 1 First; ( ) 2 Second; ( ) 3 Third

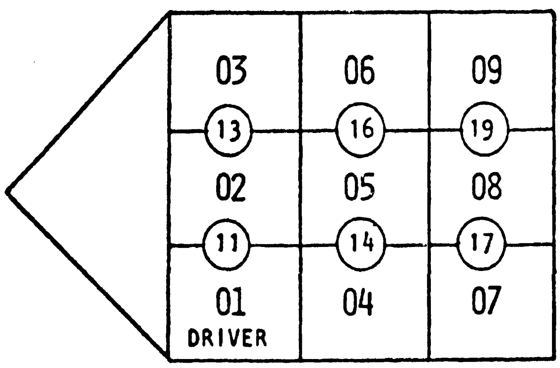
VDI

* *

OCCUPANT SEAT POSITION NUMBER

Mark an X to locate the position of *ALL* occupants in the vehicle.

Use this number to identify the occupants in the subsequent occupant sections.



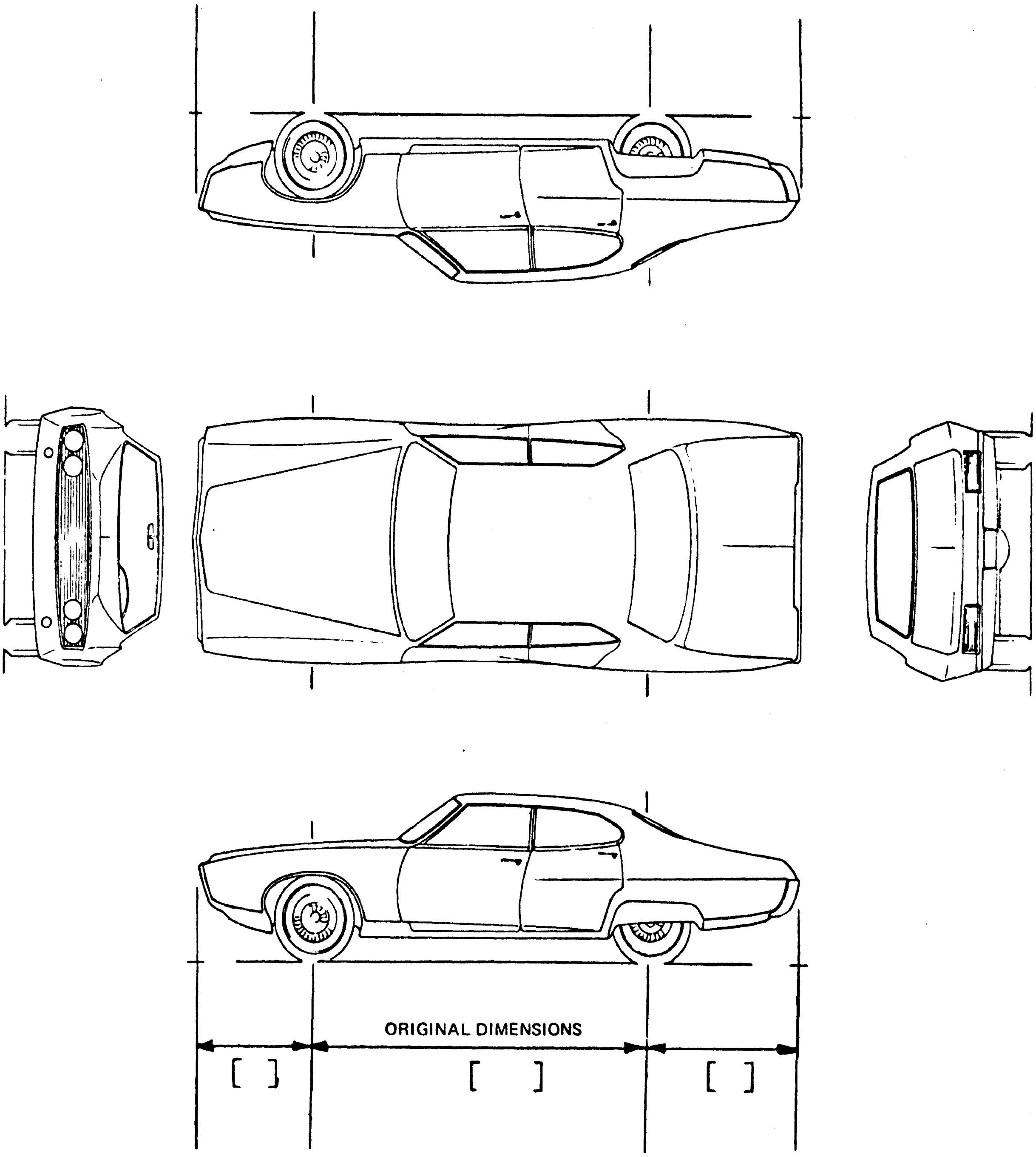
If 2 people occupy the same seat (i.e. sitting on a lap, etc.) replace the 0 in the seat number with a 2 to identify the person sitting on the lap of the other occupant.

TOTAL NUMBER OF OCCUPANTS IN VEHICLE __ __ (79 80)

ATTACH POLAROID OF OTHER VEHICLE
OR OBJECT STRUCK
(optional)

ATTACH POLAROID OF SCENE
(optional)

SKETCH CASE VEHICLE DAMAGE



VEHICLE SKETCH

ATTACH POLAROID OF CASE VEHICLE

Picture should depict major damage to vehicle (corresponding to Primary VDI).

ACCIDENT SCHEMATIC

CASE VEHICLE (A): ____________________

OTHER VEHICLE (B): ____________________

THIRD VEHICLE (C): ____________________

ACCIDENT DESCRIPTION: ____________________

NORTH

CARD 0 4
1 2
CASE NO.
Dup Col 3-8 or __ __ - __ __ __ __
3 4 5 6 7 8

OCCUPANT SECTION

OCCUPANT SEAT POSITION NUMBER __ __ (9, 10)
See Page 5 for Code Values.

