July 1983
Technical Report

DOT HS-806-430

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

An Evaluation of Side Marker Lamps for Cars, Trucks and Buses

PLANS AND PROGRAMS
Office of Program Evaluation

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-806 430		

4. Title and Subtitle	5. Report Date
An Evaluation of Side Marker Lamps for Cars, Trucks and Buses	July 1983
	6. Performing Organization Code: NPP-10
7. Author(s): Charles Jesse Kahane, Ph.D.	8. Performing Organization Report No.
9. Performing Organization Name and Address: Office of Program Evaluation, National Highway Traffic Safety Administration, 400 7th St., S.W., Washington, D.C. 20590	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C. 20590	13. Type of Report and Period Covered: NHTSA Technical Report
	14. Sponsoring Agency Code

15. Supplementary Notes

An agency staff review of an existing Federal regulation performed in response to Executive Order 12291.

16. Abstract

Side marker lamps were installed in cars, trucks, buses, trailers and multipurpose passenger vehicles in response to Federal Motor Vehicle Safety Standard 108. The purpose of side marker lamps is to enable a driver to see another vehicle that is approaching at an angle at night--and to see it early enough that the driver can stop in time to prevent a collision or, at least, slow down to reduce the severity of the collision. The objectives of this agency staff evaluation are to determine how many accidents, casualties and damages are prevented by side marker lamps and to measure the actual cost of the lamps. The evaluation is based on statistical analyses of North Carolina, Texas and Fatal Accident Reporting System data, a study of travelling speeds in fatal angle collisions, and cost analyses of production lamp assemblies. It was found that:

- Side marker lamps annually prevent 106,000 accidents, 93,000 nonfatal injuries and $347 million in property damage.
- The lamps have not been effective in reducing fatalities.
- They add $21 (in 1982 dollars) to the lifetime cost of owning and operating a motor vehicle.

17. Key Words	18. Distribution Statement
side marker lamp; lighting; conspicuity; side impact; angle collision; accident analysis; evaluation; statistical analysis; cost effectiveness.	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	177	

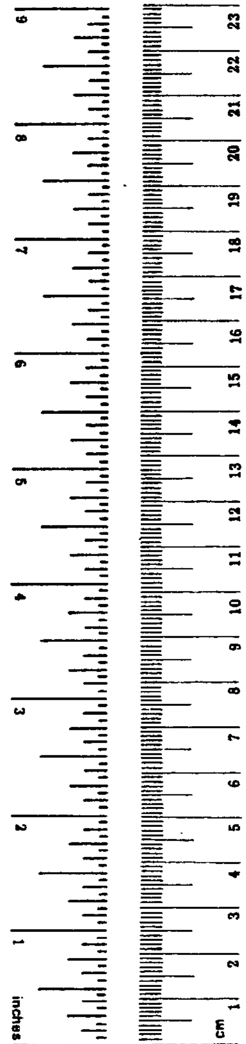
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

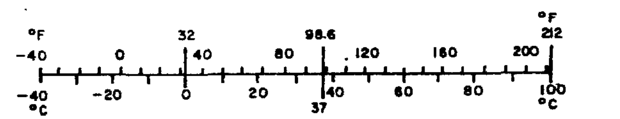
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF ABBREVIATIONS

AMA	Automobile Manufacturers Association (now known as MVMA)
AMC	American Motors Corporation
CY	Calendar Year
df	degrees of freedom
FARS	Fatal Accident Reporting System
MVMA	Motor Vehicle Manufacturers Association
MY	Model Year
NAS	National Accident Summary
NASS	National Accident Sampling System
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
SAS	Statistical Analysis System
SML	Side Marker Lamp
TAD	Traffic Accident Data project accident severity scale

ACKNOWLEDGEMENTS

I thank Roman Brooks, Kevin Cavey, Mike Perel and Taylor Vinson for reviewing the manuscript and for their helpful suggestions on data sources and analysis methods.

Alleyne Monkman and Michele Stewart typed the report.

SUMMARY

The most notable change in motor vehicle lighting during the period 1965-75 was the installation of side marker lamps on most cars, trucks and buses in 1968. Before that year, most vehicles did not have any illumination visible from the side. The purpose of side marker lamps is to enable a driver to see another vehicle that is approaching at an angle at night (or is standing still with its side facing the driver)--and to see it early enough that the driver can stop in time to prevent a nighttime angle collision or, at least, slow down or take evasive action to reduce the severity of the collision.

Federal Motor Vehicle Safety Standard 108 regulates the lamps, reflectors and associated equipment for cars, trucks, trailers, buses, multi-purpose passenger vehicles and motorcycles. It became effective on January 1, 1968, for vehicles wider than 80 inches (large trucks and buses) and on January 1, 1969, for the other vehicles.

Executive Order 12291 (February 1981) requires agencies to evaluate their existing major regulations, including any rule whose annual effect on the economy is $100 million or more. 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 response to a standard and to assess cost-effectiveness.

This report is an evaluation of side marker lamps for cars, trucks, vans and buses--the only significant change in the lighting systems of

production vehicles that more or less coincided with the effective date of Standard 108. They were introduced voluntarily by manufacturers, typically one year before the standard's effective date. The other lighting systems of motor vehicles (headlamps, brake lights, etc.) for the most part already met Standard 108 many years in advance because they complied with SAE Standards and Recommended Practices that were incorporated, by reference, into Standard 108.

