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Report 03169-II

ACQUISITION OF INFORMATION ON EXPOSURE AND ON NON-FATAL CRASHES

Volume II - Accident Data Inaccuracies

Robert E. Scott
Philip S. Carroll

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48104

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16. Abstract
This volume presents information on inaccuracies in existing sources of highway accident data, on methods for correcting these inaccuracies, and on methods for improving accident injury data by use of hospital records. The major error in existing accident data is bias due to under-reporting; this is due to lenient criteria and policies for reporting of accidents. There is a lack of uniformity in non-reporting among states. A comparison was made between accidents admitted on a driver survey and official records. About 35% of survey accidents were in the records, and 33% of accidents in the records were recalled in the survey. For injury, tow-away, and high-damage accidents, the percentage of reported accidents were higher. In a study of the accuracy of police injury codes, it was found that very low percentages of really severe injuries actually occurred in cases with severe-injury police codes.

It was determined that corrections in accident-frequency totals may be accomplished by extrapolations of reported totals, using ratios of non-reporting derived from sample comparisons between official records and driver surveys. Also, available national summaries of hospital records could be used to improve estimates of the number and severity of accident injuries.

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PREFACE

This is Volume II of the final report on Contract FH-11-7293, "Acquisition of Information on Exposure and on Non-Fatal Crashes." It covers Phase II of the contract (Information on Non-Fatal Crashes).

Requirements, approaches and findings are presented for each of the three tasks in Phase II. Final conclusions and recommendations are presented with regard to future programs for reducing inaccuracies in accident data, and standardizing estimates of accident involvements.

The results of this study are intended to aid in the improvement of accident data, which may then be combined with exposure survey data to produce meaningful accident rates for highway safety evaluations.

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SECTION 1
INTRODUCTION

This volume presents the results of Phase II -- Information on Non-Fatal Crashes. Its purposes in accordance with the Statement of Work in Appendix A are to determine:

1. Reliability and usefulness of current sources of data on highway accidents and injuries.
2. Methods for eliminating the effects of major biases and inaccuracies in current sources of accident data.
3. Feasibility of using hospital records for improving estimates of the number and severity of accident injuries.

Improved highway accident data is necessary for future evaluations of highway safety countermeasures. It is expected that the major use of accident data in highway safety evaluation will be in the derivation of accident rates. Within various classes of highway travel, appropriate accident rates may be derived with accident involvement frequencies in the numerator and corresponding exposure data (vehicle miles of travel) in the denominator. It is important that the estimates of both numerator and denominator be as accurate as possible, in terms of biases and random errors.

In Volume I of this report, recommendations are presented for future programs of exposure data collection. The purpose of this volume is to present recommendations for improvements in future accident data that will be commensurable with the new exposure data.

SECTION 2
SUMMARY

This volume presents the requirements, approaches and findings pertaining to each of the three tasks of Phase II - Information on Non-Fatal Crashes (see contract work statement, Appendix A). Summaries of each of the tasks are given under the headings below.

ANALYSIS OF ACCIDENT DATA INACCURACIES (Task 1)

The requirement of this task is to "analyze current sources of crash and injury statistics" in terms of their reliability and usefulness in estimating true frequencies of highway accidents and injuries. Emphasis was placed on the study of accident data biases due to under-reporting of certain kinds of accidents. Interviews were made of accident experience of drivers, and results were compared with official accident records of the same drivers. Also, injury records were compared with hospital diagnoses of accident injuries to indicate internal inaccuracies of accident reports.

There is a considerable variation in accident reporting requirements among the states. Only 36 states require immediate notification of police in case of a traffic accident. However, all states require "financial responsibility" reporting in case of a traffic fatality or injury, and most require it when damage exceeds a statutory amount (up to $250.). In practice, all states provide a form for police reports, regardless of statutes, and all have policies--if only unwritten--to investigate as many traffic accidents as possible within manpower constraints. However, because of these constraints, a great many accidents go unreported, and there is considerable non-uniformity among states as to the degree of underreporting within states. Finally, there is a great deal of non-uniformity of the accuracy of reporting by police agencies both among the states and within them. In the mass accident data which is collected, statistics are in error due to both random observational error and systematic underreporting biases.

In the comparisons of interview accident data versus drivers' official records, frequency of accident was determined in three categories: those accounted for in both survey and records, those in survey but not in records, and those in records but not in survey. There was no way to determine actual accidents not in survey or records. Approximately 35% of all survey accidents were in driver records, and 33% of drivers' recorded accidents were recalled in the survey. For injury accidents, tow-away accidents and high-damage accidents, the percentage of reported accidents were much higher.

In the analysis of accuracy of injury reporting, police injury codes were compared with an AMA injury scale derived from hospital records in Washtenaw County. The most significant finding was the low incidence of severe injuries (AMA scale) in cases which were indicated as severe in the police codes. Only 15.5% of the victims with the highest police code had a really severe injury according to the AMA scale. In addition to these inaccuracies, a sample of police injury codes in 17 states revealed a glaring inconsistency in the distribution of injury codes among states.

CORRECTIONS FOR ACCIDENT DATA INACCURACIES (Task 2)

The purpose of this task was to determine "methods for elimination of effects of major biases and inaccuracies in current information." General recommendations include standardization of accident reporting criteria, simpler report forms, using auxiliary data (e.g. licensing information), improved data processing and improved police training for accident reporting. A potential quantitative method of eliminating underreporting bias is the method of the preceding task, i.e., determining ratios of underreporting through sample surveys of drivers' accident experience and comparisons with official records. The derived ratios could be used to extrapolate corrected accident totals from counts in the official records. However, the survey and record searching costs would be quite high with respect to the normal costs of accident data analysis, even on a sampling basis. This would be especially true if the procedures included derivation of separate ratios for each of the exposure classifications recommended in Volume I or if performed in each state. Further study of potential simplifications of these procedures is recommended.

HOSPITAL RECORDS OF ACCIDENT INJURIES (Task 3)

The purpose of this task if to "determine the feasibility of using hospital records for estimating number and severity of serious injuries." The source of hospital records considered most applicable to this task is the Commission on Professional and Hospital Activities (CPHA), which summarizes about 30% of all U. S. hospitalizations annually. Their past data has included indicators of highway accident victims. However, it does not include emergency treatment in which victims are not subsequently admitted as in-patients. CPHA data on the length-of-stay in a hospital appears to be the best measure of accident severity. This data could be correlated with samples of police injury codes in order to derive corrections in both frequency and severity of injury. In future standardized accident reports, injury codes will be improved. At that time, consideration should be given to detailed procedures for the use of CPHA records and samples of emergency-room records in correcting injury data.

SECTION 3

ANALYSIS OF ACCIDENT DATA INACCURACIES

ACCIDENT DATA ERROR SOURCES

The mass accident data available to researchers is provided through the statutory mechanisms of the individual states. Every state has statutory requirements requiring the reporting of traffic accidents. While there is considerable variation in reporting requirements among the states, there is also a degree of commonality in philosphy. The similarity between states is partially the result of activities of the National Safety Council. State statutes have also been influenced greatly by efforts of the National Committee on Uniform Traffic Laws and Ordinances, and in turn the response of the states is reflected in the Uniform Vehicle Code developed by the committee. The Northwestern University Traffic Institute has also contributed greatly to the standards on traffic accident data collection and to the techniques of accident investigation.

Three reporting schemes are in common use among the states, although all three are used in only a few states. Two of the methods constitute written reports submitted to a state agency directly by the drivers involved. Written reports are required by the acts collectively called "financial responsibility laws." These reports must be submitted within some period of time following the accident, varying from two to thirty days. Reports provided in accordance with financial responsibility laws will be referred to here as financial responsiblity reports. Several states also require written reports from the drivers independently of the financial responsibility reports in compliance with state statutes on "rules of the road". Such reports will be referred to as "written reports." Most states (but not all) require immediate notification of a law enforcement agency following accidents of specified severity. State laws and local ordinances on regulations then dictate whether the police investigate and report the accident. The reports resulting from investigation by law enforcement officers will be referred to as "police reports".

The conditions which establish reporting requirements vary considerably. All states require a financial responsibility report if all drivers involved have liability insurance. The financial responsibility reports usually require information on the people involved in any injury or property damage, but little data describing the incident or relating to crash or precrash events. The data is usually given relative to, and in anticipation of, litigation. Under these circumstances, the data could not be considered either objective or reliable. Few states use the financial responsibility reports for statistical purposes or an an official file for compilation of accident data. Written reports prepared by drivers differ from financial responsibility reports in that more complete information regarding the circumstances of the accident is usually required, and they are used for state accident files and thus contribute to the official compilation of state accident experience and to national statistics. However, they do suffer from lack of the objectivity provided by an independent observer.

Thirty six states have statutes requiring immediate notification of law enforcement officers in case of accident. The statutes typically follow the recommendations of the National Committee on Uniform Traffic Laws and Ordinances. The Uniform Vehicle Code of 1968 recommends immediate reporting of all accidents which result in injury or death of any person or total damage to property to an apparent extent of $100. While statutes, regulations, and local ordinances govern the investigation required upon notification of such an accident, an investigation and a police report are usually required for all such crashes.

Indeed all states provide a form for police reports, regardless of statutes regarding notification. The police reports provide most of the mass accident data available. Considerable non-uniformity exists,however, among the state requirements for immediate notification. Thus the mass accident data is obtained primarily from reports of police investigations collected under a variety of reporting criteria.

Any inferences drawn from the mass data are subject to error. The errors may be conceptualized by considering the accident data as the result of a survey, albeit a rather unique survey. The elements of the survey are the individual accidents.

In the terminology of Kish, the sampling is "fortuitous" and consists of all accidents for which official reports are accumulated.[1] This same set is the survey population, which in normal surveys would be carefully defined, and selected after thorough planning. The target population, which a classical survey is intended to represent, is selected by the analyst after the data has been collected.

The analyst may wish to examine only fatal or injury accidents, or those in a stratum of his interest. The most frequently selected basis of stratification or partitioning is some measure of severity. If interest is limited to the high severity cases,we frequently assume our sample is exhaustive--that all such cases have been reported. Our sampling scheme is equivalent to sampling without replacement with a sample size approaching that of the target population. Sampling errors then become very small. Each such sample from <u>the same target population</u> is nearly identical, and the sample variance approaches zero.

Under the above conditions, i.e. nearly exhaustive sampling, the non-sampling errors-consisting of observational or measurement inaccuracies-dominate. Mistakes in investigating and recording accident data might include incorrectly recording the time of the accident, environmental conditions, information on occupants etc. Subjective information, e.g. the primary contributing circumstances and probable cause, are most difficult to ascertain reliably. A source of error which is often neglected results from lack of quality control in data processing of accident data. Many organizations which have adopted machine processing assume that the introduction of computer technology inherently assumes quality control, while in fact an additional source of error is introduced.

Observational errors may be composed of "random" components which increase variability, and systematic errors or biases. The latter are perhaps the more insidious because they cannot be intrinsically detected or evaluated. The two types of errors, random and systematic, are coupled in their effects upon our techniques of statistical inference because of their combined influence on probability statements. With a knowledge or estimate of error variance we frequently examine questions of probability associated with our target statistics, as in the computation of confidence intervals. Unrecognized bias effectively displaces the distribution of the subject parameters, and probability statements based on only the variance are in error. Since the displacement is generally away from the mode of a symmetrical distribution, e.g. a normal asymptotic approximation, one tail of the density function is decreased and the other increased, leading to over-optimistic confidence intervals.

As the target accident population of the analyst is broadened, the sampling provided by the available mass accident data becomes less complete. In particular, as the severity level of crashes of interest is lowered, additional strata are added to the survey population. Reporting of low-severity crashes is not complete so the lower strata do not represent exhaustive coverage. Then a significant proportion of the crash population is not included in the available data. The intended exhaustive sample is thus degraded by significant non-observation equivalent to non-response in a classical survey.

Non-observation produces a bias in survey results. The effects may be illustrated rather simply. We may wish to compute the mean of an observed variable. If the mean of a population characteristic X is $\bar{X}$ when the sample is complete, the error from non-observation may be computed by partitioning the target population into two sets. Then the target estimate can be expressed as

$$\bar{X} = W_1 \bar{X}_1 + W_2 \bar{X}_2$$

where group 1 is the set of collected data and group 2 is the set excluded from the data collection -- the unreported accidents. The proportion of the cases which are excluded is W_2 where $W_1 + W_2 = 1$. The error in estimating the mean of the target population correctly, relative to estimated results is

$$\frac{\delta \bar{X}}{\bar{X}_1} = \frac{\bar{X} - \bar{X}_1}{\bar{X}_1} = W_2 \frac{(\bar{X}_2 - \bar{X}_1)}{\bar{X}_1}$$

and the desired estimate is given by $\bar{X} = \bar{X}_1 \left(1 + \frac{\delta \bar{X}}{\bar{X}_1}\right)$.

Underreporting will have little effect on the estimate if 1) the proportion of accidents not reported, W_2, is small or 2) the mean of the non-observed values X_2 is nearly the same as that of the recorded accidents. Unfortunately, neither condition is true in the low severity strata.

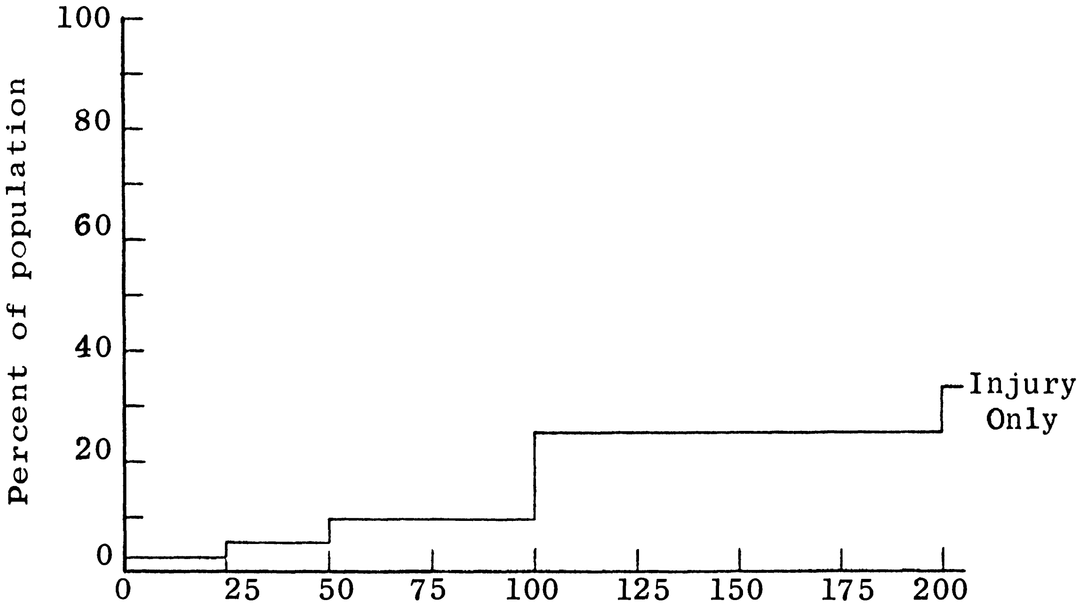
If the estimates are to provide comparisons between classes, as a before-after evaluation of a countermeasure program or for comparing jurisdictions or states, the effects of bias may largely cancel in the comparison. If there are any geographic or temporal differences in underreporting however, the estimates will be contaminated.

