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USAGE AND EFFECTIVENESS OF SEAT AND SHOULDER BELTS IN RURAL PENNSYLVANIA ACCIDENTS

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Prepared by:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
RESEARCH AND DEVELOPMENT
OFFICE OF STATISTICS AND ANALYSIS

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USAGE AND EFFECTIVENESS OF SEAT AND SHOULDER BELTS IN RURAL PENNSYLVANIA ACCIDENTS

By: Charles J. Kahane, Ph.D.

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The Mathematical Analysis Division Technical Note series consists of short technical notes, significant statistical information with brief interpretation or analysis, and other mathematical or statistical results that are of sufficient interest to merit a brief informal exposition and low-cost dissemination.

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ABSTRACT

This report presents an analysis of lap-belt and shoulder-belt usage and effectiveness in rural Pennsylvania accidents. The data were collected by the Pennsylvania State Police under an agreement with the National Highway Traffic Safety Administration. The collection took place in late 1971 and early 1972 and it employed the Bilevel technique.

The results obtained in this study show that safety belts are highly effective in reducing occupant injuries and fatalities. In general, the results are similar to previous studies using police-reported data.

There is a discussion of ejection during the crash and its effect on injury rates.

A model for estimating the extent and the significance of incorrect lap-belt usage reporting is developed.

USAGE AND EFFECTIVENESS OF SEAT AND SHOULDER BELTS IN RURAL PENNSYLVANIA ACCIDENTS

INTRODUCTION

In late 1971 and early 1972, the Pennsylvania State Police filled out a supplemental form in connection with each rural accident report. This form contained questions on occupant restraint usage and driver education and experience, in order to analyze the role of these factors in accident and injury causation. In this analysis of the data, interest is focused on seatbelt usage, injury risk, and ejection. Later reports will devote more attention to driver education and experience.

The combination of a standard police accident report and a brief special-interest supplemental form, also filled out by the police officer, constitutes a bilevel data collection system. Researchers of the Traffic Accident Data Project developed the system because it appeared to be an inexpensive, rapid-response data source for highway safety research [13]. It is especially appropriate when there arises a new safety question of the sort that requires an urgent answer that needs a large amount of relatively simple data. In a matter of days an appropriate supplemental form is prepared, and it is added to the basic police report for several months in selected areas: it is neither timely nor cost-effective to go beyond the police for data collection for such questions.

Large police-level and bilevel data files have often been used during the past 15 years for statistical analyses of seatbelt injury and fatality reduction. Joksch [4] provides a bibliography and summaries of past studies.

Of particular interest among these are Campbell and Levine's work utilizing North Carolina data [7], Kihlberg's employing Utah data [6], and Richardson's Oregon study [9]. The approach used in this study is similar to that used in these three studies.

This study deals only with the accident-involved population. It does not examine belt usage among nonaccident-involved motorists nor does it address psychological factors in belt usage. Such questions, obviously are beyond the purview of the bilevel system.

PART 1: DATA TABULATION AND ANALYSIS

CONCLUSIONS ON SEATBELT EFFECTIVENESS

The results from rural Pennsylvania are quite consistent with those from other studies of large police data files (e.g., North Carolina [7], Utah [6], and Oregon [9]):

1. Usage: Out of 40,000 automobile occupants involved in police-reported accidents (i.e., pedestrians and truck occupants excluded),

    18 percent were reported wearing the lap belt only,

    2 percent were reported wearing the lap belt and shoulder harness,

    80 percent were reported as unrestrained

at the time of the crash.

The unrestrained group includes a sizable number (12,000) of occupants of older cars in which some or all positions were not equipped with belts. Furthermore, the data indicated that occupants of older cars are less likely to use belts even when they are installed. As a result, the usage rates for newer cars are considerably higher. For instance, among the

13,000 drivers and right-front passengers of 1968-1972 cars, who had both lap and shoulder belts available,

25 percent were reported wearing the lap belt only,

6 percent were reported wearing the lap belt and shoulder harness,

69 percent were reported as unrestrained

at the time of the crash.

2. Effectiveness:

TABLE 1

INJURY RATES BY RESTRAINT USAGE FOR
AUTOMOBILE OCCUPANTS INVOLVED IN RURAL PENNSYLVANIA ACCIDENTS

RESTRAINT USAGE	FATALITIES		FATAL OR SERIOUS INJURIES*		ALL INJURIES		ALL OCCUPANTS
	Number	Percent	Number	Percent	Number	Percent	Number
Lap Belt Only	12	0.17%	445	6.43%	1,134	16.40%	6,915
Lap and Shoulder Belt	0	0.0%	44	5.40%	128	15.71%	815
None	191	0.63%	4,070	13.67%	7,995	26.46%	30,212

In 1971-1972 rural Pennsylvania accidents,

- The lap belted occupants had a 73 percent lower fatality rate, a 53 percent lower serious injury rate, and a 38 percent lower injury rate than the unrestrained occupants.

*The police code three levels of nonfatal injury: A, B, and C. It has been customary to call "A" injuries "serious" and to lump these with fatalities. For more discussion, see page 12 and pages 53-54.

- None of the 815 lap-shoulder belted occupants were killed. They had a 60 percent lower serious injury rate and a 41 percent lower injury rate than unrestrained occupants.

3. Characteristicsof the Belted Population:

(a) Lap belt usage is higher in crashes with higher preimpact speeds (e.g., 26 percent at 61-70 mph versus 16 percent at 21-30 mph). Evidence will be given to show this is due to higher usage on long intercity drives than on trips near the home.

(b) Lap belt usage is higher for drivers (21 percent) and right front passengers (17 percent) than it is for rear seat passengers (11 percent) and center front passengers (8 percent). The front outboard positions, on the whole, happen to be the ones where occupants are most vulnerable to injury.

(c) Lap belt usage decreases as the age of the car increases. The oldest cars are seldom equipped with restraints. Since fewer property-damage accidents of old cars are reported to the police, the calculated injury rate for police-reported accidents increases with the age of the car.

The above relationships are more pronounced with regard to lap/shoulder belt usage.

4. Belt Effectiveness in Specific Configurations:

(a) Belts reduced fatal and serious injuries most for front-seat passengers (59 percent) but were nearly as effective for drivers

(53 percent) and rear-seat passengers (51 percent).

(b) Belts were effective at all speeds, but especially so for normal highway speeds (40-70 mph) where they reduced fatal and serious injuries by 62 percent.

(c) Belts, when worn, were equally effective in new vehicles (1968-1971) and older ones (1964-1967).

(d) Belts were effective for all impact types. Even in rear impacts they reduced fatal and serious injuries by 39 percent.

(e) Belts prevent most ejections. (See "Conclusions on Ejection.")

5. Interpretation:

These impressive reduction figures give the "true" injury reduction due to seatbelts alone (i.e., the percentage of injuries to the unrestrained occupants that would have been avoided had they worn belts at the time of the crash) only if the following two assumptions are valid:

(1) The crashes of belted occupants were, on the average, similar to those of unbelted occupants with regard to vehicle impact area, energy dissipation during crash, etc. - i.e., different injury rates for the two groups may be attributed to belts alone.

(2) The State Police assessment of belt use is accurate.

In the following, it will be argued by presentation of and inference from the data that assumption (1) is, by and large, correct for the lap-belted population. There are certain factors that make the crashes of belted occupants more severe than those of unrestrained. These factors cause the gross reduction figures to be an underestimate of true lap belt effectiveness:

the higher preimpact speeds of belted involvements is an example. But others cause the gross figures to be overestimates. It will be shown that none of these factors are very large, and that they partly cancel each other out.

Unfortunately, not all of these factors can be addressed by direct tabulation of the Pennsylvania data. Assumption (2), also, can obviously not be tested by simple data tabulation. Therefore, a full discussion of these assumptions cannot be given in this part of the study, but only in "Part 2: Other Analyses and Speculations."

The "Synopsis" of Part 2 ties together the discussion of assumptions (1) and (2), and speculates that the unrestrained occupants would have had 38-43 percent fewer fatal or serious injuries if they had used their lap belts.

The lap-shoulder belt also appears to be highly effective, but there are not enough data to make a good test of either assumption. This study does not speculate how many additional deaths and injuries might have been avoided if the unrestrained occupants had used both belts.

CONCLUSIONS ON EJECTION*

1. Injury Associated with Ejection:

In rural Pennsylvania, ejectees were enormously overrepresented among the dead and the injured, as is shown in Table 2:

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*Includes partial ejection.

TABLE 2

NUMBER AND PERCENTAGE EJECTED BY INJURY SEVERITY

INJURY SEVERITY	EJECTEES Number	EJECTEES Percent	NONEJECTEES Number	NONEJECTEES Percent
Fatalities	71	34.5%	135	65.5%
Fatal or Serious Injuries	477	10.5%	4,076	89.5%
All Injuries	651	7.6%	8,539	92.4%
All Occupants	801	2.1%	36,828	97.9%

Most ejections occur in high-speed accidents, and this is a contributing factor to their injury severity. The probability of ejection is low (below 2 percent) at preimpact speeds up to 50 mph. At that speed it crosses a "threshhold" (the term is used metaphorically). The probability increases sharply with increasing speed in the 50-70 mph range. Above 70 mph, it appears to level off at a very high rate (25-30 percent).

It is also possible to compare the effect of ejection (i.e., being free to strike objects outside the vehicle) to that of unrestrained nonejection (i.e., being free to strike objects within the vehicle). Within each speed range, the ejected occupant is three and a half times as likely to suffer fatal or serious injury as the unrestrained nonejected occupant who, in turn, is two and a half times as endangered as the restrained occupant.

2. Ejection and Belts:

Lap-belted occupants had a 68 percent lower ejection and partial ejection rate than unrestrained occupants and lap/shoulder-belted had a 72 percent lower rate than unrestrained.

In terms of belts' overall fatality and injury reduction, the effect of belts in preventing ejection is only one-fourth to one-third as important as that of preventing the striking of objects within the car. The "Discussion on Ejection" elaborates on these factors.

RECOMMENDATIONS

1. Continue Campaigns and Legislative Effort to Increase Belt Usage:

Lap-belted occupants in rural Pennsylvania accidents had a dramatically lower fatality and injury rate than the unrestrained (over 50 percent); the data also indicate that the latter could have spared themselves many deaths and injuries if they had used belts (40 percent). The first recommendation is that the highway safety community continue to take lap belts seriously as a life-saving device and to support all sensible programs that would lead to increased active restraint usage, including mandatory seatbelt usage laws.

2. Improve Accuracy of Belt Usage Data:

A major unsolved problem, discussed at length in Part 2, is the accurate determination of whether or not belts were worn at the time of the crash. Ideally, some modification should be made in the seatbelt hardware which would give foolproof evidence of usage during a crash. In the absence of such a system, utilization of interviewing techniques such as randomized response should be explored. Accurate determination becomes more important in the States passing mandatory belt usage laws.

3. Additional Data Fields:

If future occupant restraint studies based on police data are to be undertaken it is recommended that information on the make, model, age, and weight of the involved vehicles be coded into the data file. The impacted areas of the vehicle should be carefully coded and edited. Wherever possible, some police-level indicator of vehicle damage, such as the TAD scale, should be included. The KABC injury scale used by police will hopefully be replaced by one that is simple yet gives a better assessment of the nature and severity of injuries. Such an improved scale has already been implemented by the New York State Police.

4. Recommendations for Further Studies:

a. Lap-shoulder Belts: Because usage of this combination had been so low, it has been difficult to estimate how much more effective it is than the lap belt alone. The 1974 model-year autos, in which the ignition-interlock system has led to greatly increased usage of the shoulder harness, should at last make possible a good statistical study of this active restraint system.

b. Ejection: The Pennsylvania data suggest that the likelihood of fatal ejection is markedly greater at 70 mph than at 50 mph. Meanwhile, the States that lowered their speed limits in late 1973 and early 1974 have experienced large declines in motor vehicle fatalities. It seems worthwhile to investigate more deeply whether decrease in ejection was a major contributing factor in this saving of lives.