Estimates of the number of accidents and casualties prevented by side marker lamps were obtained by statistically analyzing accident data from the North Carolina and Texas State files and the Fatal Accident Reporting System. The analyses of nonfatal accidents resulted in precise, statistically significant effectiveness estimates. The analyses of fatal crashes did not produce statistically significant estimates and were supplemented by an engineering study: did drivers in fatal crashes have enough room to stop or slow down after they saw the lamps? The cost of side marker lamps was estimated by analyzing lamp components of a representative sample of cars and by obtaining data on repair frequencies and costs.

The evaluation does not develop a detailed model which predicts side marker lamp effectiveness as a function of their intensity, size, luminance or as a function of accident parameters. That model could be useful for studying the effect of potential changes in side marker lamp requirements, but the in-depth accident and laboratory data that would be needed to develop it do not exist at this time. Instead, the evaluation is limited to assessing the actual costs and benefits of current production lamps--whose design has remained largely unchanged during 1970-83.

The most important conclusion of this study is that side marker lamps are effective in preventing nonfatal accidents and injuries--close to 100,000 of each per year. The conclusion is based almost entirely on statistical analyses of accident data, yet can be drawn firmly because of the exceptional precision and consistency of those analyses:

- Identical results were obtained from North Carolina and Texas.

- Two virtually independent analysis techniques were used on each file. One was straightforward (simple comparison of model years 1967 when most vehicles did not have the lamps and 1968 when most did) and the other complex (regression): they produced the same effectiveness estimate.

- Several techniques were used to check for biases in the effectiveness estimates. They suggested that the estimates were unbiased.

The other conclusion is that side marker lamps had little or no effect on fatalities. The conclusion is based on a combination of statistical analysis and engineering judgement and it is less firm than the preceding one. The statistical analysis of fatal crashes yielded an effectiveness estimate just below zero but (because the Fatal Accident Reporting System is a smaller file than North Carolina or Texas) with relatively wider confidence bounds including a range of positive and negative values. The engineering analysis did not yield a specific estimate but did suggest that the effect, if any, was a fraction of the one in nonfatal crashes. The conclusion that the actual effect is essentially zero is conservative and consistent with both analyses.

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

Principal Findings

Effectiveness of side marker lamps

o If none of the cars, trucks and buses operating on the roads during 1980 had been equipped with side marker lamps there would have been 661,000 police-reported nighttime angle collisions. If all of those cars, trucks and buses had been equipped with side marker lamps, there would only have been 555,000 collisions. In other words, the lamps reduce the number of nighttime angle collisions by 16 percent. The accident reduction is statistically significant (confidence bounds: 10 to 22 percent).

o Side marker lamps reduce the number of personal injuries in nighttime angle collisions by 21 percent. The reduction is statistically significant (confidence bounds: 12 to 29 percent).

o The statistical analyses of fatal angle collisions did not indicate a significant effect for side marker lamps (confidence bounds for effectiveness: -25 to +13 percent). An analysis of crash speeds, sighting and stopping distances suggested that the effectiveness of side marker lamps in fatal crashes, if any, is at most 1/4 as high as in nonfatal crashes: at the travelling speeds prevalent in most fatal crashes, either the lamps are seen too late for drivers to react to them and stop or slow down or the headlamps are more readily visible than the side marker lamps.

Cost

o The costs per vehicle (in 1982 dollars) for side marker lamps are the following:

Initial purchase price increase	$16.76
Lifetime fuel consumption due to 2 pound weight increase	2.00
Lifetime fuel consumption: electric power to light the lamps	2.19
Lifetime cost of replacement bulbs	0.27
TOTAL COST PER VEHICLE	$21.22

o The annual cost of side marker lamps in the United States (based on 12.3 million cars, trucks and buses sold) is $261 million.

Annual benefits

o The annual benefits, when all cars, trucks and buses in the United States have side marker lamps, will be:

Reduction of	Best Estimate	Confidence Bounds
Police-reported accidents	106,000	65,000 - 149,000
Nonfatal injuries	93,000	51,000 - 132,000
Property damage	$347M	$213 - 488M

Cost-effectiveness

o Since side marker lamps save 93,000 injuries and cost $261 million, they eliminate 360 injuries per million dollars of cost (confidence bounds: 200 to 500).

o Since side marker lamps save $347 million in property damages and cost $261 million, they save consumers $86 million per year (confidence bounds: -48 to +227 million dollars saved per year).

Conclusions

o Side marker lamps have significantly reduced the number of nighttime angle collisions that occur in the United States.

o The lamps have significantly reduced the number of nonfatal injuries that occur in nighttime angle collisions, because they reduce the severity of accidents and/or prevent them entirely.

o The lamps have little or no effect on fatalities. Most fatal nighttime angle collisions involve one of the vehicles travelling at high speed or both vehicles travelling at similar speeds. In the first case, by the time that the high-speed driver sees the other vehicle's side markers, there is no longer room to stop or substantially slow down; in the second case, each driver can see the other vehicle's headlamps more easily than the side marker lamps.

o Side marker lamps are a cost-effective safety device.

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 Evaluation of Federal Motor Vehicle Safety Standards

Executive Order 12291, dated February 17, 1981, requires Federal agencies to perform evaluations of their existing regulations, including those rules which result in an annual effect on the economy of $100 million or more [8]. The evaluation shall determine the actual costs and actual benefits of the existing rule.

The National Highway Traffic Safety Administration began to evaluate its existing Federal Motor Vehicle Safety Standards in 1975. Its goals have been to monitor the actual benefits and costs of safety equipment installed in production vehicles in response to standards and, more generally, to assess whether a standard has met the specifications of the National Traffic and Motor Vehicle Safety Act of 1966 [21]: practicability, meet the need for motor vehicle safety, protect against "unreasonable" risk of accidents, deaths or injuries, provide objective criteria. The Agency has published 7 comprehensive evaluations to date.