The principal errors in accident data collection and analysis may be summarized as 1) observational error in the data collected and 2) biases resulting from underreporting. The succeding paragraphs of this section deal with pilot measurements of these errors. Emphasis will be placed on the underreporting of traffic accidents and on errors resulting from traditional interpretation of injury data provided in official accident report files.

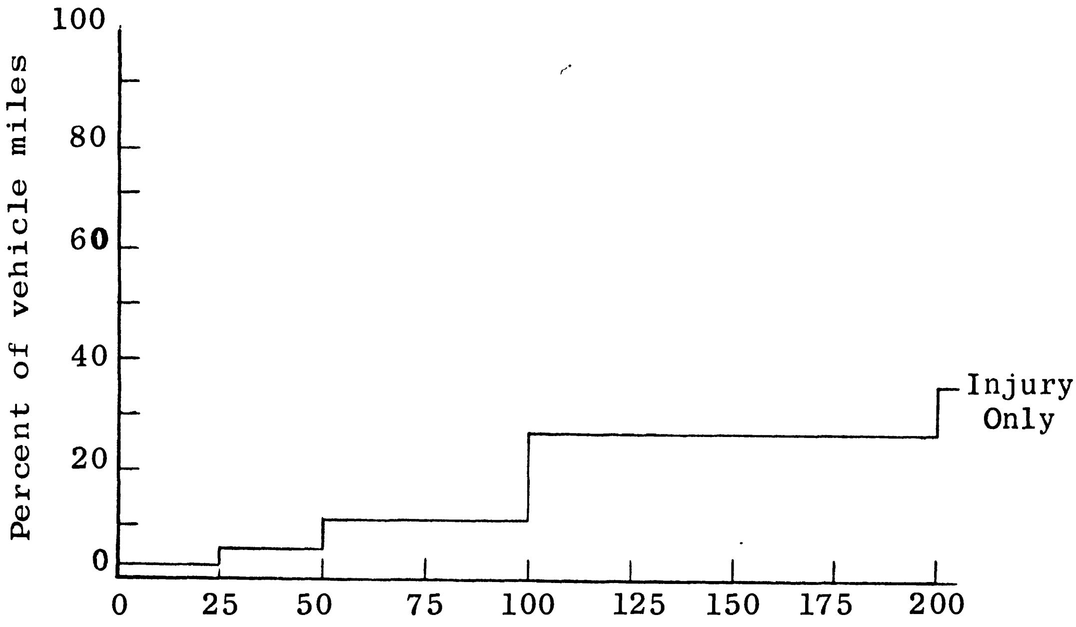
UNDERREPORTING OF ACCIDENTS

The state reporting requirements for accidents have been discussed in previous paragraphs. The requirements for notification of property damage accidents vary widely among the states and have been subject to periodic revision, so that neither uniformity nor stability has been achieved. Even the duty to report injury accidents through police accident reports varies, although not as widely.

Cumulative distributions of property damage reporting requirements in percent of the U.S. population (1960) and in percent of total annual vehicle miles in the U.S. are given in Figure 1. The curves for both vehicle miles and population are nearly identical. Three states (Colorado, Nevada, Rhode Island) and the District of Columbia require immediate notification of a law enforcement agency in the event of an accident with any material damage. These areas include 2.2 percent of the population and the same proportion of the annual vehicle miles in the U.S. A total of 21 states require notification if the damage is over 100 dollars. These states include 24% of the population and 27% of the vehicle miles. Accidents with damage 200 dollars or greater must be reported to the police in 24 states (including those with a lower threshold) and include 32% of the population and 36% of the vehicle miles.



Property Damage in Dollars
b. By population



Property damage in Dollars
a. By vehicle miles

Figure 1

Distribution of State Requirements that Accidents be Immediately Reported to Police

Thus we might expect that 36% of the property damage accidents in the U.S. would be reported under statutory sanctions. Injury and fatal accidents must be so reported in states accounting for 64% of the driving.

It would be convenient if we could assume that a simple distribution based on statutory requirements would provide a reliable estimate of underreporting. Unfortunately, the reporting (notification) decision is a complex process, not at all adequately described by legal requirements alone. While fatalities are recorded reliably, minor injury and property damage accidents are significantly underreported. Drivers involved in an accident may or may not be aware of the state and local statutes. They are, however, subject to other concerns and pressures. These may involve operators license sanctions, considerations of culpableness degree of intent to repair damage, characteristics of insurance coverage and practices in the area, as well as the individual motives of the drivers. Undoubtedly other factors which have not been listed also play an important role.

Variations in reporting accidents do not depend solely upon the parties involved. Local police regulations and practices may vary within a state or even on a local level. While California does not require police reports of property damage accidents, Smith has noted that "the State Highway Patrol has a written policy of investigating and filing reports on all accidents (including property damage only) that are brought to their attention or that they observe on roadways patrolled by them".[2] Smith further states that the policies of the cities vary, some reporting only severe damage crashes while others attempt to report all accidents. Thus the state accident files do not reflect the statutory threshold. Similar non-uniformity can be found in Michigan, which requires reports of all crashes with apparent damage of 200 dollars or more. Until 1966 the requirement was based on a "tow away" criteria. Undoubtedly many residents of Michigan are not yet aware of the newer criteria. While the State Police attempt to adhere to the state law, they will submit a report--and it is included in the official accident file--if a driver requests a police investigation. Thus the file contains records of minor property damage accidents. Conversely, the Detroit Police Department when faced with insufficient manpower and steadily increasing work loads, adopted a policy in 1968 of not responding to accidents if no person was injured, the vehicles could be moved under their own power, alcohol or the use of drugs was not involved and it was not a hit-and-run. Thus the majority of property damage accidents in Detroit might be unreported.

Roosemark and Fräki report a survey conducted in Sweden in 1965 in which the accident experience of approximately 3,000 interviewees was examined.[3] They found that both property damage and injury accidents were underreported. While the reporting criteria were not given, the ratio of reported crashes to those that were legally reportable is given in Table 1.

TABLE 1

ACCIDENT REPORTING IN SWEDEN
VERSUS COST OF REPAIRS IN DOLLARS,
1963 - 1964

Cost of Repair in Dollars	Approximate Percentage Reported
10	16
50	17
120	12
250	38
500	48
1,000	50

Approximately one fifth of the property damage accidents were reported and surprisingly, only half the injury accidents.

McGuire and Kersh discuss several studies of accident reporting in the U.S.[4] They examined the official records of 500 Mississippi drivers who reported 110 accidents in interviews and found that 52 percent of the accidents were in the state Highway Patrol files. They also found statistically significant differences in reporting by sex. Male drivers evidently reported 66 percent, and female drivers only 33 percent. The reporting of accidents with property damage of over 100 dollars (53%) was not significantly different than those with damage over 50 dollars (52%). McGuire and Kersh also present the results of a similar study in California. Fifty three accidents were found in interviews with 122 drivers. Forty three, or 81 percent, were found in state records. The authors do not indicate however, whether the interview and state records were compared on the basis of individual accidents, or if aggregate counts for each person were compared. This can substantially affect the results if the official records contain accidents not recalled in the interview.

The study by Smith, also conducted in California, was restricted to 438 accidents of vehicles of the Division of Highways, but excluding accidents peculiar to Division operations.[2] The accidents were reported to the Division in accordance to strict regulations. The Division accident reports were then matched individually with California Highway Patrol Records which constitute the official file of State accident experience. The proportions reported in the state file are given in Table 2.

Thus both the fatal and injury accidents were reported reliably, but only a little over third of the property damage accidents were reported. The underreporting of property damage crashes might be surprising since the drivers were state employees who must report the accidents to their Division. On the other hand, this reporting was in a state that does not require reporting of property damage crashes.

TABLE 2

REPORTING OF ACCIDENTS OF CALIFORNIA DIVISION OF HIGHWAY VEHICLES

	Number	Percent Reported
Fatal	3	100
Injury	89	93
Property Damage	346	38

In 1958 the U.S. Bureau of Public roads and the Illinois Division of Highways conducted a large survey of the costs of and frequencies of accidents in Illinois.[5] Although the objective of the survey was a determination of the total cost of accidents to Illinois drivers, the incidence of underreporting was examined to provide comprehensive cost estimates. The survey consisted of questions sent to approximately 14,000 registered drivers. The proportion of involvements reported in the state files, after expansion to the state population, was 24.1 percent for passenger cars and 19.6 percent for trucks or an aggregate of 23.7 percent for all types of vehicles. The property damage reporting criteria in Illinois during the time covered by the survey was 100 dollars, although the reporting was not examined with regard to accident severity. The reporting is given for <u>involvements</u> rather than accidents. Only if the average number of involvements (vehicles) per accident is the same for both reported and unreported accidents would the figures also apply for accidents.

A very similar study of the costs of accidents in the Washington, D. C. metropolitan area in 1965 was conducted by Wilbur Smith and Associates.[6] The reporting in Washington was 48 percent, 32 percent in Maryland, and 30 percent in Virginia. It is interesting to note that accidents of any material damage must be reported to the police in Washington, while only those involving injuries or fatalities must be reported to police in Virginia and none must be reported in Maryland. Financial responsibility reports are required in all three areas. The heavy traffic patterns which involve all three jurisdictions would suggest that individual motorists may not adapt their reporting behavior to the particular accident locale, and that the aggregate result of 36 percent for the total sample might be more appropriate. We certainly cannot closely correlate the results with the legal criteria of each state.

The results of studies which have been discussed in the preceding paragraphs suggest that underreporting is substantial, and not closely related to statutory requirements. State regulations can not provide an effective basis for estimating total accident frequency by severity. Estimation of the incidence of crashes of low severity must depend on determination of reporting rates for appropriate strata. The exposure survey reported in Volume I provides a means by which the underreporting might be examined by severity, and the problems of extending the scope of such a survey may be studied.

Interviewees may be asked about their accident experience over a defined period. The accidents recalled in the survey will include both unreported and reported incidents. The responder may not know if each recalled incident was reported. Even if his memory is reliable, he is only aware of the notification of police, i.e. he has no way of knowing if a report was completed and included in official state files. Therefore an independent check is necessary to determine which accidents identified on the survey were unreported.

The set of possible responses may be described by the elements in the array depicted in Figure 2.

		Survey Response S	Survey Response $\bar{S}$
Official Reports	R	N_{RS}	$N_{R\bar{S}}$
	$\bar{R}$	$N_{\bar{R}S}$	$N_{\bar{R}\bar{S}}$

Figure 2 Array of Accident Reporting and Survey Response.

The columns indicate response on the survey where S denotes accidents recalled and $\bar{S}$ denotes accidents not recalled. The rows represent the contents of official state accident files, R denoting reported accidents, and $\bar{R}$ unreported events. The total number of reported accidents in which the survey population was involved is then $N_R = N_{RS} + N_{R\bar{S}}$. The proportion of accidents which are reported is then $N_R/(N_R + N_{\bar{R}})$.

The total number of accidents recalled on the survey is $N_S = N_{RS} + N_{\bar{R}S}$. Without matching the survey result with state accident files accident by accident, we may only determine N_R and N_S. Accidents which are neither reported or recalled, $N_{\bar{R}\bar{S}}$, can not be identified by either the survey or official accident files. If we assume that the recall capability is independent of whether or not an accident was reported, we may estimate $N_{\bar{R}\bar{S}}$ by linear extrapolation.

The observed lack of recall capability and underreporting can be expressed respectively as:

$$K = \frac{N_{R\bar{S}}}{N_{RS}} \qquad L = \frac{N_{\bar{R}S}}{N_{RS}}$$

A linear extrapolation for estimating $N_{\bar{R}\bar{S}}$ allows us to estimate $N_{\bar{R}}$ and $N_{\bar{S}}$.

$$N_{\bar{R}} = LN_R$$

$$N_{\bar{S}} = KN_S$$

The estimated proportion of accidents reported is

$$P_R = \frac{N_{RS}}{N_S} = \frac{1}{1 + L}$$

and the estimated proportion recalled is

$$P_S = \frac{N_{RS}}{N_R} = \frac{1}{1 + K}$$

Estimation of P_S is only possible if N_{RS} and $N_{R\bar{S}}$ are identified, and this requires checking each accident recalled in the survey with state records, a rather formidable task if the survey is large and the state accident records are not maintained in computer files. While we cannot expect interviewees to have high recall capability and thus achieve low values of K, their recall may be independent of the factors that influence reporting. If we can demonstrate such an independence, and that recall is a stable process, we might estimate K in a modest survey, and expand the estimate to a much larger population. Extensive surveys could then be used to estimate underreporting without the burden of searching state files for individual accidents. Furthermore, estimates of underreporting would be feasible in areas or states that do not maintain files which allow machine data processing for matching individual accidents. The proportion of accidents which are reported could then be estimated for the survey population as

$$P_R = \frac{N_R}{N_S} \qquad \frac{1}{(1 + K)}$$

where N_R and N_S are aggregate numbers of accidents included in state files and survey response respectively, but adjusted in accordance with the survey sampling plan. The results should also be stratified by accident severity.

The surveys conducted for measurements of exposure were used to study measurement of both K (recall capability) and L (under-reporting).

The preliminary survey conducted in Washtenaw County in August 1969 included questions regarding accident experience over the previous three years. The information collected on each accident included:

1) Month and year of accident
2) Number of cars involved
3) Property damage to interviewee's vehicle
4) Personal injury
5) Violation issued

Each response was checked against the state driver record of each individual. The information common to each source (survey and driver) which could be used to establish a match were:

1) Month and year
2) Number of vehicles
3) Injury accident
4) Violation issued

Since interviewee's cannot be expected to recall dates accurately over three years, a discrepancy of six months was allowed on dates. The wide latitude on dates was necessary to prevent rejection of a large number of accidents that matched in all other respects.

Experience also indicated that the number of accidents per person was low enough to prevent significant likelihood of a mismatch. Using this criteria for acceptably matched dates, accidents indicated on both the survey and driver record were considered adequately and uniquely identified if three of the four descriptors, including date, were the same on both sources. The date on the driver record was considered the correct date of accidents on both sources. The accident was rejected from further consideration if this date was not within the period covered by the survey.

A total of 448 drivers were interviewed in the preliminary survey. Among this sample, 86 accidents were recalled by the drivers and 106 were listed on their driver records. The results are given in Table 3. Only 45 percent of all accidents recalled on the survey were reported and included in state files. The reporting of accidents for which a violation was issued were reported with high reliability, 93 percent. However, the violation would not be issued except by a police officer.

The variation in reporting with property damage shows a marked relation to the amount of damage, with very low reporting of accidents with less than 200 dollars damage. We might also note that injury accidents were also underreported.

