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An Evaluation of Center High Mounted Stop Lamps Based on 1987 Data

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16. Abstract

Center High Mounted Stop Lamps (CHMSL) have been standard equipment on passenger cars since September 1, 1985, as required by Federal Motor Vehicle Safety Standard 108. The purpose of CHMSL is to safeguard a car from being struck in the rear by another vehicle: whenever brakes are applied, the CHMSL warns drivers of following vehicles that they must slow down. This report evaluates the effectiveness, benefits and costs of CHMSL based on their on-the-road experience during calendar year 1987, when approximately 1/4 of the passenger car fleet in the United States was CHMSL equipped. The effectiveness analysis is based on police reported accident files from 11 States. Cost estimates are based on detailed engineering analyses of 30 production CHMSL assemblies. It was found that:

- CHMSL equipped cars were 17 percent less likely to be struck in the rear while braking than the cars without CHMSL (confidence bounds: 13 to 21 percent).
- When all cars on the road have CHMSL, they will prevent 126,000 police reported accidents, 80,000 nonfatal injuries and $910,000,000 in property damage per year.
- CHMSL add $10.48 (in 1987 dollars) to the lifetime cost of owning and operating a car.
- At the effectiveness levels observed in the 1987 data, the CHMSL is a very cost effective safety device.

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SUMMARY

Center High Mounted Stop Lamps (CHMSL) have been standard equipment on all new passenger cars sold in the United States since September 1, 1985, as required by Federal Motor Vehicle Safety Standard 108. The purpose of CHMSL is to safeguard a car from being struck in the rear by another vehicle: whenever brakes are applied, the CHMSL sends a highly conspicuous, unambiguous message to drivers of following vehicles that they must slow down.

Executive Order 12291 (February 1981) requires agencies to evaluate the effectiveness, benefits and costs of their existing regulations. When NHTSA promulgated the CHMSL requirement in 1983, it published a Plan describing how the lamps would be evaluated subsequent to the effective date. Pursuant to the Plan, NHTSA published a preliminary effectiveness evaluation in 1987, based on early (Summer 1986) accident experience with production CHMSL. In that study, CHMSL equipped cars were 22 percent less likely to be struck in the rear while braking than cars without CHMSL.

This report follows up on the preliminary study, as stated in the Plan. It evaluates the effectiveness, benefits and costs of CHMSL based on their on-the-road experience during the full calendar year 1987, when approximately 1/4 of the passenger car fleet in the United States was CHMSL equipped. The effectiveness analysis is based on police reported accident files from all the States which submit their files to NHTSA and have data elements suitable for the analysis, a total of 11 States:

Florida	Indiana	Louisiana
Maine	Maryland	Michigan
Missouri	Pennsylvania	Tennessee
Texas	Utah	

The States have a wide geographic distribution. Four of the 10 most populous States are included.

The involvement rate in rear impacts for model year 1986-87 cars (all CHMSL equipped) is compared to 1980-85 cars (mostly without the lamps). The involvement rate is defined to be the ratio of rear impacts to non-rear impacts. "CHMSL effectiveness" is the reduction of the model year 1986-87 involvement rate relative to model year 1980-85, adjusted upward to reflect three factors: (1) About 10 percent of the 1980-85 cars were built or retrofitted with CHMSL; (2) A "vehicle age" effect whereby newer cars have a higher proportion of rear impacts than old cars - a bias that makes CHMSL look less effective than they really are; (3) Not all rear impacts are "CHMSL relevant" collisions in which the struck car was braking and the stop lamps were actuated prior to impact (and the State data do not distinguish between "CHMSL relevant" collisions and other rear impacts) - based on earlier studies, the effectiveness in reducing "CHMSL relevant" collisions is approximately 1.5 times as large as the effectiveness in reducing all rear impacts.

The 11 States contained records of over 80,000 CHMSL equipped cars in rear impact crashes. With that kind of sample, it was possible not only to estimate overall effectiveness precisely but to compare effectiveness in various crash types, environmental conditions, etc. (although not all of the State files could be used for some of the detailed analyses). Whereas the effectiveness estimates are uniformly positive, one caveat is that these fairly big positive numbers are derived - by the upward adjustment procedures described above - from initially smaller ones. Cost estimates are based on detailed engineering analyses of 30 production CHMSL assemblies. National Accident Sampling System data and NHTSA's studies of the societal cost of accidents are used, together with the State effectiveness estimates, in the analysis of benefits (crashes, injuries and damages avoided).

The principal findings and conclusions of the evaluation are the following:

Principal Findings

- CHMSL equipped cars were 17 percent less likely to be struck in the rear while braking than the cars without CHMSL. This is the weighted average of the results for 1987 data from 11 States. The confidence bounds for effectiveness are 13 to 21 percent.

- The observed effectiveness of CHMSL, by State, was:

Florida	23 percent	Missouri	20
Indiana	7	Pennsylvania	24
Louisiana	17	Tennessee	16
Maine	12	Texas	12
Maryland	11	Utah	10
Michigan	17		

The observed differences between States may be due to statistical error (limited sample sizes) and variations in driving environments, data definitions or accident reporting thresholds.

o The effectiveness of CHMSL in specific crash situations was as follows:

By crash severity

In crashes with property damage only	14 percent
In injury crashes	22
In fatal crashes	none
In nontowaway crashes	16
In towaway crashes	18

By crash type/driver actions

In 2 vehicle collisions	15
In 3 or more vehicle collisions	22
Front to rear collisions (with frame engagement)	21
Sideswipes (traveling same direction)	11
The <u>other</u> vehicle "following too closely"	25
The CHMSL vehicle "slowing down"	26
The CHMSL vehicle "stopped"	23
The CHMSL vehicle "turning"	16
The CHMSL vehicle "going straight"	14

By environmental/roadway conditions

During daylight	20
At night, dawn or dusk	8
Not at a traffic signal	19
At a traffic signal	15
Rural	22
Urban	16

By vehicle type

Cars with amber rear turn signals	18
Cars with red rear turn signals	17
Sedans, coupes or hardtops	17
Station wagons or hatchbacks	8

- The incremental costs of CHMSL per car (in 1987 dollars, discounted to net present values) are the following:

Initial purchase price increase	$9.05
Lifetime fuel consumption due to .95 pound weight increase	.95
Replacement of burnt out bulbs	.48
TOTAL COST PER CAR	$10.48

- The annual cost of CHMSL in the United States (based on 10 million cars sold) is $105 million.

- When all cars on the road have CHMSL, the annual benefits to the public are estimated to be the following:

Police reported crashes avoided	126,000
Nonfatal injuries avoided	80,000
Property damage and associated costs avoided (police reported and lower severity crashes)	$910 million

Conclusions

- CHMSL significantly reduced a car's risk of being struck in the rear by another vehicle.

- CHMSL are at least as effective in injury and in towaway crashes as in noninjury and nontowaway crashes.

- CHMSL are especially effective in preventing chain collisions involving 3 or more vehicles.

- CHMSL are significantly more effective in the daytime than at night. They also appear to be more effective away from traffic signals than at signals; in rural than in urban areas. In general, the simpler the accident scene, the more effective the CHMSL. The more a driver is distracted by other lights or traffic features, the less effective the CHMSL.

- At the effectiveness levels observed in the 1987 data, the CHMSL is a very cost effective safety device.

CHAPTER 1

INTRODUCTION AND BACKGROUND

Center High Mounted Stop Lamps (CHMSL) have been standard equipment on all new passenger cars sold in the United States since September 1, 1985. They are required by an October 1983 amendment [9] of Federal Motor Vehicle Safety Standard 108 [3]. CHMSL are red stop lamps mounted on the centerline of the rear of a passenger car, generally higher than the stop lamps on the sides of the car. They are activated by braking and are off at other times. The purpose of CHMSL is preventing crashes by reducing the reaction time for drivers to notice that the car in front of them is slowing down.

There are several hypotheses why CHMSL might stimulate a quicker reaction than conventional stop lamps. The central and raised location of CHMSL puts them "in an area of the forward visual field toward which a following driver most often glances [5]." Since its central location makes "the CHMSL separate and distinct from all other rear lamps and signals, any possible ambiguity of the signal is reduced," especially, the "likelihood that the signal will be interpreted as a directional signal [5]" (turn signal or tail lamp). The CHMSL, in combination with the two lower side mounted lamps, forms a triangle which could be an additional cue to get the driver's attention. The high mounting of the lamp might make it visible through the windows of a following vehicle and enable the driver of the third vehicle in a chain to react to the first car's braking. Some drivers may interpret the high mounted lamp as a warning to keep their distance; by following at a safer distance, they have more room to stop.

1.1 Evaluation of CHMSL

Executive Order 12291 (February 1981) requires agencies to evaluate their existing regulations [10]. The objectives of an evaluation are to determine the actual benefits - lives saved, injuries prevented, damages avoided - and costs of safety equipment installed in production vehicles in connection with a rule. This report evaluates the effectiveness, benefits and costs of CHMSL based on their on-the-road experience during 1987, when approximately 1/4 of the passenger car fleet in the United States was CHMSL equipped. The report follows up on NHTSA's preliminary evaluation based on CHMSL performance in mid 1986 [14]; it may be followed, in turn, by a final evaluation after the majority of cars on the road have CHMSL.

The CHMSL rule has evolved through the full cycle of experimental research, test fleets, regulatory analysis, rulemaking and evaluation. During 1974-79, experimental research with CHMSL equipped cars showed significant reductions in reaction time relative to conventional stop lamps [12], pp. III-19 - III-23, [5]. In 1976-79, NHTSA sponsored installation of CHMSL on test fleets comprising over 3000 vehicles. The CHMSL equipped cars had significantly fewer rear impacts than control groups with conventional lamps. The Regulatory Impact Analysis, published in 1983, includes detailed projections of the accidents, injuries and damages that might be avoided with CHMSL as well as a cost estimate [12].

It concludes that CHMSL would almost certainly be cost effective. When the CHMSL rule was promulgated in 1983 (with an effective date of September 1, 1985), a comprehensive evaluation plan [7] was published at the same time, outlining statistical and engineering analyses to determine the actual effectiveness and cost of production CHMSL. The preliminary evaluation published in 1987 [14] as well as this report follow the guidelines of the evaluation plan.

CHMSL retrofit kits are relatively easy to manufacture and install. Favorable public opinion and support by motorist groups such as the American Automobile Association helped create a substantial market for retrofit CHMSL. Inquiries to lamp manufacturers and the AAA reveal that approximately 4,000,000 CHMSL retrofit kits had been manufactured or imported into the United States by mid 1986 and most of them were installed on model year 1980-85 cars [14], p. 5. More cars have been retrofitted since then. It is likely that 10 percent of model year 1980-85 cars (or at least 1984-85 cars) had been retrofitted by mid 1987. As will be shown in Section 2.4, the percent of retrofits is one of the variables in the formula for estimating CHMSL effectiveness from accident data.

1.2 Results of earlier effectiveness and cost studies

The initial effectiveness studies are based on the 1976-79 test fleets [12], III-8 - III-18. The first test fleet consisted of Washington taxicabs [20]. Some taxis were equipped with CHMSL or other innovative stop lamps, while a control group of the same makes, models and driver characteristics had conventional stop lamps. Drivers reported all crash involvements; specifically, they reported whether they were struck in the rear while braking. That is the type of crash where CHMSL are most likely to have an effect; it is called a "CHMSL relevant" rear impact throughout this report. In the field tests, 67 percent of rear impacts were "CHMSL relevant" while the other 33 percent did not involve braking by the lead car. The most important finding of the field test with Washington taxicabs is that the CHMSL equipped cars had 54 percent fewer "CHMSL relevant" rear impacts per million miles than the control group.

NHTSA validated the first study with a larger test fleet of telephone company cars (2,500 with CHMSL) in 4 regions of the United States [25]. The results are nearly identical: the CHMSL equipped cars had 53 percent fewer "CHMSL relevant" rear impacts per million miles than the control group.

The Insurance Institute for Highway Safety sponsored a field test with New York City taxicabs and obtained an average 51 percent reduction of CHMSL relevant crashes [24].

The test fleets made a convincing case for CHMSL. They also set a precedent which influenced subsequent evaluations. Effectiveness was measured as a reduction of "CHMSL relevant" crashes, where the driver was braking before being struck. That is an intuitively reasonable measure and it was a convenient one in these studies, where the drivers reported the accidents and could say whether they used their brakes.

Subsequent evaluations based on police reported accidents have used the same measure of effectiveness. This has been inconvenient, because police data do not necessarily provide information about pre-crash braking - instead, the reduction of all types of rear impacts is calculated and then "adjusted" to estimate the reduction of relevant rear impacts (see Section 2.4).

NHTSA's Final Regulatory Impact Analysis [12] (FRIA), dated October 1983 based its effectiveness estimate on the field tests and its cost estimate on analyses of prototypes. Benefits (crashes, injuries and damages avoided) were projected based on quite conservative assumptions about the types of crashes in which CHMSL would be effective. The main predictions of the FRIA were:

Effectiveness	50 percent reduction of CHMSL relevant crashes (field test results rounded down)
Cost per car	$4.13-6.76 in 1982 dollars, which is equivalent to $4.86-7.95 in 1987 dollars
Injury reduction	40,000 per year (50 percent effectiveness was not assumed to apply to injury crashes; instead, NHTSA postulated a speed distribution for injury crashes and projected how improved reaction times with CHMSL would change this distribution)
Damage reduction	$434 million per year (conservative estimate of $282 average damage per crash involved vehicle; conservative assumption of the number of rear impact crashes; no effectiveness assumed in rural crashes)

Although the data in the FRIA and this report are not strictly comparable, it is noteworthy that the FRIA projects an effectiveness 3 times as high as the result found in this report (50 vs. 17 percent), but benefits only half as large as those found in Section 4.1 of this report. That is because of conservative assumptions about the applicability of the effectiveness estimate. NHTSA noted in the FRIA that the field tests mostly involved crashes of low severity; the effectiveness was not assumed to apply in higher severity situations such as most injury crashes, rural crashes, etc. By contrast, the analyses of this report show a lower overall effectiveness but CHMSL are at least as effective in injury and rural accidents as in lower speed crashes (see Chapter 3).