1.2 Evaluation of Standard 108

Federal Motor Vehicle Safety Standard 108 regulates lamps, reflective devices and associated equipment for passenger cars, trucks, trailers, buses, multipurpose passenger vehicles and motorcycles [6]. Standard 108 took effect for motor vehicles wider than 80 inches (mostly large trucks and buses) on January 1, 1968, and for motor vehicles less than 80 inches wide (cars, light trucks, motorcycles, etc.) on January 1, 1969, with a number of subsequent amendments. The lighting systems covered by the standard include headlamps, taillamps, brake, license plate, parking, side marker, backup, warning, identification and clearance lights, turn signals, and the lenses, reflectors, and flashers associated with the lights.

Standard 108 incorporates by reference a large number of SAE Recommended Practices and Standards concerning lighting and makes them mandatory for vehicles sold in the United States. The SAE Recommended Practices cover each of the lighting systems in detail and in many cases were written well before Standard 108, in some cases before 1940. The development of lighting systems for vehicles has proceeded on a more or less continuous basis during the 20th century. In most of the lighting systems, Standard 108 did not result in dramatic changes but tended to codify existing practices. Likewise, in most of the lighting systems, there were no major changes made voluntarily by manufacturers during, or just before, the period when Standard 108 took effect.

Side marker lamps are the one important exception. They were voluntarily installed on most model year 1968 cars and light trucks--two years before Standard 108 required them and 4 years after the SAE issued Recommended Practice J592 for optional side marker lamps--whereas most 1967 models had no side marker lamps or other form of illumination visible from the side. Their objective is to enable a driver to see another vehicle approaching at an angle, at night. Since nighttime angle collisions are extremely common events (660,000 per year reported in the United States), side marker lamps address an important safety problem and, potentially, have large safety benefits.

By contrast, other vehicle lighting changes took place many years before or after the implementation of Standard 108. They were modifications of existing systems rather than introductions of new ones and/or had more limited potential for safety benefits. Other principal changes were: the use of 4 headlamps with separate high beams, introduced in many 1958 models--but the earlier 2 headlamp systems with combined high and low beams performed basically the same functions. Backup lights were introduced in 1962, 7 years before Standard 108--but collisions involving a backing vehicle are much rarer than nighttime angle collisions, especially at higher levels of severity. Standard 108 was amended to allow a more powerful upper beam in headlamps beginning model year 1979--10 years after the effective date of the original standard. Moreover, the use of more powerful headlamps is an option, not a requirement and the lamps were only installed on certain makes and models.

1.3 Side marker lamps

Standard 108 currently requires that passenger cars, trucks, buses, trailers and multipurpose passenger vehicles have side marker lamps at the front end and rear of each side of the vehicle. The front lamp must be amber and the rear lamp red. They should be as close to the end of the vehicle as possible and not less than 15 inches above the ground. There are to be reflex reflectors, also, at the same general location and of the same colors. If the vehicle is more than 30 feet long, there shall be additional amber lamps and reflectors, one on each side, at the midpoint of the side of the vehicle.

Standard 108 incorporates, by reference, SAE Recommended Practice J592 on side marker lamps (and also clearance and identification lamps) [23]. The Recommended Practice itself has been revised many times, but its clauses referring to side marker lamps have remained virtually unchanged since 1964: it requires a minimum candela of 0.62 for the amber lamps and 0.25 for the red lamps from each of 9 measurement points.

The lamps and reflectors became mandatory on vehicles over 80 inches wide on 1/1/68 (large trucks and buses). Narrower vehicles (mostly cars and light trucks) were required to have the lamps and reflectors after 1/1/70. Between 1/1/69 and 1/1/70, several options were available for these vehicles. Manufacturers could use a lamp only, a reflector only (or both, together) on the front. They had similar choices available for the rear. They could choose different options for the front and for the rear. Motorcycles do not have side marker lamps.

Throughout this report, units that consist of a reflector but no lamp are not counted as side marker lamps. Thus, the model year 1968 and 1969 cars that have reflectors only, front and rear, are considered unequipped with SML. Those that have a reflector in the front and a lamp in the back, or vice versa, are considered "half" equipped with SML. The report does not separately evaluate the benefits of reflectors, only of the lamp/reflector system.

The side marker lamps are lit whenever the vehicle's parking and taillights are on.

In actual practice, two systems have been used to meet the requirement for lamps. The more common one is to mount small lamps on the side of the vehicle--in or on the fenders. The lens of the lamp usually serves as a reflex reflector when the lights are off. Manufacturers typically use 2 candlepower bulbs (but the colored and reflectorized lens reduces the amount of light emitted from the vehicle to values close to the SAE minimum specifications). The other system is to design parking and taillamps in a manner to make them visible from the side of the vehicle--they are called "wraparound" parking and taillights in this report and are counted as side marker lamps.

As noted above, the domestic manufacturers installed SML on most model year 1968 vehicles, one year before reflectors were required and two years before lamps were mandatory. Nevertheless, there were some 1968 and 1969 models that only had reflectors at the front, rear, or both positions (see Section 3.5). All 1970 and subsequent models have had the full lamp/reflector system at both positions. Side marker lamps, (usually wraparound parking and taillights) appeared on a number of domestic passenger car models, beginning in 1964, including all the luxury cars and also such high volume cars as 1966-67 Chevrolet Impala (see Table 3-2). (There were occasional models with wraparound lights even prior to 1964.) The voluntary installation of SML on luxury cars, as well as the marketing of retrofit kits for unequipped cars by a number of suppliers seems to indicate that the lamps were appreciated by the public.