The recall capability of the persons interviewed was only 37 percent, but did appear more stable than reporting across the classes of accidents shown. The recall proportion P_S was not calculated versus property damage because the amount of damage was only available from survey data, and not on the driver records.

The data of Table 3 represents accident experience over a three year period, July 1966 to August 1969 inclusive. This is a long period over which to expect reliable recall. If a shorter period is used however, the amount of data (number of accidents) is reduced. Thus the selection of an appropriate period involves a trade off between recall capability and sample size. To examine

TABLE 3

ACCIDENT REPORTING, PRELIMINARY SURVEY

448 RESPONSES

	N_{RS}	$N_{\bar{R}S}$	$N_{R\bar{S}}$	K	L	P_S	P_R
All Accidents	39	47	67	1.72	1.20	0.37	0.45
Violation Indicated	24	2	34	1.41	0.08	0.41	0.93
No Violation Ind.	15	45	33	2.20	3.00	0.31	0.25
PD < $200	1	20	--	----	20.00	----	0.05
200 ≤ PD ≤ 500	4	15	--	----	3.75	----	0.27
PD > 500	3	5	--	----	1.67	----	0.38
Injury Accident	12	6	25	2.08	0.5	0.32	0.67
Non-Injury Accident	25	41	42	1.68	1.64	0.37	0.37

the effect of the period, the proportion recalled P_S was computed for each of the three calendar years. For the twelve months starting July 1, 1966, the recall was $P_S = 0.21$; for the year following July 1, 1967, $P_S = 0.38$; and in the last full year $P_S = 0.48$. Thus over the three years the recall improved from 21 percent to 48 percent, more than double. A chi-square test of a three by two contingency table failed to show significance at the 5% level however, partly because of the limited sample size. Thus, while recall improved the improvement is not substantiated with confidence.

The preliminary survey of Washtenaw County was followed by a much larger pilot survey in the spring of 1970. A complete description of the survey is given in Appendix C and will not be repeated here. The questions on accident experience included the number of accidents in the previous twelve months and in the previous three years. The interviewee was also asked if each of the three most severe accidents were reported, i.e. police wrote down information about the accident. This information does not provide the detail necessary to individually match accidents against the contents of state files and determine the cell counts depicted in Figure 2. The information does allow an estimate of underreporting if a suitable estimate of K and thus P_S can be obtained. To examine this possibility the questionaire used in the Detroit SMSA was expanded to include additional detail. In addition to the number of accidents in the previous twelve months, the following items were asked for each of the three most severe accidents.

1) Month, year
2) Was a police report written,
3) Was anyone injured,
4) Were any vehicles towed away,
5) Was your car damaged, if so what was the estimated dollar damage.

The number of interviews completed in the Detroit SMSA were comprised of 238 in the city of Detroit and 338 in Oak Park, a suburb on the northern edge of Detroit. Counts of each cell of the recall-reporting matrix were computed after matching each accident with state driver records. The observed values of K, L, P_S, and P_R were then computed for the total sample and for the following strata:

1) Office: Detroit VS Oak Park
2) Sex: M VS F
3) Socio-economic scale: 1-3 VS 4-5
4) Education level
   A. High school not complete
   B. High school
   C. 4 yr. college
5) Unemployed
   A. Housewife
   B. Student
   C. Other
6) Police report VS No police report
7) Injury accident VS No injury
8) Vehicle towed away VS Not towed
9) Property damage
   A. $PD < 200$
   B. $200 \leq PD \leq 500$
   C. $PD > 500$
   D. Car totaled

The computed values of P_S and P_R were tested for statistical significance between the above levels (strata) using chi-square tests of contingency tables. In the case of all two way splits (2 X 2 tables) this test is equivalent to standard tests between proportions. Significant differences at the 10% level or lower were found only in comparisions 7, 8, and 9 above. Computations of P_S (recall) were not possible for items 8 (towed) and 9 (property damage) since these parameters are not included on the driver records.

The results of the interviews in the Detroit SMSA are given in Table 4 for all accidents in a single group, and for partitioning on

TABLE 4

ACCIDENT REPORTING, PILOT SURVEY: DETROIT SMSA

576 RESPONSES

	N_{RS}	$N_{\bar{R}S}$	$N_{R\bar{S}}$	K	L	P_S	P_R
All Accidents	26	49	52	2.00	1.88	0.33±0.10	0.35± 0.11
Injury	13	2	14	1.08	0.15	0.48±0.19	0.87±0.17
No Injury	13	47	38	2.92	3.62	0.25±0.12	0.22±0.10
Towed	13	8	--	----	0.62	---------	0.62±0.21
Not Towed	13	41	--	----	3.15	---------	0.24±0.11
PD < 200	5	18	--	----	3.60	---------	0.22±0.17
200 ≤ PD ≤ 500	7	15	--	----	2.14	---------	0.32±0.19
PD ≤ 500	12	33	--	----	2.75	---------	0.27±0.13
PD > 500	11	6	--	----	0.545	---------	0.65±0.23
Police Report	25	25	52	2.08	1.00	0.32±0.10	0.50±0.14
No Police Report	1	23	0	0	23	1 ± -----	0.04±----

each variable that resulted in chi-square tests of significance at the 10% level or lower.

Empirical values of P_S and P_R are also given along with their confidence interval. The 95 percent confidence intervals were computed using the familiar normal approximation for testing proportions. The intervals should be interpreted with caution. The sample sizes, either $N_{RS} + N_{\bar{R}S}$ or $N_{RS} + N_{R\bar{S}}$, are not large and the normal approximation is not justified for all entries. The tabulated intervals do give some indication of the precision of the estimation however, and are included for this reason.

A total of 127 accidents were noted by the participants in the survey or were indicated on the driver record of those who recalled an accident. As indicated in Table 4, 35 percent of the accidents recalled were reported. This is slightly lower than the result obtained in Washtenaw County (45%), but the difference is not significant at the 5% level. Recall in both areas was similar, about one third. If the results in Washtenaw County and Detroit are combined, the results are $P_S = 0.35$ and $P_R = 0.40$.

Injury accidents were reported nearly four times as reliably as non-injury accidents. They were also recalled twice as reliably. Accidents from which the interviewee's vehicle was towed from the scene were reported with a reliability nearly three times as great as for those not towed away. Reporting of property accidents was dependent on the amount of damage, but the greatest change was for damage greater than 500 dollars. Those with damage of less than 200 dollars, the legal reporting criteria, were reported with 22 percent reliability. Those which were legally reportable ($PD \geq \$200$) were reported with 46 percent reliability. Thus the legal criterion does not appear to provide a stratification as significant as does 500 dollars. The percentage of vehicles in each damage category that were towed from the scene is shown in Figure 3.

The significance levels obtained in the chi-square tests were: injury VS no injury, 8% on recall and less than 1% on reporting; towed VS not towed, 0.5% on reporting; property damage above $500 VS less than $500, 1% on reporting; property damage less than $200 VS more than $200, 9.9% on reporting.

The results on the question "was a police report taken at the scene?" deserve noting. One would not be surprised at the low counts under N_{RS} and $N_{R\bar{S}}$ for "no police report". The one case under N_{RS} would indicate no report was written to the knowledge of the victim, yet one did appear in the state records. Incidence of this occurrence would be low. The noteworthy result was that for only 50 percent of the accidents for which the survey response was yes (i.e. a report was written) could a report be found in state driver records. It cannot be determined whether a report was actually completed but not forwarded, or if the policeman was writing something other than a formal accident report.

The questionnaire used in the pilot survey, with the exception of Detroit, included the following information regarding accidents:

1) How many accidents since January 1969 (approximately 12 months)?
2) How many accidents in the previous three years?
3) For each of the three most severe accidents since January 1969, the month and year and whether a policeman wrote a report.

From this information values of N_S the total number of accidents in one year recalled in the survey, and N_R the total number in the state files for the interviewees could be determined readily for states that have computerized driver records with accidents listed. This would allow a trial of estimating underreporting using an estimated factor (K) for recall derived from the Michigan sample.

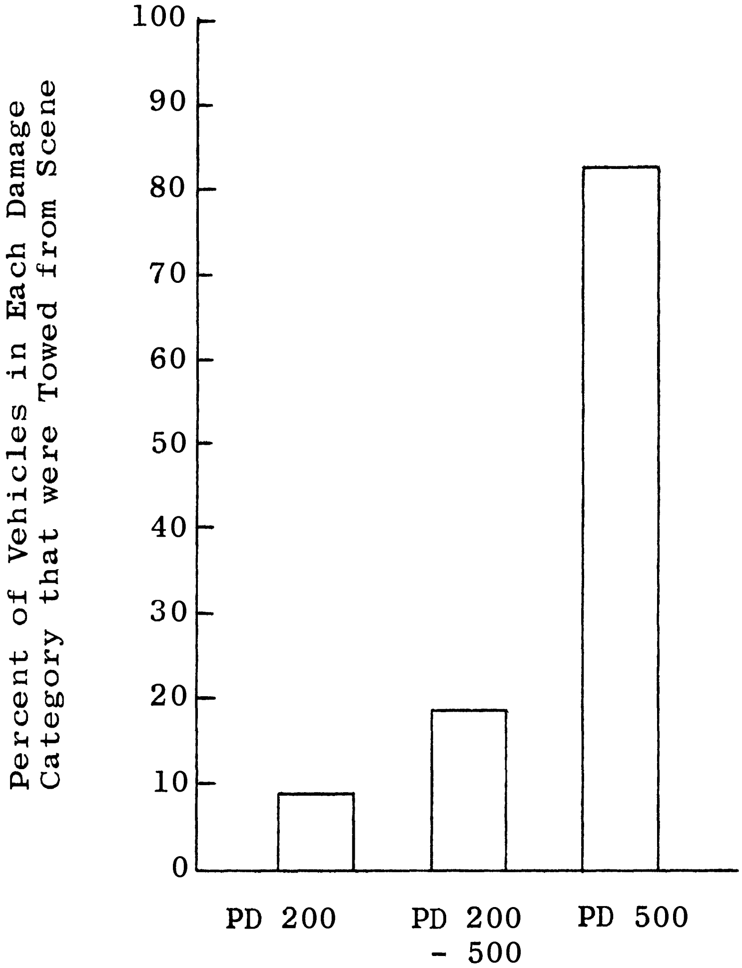


Figure 3

Tow Away by Property Damage,
Pilot Survey: Detroit SMSA

Four states were selected to represent rural and urban areas, and a range of state reporting criteria. The states selected were Colorado which requires notification of the police for all accidents with injury or any property damage, Massachusetts which requires a written financial responsibility report for injury or damage over 200 dollars but not immediate notification, South Carolina which requires immediate notification for injury and property damage over 100 dollars, and Virginia which requires notification for injury accidents only. Each of the four states was able to provide an accident summary from the driver records of individuals.

A summary of the number of interviews, number of accidents recalled, and the number found on the state drivers records of people who recalled an accident is shown in Table 5.

TABLE 5

ACCIDENT REPORTING, PILOT SURVEY: FOUR STATES

State	Number of Interviews	N_R (Accidents Reported)	N_S (Accidents Recalled)	P_R
Colorado	289	39	27	0.26
Massachusetts	518	3	48	----
South Carolina	82	1	5	----
Virginia	306	47	19	0.87

The computed reporting proportions (P_R) were obtained using as an estimation

$$P_R = \frac{N_R}{N_S} \cdot \frac{1}{(1+K)}$$

where the recall ratio was K = 1.83, the value obtained from the Washtenaw County and Detroit samples. Values of P_R are not shown for Massachusetts because the number of accidents included on the driver records was so low that one suspects not all reported accidents are entered on the record. The total sample in South Carolina was too small to warrant presenting an estimated P_R.

The results for Colorado and Virginia are the opposite of what we would expect in considering the state reporting requirements since all accidents with damage must be reported in Colorado. The computation or more precisely, the estimation, of P_R is sensitive to recall expressed either as K or P_R. The values obtained from the Michigan surveys are of limited precision because of the small samples, and do not warrant strict interpretation of the data shown in Table 5.

Before the estimation procedures suggested above are used in practice, a much more reliable estimate of the recall proportion must be obtained, and the stability of the estimate should be evaluated over several populations. Such an evaluation will only be feasible in areas which maintain accident record systems that permit computer processing for searching accident files and matching individual accidents with the survey data.

INJURY SEVERITY DATA

The two primary costs of accidents to society are economic loss including effects of disability, and suffering from personal injury. The term injury is used here in the medical or physiological sense, that is morbidity or mortality. While it is obvious that the economic loss as a consequence of property damage may be directly and tractably related to accident severity and damage, measurement of the consequence of injury is not so direct. On the other hand, categorizing an accident as fatal, injury, or property damage is not a satisfactory compromise. Many of the program and vehicle standards that have been introduced or are contemplated are addressed to not the elimination of accidents, but the reduction of injury, as well as property damage, and the consequence of injury. Klein and Waller suggest that our focus and priorities should be shifted "from the prevention and reduction of the number of crashes to the prevention or reduction of the human and economic losses that result from crashes"[7]. Thus the incidence and degree or severity of injury becomes a very important measure of the performance of our endeavors in highway safety.

Appropriate measures of injury severity might relate to the consequence of the injury and the attendant loss. Thus we might consider such factors as period of disability, length of hospitalization which might correlate well with both disability and economic loss, and degree of permanent disability. All of these are factors which have been considered as appropriate severity measures. Presently, however, we are unable to divorce such "ultimate measures" from the effects of treatment and extended care, and relate them to the physical accident descriptors or to particular countermeasures. Furthermore such factors can not now be assigned in on-the-scene accident investigations. Therefore we have traditionaly used measures of injury which are more directly related to accident physics and suitable for field use.

Non fatal injury accidents are identified in mass accident data by use of an injury code. The accident reports of all but seven states employ the code published by the National Safety Council.[8] The code was devised to permit rapid evaluation by police officers in the field. Each person involved in an accident which is investigated by the police is assigned one of the following five codes:

K = Fatal
A = Visible signs of injury, as bleeding wound or distorted member, or had to be carried from scene.
B = Other signs of injury, as bruises, abrasions, swelling.
C = No visible injury but complaint of pain or momentary unconsciousness.
O = No indication of injury.

The classifications are listed above just as they are frequently stated on accident report forms.

While the above code permits rapid evaluation under adverse circumstances and with minimal examination of the victim, it does not provide a reliable scale of the severity of injury. Obviously many injuries in the A category are minor, such as superficial lacerations accompanied by moderate but easily controlled bleeding. Conversely, the C category could include severe and potentially life-threatening internal injuries such as a ruptured spleen.

The code used by police will be referred to as the police code without implication of origin or disapprobation. Although the code does not serve any of the possible functions of an injury severity scale per se, there exists the possibility of calibrating the code against a more suitable scale. Clearly a calibration could be valid only in a statistical sense. Nevertheless, the principle advantage of mass data as represented by the police code is the capability for statistical inference. Calibration of the code would thus be valuable even though meaningless on an individual basis.