NHTSA's preliminary evaluation of CHMSL [14] is based on police reported accidents that occurred at the 50 National Accident Sampling System (NASS) areas during June-August 1986, a nationally representative data set. The involvement rate in rear impacts for model year 1986 cars (all CHMSL equipped) is compared to 1985 cars (mostly without the lamps). The sample included 1571 CHMSL equipped cars with rear impact damage (15 times larger than the sample in the field tests, but 1/50 as many cases as were used in the analyses of this report). The principal findings were:

Effectiveness	22 percent reduction of CHMSL relevant crashes
Confidence bounds	Not explicitly stated, but appear to be at least as wide as 11-33 percent, based on Table 1 (Assume that the 4 numbers in Table 1 have Poisson variances: this will result in the narrowest possible confidence bounds, viz. 11-33 percent, with no additional allowance for the data being derived from a cluster sample.)
Impact type	CHMSL likely to be more effective in crashes involving 3 or more vehicles than in 2 vehicle crashes
Rural/urban	No big differences in the effect of CHMSL between rural and urban areas

The effectiveness estimates of this report (17 percent) and the preliminary evaluation are not directly comparable, being derived from different sampling schemes. Nevertheless, the confidence bounds for the preliminary evaluation (no less than 11-33 percent) are obviously wide enough to "include" the estimate of this report and be "compatible" with it. This report confirms the preliminary finding that CHMSL are likely to be especially effective in crashes involving 3 or more vehicles. This report also confirms that there are no big differences in CHMSL effect between rural and urban crashes, although it suggests effectiveness may be slightly higher in rural areas.

The effectiveness results raise obvious questions. Do the effectiveness changes from over 50 percent in the test fleets, to 22 percent in the preliminary evaluation, to 17 percent in the 1987 data represent a significant downward trend? As more and more cars on the road have CHMSL, are drivers becoming "acclimatized" to the lamps and not paying quite as much attention to them [13]? What will happen in the next study?

Even the first question is not easy to address because the different samples and methods in the various studies makes it hard to compare their results (although the difference of 22 and 17 percent in the last two studies cannot be considered "significant" in any sense). Needless to say, the results of this report do not yet constitute a "final" assessment of CHMSL effectiveness. As recommended in the Evaluation Plan [7], p. 3, this report will be followed up with another analysis of State data in 2 or 3 years.

CHAPTER 2

OVERALL EFFECTIVENESS

Analyses of 1987 accident data from 11 State files yield an estimate that CHMSL equipped cars are 17 percent less likely to be struck in the rear while braking than cars without CHMSL. The accident reduction for CHMSL is statistically significant. The confidence bounds for effectiveness are 13 to 21 percent.

2.1 Data sources

The analysis requires a large sample of accident data which identify the model year of a car (pre-CHMSL or CHMSL-equipped) and the impact location (rear impact vs. other). State accident files are suitable for the analysis. The most recent accident data should be used in order to estimate the current effectiveness of CHMSL; as of January 1989, accident files for 1987 are the latest available State data.

NHTSA receives accident files from about half the States and maintains them for analysis. As of January 1989, 24 State files for calendar year 1987 were on line. Data from Alabama, Arizona, California, Colorado, Georgia, Illinois, Kansas, New Jersey, New Mexico, Ohio, Oregon and Washington were not used for the evaluation of CHMSL because they do not indicate the vehicle impact area. Minnesota data were not used because they do not indicate the model year. The remaining 11 State files are included in the CHMSL analysis:

Florida	Indiana	Louisiana
Maine	Maryland	Michigan
Missouri	Pennsylvania	Tennessee
Texas	Utah	

Although not a probability sample, these States have a wide geographic and demographic distribution. Maine, Maryland and Pennsylvania are in the Northeast. Indiana, Michigan and Missouri are in the Midwest. Florida, Louisiana and Tennessee represent the Southeast and South Central areas. Texas and Utah are in the Southwest and West. Four of the 10 most populous States are included (Florida, Michigan, Pennsylvania and Texas).

2.2 The basic contingency table

The objective of the analysis is to compare the likelihood of CHMSL equipped vs. pre-CHMSL cars being involved, while braking, as the struck vehicle in front to rear collisions with other vehicles (so-called "CHMSL relevant" crash involvements). CHMSL are assumed to have little or no effect on accident risk in crash modes other than rear impacts - i.e., the striking car in a front to rear collision or either car in a head-on or front to side collision - or even in rear impacts where the driver did not activate the lamp by braking. These other crash modes act as a control group. Ideally, it would be possible to tabulate the passenger car involvements in crashes by vehicle type (pre-CHMSL or CHMSL-equipped) and crash type (CHMSL-relevant or other). Let

A = n of pre-CHMSL cars in CHMSL relevant crashes (struck in the rear while braking)
B = n of pre-CHMSL cars involved in other vehicle to vehicle collisions
C = n of CHMSL equipped cars in CHMSL relevant crashes
D = n of CHMSL equipped cars involved in other vehicle to vehicle collisions

The basic contingency table is:

Type of Car	Number of Involvements: CHMSL Relevant	Number of Involvements: Not CHMSL Relevant
Pre-CHMSL	A	B
CHMSL equipped	C	D

The CHMSL equipped cars have D/B times as much exposure as the pre-CHMSL cars. Based on this exposure ratio, the expected number of CHMSL-relevant impacts in the CHMSL equipped cars is D/B x A. In fact, there are only C CHMSL-relevant impacts in the CHMSL-equipped cars. That is a reduction of

$$1 - [(C/A) / (D/B)]$$

in the probability of being struck in the rear while braking.

State data, however, do not identify exactly which cars have CHMSL; they only identify the model year and the make/model. All cars from model year 1986 onwards have CHMSL. Up through 1985, about 10 percent of the fleet has been retrofitted with CHMSL; also 1985 Cadillacs and a small number of other cars had them as original equipment (see Section 1.1). The best that can be done with State data is to exclude Cadillacs from the analysis, perform analyses of a pre-CHMSL vs. a CHMSL-equipped model year, and subsequently adjust the results to account for the retrofits (see Section 2.4). State data identify whether a car was struck in the rear or rear corner, but they cannot be relied on to indicate whether the car had been braking prior to the accident (CHMSL relevant crash). The best that can be done is to perform the analysis for rear impacts (including rear corner impacts) vs. a control group of side and frontal impacts, subsequently adjusting the results for the "irrelevant" rear impacts which did not involve braking.

Each State has its own unique ways of defining vehicle impact areas, crash mode, etc. Each State's data is analyzed separately from the others. The basic analysis approach is to extract the records of passenger cars involved in collisions with another motor vehicle in operation (car, truck, motorcycle, etc., but not a pedestrian, bicycle, or parked motor vehicle). The records are tabulated by impact area (rear or rear-corner impact vs. other impacts) for one specific pre-CHMSL model year vs. one CHMSL-equipped model year, yielding a 2 x 2 contingency table. For example, Florida data yield the following contingency table for model year 1985 (last year without CHMSL) vs. 1986 (first year with CHMSL):

	Number of Cars in 1987 Florida Collisions	
Model Year	With Rear Impact Damage	Without Rear Impact Damage
1985	6,517	19,708
1986	6,883	22,345

The contingency table shows that model year 1985 cars had 6,517 rear or rear-corner impacts in Florida during 1987. The control groups of frontal and side impacts included 19,708 cars of model year 1985 and 22,345 cars of model year 1986. In other words, the 1986 cars had 22,345/19,708 or 1.1338 times as much exposure as the 1985 cars. Based on the exposure ratio of 1986 to 1985, the expected number of rear impacts for 1986 cars would be 1.1338 x 6,517 = 7,389. In fact, there were only 6,883 rear impacts for model year 1986. That is a reduction of

$$1 - 6{,}883/7{,}389 = 1 - \left(\frac{6883}{6517} \bigg/ \frac{22345}{19708}\right) = 7 \text{ percent}$$

In other words, model year 1986 cars had a 7 percent lower risk of being involved in a rear impact collision than model year 1985 cars.

2.3 Regression estimate: combining tables for various model years

The preceding contingency table of model year 1985 vs. 1986 is only one of many that can be extracted from State accident files. There are two model years of CHMSL equipped cars: 1986 and 1987. Any of the years up to 1985 could be used as the pre-CHMSL comparison group. Ideally, if the data were unbiased, each of these tables would be expected to yield similar effectiveness estimates. The simple arithmetic average of these estimates (or the estimate based on a single table pooling all the data) would accurately indicate the effect of CHMSL.

There are, however, biases in the data. They are quite evident in the following series of estimates from Florida, in which 1986 and 1987 CHMSL equipped cars are each compared to pre-CHMSL model years from 1980 through 1985:

	Observed CHMSL "Effect" (%)		Observed CHMSL "Effect" (%)
1986 vs. 1980	-19	1987 vs. 1980	-22
1986 vs. 1981	-11	1987 vs. 1981	-13
1986 vs. 1982	-7	1987 vs. 1982	-10
1986 vs. 1983	-2	1987 vs. 1983	-4
1986 vs. 1984	+5	1987 vs. 1984	+3
1986 vs. 1985	+7	1987 vs. 1985	+5

There is an obvious trend toward increasingly unfavorable "results" for

CHMSL as the difference between the comparison model years increases. At one extreme, in the 85 vs. 86 comparison (1 year difference), the result is a 7 percent improvement for CHMSL. At the other extreme, in the 80 vs. 87 comparison (7 year difference), the CHMSL equipped cars have 22 percent higher rear impact risk than the ones without CHMSL. There are similar trends in the other States (see Appendix B).

The bias in the series is called the "vehicle age effect" and it occurs often in statistical analyses of accident data [16], [17], Chapters 3 and 4, [18]. Here, all of the accidents occurred in calendar year 1987. The earlier model years are older cars - e.g., the model year 1980 cars are 7 years old. Older cars have relatively fewer rear impacts and/or relatively more frontal and side impacts for reasons unrelated to stop lamps - i.e., because their drivers and/or driving environments differ from new cars. Thus, despite CHMSL, new cars have a lot more rear impacts <u>relative to</u> frontal and side impacts than 7 year old cars. That manifests itself as a spurious negative "effect" for CHMSL. It is noteworthy how steady the age effect is in the Florida series, e.g., the comparisons with 1986 cars: -19, -11, -7, -2, +5, +7. Observed effectiveness decreases by an average of approximately 5 percent for each additional year of age difference.

The real question is, "What would be the effect of CHMSL if there were zero age difference - if the pre-CHMSL and CHMSL-equipped cars were the same age?" Linear regression provides an answer. The 12 data points for the regression are the observed effectiveness values shown above. The dependent variable is the observed effectiveness. The independent variable is the age difference of the pre-CHMSL and CHMSL equipped model years. For example, the 80 vs. 86 comparison provides a data point with dependent variable -19 and independent variable 6. Also, the data points are weighted: the most recent control groups (84 and 85) are more reliable for estimating the effect of CHMSL than the older control groups (which are primarily used for estimating the age effect). The 85 vs. 86, 84 vs. 86, 85 vs. 87 and 84 vs. 87 comparisons can be considered, say, twice as important as the other comparisons. In other words, they are given a weight of 4 in the least squares regression formula while the other points are given a weight of 1.

The regression equation is:

$$y = A + B x$$

where

y = dependent variable = observed effect of CHMSL

A = regression intercept = TRUE EFFECT OF CHMSL

B = regression coefficient = age effect per year

x = independent variable = age difference, pre-CHMSL vs. CHMSL

In other words, the intercept of the regression line estimates what the effect of CHMSL would have been if there was no age difference between the pre-CHMSL and CHMSL equipped cars. In Florida, the regression line is:

$$y = 14.09 - 4.88 x$$

Thus, CHMSL reduces rear impacts by 14.09 percent (without correcting for retrofits and "relevant" rear impacts).

Appendix A specifies in detail the data definitions used in obtaining the contingency tables for each of the States. Appendix B shows the basic tables for each State, the 12 regression data points for each State, the regression intercept and the age effect.

2.4 Adjusting effectiveness for retrofits and "relevant" crashes

It was estimated in Section 1.1 that about 10 percent of pre-CHMSL cars have been retrofitted with CHMSLs. Thus, the estimate of 14.09 percent effectiveness in Florida is the reduction in rear impacts for a 100 percent CHMSL fleet relative to a 10 percent CHMSL fleet. That underestimates the effect of going from 0 percent to 100 percent. Let

e = effect of going from 0 to 100 percent CHMSL

E = effect of going from 10 to 100 percent CHMSL

Then

$$e = E / (.9 + .1E)$$

because

$$1 - E = [1 - e] / [.9 + .1(1 - e)]$$

For example, the estimated reduction of rear impacts for 100 percent vs. zero CHMSL in Florida is

$$.1409 / (.9 + .1 \times .1409) = 15.41 \text{ percent}$$

The estimated reduction of rear impacts of all types underestimates the reduction of "relevant" rear impacts, where the struck car was braking and activated the stop lamps. The earlier NHTSA field tests [5], in which drivers were asked about their precrash actions, suggest that 67 percent of rear impacts are "relevant." Thus, the effectiveness of CHMSL in reducing "relevant" impacts is

$$e' = e / .67$$

In Florida, the effectiveness of CHMSL in reducing relevant impacts is

$$e' = .1541 / .67 = 23.00 \text{ percent}$$

This last adjustment factor is used primarily to make the effectiveness estimates of this report comparable to those in earlier studies (see Section 1.2). Although it inflates "effectiveness," it does not affect net benefits, as will be seen in Chapter 4.

2.5 Effectiveness estimates by State

Similar regression procedures and adjustments are used in the other 10 States and yield the following estimates for CHMSL effectiveness in reducing "relevant" accidents (details in Appendix B):

Florida	**23.00 percent**	**Missouri**	**20.37**
Indiana	**6.83**	**Pennsylvania**	**23.80**
Louisiana	**16.51**	**Tennessee**	**15.62**
Maine	**12.33**	**Texas**	**11.75**
Maryland	**11.34**	**Utah**	**9.71**
Michigan	**17.21**		

It is noteworthy that CHMSL are effective in <u>every</u> State and every region of the country, with the reduction ranging from 7 percent in Indiana to 24 percent in Pennsylvania. Variations between the States could be due to statistical error, definitions of what is a "rear" impact, types of driving, roadways or exposure.

2.6 Averaging effectiveness across the States

The best estimate of CHMSL effectiveness is some kind of average across the States. It is undesirable to pool the data from the States when each State has its unique definitions of reportable accidents, rear impacts, etc. There is also the risk of distorting the results - e.g., a State which has high rear impact involvement rates might also have a high percentage of new cars. A better way is to take an average of the individual effectiveness estimates presented in Section 2.5. It should be a weighted average because some States obviously have a larger share of the exposure than others. One possible weight factor is the number of reported accidents. That is undesirable because it gives undue weight to States that have low reporting thresholds and, as a result, spuriously high accident rates.

A better alternative is to weight by the number of registered passenger cars. In 1987, the numbers of registered cars were [21]:

Florida	8,752,000	Missouri	2,741,000
Indiana	3,241,000	Pennsylvania	6,267,000
Louisiana	1,868,000	Tennessee	3,298,000
Maine	694,000	Texas	8,495,000
Maryland	2,830,000	Utah	760,000
Michigan	5,493,000		

With these weights, the average effectiveness of CHMSL is 16.95 percent.