The objective of side marker lamps is to make a vehicle visible from the side to drivers of other vehicles, at night or at other times when there is reduced visibility including dawn and dusk [5], p. 5-13. The advance warning provided by the lamps has the potential to enable drivers to avoid a collision when approaching one another at an angle, at night. The purpose of locating the lamps as close to the ends of the vehicle as possible is to reveal its length; the purpose of making the front lamp amber and the rear lamp red is to reveal the vehicle's direction of travel.

Side marker lamps cannot be expected to prevent daytime collisions because they are too dim to add appreciably to a vehicle's conspicuity by day [5]. They cannot be expected to prevent head-on, rear-end or sideswipe collisions because they are considerably dimmer than the headlights or taillights of the other vehicle, which are usually visible prior to such collisions.

Thus, vehicle-to-vehicle nighttime angle collisions are the specific type of crash which side marker lamps have the potential to reduce in frequency or severity. Moreover, installation of SML on either vehicle in a front-to-side collision--the "striking" or the "struck" vehicle--might have been beneficial in preventing that collision: when two vehicles approach each other at an angle, each driver potentially has an opportunity to see the side of the other vehicle and take action to avoid a collision (see Section 3.1). Also, the determination of which vehicle is "striking" and which is "struck" is not made until the last moments before contact: in many cases the faster moving vehicle ends up being "struck" in the side. In other words, SML could reduce the likelihood of a vehicle's involvement in an angle collision, as a striking vehicle or as a struck vehicle.

1.4 Evaluation objectives and limitations

This report, then, consists of analyses of vehicle involvements in nighttime angle collisions. The risk of nighttime angle collision involvements, for vehicles of a certain model year, is expressed as a ratio of nighttime to daytime involvements (the latter being unaffected by SML) in Chapters 4 and 5 or as a rate of nighttime involvements per 1000 exposure years in Chapter 6. Since 1968 was the first year in which SML were installed in most vehicles, the analyses of Chapter 4 focus on the accident experience of model year 1968 versus model year 1967 vehicles. Chapter 5 considers a wider range of model years (1964-72) and performs regressions on the ratio of nighttime to daytime crashes as a function of SML installation, vehicle age and other factors.

Since cars, trucks (including vans) and buses are equipped with side marker lamps, all 3 types of vehicles are included in the data. In fact, this is the first NHTSA evaluation that is not limited to passenger cars.

The objective is to find out how many fewer nighttime angle collisions there would be each year if every registered car, truck and bus in the United States were equipped with side marker lamps than if none of the vehicles on the road in this country had any side marker lamps.

Likewise, the cost of side marker lamps is the average annual fleetwide costs of lamps relative to a baseline case of vehicles that have no side marker lamps at all. The cost includes the increase in the initial purchase price of a vehicle, incremental fuel consumption and any growth in repair costs.

The evaluation does not contain in-depth accident analyses to show how side marker lamps helped prevent (or failed to prevent) an individual accident. It does not develop a detailed model which predicts SML effectiveness as a function of their intensity, size, luminance or as a function of accident parameters (although the rudiments of such a model are discussed in Section 7.3.2). Accident and laboratory data are unavailable for either of those efforts. Instead, the evaluation is based on statistical analyses of accident data files that are considerably larger than any that were previously used to study SML (see Chapter 2) and which, as a result, have generated unambiguous, statistically significant results.

CHAPTER 2

EARLIER STUDIES OF SIDE MARKER LAMPS

There are four published studies of side marker lamp effectiveness based on statistical analysis of State accident data. All were performed under contract to NHTSA. One engineering study of side marker lamps was found in the Agency's public dockets.

2.1 New York State Department of Motor Vehicles (1973)

New York State accident files for 1968 and 1969 were analyzed by the Department of Motor Vehicles under contract to NHTSA [22]. The effectiveness of side markers lamps was studied by tabulating vehicle involvements in two-car intersection accidents. The vehicle involvements were tabulated by

- o side marker lamp status: MY 1968-69 - Yes; MY 1965-67 - No;
- o light condition: Daylight; Dawn, dusk, or night

The resultant table was

	65-67	68-69
Daylight	38,116	30,410
Reduced light	18,262	14,252

The table is comparable to those shown in Chapter 4 of this report and can be analyzed by the same method. In other words, it indicates that the installation of side marker lamps on one car reduces its likelihood of nighttime intersection collision involvements by

$$1 - \frac{14,252}{30,410} \Big/ \frac{18,262}{38,116} = 2 \text{ percent}$$

Since the chi-square for the table is 2.64, the reduction is not statistically significant (one sided $\alpha = .05$) although it comes close. (Note that the chi-square of 74.2 reported for Table 4 of [22] is inappropriate for the analysis of side marker lamp effectiveness because the table includes an irrelevant control group.) The reduction is lower than the 7-8 percent observed in the North Carolina and Texas analyses of this report. A possible explanation for at least part of the difference is that the category of "intersection accidents," as defined in New York data, may contain many crashes that were not really angle collisions, but merely occurred at an intersection.

The study contains data that make it possible to analyze effectiveness by a different approach (although the analysis itself is not presented in [22]). The next table is a subset of preceding table, limited to those accident involvements where both cars in the collision were in the same model year group (pre or post - SML):

	65-67*	68-69**
Daylight	26,791	5,016
Reduced light	12,823	2,208

* Other car in the collision: MY 50-67

** Other car in the collision: MY 68-69

This table is essentially comparable to the approach used by Knoop, Ball and Northrop to calculate "full effectiveness" (see Section 2.3). It indicates that the installation of side marker lamps on two cars reduces the likelihood of nighttime intersection collisions by

$$1 - \frac{2208}{5016} \frac{12,823}{26,791} = 8 \text{ percent}$$

Since the chi-square is 9.14, the reduction is statistically significant. The reduction, however, is lower than the 15 percent, derived in this report, for equipping both vehicles with SML. Again, a possible explanation is that "intersection collisions" include many accidents that are not really angle collisions.