OCCUPANT POSTURE (11)
( )1 Normal Seated Position
( )9 Unknown
( )2 Other, Describe: ______________

____

SEX (12)
( )1 Male
Female:
( )2 Pregnancy Unknown
( )3 Pregnant
( )4 Not Pregnant
( )9 Unknown

OCCUPANT IS A: (13)
( ) 1 Adult - over 12 years.
( ) 2 Child - 2 to 12 years.
( ) 3 Infant - under 2 years.
( ) 9 Unknown

AGE
__ __ (14, 15) Years (00,01, 02-98)
⇩
__ __ (16, 17) Months if infant (to 24 months)
( ) Unknown age-- code appropriate line 99

WEIGHT
__ __ __ (18, 19, 20) Pounds
( ) Unknown weight-- code 999

HEIGHT
___Feet, ___Inches = __ __ (21, 22) In.
( ) Unknown Height-- code line 99

OCCUPANT SECTION SEQUENCE
No. __ __ (23, 24)

CRASH OCCUPANT MEDICAL
Treatment/Mortality
25,26 ( )00 None
( )01 First Aid at Scene
Consulted Physican:
( )10 Unknown, but "Stated would"
( )11 Unknown, but "Directed to"
( )12 Did Consult Physician
( )02 Treated at Hospital/Clinic but Not Admitted
( )03 Hospitalized (observation less than 24 hours)
( )04 Hospitalized for Over 24 Hours or Significant Treatment
( )05 Fatal - Dead at Scene
( )06 Fatal - DOA
( )07 Fatal - Dead within 24 Hours
( )08 Fatal - Dead 24 Hours - 1 Year
( )09 Fatal - Period to Death Unknown
( )99 Unknown

Overall Police Injury Severity (KABC)
NOTE: REPORT POLICE JUDGEMENT.
27
( ) 0 No Injury
( ) C Possible Injury
( ) B Nonincapacitating Injury
( ) A Incapacitating Injury
( ) K Fatal Injury
( ) U Unknown

OVERALL SEVERITY OF INJURIES
28,29
( ) 00 None
( ) 01 Minor
( ) 02 Non-Dangerous, Moderate
( ) 03 Non-Dangerous, Severe
( ) 04 Dangerous, Serious
( ) 05 Dangerous, Critical
( ) 06 Fatal Lesions in 1 Region
( ) 07 Fatal Lesions in 1 Region + 4 or 5 above
( ) 08 Fatal Lesions in 2 Regions
( ) 09 Fatal Lesions in 3 or More Regions
( ) 10 Fatal, Details Unknown
( ) 98 Injury Unknown
( ) 99 Injured, Severity Unknown

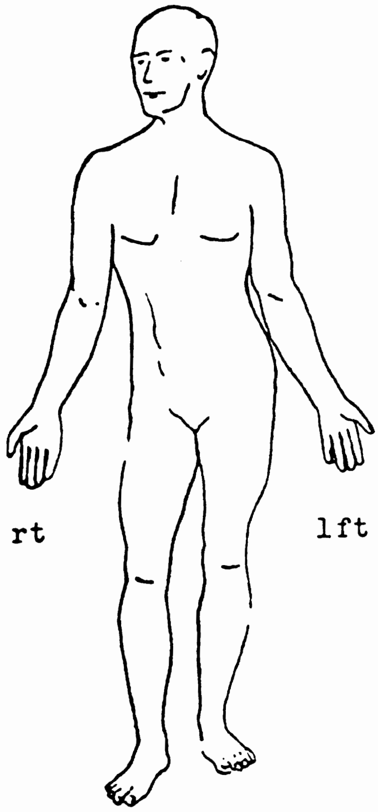
Occupant Ejection/Entrapment
30
( )9 Unknown if Ejected or Trapped

Ejection:
(No or Unknown Entrapment)
( )1 None
( )2 Partial
( )3 Complete
( )4 Extent Unknown
Describe ______________

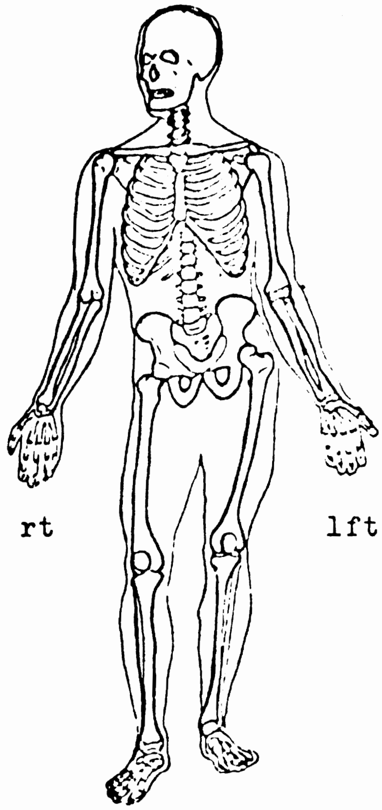
Trapped with:
( )5 No Ejection
( )6 Partial Ejection
( )7 Unknown Ejection