DISCUSSION ON THE BELTED POPULATION

Introduction: One objective of the discussion is simply to find the belt-usage rates under various circumstances. Such information can be useful by itself: for example, if the data revealed that persons over 65 rarely wore belts, this would be good motivation for highway safety commercials on television programs that the older person is most likely to view. Thus, tables are given relating belt usage to many of the other variables on the automated file.

A few of the variables, such as preimpact speed and area of impact, are known to be major causal factors in determining injury severity. A more detailed analysis for these variables is needed for the other objective: the determination whether, belt usage aside, the unrestrained population was involved in more risky crash situations than the belted group. Such an analysis consists of finding the usage rates for different values or class intervals of the variable, finding the injury rates of the unbelted population for different values of the variable, and determining the effectiveness of belts for each value. Finally, one takes a weighted average of the injury rates corresponding to the unbelted distribution of the variable, and one compares the resulting standardized belt effectiveness to the gross or "crude" effectiveness.* For example, if the belted group has an unstandardized injury rate that is 53 percent lower, and the belted and unbelted groups are alike except for speed, and the belted group has somewhat higher speed involvements, then the standardized injury rate for the belted group will be more than 53 percent lower, say 54 percent lower. This, then, would have been the decrease in injuries if unrestained occupants had used belts, and one could say, "the unstandardized reduction was an underestimate, by 1 percent, of the true injury reducing effect."

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*For details, see Appendix B.

In the "Synopsis: a Scorecard for Lap-Belt Effectiveness," all these adjustments (such as the 1 percent for speed above) will be added simultaneously to the unstandardized reduction in order to obtain an estimate of the "true" injury reduction that would have happened if unbelted occupants had buckled up. (In fact, the adjustment factors are not strictly additive, but since the variables used here are nearly independent and the adjustments are relatively small, simple addition is, in this case, entirely adequate).

All of the tables in this discussion (Part 1) derive directly from the Pennsylvania data. In a few cases (e.g., in the comparison of single and multiple vehicle crashes) this was impossible because the information is unavailable on NHTSA's automated data file. Deductive arguments and outside data sources had to be employed in those cases, which are dealt with in Part 2.

The reader will note the absence of statistical testing such as "chi-square." The author wishes to point out that such testing is not called for unless the data are a sample of <u>something</u> and thereby subject to sampling errors. For instance, one could claim the data are representative of the national accident picture, but the author certainly does not wish to make such a claim. The lap-belted population is sometimes construed as a sample of the total population and, in those cases, the chi-square could have been used. Yet even then it is not very instructive: with 40,000 cases any difference large enough to be of practical significance tends to be statistically singificant, too. Nonsampling errors, such as incorrect reporting, overshadow sampling errors.

For the benefit of the reader, however, injury rates based on small numbers have been asterisked. It was decided arbitrarily that rates based on fewer than ten injuries are "small numbers," regardless of the number of uninjured occupants.

Three levels of injury severity are used in the tables: fatal, fatal or serious, any. The second includes police codes K and A -- the injury scale used by the police is discussed in "Limitations of the Data," page 38. The criterion, "fatal or serious," is used here primarily to assure compatibility with the many other studies that have employed it [6], [7], [10], [11], [12].

1. Belt Usage by Occupant Position

TABLE 3

BELT USAGE BY OCCUPANT POSITION FOR ACCIDENT-INVOLVED AUTOMOBILE OCCUPANTS RURAL PENNSYLVANIA 1971-72

	BELT USAGE			
Occupant Position	Lap Belt Only	Lap and Shoulder	None	Number of Occupants
Driver	21.2%	2.8%	76.0%	22,006
Center Front	7.5%	-	92.5%	1,569
Right Front	17.1%	2.3%	80.6%	8,895
Left Rear	11.1%	-	89.9%	2,008
Center Rear	7.0%	-	93.0%	976
Right Rear	13.0%	-	87.0%	2,448

Belt usage is by far the highest for the front outboard positions. These have for many years been considered the most injury-prone. Table 4 shows that the Pennsylvania data bear this out.

TABLE 4

INJURY RATES BY OCCUPANT POSITION, FOR UNRESTRAINED OCCUPANTS

Occupant Position	INJURY SEVERITY Fatal or Serious Injury	Any Injury
Driver	14.6%	27.4%
Center Front	11.8%	25.3%
Right Front	14.6%	28.9%
Left Rear	9.3%	20.0%
Center Rear	7.6%	19.5%
Right Rear	8.6%	20.1%

The higher injury rates for driver and right front need not be due entirely to the inherent danger of these positions. Another factor could be that the most dangerous driving is rarely done when the car is full (e.g., a family outing). At any rate, the fact that belt usage is lower for the safer positions masks some of the belts' effectiveness and, as a result, the gross fatal and serious injury reduction for belted occupants understates, by about 2 percent, the injury reduction that unrestrained occupants would have experienced if they had buckled up.*

It is also interesting to check the belts' effectiveness in each position.

*Assuming that belt usage and seating position are the only differences in the crash experience of belted and unbelted occupants; for details on this methodology see the introduction to this discussion.

TABLE 5

FATAL AND SERIOUS INJURY REDUCTION[1]
FOR RESTRAINED OCCUPANTS BY OCCUPANT POSITION

Occupant Position	FATAL AND SERIOUS INJURY REDUCTION with Lap Belt Only	with Lap and Shoulder Belt
Driver	53%	66%
Center Front	58%	-
Right Front	59%	54%
Left Rear	56%	-
Center Rear	81%[2]	-
Right Rear	41%	-
(All Rear Seats)	51%	-

They appear nearly as effective in the rear as in the front. However, it is possible that the rear effectiveness is somewhat exaggerated due to reporting errors; see "Limitations of the Data."

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[1]Relative to unrestrained occupants of the same position.

[2]Injury rate based on fewer than ten injuries.

2. Belt Usage versus Preimpact Speed

TABLE 6

OCCUPANT BELT USAGE BY BRACKETED
PREIMPACT SPEED OF THE VEHICLE

Preimpact Speed	RESTRAINT SYSTEM USAGE Lap Belt Only	Lap and Shoulder	None	Number of Occupants
0	20.0%	2.0%	77.8%	3,141
1-10	16.1%	1.4%	82.5%	5,125
11-20	17.2%	1.9%	80.9%	3,487
21-30	16.2%	1.8%	82.0%	4,755
31-40	17.3%	1.6%	81.1%	7,478
41-50	18.4%	2.2%	79.4%	7,215
51-60	21.3%	3.4%	75.3%	4,435
61-70	25.7%	5.2%	69.1%	1,792
71+	11.8%	1.7%	86.5%	229

Usage is uniformly low at the low speeds and then climbs steadily as highway speeds are approached. This is consistent with the widely held notion that persons are less likely to use belts on short trips close to home. The sharp drop in usage above 70 mph*, on the other hand, seems to contradict the view that the wearing of belts encourages reckless driving because it gives the driver a sense of invulnerability.

The relationship with speed for lap-shoulder belts is even stronger than for lap belts alone.

The reader should also note in the right column of Table 6 the preponderance of crashes in the 31-50 mph range, and their relative scarcity at lower speeds. This reflects, of course, the fact that the file contains rural accidents exclusively -- rear-enders and fender-benders are underrepresented. The Pennsylvania data cannot be directly extrapolated to the national accident scene.

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*65 mph is the highest limit to be found on Pennsylvania roads.

Table 7 shows, not surprisingly, that the injury rates rise sharply as preimpact speed rises.

TABLE 7

INJURY RATES OF UNRESTRAINED OCCUPANTS
BY BRACKETED PREIMPACT SPEED
OF THE VEHICLE IN WHICH THEY TRAVELED

	INJURY RATES	
Preimpact Speed	Fatal and Serious Injury	Any Injury
0	3.6%	16.0%
1-10	5.3%	15.0%
11-20	6.6%	17.0%
21-30	10.5%	22.6%
31-40	14.6%	28.6%
41-50	18.7%	33.1%
51-60	21.6%	37.5%
61-70	24.8%	39.4%
71+	61.6%	75.3%

The fact that belt usage is lower for the (safer) lower speeds masks some of the belts' effectiveness and, as a result, the gross fatal and serious injury reduction understates, by about 1 percent, the injury reduction that unrestrained occupants would have experienced if they had buckled up.*

At which speeds is the belt most effective?

*For details on this methodology see the introduction to "Discussion on the Belted Population."

TABLE 8

FATAL AND SERIOUS INJURY REDUCTION[1] FOR RESTRAINED OCCUPANTS, BY PREIMPACT SPEED BRACKET

Preimpact Speed	FATAL AND SERIOUS INJURY REDUCTION with Lap Belt Only	with Lap and Shoulder Belts
0	52%	56%[2]
1-10	52%	100%[2]
11-20	32%	53%[2]
21-30	38%	67%[2]
31-40	48%	67%[2]
41-50	62%	69%
51-60	64%	63%
61-70	54%	53%
71+	34%	100%[2]

For preventing fatal and serious injuries, lap belt effectiveness peaks at highway speeds whereas lap-shoulder belt effectiveness is uniformly high.

[1]Relative to unrestrained occupants of the same speed bracket.

[2]Using an injury rate based on fewer than ten injuries.

TABLE 9

OVERALL INJURY REDUCTION[1] FOR RESTRAINED OCCUPANTS BY PREIMPACT SPEED BRACKET

Preimpact Speed	OVERALL INJURY REDUCTION with Lap Belt Only	with Lap and Shoulder Belts
0	19%	21%[2]
1-10	40%	35%[2]
11-20	26%	64%[2]
21-30	28%	18%[2]
31-40	38%	32%[2]
41-50	43%	57%
51-60	47%	46%
61-70	50%	54%
71+	36%	100%[2]

Belts were nearly as effective in reducing the number of injuries of any kind as they were in lessening just the fatal and serious ones. This refutes yet once again, as so many other studies already have in the past 10 years [1], [4], [5], [6], [7], [9], the opinion held in some circles that lap belts have "been demonstrated to produce an overall reduction from severe to less severe injury rather than an increase in the incidence of no injury [2]". Quite the contrary: in Pennsylvania, the ability of the lap belt to change an injury to no injury at all actually <u>increased</u> as the accidents became more severe, up to 70 mph.

[1]Reduction in the rate of all police-reported injuries (K, A, B, C) relative to unrestrained occupants in the same speed bracket.

[2]Using an injury rate based on fewer than ten injuries.

3. Usage versus Age of the Vehicle

The model years of the vehicles are not coded on the automated file. This makes it impossible to estimate directly the relationship of usage and vehicle age. But, it is possible to gain some information on age effects. For each occupant, the seating position and the avilability of belts are coded. Since the belts were introduced in the different positions at different times, one may use these fields to discern the relative ages of cars. By solving simultaneous linear equations,[1] one may determine the following distribution of cars in rural Pennsylvania accidents.

TABLE 10

CALCULATED[1] DISTRIBUTION OF VEHICLES BY NUMBER OF BELTS INSTALLED, FOR AUTOS INVOLVED IN RURAL PENNSYLVANIA ACCIDENTS, 1971-72

Number of Belts Installed	Percentage of Vehicles
8 (6 lap and 2 shoulder)	42.8%
6 lap belts	27.9%
4 lap belts (outboard positions only)	5.8%
2 lap belts (driver and right front)	7.3%
0	16.2%

The relative ages of cars are worth knowing because the occupants of older cars have higher calculated injury rates.[2] (Since older cars have less monetary value, a large fraction of their property damage accidents fall below the dollar threshhold for police reporting. As a result, an artificially larger fraction of those that do get reported will involve injury). By solving a second set of simultaneous equations,[1] one may determine the inflation of the injury rate due to vehicle age.

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[1]See Appendix B.

[2]See Joksch [5].