The efficacy of SML in injury-producing accidents was tested by tabulating the fatal and serious (K or A-level) injuries, as follows:

K + A

	65-67*	68-69**
Daylight	1045	163
Reduced light	749	83

*Other car in the collision: MY 50-67

**Other car in the collision: MY 68-69

(Note that the data are derived from Table 5 of [22] and not Table 6, where the SML-equipped sample size was inflated to equal the pre-standard sample and an inappropriate chi-square was calculated.) The table indicates a 29 percent reduction of injuries for side marker lamps. Since chi-square is 5.75, the reduction is statistically significant. The effectiveness is, in fact, considerably higher than the levels obtained in this report. It should be noted, though, that the table is based on a small sample (especially in comparison to those used in this report) and the results could have substantial sampling error.

In short, the New York study indicated that side marker lamps significantly reduced nightime intersection collisions.

2.2 Joksch (1973) - Texas data

State accident files from Texas for 1971 and 1972 were analyzed by Joksch [12]. He selected passenger cars that were struck in the side, with some damage to the passenger compartment (TAD codes LP, RP, LFQ, RFQ, LBQ, RBQ). It is a conservative approach, because these are the cars most likely to have been visible from the side immediately prior to the collision -i.e. the cars where side marker lamps might have the largest potential effect. Necessarily, the approach reduces the available sample size, because it excludes cars in angle collisions that were damaged on the front or corners and which, prior to the collision, might also have presented a side view to the other car.

Joksch tabulated the side impact involvements by model year and light condition (daytime vs. nighttime). About 14 percent of the side impacts of 1967 cars happened at night versus just 13 percent for the 1968 cars. In relative terms, this is a reduction of

$$1 - \frac{13}{14} \Big/ \frac{87}{86} = 8 \text{ percent}$$

in the likelihood of nighttime angle collisions, which is virtually identical to the reductions found in this report.

Joksch notes, however, that there may have been a slight (although nonsignificant) trend toward fewer nighttime accidents, relative to daytime, in the model years before and after 1967-68. If that trend is real and due to vehicle age, he suggests that the effect of side marker lamps may only have been to reduce nighttime involvements from 13.5 to 13 percent of side impacts: a relative reduction of 4 percent. That reduction would still be compatible with the results of this report.

2.3 Knoop, Ball and Northrop (1980)

Texas, New York and North Carolina data were analyzed under contract to NHTSA [17]. The study differs from the preceding two in that the unit of analysis is an accident rather than a vehicle involvement. Knoop selected the angle collisions involving two passenger cars which occurred at an intersection or a driveway access and in which one car had frontal damage and the other, side damage. Accidents may belong to one of three categories with respect to side marker lamps: neither car has SML, one car has them, both cars have them. Thus, two measures of effectiveness were calculated:

- o "full" effectiveness: both cars with SML versus neither car with them
- o "partial" effectiveness: one car with SML versus neither car with them

The measure of effectiveness is the reduction of nighttime angle collisions relative to daytime angle collisions.

The cars in [17] cover a relatively wide range of model years and the SML-equipped cars are, on the average, 4-5 years newer than the unequipped cars. That raises a possibility of vehicle age-related biases. The contractor was directed to control or compensate for possible biases by the following techniques:

- o Use of control variables (such as rural/urban, type of highway) and multidimensional contingency table analysis
- o Use of a control group of single vehicle crashes. The reduction of nighttime angle collisions relative to daytime angle collisions is measured relative to the control group, as follows:

$$E_{(Full)} = \left[1 - \frac{\left[\dfrac{\left[\text{Number of Daylight Angle Collisions between Pre-Standard Vehicles}\right]}{\left[\text{Number of Reduced Light Angle Collisions between Pre-Standard Vehicles}\right]} \times \dfrac{\left[\text{Number of Reduced Light Angle Collisions between Post-Standard Vehicles}\right]}{\left[\text{Number of Daylight Angle Collisions between Post-Standard Vehicles}\right]} \right]}{\left[\dfrac{\left[\text{Number of Daylight Single Vehicle Accidents Involving Pre-Standard Vehicle}\right]}{\left[\text{Number of Reduced Light Single Vehicle Accidents Involving Pre-Standard Vehicle}\right]} \times \dfrac{\left[\text{Number of Reduced Light Single Vehicle Accidents Involving Post-Standard Vehicle}\right]}{\left[\text{Number of Daylight Single Vehicle Accidents Involving Post-Standard Vehicle}\right]} \right]^2} \right] \times 100$$

$$E_{(Partial)} = \left[1 - \frac{\left[\dfrac{\left[\text{Number of Daylight Angle Collisions between Pre-Standard Vehicles}\right]}{\left[\text{Number of Reduced Light Angle Collisions between Pre-Standard Vehicles}\right]} \times \dfrac{\left[\text{Number of Reduced Light Angle Collisions between One Pre- and One Post-Standard Vehicle}\right]}{\left[\text{Number of Daylight Angle Collisions between One Pre- and One Post-Standard Vehicle}\right]} \right]}{\left[\dfrac{\left[\text{Number of Daylight Single Vehicle Accidents Involving Pre-Standard Vehicle}\right]}{\left[\text{Number of Reduced Light Single Vehicle Accidents Involving Pre-Standard Vehicle}\right]} \times \dfrac{\left[\text{Number of Reduced Light Single Vehicle Accidents Involving Post-Standard Vehicle}\right]}{\left[\text{Number of Daylight Single Vehicle Accidents Involving Post-Standard Vehicle}\right]} \right]} \right] \times 100$$

The specific data sets used for the analysis were Texas 1972, 73 and 74; New York 1974; and North Carolina 1973, 74 and 75. The Texas sample was 5 times as large as the other two.