INDICATE LOCATION OF INJURIES, INCLUDING MAJOR BRUISES

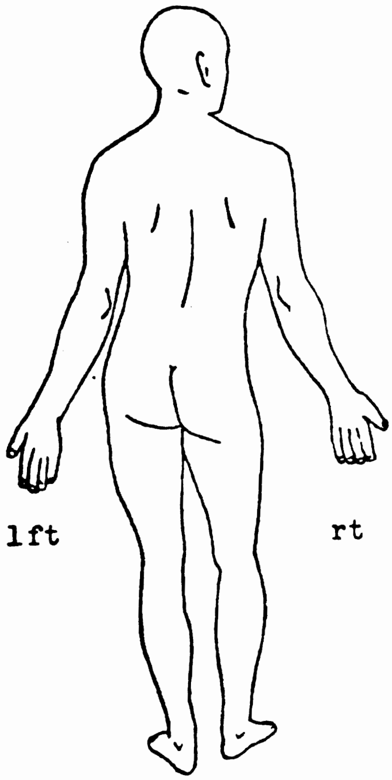
31
1( ) NO INJURIES
2( ) INJURED

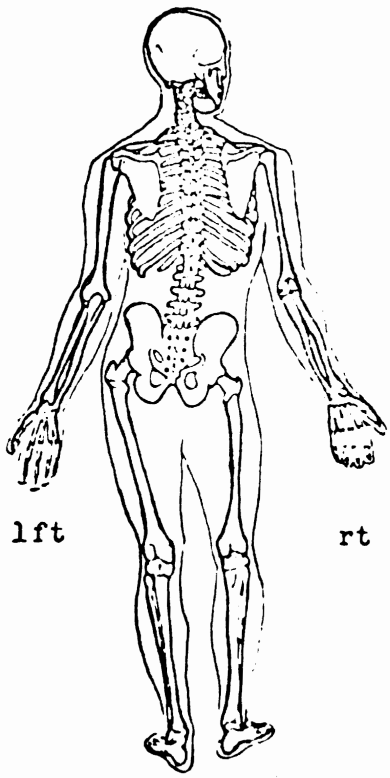


SOFT TISSUE INJURIES



SKELETAL INJURIES





X Rays: ______________________________

Other Tests: ______________________________

INJURY INFORMATION

BEST SOURCE OF INJURY INFORMATION

31
( ) 1 Hospital/Doctor
( ) 2 Personal interview with occupant
( ) 3 Personal interview with other occupant
( ) 4 Other: ______________________________

OCCUPANT INJURY CLASSIFICATION

CARD NO. 1-2	I.D. 3-10	BODY REGION 11	ASPECT 12	LESION 13	SYSTEM/ORGAN 14	SEVERITY 15	BODY REGION 16	ASPECT 17	LESION 18	SYSTEM/ORGAN 19	SEVERITY 20	BODY REGION 21	ASPECT 22	LESION 23	SYSTEM/ORGAN 24	SEVERITY 25	RESTRAINT CAUSED 26
05	DUPLICATE COLUMNS 3-10																
06																	
07																	
08																	
09																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	

NOTE areas of occupant contact.

____

____

____

____

3 - DEFINITE
2 - PROBABLE
1 - POSSIBLE
9 - UNKNOWN

RESTRAINT DEVICE & USAGE

CARD 2 0 / 1 2
Dup col 3-10

occupant seat
position number__ __

DEVICE STATUS

AT TIME OF COLLISION

	SOURCE USED	LAP BELT		SHOULDER BELT		OTHER DEVICE ①		CHILD SEAT	
EQUIPPED for this POSITION		11 1( ) Y 2( ) N 9( ) U	Original Equipment 12 1( ) Y 2( ) N 9( ) U	13 1( ) Y 2( ) N 9( ) U	Original Equipment 14 1( ) Y 2( ) N 9( ) U	15 1( ) Y 2( ) N 9( ) U	Original Equipment 16 1( ) Y 2( ) N 9( ) U	17 1( ) Y 2( ) N 9( ) U	Mfg: ____ Model: ____
BELTS OPERABLE		18 1( ) Y 2( ) N 9( ) U	Malfunction 19 1( ) ② Defeat 2( ) ③	20 1( ) Y 2( ) N 9( ) U	Malfunction 21 1( ) ② Defeat 2( ) ③	22 1( ) Y 2( ) N 9( ) U	Malfunction 23 1( ) ② Defeat 2( ) ③	24 1( ) Y 2( ) N 9( ) U	Malfunction 25 1( ) ② Defeat 2( ) ③
INTERLOCK BUZZER FUNCTIONAL		26 1( ) Y 2( ) N 9( ) U	Malfunction 27 1( ) ② Defeat 2( ) ③	28 1( ) Y 2( ) N 9( ) U	Malfunction 29 1( ) ② Defeat 2( ) ③	30 1( ) Y 2( ) N 9( ) U If ACRS --④	Malfunction 31 1( ) ② Defeat 2( ) ③		

CARD 2 1 / 1 2
Dup col 3-10

DEVICE USAGE

		Response	Judgement	Response	Judgement	Resp	ACRS Deploy	Judge	Response	Judgement
VEHICLE	11 (1)Y (2)N (7)UA		12,13		14,15		16 1( ) Y 2( ) N 9( ) U	17,18		19,20
INJURY DATA	21 (1)Y (2)N (7)UA		22,23		24,25		26 1( ) Y 2( ) N 9( ) U	27,28		29,30
INTERVIEW OCCUPANT	31 (1)Y (2)N (7)UA	32 1( ) Y 2( ) N 6( ) NR	33,34	35 1( ) Y 2( ) N 6( ) NR	36,37	38 1( ) Y 2( ) N 6( ) NR	39 1( ) Y 2( ) N 9( ) U	40,41	42 1( ) Y 2( ) N 6( ) NR	43,44
INTERVIEW: ____	45 (1)Y (2)N (7)UA	46 1( ) Y 2( ) N 6( ) NR	47,48	49 1( ) Y 2( ) N 6( ) NR	50,51	52 1( ) Y 2( ) N 6( ) NR	53 1( ) Y 2( ) N 9( ) U	54,55	56 1( ) Y 2( ) N 6( ) NR	57,58
INTERVIEW: ____	59 (1)Y (2)N (7)UA	60 1( ) Y 2( ) N 6( ) NR	61,62	63 1( ) Y 2( ) N 6( ) NR	64,65	66 1( ) Y 2( ) N 6( ) NR	67 1( ) Y 2( ) N 9( ) U	68,69		
CONCLUSION			70,71		72,73		74 1( ) Y 2( ) N 9( ) U	75,76		77,78

YES		NO
+3	DEFINITE	-3
+2	PROBABLE	-2
+1	POSSIBLE	-1

00 UNKNOWN
99 NOT APPLICABLE

Y = YES
N = NO
U = UNKNOWN
NR = NO RESPONSE
UA = UNAVAILABLE

Response = Literal response of interviewee.
Judgement = Interviewer's best judgement of and confidence in interviewees response to question of restraint usage.