TABLE 11

FATAL AND SERIOUS INJURY RATES FOR UNRESTRAINED OCCUPANTS, BY NUMBER OF BELTS INSTALLED IN THEIR VEHICLE (A PROXY FOR VEHICLE AGE)

Number of Belts Installed	FATAL AND SERIOUS INJURIES Absolute Rate	Increase over Youngest Vehicle Age Group
8	12.4%	-
6	13.3%	6%
4	12.9%	4%
2	13.9%	11%
0	17.8%	43%

Since the unbelted occupants are more likely to be riding in the "less safe" older cars, the comparison of injury rates for belted and unbelted injury rates is biased to the disadvantage of the latter. The gross fatal and serious injury reduction for belted occupants overstates, by about 3 percent, the injury reduction that unrestrained occupants would have experienced if they had buckled up[1].

This effect is further increased, but only a little, by the fact that people are less likely to use belts in older cars even when they are installed.

[1]See the introduction to "Discussion on the Belted Population".

TABLE 12

LAP BELT USAGE BY DRIVERS AND RIGHT FRONT PASSENGERS IN NEW CARS (1968-72) (WITH SHOULDER BELTS INSTALLED) AND IN OLDER CARS (1964-67)

Model Years (Restraint Systems Available)	LAP BELT USAGE By Drivers	By Right Front Passengers
1968-72 (Lap + Shoulder Installed)	32.9%[1]	27.8%[1]
1964-67 (Lap only Installed)	24.3%	18.2%

A final question worth asking is whether belts, when worn, are more effective in newer cars.

TABLE 13

FATAL AND SERIOUS INJURY REDUCTION[2] FOR RESTRAINED DRIVERS AND RIGHT FRONT PASSENGERS OF NEW CARS (1968-72) AND OLDER CARS (1964-67)

Model Years	FATAL AND SERIOUS INJURY REDUCTION With Lap Belt Only	With Lap and Shoulder Belts
1968-72	52%	58%
1964-67	49%	-

The differences are negligible. Apparently the combination of the lap belt and energy absorbing steering column (introduced with the 1968 models) did not present a vast improvement over the lap belt alone.

[1]Includes users of lap and shoulder belts.

[2]Relative to unrestrained drivers and right front passengers of cars of the same age.

4. Effectiveness by Impact Type

This matter is still unresolved. Opinions within the highway safety community range from the view that belts reduce ejection but are worthless otherwise to the view of the American Safety Belt Council [1] that belts reduce impact forces in all collision types. The results from Pennsylvania, presented in Tables 14 and 15, support the latter view.

TABLE 14

FATAL AND SERIOUS INJURY REDUCTION[1]
FOR RESTRAINED OCCUPANTS, BY DAMAGED
AREA OF THEIR VEHICLE

Damaged Area	FATAL AND SERIOUS INJURY REDUCTION With Lap Belt Only	With Lap and Shoulder Belts	Number of Occupants
Front	60%	85%[2]	5,650
Side	48%	54%[2]	6,317
Rear	39%[2]	100%[2]	2,184
"Multiple"	54%	57%	16,716

TABLE 15

OVERALL INJURY REDUCTION[1] FOR RESTRAINED
OCCUPANTS, BY DAMAGED AREA OF THEIR VEHICLE

Damaged Area	INJURY REDUCTION With Lap Belt Only	With Lap and Shoulder Belts
Front	44%	55%
Side	40%	46%
Rear	33%	59%[2]
"Multiple"	40%	40%

[1]Relative to unrestrained occupants whose cars has the same damaged area.

[2]Using an injury rate based on fewer than ten injuries.

TABLE 16

INJURY RATES FOR UNRESTRAINED OCCUPANTS, BY DAMAGED AREA OF THEIR VEHICLES

Damaged Area	INJURY RATE Fatal and Serious	Any Injury
Front	17.9%	32.2%
Side	6.2%	14.7%
Rear	2.9%	19.9%
"Multiple"	18.1%	33.0%

TABLE 17

BELT USAGE BY DAMAGED AREA

Damaged Area	RESTRAINT SYSTEM USAGE Lap Belt Only	Lap and Shoulder Belt	Number of Occupants
Front	21.8%	2.5%	5,650
Side	23.2%	2.2%	6,317
Rear	25.6%	2.8%	2,184
"Multiple"	21.0%	2.7%	16,716

Table 17 shows that, on the Pennsylvania file, the "multiple" category contains over half of the occupants. Clearly it contains not only the rollovers and true multiple impacts (which, for comparison, amount to only 10 percent of the Oregon involvements [9]) but also most other wide or deep impacts. Indeed, Table 16 shows the "multiple" category to be a mélange of severe accidents. The remaining three categories consist of the less severe, more concentrated impacts.

The remarkable effectiveness of lap belts in front and rear impacts is surprising.

6. Usage vs. length of the Trip

It has for many years been a maxim that people buckle up more on long trips. Whereas "distance from home" was not an item on the Pennsylvania supplemental form, and although the file, of course, contains only rural accidents, there is still an excellent proxy variable for testing the maxim, viz. "driver familiarity with route," (which was actually collected for a study of driver education and experience). Presumably, a driver taking a long highway trip will, in general, not have covered the route "frequently". As Table 18 shows, the old saying could hardly be more true than in Pennsylvania.

TABLE 18

LAP BELT USAGE FOR DRIVERS WHO HAD THE BELT AVAILABLE, BY DRIVER FAMILIARITY WITH THE ROUTE HE WAS USING AT THE TIME OF THE CRASH

Driver Familiarity with Route	Driver Lap Belt Usage
Frequent	25.7%
Occasional	33.0%
First Time	37.2%

By the way, this also gives support for the assertion that belted occupants are involved in higher speed crashes merely because they are more likely to be on a long highway drive, rather than due to the use of belts promoting an "attitude of carelessness."

7. Usage by Sex and Age

Table 19 shows that, in the aggregate, men are more likely to use belts, than are women.

TABLE 19

LAP BELT USAGE BY SEX, FOR
OCCUPANTS WHO HAD A BELT AVAILABLE

	SEX	
	Male	Female
Lap Belt Usage	26.9%	21.5%
Number of Occupants	19,160	12,308

Much of the difference arises, however, because men are more likely to drive, women are more likely to be passengers, and usage is higher for drivers. Table 20 breaks down the data by occupant position.

TABLE 20

LAP BELT USAGE BY SEX AND OCCUPANT
POSITION, FOR OCCUPANTS WHO HAD A BELT AVAILABLE

Occupant Position	LAP BELT USAGE	
	Male	Female
Driver	30.8%	22.6%
Center Front	12.2%	9.5%
Right Front	20.3%	24.9%
Left Rear	13.7%	15.4%
Center Rear	12.4%	7.8%
Right Rear	15.5%	18.6%

Indeed, usage differs mainly in the driver's seat. Most of this difference is, no doubt, merely a reflection of the fact that the male usually does the driving on long trips.

TABLE 21

LAP BELT USAGE BY OCCUPANT AGE GROUP, FOR OCCUPANTS WHO HAD A BELT AVAILABLE

Age Group	Lap Belt Usage	Number of Occupants
0-14	15.6%	2,738
15-19	16.4%	6,498
20-24	27.1%	6,543
25-29	29.4%	3,090
30-34	28.8%	1,944
35-39	28.6%	1,556
40-44	27.5%	1,671
45-49	28.4%	1,744
50-54	28.6%	1,590
55-59	29.6%	1,328
60-64	31.6%	1,030
65+	27.7%	1,666

Table 21 shows that children and adolescents' usage rates are low, but the rate for adults is the same for all ages. The reader should note, by the way, that 43 percent of the accident-involved occupants are 15-24 years old.

8. Usage versus Weather and Roadway Conditions

TABLE 22

LAP BELT USAGE FOR OCCUPANTS WHO HAD A BELT AVAILABLE, BY WEATHER CONDITIONS AT THE TIME OF THE CRASH

Weather Conditions	Lap Belt Usage	Number of Occupants
Clear	22.8%	16,417
Rain	27.2%	5,749
Foggy	22.6%	1,128
Snow	33.6%	2,784

TABLE 23

LAP BELT USAGE FOR OCCUPANTS WHO HAD A BELT AVAILABLE, BY ROADWAY CONDITIONS AT THE TIME OF THE CRASH

Roadway Conditions	Lap Belt Usage	Number of Occupants
Dry	23.1%	18,782
Wet	25.2%	8,721
Icy	30.2%	1,788
Snowy	33.3%	1,914

9. Usage versus Driver Education

TABLE 24

DRIVER LAP BELT USAGE FOR DRIVERS, WITH AND WITHOUT DRIVER EDUCATION, WHO HAD A BELT AVAILABLE

Driver Education Taken	Driver Lap Belt Usage	Number of Drivers
Yes	31.8%	8,104
No	26.1%	8,465

The reader should avoid jumping to the conclusion that the increased usage for educated drivers is wholly due to the attitude of carefulness that driver education might instill. Much of the increase may be due to the fact that educated drivers are more likely to live in cities, so that their crashes on long intercity trips are on this rural file, while their crashes on short urban trips, of course, cannot be on this file.

DISCUSSION ON EJECTION

1. Likelihood of Ejection versus Preimpact Speed

TABLE 25

PERCENTAGE OF OCCUPANTS EJECTED* BY PREIMPACT SPEED OF THEIR VEHICLE RURAL PENNSYLVANIA 1971-1972

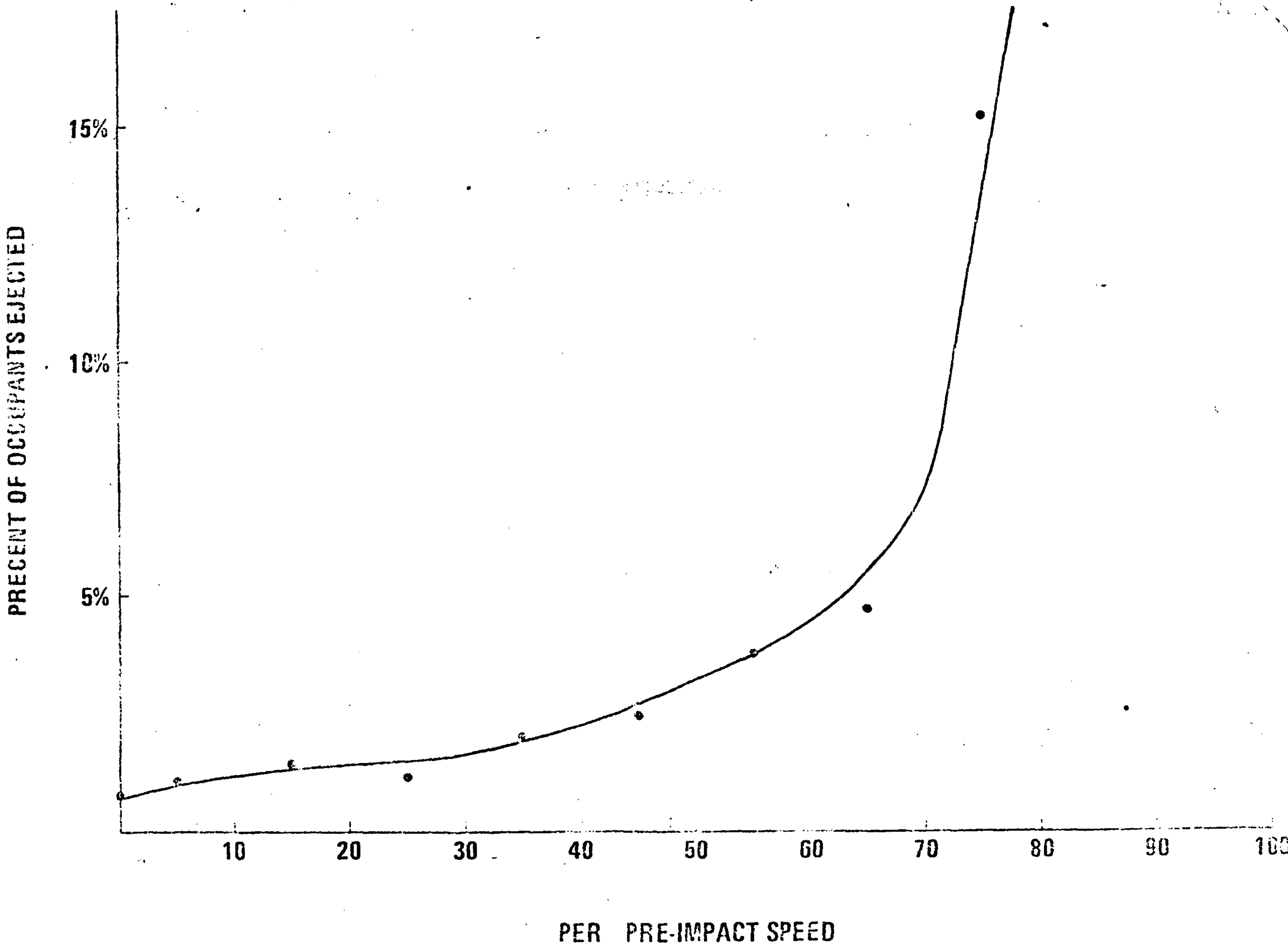
Preimpact Speed	Percent of Occupants Ejected*	Number Ejected*
0	.7%	23
1-10	1.0%	52
11-20	1.3%	46
21-30	1.1%	55
31-40	1.9%	151
41-50	2.3%	176
51-60	3.5%	162
61-70	4.7%	87
71+	24.2%	59

Table 25 and Figure 1 show that the likelihood of ejection varies nonlinearly with preimpact speed. Up to 30 mph the percentage ejected is low and stable, around 1 percent. In the range of highway speeds from 35 to 65 mph, the chance of being ejected increases in a nearly linear fashion, from 1.9 percent at 35 mph to 4.7 percent at 65 mph. Above this speed, the curve abandons its linear ways and it skyrockets.