2.7 Confidence bounds

A procedure for obtaining conservative (i.e., relatively wide) confidence bounds is to measure the variation of the 11 individual State estimates. That takes into account not only sampling error within States but also State to State differences in accident definitions, drivers, highways, etc. Although the best estimate of effectiveness was obtained by a weighted rather than a simple average, the most straightforward way to measure variance is to consider the 11 State estimates as a simple random sample. The 11 estimates, as noted above, range from 6.83 to 23.80. The standard deviation of the individual State estimates is 5.50. The standard deviation of the estimated average effectiveness based on a sample of 11 States is $5.50 / 11^{.5} = 1.66$. If the sample mean is t distributed with 10 degrees of freedom, a lower confidence bound for the effectiveness of CHMSL is

$$16.95 - 2.228 \times 1.66 = 13.25 \text{ percent}$$

while the upper bound is

$$16.95 + 2.228 \times 1.66 = 20.65 \text{ percent}$$

These are 95 percent confidence bounds in the sense that two-sided alpha is .05. Since $t = 16.95/1.66 = 10.21$ is far into the critical range of a t distribution with 10 degrees of freedom, the reduction for CHMSL is statistically significant (alpha is less than .05 or for that matter .0001).

2.8 A test for biases in the regression estimator

While the net results for CHMSL are positive in every State, a glance at Appendix B shows that the results of individual model year to model year comparisons are usually negative, breaking into the plus side only for the most recent control groups. The estimation method relies heavily on the regression step and on the assumption that the "vehicle age effect" calibrated by the regressions is what it claims to be. Could there be some bias in the analysis procedure that takes mostly negative numbers and gives a positive net result that has nothing to do with CHMSL?

The validity of the estimation procedure is tested by running a similar estimate on the pre-CHMSL model years only. It is pretended that model years 1984 and 1985 are "post-standard" while 1980-83 are "pre-standard." Of course, no major change in lamps happened in 1984. The effectiveness of this nonexistent standard is first calculated for 8 model year pairs: 80 vs. 84, 81 vs. 84, 82 vs. 84, 83 vs. 84, 80 vs. 85, 81 vs. 85, 82 vs. 85 and 83 vs. 85. Then, the 8 data points are entered into a regression, which calibrates the age effect and the "true effect" of the standard. If this true effect is consistently positive (or negative), that could indicate a bias in the estimation procedure. In fact, the results for the 11 States were:

Florida	- .69 percent	Missouri	+ .81
Indiana	-6.07	Pennsylvania	-13.64
Louisiana	-3.03	Tennessee	- 2.88
Maine	+3.42	Texas	+ 1.19
Maryland	+1.76	Utah	- 3.60
Michigan	- .62		

The weighted average of the effects is about -2.6 percent. Seven of the States had negative results while 4 had positive. Thus, the regression procedure does not show a strong bias in either direction.

CHAPTER 3

EFFECTIVENESS IN SPECIFIC SITUATIONS

Analyses of accident data from 11 State files show that CHMSL are substantially more effective during daylight (20 percent reduction of "relevant" rear impacts) than at night (8 percent). They are definitely more effective in preventing collisions involving 3 or more vehicles (22 percent) than 2 vehicle collisions (15 percent). They are significantly more effective in injury crashes (22 percent) than property damage crashes (14 percent). It also appears that CHMSL are more effective on rural roads than in urban areas; in front-to-rear crashes than in sideswipes; for sedans than for station wagons. An analysis of the Fatal Accident Reporting System does not show any fatality reduction for CHMSL, but the amount of data is still too small for definitive conclusions.

3.1 Analysis technique (States with missing data elements)

The objective of the analysis is to see if CHMSL are more effective in some types of crashes than others. For example, do they work better in the daytime or at night? The analysis is performed much the same way as in Chapter 2, using 1987 accident data from 11 States. Passenger car involvements in multivehicle collisions are tabulated by model year and impact area (rear vs. other). But here, additionally, they are classified by light condition: daylight vs. reduced light. Separate effectiveness analyses are performed for the daylight collision involvements and the nighttime ones.

Eleven comparative analyses of effectiveness were performed, using variables that frequently occur on State files:

Effectiveness by crash severity
- o Property damage only vs. injury vs. fatal crash
- o Nontowaway vs. towaway crash

Effectiveness by crash type/driver actions
- o Two vehicle crash vs. three or more vehicle crash
- o Front to rear impact [with frame engagement] vs. sideswipe [same direction, no frame engagement]
- o Striking car "following too close"
- o Struck car slowing down vs. stopped vs. "going straight ahead" vs. turning

Effectiveness by environmental/roadway conditions
- o Daylight vs. reduced light (nighttime, dawn or dusk)
- o At a traffic signal or stop sign vs. not at a signal
- o Urban vs. rural

Effectiveness by vehicle type
- o Cars with amber rear turn signals vs. red rear turn signals
- o Sedan, hardtop, coupe vs. station wagon, hatchback

In the example described above, the analysis is performed for daylight rear impacts (affected by CHMSL) vs. daylight front and side impacts (the "control group"). The control group should consist of all vehicle involvements which occur at the same times, places, vehicle types, and severities as the test group, but are not rear impacts (and are not significantly affected by CHMSL). The daylight front and side impacts are a good control group for daylight rear impacts because they are the most extensive group of crashes occurring at the same time as the test group (daylight hours). Similarly, the appropriate control group for towaway rear impacts is towaway front and side impacts.

The analysis is different for the four comparisons included in "effectiveness by crash type/driver actions." The appropriate control group for cars that were struck in the rear while stopped is not just the cars that were struck in the front or side while stopped: it is all cars that were struck in the front or side (i.e., the full control group defined in Chapter 2). As stated above, the control group should consist of all vehicle involvements which occur at the same times, places, vehicle types, and severities as the test group, but are not rear impacts (and are not significantly affected by CHMSL). Any front or side impact, regardless of whether the car was stopped, meets that criterion - because "stopped rear impact" puts no restrictions on times, places, vehicle types or severities. Similarly, the appropriate control group or measure of exposure for cars that were struck in the rear in a 3 vehicle collision is not just the cars that were struck in the front or side in a 3 vehicle collision: it is all cars that were struck in the front or side.

As in Section 2.3, effectiveness estimates are calculated in the individual States using a regression estimator based on comparisons of model years 1980-85 vs. 1986-87. These estimates are inflated to adjust for retrofit CHMSLs and "relevant" rear impact crashes, as in Section 2.4.

Finally, the individual estimates are averaged across the States. That is a straightforward process when estimates are available from each of the 11 States. The weighted average, based on the number of registered passenger cars in each State, is used as in Section 2.6. Some of the 11 variables, though, do not appear in all 11 State files (or they do appear on a State file but are coded "unknown" in most of the cases). Use of the weighted average in the remaining States could lead to a bias. For example, suppose the variable is missing in Louisiana and Utah, which had the lowest overall effectiveness estimates for CHMSL (see Section 2.6). The average for the remaining 9 States would be biased upwards.

A better technique is to use a weighted difference estimator, as illustrated by the following example for CHMSL effectiveness when the struck car had been slowing down (according to the police report):

	Overall Effect (E1)	Effectiveness When Slowing Down (E2)	E2 - E1	Reg. Pass. Cars (000)
Florida	23.00	unknown	unknown	
Indiana	6.83	33.66	+26.83	3241
Louisiana	16.51	50.82	+34.31	1868
Maine	12.33	41.42	+29.09	694
Maryland	11.34	unknown	unknown	
Michigan	17.21	unknown	unknown	
Missouri	20.37	22.40	+ 2.07	2741
Pennsylvania	23.80	24.64	+ .84	6267
Tennessee	15.62	unknown	unknown	
Texas	11.75	14.75	+ 3.00	8495
Utah	9.71	unknown	unknown	
11 State Wtd Average	16.95			

Note that the effectiveness of CHMSL for cars that were struck in the rear while "slowing down" is higher than the overall effectiveness in all 6 States that identified which cars were slowing down - i.e., the difference E2 - E1 is always positive. The difference estimator takes the weighted average of the differences (in the States where results are known) and adds it to the overall effectiveness estimate:

$$16.95 + \frac{26.83 \times 3241 + 34.31 \times 1868 + 29.09 \times 694 + 2.07 \times 2741 + .84 \times 6267 + 3.00 \times 8495}{3241 + 1868 + 694 + 2741 + 6267 + 8495}$$

= 25.85 percent effect for CHMSL when the struck car was slowing down

Binomial tests are used to check if there are significant differences in CHMSL effectiveness for two mutually exclusive crash situations. For example, it will be shown that CHMSL are estimated to be more effective in daylight than in reduced light in 9 of the 11 States. Since a binomial experiment with p = .5 has a 3 percent chance of 9 or more successes in 11 trials (e.g., an honest coin has a 3 percent chance of landing heads 9 or more times in 11 tosses), it is concluded that CHMSL are significantly more effective in daylight than in reduced lighting conditions. Use of the binomial (nonparametric) test is a good way to avoid obtaining spurious significant differences; parametric methods based on the magnitudes of the differences within States would have entailed a greater risk of spurious significant findings, since anomalous results for a single State could distort the averages.

Appendix A shows how the classification variables are derived from the various State data files.

3.2 Effectiveness by crash severity

All the State files except Maine allow easy distinction between property damage accidents and injury accidents. A vehicle is involved in an injury accident if anyone in the crash is injured - an occupant of that vehicle and/or an occupant of one of the other vehicles. A property damage accident is one in which nobody is injured. The CHMSL effectiveness estimates for property damage vs. injury accidents are as follows:

	CHMSL Effectiveness (%)	
	Property Damage Only	Injury Crash
Florida	20.15	25.14
Indiana	3.88	17.30
Louisiana	11.14	27.93
Maine	unknown	unknown
Maryland	6.87	14.66
Michigan	16.31	19.17
Missouri	21.86	17.21
Pennsylvania	17.19	25.29
Tennessee	7.65	36.63
Texas	8.87	16.49
Utah	8.62	12.11
BEST ESTIMATE	13.50	21.66

The best estimates are that CHMSL reduce the likelihood of being struck in the rear, while braking, with nobody injured, by 14 percent; the reduction of injury crashes is 22 percent. In 9 of the 10 States (all except Missouri), effectiveness is higher in injury crashes than property damage crashes. It is concluded that CHMSL are significantly more effective in reducing injury crashes than property damage crashes. This is a highly encouraging result for CHMSL.

For an analysis of fatal crashes, NHTSA's Fatal Accident Reporting System [8], which is based on records from all of the States, is obviously a more complete data source than the 11 State files. Nevertheless, since fatal rear impact crashes are much rarer than head-on or angle collisions, the sample is still small. While the analyses of State files are based only on calendar year 1987 data (to estimate current effectiveness), 1986 and 1987 FARS data are used here to get the largest possible sample. Fatal rear impact collisions are not only rare, they also differ from other rear impacts in that they are likely to involve an intoxicated driver in the striking vehicle (inattention to CHMSL) or much higher speeds and/or tractor trailers (long braking distances, even if CHMSL are seen) [15], pp. 91-95. The basic contingency tables for FARS are at the end of Appendix B. The series of effectiveness estimates (defined in Section 2.3) based on FARS are as follows:

	Observed CHMSL "Effect" (%)		Observed CHMSL "Effect" (%)
	Calendar Year 1987		
MY 1986 vs. 1980	-8	1987 vs. 1980	-14
1986 vs. 1981	+13	1987 vs. 1981	+8
1986 vs. 1982	+10	1987 vs. 1982	+6
1986 vs. 1983	-1	1987 vs. 1983	-6
1986 vs. 1984	+2	1987 vs. 1984	-4
1986 vs. 1985	+2	1987 vs. 1985	-3
	Calendar Year 1986		
MY 1986 vs. 1980	-33		
1986 vs. 1981	-26		
1986 vs. 1982	-13		
1986 vs. 1983	+3		
1986 vs. 1984	+2		
1986 vs. 1985	-13		

The haphazard fluctuation of the FARS estimates contrasts sharply, for example, with the Florida results (Section 2.3), which showed a strong trend from minus to plus. The 18 FARS results are input to a regression analysis similar to the one in Section 2.3. The regression line is

$$y = -0.14 - 1.10\ x$$

In other words, CHMSL has little or no observed effect (-0.14 percent) on fatal rear impacts. Before any definitive conclusions can be reached, though, the analysis will need to be repeated with more data in a future report.

Crash "severity" can also be classified by the extent of damage to the vehicles. All the State files except Tennessee and Utah distinguish between nontowaway and towaway crashes. A vehicle is involved in a towaway crash if any of the vehicles is towed from the scene - the case vehicle or one of the others. The CHMSL effectiveness estimates for nontowaways vs. towaways are as follows:

	CHMSL Effectiveness (%)	
	Nontowaway Crash	Towaway Crash
Florida	24.47	21.60
Indiana	4.49	16.62
Louisiana	12.71	29.35
Maine	15.88	4.42
Maryland	11.63	7.83
Michigan	15.10	16.44
Missouri	19.76	28.33
Pennsylvania	20.41	24.06
Tennessee	unknown	unknown
Texas	11.35	11.62
Utah	unknown	unknown
BEST ESTIMATE	16.05	18.09

The best estimates are that CHMSL reduce relevant nontowaway involvements by 16 percent and towaways by 18 percent. CHMSL do better on towaways in 6 States and nontowaways in 3; that is not significantly different from a 50/50 split. In the 4 largest States (Florida, Michigan, Pennsylvania, Texas), the differences are negligible. It can be concluded that CHMSL are about equally effective in towaways and nontowaways.

3.3 Effectiveness by crash type/driver actions

All 11 State files identify the number of vehicles involved in an accident. The CHMSL effectiveness estimates for 2 vehicle collisions vs. collisions of 3 or more vehicles are as follows:

	CHMSL Effectiveness (%)	
	2 Vehicle Collision	3 or More Vehicles
Florida	17.07	31.53
Indiana	6.16	10.08
Louisiana	14.16	24.35
Maine	12.53	36.93
Maryland	7.53	20.02
Michigan	17.71	14.06
Missouri	18.80	25.55
Pennsylvania	20.75	28.96
Tennessee	14.06	22.87
Texas	11.36	14.56
Utah	10.60	8.24
BEST ESTIMATE	14.75	21.84

The best estimates are that CHMSL reduce the likelihood of being the lead car in a 2 vehicle collision, while braking, by 15 percent; they reduce the likelihood of being one of the struck cars in a 3 vehicle collision, while braking, by 22 percent. In 9 of the 11 States (all except Michigan and Utah), effectiveness is higher in 3 vehicle collisions than 2 vehicle collisions. That means CHMSL are significantly more effective in preventing 3 vehicle collisions than 2 vehicle crashes. The result confirms the trend that was noted in the preliminary evaluation of CHMSL [14], pp. 14-18 (see Section 1.2). It is consistent with the hypothesis that CHMSL are especially effective in preventing chain collisions because they enable a driver to see if the car two vehicles ahead is braking.