A pilot calibration was conducted by assigning an injury severity index to accident victims on the basis of hospital records and comparing the result with the police code assigned at the time of the accident.

Accident reports were available from Washtenaw County, Michigan for the period 1966 through 1970. This set includes data on over 19,000 accidents. In addition to the police injury code on each person involved in the crash, the report indicates the hospital to which the injured were taken, although not on an individual basis. A list of 1069 victims who were possibly conveyed to St. Joseph Mercy Hospital in 1968 and 1969 was compiled and checked against both the inpatient and emergency room hospital records. Records were found for 545 of the victims including 5 fatalities. The remaining 524 victims, while in an accident from which someone was conveyed to the hospital, did not seek medical care at St. Joseph. Senior medical students reviewed the hospital records of each patient and assigned the appropriate injury code.

Selection of an injury scale for use in the evaluation was based on requirements that the scale: (1) assess the severity of injury and the condition of the patient immediately following injury and not include measures of the treatment given or the response to treatment, (2) include effects of impact that might be evident only with diagnostic aids such as radiology, and (3) must be based on the information normally provided by medical records. A suitable scale is provided by the American Medical Association's Abbreviated Injury Scale (AIS) established by an Ad Hoc Committee on Vehicle and Injury Scaling.[9] The AIS, which was based on scales developed by the Cornell ACIR project and General Motors, now enjoys widespread use by accident investigation projects sponsored by the Automotive Manufacturers Association and the National Highway Traffic Safety Administration.

The AIS classifies each individual in the general categories of 1 - Minor, 2 - Moderate, 3 - Severe (not life-threatening), 4 - Severe (life-threatening, survival probable), 5 - Critical (survival uncertain), and four categories of fatal injuries. In addition to rating each injury individually, the overall effect of multiple injuries may be rated. The AIS does not explicitly provide for multiple injuries which may be additive in their physiological effects, hence some subjective judgement is necessary in categorizing these cases.

The version of the AIS used in examining the relation between typical use of the police code and injury severity is given in Appendix L. Although most publications of the scale imply equivalent police codes they were purposefully omitted here since an inference of correspondence is not justified by definition or current police usage. An overall AIS code was assigned to each patient for whom hospital records could be found. The information necessary to assign the four fatal AIS codes is normally not provided by medical records unless an autopsy report is available. Since this project was primarily concerned with non-fatal accidents, all fatalities were included in a single code. In addition, the disposition of each was recorded as (1) treated in emergency room and released or (2) admitted or (3) transferred to another hospital. If the patient was admitted, the number of days in the hospital was recorded.

The recorders were also instructed to assign a police code for each patient, based on the evidence of injury that would, in the judgement of the reviewer, have been available to law enforcement officers at the scene. The objective of recording the police codes was to attempt an examination of the reliability with which the codes were originally assigned. However, the reviewers were generally not able to retrospectively apply the police scale using medical record data.

Comparison of Distribution of Abbreviated Injury Scale and Police Codes

The distribution of the police codes (as assigned at the scene of the crash) and the AIS for the 540 non-fatal victims for whom medical records were found is shown in Figure 4. The distributions are given in columnar percent with the total number of victims by row and column along the side and across the top. The data of Figure 4 include both patients admitted and those treated and released in the emergency suite. The more striking feature of the data is the small percentage of victims with the more serious (higher) AIS codes. The mean AIS code for each police code is given in Table 6.

Table 6

Mean AIS code by Police Code

Police Code	Mean AIS Code	Number
A	1.56	302
B	1.12	134
C	1.06	86
O	0.947	18

Thus only a small fraction of A injuries are found in the higher AIS codes, indicating that most A injuries are of only minor or moderate severity. This is not unexpected or inconsistent with the definition of A injuries. Conversely, we might expect some incidence of internal injuries which might be "Severe" on the AIS scale, such as abdominal organ damage, which might be classed as "complaint of pain" (C) at the scene. There were no such cases among the 540 victims studied. The absence of such an occurrence might be explained by a combination of low incidence and

AIS Code	A	B	C	O	(count)
(count)	302	134	86	18	
0	1.0	2.2	8.1	22.2	17
1	62.3	87.3	82.6	72.2	389
2	21.2	7.5	4.7	5.6	79
3	11.4	2.2	4.7	0.0	43
4	2.3	0.7	0.0	0.0	8
5	1.3	0.0	0.0	0.0	4
Total	100.0	100.0	100.0	100.0	

Police Injury Code

Figure 4

Distribution of AIS Codes of Hospital Patients by Police Injury Code limited sample size, or by the gross characteristics of injury processes. Serious internal injuries resulting from blunt trauma require large forces. While such forces are potentially available from the high energy expended in collisions, they may also result in epidermal or skeletal injury. Thus the internal injuries may frequently be accompanied by visible injury, and the victim coded as an "A" casualty.

The possibility of the severe internal injury without significant visible injury was examined using the records of investigations of serious crashes involving 1036 injured victims (victims of crashes investigated by D. Huelke of HSRI, The University of Michigan, or A. Siegel of the Trauma Research Group, UCLA). Only two victims suffered severe internal injuries without accompanying injury likely to result in an A code. This would lend credence to the inference that severe or serious injuries would not be likely among the B and C populations.

Figure 4 indicates that eighteen victims who were listed as uninjured in official accident reports were examined in the hospital and fourteen of these were injured. This might lead one to suspect an underreporting of injury accidents, i.e. injury accidents reported as property damage crashes. Such a conclusion is unwarranted however. In each of the above cases, the victim originally reported as uninjured accompanied a more severely injured victim to the hospital. In only one case were the unreported injuries of a "moderate" level on the AIS.

Figure 4 may be used to estimate the proportion of each police code that corresponds to particular levels of the AIS. Questions of particular interest are what proportion of the victims suffered significant injury (codes 2 on the AIS), and what proportion suffered severe or more serious injury (codes 3). These proportions are shown in percentages for each police code in Figure 5 along with the 95% confidence intervals. Only 15.5% of the

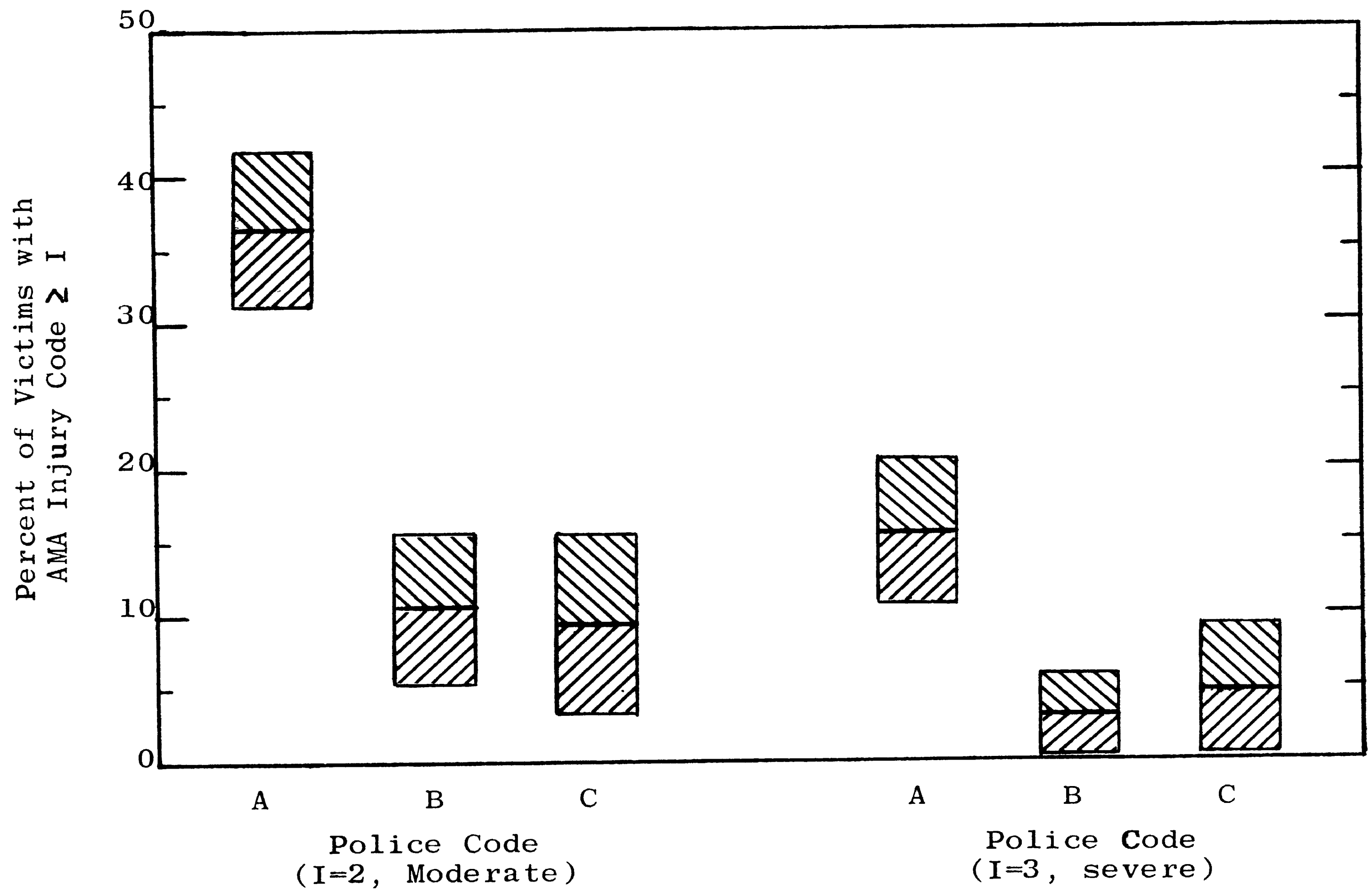


Figure 5

Proportion of Hospital Patients with
Significant Injury, by Police Code

A victims, and less than 5% of the B and C victims seen in the hospital were injured severely.

The data discussed above is based on crash victims examined or treated at St. Joseph Mercy Hospital. St. Joseph is only one of several hospitals to which victims of crashes in Washtenaw County are conveyed. Furthermore, the data do not include victims who were not treated or who did not seek medical assistance. Thus two sources of bias are possible in the data presented in Figures 4 and 5. First, The University Medical Center receives many accident victims, and one might suspect many of the more critical patients might be taken there. Second, not all accident victims coded A through C are taken to a hospital. These factors will be discussed in succeeding paragraphs.

The number of individual victims taken to each medical facility in the county is not available. However, an estimate may be obtained by examining the injury codes and the disposition of victims for each accident. Table 7 gives the police injury code of all occupants of the vehicles involved in crashes and the hospital or disposition of victims of each crash. The disposition is by crash and not by individual. The table contains data on 51,399 victims of 19,668 crashes in Washtenaw County from 1965 through 1969. Of the A, B, and C victims in the county, 32.7% were in crashes from which the injured were taken to St. Joseph and the equivalent figure for the University hospital was 18.3%. The other hospitals and clinics are associated with much smaller percentages of the victims listed in Table 7.

The distribution of the police codes among the hospitals was examined using chi squared tests of contingency tables. When codes A-O were compared for St. Joseph and University hospitals, the hypothesis that the distributions were the same was rejected at the 0.1% level. However, the major contributors to the high

Table 7

Distribution of Police Codes
by Hospital on Accident Reports

	Refused Treatment	Univ. of Michigan	Veterans	St. Joseph	St. Pauls	Saline	Beyer	Ypsilanti Med. Center	Private Physician	Missing Data	Total
K	4	75	0	41	0	1	2	2	4	16	145
A	228	1001	9	1743	1	39	244	32	135	224	3656
B	684	485	1	918	2	34	144	25	348	349	2990
C	1325	506	5	893	1	31	148	26	596	701	4232
O	3136	1599	10	2422	1	62	317	58	1234	31537	40376
Total	5377	3666	25	6017	5	167	855	143	2317	32827	51399

chi-square were a higher incidence of B's and a lower incidence of O's at St. Joseph with a nearly expected incidence of A's at each. When a table was constructed using only codes A-C, the difference was not significant at the 40% level. A similar result was obtained when a 2 by 2 table was used to compare the A's with B's plus C's at the two hospitals. These observations would tend to refute the hypothesis that the choice between hospitals was made on the basis of severity of non-fatals.

The distribution of codes between St. Joseph and all other hospitals (grouped) was also tested using contingency tables. When codes A-O were tested, the result was significant at the 8% level, because at St. Joseph the incidence of A's was high and O's low. When only codes A through C (injured) were used, the significance level was 60%.

These results would suggest that on a county wide basis, any bias in the severity of patients at St. Joseph is in the direction of greater severity. Thus incidence of significant or severe injury among the officially reported injury codes (police) would be similar to, or less than, the estimates based on victims taken to St. Joseph.

Estimating Injury Severity from Police Codes

The distribution of injuries given in Figures 4 and 5 are for those victims examined in the emergency room of St. Joseph. Not all victims in a crash for which the accident report listed a hospital actually sought medical care. Furthermore, not all accident reports list a hospital. If we make certain reasonable assumptions, however, we may extrapolate or expand the data available at St. Joseph to the entire county crash population. We shall assume that: 1) victims of crashes which did not have a hospital or other source of medical care listed on the accident report did not sustain injuries of consequence, and 2) those occupants or victims which were in a crash from which injured were taken to a medical facility but were not themselves examined or treated did not sustain injuries of consequence. The data collected at St. Joseph will be considered a representative sample of victims and injuries of crashes for which a medical facility was listed in the official report. The data discussed in the previous section suggests that any bias in the sample from St. Joseph would lead to a pessimistic result, that is, an over-estimate of the incidence of serious injury.

Using the notation $P_p(I|E)$ for the estimated conditional probability that a victim with an injury of police code p is actually of severity I on the AIS given the occurrance of event E, the probability of the AIS code can be expressed as

$$P_p(I) = P_p(I|E)\ P_p(E|H)P_p(H)$$

where E denotes the victim was examined in a medical facility and H denotes that a medical facility was listed on the accident report. Thus $P_p(I)$ is the estimated proportion of all police codes p with an AIS code of I.