① Specify & describe device: ____________________
Describe irrespective of source. Source of Information
② Malfunction: ____________________
③ Defeat: ____________________
④ Summarize status of ACRS: ____________________

Occupant Seat
Position Number _ _

OCCUPANT SUPPLEMENT

CARD $\frac{2}{1}$ $\frac{2}{2}$
Dup col 3-10

Restraint Maladjustment

11-13
( )991 Yes
( )992 No
( )993 Not Applicable, Not Worn
( )999 Unknown

Factors Determining Restraint Usage Classification

Contribution to Evaluation

Choose one of the following code values for each factor:

(1) Supported evaluation
(2) Contradicted evaluation
(3) Neither supported nor contradicted evaluation
(4) No response*
(5) Not applicable**

Column and Factor	Factor Availability			No	Not
	Sup.	Cont.	Neither	Resp.*	Applic.**
20 Belt or Fittings Damaged by Occupant Loading	1( )	2( )	3( )	4( )	5( )
21 Location or Condition of Belts	1( )	2( )	3( )	4( )	5( )
22 System Defeated	1( )	2( )	3( )	4( )	5( )
23 Exterior Vehicle Damage or Occupant Contact Points	1( )	2( )	3( )	4( )	5( )
24 Police Report	1( )	2( )	3( )	4( )	5( )
25 Police or Witness Observation	1( )	2( )	3( )	4( )	5( )
26 Subject Interview	1( )	2( )	3( )	4( )	5( )
27 Other Interview	1( )	2( )	3( )	4( )	5( )
28 Occupant Injury Pattern	1( )	2( )	3( )	4( )	5( )
29 Belt Caused Injury	1( )	2( )	3( )	4( )	5( )
30 Occupant Ejected	1( )	2( )	3( )	4( )	5( )

* No Response - Vehicle inspected, report obtained or interview conducted but factor undeterminable or interviewee refused to respond.

** Not Applicable - No vehicle inspection, report or interview, or other not applicable.

APPENDIX B

DERIVED DAMAGE SEVERITY MEASURE
USING THE COLLISION DEFORMATION CLASSIFICATION

A damage severity measure based upon all six components of the Collision Deformation Classification (CDC, SAE-J224a), was developed for use as a crash severity control variable. While the CDC deformation extent, by itself, provides a workable severity control variable, further severity information is contained in the CDC direction, location, and distribution codes.

The sample selected for development of the variable included all unrestrained occupants over nine years old from the three teams. This provides a reconstructed data set of 7,652 cases. Each case contains a variable for each of the six elements of the CDC (direction, deformation location, horizontal location, vertical location, damage distribution, and deformation extent) and AIS ("0" for AIS=0,1 and "1" for AIS=2-9). To provide longitudinal symmetry all right and left codes were combined as "mirror images." For example, the clock pairs 1:11, 2:10, 3:9, 4:8, and 5:7 were combined into five codes and the general damage areas "R" and "L" were combined (Table B-1). The AID (Automatic Interaction Detector) program was then used to group the CDC's by their ability to predict the dichotomous dependent variable for injury. The AID program examines each of the independent variables (the individual elements of the CDC) and selects a hierarchical sequence of successive two-way spits on each independent variable. Each split is selected to yield the greatest reduction in the unexplained variability in the dependent variable. This process eventually led to identification of 23 subgroups of the population of CDC's, thus defining a crash severity variable of the 23 levels given in Table B-2

The first three splits were on the extent code, resulting in four deformation extent classes: 1, 2 and unknown, 3, and 4-9. Then each extent class (except 1) split into further subgroups, according to how well the other CDC

Table B-1

COLLISION DEFORMATION CLASSIFICATION
CODES USED FOR AID

1. Force Direction - O'clock Direction of Principal Force at Impact

   12, 1:11, 2:10, 3:9, 4:8, 5:7, 6, 0 (non-horizontal)

2. Deformation Location - General Area of Deformation

F - front	T - Top
RL - Right or Left	U - Undercarriage
B - Back (rear)	X - Unclassifiable
	? - Unknown

3. Horizontal Location - Specific Horizontal Location of Deformation

   D - Distributed
   RL - Right or Left Third of Front or Rear
   C - Center Third of Front or Rear
   P - Center Third of Right or Left Side or Top
   F - Front Third of Right or Left Side or Top
   B - Back Third of Right or Left Side or Top
   Y - Front Two-thirds of Right or Left Side or Top
   Z - Rear Two-thirds of Right or Left Side or Top
   YZ - Right or Left Two-thirds of Front or Rear

4. Vertical Location - Specific Vertical Location of Deformation

A - All	M - Middle-over frame to belt line
H - Top of Frame to Top	L - Low-top of frame and below
E - Everything Below Belt Line	X - Undercarriage
G - Belt Line and Above	? - Unknown

5. Damage Distribution - General Type of Damage Distribution

W - Wide Impact Area	O - Rollover
N - Narrow Impact Area	A - Overhanging Structure
S - Sideswipe	E - Corner
	? - Unknown