The effectiveness of side marker lamps (percentage of nighttime angle collisions eliminated) was

	Full Effectiveness		Partial Effectiveness	
	Estimate	Confidence Bounds*	Estimate	Confidence Bounds*
Texas 72-74	17	14-21	12	9-15
New York 74	13	3-22	1	-7-10
North Carolina 73-75	27	19-34	16	9-23
3 States combined	18	14-22	11	8-14

*one-sided α =.05

Agency staff reviewed the results and concluded that further analyses on side marker lamps should be performed, in part on the same data sets, using different analytic techniques. The reasons for that conclusion were:

- o The full and partial accident avoidance estimates of 18 and 11 percent, respectively, were higher than those in the two preceding publications. They also appeared high relative to "intuitive" expectations of the effect of SML. That by itself was sufficient motivation to check the results by using other analysis techniques.

- Subsequent Agency experience gained in preparing an evaluation of head restraints [14], Sections 5.3 and 5.6, provided insights on analysis of State data. It showed that the use of a wide range of model years creates a risk of vehicle-age related biases and that, with State data, control variables and multidimensional contingency table analyses do not appear to compensate for much of the biases. Likewise, the use of a control group consisting of a different crash mode may not result in an appropriate correction for bias - especially when the test and control groups are as dissimilar as angle collisions and single-vehicle crashes. Indeed, Knoop et al. found that both of these control techniques had less than 1 percent effect on their overall effectiveness estimates. It was found that the most suitable control techniques with State data are to restrict the range of model years as much as possible (as in Section 5.6.2 of [14] or Chapter 4 of this report) or to perform regressions (as in Section 5.6.3 of [14] or Chapter 5 of this report).

- 1969 was used as the initial model year that cars has SML; in fact most new cars had them in 1968. This creates a bias against side marker lamps in Knoop et al's work (although the bias is relatively small in view of the wide range of model years included in the analysis).

2.4 Chi and Easterling (1983) - North Carolina data

Under contract to NHTSA, the Highway Safety Research Center extracted records of cars, trucks and buses involved in angle collisions in North Carolina during 1971-80 and ran preliminary regressions on the ratios of nighttime to daytime collisions. The preliminary regressions included vehicles of model years 1960-80. They generated effectiveness estimates with obvious biases -viz., identical regressions for a control group of rear-end and head-on collisions produced strongly negative results. Based on a similar experience with Texas data on side door beams [15] , p. 277, C.J. Kahane, the NHTSA Contract Technical Manager, concluded that the biases could be removed by limiting the data to a narrower range of model years. Kahane performed the analyses of Chapters 4 and 5 of this report, using Chi and Easterling's accident tabulations.

Chi decided, however, to independently pursue the same method for controlling biases and produced a report [4] very similar to Chapter 5 of this study, submitting it to NHTSA after Chapter 5 was completed. The reports differ only in that

o Using information supplied by NHTSA, Chi assumed that all MY 68 and 69 cars had SML. Subsequent investigation indicated that 12 percent of MY 68 cars and 15 percent of MY 69 cars did not.

o Chapter 5 uses model years 1964-72; Chi uses model years 1964-71 and subsets thereof.

Given these minor discrepancies, it is reassuring to note that Chi's results (15 percent accident reduction and 20 percent injury reduction - see the second lines of Tables 10 and 11, respectively) are nearly the same as the findings of this report (16 and 21 percent, respectively).

2.5 Ford Motor Company (1976)

One engineering study of side marker lamps was found in the literature and in public dockets. It forms part of a letter from Ford to NHTSA [18]. NHTSA had claimed that the rear side marker lamps on 1972-74 Mercury Capris did not conform to the color requirements of Standard 108. Ford appealed the finding on various grounds, one of which was inconsequentiality to safety. Specifically, Ford pointed out that the headlamps and taillamps of those cars were installed in a manner that their beams could be seen from many points to the side of the car, leaving just a small region where the side marker lamps and no other lamps were visible. Thus, Ford claimed that side marker lamps had minimal benefits for Capris.

Ford's letter does not address other topics that would have to be included in a detailed engineering study of SML effectiveness, such as the distance at which the lamps become visible to an approaching driver or a comparison of that distance and the approaching vehicle's stopping distance.

2.6 Indiana Tri-Level Study

The University of Indiana's Tri-Level Study provided detailed information on the causes of traffic accidents involving 2678 vehicles [28]. The information is often useful in identifying safety problems relevant to some of the standards. But the Indiana causal taxonomy is not suitable for identifying problems relevant to side marker lamps. The investigators found 10 cars that may have crashed because the vehicle they struck "blended in with the background." But the data are not further subdivided - as a result, it is unknown whether any of these were nighttime angle collisions involving a car without side marker lamps.

2.7 Summary

Four published statistical analyses of side marker lamp effectiveness each strongly support a conclusion that the lamps significantly reduce nighttime angle collisions. Their effectiveness estimates are statistically compatible with the findings of this report.

CHAPTER 3

DATA FOR ANALYZING SIDE MARKER LAMP EFFECTIVENESS

Records of crash-involved vehicles are extracted from North Carolina and Texas State accident files and from the Fatal Accident Reporting System (FARS) for the statistical analyses of side marker lamp effectiveness described in Chapters 4-7.