Estimates using data from the Washtenaw County accident reports and the St. Joseph sample are given in Tables 8 and 9 by each police injury code and for codes A, B, C together. This latter group represents the number of "injured" reported for motor traffic accidents by individual states. Thus Table 8 indicates that of all victims coded A, B, or C, 68% were included in accident reports which listed a medical facility to which someone in the accident was taken for examination or treatment. This is the probability a facility was listed given the person was in an accident $P_p(H)$. The probability that a particular name from reports listing a hospital will be found in medical records indicating the victim sought medical assistance,

TABLE 8

Factors in the Expansion of St. Joseph Injury Data to Injury Estimates for Washtenaw County

Estimated Proportions	Police Injury Code A	B	C	O	A+B+C
1. Victims on Reports with Hospital listed $P(H)$	0.876	0.655	0.521	0.141	0.677
95% Confidence Interval	± 0.010	± 0.017	± 0.015	± 0.003	± 0.009
2. Victims Found in Hospital Records $P(E/H)$	0.834	0.644	0.573	0.053	0.725
95% Confidence Interval	± 0.039	± 0.067	± 0.081	± 0.024	± 0.033
3. Victims who seek Medical Care $P(E)=P(E/H)\,P(H)$	0.731	0.422	0.299	0.0074	0.491
95% Confidence Interval	± 0.036	± 0.045	± 0.043	± 0.003	± 0.023
4. Proportion of Hospital Patients with AIS code > 2 $P(I \geq 2/\overline{E})$	0.365	0.105	0.093	0.056	0.253
95% Confidence Interval	± 0.054	± 0.052	± 0.061	-----	± 0.037
5. Proportion of Hospital Patients with AIS code > 3 $P(I \geq 3/\overline{E})$	0.156	0.030	0.047	0	0.105
95% Confidence Interval	± 0.048	± 0.029	± 0.045	-----	± 0.026

TABLE 9

Estimated Incidence of Significant Injury
Among All Persons Involved in Accidents
in Washtenaw County

Injury Severity	Police Injury Codes A	B	C	O	A+B+C
1. Estimated Incidence of AIS codes $\geq$ 2 (Moderate or greater)	0.267	0.044	0.028	0.0004	0.124
95% Confidence Interval	$\pm$0.043	$\pm$0.023	$\pm$0.020	------	0.021
2. Estimated Incidence of AIS codes $\geq$ 3 (Severe or greater)	0.114	0.013	0.014	0	0.052
95% Confidence Interval	$\pm$0.031	$\pm$0.012	0.014	------	0.014

is $P(E \mid H)$ and is given in item 2 of the table. This data was based on the search for names of victims among the hospital records at St. Joseph. Item 3 gives the estimated fraction of occupants included in accident reports who sought medical aid. The proportion of hospital patients with AIS codes $\geq$ 2 (moderate injury) and $\geq$ 3 (severe injury) are given in items 4 and 5. These proportions are the results which are shown in Figure 5. The products of item 3 and items 4 and 5 are the estimated proportions of accident victims with injury severity greater than the indicated AIS code-P_p $(I \geq 2)$ and P_p $(I \geq 3)$-and are given in Table 9.

It should be again stated that the non-zero proportion for police code O does not indicate an underreporting of injury accidents. Therefore, the codes A, B, and C have been grouped in the last column. This last result indicates the incidence of significant injury among the victims reported in the "injury" category on police accident summaries.

The 95% confidence intervals listed for items 1, 2, 4, and 5 of Table 8 were computed using traditional methods of estimating proportions. Specifically, the distribution of the observed frequency of successes from a binomial distribution was assumed to be asymptotically normal for samples with expected frequencies greater than 5.[10] Thus the 95% confidence interval is given by

$$C.I. \cong Z_\alpha \left[\frac{P\,(1-P)}{n}\right]^{\frac{1}{2}}$$

where $Z = 1.96$ for the 95% confidence interval. The confidence intervals for item 3 of Table 8 and the result in Table 9 were computed by deriving the variance of $P(A)$ where

$$P(A) = P(A \mid B)\, P(B)$$

and assuming the resulting distribution, which is also a bivariate, is asymptotically normal. When this technique was used to compute the confidence intervals for Table 9, it was assumed that the distribution of P (E) would be determined by the size of sample used to estimate P (E|H) since this sample was much smaller than that of P (H).

The more significant findings of this examination of injury severity are the low incidence of moderate or greater injury among the police codes, including the A victims; and the failure of the police scale to categorize severity except among the minor injuries. No severe injuries were found in the B and C cases, while only 13.5% of the A victims apparently sustain moderate injuries on the AIS, and only 11.4% are injured with a severity of "severe" or greater.

Stability of Officially Reported Injury Data

The discussion of the previous section provides an evaluation and calibration of the injury data provided on official accident reports of jurisdictions which use the classifications recommended by the National Safety Council.[8] Forty states use the "police" injury code on accident report forms, but approximate annual vehicle miles in these is 89 percent of the annual mileage of the United States.[11] The jurisdictions which do not use the classification are Alabama, Delaware, D.C., Georgia, Nevada, Missouri, New Hampshire, North Dakota, Rhode Island, Virginia, West Virginia. The reporting forms of these ten states and the District of Columbia require indication of injury. Several of these states interpret and report the injury incidence in terms which are related to the police code by categorizing them as "severe", "moderate", or "slight". These terms are frequently common interpretations of the police codes, A, B, and C respectively. However, in this usage, i.e., with regard to police codes, the terms should not be confused with the AIS codes. Tables 8 and 9 indicate the error that arises from assuming all A injuries are severe.

Since the police code enjoys widespread use for reporting the physiologic consequence of accident experience, calibration of the scale is attractive, and a pilot calibration of limited scale has been discussed. The expansion of any such result to a much wider accident population is dependent upon the stability of the measurement and reporting process as well as the sample used.

Nearly all states report annual summaries of injuries in motor vehicle traffic accidents by the police code; more states publish such a summary than the number that use the code on state accident report forms. A sample of the distribution of the police codes for 17 states is shown in Figure 6. The striking non-uniformity of the distributions is immediately evident. The relative incidence of A injuries of the states varies from approximately 13% of the reported injuries for Iowa and Oklahoma to 65% for Virginia or a ratio of five to one. Trends in the distributions are shown in Figure 7.

The wide variation among states likely is the result of several factors. These include differences in the behavioral traits of drivers, vehicles in use, environmental factors and application of the injury scale. Those states with large urban populations might be expected to have a higher relative incidence of low speed crashes than the largely rural sparcely populated areas, and hence a greater incidence of minor injury. The variation of the C level would be sensitive to the threshold of superficial lesion or complaint at which a victim enters the injury classes. This threshold is related both to the interpretation of the code and criteria for reporting accidents.

Differences in the threshold for C injuries would not affect the ratio between A and B, although both would be proportionately displaced. Thus the differences among the initial slopes of the data in Figure 6 would not be explained by differences in the inclusion of minor injury. We may also note that the ratio of rel-

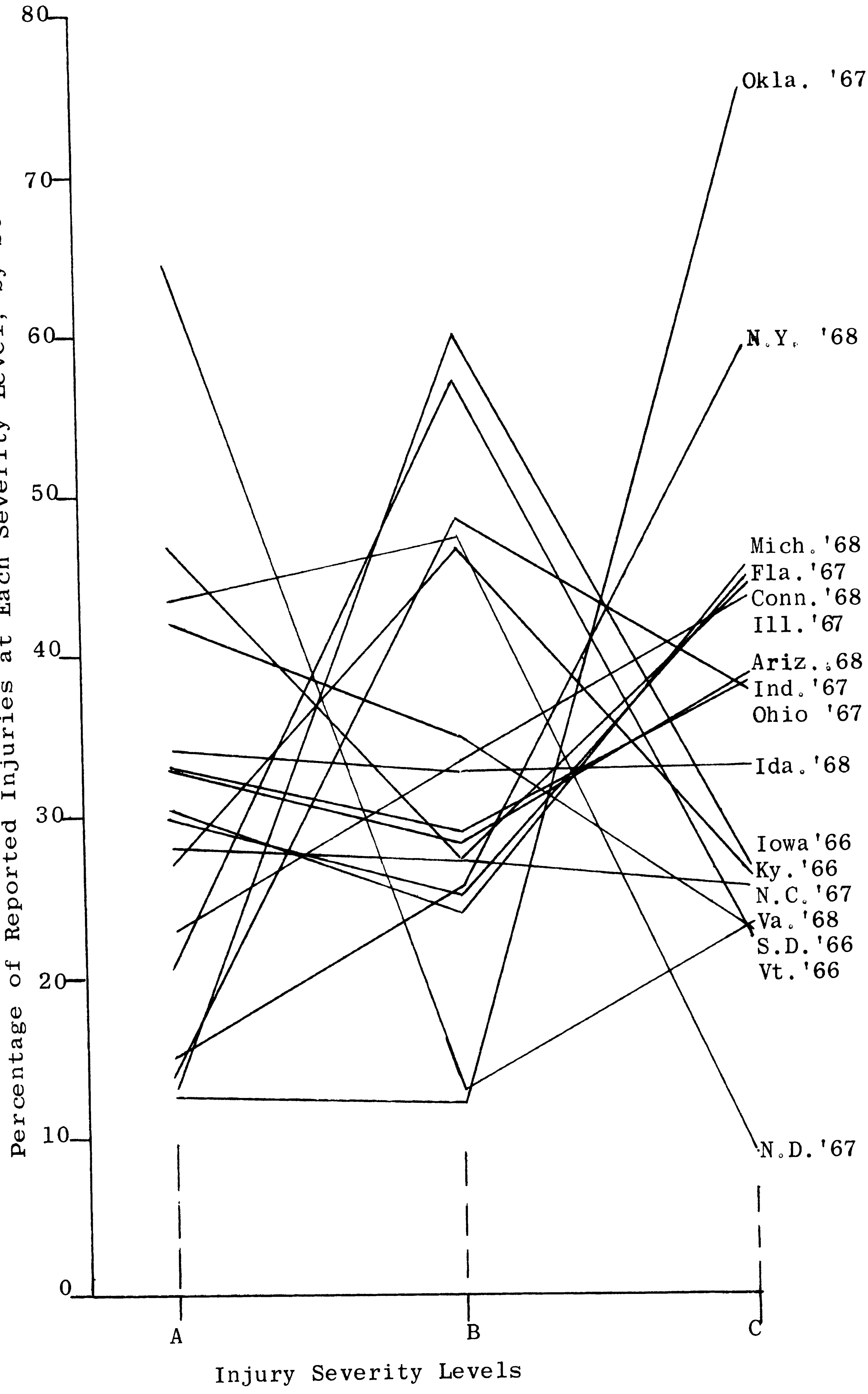


Figure 6 **Distribution of Injury-Severity Reporting** Among States

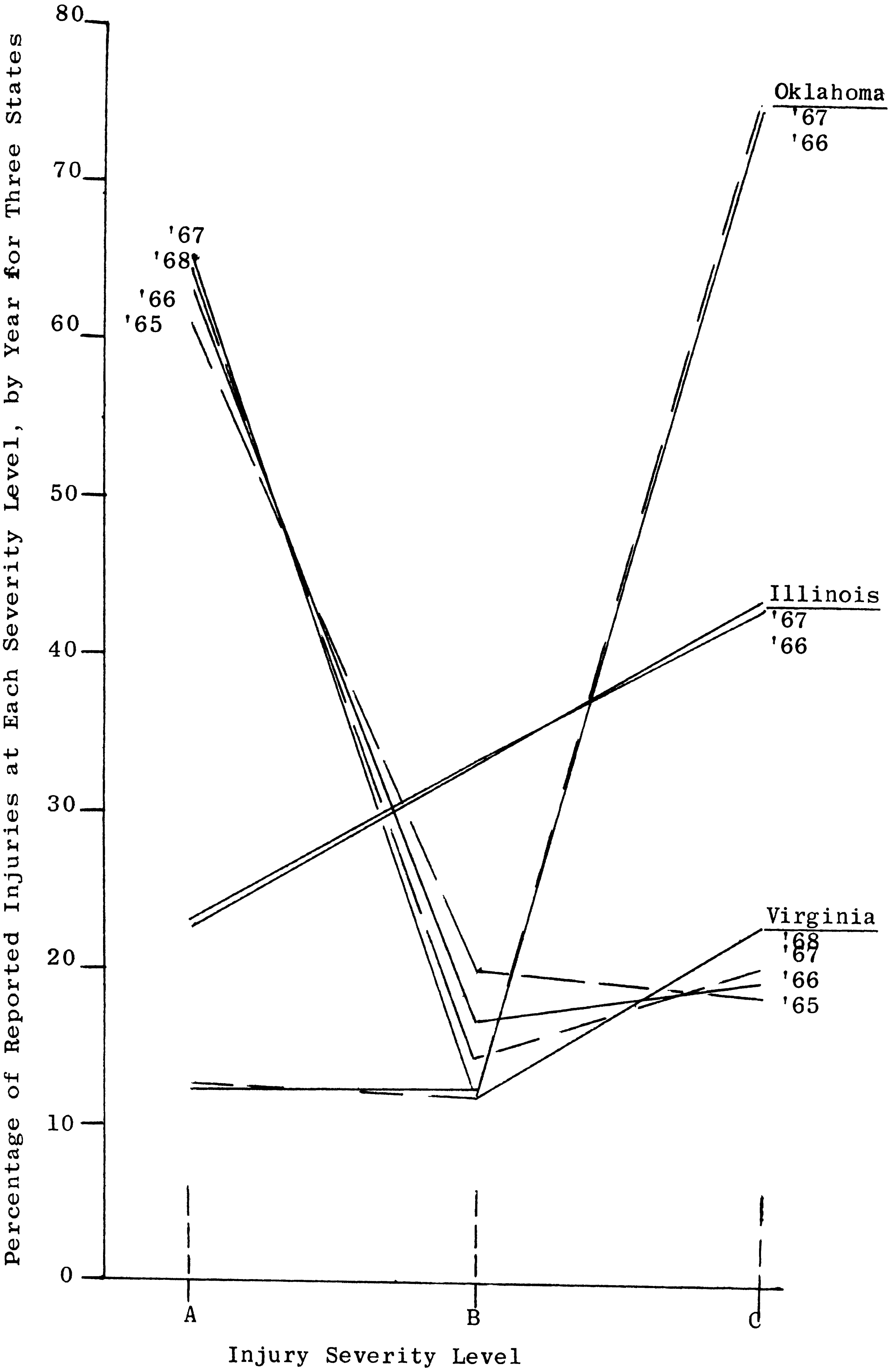


Figure 7
Trends in Injury-Severity Reporting Distributions

ative A to B incidence is low in Iowa and Vermont which are both rural states, near unity in Idaho, Oklahoma, and New York, and less than unity in Virginia and Connecticut. Thus the variations are not consistent with the degree of urbanization. These observations suggest that much of the variation must be attributed to non-uniformity of scale interpretation and use.

The data presented in Figures 6 and 7 are aggregates for entire states. Variability or lack of uniformity exists also within states and at local levels. Figure 8 illustrates the lack of uniformity among eight heavily populated counties of Michigan using coordinate scales identical to those of Figures 6 and 7. Wayne County which has the lowest ratio of A to B cases, contains the City of Detroit and has a population of 2.6 million. Genesee County has the highest ratio of A's to C's and contains Flint, the third largest city of Michigan. All eight counties contain sections of interstate highways. Thus the effects of urbanization factors are not clear. Nevertheless, the ratio of the relative frequency of A codes among the eight is 1.7.

The variability of Figure 8 occurs in spite of uniform accident forms and a single state accident reporting law. The motor vehicle statutes of the State of Michigan require that all accidents be reported to the police immediately and a standard official report submitted, for all accidents resulting in death or injury to any person or total damage to all property of an apparent extent of two hundred dollars or more. Such a law does not assure uniform local reporting procedures.