6. Deformation Extent - 9 Deformation Extent Zones

Table B-2

DERIVED CRASH SEVERITY SUBGROUPS

Sub-group Number	Number Cases	Percent AIS>2	Force Direction	Deformation Location	Horizontal Location	Vertical Location	Damage Distribution	Deformation Extent
1	62	.000	12,1:11,2:10,0	--	RL,P,F,B,Z	H,L,M,X	--	3
2	627	.032	--	--	P,F,B	--	--	2,?
3	322	.056	--	--	D,RL,YZ,C,Y,Z,?	H,M,G	--	2,?
4	2370	.062	--	--	--	--	--	1
5	270	.070	3:9,4:8,5:7,6	--	RL,P,F,B,Y,Z,?	H,E,L,M,G,X	--	3
6	73	.082	4:8,5:7,6,12	RL,B,T,U,X	D,YZ,C,Y	--	--	3
7	1225	.109	--	--	RL,Y,Z	A,E,L,X,?	--	2,?
8	1048	.148	--	--	D,YZ,C	A,E,L,X,?	W,S	2,?
9	373	.153	1:11,2:10	--	RL,P,F,B,Z,?	E,G	--	3
10	76	.184	--	--	F	--	--	4-9
11	80	.188	1:11,2:10,3:9,0	RL,B,T,U,X	D,YZ,C,Y	--	O,?	3
12	113	.230	12,0	--	RL,P,F,B,Z,?	E,G	--	3
13	82	.244	--	B,T	D,RL,Y,Z,?	--	--	4-9
14	49	.245	--	F,RL,U,X	D,RL,Y,Z,?	--	E	4-9
15	209	.287	**1:11,2:10,3:9,0**	**RL,B,T,U,X**	**D,YZ,C,Y**	--	**W,S**	**3**
16	52	.288	2:10,4:8,6,12	F,RL,U,X	D,RL,Y,Z,?	--	W,N,S,O,A	5,6,8,9
17	93	.290	--	--	D,YZ,C	A,E,L,X,?	N,O,E,?	2,?
18	55	.327	--	--	RL,P,F,B,Z,?	A	--	3
19	40	.375	5:7,6,0	--	YZ,C,P,B	--	--	4-9
20	226	.381	--	F	D,YZ,C,Y	--	--	3
21	57	.526	2:10,4:8,6,12	F,RL,U,X	D,RL,Y,Z,?	--	W,N,S,O,A	4,7
22	66	.606	1:11,3:9,5:7,0	**F,RL,U,X**	D,RL,Y,Z,?	--	W,N,S,O,A	4-9
23	84	.762	1:11,2:10,3:9,4:8,12	--	YZ,C,P,B	--	--	4-9
	7,652	.1302						

classification codes predicted the percentage of occupants with an AIS of 2 or more. Since AID groups the CDC codes by their ability to predict, some of the 23 resulting subgroups do not look very logical, primarily because seemingly unrelated CDC's with a common percentage of AIS=2 or more were grouped. Some of the subgroups with only one basic type of CDC have a fairly direct interpretation. For example, subgroups 2 and 20 are, respectively, one-third side damage* with an extent code of 2 or unknown (?), and front damage to the center-one-third (C) or wider damage with an extent code of 3. Interestingly, subgroup 1 (least severity) all had a CDC extent code of 3. A closer look at the individual CDC's in this subgroup reveals that the majority are front damage that occurred over the top of the vehicle frame (vertical location=M).

All of the cases in the complete set of restraint study data were then coded into the 23 crash severity subgroups as defined in Table B-2. Since the AID run was restricted to a subset of the entire data set, there was the possibility that the resultant severity definition might not cover all of the remaining cases. Only five restrained occupants (.05 percent) were not covered. These five cases were almost identical in CDC's and mean percentage of AIS$\geq$2 to severity subgroup 8, and so were assigned to that subgroup.

The final derived damage severity measure used as a control variable in this report bracketed the 23 subgroups into six groups on the basis of both maximum difference between combined groups and equal cell sizes. The six severities are described in Table B-3 in terms of the number of occupants and mean percentage of AIS 2 or more for the same sample of occupants used for the AID analysis. Three

*P, F, and B codes are restricted to side damage of the front, passenger (center), or back third of the vehicle.

frequent CDC's in each of the six groups are also displayed. Group 1 contains minor-front-fender and grillwork damage. Group 2 contains minor-wide-frontal damage. Group 3 contains completely unknown CDC's along with moderate-front-corner damage. Group 4 contains moderate-wide-frontal damage. Group 5 contains severe damage to the side two-thirds and front corners as well as severe rollovers. Group 6 contains severe-wide-frontal damage.

Table B-3

COMBINED DAMAGE SEVERITY GROUPS

Combined Group Number	Includes Subgroup Number(s)	Number Cases	Percent AIS>2	Frequent CDC's
I	1-3	1011	.038	10-FLEW-1, 09-LFEW-1, 12-FYMW-1
II	4-6	2713	.063	12-FDEW-1, 12-FYEW-1, 11-FYEW-1
III	7	1225	.109	??-????-?, 12-FLEW-2, 11-FLEE-2
IV	8-9	1421	.148	12-FYEW-2, 12-FDEW-2, 11-FYEW-2
V	10-17	754	.251	10-LYEW-3, 00-TDHO-3, 12-FLEW-3
VI	18+	528	.470	12-FYEW-3, 11-FYEW-3, 12-FDEW-3
		7652	.130	

APPENDIX C

SUPPLEMENTAL TABLES

The tables included in this appendix were not used in the same form in the analysis or in the major body of the report. They are presented here for the benefit of those who might wish to have the entire distribution of injury severity data available.