All of the State files except Maine and Texas have a data element at the accident level called "manner of collision" or a similar name, with values like "front to rear," "head on," "angle," etc. The Michigan variable by that name is not useful because it is unknown in most cases. That leaves 8 States which specifically identify "front to rear" collisions as opposed to other crashes that may have resulted in rear impact damage to one of the vehicles. Moreover 5 of these 8 States have a separate category for "sideswipe - both vehicles moving in the same direction" as opposed to front to rear impacts with frame engagement. Here are the CHMSL effectiveness estimates for "front to rear collisions" vs. "sideswipes - same direction" as well as the overall effectiveness (for comparison purposes):

	CHMSL Effectiveness (%)		
	Front to Rear Collision	Sideswipe Same Direction	Overall
Florida	25.54	unknown	23.00
Indiana	15.79	- 4.21	6.83
Louisiana	19.20	11.15	16.51
Maine	unknown	unknown	12.33
Maryland	15.37	14.72	11.34
Michigan	unknown	unknown	17.21
Missouri	22.96	13.07	20.37
Pennsylvania	25.46	unknown	24.64
Tennessee	25.45	unknown	15.62
Texas	unknown	unknown	11.75
Utah	3.89	- 1.30	9.71
BEST ESTIMATE	20.75	11.30	16.95

In all 5 States which identify sideswipes as a separate category, effectiveness is higher in front to rear collisions than sideswipes. That means CHMSL are significantly more effective in preventing front to rear collisions than sideswipes. The result is intuitively reasonable because front to rear collisions are likely to involve cars traveling in the same lane and a lead car that is slowing down. Sideswipes may often involve cars traveling in different lanes. The lead car may not be braking at all and if it is, the CHMSL is off to the side of the following driver's visual field.

In 7 of the 8 States which identify "front to rear collisions" as a separate category, the effectiveness there is higher than overall CHMSL effectiveness (all except Utah). This is also a significant result and an intuitively reasonable one, since the front to rear collisions are the type where the lead car is likely to be braking and the following car likely to see the CHMSL.

Five State files have a "violations charged" data element at the accident level. That makes it easy to classify cars struck in the rear as to whether or not the <u>striking</u> vehicle's driver was charged with "following too closely." Here are the CHMSL effectiveness estimates in crashes where the striking vehicle was "following too closely" as well as the overall effectiveness of CHMSL (for comparison purposes):

	CHMSL Effectiveness (%)	
	Striking Vehicle "Following Too Closely"	Overall
Florida	unknown	23.00
Indiana	19.04	6.83
Louisiana	unknown	16.51
Maine	23.38	12.33
Maryland	15.65	11.34
Michigan	19.24	17.21
Missouri	unknown	20.37
Pennsylvania	36.81	24.64
Tennessee	unknown	15.62
Texas	unknown	11.75
Utah	unknown	9.71
BEST ESTIMATE	25.16	16.95

In all 5 States, CHMSL are more effective in preventing crashes where the striking car was "following too closely" than in other crashes. That is a statistically significant finding. The result is not as definitive as some of the others because it is based on only 5 States, the numbers of crashes in which tailgating was charged is just a fraction of the total, and the decision on whether to charge violations is at least partially subjective. Nevertheless, the result supports a hypothesis that CHMSL may have yet another safety benefit: some drivers may interpret the high mounted lamp as a warning to keep their distance. By following at a safer distance, they have more room to stop.

All of the States have data elements at the accident and/or vehicle level which describe the movement or intended movement of the struck vehicle just before the collision. For this evaluation, as documented in Appendix A, each State's variables are recoded into 4 major categories: the struck vehicle was slowing down (includes preparing to stop), stopped, going straight, or turning (includes preparing to turn). Vehicles that did not clearly fit into these categories (e.g., backing up, skidding, unknown) are excluded from this analysis. Maryland data could not be used since most vehicles were outside the 4 categories. In some States there is a single code for "stopped or slowing down": these are shown as "stopped," below. CHMSL effectiveness as a function of the struck car's movement is as follows:

CHMSL Effectiveness (%)

	Slowing Down	Stopped	Going Straight	Turning
Florida	unknown	28.65	14.02	17.80
Indiana	33.66	16.58	5.87	- 2.51
Louisiana	50.82	11.03	22.93	24.87
Maine	41.42	41.11	12.73	5.52
Maryland	unknown	unknown	unknown	unknown
Michigan	unknown	31.45	13.59	16.24
Missouri	22.40	23.21	18.97	23.22
Pennsylvania	24.64	24.47	28.21	unknown
Tennessee	unknown	28.84	15.06	- 2.07
Texas	14.75	14.91	7.98	19.78
Utah	unknown	12.23	0.69	35.62
BEST ESTIMATE	25.85	23.04	14.39	16.02

The rank order of the effectiveness estimates is intuitively reasonable. CHMSL are most effective when the struck car is in the process of slowing down or stopping: these are situations where the struck car is usually braking, activating the CHMSL. They are less useful when the struck car is turning or preparing to turn: brakes might not yet have been applied and the turn signal may already be giving the following driver a signal to slow down. Effectiveness is lowest when the struck car is "going straight ahead." One problem with the results is that they are positive even in the "going straight ahead" situation. At first glance, it might be assumed that these cars are not braking, so why would CHMSL have any effect? Could this indicate that the analysis method is biased in favor of CHMSL? A more likely explanation is that it is difficult for investigators to determine exactly what cars were doing before a crash and many of the cars coded as "going straight ahead" were actually braking at some time before the crash.

3.4 Effectiveness by environmental/roadway conditions

The most clearcut finding in this chapter is that CHMSL are more effective during daylight than in reduced light conditions such as nighttime (with or without street lighting), dawn or dusk. All the State files include "light condition" as a data element, with hardly any unknowns. The CHMSL effectiveness estimates by light condition are as follows:

	CHMSL Effectiveness (%)	
	Daylight	Reduced Light
Florida	25.60	14.38
Indiana	9.30	- .26
Louisiana	17.70	17.17
Maine	13.02	25.60
Maryland	9.02	17.04
Michigan	18.47	12.55
Missouri	22.30	11.33
Pennsylvania	31.34	3.35
Tennessee	19.17	5.84
Texas	14.24	3.23
Utah	17.93	-19.01
BEST ESTIMATE	19.77	8.47

The best estimates are that CHMSL reduce relevant rear impacts by 20 percent during daylight and by only 8 percent at night. That is the largest relative difference in this chapter. In 9 of the 11 States (all except Maine and Maryland), effectiveness is higher during daylight. It is concluded that CHMSL are significantly more effective during daylight hours than at other times. One possible explanation is that the driver's field of view is less cluttered by lamps during daylight: CHMSL and the triangle they make with the regular stoplamps are the only lights in front of the driver. At night, street lights, headlamps and taillamps of other vehicles may distract the driver. A second possibility is that regular stoplamps are hard to see during the daytime, because they are not that much brighter than ambient surfaces; thus, the CHMSL (directly in front of the driver) provides extra help by day. Another factor, undoubtedly, is that a substantial percentage of nighttime drivers are insufficiently alert or defensive because of alcohol or other factors; they don't react to the CHMSL at all or not in time.

State files usually include one or more data elements indicating what traffic signs or signals, if any, were at the scene of the crash (except the 1987 Pennsylvania file at NHTSA does not have this data element, even though it is on the hard copy forms). For the purpose of this analysis, a crash is defined to occur "at a traffic signal" if the sign or signal is at a fixed location and necessitates the driver's attention: traffic lights, stop signs, flashing lights, yield signs, railroad crossing signs. Not counted as "traffic signals" are stripes to indicate the edge of the trafficway, lane markings, advisory signs, etc. The CHMSL effectiveness estimates away from signals and at signals are as follows:

	CHMSL Effectiveness (%)	
	Not at a Traffic Signal	At a Traffic Signal
Florida	23.66	22.01
Indiana	7.53	7.39
Louisiana	25.67	8.35
Maine	9.92	25.22
Maryland	15.90	4.41
Michigan	18.25	16.31
Missouri	23.22	16.81
Pennsylvania	unknown	unknown
Tennessee	10.15	27.60
Texas	15.17	6.30
Utah	10.95	7.60
BEST ESTIMATE	18.57	15.48

The best estimates are that CHMSL reduce relevant rear impacts by 19 percent at locations where there are no traffic signals and by 15 percent at signals. In 8 of 10 States (all except Maine and Tennessee), effectiveness is higher away from signals. That is a borderline significant effect (p = .055 on the exact binomial test). Moreover, the 3 large States (Florida, Michigan, Texas) have higher effectiveness where there are no signals. The results lean in the direction of slightly higher CHMSL effectiveness when there are no traffic signals.

All the files except Maine have a "rural-urban" data element or a "population group" variable which permits rural/urban classification (places with fewer than 2,500 inhabitants are rural). The CHMSL effectiveness estimates in rural and urban areas are as follows:

	CHMSL Effectiveness (%)	
	Rural	Urban
Florida	23.89	22.37
Indiana	4.28	8.00
Louisiana	17.13	15.96
Maine	unknown	unknown
Maryland	15.63	9.96
Michigan	17.19	17.15
Missouri	29.87	18.24
Pennsylvania	34.22	21.62
Tennessee	10.54	15.47
Texas	23.15	10.44
Utah	45.37	3.01
BEST ESTIMATE	21.78	15.95

The best estimates are that CHMSL reduce relevant rear impacts by 22 percent in rural areas and by 16 percent in urban areas. In 8 of 10 States (all except Indiana and Tennessee), effectiveness is higher in rural places. That is a borderline significant effect (p = .055 on the exact binomial test), reinforced by the fact that the 4 large States all have higher effectiveness in rural areas.

The three comparisons for environmental and roadway conditions (daylight/dark, nonsignaled/signaled, rural/urban) point to a consistent and intuitively reasonable hypothesis: the simpler the accident scene, the more effective the CHMSL. When the driver's attention is diverted from CHMSL by the clutter of lights that begins after dark, or by the need to look at traffic signals, or by parked cars, vehicles in parallel lanes and other urban traffic characteristics - CHMSL effectiveness is lower.

3.5 Effectiveness by vehicle type

One hypothesis why CHMSL might be effective is that its central location makes it distinct from other rear lamps and signals, reducing, for example, the likelihood that stop lamps would be confused with turn signals. A possible extension of this hypothesis is that CHMSL might be less effective in cars with amber rear turn signals (where the distinctive color of the turn signal already makes it hard to confuse with stop lamps) than in cars with red rear turn signals (where, in the absence of CHMSL, the turn signals and stop lamps look about the same). Four of the State files have detailed make/model information that can be used to identify those cars which consistently had amber rear turn signals throughout 1980-87 (e.g., Nissan, Toyota, Volkswagen, Chevrolet Camaro, etc.) vs. those with consistently red signals (e.g., most Chrysler Corporation cars, Mercury, Lincoln, Pontiac Firebird, etc.). Makes and models which switched from red to amber or vice versa during 1980-87 are not used in the analysis. The CHMSL effectiveness estimates by turn signal type are as follows:

	CHMSL Effectiveness (%)	
	Cars with Amber Rear Turn Signals	Cars with Red Rear Turn Signals
Florida	unknown	unknown
Indiana	6.13	7.25
Louisiana	unknown	unknown
Maine	unknown	unknown
Maryland	12.03	25.03
Michigan	unknown	unknown
Missouri	unknown	unknown
Pennsylvania	29.29	25.24
Tennessee	unknown	unknown
Texas	9.78	7.08
Utah	unknown	unknown
BEST ESTIMATE	17.78	17.40

The best estimates are that CHMSL effectiveness is nearly identical in cars with amber rear turn signals (17.8%) and red rear turn signals (17.4%). Observed CHMSL effectiveness is higher in the cars with amber turn signals in 2 of the 4 States. Obviously, these data do not support a hypothesis that CHMSL effectiveness is lower in cars with amber rear turn signals. These results are really not surprising because only 10-20 percent of the rear impact collisions in the State data files involved a car which was turning; in 80-90 percent of rear impact collisions, the turn signals are not in operation and their color is irrelevant.

The location of CHMSL can influence their conspicuity. In sedans, hardtops and coupes, CHMSL are usually on the rear deck, a conspicuous location directly in the following driver's field of view. On station wagons and hatchbacks, the CHMSL is sometimes just under the roof, where it might not be as as noticeable. Seven of the State files have a "vehicle body style" data element which identifies station wagons and, in some cases, hatchbacks from other passenger cars. Station wagons are a small percentage of cars to begin with and their sample may be further reduced due to underreporting on this data element. The following results on CHMSL effectiveness by car type have a lot of sampling error for the station wagons:

	CHMSL Effectiveness (%)	
	Sedan, Coupe, Hardtop	Station Wagon, Hatchback
Florida	unknown	unknown
Indiana	unknown	unknown
Louisiana	unknown	unknown
Maine	17.72	5.95
Maryland	11.59	2.91
Michigan	18.22	-15.53
Missouri	19.09	44.35
Pennsylvania	23.84	20.86
Tennessee	16.00	1.85
Texas	12.28	5.46
Utah	unknown	unknown
BEST ESTIMATE	17.37	8.24

The State to State variation for station wagons is too large for the "best estimate" to be statistically meaningful. Nevertheless, the observed effectiveness is higher in sedans than in station wagons in 6 of 7 States (all except Missouri). That is a borderline significant effect ($p = .063$ on the exact binomial test), reinforced because effectiveness is higher in sedans in the 3 large States (Michigan, Pennsylvania, Texas). The results lean toward a tentative conclusion that CHMSL may be less effective in station wagons than in other cars. It might be due to the conspicuity factor suggested above or it could be for other reasons such as different exposure patterns for the two types of vehicles.

CHAPTER 4

BENEFITS AND COSTS

When all cars have CHMSL, the lamps will prevent an estimated 126,000 police reported crashes per year (and a much larger number of low speed crashes). CHMSL will prevent 80,000 injuries per year. The accident reduction due to CHMSL will reduce property damage and its associated societal costs by $910,000,000 per year (in 1987 dollars). CHMSL add $9 to the price of a car and 1 pound to its weight. Thus, the annual cost of CHMSL to consumers is about $100,000,000, which is a fraction of the benefits.