3.1 Data needs and guidelines

o Standard 108 requires that side marker lamps be installed on passenger cars, trucks and buses and multipurpose passenger vehicles. As a result it is appropriate to include all of these vehicle types in the study. Only motorcycles, farm vehicles, etc., are excluded.

o The purpose of side marker lamps is to make the side of a vehicle visible to other drivers. The type of crash in which side marker lamps have an effect is one in which the side of one vehicle passes through the field of view of the driver of another vehicle during the pre-contact phase of the crash (or, perhaps, both vehicles' sides pass through the other drivers' fields of view). The type of crash that can be identified on State data files and comes closest to meeting these requirements is a two-vehicle collision in which one vehicle is damaged in the front and the other, in the side.

On State files where vehicle damage location is often unknown--i.e., North Carolina--cases are selected on the basis of a description of the crash mode or pre-crash maneuvers.

Both the "struck" (side-damaged) and "striking" (frontally damaged) vehicles are included in the study, because the installation of side marker lamps on either of the vehicles could have been beneficial in preventing a collision: when two vehicles approach one another at an angle, each driver potentially has an opportunity to see the side of the other vehicle and take action to avoid a collision. Moreover, the implications of "striking" and "struck" are quite different in angle and rear-end collisions. In the latter, the lead car is always "struck" and the burden of accident avoidance rests primarily on the driver of the following car - "struck" denotes a passive role in the crash. But in angle collisions, the determination of which car is "struck" in the side often occurs at the last moment before contact and is not preordained at the beginning of the crash sequence--both drivers may have an opportunity to prevent contact and "struck" does not imply a passive role in the crash.

o Side marker lamps are primarily effective in reduced light conditions, when a car's lamps are lit but the rest of the vehicle's side is difficult to see. Thus, accidents that occurred under reduced light conditions--darkness (with or without lights), dawn, and dusk--are extracted. The analyses, however, generally compare the number of reduced-light angle collisions to the number of daylight angle collisions. Therefore, daylight crashes are also extracted.

o The model year of the vehicle must be known in order to determine whether it was equipped with side marker lamps. The analyses of Chapters 4-7 are limited to model years 1964-72 or even smaller ranges.

o It is desirable to have data files from as many calendar years as possible. The more years of data, the larger the sample size. Furthermore, for the regression analyses, it is desirable to have many years of data in order to reduce the correlation among two independent variables: side marker lamp installation and vehicle age. In other words, there should be some old vehicles with lamps and some relatively new ones without them. North Carolina, Texas and FARS are the only files for which a long series of calendar years is available to NHTSA.

o The vehicles are subdivided into two groups according to the severity of the accident in which they were involved: crashes resulting only in property damage vs. those in which someone was injured or killed. The subdivision is, of course, not made on FARS since all its accidents are fatal. The motivation is that in Chapters 4 and 5 separate analyses will be performed for injury accidents alone and for injury and property damage accidents combined--in order to check if side marker lamps are equally effective at different severity levels. Note that the severity level applies to the accident, not the vehicle--i.e., a vehicle involvement is classified as an "injury accident involvement" if someone in the other car was injured, even if no one in the subject vehicle was injured.

o In summary, all cars, trucks and buses involved in angle collisions (front-to-side, preferably) with another car, truck or bus, with known light condition, model year and accident severity are extracted and a 4-way table is prepared:

- by light condition (daylight, reduced light)
- by model year (1964, 65 ......, 72)
- by calendar year (depends on the State)
- by accident severity (property damage, injury or fatal; n.a. on FARS)

The 4-way table is used to generate two 3-way tables; one adding up the cell entries for property damage and injury accidents and the other limited to injury accidents.

For the contingency table analyses of Chapter 4, the table entries of each 3-way table are summed across calendar years to obtain 2-way tables by light condition and model year. For the regression analyses of Chapter 5, the entries in the 3-way tables are transformed into data points for the regression, as explained in Section 5.1.

o Similar 4-way tables are prepared for a control group of vehicles involved in 2-vehicle crashes that are not angle collisions (i.e., mostly rear-end or head-on). The control group is not used directly in the calculation of effectiveness estimates for side marker lamps. Rather, some of the analyses of Chapters 4-6 are performed independently on the control group to check if there are any spurious "effects" for side marker lamps.

3.2 North Carolina data

Automated North Carolina accident files were available for every year from 1971 to 1980. Dr. G. Y. H. Chi of the Highway Safety Research Center, under contract to NHTSA, performed the data extraction [4].

The principal difficulty in working with North Carolina data is the definition of an angle collision. Vehicle damage location, using the TAD classification scheme [29], is a data element on the file but is missing on a large percentage of cases (up to 60% in the early 1970's). It was felt that selection of known front-to-side collisions, based on TAD, would lead to an excessive data loss. As a result, the contractor was directed to use the variable "accident type" which is a sort of summary of precrash maneuvers. The objective was to be as inclusive as possible and to use all accident types where one driver might have been able to see the side of the other vehicle. Three accident types were included: "angle collision," "left turn across traffic" and "right turn across traffic." (On the two latter types, the side of the vehicle that is turning would usually become visible, at some point in the turn, to an approaching vehicle).

The second difficulty is that the variable "accident type" did not appear on the 1971 and 1972 files. For these two years, Chi selected cases based on damage location and precrash maneuvers of each vehicle, resulting in a large data loss due to missing data on damage location.

Light condition, accident severity and vehicle model year could be read directly from the data file, with few missing data.

Cases in which one or both vehicles were pre-1960 were excluded from the study, since it was unknown if any of them had wraparound lights that served the purpose of side marker lamps.

Collisions involving 2 trucks (and no passenger cars) were inadvertently excluded, resulting in a small data loss.