---

*Includes partial ejection.

FIGURE 1: LIKELIHOOD OF OCCUPANT EJECTION BY PRE-IMPACT SPEED OF THEIR VEHICLE



One may view the speed-ejection curve as having three segments and two boundaries or "threshholds" between segments:

(1) At low speeds, ejection is not a major safety problem. It is rare and not speed-sensitive.

(2) At high speeds, ejection is a major safety problem, and the problem increases with increasing speed.

(3) At immoderate speeds, ejection is a commonplace occurrence.

Probably, if a finer measure of accident severity than preimpact speed were used (e.g., velocity change during impact), the tripartite form of the curve of Figure 1 would be even more pronounced.

2. Ejection Fatalities by Speed

Overall, 36 percent of the fatalities were ejectees. No less than 45 percent of those who died in crashes with preimpact speeds over 60 mph had been ejected. One may best grasp the magnitude of the rural highway fatality problem by looking at the absolute numbers, rather than rates, of ejected and nonejected fatalities by speed brackets.

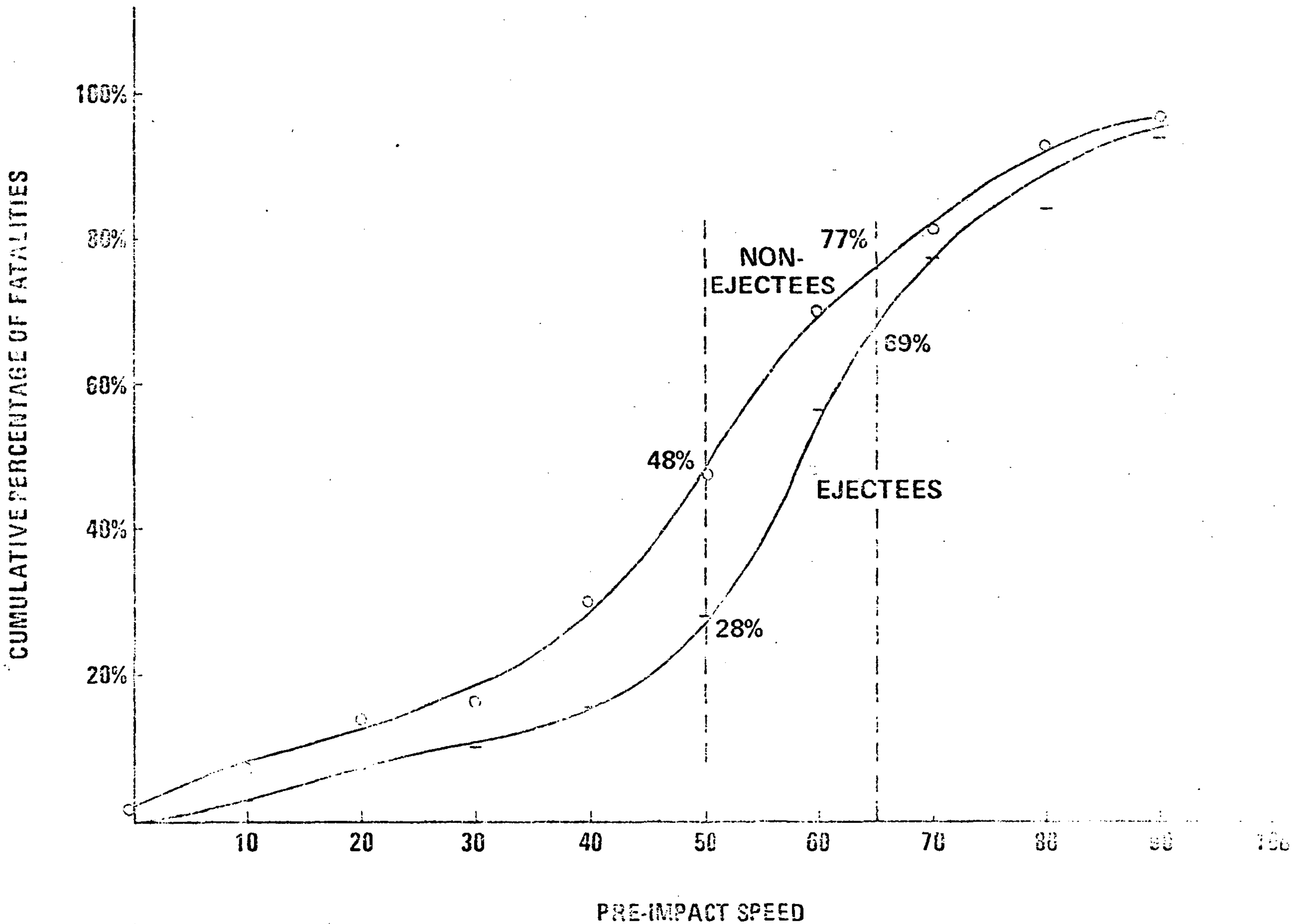
TABLE 26

NUMBERS OF EJECTED AND NONEJECTED
FATALITIES IN VARIOUS PREIMPACT SPEED BRACKETS
AND PERCENT OF FATALITIES DUE TO EJECTION BY SPEED BRACKET

Preimpact Speed	No. of Ejected Fatalities	No. of Nonejected Fatalities	% of Fatalities Due to Ejection
0	0	2	0%
1-10	2	8	20%
11-20	3	7	30%
21-30	2	4	33%
31-40	4	17	19%
41-50	9	23	28%
51-60	20	29	41%
61-70	15	15	50%
71+	16	23	41%
Totals	71	128	36%

Table 26 and Figure 2 show in absolute terms the role of the first "threshhold speed" for ejection. The cumulative distribution curve for nonejected fatalities has a steady steep slope from 40 to 70 mph - i.e., throughout the range of highway speeds. The curve for killed ejectees, on the other hand, is rather flat up to about 50 mph and then suddenly enters the steep part of the S. This is the first threshhold above which the car gets hit hard enough to provide avenues and kinetics for ejection. Forty-one percent of the ejection fatalities occur between 50 and 65 mph. This amounts to 14 percent of all rural fatalities. Many of these might well have been saved by lowering rural speed limits, or by building cars for which the ejection threshhold speed is about 10 mph higher.

FIGURE 2: SPEED DISTRIBUTION FOR EJECTED AND NONEJECTED FATALITIES



3. Ejection Injuries by Speed

Overall, 11% of the fatalities and serious injuries were ejectees. Table 27 breaks down the absolute numbers by speed brackets.

TABLE 27

NUMBER OF EJECTED AND NONEJECTED FATAL AND SERIOUS INJURIES IN VARIOUS PREIMPACT SPEED BRACKETS. PERCENT OF FATAL AND SERIOUS INJURIES DUE TO EJECTION BY SPEED BRACKET.

Preimpact Speed	FATAL AND SERIOUS INJURIES No. Ejected	No. Nonejected	% Due to Ejection
0	5	91	5%
1-10	20	223	8%
11-20	13	200	6%
21-30	23	442	5%
31-40	77	912	8%
41-50	110	1,082	10%
51-60	109	709	13%
61-70	76	297	20%
71+	50	86	37%
Totals	483	4,042	11%

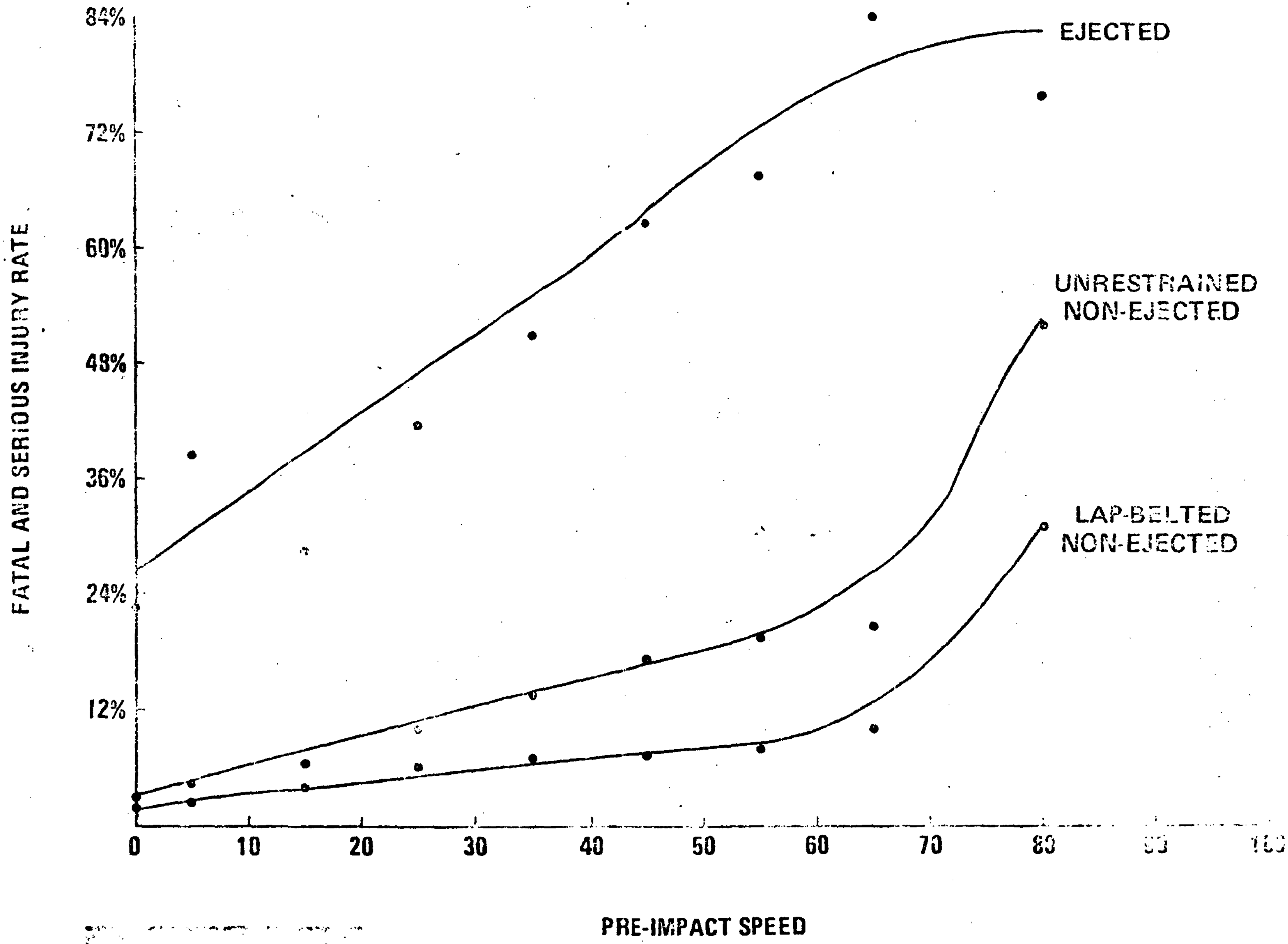
TABLE 28

FATAL AND SERIOUS INJURY RATES BY
PREIMPACT SPEED FOR EJECTED, UNRESTRAINED
NONEJECTED, AND LAP-BELTED NONEJECTED OCCUPANTS

Preimpact Speed	FATAL AND SERIOUS INJURY RATES Ejected	Unbelted Nonejected	Belted Nonejected
0	22.7%	3.3%	1.8%
1-10	38.5%	4.8%	2.4%
11-20	28.3%	6.2%	4.1%
21-30	41.8%	10.1%	6.1%
31-40	51.0%	13.7%	7.2%
41-50	62.9%	17.4%	7.2%
51-70	87.4%	20.7%	10.4%
71+	75.8%	52.3%	31.0%

Table 28 and Figure 3 show that at the highway speeds, ejection (the freedom to hit objects outside the car) is about three and a half times as risky as unrestrained nonejection (the freedom to hit objects inside the car) which is in turn two and a half times as dangerous as belted nonejection.