4.1 Benefits: accident, injury and property damage reduction

The National Accident Sampling System (NASS), until 1985, was a probability sample of the nation's police-reported crashes, including towaways and nontowaways [22], [23]. It is useful for estimating the number of rear impact crashes in the United States per year. More precisely, what is needed is a count of crashes involving 2 or more vehicles in transport (and no pedestrians or bicyclists) in which at least one passenger car has rear impact damage. That matches the definition of "rear impact crash" which was used in the effectiveness analyses based on State data (Chapter 2). With NASS data, it is straightforward to identify "crashes involving 2 or more vehicles in transport," "no pedestrians or bicyclists" and what is a "passenger car." There are several ways of identifying "rear impact damage." The definition used here is chosen because it virtually eliminates missing data. A car "has rear impact damage" if:

- The primary <u>or</u> secondary General Area of Damage in the Collision Deformation Classification [4] is 'B' <u>or</u>
- The primary <u>or</u> secondary Direction of Force in the Collision Deformation Classification is 4:00-8:00 (or 24-28, 44-48, etc.) <u>or</u>
- The NASS variable IMPTYPE = 4 (rear impact) <u>or</u>
- The crash involves exactly two vehicles in transport and it is a rear to rear collision (MANCOLL = 3) <u>or</u>
- The crash involves exactly two vehicles in transport and it is a front to rear collision or sideswipe (same direction) (MANCOLL = 1 or 5) and the car's role is "struck" or "striking and struck" (VEHROLE = 2 or 3).

During 1983-85, the last 3 years before CHMSL were required on passenger cars, the NASS estimates of police reported crashes in the United States and multivehicle crashes in which at least one car had rear impact damage are as follows:

	Police-Reported Crashes	Rear Impact Crashes
1983	5,858,000	1,076,000
1984	5,905,000	1,138,000
1985	6,080,000	1,121,000
3 YEAR AVERAGE	5,948,000	1,112,000

Without CHMSL, there are 1,112,000 police reported crashes per year in which a car is struck in the rear. As noted in Section 2.4, only 67 percent of these crashes are estimated to be "relevant" rear impacts in which the car was braking (and CHMSL might have made a difference). Thus, there are

.67 x 1,112,000 = 745,000 "relevant" rear impact crashes per year

It is estimated that CHMSL eliminate 16.95 percent of "relevant" rear impact crashes (see Section 2.6). As a result, when all cars have CHMSL, there will be

$$.1695 \times 745,000 = 126,000$$

fewer police reported crashes each year.

The estimation of injury reduction is similar. It should be noted that, when CHMSL prevents a collision from happening, it prevents all the injuries that would have happened in that crash: not only in the struck car but even in the other cars, trucks or motorcycles involved. Here are the 1983-85 NASS estimates of numbers of persons injured in crashes in the United States - and the numbers of persons injured in multivehicle crashes in which at least one car had rear impact damage are as follows:

	Persons Injured in Crashes	Rear Impact Crash Injuries
1983	3,404,000	677,000
1984	3,600,000	762,000
1985	3,367,000	643,000
3 YEAR AVERAGE	3,457,000	694,000

Without CHMSL, there are 694,000 car, truck and motorcycle occupants injured per year in crashes in which a car is struck in the rear. Only 67 percent of these injuries are estimated to be in "relevant" rear impacts in which the car was braking. Thus, there are

$$.67 \times 694,000 = 465,000 \text{ injuries}$$

in "relevant" rear impact crashes per year.

The analysis in Section 3.2 suggests that CHMSL may well be significantly more effective in reducing injury crashes than property damage crashes: they are estimated to reduce "relevant" injury crashes by 21.66 percent. That would imply a reduction of

$$.2166 \times 465{,}000 = 101{,}000 \text{ injuries per year}$$

For a more conservative estimate, the overall effectiveness of CHMSL (16.95 percent) could still be assumed to apply to injury crashes as well. In that case, when all cars have CHMSL, there would be

$$.1695 \times 465{,}000 = 79{,}000 \text{ fewer injuries per year.}$$

Another measure of the benefit of CHMSL is the cash value of the property damage avoided when the lamps prevent crashes. Benefits are not limited to the reduction of police reported crashes. Ther should be a proportionally similar reduction of damages below the police reporting threshold in which repairs are paid by insurance companies or the owners themselves. NHTSA has estimated the societal cost (in 1986 dollars) of property damage in all of these types of crashes during 1986 [6], Table 5. The total cost of "property damage only" accidents is $29,594,000,000, including the cost of the damage itself plus associated legal and insurance costs, etc. The cost of property damage in nonfatal, nondangerous injury crashes (AIS 1-3) is $4,151,000,000 (based on the results in Section 3.2, no effectiveness is assumed for CHMSL in fatal or dangerous injury crashes). Thus, a total of $33,745,000,000 in societal costs can be ascribed to property damage. Based on the increase in the Consumer Price Index for new cars from 224.4 to 232.5, that translates to $35,000,000,000 in 1987 dollars.

The next job is to estimate what proportion of the damage occurs in rear impact crashes (reported or unreported). Little information is available on the unreported crashes; it may be best to use the 1983-85 NASS data on police reported accidents and assume the same proportions apply to the unreported ones. Here are the 1983-85 NASS estimates of the number of <u>vehicles</u> involved in police reported crashes in the United States - and the number of vehicles (including the striking cars, trucks and motorcycles) involved in multivehicle crashes in which at least one car had rear impact damage:

	Vehicles in Police Reported Crashes	Vehicles in Rear Impact Crashes	Percent in Rear Impact Crashes
1983	9,865,000	2,246,000	22.77
1984	10,091,000	2,377,000	23.55
1985	10,450,000	2,361,000	22.60
3 YEAR AVERAGE	10,135,000	2,328,000	22.97

The proportion of damage costs that occurs in rear impact crashes should be about the same as the proportion of crash involved vehicles that are in rear impact crashes. Without CHMSL, 22.97 percent of crash involved vehicles are in rear impact crashes and

$$.2297 \times \$35,000,000,000 = \$8,040,000,000$$

property damage occurs each year in rear impact crashes. Only 67 percent of the damage is estimated to be in "relevant" rear impacts in which the struck car was braking. Thus, there is

$$.67 \times \$8,040,000,000 = \$5,390,000,000$$

property damage in "relevant" rear impact crashes per year. If the estimate that CHMSL eliminates 16.95 percent of "relevant" police reported rear impact crashes is also valid for unreported crashes, the property damage reduction for CHMSL would be

$$.1695 \times \$5,390,000,000 = \$910,000,000 \text{ per year}$$

4.2 Cost analysis

During 1985-88, a NHTSA contractor estimated the purchase price increase and weight added to passenger cars by CHMSL [2], [19]. Estimates were obtained for a representative sample of 15 cars of model year 1986, the first year the lamps were required. These were supplemented by 15 cars of model year 1987: 14 that were not in the 1986 sample and one car in the 1986 sample whose lamps were redesigned (Cadillac DeVille). The contractor disassembles or "tears down" each CHMSL to the lowest possible level of component parts. The contractor weighs the parts and estimates the cost of materials, labor, tooling, variable burden and assembly. Manufacturers' and dealer' markups and taxes are added to calculate the purchase price increase for CHMSL. The cost estimate includes the lamp assembly plus the wiring harness and all other modifications to the car's electrical system. The results, calculated in 1987 dollars, are shown in [19], pp. 23 and 26. The following table includes the contractor's results plus the 1986 and 1987 sales of the 30 cars in the sample (based on the 1987 and 1988 Automotive News Market Data Books [1]):

	Weight Increase (Pounds)	Price Increase (1987$)	1986 Sales (000)	1987 Sales (000)	86-87 Sales (000)
DOMESTIC CARS					
86 Cadillac DeVille	1.02	$6.76	203	n.a.	203
87 Cadillac DeVille	.99	8.29	n.a.	235	235
86 Chevrolet Camaro	1.49	12.98	163	117	280
86 Chevrolet Cavalier	1.09	8.01	357	307	664
87 Chevrolet Celebrity	.84	7.41	409	306	715
86 Chrysler 5th Avenue	1.05	7.76	107	58	165
86 Dodge Aries	.78	6.63	108	99	207
87 Dodge Shadow	.55	7.46	20	77	97
86 Ford Crown Victoria	1.19	12.12	134	118	252
86 Ford Escort	.62	8.69	402	392	794
87 Ford Mustang	1.08	12.30	168	173	341
87 Ford Taurus	1.16	10.65	263	355	618
86 Ford Tempo	1.15	11.88	265	219	484
87 Ford Thunderbird	1.03	10.38	141	133	274
86 Mercury Cougar	1.42	11.83	114	111	225
86 Olds Cutlass Supreme	1.03	8.27	192	93	285
87 Olds Delta 88	.89	7.25	261	169	430
86 Olds 98	1.02	8.24	109	72	181
87 Plymouth Horizon	.70	9.74	111	46	157
86 Pontiac Fiero	.53	6.30	68	42	110
					6717
IMPORTS					
86 Honda Accord	.80	9.02	325	335	660
87 Honda Civic CRX	.91	7.11	236	221	457
87 Hyundai Excel	.64	8.44	169	264	433
87 Mazda 626	.74	7.92	92	74	166
87 Mercedes 190	.81	9.66	22	18	40
86 Nissan Maxima	1.04	9.20	113	94	207
87 Nissan Sentra	1.15	10.41	211	240	451
87 Subaru Wagon	1.05	7.69	77	82	159
86 Toyota Camry	.89	8.52	152	187	339
87 Toyota Corolla	.73	8.23	159	164	323
					3235
86-87 SALES WTD AVERAGE	0.95	$9.05			

Several trends are evident from the table. One is that the price and weight of CHMSL varies within a relatively narrow range. As a result, the sample of 30 cars is more than adequate for a precise estimate of average cost and weight. There does not appear to be much correlation between the cost of CHMSL and the size or price of the car - e.g., the CHMSL for Olds 98 and Mercedes 190 are about average in cost. There are no large differences between types of cars or between domestics and imports. That increases the accuracy of the estimate. The table notes that the domestic cars in the sample accrued 6,717,000 sales during 1986-87, which is 46.7 percent of the 14,382,000 domestic cars sold in 1986-87 (excluding "transplants" - i.e., cars assembled in North America by overseas manufacturers). Imports in the sample sold 3,235,000 during 1986-87, which is 44.3 percent of the 7,297,000 import sales (plus transplants). In other words, the sample has the right mix of domestic and imported models.

With 1986-87 sales (the last column on the table) as a weight factor, the average price increase for CHMSL is $9.05 (in 1987 dollars) and the weight increase per car is 0.95 pound.

The consumer cost of CHMSL over the life of a car is the sum of the purchase price increase and any operating costs such as fuel or repairs. Each pound of weight added to a car results in a 1.17 gallon increase in lifetime fuel consumption [11]. Since the cost of fuel has varied in recent years, it is best to use a round number such as $1 for the net present value of the increase in fuel consumption per pound of weight added to the car (i.e., 1.17 gallons x price per gallon x discount factor). CHMSL, which weigh 0.95 pound, add approximately $0.95 to lifetime fuel consumption as a result of the weight increase. Since CHMSL are almost always inside the passenger compartment, they do not add to aerodynamic drag, so there is no fuel penalty other than the weight increase.

CHMSL bulbs may burn out and require replacement. NHTSA's evaluation of side marker lamps suggested that each of those lamps has about 1 chance in 5 of being replaced over the life of the car [16], p. 135. Since CHMSL are switched on and off more frequently than side marker lamps, they might wear out sooner. It is assumed that CHMSL bulbs are replaced once during the life of the car, typically during the car's 8th year. At a retail cost of $1 for the bulbs and a discount factor of .478 (10 percent for 7 years, since the replacement is in the 8th year), the net present value of the repair is $0.48.

The lifetime consumer cost per car is the sum of the purchase price increase, the fuel penalty and bulb replacement:

$9.05 + .95 + .48 = $10.48 per car

Since 10,000,000 passenger cars are sold annually in the United States, the total cost of CHMSL is approximately $105,000,000. That is just a fraction of the estimated property damage reduction of $910,000,000. Since the damage reduction pays for the lamps many times over and, in addition, the lamps prevent many injuries, it is obvious that CHMSL are cost effective.

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APPENDIX A

STATE AND FARS DATA DEFINITIONS

FLORIDA

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DATA CHUCK1; SET FLACC.ACC;                              creation of analysis file
 IF NUM_VEH GE 2;                                        2 or more vehicle crashes
 IF EVENT1=4 OR EVENT1=11 OR EVENT1=12 OR EVENT1=14 OR EVENT1=15 OR
 EVENT1=34 THEN DELETE;    excl "veh" which are ped, bike, parked car, etc.
 KEEP CASENO DAM_SEV EVENT1 EVENT2 INJSEV LANDUSE LIGHT NUM_VEH
 RD_SYS TR_CNTL1 TR_CNTL2 TAR_DAM;
DATA CHUCK2; SET FLVEH.VEH;
 IF VEH_TYPE='01';                                                 passenger car
 IF PNT_IMP NE 88;                               exclude unknown damage location
 IF 78 LE VEH_YR LE 88;
 IF MAKE NE 'CADI' AND MAKE NE 'CAD ';                         exclude Cadillacs
 IF 8 LE VEH_MOV LE 9 THEN DELETE;                           exclude parked cars
 KEEP CASENO VEHNO MAKE PNT_IMP VEH_MOV VEH_YR VIN;
DATA FLA.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NUM_VEH GE 2 AND 78 LE VEH_YR LE 88;

DATA CHUCK1; SET FLA.ACCVEH;                          generates contingency tables
IF 80 LE VEH_YR LE 87;                                         model years 1980-87
IF 7 LE PNT_IMP LE 9                                        rear vs. other impacts
 THEN DAMAGE='BACK ';  ELSE DAMAGE='OTHER';
IF LIGHT=1 THEN DAYLIGHT='YES'; ELSE IF 2 LE LIGHT LE 5 THEN
 DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';                             light condition
IF 3 LE TR_CNTL1 LE 8 OR 3 LE TR_CNTL2 LE 8 THEN SIGNAL='YES';
 ELSE IF 1 LE TR_CNTL1 LE 9 OR 1 LE TR_CNTL2 LE 9 THEN
 SIGNAL='NO'; ELSE SIGNAL='UNK';                     presence of traffic signal
IF 2 LE INJSEV LE 6 THEN INJURY='YES'; ELSE INJURY='NO';          injury crash
IF NUM_VEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';       2 veh vs. 3 or more
IF LANDUSE=1 THEN RURAL='YES'; ELSE RURAL='NO';                     rural/urban
IF EVENT1=1 OR EVENT2=1 THEN CRSHMODE='REAR ';
 ELSE CRSHMODE='OTHER';                                    manner of collision
IF VEH_MOV=2 THEN VEHMANU='STOPPED ';                includes 'slowing down'
 ELSE IF VEH_MOV=5 OR VEH_MOV=3 OR VEH_MOV=10
 THEN VEHMANU='TURNING ';
 ELSE IF VEH_MOV=1 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                         precrash movement of struck veh
IF DAM_SEV=1 THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                   towaway
KEEP VEH_YR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL
 CRSHMODE VEHMANU TOWAWAY;
PROC FREQ; TABLES VEH_YR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 VEHMANU TOWAWAY) * VEH_YR * DAMAGE / LIST NOCUM;       contingency tables
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INDIANA