Table C-1

DISTRIBUTION OF OVERALL AIS BY TEAM
OUTBOARD-FRONT-SEAT OCCUPANTS

Data weighted by inverse of sampling fraction

AIS	TEAM CALSPAN		HSRI		SwRI	
	N	%	N	%	N	%
0	1843	47.5	1839	44.3	2547	51.3
1	1548	39.9	2000	48.2	1913	38.5
2	358	9.2	196	4.7	413	8.3
3	90	2.3	88	2.1	56	1.1
4	9	0.23	8	0.19	13	0.3
5	5	0.13	5	0.12	3	0.06
6	6	0.15	9	0.22	9	0.18
7	3	0.08	5	0.12	2	0.04
8	14	0.36	0	0	5	0.10
9	1	0.03	1	0.02	1	0.02
10	2	0.05	2	0.05	2	0.04
Total	3879	100	4153	100	4964	100
2-10	488	12.6	314	7.6	504	10.2
3-10	130	3.4	118	2.8	91	1.8

Table C-2

INJURY SEVERITY BY RESTRAINT USED AND TEAM - 1973

		Overall AIS											
		0	1	2	3	4	5	6	7	8	9	10	N
CALSPAN													
Unrestrained	N	564	510	128	37	3	0	5	1	5	1	2	1256
	%	44.9	40.6	10.2	2.9	0.2	0	0.4	0.1	0.4	0.1	0.2	
Lap Belt	N	246	185	25	7	0	1	0	0	0	0	0	464
Only	%	50.3	39.9	5.4	1.5	0	0.2	0	0	0	0	0	
Fully	N	41	22	1	0	0	0	0	0	0	0	0	64
Restrained	%	64.1	34.4	1.6	0	0	0	0	0	0	0	0	
HSRI													
Unrestrained	N	578	628	69	34	2	2	2	3	0	0	2	1320
	%	43.8	47.6	5.2	2.6	0.2	0.2	0.2	0.2	0	0	0.2	
Lap Belt	N	257	228	15	6	1	0	0	0	0	0	0	507
Only	%	50.7	45.0	3.0	1.2	0.2	0	0	0	0	0	0	
Fully	N	40	34	3	1	0	0	0	0	0	0	0	78
Restrained	%	51.3	43.6	3.8	1.3	0	0	0	0	0	0	0	
SwRI													
Unrestrained	N	619	572	160	24	6	1	3	2	3	1	0	1391
	%	44.5	41.1	11.5	1.7	0.4	0.1	0.2	0.1	0.2	0.1	0	
Lap Belt	N	473	340	56	3	2	0	0	0	1	0	0	875
Only	%	54.1	38.9	6.4	0.3	0.2	0	0	0	0.1	0	0	
Fully	N	37	29	3	0	0	1	0	0	0	0	0	70
Restrained	%	52.9	41.4	4.3	0	0	1.4	0	0	0	0	0	

Table C-3

INJURY SEVERITY BY RESTRAINT USED AND TEAM - 1974

		Overall AIS											
		0	1	2	3	4	5	6	7	8	9	10	N
CALSPAN													
Unrestrained	N	451	429	127	29	3	1	0	0	4	0	0	1044
	%	43.2	41.1	12.2	2.8	0.3	0.1	0	0	0.4	0	0	
Lap Belt	N	86	37	9	2	0	0	1	0	2	0	0	137
Only	%	62.8	27.0	6.6	1.5	0	0	0.7	0	1.5	0	0	
Fully	N	309	228	29	9	2	1	0	1	0	0	0	579
Restrained	%	53.4	39.4	5.0	1.6	0.3	0.2	0	0.2	0	0	0	
HSRI													
Unrestrained	N	357	540	53	24	2	2	5	2	0	0	0	985
	%	36.2	54.8	5.4	2.4	0.2	0.2	0.5	0.2	0	0	0	
Lap Belt	N	39	45	8	0	0	0	0	0	0	0	0	92
Only	%	42.2	48.9	8.7	0	0	0	0	0	0	0	0	
Fully	N	378	285	25	13	1	1	2	0	0	0	0	705
Restrained	%	53.6	40.4	3.5	1.8	0.1	0.1	0.3	0	0	0	0	
SwRI													
Unrestrained	N	490	375	108	19	4	0	3	0	1	0	1	1001
	%	49.0	37.5	10.8	1.9	0.4	0	0.3	0	0.1	0	0.1	
Lap Belt	N	58	36	1	0	0	0	0	0	0	0	0	95
Only	%	61.1	37.9	1.1	0	0	0	0	0	0	0	0	
Fully	N	544	344	37	5	1	0	2	0	0	0	1	934
Restrained	%	58.2	36.8	4.0	0.5	0.1	0	0.2	0	0	0	0.1	

Table C-4

INJURY SEVERITY BY RESTRAINT USED AND TEAM - 1975

		Overall AIS 0	1	2	3	4	5	6	7	8	9	10	N
CALSPAN													
Unrestrained	N	73	95	33	6	1	2	0	1	2	0	0	213
	%	34.3	44.6	15.5	2.8	0.5	0.9	0	0.5	0.9	0	0	
Lap Belt Only	N	7	9	1	0	0	0	0	0	0	0	0	17
	%	41.2	52.9	5.9	0	0	0	0	0	0	0	0	
Fully Restrained	N	66	33	5	0	0	0	0	0	1	0	0	105
	%	62.9	31.4	4.8	0	0	0	0	0	1.0	0	0	
HSRI													
Unrestrained	N	109	104	20	10	2	0	0	0	0	0	1	246
	%	44.3	42.3	8.1	4.1	0.8	0	0	0	0	0	0.4	
Lap Belt Only	N	9	7	0	0	0	0	0	0	0	0	0	16
	%	56.3	43.8	0	0	0	0	0	0	0	0	0	
Fully Restrained	N	72	39	3	0	0	0	0	0	0	0	0	114
	%	63.2	34.2	2.6	0	0	0	0	0	0	0	0	
SwRI													
Unrestrained	N	175	127	37	4	0	1	1	0	0	0	0	345
	%	50.7	36.8	10.7	1.2	0	0.3	0.3	0	0	0	0	
Lap Belt Only	N	9	6	0	0	0	0	0	0	0	0	0	15
	%	60.0	40.0	0	0	0	0	0	0	0	0	0	
Fully Restrained	N	142	84	11	1	0	0	0	0	0	0	0	238
	%	59.7	35.3	4.6	0.4	0	0	0	0	0	0	0	