FIGURE 3: FATAL AND SERIOUS INJURY RATES BY PREIMPACT SPEED FOR EJECTED, UNRESTRAINED NONEJECTED, AND LAP-BELTED NONEJECTED OCCUPANTS



4. Ejection and Belt Usage

TABLE 29

EJECTION RATES BY RESTRAINT SYSTEMS USAGE

Restraint Systems Usage	EJECTION RATES Complete Ejection	Complete or Partial Ejection
None	1.50%	2.45%
Lap Belt Only	0.34%	0.76%
Lap & Shoulder Belts	0.62%	0.74%

Table 29 shows that both types of belts were extremely effective in preventing ejection: they reduced its likelihood by about 70 percent.

Although prevention of ejection is clearly an important component of the injury reduction due to belts, one may show with some simple arithmetic that it is only a fraction of their overall salutary effect, even for lap belts.

Lap-belted occupants had a 69 percent lower ejection rate than unrestrained occupants. The belted ejectees did not have significantly different injury and fatality rates than the unbelted ejectees. Now, ejectees comprise 36 percent of the fatalities, 11 percent of the seriously injured, and 7.6 percent of the injured. If ejection-reduction had been the only salutary effect of lap belts, then the lap-belted occupants would have experienced, at most, a 69% x 36% = 25% fatality reduction, a 69% x 11% = 8% fatal and serious injury reduction, and a 69% x 7.6% = 5% injury reduction. Since, in fact, the Pennsylvania lap-belted occupants experienced fatality, fatal and serious injury, and injury reductions of 72 percent, 53 percent, and 38 percent rather than 25 percent, 8 percent, and 5 percent, one can easily see that the effect of belts preventing the occupant from striking objects outside the car is much less important than their effect of preventing the striking of objects within the car.

LIMITATIONS OF THE DATA

The tabulations presented up to this point leave unanswered several questions relevant to the accurate determination of belt usage and effectiveness. Certain data fields needed for a thorough restraint systems study were not collected or encoded in the Pennsylvania Bilevel. Other fields, which were collected, may be subject to imprecision (random error) or inaccuracy (systematic error). In Part 2, the following issues will be shown relevant and essential to the study:

1. Incorrect Lap-Belt Usage Reporting
2. Incorrect Lap-Shoulder Belt Usage Reporting
3. Single versus Multivehicle Crashes
4. Imprecision Inherent in Police-Collected Data

Part 2 will discuss these issues by drawing on mathematical modeling, data from other States, and speculation.

In addition to these issues, there are three specific shortcomings of the Pennsylvania Bilevel data file that have already been discussed:

(a) The impacted area of the vehicle was coded in an unorthodox manner: over half the vehicles had "multiple" impacts. As a result, this important accident classifier could not be used effectively.

(b) The age of the vehicle was not coded. Vehicle age is rather correlated with injury rate, and it should not be ignored. The only clue to vehicle age in the automated file is seat belt availability, and the latter is coded only for the occupied seats.

(c) The file, of course, does not contain any urban accidents. Therefore, it should not be considered representative of the national accident picture.

PART 2: OTHER ANALYSES AND SPECULATIONS

Part 1's "Conclusions on Seat Belt Effectiveness: Interpretation" argued that any effort to find the "true" injury reduction due to seat belts alone (i.e. the percentage of injuries to the unrestrained occupants that would have been avoided had they worn belts at the time of the crash) would have to include tests of the following two hypotheses:

(1) The crashes of belted occupants were, on the average, similar to those of unbelted occupants with regard to vehicle impact area, energy dissipation during crash, etc. - i.e. different injury rates for the two groups may be attributed to belts alone.

(2) The State Police assessment of belt use is accurate.

Hypothesis (1) was tested only partially and (2) not at all by the straightforward data tabulations of Part 1. The testing will be completed here by drawing on mathematical models and data from other States. The results herein are of a speculative nature. Nevertheless, without them, it would have been impossible to make even the approximate assessment of true lap belt effectiveness that forms the "Synopsis" of this study.

INCORRECT LAP BELT USAGE REPORTING

There has been speculation [8] that some unbelted occupants tell policemen and investigators and sometimes even tell themselves that they wore belts. They may be doing this for various reasons. Many, having been told that belts are safe and are used by good citizens, may want to make a good impression on the policeman or investigator.

This speculation is supported by studies in North Carolina [14] and New York [12] which prove that randomly selected occupants reporting to investigators overstate their belt usage by as much as 25%. Unfortunately no study has been made on accident-involved occupants reporting to policemen at the crash scene.

Incorrect reporting is no trifling matter, for the sensitivity of belted injury reduction to usage reporting errors is very great. Consider their effect, for instance, under the following conditions:

(a) no lap belted occupant is reported "unrestrained."

(b) no fatally or seriously injured unrestrained occupant is reported "lap belted." (when there are major injuries there is usually some visible evidence whether belts were used, the police are less likely to rely on hearsay, and surviving witnesses will be too traumatized to worry about making a good impression.)

(c) Five percent of the unrestrained, not seriously injured occupants are reported "lap belted."

Figure 4 shows that this 5 percent reporting error can lead to 72 percent exaggeration of lap belt effectiveness on data files such as the Pennsylvania Bilevel.

FIGURE 4

AN EXAMPLE SHOWING SENSITIVITY OF REPORTED LAP BELT EFFECTIVENESS TO USAGE REPORTING ERRORS

Assume: Total number of occupants = 40,000
True lap belt usage = 15%
True fatal and serious injury rates:

Lap belted = 7.5% | Unrestrained = 10%

Calculation of true injury reduction:

Total lap belted occupants: 6,000	Total unrestrained occupants: 34,000
With fatal or serious injury: 450	With fatal or serious injury: 3,400
Without fatal or serious injury: 5,550	Without fatal or serious injury: 30,600
True injury rate: 7.5%	True injury rate: 10%

True lap belt effectiveness: 25%

Now assume 5% of unrestrained, not seriously injured, are reported as "lap belted":

5% x 30,600 = 1,530

Calculation of reported "injury reduction":

Reported lap belted occupants: 6,000 + 1,530 = 7,350	Reported unrestrained occupants: 34,000 - 1,530 = 32,470
With fatal or serious injury 450	With fatal or serious injury: 3,400
Without fatal or serious injury: 5,550 + 1,530 = 7,080	Without fatal or serious injury: 30,600 - 1,530 = 29,070
Reported injury rate: 5.97%	Reported injury rate: 10.47%

Reported "lap belt effectiveness": 43%

Summary:

True lap belt effectiveness: 25%
Reported lap belt effectiveness: 43%
Error of reported effectiveness: 72%
Error of reported usage: 5%

True belt usage may be conclusively established only when appropriate seat belt hardware modifications occur (see "Recommendations"). In the meantime, however, speculative upper bounds for the percentage of incorrect reports can be obtained by a simple analytic method.

The method consists merely of noting that the lower the reported seat belt usage, the higher the exaggerating effect of a fixed percentage of error among the unbelted, uninjured. If one looks simultaneously at two subgroups of the accident involved occupants, one of which has high belt usage and the other low, one may derive upper bounds for error and lower bounds for true effectiveness. By looking at several such pairs, one may zero in on realistic error percentages and injury-reduction figures.

For instance, the Pennsylvania data show lap belts reduce injuries by 49% for drivers and by 46% in the rear seat.* This seems very high, especially for the rear seat. Now, belt usage is lower in the rear, so the same error percentage front and rear would have a larger exaggerating influence on rear effectiveness.

Indeed, Table 30 and Figure 5 give the true effectiveness of lap belts for driver and rear seat, given various error percentages, assumed to be the same for drivers and rear seat passengers.

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*Relative to occupants of those positions who had lap belt available but did not use it.

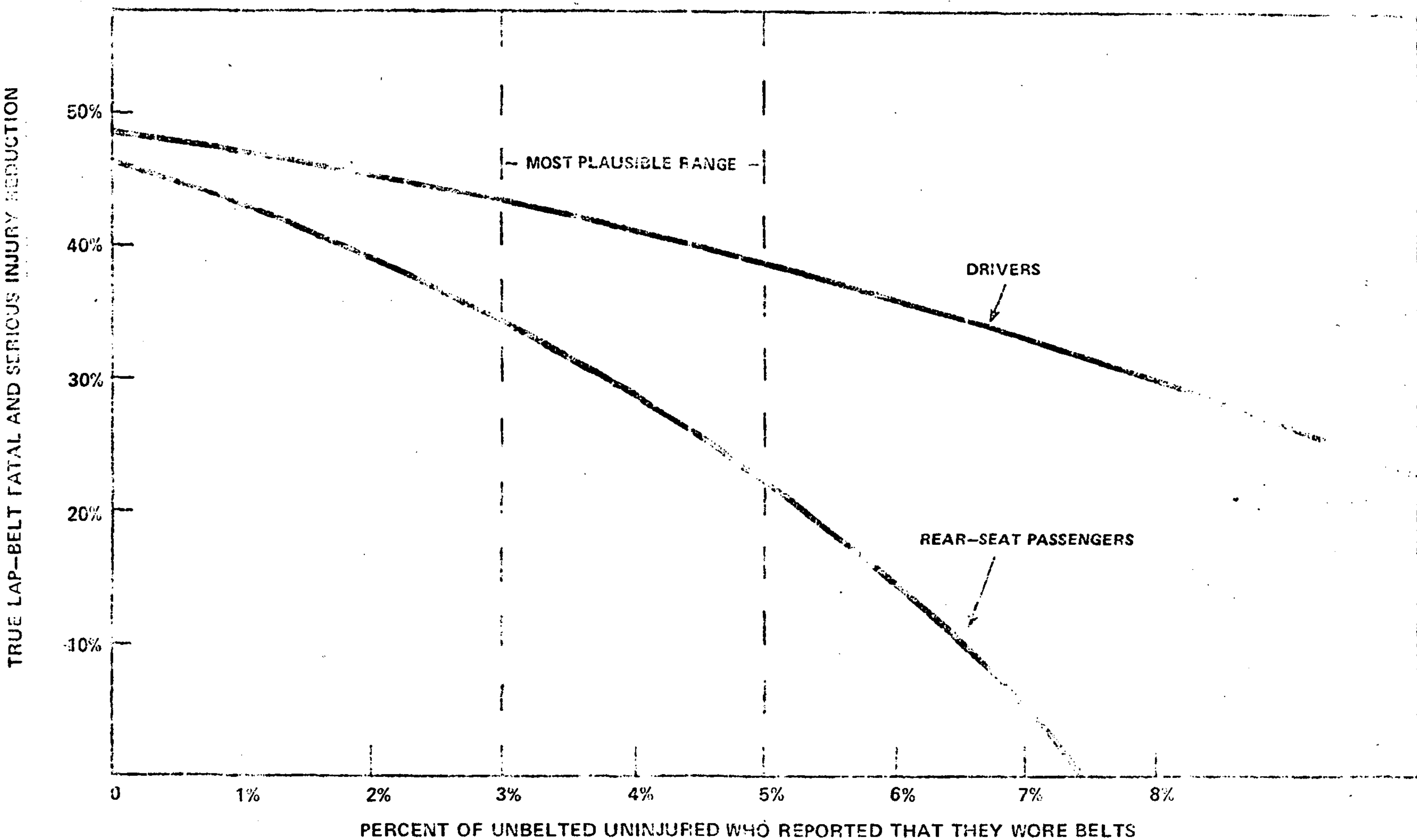
(Note that when there is no error, the true effectiveness are 49% and 46%, the ones reported above.) The numbers in Table 30 were obtained by applying, in reverse, the arithematic that was illustrated in Figure 4, but using the reported lap belt usage and injury rates, for drivers and for rear seat passengers of the Pennsylvania Bilevel data file.