The variability in injury classification may be related in part to variation in the training of police officers. The legislature of the State of Michigan has established a "Law Enforcement Training Council" which for the present serves as an advisory function. The council has established a recommended

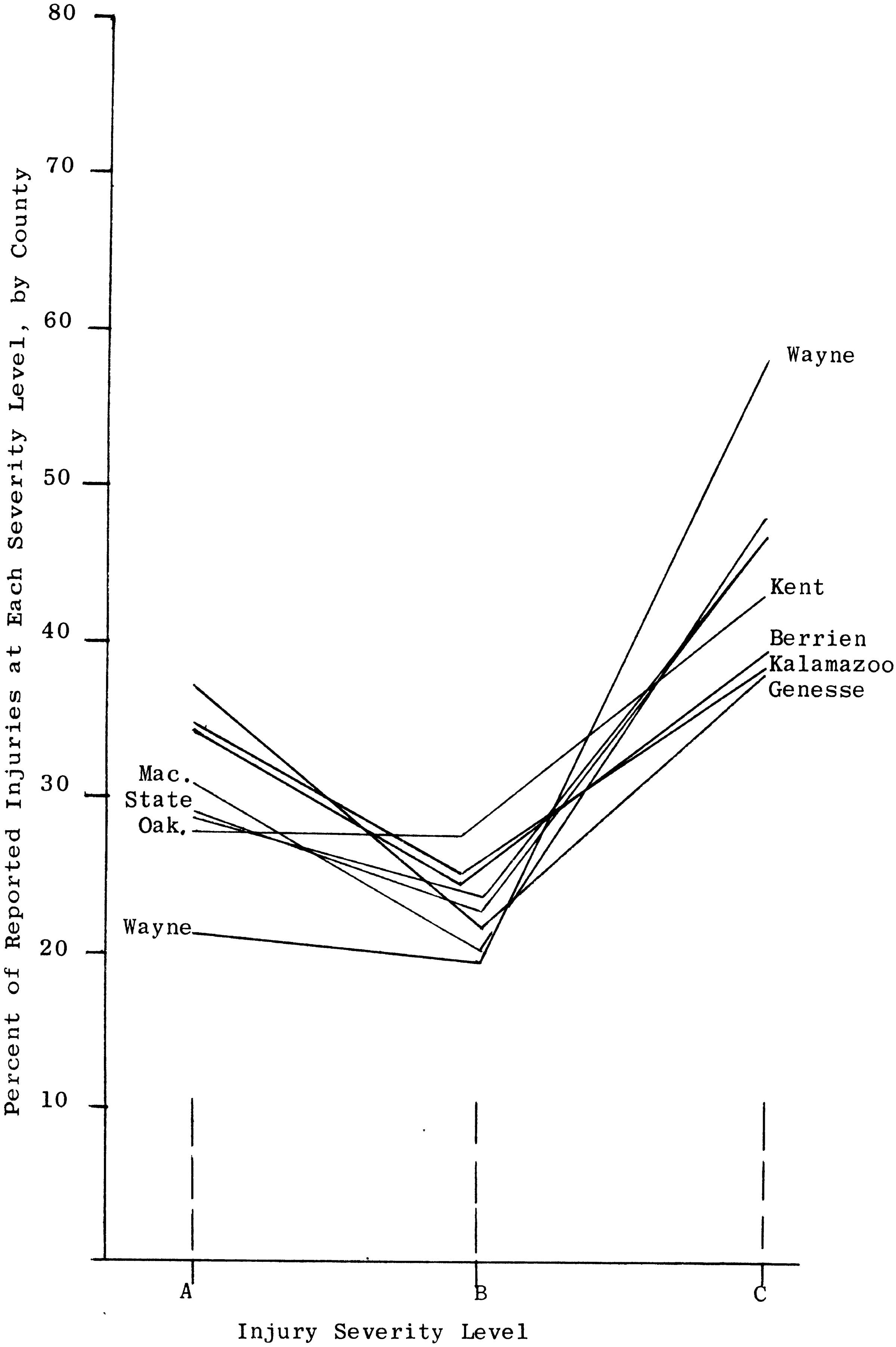


Figure 8 Distribution of Injury
Severity Reporting Among Eight Counties of Michigan

mimimum training program for police officers and it certifies academies which meet the minimum standards. Twenty four academies are operated in Michigan which have been certified by the Council. A questionnaire was sent to each academy to determine differences in education and training with regard to the use of the Michigan Official Accident Report Form. The following questions were included:

(1) In your school or academy approximately how many hours of instruction, if any, are devoted to the use and interpretation of the Michigan Official Traffic Accident Report Form.

(2) Please indicate, by check-mark, any instructional methods used in relation to explanation of the Michigan Official Traffic Accident Report Form.

Lecture ( ) Audio and/or Visual Aids ( )
Discussion ( ) Please Explain:
Supervised On-the-Road Training ( )
Booklet ( ) Title:
Other:

(3) We feel that the Michigan Official Traffic Accident Report Form is self-explanatory and do not devote time to its interpretation. ( )

Twenty two of the academies returned the questionnaire with specific responses. A summary of the responses is given in Table 10. The time and aids devoted to accident investigation and the use of the state accident report are varied. Only six of the twenty two responding academies use the official manual on the state report form for instructional purposes, and less than half use field exercises or training outside the classroom. The time devoted to the subject is equally varied. Four academies devote less than half a day to accident investigation, while only six spend more than the equivalent of one full day to the subject. It is not surprising that reporting procedures are not uniform if the survey of

TABLE 10

SURVEY OF ACCIDENT INVESTIGATION TRAINING OF

TWENTY-FOUR MICHIGAN POLICE ACADEMIES

1. Instruction Methods and Aids Used	Number
Lecture	21
Discussion	21
Supervised on-the-road training	6
Booklet	10
Audio and/or visual aids	7
Use of Michigan State Police Manual*	6
Other: Practical exercise	3
Guest lectures	1

2. Hours of Instruction on Use of Accident Report Form

Hours	Number
0	1
1	2
3	1
4	8
5-7	4
8-10	4
16	2

* Instructions for completing State of Michigan Official Traffic Accident Report, Michigan State Police, February 1966.

academies reflects an actual variation in the training of police officers in the state.

The discussion of injury reporting presented here has been directed to the information provided by the police injury code and inferences that may be drawn from injury statistics based on the code. While this project was in progress, the Traffic Accident Data Project Steering Committee of the National Safety Council's Traffic Conference published a new injury classification scale.[12] The new injury classifications are given in Appendix M. While the new classification has the same number of levels and is similar to the code now in use, there are also significant differences. On the new scale, the most severe non-fatal category is defined only in terms of impairment. This is an improvement over the previous scale and should result in fewer minor injuries being coded in the most severe level. If the new scale receives widespread introduction, both the validity of the severe code and the uniformity of use among agencies should improve.

SECTION 4

CORRECTIONS FOR ACCIDENT DATA INACCURACIES

SOURCES OF INACCURACY

General categories of errors in mass accident data compiled from state files of police accident reports were discussed in Section 3. The two most significant sources were categorized as 1) bias resulting from underreporting, and 2) errors in recording of information on individual reports and in data processing.

Underreporting is a particularly significant problem because a large portion of property damage accidents are not reported in accordance with the statutory criteria of individual states. Furthermore, the criteria of the states are not uniform. The underreporting bias has two facets. First, an analyst cannot assume the unknown data represent a target accident population of low severity without accepting the consequences of large non-observation. Secondly, he may not restrict his interest to accidents with severity sufficiently high to restrict underreporting without accepting bias from the inclusion of low severity accidents. The Michigan sample demonstrated that accidents which are not legally reportable are often included in the official files. The latter bias, inclusion of low severity accidents, was also noted in the California study by Smith,[2] and in Mississippi as reported by McGuire and Kersh.[4] Indeed, reporting is not closely related to legal criteria. Criteria which are based on total dollar damage are difficult to assess at the scene. A damaging accident is a rare occurrence to most drivers involved in crashes. Aside from problems of inflation the average victim does not have the experience necessary to reliably estimate the costs of structural repair. While the injury criteria would seem less nebulous, it is not without problems. Many if not most of the C injuries are very minor or superficial. While the definition of this category may appear ambiguous, the victims who must take the first action for reporting are not aware of the code, and the injury criteria is not defined in reporting statutes. Minor injury crashes are subject to uncertainties and variations in individual perception and response to discomfort that also lead to non-uniform reporting.

A significant bias has been shown in traditional interpretations of the police injury code as an indicator of injury severity quite apart from the uncertain threshold of injury discussed in the preceding paragraph. While the pilot calibration of the police code against the Abbreviated Injury Scale indicated some variable error, bias errors were much more significant because normal interpretation of the higher police codes, excluding fatals, leads to considerable overestimation of severe injury.

The data on state accident reports is subject to errors which may produce both random and systematic (bias) error in the analysis of records. Objective information such as sex, age, time of accident, type and make of vehicle, type of collision, etc., may be recorded incorrectly. Such errors will tend to have predominantly variable components with relatively small biases. Subjective data however, such as speed before collision and at impact, previous action of drivers, and particularly information about vehicle paths, all involve judgement which decreases the reliability of the data and hence increases the variability of error. Significant biases can also be introduced if local tradition or policy affects the recording practices in the event of uncertainty.

The reasons for both underreporting and observational error are complex. The reporting of an accident, i.e., inclusion of a report in state files, is not closely related to reporting or notification statutes. The regulations and practices of state and local law enforcement agencies vary widely and do not necessarily reflect statutory requirements. Furthermore, the police usually must depend upon citizens to notify them of an accident. Notification by the public or those involved is also highly variable. Even if victims of a crash know of the legal requirements, they may be influenced by many other considerations. If police officers and victims attempt to follow literal interpretations of statutes, variation and uncertainties in reporting thresholds will still result because estimates of property damage values must be made without experience, and interpretation of injury is variable.

Observational errors on original reports--errors in recording data correctly--while within the province of the investigating and recording officers, are likewise complex. Many of the errors result from pressures and conflicts at the scene of the crash. The officers present may, with some justification, feel that priorities for directing traffic and caring for the injured conflict with conscientious investigation and recording. These factors along with adverse environmental conditions may lead to error, even to associating people with the incorrect vehicle, error in vehicle description, etc. These errors are compounded by not infrequent lack of motivation and understanding of the accident reporting function. Interviews with several officers indicate that many do not understand the principles of accident investigation, and equally if not more significant, do not know why accident data is collected nor how the information is used outside their own immediate jurisdiction. This is not to be interpreted as a condemnation of traffic officers, since the phenomena should not be unexpected in view of historical lack of uniformity in the utilization of accident data. Researchers have a tendency to assume that accident reports have been collected for the purpose of providing them with a reliable source of data upon which they may exercise sophisticated and powerful analytical tools. The concepts of statistical inference are not universally understood by the officer in the field. His experience and knowledge of the use of official reports may not extend beyond the courtroom, and criminal and civil proceedings, or administrative control of local enforcement programs. The wide variation in the local practices for investigation and reporting of accidents, and the use of the information, have been noted in other stüdies.[13, 14]

IMPROVEMENT OF MASS ACCIDENT DATA

The errors included on police accident reports and the inaccuracies in the results of analysis of state files of accident reports can be reduced by changes in the procedures of collecting and processing the data. Several recommendations for improving the quality of data will be discussed. Some, if not all of the recommendations have been offered by other authors.[13,14] These recommendations do not quantitatively identify errors nor provide explicity correction factors. Their implementation, however, would lead to improved quality of data with errors of less variability and bias, and more explicit definition of "survey" populations.

1. Standardization and simplification of reporting criteria.

The reporting criteria presently used by states present problems of both non-uniformity and difficulty of enforcement. Furthermore, using property damage in dollars results in a criterion that is difficult to apply at the scene of a crash. Several investigators have suggested using tow-away or vehicle immobilization as a property damage criteria, and we endorse this recommendation.[14] The two primary advantages of such a criterion are uniformity and ease of enforcement.

This criterion is not without problems however. Immobilization-- or a requirement for towing assistance --is not a unique measure of either the energy dissipated in a crash or the physical damage to the vehicles, thus it is not a unique measure of accident severity. Immobilization may be caused by the environment and not by damage. We may not wish to include as a reportable accident for example, those events which result in a vehicle leaving the road without damage or injury, but becoming "stuck" and unable to reenter the roadway without assistance. Even if this problem is avoided by careful legislation, the problem of severe damage without immobilization remains. Accident investigators in Washtenaw County have noted several accidents of considerable damage, but from which the vehicles were or could have been driven. These have included a car with 14 inches of crush in the side and a rollover, neither of which was an injury accident. On the other hand, a relatively mild crash may damage a radiator, deflect sheet metal into a tire, rendering the vehicle inoperable. Furthermore the incidence of disabling damage may change significantly with the introduction of anticipated countermeasures and vehicle standards such as an energy absorbing bumper. A successful countermeasure intended to reduce repair costs may thus be manifest in the accident data as a reduction in the number of accidents.

Jurisdictions which have reporting requirements higher than recommended by the Uniform Vehicle Code (e.g. California), or which do not strictly follow state statutes for operational reasons (e.g. the city of Detroit), may wish to avoid problems associated with the investigation and processing of large numbers of minor accidents. Adoption of an immobilization criteria would be responsive to these regional or local problems without introducing non-uniformity.

Two accident files were examined to provide some insight into the effect of a rigorously enforced tow-away criteria. One is a file of all reported 1969 accidents in Denver and the surrounding four counties which contained records of over 44,000 accidents.

Non-injury accidents comprise 78 percent of the cases in the file. One or more vehicles was towed from the scene of 29 percent of the non-injury accidents. Similar data on 29,000 accidents in Oakland County, Michigan in 1969 indicate that 28 percent of the non-injury accidents involved a tow-away. While it is possible that some tow-away cases are not represented in either file, these results indicate that the number of property damage accidents in state files might be reduced to approximately one quarter of their present number if such a criteria were used. It is interesting to note that the two figures above are nearly equal even though the respective reporting criteria are quite different.

2. Simplification of accident report forms.

The quality of data collected could be improved by reducing the number of information items required on each report form. Alternative forms, based on careful consideration, which are simpler than typical forms used presently have been suggested by several studies. Notable among these is the form recommended by Blumenthal and Wuerdeman.[14] Using simpler forms including fewer subjective items but concentrating on objective data will improve quality considerably. The information which is collected should serve the requirements of the National Accident Summary File maintained by the National Highway Traffic Safety Administration. A list of the data included in the summary file is given in Table 11. The data need not be taken in the form and strata of Table 11, but the summary data must be derivable from the report forms. The data collected should also provide the elements from the report forms. The data collected should also provide the elements that were found to be useful in describing unique exposure groups in the exposure study of Volume I. In addition to several of the elements of Table 11, these exposure-predicting variables include the vehicle age (greater or less than 5 years) and type of road (streets or other).