Table C-5

CDC-EXTENT CODE BY RESTRAINT USED AND TEAM - 1973

		CDC-EXTENT										
		0	1	2	3	4	5	6	7	8	9	N
CALSPAN												
Unrestrained	N	366	284	336	211	44	13	12	2	1	3	1272
	%	28.8	22.3	26.4	16.6	3.5	1.0	0.9	0.2	0.1	0.2	
Lap Belt Only	N	191	94	115	53	6	4	1	0	0	1	466
	%	41.0	20.2	24.9	11.4	1.3	0.9	0.2	0	0	0.2	
Fully Restrained	N	40	8	9	6	0	1	0	0	0	0	64
	%	62.5	12.5	14.1	9.4	0	1.6	0	0	0	0	
HSRI												
Unrestrained	N	54	468	486	251	40	21	4	1	3	9	1337
	%	4.0	35.0	36.4	18.8	3.0	1.6	0.3	0.1	0.2	0.7	
Lap Belt Only	N	10	236	164	75	16	10	3	3	0	2	519
	%	1.9	45.5	31.6	14.5	3.1	1.9	0.6	0.6	0	0.4	
Fully Restrained	N	3	30	31	10	3	1	0	0	0	0	78
	%	3.8	38.5	39.7	12.8	3.8	1.3	0	0	0	0	
SwRI												
Unrestrained	N	69	444	481	324	84	15	7	2	3	5	1434
	%	4.8	31.0	33.5	22.6	5.9	1.0	0.5	0.1	0.2	0.3	
Lap Belt Only	N	67	322	293	151	32	3	0	3	0	8	879
	%	7.6	36.6	33.3	17.2	3.6	0.3	0	0.3	0	0.9	
Fully Restrained	N	8	29	27	10	0	0	0	0	0	0	74
	%	10.8	39.2	36.5	13.5	0	0	0	0	0	0	

Table C-6

CDC-EXTENT CODE BY RESTRAINT USED AND TEAM - 1974

		CDC-EXTENT										
		0	1	2	3	4	5	6	7	8	9	N
CALSPAN												
Unrestrained	N	359	180	265	186	42	11	6	2	0	1	1052
	%	34.1	17.1	25.2	17.7	4.0	1.0	0.6	0.2	0	0.1	
Lap Belt	N	64	28	29	12	2	2	0	0	1	0	138
Only	%	46.4	20.3	21.0	8.7	1.4	1.4	0	0	0.7	0	
Fully	N	176	142	152	78	17	4	6	6	0	0	581
Restrained	%	30.3	24.4	26.2	13.4	2.9	0.7	1.0	1.0	0	0	
HSRI												
Unrestrained	N	20	359	366	191	34	14	18	0	0	4	1006
	%	2.0	35.7	36.4	19.0	3.4	1.4	1.8	0	0	0.4	
Lap Belt	N	10	39	27	13	3	0	0	0	0	0	92
Only	%	10.9	42.4	29.3	14.1	3.3	0	0	0	0	0	
Fully	N	25	286	254	112	19	8	5	1	0	2	712
Restrained	%	3.5	40.2	35.7	15.7	2.7	1.1	0.7	0.1	0	0.3	
SwRI												
Unrestrained	N	62	436	273	217	57	8	0	5	1	0	1059
	%	5.9	41.2	25.8	20.5	5.4	0.8	0	0.5	0.1	0	
Lap Belt	N	12	33	36	14	4	0	0	0	0	0	99
Only	%	12.1	33.3	36.4	14.1	4.0	0	0	0	0	0	
Fully	N	79	345	286	179	41	11	10	2	0	0	953
Restrained	%	8.3	36.2	30.0	18.8	4.3	1.2	1.0	0.2	0	0	

Table C-7

CDC-EXTENT CODE BY RESTRAINT USED AND TEAM - 1975

		CDC-Extent										
		0	1	2	3	4	5	6	7	8	9	N
CALSPAN												
Unrestrained	N	65	58	38	37	9	2	5	0	0	1	215
	%	30.2	27.0	17.7	17.2	4.2	0.9	2.3	0	0	0.5	
Lap Belt	N	6	7	2	1	0	0	0	0	1	0	17
Only	%	35.3	41.2	11.8	5.9	0	0	0	0	5.9	0	
Fully	N	32	33	24	14	1	0	0	0	0	1	105
Restrained	%	30.5	31.4	22.9	13.3	1.0	0	0	0	0	0.1	
HSRI												
Unrestrained	N	14	85	88	42	13	1	2	2	0	7	254
	%	5.5	33.5	34.6	16.5	5.1	0.4	0.8	0.8	0	2.8	
Lap Belt	N	0	11	1	4	0	0	0	0	0	0	16
Only	%	0	68.8	6.3	25.0	0	0	0	0	0	0	
Fully	N	6	54	31	19	3	2	2	0	0	1	118
Restrained	%	5.1	45.8	26.3	16.1	2.5	1.7	1.7	0	0	0.8	
SwRI												
Unrestrained	N	19	137	104	81	9	1	0	0	0	1	118
	%	5.3	38.2	29.0	22.6	0.3	0.3	0	0	0	1.7	
Lap Belt	N	0	4	4	5	2	0	0	0	0	0	15
	%	0	26.7	26.7	33.3	13.3	0	0	0	0	0	
Fully	N	20	106	61	50	6	2	0	0	0	0	245
Restrained	%	8.2	43.3	24.9	20.4	2.4	0.8	0	0	0	0	

APPENDIX D

CANDIDATE CONTROL VARIABLES

A number of candidate control variables for the multivariate analyses were identified using both analysis of variance and chi-square tests. These are variables that are associated with injury and have different distributions across restraint and model year.

Several of the candidate variables were not used in the final models because they did not contribute significantly to the fit of the models. Elimination of these variables is discussed in Section 5.2.2.

The proportion of occupants receiving injuries of AIS$\geq$2 is given here for each level of the candidate variables which were not used in the models.