TABLE 30

TRUE LAP-BELT EFFECTIVENESS: THE DRIVERS AND REAR-SEAT OCCUPANTS WHO REPORTED USING LAP BELTS HAD 48.66% AND 46.48% LOWER FATAL AND SERIOUS INJURY RATES, RESPECTIVELY, THAN UNRESTRAINED OCCUPANTS OF THE SAME POSITION WHO HAD BELTS AVAILABLE. GIVEN IN THE LEFT COLUMN PERCENTAGE OF UNRESTRAINED UNINJURED WHO REPORTED THEY WORE BELTS, THE FIGURES ON THE SAME ROW IN THE TWO RIGHT COLUMNS GIVE THE TRUE INJURY REDUCTION EXPERIENCED BY BELTED DRIVERS AND REAR-SEAT OCCUPANTS.

Percentage of Unrestrained Uninjured Who Reported Using Belts	TRUE FATAL AND SERIOUS INJURY REDUCTION FOR LAP-BELTED OCCUPANTS % for Drivers	% for Rear-Seat Occupants
0.00	48.66	46.48
.20	48.32	45.81
.40	47.97	45.12
.60	47.62	44.42
.80	47.27	43.69
1.00	46.91	42.95
1.20	46.54	42.19
1.40	46.17	41.40
1.60	45.79	40.59
1.80	45.41	39.76
2.00	45.02	38.91
2.20	44.63	38.03
2.40	44.23	37.13
2.60	43.82	36.20
2.80	43.41	35.24
3.00	42.99	34.25
3.20	42.56	33.23
3.40	42.13	32.18
3.60	41.69	31.09
3.80	41.25	29.97
4.00	40.80	28.81
4.20	40.34	27.61
4.40	39.87	26.37
4.60	39.39	25.08
4.80	38.91	23.75
5.00	38.42	22.37
5.20	37.92	20.94
5.40	37.41	19.46
5.60	36.90	17.91
5.80	36.37	16.31
6.00	35.84	14.64
6.20	35.30	12.91
6.40	34.74	11.10
6.60	34.18	9.21
6.80	33.61	7.25
7.00	33.02	5.19
7.20	32.43	3.04
7.40	31.83	.79
7.60	31.21	-1.57
7.80	30.58	-4.04
8.00	29.94	-6.64

FIGURE 5: TRUE LAP–BELT EFFECTIVENESS, GIVEN A PERCENTAGE OF UNRESTRAINED UNINJURED WHO REPORTED THEY WORE BELTS.



If 3 percent had been in error, the true effectiveness for drivers would have been 43 percent and for rear seat occupants, 34 percent. This is closer to the accepted ratio of front to rear belt effectiveness. With 5 percent errors, the figures would be 38 percent and 22 percent. At 6 percent, they are 36 percent and 15 percent, which already seems too large a disparity between front and rear effectiveness; and a error rate of 8 percent is out of the question, because it would mean belts increase injuries by 6 percent in the rear. In conclusion, it appears reasonable to speculate that 3-5 percent of the unbelted, uninjured occupants with belts available reported that they were belted, and that the true seat-belt effectiveness in reducing fatal and serious injuries in rural Pennsylvania was 42-47 percent, rather than the reported 53 percent.

INCORRECT LAP-SHOULDER BELT USAGE REPORTING

It is also difficult to determine how many, if any, uninjured unrestrained occupants, if any, deliberately misinformed the police that they had worn lap/shoulder belts. Furthermore, there may be several inadvertent misclassifications of lap/shoulder-belted occupants as lap-belted, and vice-versa. Since there are so few reported lap/shoulder users in the data, the number misclassified may be relatively important.

SINGLE VERSUS MULTI-VEHICLE ACCIDENTS

Single-vehicle accidents (ran-off-road, hit-fixed-object) are a major safety problem. Nationwide, only 24.5 percent of the rural automobile involvements are single vehicle, but these produce 37.9 percent of the injuries and 49.8 percent of the fatalities.* Single-vehicle accidents have traditionally been associated with careless driving habits or alcohol, so one might expect belt usage to be lower than in multi-vehicle involvements. If this were true, belted occupants would have a significantly lower injury rate even if belts were totally ineffective, simply because they are in less severe accidents. It is important to find out how much lower.

Unfortunately, the automated version of the Pennsylvania file to which NHTSA has access cannot distinguish the number of vehicles in the accident. But there are some other ways to get some information on it. For instance, the proportion of multi-vehicle accidents is lower at night, and so is belt usage.

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* Figures taken from the National Accident Summary File, 1971 [15].

TABLE 31

BELT USAGE[1] AND THE PERCENTAGE OF RURAL INVOLVEMENTS THAT ARE MULTI-VEHICLE[2] BY HOUR GROUP

Hour Group	Lap Belt Usage	Percent Multi-Vehicle
1:01- 4:00	22.5%	45.8%
4:01- 7:00	27.4%	57.5%
7:01-10:00	29.4%	80.6%
10:01-13:00	26.1%	81.5%
13:01-16:00	25.3%	82.1%
16:01-19:00	25.9%	80.2%
19:01-22:00	22.3%	69.2%
22:01- 1:00	19.7%	58.5%

There is some correlation ($r = .583$), so one might conclude that one reason belt usage is lower at night is the higher proportion of single-vehicle types among the involved. If one assumed this is the only reason, one may run a regression, with usage as the dependent variable.[3] The outcome is 16.5 percent usage in single-vehicle accidents and 28.5 percent in multiple. Of course, since it is almost certain that usage is lower at night even for multiple-vehicle crashes, 16.5 percent is too low and 28.5 percent is too high.

Another source of information is the violation charged to drivers.

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[1] Figures taken from the Pennsylvania Bi-Level File.

[2] Figures taken from the National Accident Summary File, 1971 [15].

[3] See Appendix B.

TABLE 32

NUMBER OF DRIVERS WITH LAP BELTS INSTALLED WHO WERE AND WERE NOT CHARGED WITH TRAFFIC VIOLATIONS AS A RESULT OF THE CRASH. ALSO, LAP-BELT USAGE FOR VIOLATORS AND NONVIOLATORS

Violation Charged?	Number of Drivers	Percent Using Lap Belts
Yes	11,407	21.1%
No	6,808	31.0%

Normally, one violation is charged per accident[1] - i.e. there were 6,808 two-car accidents and 4,599 one-car accidents. If one assumed that belt usage for two-car accident drivers is the same whether they are charged or not, one would obtain 21.3 percent usage in single-vehicle and 31.0 percent in multiple. Of course, since it is almost certain that the at-fault driver is less likely to use belts than the not-at-fault driver in the multi-vehicle crash, 21.3 percent is too low and 31.0 percent is too high.

The best educated guess one can make is that

$$\frac{5}{4} \leq \frac{\text{Lap belt Usage in Multi-vehicle}}{\text{Lap belt Usage in Single-Vehicle}} \leq \frac{4}{3}$$

[1]The violation goes to the one driver in a single-vehicle accident and to the "most responsible" driver in a multi-vehicle accident.

Such ratios also seem in line with those in the other States given in Table 33.

TABLE 33

LAP BELT USAGE FOR DRIVERS INVOLVED IN SINGLE- AND IN MULTIPLE-VEHICLE CRASHES, IN NORTH CAROLINA, 1968,[1] AND IN WESTERN NEW YORK STATE, 1970[2]

Type of Involvement	LAP BELT USAGE North Carolina, 1968[1]	Western New York, 1970[2]
Single-vehicle involvement	13.5%	33.3%
Multi-vehicle involvement	16.5%	43.0%

Although single-vehicle accidents have double the serious injury rate of multi-vehicle, some of this is due to the former's higher preimpact speeds. Do single-vehicle accidents have more injuries than multi-vehicle crashes of the same speed? Figures from Washtenaw County, Michigan,[3] given in Table 20, address this question.

---

[1] Campbell and Levine [7].

[2] Figures taken from CALSPAN Level 1, 1970 [16].

[3] Figures taken from Washtenaw County, 1969-73 [17].

TABLE 34

FATAL AND SERIOUS INJURY RATES FOR OCCUPANTS INVOLVED IN SINGLE- AND IN MULTIPLE-VEHICLE CRASHES BY PRE-IMPACT SPEED FOR THE VEHICLE THEY WERE TRAVELING IN, WASHTENAW COUNTY, MICHIGAN, 1969-1973[1]

Pre-Impact Speed	FATAL AND SERIOUS INJURY RATES Single-Vehicle Involvements	Multi-Vehicle Involvements
31-40 mph	16.8%	9.7%
41-50	16.9%	12.5%
51-60	22.5%	13.1%
61-70	21.5%	12.4%
71+	37.6%	22.4%

More sketchy figures from North Carolina[2] are given in Table 21.

TABLE 35

FATAL AND SERIOUS INJURY RATES FOR UNRESTRAINED OCCUPANTS IN SINGLE- AND MULTI-VEHICLE CRASHES, BY PRE-IMPACT SPEED, NORTH CAROLINA, 1968[2]

Pre-Impact Speed	FATAL AND SERIOUS INJURY RATES Single Vehicle	Multi-Vehicle
30-49 mph	13.1%	6.2%
50+	21.0%	15.2%

It is reasonable to conclude that single-vehicle accidents produce a 50 percent higher serious injury rate than multi-vehicle accidents of the same speed.

[1] Figures taken from Washtenaw County, 1969-73 [17].

[2] Campbell and Levine [7].

Under the above assumptions on decreased belt-usage and increased risk in single-vehicle accidents, the belted population would have had a 3 to 4 percent lower injury rate even if belts were totally ineffective. Thus, the comparison of injury rates for belted and unbelted occupants is biased to the disadvantage of the latter. One may speculate that the gross fatal and serious injury reduction for belted occupants overstates, by about 3 to 4 percent, the injury reduction that unrestrained occupants would have experienced if they had buckled up.[1]

IMPRECISION INHERENT IN POLICE-COLLECTED DATA

A. The police injury scale, has codes K= Killed, O= no injury, and injuries of severities A, B, and C. The latter three are defined as follows:

A - Visible signs of injury, bleeding, distorted member or had to be removed from scene

B - Other visible injury, bruises, swelling, limping, abrasions

C - No visible injury, but complaint of pain, dizziness, etc.