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DATA CHUCK1; SET INACC.ACC;                              creation of analysis file
 IF NUM_VEH GE 2;                                        2 or more vehicle crashes.
 KEEP CASENO NUM_VEH SEVERITY URBAN POP_GRP RD_CLS PRIM_CON
 COL_DGRM LIGHT;
DATA CHUCK2; SET INVEH.VEH;
 IF VEH_TYP='01' AND INVOLVE1='01';                                   passenger car
 IF INIT_IMP NE 'U ';                           exclude unknown damage location
 MODELYR=INPUT(VEH_YR,2.0);
 IF 78 LE MODELYR LE 88;
 IF VEH_MK NE 'CADI' AND VEH_MK NE 'CAD ';                     exclude Cadillacs
 KEEP CASENO VEHNO VEH_MK VEH_MDL MODELYR TOWED INIT_IMP DAM_EST
 VEH_ACTN TRF_CNT1 TRF_CNT2;
DATA INDY.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NUM_VEH GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET INDY.ACCVEH;                          generates contingency tables
IF 80 LE MODELYR LE 87;                                          model years 1980-87
IF INIT_IMP='05' OR INIT_IMP='06' OR INIT_IMP='07'
 THEN DAMAGE='BACK ';  ELSE DAMAGE='OTHER';                rear vs. other impacts
IF LIGHT='1' THEN DAYLIGHT='YES'; ELSE IF LIGHT='2' OR LIGHT='3'
 OR LIGHT='4' OR LIGHT='5' THEN  DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';
TRAFCON1=INPUT(TRF_CNT1,2.0); TRAFCON2=INPUT(TRF_CNT2,2.0);
 IF 1 LE TRAFCON1 LE 8 OR 1 LE TRAFCON2 LE 8 THEN SIGNAL='YES';
 ELSE IF 9 LE TRAFCON1 LE 12 OR 9 LE TRAFCON2 LE 12 THEN
 SIGNAL='NO'; ELSE SIGNAL='UNK';                        presence of traffic signal
IF 1 LE SEVERITY LE 2 THEN INJURY='YES'; ELSE INJURY='NO';       injury crash
IF NUM_VEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';         2 veh vs. 3 or more
IF POP_GRP=. OR 1 LE POP_GRP LE 2 THEN RURAL='YES';
 ELSE RURAL='NO';                      'rural' should include villages up to 2500
IF COL_DGRM='01' THEN CRSHMODE='REAR STRT';            manner of collision=rear
 ELSE IF COL_DGRM='03' THEN CRSHMODE='SIDESWP';    sideswipe, same direction
 ELSE IF COL_DGRM='11' OR COL_DGRM='15' THEN CRSHMODE='REAR TURN';
 ELSE CRSHMODE='OTHER';                                'rear turn' extremely rare
IF PRIM_CON='14' THEN FOLLOW='YES'; ELSE FOLLOW='NO';      followed too close
IF VEH_ACTN='16' THEN VEHMANU='STOPPED ';
 ELSE IF VEH_ACTN='15' THEN VEHMANU='SLOWING ';
 ELSE IF VEH_ACTN='02' OR VEH_ACTN='03' OR VEH_ACTN='04'
 OR VEH_ACTN='05' THEN VEHMANU='TURNING ';
 ELSE IF VEH_ACTN='01' THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                           precrash movement of struck veh
IF TOWED='Y' THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                    towaway
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 FOLLOW VEHMANU TOWAWAY;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE FOLLOW
 VEHMANU TOWAWAY) * MODELYR * DAMAGE / LIST NOCUM;         contingency tables
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LOUISIANA

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DATA CHUCK1; SET LNACC.ACC;                                   creation of analysis file
 NUMVEH=INPUT(NUM_VEH,2.0);
 IF NUMVEH GE 2;                                              2 or more vehicle crashes
 IF ACC_TYP='C' OR ACC_TYP='E' OR ACC_TYP='F' OR ACC_TYP='G'
 THEN DELETE;               excl "veh" which are ped, bike, parked car, etc.
 KEEP CASENO ACC_TYP TYP_COLL HWY_TYP LIGHT NUMVEH POPUL RDWY_TYP;
DATA CHUCK2; SET LNVEH.VEH;
 IF VEH_TYPE='A';                                                         passenger car
 IF IMPACT NE ' ';                                     exclude unknown damage location
 MODELYR=INPUT(VEH_YR,2.0); IF 78 LE MODELYR LE 88;
 IF MVMT_PR='R' THEN DELETE;                                       exclude parked cars
 KEEP CASENO VEHNO CONTROL DAM_SCL DISABLED NO_INJ IMPACT MVMT_PR MODELYR;
DATA LOU.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NUMVEH GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET LOU.ACCVEH;                              generates contingency tables
IF 80 LE MODELYR LE 87;                                            model years 1980-87
IF IMPACT='F' OR IMPACT='G' OR IMPACT='H'
 THEN DAMAGE='BACK '; ELSE DAMAGE='OTHER';                    rear vs. other impacts
IF LIGHT='A' THEN DAYLIGHT='YES'; ELSE IF
 LIGHT='B' OR LIGHT='C' OR LIGHT='D' OR LIGHT='E' THEN
 DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';                                   light condition
IF CONTROL='A' OR CONTROL='B' OR CONTROL='C' OR CONTROL='D' OR
 CONTROL='E' OR CONTROL='F' OR CONTROL='G' OR CONTROL='H' OR
 CONTROL='I' OR CONTROL='J' OR CONTROL='K' OR CONTROL='L' OR
 CONTROL='M' OR CONTROL='N' THEN SIGNAL='YES';
 ELSE IF CONTROL='O' OR CONTROL='P' OR CONTROL='Q' OR
 CONTROL='R' OR CONTROL='S' OR CONTROL='U' OR CONTROL='V'
 THEN SIGNAL='NO'; ELSE SIGNAL='UNK';                     presence of traffic signal
IF NO_INJ GE 1 THEN INJURY='YES'; ELSE INJURY='NO';                       injury crash
IF NUMVEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';               2 veh vs. 3 or more
POP=MOD(POPUL,10); IF POP=9 THEN RURAL='YES'; ELSE RURAL='NO';           rural/urb
IF TYP_COLL='B' THEN CRSHMODE='REAR    ';                          manner of collision
 ELSE IF TYP_COLL='D' THEN CRSHMODE='SIDESWP'; ELSE CRSHMODE='OTHER';
IF MVMT_PR='A' THEN VEHMANU='STOPPED ';
 ELSE IF MVMT_PR='K' OR MVMT_PR='M' OR MVMT_PR='N' OR
 MVMT_PR='I' OR MVMT_PR='J' OR MVMT_PR='L' OR MVMT_PR='O'
 OR MVMT_PR='P' THEN VEHMANU='TURNING ';                          precrash movement
 ELSE IF MVMT_PR='Q' THEN VEHMANU='SLOWING ';                         of struck veh
 ELSE IF MVMT_PR='B' THEN VEHMANU='STRAIGHT'; ELSE VEHMANU='OTHER';
IF DISABLED='1' THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                      towaway
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL
 CRSHMODE VEHMANU TOWAWAY;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 VEHMANU TOWAWAY) * MODELYR * DAMAGE / LIST NOCUM;            contingency tables
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MAINE

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DATA CHUCK1; SET MEACC.ACC;                                  creation of analysis file
 IF UNIT_INV GE 2;                                           2 or more vehicle crashes
 IF 5 LE ACC_TYPE LE 6 OR ACC_TYPE=9 THEN DELETE;               excl ped, bike, etc.
 IF 13 LE ACT_VEH1 LE 14 THEN DELETE;
 IF 13 LE ACT_VEH2 LE 14 THEN DELETE;                           exclude parked cars
 KEEP CASENO ACC_TYPE TRF_CNTL LIGHT ACT_VEH1 ACT_VEH2
 HFAC_VH1 HFAC_VH2 UNIT_INV;
DATA CHUCK2; SET MEVEH.VEH;
 IF 1 LE VEH_TYP LE 4;                                                passenger car
 IF 1 LE DAM_CODE LE 10;                            exclude unknown damage location
 IF 78 LE VEH_YR LE 88;
 IF VEH_MAKE NE 5;                                                exclude Cadillacs
 KEEP CASENO VEHNO VEH_MAKE VEH_YR DAM_CODE VEH_TYP TOWED DAM_EST;
DATA MAINE.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF UNIT_INV GE 2 AND 78 LE VEH_YR LE 88;

DATA CHUCK1; SET MAINE.ACCVEH;                          generates contingency tables
IF 80 LE VEH_YR LE 87;                                            model years 1980-87
IF 4 LE DAM_CODE LE 6 THEN DAMAGE='BACK'; ELSE DAMAGE='OTHER';
IF LIGHT=2 THEN DAYLIGHT='YES'; ELSE IF                              light condition
 1 LE LIGHT LE 6 THEN DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';
IF 1 LE TRF_CNTL LE 6 OR 8 LE TRF_CNTL LE 9 OR TRF_CNTL=11 THEN
 SIGNAL='YES'; ELSE IF 7 LE TRF_CNTL LE 13 THEN SIGNAL='NO';
 ELSE SIGNAL='UNK';                                        presence of traffic signal
IF TOWED='2' THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                           towaway
IF UNIT_INV=2 THEN NUMVEHIN=2; ELSE NUMVEHIN=3;                 2 veh vs. 3 or more
IF VEHNO=1 THEN ACTVEH=ACT_VEH1; ELSE IF VEHNO=2 THEN
 ACTVEH=ACT_VEH2; ELSE ACTVEH=.;
 IF 3 LE ACTVEH LE 7 THEN VEHMANU='TURNING ';
 ELSE IF ACTVEH=11 THEN VEHMANU='STOPPED ';
 ELSE IF ACTVEH=10 THEN VEHMANU='SLOWING ';
 ELSE IF ACTVEH=1 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                             precrash movement of struck veh
IF VEH_TYP=4 THEN STAWAGON='YES';
 ELSE STAWAGON='NO';                                         sedan vs. station wagon
IF HFAC_VH1=4 OR HFAC_VH2=4 THEN FOLLOW='YES'; ELSE FOLLOW='NO '; too close
KEEP VEH_YR DAMAGE DAYLIGHT SIGNAL TOWAWAY NUMVEHIN
 FOLLOW VEHMANU STAWAGON;
PROC FREQ; TABLES VEH_YR * DAMAGE
 (DAYLIGHT SIGNAL TOWAWAY NUMVEHIN FOLLOW
 VEHMANU STAWAGON) * VEH_YR * DAMAGE / LIST NOCUM;             contingency tables
```

MARYLAND

```
DATA CHUCK1; SET MDACC.ACC;                              creation of analysis file
 IF ACC_TYPE=1 AND NUM_VEH GE 2;       2 or more veh crashes excl peds, etc.
 KEEP CASENO ACC_SEVE NUM_VEH COL_TYPE CITY RD_TYPE EVENT1-EVENT3
 FUNC_1 ILLUM PRM_CAUS SEC_CAUS;
DATA CHUCK2; SET MDVEH.VEH;
 IF VEH_TYP=2 OR VEH_TYP=3;                                          passenger car
 MODELYR=INPUT(VEH_YR,2.0);
 IF 78 LE MODELYR LE 88;
 IF VEH_MK NE 'CADIL' AND VEH_MK NE 'CADI ' AND VEH_MK NE 'CAD  ';
 KEEP CASENO VEHNO VEH_MK VEH_MD VIN_NUM MODELYR VEH_TYP DAM_SER
 PT_IMPCT AR_DAM1-AR_DAM3;
DATA MARYLD.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NUM_VEH GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET MD.ACCVEH;                           generates contingency tables
IF 80 LE MODELYR LE 87;                                       model years 1980-87
IF 7 LE PT_IMPCT LE 9 OR 7 LE AR_DAM1 LE 9 OR 7 LE AR_DAM2 LE 9
 OR 7 LE AR_DAM3 LE 9                                      rear vs. other impacts
 THEN DAMAGE='BACK ';  ELSE DAMAGE='OTHER';
IF ILLUM=1 THEN DAYLIGHT='YES'; ELSE IF 2 LE ILLUM LE 6 THEN
 DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';                              light condition
IF 1 LE FUNC_1 LE 4 OR FUNC_1=10 THEN SIGNAL='YES';
 ELSE SIGNAL='NO ';                                   presence of traffic signal
IF 2 LE ACC_SEVE LE 5 THEN INJURY='YES'; ELSE INJURY='NO';       injury crash
IF NUM_VEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';        2 veh vs. 3 or more
IF CITY='RURAL                ' THEN RURAL='YES'; ELSE RURAL='NO';
IF COL_TYPE=3 THEN CRSHMODE='REAR STRT';
 ELSE IF COL_TYPE=7 THEN CRSHMODE='SIDESWP';
 ELSE IF 4 LE COL_TYPE LE 5 THEN CRSHMODE='REAR TURN';
 ELSE CRSHMODE='OTHER';                                       manner of collision
IF PRM_CAUS=14 OR SEC_CAUS=14 THEN FOLLOW='YES'; ELSE FOLLOW='NO';
IF VEH_TYP=3 THEN STAWAGON='YES'; ELSE STAWAGON='NO';     sedan vs. stawagon
IF EVENT1=6 OR EVENT2=6 OR EVENT3=6 THEN VEHMANU='STOPPED ';
 ELSE IF EVENT1=3 OR EVENT2=3 OR EVENT3=3 THEN VEHMANU='SLOWING ';
 ELSE IF 12 LE EVENT1 LE 15 OR 12 LE EVENT2 LE 15 OR
 12 LE EVENT3 LE 15 THEN VEHMANU='TURNING ';
 ELSE IF EVENT1=1 OR EVENT2=1 OR EVENT3=1 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                          precrash movement of struck veh
IF DAM_SER=1 THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                     towaway
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 FOLLOW STAWAGON VEHMANU TOWAWAY;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE FOLLOW STAWAGON
 VEHMANU TOWAWAY) * MODELYR * DAMAGE / LIST NOCUM;      contingency tables
```

MICHIGAN