Table D-1

PROPORTION OF AIS>2 IN PERCENT
BY VEHICLE BODY TYPE

Body Type	Team					
	CALSPAN		HSRI		SwRI	
	%	N	%	N	%	N
Subcompact	12.8	744	7.3	975	11.2	1106
Compact	11.4	1143	8.9	982	9.5	1216
Intermediate	14.4	866	7.7	1041	11.1	1408
Full Size	11.7	1022	7.3	1069	8.7	1261

Table D-2

PROPORTION OF AIS>2 IN PERCENT
BY TYPE OF COLLISION

Collision	Team					
	CALSPAN		HSRI		SwRI	
	%	N	%	N	%	N
Single Vehicle	14.5	1374	11.5	820	18.2	765
Head On	21.6	444	14.0	380	18.5	211
Rear End	8.1	768	4.7	814	6.3	954
Side Swipe	5.1	156	6.7	119	14.3	28
Intersection	9.9	1310	6.3	1911	8.6	3017

Table D-3

PROPORTION OF AIS$\geq$2 IN PERCENT
BY IMPACT FORCE DIRECTION

Direction	CALSPAN		HSRI		SwRI	
	%	N	%	N	%	N
Front (11,12,01 o'clock)	12.5	2486	7.3	2413	11.6	2333
Other (02-10 o'clock)	12.1	978	8.0	1495	8.7	2234

Table D-4

PROPORTION OF AIS$\geq$2 IN PERCENT
BY SEAT LOCATION

Seat	CALSPAN		HSRI		SwRI	
	%	N	%	N	%	N
Driver	12.1	3034	8.0	3032	10.3	3713
Right Front	11.9	1111	7.1	1049	9.6	1284

Table D-5

PROPORTION OF AIS>2 IN PERCENT
BY SIDE OF VEHICLE STRUCK
(Side Impacts Only)

Side	Team					
	CALSPAN		HSRI		SwRI	
	%	N	%	N	%	N
Same as Occupant	14.7	597	8.7	694	9.4	939
Opposite Occupant	7.7	585	7.1	702	9.3	917

Table D-6

PROPORTION OF AIS>2 IN PERCENT
BY SEX

Sex	Team					
	CALSPAN		HSRI		SwRI	
	%	N	%	N	%	N
Male	11.6	2542	7.4	2378	10.4	2876
Female	13.5	1513	8.3	1695	9.7	2110

Table D-7

PROPORTION OF AIS≥2 IN PERCENT
BY AGE OF OCCUPANT

Age	CALSPAN %	CALSPAN N	HSRI %	HSRI N	SwRI %	SwRI N
0 - 10	10.0	40	10.0	70	5.2	77
11 - 20	9.8	961	6.7	1118	9.6	1364
21 - 30	12.0	1283	6.8	1315	9.1	1844
31 - 40	11.7	512	8.8	580	11.7	634
41 - 50	14.8	499	9.7	421	10.9	431
51 - 60	13.6	405	7.7	336	12.2	301
61 - 70	14.3	231	11.6	146	11.0	209
70 - 85	12.6	89	9.5	84	21.1	95
Over 85	15.4	13	28.7	7	4.6	22

(Team: CALSPAN, HSRI, SwRI)

APPENDIX E

ESTIMATED MODEL PARAMETERS

Table E-1

ESTIMATED PARAMETERS FOR THE STATISTICAL MODEL
WITH DAMAGE SEVERITY AND YEAR OF MANUFACTURE

PARAMETER		TEAM	
	HSRI	CALSPAN	SwRI
Mean	0.1226	0.1756	0.1490
1973	-0.0011	-0.0064	0.0096
1974	-0.0024	0.0052	0.0057
1975	0.0035	0.0012	-0.0153
Severity Class 1	-0.0909	-0.1412	-0.1304
2	-0.0883	-0.1012	-0.1042
3	-0.0629	-0.0768	-0.0597
4	-0.0247	-0.0383	-0.0242
5	0.0770	0.0967	0.0346
6	0.1898	0.2608	0.2838
R^2	97.8%	94.0%	93.6%

Table E-2

ESTIMATED PARAMETERS FOR THE STATISTICAL MODEL
WITH DAMAGE SEVERITY AND RESTRAINT USED

PARAMETER	HSRI	TEAM CALSPAN	SwRI
Mean	0.104	0.1579	0.1344
None	0.0183	0.0344	0.0265
Lap Only	-0.0013	-0.0038	-0.0085
Lap plus Shoulder Belt	-0.0170	-0.0306	-0.0180
Severity Class 1	-0.0777	-0.1224	-0.1062
2	-0.0728	-0.0889	-0.0906
3	-0.0522	-0.0940	-0.0440
4	-0.0625	-0.0351	-0.0202
5	0.0811	0.0885	0.0176
6	0.1841	0.2519	0.2434
R^2	73.7%	90.2%	74.3%

Table E-3

ESTIMATED PARAMETERS FOR THE STATISTICAL MODEL
WITH A RESTRAINT X MODEL YEAR INTERACTION

Parameter	HSRI	TEAM CALSPAN	SwRI
Mean	0.0872	0.1414	0.1097
1973	0.0003	-0.0260	0.0031
1974-5	-0.0003	0.0260	-0.0031
No Restraint in 1973	0.0269	0.0513	0.0287
Lap only in 1973	-0.1000	0.0074	0.0043
Full in 1973	-0.0169	-0.0587	-0.0330
None in 1974-5	0.0227	0.0333	0.0457
Lap only in 1974-5	0.0158	0.0106	-0.0411
Full in 1974-5	-0.0385	-0.0439	0.0046
Severity Class 1	-0.0702	-0.1203	-0.0899
2	-0.0658	-0.0795	-0.0737
3	-0.0437	-0.0861	-0.0438
4	-0.0518	-0.0276	-0.0063
5	0.0503	0.0752	0.0179
6	0.1812	0.2383	0.1956
R^2	68.2%	81.2%	68.1%