In this study, "serious" injury meant A injury, but in fact this scale is not a particularly fine measure of threat to life or extent of disablement. Many minor but highly visible lacerations are coded "A," while a fair number of severe neurological injuries are coded "C." Nevertheless, there is a fairly good correlation between the A, B, C scale and injury severity in the sense that the majority of life-threatening

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[1] See the Introduction to Part 1's "Discussion on the Belted Population" for details on this methodology.

or disabling injuries are codes "A" and the majority of injuries coded "A" are at least partially disabling,* Hence, it is not invalid to use "A" to denote "serious" injury: it is merely imprecise. The loss of precision stemming from the use of the police injury scale is more than offset by the extremely large number of occupants on the Pennsylvania file, which minimizes imprecision due to sampling error.

There are, however, circumstances under which the use of "A" to denote serious injuries could bias the results: this could happen if the "A" injuries of belted occupants, on the average, were of different severity than the "A" injuries of unrestrained occupants. This possibility is not entirely counter-intuitive: the sanguinary but often superficial injuries resulting from contacting glass are especially characteristic of unbelted occupants. Since bleeding injuries are usually coded "A," it is thus possible that the "A" injuries of unrestrained occupants are slightly less serious than those of belted occupants. But such intuition that these might be a bias in the favor of belted occupants has not, to this point, been substantiated by any study of accident data.

Similarly, the lack of sharp measures of accident severity complicated some of the discussion. Police-estimated preimpact speed is a poor substitute for velocity change during impact.

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* See also CALSPAN Tri-Level Study [3].

SYNOPSIS: A SCORECARD FOR LAP BELT EFFECTIVENESS

In rural Pennsylvania, 1971, the crash-involved occupants who said they used lap belts had a 53 percent lower fatal and serious injury rate than those who said they used no belts. But what percentage of unbelted fatalities and serious injuries would have been saved if everybody had worn belts? Not 53 percent, it was shown in the discussion, because the unbelted population experienced different accident types than the belted and because not everyone who said they wore belts actually wore them. The discussion also assessedone by one the sizes of these factors in perturbing that figure. Now is the time to follow through what was proposed in the introduction to the "Discussion on the Belted Population" and to add up the factors and estimate how many would indeed have been saved:

ENTER 53%	because reported belted occupants had 53% fewer fatal and serious injuries	53%
ADD 2%	because the belted occupied more dangerous seating positions	+2% 55%
ADD 1%	because belt usage was higher in highway speed crashes	+1% 56%
SUBTRACT 3%	because belt usage was lower in older cars	-3% 53%
SUBTRACT 3-4%	because, in each speed group, belt usage was lower in single vehicle accidents	-3 -4% 49 -50%
SUBTRACT 6-11%	because 3-5% of the unbelted uninjured told police that they used belts	-6 -11% 38 -43%

38 -43% REDUCTION IN FATAL AND SERIOUS INJURIES for unbelted occupants in rural Pennsylvania, 1971, if they had taken the time to buckle up their lap belts.

LIST OF REFERENCES

BOOKS AND ARTICLES:

[1] American Safety Belt Council, "The Automotive Safety Belt Story," New Rochelle, New York, 1970.

[2] Anderson, T.E. and K. Perchonok, "Utility of Property Damage Data in Vehicle Injury Source Analyses," Calspan Corporation, Buffalo, 1973, p. 3

[3] Garrett, J. W., R.C. Braisted and D.F. Morris, Tri-Level Accident Research Study, pp. 54-59 Calspan Laboratory, Buffalo, 1972.

[4] Joksch, H.C. and Horace Wuerdemann, "Estimating the Effects of Crash Phase Injury Countermeasures-I, The Reduction of the Fatality Risk," Accident Analysis and Prevention, Vol. 4 No. 2, pp. 89-108, Pergamon Press, Oxford, 1972.

[5] Joksch, H.C. and Horace Wuerdemann, "Estimating the Effects of Crash Phase Injury Countermeasures-II, The Fatality Trend and its Modification by Countermeasures," Accident Analysis and Prevention, Vol. 5 No. 1, pp. 1-26, Pergamon Press, Oxford, 1973.

[6] Kihlberg, J.K., Efficacy of Seat Belts in Injury and Noninjury Crashes, in Rural Utah, Calspan Laboratory, Buffalo, 1969.

[7] Levine, D.N. and B.J. Campbell, Effectiveness of Lap Seat Belts and the Energy Absorbing Steering System in the Reduction of Injuries, University of North Carolina, Chapel Hill, 1971.

[8] Mela, D.F., "How Accurate Are Seat Belt Statistics?," Highway Safety Highlights, Vol. 7 No. 12, University of North Carolina, Chapel Hill, 1974.

[9] Richardson, H.A., "Statistical Analysis of Safety Belt Usage in the State of Oregon," to appear.

[10] State of New York Department of Motor Vehicles, An Analysis of Accidents in New York State by Make of Vehicle, U.S. Report No. DOT/HS-800 735, 1972.

[11] State of New York Department of Motor Vehicles, Two Car Collision Study, Approved for U.S. Government only.

[12] State of New York Department of Motor Vehicles, VSDSS Research Studies, U.S. Report No. DOT/HS- 800 780, 1973.

[13] Traffic Accident Data Project, **Policies & Programs**, pp. 1-11, National Safety Council, Chicago, 1968.

[14] Waller, P.F. and P.Z. Barry, "Seat Belts: a Comparison of Observed and Reported Use," University of North Carolina, Chapel Hill, 1969.

DATA FILES:

[15] National Accident Summary File of 1971 accidents in 39 States, National Highway Traffic Safety Administration.

[16] New York Level I File of 1970 Accidents in eight western counties, Highway Safety Research Institute, Ann Arbor, Michigan.

[17] Washtenaw County File of 1969-1973 accidents in that Michigan county, Highway Safety Research Institute, Ann Arbor, Michigan.

Appendix A: Data Collection Protocol

The following pages contain the protocol used for collecting data for this study. It was used by the Pennsylvania State Police in 1971-72, and it is a good example of the Bilevel concept: the first two pages are merely the report form used by the State Police for all accidents. The third page is the supplemental form, designed and used only for this study, and filled out by the policeman at the accident scene. Instructions to the police for filling out the supplemental form are attached.

18664

SP-7-0015 PART 1

PENNSYLVANIA STATE POLICE

ACCIDENT REPORT

1. DATE: 18 Oct 71
2. INCIDENT NO.: P6-14504
3. TROOP: P
4. STATION:
5. CODE: 326
6. INVESTIGATOR:
7. BADGE NO.: 2072
8. DAY OF WEEK: onday
9. HOUR: 1325
10. DATE OF ACCIDENT: Oct 71, 19
11. CHECK IF HIT-RUN: ☐
12. SEVERITY: ESTIMATED TOTAL DAMAGES: $ 500.00 NUMBER INJURED: 1 NUMBER KILLED: 0

VEHICLE NO. 1

13. OPERATOR'S NAME:
14. OPERATOR'S NO. & STATE: Penna.
15. SEX: M
16. D.O.B.: 1 Aug 52
17. STREET ADDRESS: CITY: STATE: Pa ZIP CODE: 18630
18. OWNER'S NAME: Same as Operator
19. VEHICLE (YEAR, MAKE, TYPE): 60 Pont Sdn
20. REGISTRATION NO. AND STATE: Pa
21. STREET ADDRESS: CITY: STATE: ZIP CODE:
22. OWNER OF TRAILER:
23. TRAILER (YEAR, MAKE):
24. REGISTRATION NO. AND STATE:
25. STREET ADDRESS: CITY: STATE: ZIP CODE:
26. VEHICLE NO. 1 REMOVED TO:
27. BY:
28. ESTIMATED DAMAGE: $ 250.00

VEHICLE NO. 2

29. OPERATOR'S NAME:
30. OPERATOR'S NO. & STATE: Penna.
31. SEX: F
32. D.O.B.: 2 Apr 38
33. STREET ADDRESS: CITY: STATE: Pa 18657
34. OWNER'S NAME:
35. VEHICLE (YEAR, MAKE, TYPE): 62 Ford SW
36. REGISTRATION NO. AND STATE: Penna
37. STREET ADDRESS: Same as Operator CITY: STATE:
38. OWNER OF TRAILER:
39. TRAILER (YEAR, MAKE):
40. REGISTRATION NO. AND STATE:
41. STREET ADDRESS: CITY: STATE:
42. VEHICLE REMOVED TO: Driven from scene
43. BY: Operator #2
44. ESTIMATED DAMAGE: $ 250.00

OTHER

45. PEDESTRIAN'S NAME:
46. SEX:
47. CHECK ONE: ☐ UNINJURED ☐ INJURED ☐ KILLED
48. STREET ADDRESS: CITY: STATE: ZIP CODE:
50. NAME OF PROPERTY OWNER:
51. DESCR. OF DAMAGED PROPERTY:
52. ADDRESS:
53. ESTIMATED DAMAGE: $

COPY ... SAFETY ... OCT 1971

54. WEATHER: ☐ RAIN ☐ SNOW ☒ CLEAR ☐ FOGGY ☐ OTHER
55. ROADWAY: ☐ WET ☐ SNOWY ☒ DRY ☐ ICY ☐ OTHER
NO. LANES: 2 WIDTH: 22 FT.

LOCATION

56. CITY-BOROUGH-TOWNSHIP: Twp CODE: 216
57. COUNTY: Wyoming CODE: 65
58. ON: (STREET NAME OR HWY. NO.) PA 29
59. ZONE: 8
60. AT INTERSECTION WITH: (upper) Mtn. View Ter. Road
61. IF NOT AT INTERSECTION: FEET ☐ N ☐ S ☐ E ☐ W OF (STATION MARKER-INTERSECTION-ETC.)

OCCUPANTS

62. NAME	ADDRESS	AGE	SEX	INJURY	VEH. #	POSITION
Operator #1		19	M	A	1	1
Operator #2		33	F	N	2	1
Margaret	Pa18657	32	F	N	2	3
William E	Pa 18657	10	M	N	2	6

POSITION IN VEHICLE: 4 1 / 5 2 / 6 3 — DRIVER IS NO. 1

INJURY CODE:
A-VISIBLE SIGNS OF INJURY, BLEEDING, DISTORTED MEMBER OR HAD TO BE REMOVED FROM SCENE
B-OTHER VISIBLE INJURY, BRUISES, SWELLING, LIMPING, ABRASIONS
C-NO VISIBLE INJURY, BUT COMPLAINT OF PAIN, DIZZINESS, ETC.
D-DEAD BEFORE COMPLETION OF REPORT
N-NO INJURY

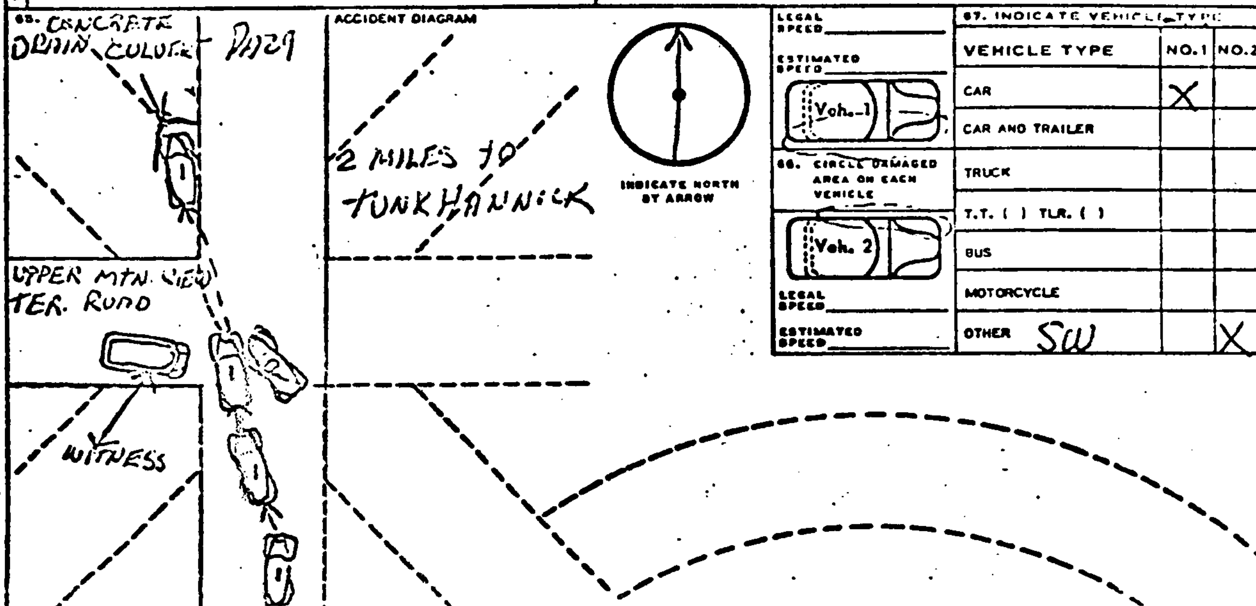
63. INJURED TAKEN TO: (Passing motorist)

REPORT NO. PG-14504

89-7-0018 PART II

64. WITNESSES NAME	ADDRESS
Edw rd C.	, Pa 18657

65. ACCIDENT DIAGRAM



67. INDICATE VEHICLE TYPE

VEHICLE TYPE	NO.1	NO.2
CAR	X	
CAR AND TRAILER		
TRUCK		
T.T. ( ) TLR. ( )		
BUS		
MOTORCYCLE		
OTHER SW		X

68. NARRATIVE

This accident occurred as both Vehicle #1 and Vehicle #2 were traveling north on PA 29. Vehicle #2 was justin the act of making her left turn onto the upper Mtn. View Ter. road. As Vehicle #2 was making the left curve Vehicle #1 attempted to overtake and Pass Vehicle #2 thus causing the collision. The right side of Vehicle #1 struck the left side of Vehicle #2. After the collision Vehicle #1 continued north on PA 29, onto the west berm and into a concreto drainage culvert.