```
DATA CHUCK1; SET MIACC.ACC;                          creation of analysis file
 IF HARMEV1=4 AND VEHFORMS GE 2;       2 or more veh crashes excl peds, etc.
 KEEP CLTWAY LGTCOND TRAFCONT CASENO ACCSEV VEHFORMS POP
 MANCOLL CIRCUMST;
DATA CHUCK2; SET MIVEH.VEH;
 IF VEHTYPE=1 AND 78 LE MODELYR LE 88;                          passenger car
 IF MAKE NE 3;                                               exclude Cadillacs
 KEEP CASENO MODELYR MAKE BODYTYPE AVOIDMAN PRIORLAT IMPCODE VEHDRBLE;
DATA MICH.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF VEHFORMS GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET MI.ACCVEH;                        generates contingency tables
IF IMPCODE NE 13; IF 80 LE MODELYR LE 87;                model years 1980-87
IF 4 LE IMPCODE LE 6 OR IMPCODE=11 THEN DAMAGE='BACK ';
 ELSE DAMAGE='OTHER';                                 rear vs. other impacts
IF LGTCOND=1 THEN DAYLIGHT='YES'; ELSE IF 2 LE LGTCOND LE 4 THEN
 DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';                         light condition
IF TRAFCONT=1 THEN SIGNAL='NO '; ELSE SIGNAL='YES';      at traffic signal?
IF 1 LE ACCSEV LE 2 THEN INJURY='YES'; ELSE INJURY='NO';        injury crash
IF VEHFORMS=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';     2 veh vs. 3 or more
IF 1 LE POP LE 3 THEN RURAL='YES'; ELSE RURAL='NO';              rural/urban
IF MANCOLL=2 THEN CRSHMODE='REAREND'; ELSE IF MANCOLL=4 THEN CRSHMODE
 ='SIDESWP'; ELSE CRSHMODE='OTHER';      manner/collision (usually missing)
IF CIRCUMST=4 THEN FOLLOW='YES'; ELSE FOLLOW='NO';       followed too close
IF BODYTYPE=5 THEN STAWAGON='YES'; ELSE STAWAGON='NO';          sedan/wagon
IF AVOIDMAN=7 THEN VEHMANU='SLOWING ';                         extremely rare
 ELSE IF AVOIDMAN=1 THEN VEHMANU
 ='STRAIGHT'; ELSE IF AVOIDMAN=12 THEN VEHMANU='STOPPED'; ELSE IF
 4 LE AVOIDMAN LE 6 THEN VEHMANU='TURNING';
 ELSE VEHMANU='OTHER';                      precrash movement of struck veh
IF VEHDRBLE=2 THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                towaway
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 FOLLOW STAWAGON VEHMANU TOWAWAY;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE FOLLOW STAWAGON
 VEHMANU TOWAWAY) * MODELYR * DAMAGE / LIST NOCUM;      contingency tables
```

MISSOURI

```
DATA CHUCK1; SET MOACC.ACC;                                  creation of analysis file
 IF NUM_VEH GE 2;                                            2 or more vehicle crashes
 IF ACC_TYPE=2 OR ACC_TYPE=5 OR ACC_TYPE=6 OR ACC_TYPE=8
 OR ACC_TYPE=9 THEN DELETE;                          excl ped, bike, parked car, etc.
 KEEP CASENO HWY_CLS LIGHT ACC_TYPE DIR_ANAL TWO_VEH ACC_SEV
 NUM_VEH POPULATN;
DATA CHUCK2; SET MOVEH.VEH;
 IF 1 LE VEH_BT LE 3;                                                   passenger car
 IF VEH_DAM='99' OR VEH_DAM='  ' THEN DELETE;                    excl unk damage loc
 MODELYR=INPUT(VEH_YR,2.0); IF 78 LE MODELYR LE 88;
 IF VEH_ACT1='13' THEN DELETE;                                   exclude parked cars
 IF VEH_MAKE='CADI' OR VEH_MAKE='CAD ' THEN DELETE;                exclude Cadillacs
 KEEP CASENO VEHNO VEH_MAKE VIN MODELYR VEH_DAM VEH_BT TRF_CNTL
 VEH_ACT1-VEH_ACT3 TOW_INFO;
DATA MO.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NUM_VEH GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET MO.ACCVEH;                               generates contingency tables
IF 80 LE MODELYR LE 87;                                           model years 1980-87
PNT_IMP=INPUT(VEH_DAM,2.0); IF 7 LE PNT_IMP LE 9
 THEN DAMAGE='BACK '; ELSE DAMAGE='OTHER';                   rear vs. other impacts
IF LIGHT='1' THEN DAYLIGHT='YES';
 ELSE IF LIGHT='2' OR LIGHT='3' OR LIGHT='4' THEN
 DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';                                 light condition
IF TRF_CNTL='1' OR TRF_CNTL='2' OR TRF_CNTL='3' OR TRF_CNTL='4'
 OR TRF_CNTL='5' THEN SIGNAL='YES'; ELSE IF TRF_CNTL='6'
 OR TRF_CNTL='7' OR TRF_CNTL='8' OR TRF_CNTL='9' THEN SIGNAL='NO ';
 ELSE SIGNAL='UNK';                                     presence of traffic signal
IF 1 LE ACC_SEV LE 2 THEN INJURY='YES'; ELSE INJURY='NO';            injury crash
IF NUM_VEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';            2 veh vs. 3 or more
IF POPULATN=12 OR POPULATN=99 THEN RURAL='YES'; ELSE RURAL='NO ';
IF TWO_VEH='61' THEN CRSHMODE='REAREND';                         manner of collision
 ELSE IF TWO_VEH='63' THEN CRSHMODE='SIDESWP'; ELSE CRSHMODE='OTHER';
IF VEH_BT=3 THEN STAWAGON='YES'; ELSE STAWAGON='NO';                     sedan/wagon
V1=INPUT(VEH_ACT1,2.0); V2=INPUT(VEH_ACT2,2.0); V3=INPUT(VEH_ACT3,2.0);
 IF V1=12 OR V2=12 OR V3=12 THEN VEHMANU='STOPPED ';
 ELSE IF 3 LE V1 LE 6 OR 3 LE V2 LE 6 OR 3 LE V3 LE 6 THEN
 VEHMANU='TURNING ';
 ELSE IF V1=8 OR V2=8 OR V3=8 THEN VEHMANU='SLOWING ';
 ELSE IF V1=1 OR V2=1 OR V3=1 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                               precrash movement of struck veh
IF TOW_INFO='Y' THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                       towaway
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 STAWAGON VEHMANU TOWAWAY;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE STAWAGON
 VEHMANU TOWAWAY) * MODELYR * DAMAGE / LIST NOCUM;            contingency tables
```

PENNSYLVANIA

```
DATA CHUCK1; SET PAACC.ACC;                                    creation of analysis file
 IF NUM_VEH GE 2;                                              2 or more vehicle crashes
 KEEP CASENO ACC_DESC PRIM_FAC EVENT LIGHT SEVERITY NUM_VEH URB_RUR;
DATA CHUCK2; SET PAVEH.VEH;
 IF VEH_TYPE=1;                                                            passenger car
 IF IMP_PT NE 99;                                        exclude unknown damage location
 IF 78 LE VEH_YR LE 88;
 KEEP CASENO VEHNO BODYTYPE IMP_PT TOWAWAY MAKE_MOD MOVEMNT VEH_YR;
DATA PENNA.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NUM_VEH GE 2 AND 78 LE VEH_YR LE 88;

DATA CHUCK1; SET PENNA.ACCVEH;                              generates contingency tables
IF 80 LE VEH_YR LE 87;                                               model years 1980-87
IF 5 LE IMP_PT LE 7 THEN DAMAGE='BACK ';
 ELSE DAMAGE='OTHER';                                             rear vs. other impacts
IF LIGHT=2 THEN DAYLIGHT='YES'; ELSE IF LIGHT=1
 OR 3 LE LIGHT LE 5 THEN  DAYLIGHT='NO';
 ELSE DAYLIGHT='UNK';                                                    light condition
IF 1 LE SEVERITY LE 4 THEN INJURY='YES';                                    injury crash
 ELSE IF SEVERITY=6 THEN INJURY='NO'; ELSE INJURY='UNK';
IF NUM_VEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';              2 veh vs. 3 or more
IF URB_RUR=1 THEN RURAL='YES'; ELSE IF 2 LE URB_RUR LE 3 THEN
 RURAL='NO'; ELSE RURAL='UNK';                                               rural/urban
IF ACC_DESC=1 THEN CRSHMODE='REAR ';
 ELSE CRSHMODE='OTHER';                                              manner of collision
IF PRIM_FAC=21 OR PRIM_FAC=34 THEN FOLLOW='YES'; ELSE FOLLOW='NO';
IF MOVEMNT=24 THEN VEHMANU='STOPPED ';
 ELSE IF MOVEMNT=23 THEN VEHMANU='SLOWING ';
 ELSE IF 25 LE MOVEMNT LE 26 THEN VEHMANU='TURNING ';
 ELSE IF MOVEMNT=18 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                                precrash movement of struck veh
IF TOWAWAY=1 THEN TOW='YES';
 ELSE IF TOWAWAY=0 THEN TOW='NO'; ELSE TOW='UNK';                                towaway
IF BODYTYPE=3 OR 5 LE BODYTYPE LE 7 THEN STAWAGON='YES';
 ELSE STAWAGON='NO';                                           sedan vs. station wagon
KEEP VEH_YR DAMAGE DAYLIGHT INJURY NUMVEHIN RURAL CRSHMODE
 FOLLOW STAWAGON VEHMANU TOW;
PROC FREQ; TABLES VEH_YR * DAMAGE
 (DAYLIGHT INJURY NUMVEHIN RURAL CRSHMODE FOLLOW
 STAWAGON VEHMANU TOW) * VEH_YR * DAMAGE / LIST NOCUM;   contingency tables
```

TENNESSEE

```
DATA CHUCK1; SET TNACC.ACC;                              creation of analysis file
 NUMVEH=INPUT(NUM_VEH,2.0);
 IF NUMVEH GE 2;                                         2 or more vehicle crashes
 IF ACC_INVL='03';         excl "veh" which are ped, bike, parked car, etc.
 KEEP CASE_NUM LIGHT ACC_TYPE AREA_D1 INT_CDE NUM_INJ NUMVEH;
DATA CHUCK2; SET TNVEH.VEH;
 IF VEH_BT='10' OR VEH_BT='11';                                     passenger car
 IF PT_IMP='N' OR PT_IMP=' ' OR PT_IMP='U' THEN DELETE;      excl unk damage
 MODELYR=INPUT(VEH_YR,2.0);
 IF 78 LE MODELYR LE 88;
 IF TYP_ACT1='13' OR TYP_ACT2='13' THEN DELETE;          exclude parked cars
 IF VEH_MAKE='CADI' OR VEH_MAKE='CAD ' THEN DELETE;       exclude Cadillacs
 KEEP CASE_NUM VEH_NUM VEH_MAKE MODELYR PT_IMP VEH_BT TRF_CNT1
 TYP_ACT1 TYP_ACT2 RD_TYP1 DAM_PROP;
DATA TENN.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK1 CHUCK2; BY CASE_NUM;
 IF NUMVEH GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET TENN.ACCVEH;                        generates contingency tables
IF 80 LE MODELYR LE 87;                                       model years 1980-87
IF PT_IMP='4' OR PT_IMP='5' OR PT_IMP='6' THEN DAMAGE='BACK ';
 ELSE DAMAGE='OTHER';                                    rear vs. other impacts
IF LIGHT='2' THEN DAYLIGHT='YES'; ELSE IF
 LIGHT='1' OR LIGHT='3' OR LIGHT='4' OR LIGHT='5'
 OR LIGHT='6' THEN DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';       light condition
IF TRF_CNT1='2' OR TRF_CNT1='3' OR TRF_CNT1='4' OR TRF_CNT1='5' OR
 TRF_CNT1='6' OR TRF_CNT1='7' OR TRF_CNT1='8' THEN SIGNAL='YES';
 ELSE IF TRF_CNT1='1' THEN SIGNAL='NO'; ELSE SIGNAL='UNK';   traffic signal
NO_INJ=INPUT(NUM_INJ,2.0);
 IF NO_INJ GE 1 THEN INJURY='YES'; ELSE INJURY='NO';            injury crash
IF NUMVEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';        2 veh vs. 3 or more
IF AREA_D1='2' THEN RURAL='YES'; ELSE RURAL='NO';                  rural/urban
IF ACC_TYPE='04' THEN CRSHMODE='REAR  ';
 ELSE CRSHMODE='OTHER';                                   manner of collision
TYPACT1=INPUT(TYP_ACT1,2.0); TYPACT2=INPUT(TYP_ACT2,2.0);
 IF 2 LE TYPACT1 LE 5 OR 2 LE TYPACT2 LE 5 THEN VEHMANU='TURNING ';
 ELSE IF 6 LE TYPACT1 LE 9 OR TYPACT1=12 OR 6 LE TYPACT2 LE 9
 OR TYPACT2=12 THEN VEHMANU='STOPSLOW';                  stopped or slowing
 ELSE IF TYPACT1=1 OR TYPACT2=1 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                        precrash movement of struck veh
IF VEH_BT='11' THEN STAWAGON='YES'; ELSE STAWAGON='NO';           sedan/wagon
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL
 CRSHMODE VEHMANU STAWAGON;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 VEHMANU STAWAGON) * MODELYR * DAMAGE / LIST NOCUM;      contingency tables
```

TEXAS

```
DATA CHUCK0; SET TXACC1.ACC1; IF TOT_VEH GE 2;
 IF FHE='2';                                          creation of analysis file
 KEEP TOT_VEH POP_GRP RD_CLASS SEVERITY LGTCOND TRA_CON
 CASENO VEH_MOV OTH_FCT;
DATA CHUCK1; SET TXACC2.ACC2; IF TOT_VEH GE 2;          2 or more veh crashes
 IF FHE='2';                 excl "veh" which are ped, bike, parked car, etc.
 KEEP TOT_VEH POP_GRP RD_CLASS SEVERITY LGTCOND TRA_CON
 CASENO VEH_MOV OTH_FCT;
DATA CHUCK2; SET TXVEH.VEH;
 IF VEH_TYP=1;                                                 passenger car
 VEH_MOD=INPUT(MK_MDL,3.0);
 IF VEH_MOD LE 35 OR VEH_MOD GE 40;                         exclude Cadillacs
 IF VEH_MOD NE 194 AND VEH_MOD NE 247 AND VEH_MOD NE 299;
 TAD=SUBSTR(VEH_DAM,1,1);
 IF TAD='F' OR TAD='L' OR TAD='B' OR TAD='R';          excl unk damage loc
 TAD2=SUBSTR(VEH_DAM,2,1);
 TAD3=INPUT(SUBSTR(VEH_DAM,3,1),1.0);
 KEEP VEH_YEAR VEH_MOD VEH_STY TAD TAD2 TAD3 FACTOR2 CASENO;
DATA TEXAS.ACCVEH(BLKSIZE=30000);
 MERGE CHUCK0 CHUCK1 CHUCK2; BY CASENO;
 IF TOT_VEH GE 2 AND VEH_MOD NE .;