Table 11

Data Elements of the
National Accident Summary File

Element Number	Data Element	Group	Group Codes
1	Accident Type and Location	Single Vehicle-rural	(1)
		-urban	(2)
		Multi-vehicle -rural	(3)
		-urban	(4)
2	Collision Type	Pedestrian	(0)
		Non-motor vehicle	(1)
		Fixed Object	(2)
		Run Off Road	(3)
		Overturned	(4)
		Other	(5)
		Head-On	(6)
		Angle Collision	(7)
		Rear-End	(8)
3	Accident Severity	Fatality	(1)
		Injury	(2)
		Property Damage	(3)
4	Road Surface	Dry	(1)
		Wet	(2)
		Snowy or Icy	(3)
		Other, unknown	(4)
5	Light Conditions	Daylight	(1)
		Dawn or Dusk	(2)
		Darkness	(3)
		Unknown	(4)
6	Contributing Circumstances	Driver Conditions	(1)
		Human Behavior	(2)
		Environment	(3)
		Vehicle Conditions	(4)
		Unknown	(5)
		None	(6)
7	Day of Week	Weekday (Mon. thru Fri.)	(1)
		Weekend (Sat. and Sun.)	(2)
		Unknown	(3)

Table 11 cont'd.

8	Hour Group	0101 - 0400	(1)
		0401 - 0700	(2)
		0701 - 1000	(3)
		1001 - 1300	(4)
		1301 - 1600	(5)
		1601 - 1900	(6)
		1901 - 2200	(7)
		2201 - 0100	(8)
		Unknown	(9)
9	Vehicle Type	Passenger Car	(1)
		Truck	(2)
		Bus	(3)
		Motorcycle	(4)
		Other	(5)
		Pedestrian	(6)
		Unknown	(7)
10	Sex	Male	(1)
		Female	(2)
		Unknown	(3)
11	Age Group	Less than 20	(1)
		20 - 24	(2)
		25 - 34	(3)
		35 - 44	(4)
		45 - 54	(5)
		55 - 64	(6)
		Greater than 64	(7)
		Unknown	(8)

The conclusions that could be drawn from data limited to the eleven to thirteen variables represented on the National Accident Summary and suggested by the results of the exposure study, in combination with the data provided by traditional or proposed report forms intended for police investigation are limited particularly with regard to causative factors. The recommendations presented here would preclude expanding the scope of mass accident data for causative investigation. Such data should be collected in limited bi-level investigations and thus prevent compromise of the quality of mass data.

3. **Use of data from external sources.**

Several of the data elements included on accident reports may be provided with greater reliability by sources other than the accident investigation.[14] Information on driver age, sex, etc., and on the involved vehicles are two areas that may be investigated using data from sources other than the accident itself. Driver information could be obtained from the driver record or licensing files. Universal use of such external sources will only be possible if driver record and registration files are efficiently integrated in a state data system. Several states cannot now provide such a data processing capability without the expenditure of considerable effort and money. An additional limitation is imposed by involvement of out-of-state parties.

4. Verification of data processing.

A possible source of observational error that has been noted is the processing of coding and keypunching of original reports. Many jurisdictions assume that the use of computers will somehow increase reliability and fail to recognize that additional error sources are added when a record system is converted to machine processing. Machine processing of accident data should include procedures for verification of coding and punching as part of a general program to monitor and maintain quality control.

5. Self-checking of consistency.

Several data elements on report forms are interrelated and can be checked for internal consistency, or provide derived data.

An excellent example of an element that may either be derived or used for a self check is "light condition" which is typically coded as daylight, darkness, dawn, or dusk. Light conditions can be computed directly from ephemeris data and thus may be a derived variable, or used as a check on time.

The Washtenaw County accident file of approximately 19,000 cases can be used to illustrate a self check of light condition and time, and provide an indicator of the validity of time information. Data on accidents which occurred in December (in the period from 1965-1969) were divided into three groups for daylight, dusk and darkness as indicated on the accident report. Histograms of the time of occurrence of each group were plotted over the daylight-dusk-night period. Of the cases that were coded as occurring in darkness, one occurred before sunset, 21 occurred in the 32 minute interval between astronomical sunset and the end of the evening civil twilight (sun 6° below the horizon), and in 50 cases the recorded time was in the 35 minute interval between the end of evening civil twilight and the end of evening nautical twilight (sun 12° below horizon). Only one case coded as "dusk" was also coded as later than one hour after sunset, and this case was just after the end of evening nautical twilight. Twenty seven cases coded "dusk" occurred within a 45 minute period preceeding sunset, 35 occurred between sunset and the end of evening nautical twilight, and five between civil and nautical twilight. The cases coded as "daylight" all had an indicated time earlier than the end of evening nautical twilight; 14 were between sunset and the end of evening civil twilight and one was before the end of evening nautical twilight.

The discrepancy was always one hour or less. While there was a slight bias in the direction of daylight this may be the result of cloud cover. Any variation in the time of dusk defined by light level would be earlier than astronomical definitions. There was little indication of discrepqncy that would result in incorrect coding of time in three-hour intervals as used in the National Data Summary.

The external sources of data available in a computer file in several states could also be used as a reference source for consistency and accuracy checks. Since such external data is not in a readily usable form in all states, the most practical use of such data would be for consistency checking rather than as a primary data source.

6. Educational program.

The problems resulting from both underreporting and observational errors would be reduced if police officers responsible for initiating and completing reports were better informed of the ultimate uses of the data and the importance of accurate observation and uniform coverage to valid statistical inference.

CORRECTION OF ACCIDENT DATA INACCURACIES

The bias remaining in accident data after appropriate measures are taken to assure the maximum feasible quality can only be removed or corrected by independent measurement of the bias. This is usually a costly process; if it is not, the alternative (independent) measurement should have been a contender for the role of the primary source. The significance of bias, and hence the effort that is appropriate to devote to correction, depends upon the final use of the data. Without identification of the use, it is impossible to assess the consequences of bias.

Accident data is frequently used to compare the rates or experience of two or more groups. The groups may be defined geographically, or by any other parameter of interest. The performance of one group may be examined at two or more times or epochs, or over an interval of time. While time might be included in a generalized classification of possible independent parameters, such a generalization is often neither convenient nor necessary.

Biases which are invariant from group to group do not prevent inferences from comparisons between groups. For example, if the underreporting of two accident types or in two states were identical, valid comparisons of the two could be made without error. If we could establish through phenomenological considerations that relative bias rates were similar, we could still draw inferences on comparative rate information for the two groups.

If the biases in several groups are not equal, the inferences that are drawn from comparisons without correcting for bias will be in error, but only from the difference in the biases--the non-cancelling error. Similarly, changes in bias with time will result in error in temporal investigations. The discussion of errors presented in Section 3 suggests that the biases resulting from underreporting vary within a state as well as from state to state and cannot be related to formal reporting criteria.

It would be possible to evaluate the bias in national statistics resulting from underreporting using the techniques demonstrated in the preceding evaluation of underreporting (Section 3). The inconclusive result of that study indicates that a program of large size would be necessary for reliable correction of bias. Since underreporting varies with local jurisdictions, there is no assurance that it does not also vary with time in the absence of the stabilizing inertia of a large rigorous system.

The result of a large national survey and data correction program--using suitable sampling procedures to ensure national representation--would be valuable for synoptic studies of accident statistics. However, the possibility of temporal changes or trends in underreporting would necessitate a measurement program capable of monitoring bias over a period of time. Implementation of a standard reporting criteria which is adaptable to field evaluation, such as a vehicle immobilization criteria, would not remove bias per se. Underreporting of property damage accidents would increase, but it would remove much of the geopolitical non-uniformity and thus minimize the effects of bias on comparative studies.

A correction of bias appropriate for national statistics would not necessarily be valid for local or even state or regional data. Thus a single correction could not be used for geographic comparisons unless the sampling plan was addressed to state-by-state representation. Unfortunately not all states maintain machine data storage that would permit convenient measurement of underreporting. Evaluation of many countermeasure programs require the use of local accident data. National or state bias corrections are not appropriate for local use. Therefore, local countermeasure program evaluation plans must use before/after accident data and either calibrations which are appropriate for the area and duration of the study, or operational procedures which provide stability over the data collection period.

It is recommended that accident data bias correction techniques based on comparisons between individual accident records and survey results, as introduced in Section 3, be studied in more detail, with special attention to the needs of local jurisdictions.

SECTION 5

HOSPITAL RECORDS OF ACCIDENT INJURIES

The purpose of this section is to discuss the possibility of obtaining data on motor-vehicle accident injuries from hospital sources as a supplement to normal accident records. The principal advantage of data from medical sources would be an expected reduction of observational error. Since the data would be based on an assessment of injury by professional medical personnel, we might expect much more reliable information on severity of injury than could be provided by non-medical investigators at the scene. Particular emphasis has been devoted to the possibility of collecting data through the Commission on Professional and Hospital Activities (CPHA).

The commission was incorporated in 1956 as a nonprofit organization to provide centralized collecting and processing of data on hospital medical care, under the sponsorship of the American College of Physicians,the American College of Surgeons, the American Hospital Association, and the Southwestern Michigan Hospital Association. The purpose of the organization, as stated in the Articles of Incorporation, include "...to develop methods...for the collection, tabulation, and analysis of information for the improvement of medical practices and administration of hospitals, and to aid hospital medical staffs in evaluating the quality of their own patient care."

CPHA collects data on each individual hospital discharge from member hospitals which participate on a voluntary subscription basis. The data for each patient is provided by the hospital on a CPHA "Case Abstract" form which is then keypunched and transferred to magnetic tape at CPHA. Be early 1970, over one thousand U.S. hospitals were participating. These hospitals provide data on over ten million patients per year which is approximately

30% of all the patients discharged by U.S. hospitals per year. Even though the member hospitals are not distributed uniformly over the country, the CPHA data provides a very significant sample of all hospitalizations, and a potentially useful source of accident injury data.

One of the more severe limitations of the CPHA data results from the omission of data on patients treated in emergency rooms and not admitted to the hospital. Thus while the data may offer low observational error, it is accompanied by substantial underreporting and hence introduces a corresponding bias. To evaluate the effect of underreporting, the dispositions of patients conveyed to hospitals were examined. Two samples were available. One was the group of patients from Washtenaw County conveyed to St. Joseph Mercy Hospital of Ann Arbor, the same sample which was the subject of the study of the police injury code discussed in Section 3. The second sample was provided by an emergency medical demonstration project conducted in the City of Detroit in 1968-1969.[15]

Data collected in the Detroit Demonstration project included the disposition in the hospital of 355 patients that could be identified as victims of traffic accidents. The police accident reports of these victims, and the police injury codes were tabulated against disposition. The result, excluding fatalities, is given in Table 12.

Table 12

Patient Disposition by Police Injury Code, Detroit

Disposition	Injury Code			
	A	B	C	Total
Treated in Emergency Room and Released	56%	64%	74%	63%
Admitted	32%	19%	12%	23%

The columns do not add to 100 since several miscellaneous dispositions such as "left without treatment", "referred to private physician", etc., are not included in either disposition of Table 12. Only 23 percent of all patients conveyed to a hospital were admitted. If CPHA records were used, 63% of the victims who received some form of medical care would not have been reported. Presumably, those who were admitted were the more severely injured, but data which would allow assessment of the degree of injury was not collected.

The data on St. Joseph patients includes considerably more detail. Of the 540 patients for whom records could be found at St. Joseph, 83 were admitted. The distribution of the Abbreviated Injury Scale codes versus the police codes for the admitted patients is given in Figure 9. These figures may be compared with those of all patients shown in Figure 4, of which they are a subset. As we would expect, the admitted patients of each police code tend to be the more severely injured as indicated by the AIS. The proportion of the patients treated at St. Joseph who were admitted is given in Table 13 for each police code.

Table 13

Patient Disposition by Police Injury Code,
St. Joseph Mercy Hospital

Police Injury Code	Percent of Patients With Indicated Police Code Who Were Admitted
A	24.2
B	5.2
C	3.5
O	0
A-C inclusive	15.9

AIS Code	A	B	C	O	
	73	7	3	0	
0	0.0	0.0	33.3	0.0	1
1	8.2	14.3	33.3	0.0	8
2	35.6	42.8	0.0	0.0	29
3	42.5	28.6	33.3	0.0	34
4	9.6	14.3	0.0	0.0	8
5	4.1	0.0	0.0	0.0	3
Total	100.0	100.0	100.0	0.0	

Police Injury Code

Figure 9

Distribution of AIS Codes of Admitted Hospital Patients by Police Code

A lower proportion of patients of each police code who were treated at St. Joseph were admitted than was observed in the Detroit project. In addition, a lower relative proportion of the B and C codes were admitted at St. Joseph. The differences between the Detroit and Washtenaw County results are statistically significant. These differences cannot be explained, but might result from different admitting policies, differences in the assignment of police codes, or actual differences in injury patterns between the two areas. The results are comparable however, and indicate that only a small fraction of the emergency room patients are admitted and an even lower proportion of all victims assigned a police injury code. The proportion of patients admitted for each AIS code is shown in Table 14.

Table 14

Patients Admitted vs. Abbreviated Injury Scale,
St. Joseph Mercy Hospital

Abbreviated Injury Scale	Percent of Patients with Indicated AIS code who Were Admitted
0	5.9
1	2.1
2	39.2
3	79.1
4	100
5	100

Thus admission of patients was not limited to those who suffered severe injury. The figure for AIS=0 however, is suspect since only one victim of this code is represented. Nevertheless, nearly 40 percent of the moderately injured victims (AIS=2) were admitted, while only 80 percent of the "severe, not life threatening" cases were admitted. Thus no clear severity level appears to provide a threshold above which data on admitted patients would not result in non-observation (underreporting) unless only the life-threatening cases were of interest. In this case the data would be contaminated by the inclusion of less severely injured victims. The apparent paradox results because patients who received only minor or moderate injuries may be admitted for observation while diagnosis is completed, or to receive treatment for problems not related to the accident; and because some rather severe injuries, such as lacerations involving arterial damage, can be treated adequately in the emergency room.

Data on admitted patients could be used to estimate the incidence of accident injury of the higher severity levels if the CPHA data could be interpreted in terms of severity, e.g., if a measure of severity could be derived from the CPHA data. The data provided by the CPHA case abstract forms which are relevent to traffic accident injury studies are (1) the length of hospital stay in days, (2) the injury diagnosis, (3) operations performed, and (4) the cause of injury. The last three items are all coded using the Hospital Adaptation of the International Classification of Diseases, Adapted.[16] This classification is essentially similar to the Eighth Revision of the International Classification of Diseases, Adapted which is published by the Public Health Service (PHS Publication No. 1693). The traffic accident victims can be identified by H-ICDA "E" codes which indicate the cause of injury. The "E" codes differentiate between drivers or passengers of motorcycles, automobiles, other land transport vehicles, and pedestrians. Unfortunately, CPHA discontinued use of the "E" codes in early 1970. Thus traffic accident victims cannot be identified on current data. Presumably, this code could be reinstated under sponsorship.