Witness stated he observed both vehicles and how the accident occurred. Vehicle #2 was traveling north on PA 29 and was approaching the intersection with her left turn signal in operation. As she was making her turn Vehicle #1 traveling in the same direction attempted to overtake and pass Vehicle #2. The right side of Vehicle #1 struck the left side of vehicle #2.

Operator #1 was only one wearing seatbelt.

69. VIOLATION(S) INDICATED

NO. 1 Passing at an intersection NO. 2

ARRESTS

70. NAME OF PERSON(S) CHARGED: Roger

71. CHARGE(S): 1003C

72. ARREST REPORT NO.(S): M123530

73. INVESTIGATING OFFICER'S SIGNATURE: [signature]

74. SUPV. INITIALS: [initials]

75. IS INVESTIGATION COMPLETED? no

18664

PENNSYLVANIA STATE POLICE

ACCIDENT STUDY SUPPLEMENT

INCIDENT NO. P6-14504

DATE 18 Oct 71

OPERATORS AND PEDESTRIANS

VEHICLE NUMBER	NO. OF DRIVERS EDUCATION COURSES TAKEN	TYPE DRIVERS EDUCATION COURSES: H. S.	COMM.	MILITARY	OTHER	DATE COURSES TAKEN (YEAR)	LENGTH OF TIME SINCE FIRST DRIVER'S LICENSE ISSUED: YEARS	MONTHS	EST. MILEAGE DRIVEN IN PAST YEAR	FAMILIARITY WITH ROUTE (WHERE ACCIDENT HAPPENED) ROUTE DRIVEN: FREQ.	OCCAS.	1ST TIME
1	1	X				1968	3	6	50,000		X	
2	None						17	6	18,000	X		
PEDESTRIAN												

ALL OCCUPANTS

POSITION IN VEHICLE: 4 1 / 5 2 / 6 3 — OPERATOR IS NO. 1

	POSITION	LAP BELTS: NOT INSTALLED	INSTALLED: USED	INSTALLED: NOT USED	SHOULDER BELTS: NOT INSTALLED	INSTALLED: USED	INSTALLED: NOT USED	EJECTED: YES	PARTIALLY	NO
VEHICLE NO. 1	1		X		X					X
VEHICLE NO. 2	1			X	X					X
	3			X	X					X
	6			X	X					X

OPERATORS ONLY — ACCIDENT INVOLVED VEHICLE

VEHICLE NUMBER	LENGTH OF TIME DRIVEN (MONTHS)	ESTIMATED MILEAGE DRIVEN
1	8	50,000
2	7	15,000

ALL VEHICLES

VEHICLE NUMBER	ESTIMATED SPEED BEFORE IMPACT (MPH)	ODOMETER READING
1	45-50	3,626
2	10-15	61874

INSTRUCTIONS

1. Print legibly with ballpoint pen.
2. Attach this form to the original (white) copy of all Traffic Accident Reports.
3. Where there is no answer or response, leave the space blank. Use "X" where applicable.
4. Complete the captioned blocks in accordance with the following instructions:

INCIDENT NO.:	Use the same Incident Number as shown on the Accident Report.
DATE:	Insert the date the accident occurred.
OPERATORS AND PEDESTRIANS:	Captions are self-explanatory.
ALL OCCUPANTS:	Captions are self-explanatory. If more than two (2) vehicles are involved, use additional forms and insert the correct vehicle number(s). In cases where the "position in vehicle" diagram is not adequate to describe occupant position, e.g., a bus, use a brief description to summarize the required information.
OPERATORS ONLY:	Vehicle Number - self-explanatory. Length of Time Driven (Months) - how many months has the operator been driving the accident vehicle. Estimated Mileage Driven - how many miles has the operator driven the accident vehicle.
ALL VEHICLES:	Captions are self-explanatory.

Appendix B: Mathematical Notes

1. Standardization of Injury Rates

The introduction to the "Discussion on the Belted population" gives the example of standardizing the belted injury rate to the pre-impact speed distribution of the unbelted occupants. Here are the details of the arithmetic:

There were 29,967 unrestrained occupants, among whom 4,037 had fatal or serious injuries, a rate of 13.47%.

There were 6,915 lap-belted occupants, among whom 445 had fatal or serious injuries, a rate of 6.44% and a reduction of 52.2% from the unrestrained.

Now, suppose that the 29,967 had worn belts, and that the 29,967 and the 6,915 were identical in all respects except speed distribution (which was higher for the 6,915). Then the number of injuries sustained by the 29,967 is the sum, over all speed brackets, of the number among the 29,967 in that speed bracket times the injury rate for those of the 6,915 who had been in that bracket, viz:

TABLE 36

FATAL & SERIOUS INJURIES IN VARIOUS SPEED BRACKETS THAT WOULD HAVE OCCURRED IF THE 29,967 UNRESTRAINED OCCUPANTS HAD WORN LAP-BELTS

Preimpact Speed Bracket MPH	Number (A) of Unrestrained Occupants	Injury Rate (B) for Belted Occupants	Injuries That Would Have Occurred (A·B)
0	2,444	1.74%	42
1-10	4,228	2.55%	108
11-20	2,820	4.49%	126
21-30	3,896	6.47%	252
31-40	6,065	7.60%	461
41-50	5,737	7.19%	412
51-60	3,342	7.84%	262
61-70	1,237	11.50%	142
71+	198	40.74%	81
Totals	ΣA= 29,967		ΣAB= 1,886

Table 36 shows they would have sustained 1,886 injuries, which is a rate of 6.29%. This is 53.3% lower than the 13.47% which the 29,967 actually did sustain. Hence, although the 6,915 belted had only a 52.2% lower injury rate than the 29,967 unbelted, the latter would have had a 53.3% lower rate if they had used belts. Thus, we can say that the 52.2% is an underestimate, by a little over 1%, of the true injury-reducing capability of lap belts.

This is the sense of the words "underestimate" and "overestimate" as they are used in the "Discussion on the Belted Population."

2. Simultaneous Linear Equations to Determine Vehicle Age Effects

The data file codes, for each occupant, his seating position and what belts were installed, if any. Table 37 gives a bivariate analysis.

TABLE 37

INSTALLATION OF LAP AND SHOULDER BELTS BY SEATING POSITION

Seating Positions	Lap and Shoulder Belts	Lap Belts Only	No Belts Installed
Drivers & RF Passengers	13,227	12,655	4,994
RR & LR	0	3,409	1,048
CF & CR	0	1,828	757

The vehicle population can be divided into five age groups according to whether 8, 6, 4, 2, or 0 belts were installed. Let Y_1, Y_2, Y_3, Y_4 and Y_5, respectively be the percentage of vehicles in each of those age groups. Then, trivially, one obtains the linear equation

$$Y_1 + Y_2 + Y_3 + Y_4 + Y_5 = 100$$

From the bivariates in Table 35, one obtains four linear equations.

$$\frac{Y_1}{13,227} = \frac{Y_2 + Y_3 + Y_4}{12,655}$$

$$\frac{Y_1}{13,227} = \frac{Y_5}{4,994}$$

$$\frac{Y_1 + Y_2}{1,828} = \frac{Y_3 + Y_4 + Y_5}{757}$$

$$\frac{Y_1 + Y_2 + Y_3}{3{,}409} = \frac{Y_4 + Y_5}{1{,}048}$$

The simultaneous solution of these equations gives the vehicle-age distribution of rural Pennsylvania accident-involved occupants, which may be found in Table 10.

It was also necessary to determine, for each vehicle age group, the inflation of the injury rate due to vehicle age, viz.

$$Z_i = \frac{\text{injury rate for occupants of cars with (10-2i) belts}}{\text{injury rate for occupants of cars with 8 belts}}$$

Trivially, $Z_1 = 1$. To solve for the other Z_i, one needs the four linear equations that can be derived from Table 38.

TABLE 38

RATIO, BY SEATING POSITION AND TYPE OF BELTS, OF FATAL AND SERIOUS INJURY RATE FOR UNRESTRAINED OCCUPANTS WHO DID NOT HAVE THAT BELT AVAILABLE TO UNRESTRAINED OCCUPANTS OF THE SAME POSITION WHO HAD THAT BELT BUT DID NOT USE IT

Seating Positions	Type of Belt	Ratio
Driver & RF	Shoulder	1.1922
Driver & RF	Lap	1.3820
RR & LR	Lap	1.2983
CF & CR	Lap	1.2432

The four derived equations:

$$\frac{Y_2 Z_2 + Y_3 Z_3 + Y_4 Z_4 + Y_5 Z_5}{Y_2 + Y_3 + Y_4 + Y_5} = 1.1922\ Z_1$$

$$Z_5 = 1.3820 \quad \frac{Y_1 Z_1 + Y_2 Z_2 + Y_3 Z_3 + Y_4 Z_4}{Y_1 \quad Y_2 + Y_3 + Y_4}$$

$$\frac{Y_4 Z_4 + Y_5 Z_5}{Y_4 + Y_5} = 1.2983 \quad \frac{Y_1 Z_1 + Y_2 Z_2 + Y_3 Z_3}{Y_1 + Y_2 + Y_3}$$

$$\frac{Y_3 Z_3 + Y_4 Z_4 + Y_5 Z_5}{Y_3 + Y_4 + Y_5} = 1.2432 \quad \frac{Y_1 Z_1 + Y_2 Z_2}{Y_1 + Y_2}$$

After substituting the values for the Yi's obtained from the previous set of equations, one obtains his five simultaneous linear equalities in the Zi's.

The solutions are given in the right column of Table 11.

3. Linear Regression on Belt Usage in Single and Multiple Vehicle Accidents

Assume lap belt usage for single-vehicle-crash-involved occupants is constant at all hours of the day, and that lap belt usage for multiple-vehicle-crash-involved occupants is too. Then one obtains a linear functional relationship, viz. % using belts (@ some hour of day) = A [% multi-vehicle (@ that hour)] + B.

The coefficients A and B were estimated by regression, using the data of Table 31, to be 0.12 and 16.5, respectively. By substituting the values 0 and 100, respectively, for the variable in

% using belts = 0.12 (% multi-vehicle) + 16.5

one immediately obtains that belt usage in single-vehicle accidents was 16.5% at all times, and in multi-vehicle accidents, 28.5%.