DATA CHUCK1; SET TEXAS.ACCVEH;                    generates contingency tables
MODELYR=INPUT(VEH_YEAR,2.0); IF 80 LE MODELYR LE 87;    model years 1980-87
IF TAD='B' OR TAD2='B' THEN DAMAGE='BACK '; ELSE DAMAGE='OTHER';
IF LGTCOND=1 THEN DAYLIGHT='YES'; ELSE IF 2 LE LGTCOND LE 5
 THEN DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';                      light condition
IF 1 LE TRA_CON LE 5 OR 7 LE TRA_CON LE 8 THEN SIGNAL='YES';
 ELSE SIGNAL='NO ';                               presence of traffic signal
IF 1 LE SEVERITY LE 4 THEN INJURY='YES'; ELSE INJURY='NO';      injury crash
IF TOT_VEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';        2 veh vs. 3 or more
IF 0 LE POP_GRP LE 1 THEN RURAL='YES'; ELSE RURAL='NO';           rural/urban
IF VEH_STY=6 OR VEH_STY=12 THEN STAWAGON='YES'; ELSE STAWAGON='NO';
IF VEH_MOV=22 OR VEH_MOV=27 OR VEH_MOV=29 THEN VEHMANU='STOPPED';
 ELSE IF VEH_MOV=23 OR VEH_MOV=24 OR VEH_MOV=25 OR VEH_MOV=26
 OR VEH_MOV=28 THEN VEHMANU='TURNING';
 ELSE IF OTH_FCT=50 OR OTH_FCT=51 THEN VEHMANU='TURNING';
 ELSE IF 40 LE OTH_FCT LE 49 THEN VEHMANU='SLOWING';
 ELSE IF VEH_MOV=20 OR VEH_MOV=21 THEN VEHMANU='STRAIGHT';
 ELSE VEHMANU='OTHER';                       precrash movement of struck veh
IF TAD3 GE 3 THEN TOWAWAY='YES'; ELSE TOWAWAY='NO';                  towaway
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL
 STAWAGON VEHMANU TOWAWAY;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL STAWAGON
 VEHMANU TOWAWAY) * MODELYR * DAMAGE / LIST NOCUM;        contingency tables
```

UTAH

```
DATA CHUCK1; SET UTACC.ACC;                                 creation of analysis file
 IF NOVEH GE 2;                                             2 or more vehicle crashes
 IF ACCTYPE='1' OR ACCTYPE='3' OR ACCTYPE='4' THEN DELETE;   excl ped, etc.
 KEEP CASENO NOVEH SEVERITY ACCTYPE LIGHT DIRANLYS LOCATION
 LOCALITY TRAFCNTL;
DATA CHUCK2; SET UTVEH.VEH;
 IF VEHTYPE='01' OR VEHTYPE='02' OR VEHTYPE='06';                   passenger car
 IF DAMAGE1='1' OR DAMAGE1='2' OR DAMAGE1='3' OR DAMAGE1='4' OR
 DAMAGE1='5' OR DAMAGE1='6' OR DAMAGE1='7' OR DAMAGE1='8' OR DAMAGE1='9';
 MODELYR=INPUT(VEHYR,2.0); IF 78 LE MODELYR LE 88;
 IF DRVINT='11' THEN DELETE;                                exclude parked cars
 KEEP CASENO VEHNO DRVINT VIN MODELYR DAMAGE1-DAMAGE6 CONCIR1-CONCIR3;
DATA UTAH.ACCVEH; MERGE CHUCK1 CHUCK2; BY CASENO;
 IF NOVEH GE 2 AND 78 LE MODELYR LE 88;

DATA CHUCK1; SET UTAH.ACCVEH;                          generates contingency tables
IF 80 LE MODELYR LE 87;                                         model years 1980-87
IF LIGHT='1' THEN DAYLIGHT='YES'; ELSE IF LIGHT='2' OR LIGHT='3'
 OR LIGHT='4' THEN DAYLIGHT='NO'; ELSE DAYLIGHT='UNK';        light condition
IF TRAFCNTL='2' OR TRAFCNTL='3' OR TRAFCNTL='4' OR TRAFCNTL='5' OR
 TRAFCNTL='6' OR TRAFCNTL='7' OR TRAFCNTL='1' THEN SIGNAL='YES';
 ELSE IF TRAFCNTL='9' THEN SIGNAL='NO'; ELSE SIGNAL='UNK';
IF SEVERITY='2' OR SEVERITY='3' OR SEVERITY='4' OR SEVERITY='5'
 THEN INJURY='YES'; ELSE INJURY='NO';                             injury crash
IF NOVEH=2 THEN NUMVEHIN='2'; ELSE NUMVEHIN='3';           2 veh vs. 3 or more
MANCOLL=INPUT(DIRANLYS,2.0); IF MANCOLL=3 THEN CRSHMODE='REAR STRT';
 ELSE IF MANCOLL=7 THEN CRSHMODE='SIDESWIPE';             manner of collision
 ELSE IF 4 LE MANCOLL LE 5 OR 8 LE MANCOLL LE 10 OR MANCOLL=19
 OR MANCOLL=22 THEN CRSHMODE='REAR TURN'; ELSE CRSHMODE='OTHER';
IF DRVINT='06' OR DRVINT='10' THEN VEHMANU='STOPSLOW';
 ELSE IF DRVINT='03' OR DRVINT='04' OR DRVINT='05' THEN VEHMANU='TURNING ';
 ELSE IF DRVINT='01' THEN VEHMANU='STRAIGHT'; ELSE VEHMANU='OTHER';
IF LOCATION='3' THEN RURAL='YES'; ELSE IF LOCATION='4' THEN RURAL='NO ';
 ELSE IF LOCALITY='5' OR LOCALITY='6' THEN RURAL='YES';
 ELSE IF LOCALITY='1' OR LOCALITY='2' OR LOCALITY='3' OR
 LOCALITY='4' THEN RURAL='NO '; ELSE RURAL='UNK';                  rural/urban
IF CRSHMODE='REAR STRT' OR CRSHMODE='SIDESWIPE' OR    use broad def of rear
 CRSHMODE='REAR TURN' OR VEHMANU='STOPSLOW' THEN DO;              impacts here
 IF DAMAGE1='7' OR DAMAGE1='8' OR DAMAGE1='9' OR DAMAGE2='7' OR
 DAMAGE2='8' OR DAMAGE2='9' OR DAMAGE3='7' OR DAMAGE3='8' OR DAMAGE3='9'
 OR DAMAGE4='7' OR DAMAGE4='8' OR DAMAGE4='9' OR DAMAGE5='7' OR
 DAMAGE5='8' OR DAMAGE5='9' OR DAMAGE6='7' OR DAMAGE6='8' OR DAMAGE6='9'
 THEN DAMAGE='BACK '; ELSE DAMAGE='OTHER'; END;
 ELSE DO; IF DAMAGE1='7' OR DAMAGE1='8' OR DAMAGE1='9'         use narrower
 THEN DAMAGE='BACK '; ELSE DAMAGE='OTHER'; END;             definition here
KEEP MODELYR DAMAGE DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE VEHMANU;
PROC FREQ; TABLES MODELYR * DAMAGE
 (DAYLIGHT SIGNAL INJURY NUMVEHIN RURAL CRSHMODE
 VEHMANU) * MODELYR * DAMAGE / LIST NOCUM;                contingency tables
```

FARS

```
DATA CHUCK1; SET FARS87.VEHICLE;                  generates contingency tables
IF M_HARM=12;                           crashes of 2 or more motor veh in transport
IF 80 LE MOD_YEAR LE 87;                                        model years 1980-87
IF 1 LE BODY_TYP LE 9;                                                passenger car
IF IMPACT2 NE 99;                                   exclude unknown damage location
IF MAKE NE 19;                                                    exclude Cadillacs
IF 4 LE IMPACT2 LE 8 OR 4 LE IMPACT1 LE 8                                  rear vs.
  THEN DAMAGE='BACK '; ELSE DAMAGE='OTHER';                           other impacts
KEEP MOD_YEAR DAMAGE;
PROC FREQ; TABLES MOD_YEAR * DAMAGE / LIST NOCUM;                contingency tables
```

APPENDIX B

BASIC TABLES FOR OVERALL EFFECTIVENESS ANALYSIS

FLORIDA

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	3514	13613	-19	-22
1981	3615	13018	-11	-13
1982	3535	12334	- 7	-10
1983	4013	13236	- 2	- 4
1984	6122	18943	+ 5	+ 3
1985	6517	19708	+ 7	+ 5
1986	6883	22345		
1987	5657	17960		

Regression coefficients: CHMSL effect +14.09
Age effect per year - 4.88

CHMSL effect adjusted for retrofits and "relevant" crashes: +23.00

INDIANA

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	4086	10143	- 4	- 8
1981	3960	9540	none	- 5
1982	3423	8708	- 6	-11
1983	3606	8897	- 3	- 7
1984	5457	12826	+ 2	- 2
1985	5590	12933	+ 4	- 1
1986	5774	13846		
1987	3966	9103		

Regression coefficients: CHMSL effect + 4.14
Age effect per year - 1.87

CHMSL effect adjusted for retrofits and "relevant" crashes: + 6.83

LOUISIANA

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	1415	5329	-13	- 8
1981	1413	5511	-17	-12
1982	1350	5191	-15	-10
1983	1366	4595	- 1	+ 4
1984	2023	6506	+ 4	+ 8
1985	1979	6503	+ 2	+ 6
1986	1951	6525		
1987	1401	4890		

Regression coefficients: CHMSL effect +10.07
Age effect per year - 3.27

CHMSL effect adjusted for retrofits and "relevant" crashes: +16.51

MAINE

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	564	1787	-12	-21
1981	569	1935	-20	-29
1982	560	1829	-16	-24
1983	710	2043	- 2	- 9
1984	951	2770	- 3	-11
1985	1001	2691	+ 5	- 2
1986	989	2795		
1987	673	2006		

Regression coefficients: CHMSL effect + 7.50
Age effect per year - 4.98

CHMSL effect adjusted for retrofits and "relevant" crashes: +12.33

MARYLAND

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	2170	3681	- 5	- 6
1981	2204	3871	- 8	-10
1982	2392	3784	+ 3	+ 1
1983	2731	4522	- 2	- 3
1984	4007	6530	none	- 2
1985	4446	6761	+ 6	+ 5
1986	4946	8026		
1987	4187	6705		

Regression coefficients: CHMSL effect + 6.89
Age effect per year - 2.21

CHMSL effect adjusted for retrofits and "relevant" crashes: +11.34

MICHIGAN

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	5408	16467	-29	-31
1981	5435	15344	-20	-22
1982	5265	14171	-14	-16
1983	6212	16100	-10	-12
1984	10216	24644	- 2	- 4
1985	11828	27131	+ 3	+ 1
1986	12695	29946		
1987	8620	19983		

Regression coefficients: CHMSL effect +10.50
Age effect per year - 5.78

CHMSL effect adjusted for retrofits and "relevant" crashes: +17.21

MISSOURI

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	1831	7770	-22	-32
1981	1830	7422	-16	-27
1982	1765	6684	- 9	-18
1983	1922	7163	- 7	-16
1984	2805	9896	- 1	-10
1985	3248	10387	+ 8	none
1986	3097	10806		
1987	2210	7079		

Regression coefficients: CHMSL effect +12.46
Age effect per year - 6.34

CHMSL effect adjusted for retrofits and "relevant" crashes: +20.37

PENNSYLVANIA

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	1664	8085	-16	-20
1981	1681	7263	- 3	- 6
1982	1588	6863	- 3	- 6
1983	1645	7439	- 8	-11
1984	2717	10449	+ 8	+ 5
1985	2762	10632	+ 8	+ 5
1986	2882	12082		
1987	2225	9040		

Regression coefficients: CHMSL effect +14.58
Age effect per year - 4.38

CHMSL effect adjusted for retrofits and "relevant" crashes: +23.80

TENNESSEE

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	1626	4427	- 2	- 1
1981	1569	4359	- 4	- 3
1982	1516	4307	- 7	- 6
1983	1704	4449	+ 2	+ 3
1984	2531	6447	+ 4	+ 5
1985	2662	6635	+ 6	+ 7
1986	2785	7424		
1987	1592	4283		

Regression coefficients: CHMSL effect + 9.52
Age effect per year - 2.11

CHMSL effect adjusted for retrofits and "relevant" crashes: +15.62

TEXAS

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	6035	18695	- 6	- 7
1981	6748	20365	- 3	- 4
1982	6457	19280	- 2	- 3
1983	5962	16954	+ 3	+ 2
1984	8616	24231	+ 4	+ 3
1985	8677	24410	+ 4	+ 3
1986	8537	24977		
1987	5925	17229		

Regression coefficients: CHMSL effect + 7.14
Age effect per year - 1.85

CHMSL effect adjusted for retrofits and "relevant" crashes: +11.75

UTAH

Model Year	N of Cars in 1987 Collisions: With Rear Impact Damage	N of Cars in 1987 Collisions: Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	Observed CHMSL "Effect" (%): MY 87 vs.
1980	776	1845	- 3	- 4
1981	736	1904	-13	-14
1982	785	1830	- 1	- 2
1983	723	1741	- 5	- 6
1984	1078	2464	+ 1	none
1985	1042	2300	+ 4	+ 3
1986	1016	2335		
1987	605	1378		

Regression coefficients: CHMSL effect + 5.89
Age effect per year - 2.23

CHMSL effect adjusted for retrofits and "relevant" crashes: + 9.71

FARS 1986

Model Year	N of Cars in Fatal 1986 Collisions: With Rear Impact Damage	Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.
1980	127	1156	-33
1981	129	1114	-26
1982	135	1049	-13
1983	154	1023	+ 3
1984	213	1434	+ 2
1985	195	1508	-13
1986	989	2795	

FARS 1987

Model Year	N of Cars in Fatal 1987 Collisions: With Rear Impact Damage	Without Rear Impact Damage	Observed CHMSL "Effect" (%): MY 86 vs.	MY 87 vs.
1980	145	1186	- 8	-14
1981	162	1064	+13	+ 8
1982	142	960	+10	+ 6
1983	140	1063	- 1	- 6
1984	188	1396	+ 2	- 4
1985	198	1467	+ 2	- 3
1986	212	1601		
1987	169	1210		