The diagnostic codes define the type of injury and the anatomy involved. They do not, however, indicate the degree of injury for all types of injury. More specifically, the AIS code cannot be uniquely determined from ICDA diagnosis codes. For example, lacerations are coded by location but not by size. Thus the AIS interpretation of laceration severity cannot be used. Similarly, while the ICDA burn codes specify the body part and the degree of burn, they do not indicate the amount of body burned in a manner consistent with the AIS. Internal organ injuries are only coded by organ or general area, not by type of injury in all cases. The CPHA codes of the 83 admitted patients at St. Joseph were examined in an attempt to correlate the diagnosis codes with the AIS, without success. One code which particularly presented problems was the H-ICDA code for "Intercranial injury of other and unspecified nature." This code was used for patients who were graded 3 on the AIS as well as one patient who expired after 105 days of unconsciousness. An injury severity measure based on energy dissipated and the immediate effect on the patient, such as the AIS scale, which could be evaluated from either the H-ICDA injury codes and/or the operation codes, does not now exist. While such a scale might be developed, the development is beyond the scope of this study.

An alternative measure of severity which was mentioned in Section 3 is the length of stay in the hospital. Since the length of stay can be determined from CPHA case abstracts, the length of stay of admitted St. Joseph patients was compared with both their AIS and police codes. The average length of stay for each of the AIS codes is shown in Figure 10, and for each of the police codes in Figure 11. The mean number of days appears to correlate reasonably well with the AIS code, although the standard deviation was over one half the mean. The high variance and the low value for AIS code 5 may be the result of the limited sample size (83 patients). The correlation was not compiled formally since the AIS code is an ordinal variable, hence correlation in the statistical sense has no meaning. Nevertheless, it appears that the length of stay might have some value as a measure of physiological severity as well as a measure of economic cost or length of tem-

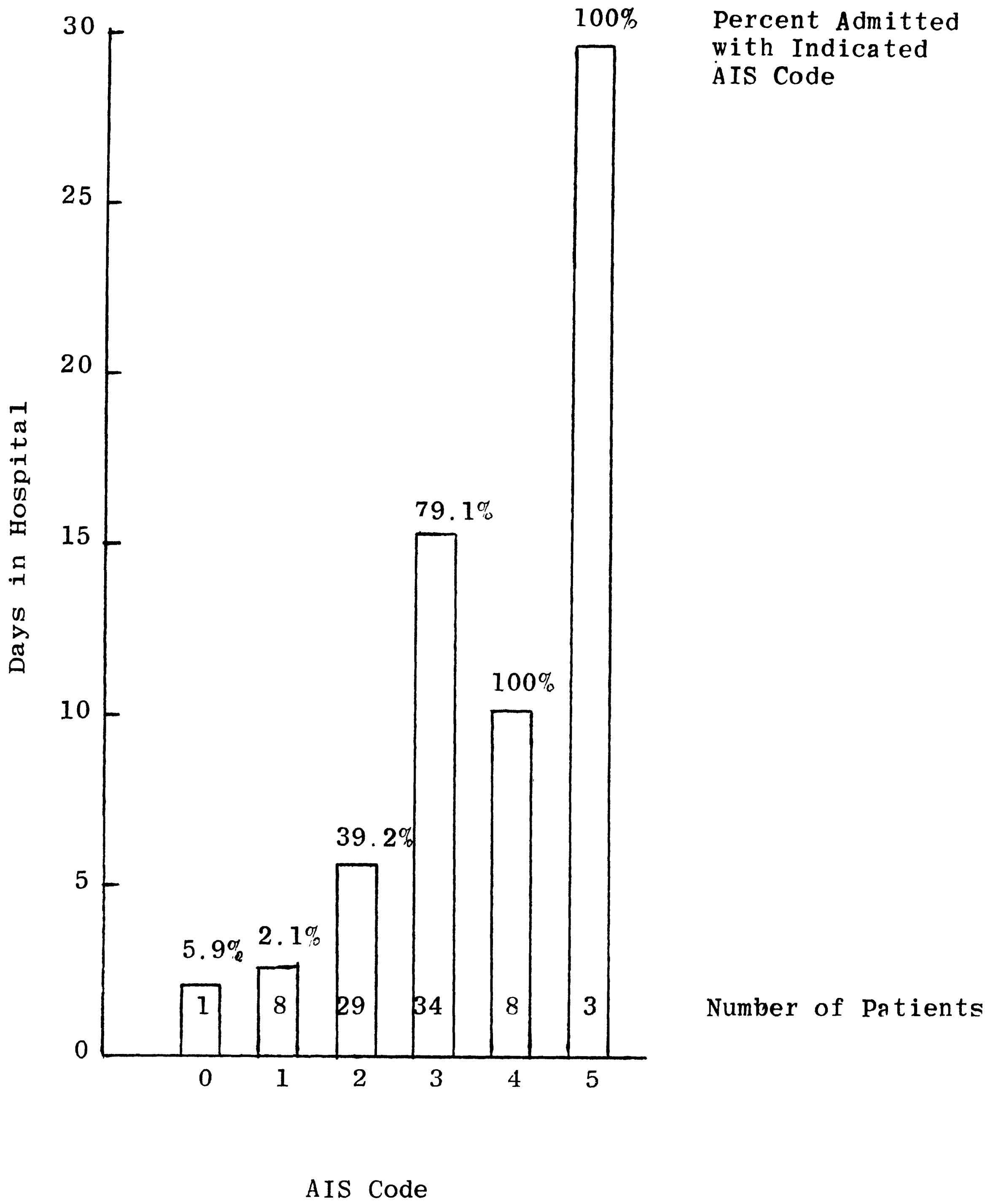


Figure 10 Distribution of Days in Hospital by AIS Code of Admitted Patient

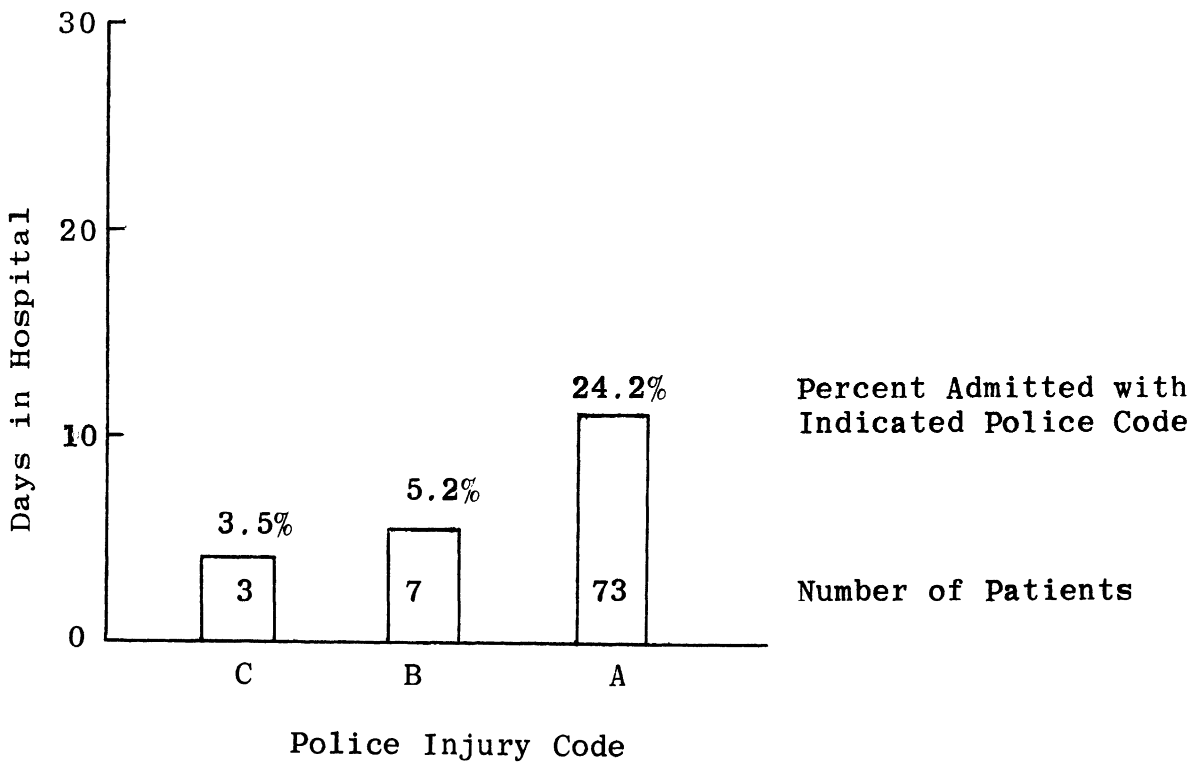


Figure 11 Distribution of Mean Number of Days in Hospital by Police Code of Admitted Patients

porary disability, As a measure of the latter two, economic loss or temporary disability, it should be recognized that many of the patients who were treated and released may have suffered disability longer than some of the admitted patients.

Thus, CPHA data should not be used unless considerable effort is devoted to evaluating possible measures of severity, including correlating the length of stay of admitted patients with the period of disability of all victims. Unfortunately, this evaluation will be difficult since CPHA has ceased using the "E" code that could identify traffic accident victims. Such an evaluation could only be made by using the inpatient and outpatient records of individual hospitals.

SECTION 6
CONCLUSIONS AND RECOMMENDATIONS

The basic conclusions of this study are as follows:

1. Current sources of highway accident data are seriously biased due to under-reporting of accidents, especially those of lower severity. Only about one third of all highway accidents are officially reported in state reocrds.

2. There is a great deal of non-uniformity in the degree of accident under-reporting among states due to differing reporting requirements.

3. There is a great deal of non-uniformity in the degree of accident under-reporting within states due to differing policies of police agencies and availability of accident investigation personnel.

4. There is a great deal of internal inaccuracy in accident reports, especially with respect to injury severity, due to differing interpretations of report items, lack of training of investigation personnel and other demands at accident scenes.

5. Corrections in accident-frequency totals may be accomplished by extrapolation of reported totals, using ratios of non-reporting derived from sample comparisons between official records and driver surveys.

Because the non-reporting ratios vary widely among jurisdictions, it is not possible to make valid corrections in accident-frequency totals within a jurisdiction unless the non-reporting ratios are calculated for that specific jurisdiction.

6. Corrections in annual, national aggregates of accident frequency would require periodic driver surveys of accident experience in a sample of jurisdictions across the country, and subsequent comparison of survey data with individual driving records to determine non-reporting ratios. The sample of jurisdictions could be a random sample of states, a random sample of counties or

all states. A random sample of states (e.g. 30) would be cheapest, but inclusion of all states would allow state-by-state correction factors for a modest cost increase.

7. Costs of providing accurate corrections of accident-frequency totals would be quite high with respect to normal costs of accident data analysis.

8. Corrections in under-reporting biases of accident data are most valuable in limited areas where evaluations of specific highway safety programs are underway. The required driver surveys and checking of official driving records can be efficiently integrated into a total evaluation program within a limited area.

9. Summaries of hospital records from the Commission on Hospital and Professional Activities (CPHA) could be used to improve estimates of the number and severity of accident injuries. However, more comprehensive improvements would require sampling of emergency room records not included in CPHA summaries.

10. Costs of improving accident injury data through CPHA summaries and samples of emergency room records would be quite high with respect to normal costs of injury data analysis.

The basic recommendations are:

1. A national program for the correction of annual accident-frequency totals in each state should be started within the National Highway Traffic Safety Administration. State-by-state accident data corrections are needed for compatibility with future exposure data, and for determination of unique accident-rate values for program evaluations in each state.

2. The proposed program should temporarily adopt the correction method introduced in this report, where non-reporting ratios are derived from sample comparisons between official records and driver surveys. Other methods should be considered as data biases change due to improvements in reporting by state and local agencies.

3. Further studies should be performed with respect to sampling

procedures for correcting accident-frequency totals using ratios of non-reporting. Consideration should be given to the type of jurisdiction sampling (sample of states, sample of counties or county groups, or all states), and to sample size requirements.

4. At a future time when improved injury scales have been standardized in official accident report forms, further study should be performed with respect to the use of CPHA hospital summaries and a sampling of emergency-room records for improvements in estimating the number and severity of accident injuries.

REFERENCES

1. Kish, L., Survey Sampling, John Wiley and Sons, N. Y., 1965.

2. Smith, R. N., The Reporting Level of California State Highway Accidents, Traffic Engineering, June 1966, pp 20-25.

3. Roosmark, P., and Fraki, R., Interview Investigation of Road Traffic Accidents, Symposium on the Use of Statistical Methods in the Analysis of Road Accidents, Road Research Laboratory, Crowthorne, Berkshire, United Kingdom, April 1969.

4. McGuire, F. L. and Kersh, R. C., Evaluation of Driver Education, University of California Publications in Education Volume 19, University of California Press, Berkeley and Los Angeles, 1969.

5. Billingsley, C. M., and Jorgenson, D. P., Analysis of Direct Costs and Frequencies of Illinois Motor-Vehicle Accidents, 1958, Public Roads, Vol. 32, No. 9, August 1963, pp 201-213.

6. A Report on the Washington Area Motor Vehicle Accident Cost Study, Wilbur Smith and Associates, U. S. Bureau of Public Roads Report PB 173 859, 1966.

7. Klein, D., and Waller, J. A., Causation, Culpability and Deterrence in Highway Crashes, Automobile Insurance and Compensation Study, U. S. Department of Transportation, Washington D. C., July, 1970.

8. Manual on Classification of Motor Vehicle Traffic Accidents, National Safety Council, Chicago, Illinois, 1962.

9. John D. States, M. D., The Abbreviated and the Comprehensive Research Injury Scales, Proceedings of the Thirteenth Stapp Car Conference, Society of Automotive Engineers, New York, December, 1969, pp 282-289.

10. John E. Freund, Modern Elementary Statistics, Third Edition, Prentice Hall, Englewood, N. J., 1967.

11. Highway Statistics, U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, 1968.

12. Manual on Classification of Motor Vehicle Traffic Accidents, Second Edition, TAD Project Technical Bulletin No. 2, American National Standard D16.1-1970, National Safety Council, Chicago, Ill., May 27, 1970.

13. Fennessy, E. F., etc. al. The Technical Content of State and Community Police Traffic Services Programs, The Travelers Research Center, Inc., National Highway Safety Bureau Contract No. FH-11-6604, September 1968.

14. Blumenthal, M. and Wuerdeman, H., A State Accident Investigation Program, The Travelers Research Center, Inc., National Highway Safety Bureau Contract No. FH-11-6688, January 1968.

15. Emergency Medical Services for an Urban Area: the Detroit Demonstration Program, Report by the Mayor's Committee for Community Renewal of the City of Detroit, and the Highway Safety Research Institute of the University of Michigan, National Highway Safety Bureau Contract No. FH-11-6901, July 1970.

16. H-ICDA, Hospital Adaptation of ICDA, Comminssion on Professional and Hospital Activities, Ann Arbor, Michigan, November 1968.