These steps produced a sample of 26,726 model year 1967 vehicles and 33,426 model year 1968 vehicles involved in angle collisions, with similar sample sizes for the other model years.

The control group consisted of the following accident types: "rear-end," "one vehicle slowing or stopping," "one vehicle backing up" and "head-on."

Chi felt that NHTSA's specifications for angle collisions were perhaps too inclusive and extracted a subset, the "refined test group," in which he was more certain that the side of one vehicle passed through the field of view of the other vehicle. Only those crashes occurring at intersections or near a driveway entrance were included. For the accident type "angle collision" he required that both vehicles be going straight and that one have frontal damage and the other, side damage. For the type "left turn across traffic," one vehicle had to be making a left turn and the other going straight or turning left. For the type "right turn across traffic," one vehicle had to be turning right and the other going straight.

The "refined test group" contains 15,775 MY 67 vehicles and 19,256 MY 68 vehicles, which is about 40 percent fewer than the NHTSA-specified sample. Much of the data loss is due to missing information on damage location.

Throughout the remainder of this report, identical analyses are performed on the NHTSA-specified sample and the refined test group. The effectiveness estimates, it turns out, are nearly identical.

The basic 4-way data tables of calendar year x model year x accident severity x light condition are shown in Appendix A.

3.3 Texas data

Automated Texas files were available for access by NHTSA for the calendar years 1972, 73 and 74. (1977 data were also available but were not used because all model years prior to 1967 are coded as "66" on that file.) The 4-way tables of calendar year x model year x accident severity x light condition, which are shown in Appendix A, were extracted directly from the master files by a COBOL program.

In Texas, the TAD code for damage location [29] is only missing on about 10 percent of the vehicles. Thus, angle collisions were defined as those 2 vehicle collisions in which one vehicle was damaged in the front (FC, FD, FL, FR) and the other, in the side (LP, RP, LF, RF, LB, RB, LD, RD). The loss of data due to missing TAD codes was considered acceptable.

Each of the 2 vehicles had to be a car, truck or bus with a known model year of 1960 or later. Light condition and accident severity were read directly from the master file.

These steps produced a sample of 38,062 model year 1967 vehicles and 45,333 model year 1968 vehicles involved in angle collisions, with similar samples for the other model years. Thus, Texas provided a larger sample than North Carolina, although the latter was derived from a longer range of calendar years. In view of these offsetting advantages, results from the 2 States should be given about equal weight.

In Texas, the control group was defined to be those vehicles involved in 2-vehicle collisions for which the damage location was known for both vehicles and which were not front-to-side impacts.

3.4 Fatal Accident Reporting System

The Fatal Accident Reporting System (FARS) is a census of the Nation's fatal traffic accidents. FARS data were available for calendar years 1975-81. The 3-way tables of calendar year x model year x light condition, which are shown in Appendix A, were extracted directly from FARS using SAS programs.

On FARS, damage location is indicated by a variable called Impact Point-Principal which employs o'clock codes. The information is missing in fewer than 5 percent of the 2-vehicle collision cases. Thus, angle collisions were defined as those 2-vehicle collisions in which one vehicle was damaged in the front (11, 12, 1) and the other, in the side (2, 3, 4, 8, 9, 10). The loss of data due to missing codes was considered acceptable.

Each of the 2 vehicles had to be a car, truck or bus with a known model year of 1960 or later. Light condition was read directly from the file (and the codes for reduced light conditions varied slightly from year to year).

These steps produced a sample of 2220 model year 1967 vehicles and 2924 model year 1968 vehicles involved in fatal angle collisions, with similar samples for the other model years. These samples are less than one-tenth as large as those from North Carolina and Texas and results based on FARS will obviously be the least statistically reliable of the three.

On FARS, as in Texas, the control group was defined to be those vehicles involved in 2-vehicle collisions for which damage location was known for both vehicles and which were not front-to-side impacts.

3.5 Introduction dates for side marker lamps

The analyses of this report require accurate knowledge of the proportion of the vehicle fleet, in a given model year, that was equipped with side marker lamps.

The assessments of side marker lamp installation used in this report are based on a variety of data sources:

o Chilton's Auto Air Conditioning and Wiring Diagrams Manual shows in detail the lamp circuits for each make and model of domestic car, indicating clearly if front and/or rear side marker lamps were installed in a given model year. In general, it is the most satisfactory information source, but there are some shortcomings: a small number of the diagrams are missing; the diagrams, by themselves, do not indicate if parking and taillamps were of the "wraparound" type and served as side marker lamps, the data in this book occasionally disagree with some of the other sources.

o Chilton's Auto Repair Manual, 1970 gives detailed listings of the types of lightbulbs on each model of car, by model year. The listings, however, are less complete than the preceding source.

o The "AMA Auto Identification Manuals" published by the Motor Vehicle Manufacturers Association contain photographs that indicate the presence or absence of side marker lamps and/or reflectors on domestic passenger cars by make, model and model year [2]. Exterior photos alone, however, do not make it clear whether a device actually contained a bulb on the inside or was merely a reflector. On the other hand, the photos are especially useful for identifying wraparound parking and taillights.

o Ward's Automotive Yearbooks and back issues of Automotive News were consulted for photographs of light trucks, multipurpose vehicles, etc.

o The agency's cost evaluation for side marker lamps [10] contains detailed part-by-part photographs of the SML of a select group of makes and models and provides authoritative information on those models.

o Recollections of NHTSA staff

Based on these sources, the proportion of new cars, trucks and buses equipped with side marker lamps is shown in Table 3-1.

The percentages are calculated by adding up the sales of models equipped with SML and dividing it by the total number of vehicles sold in a given model year. If a model had front SML but none at the rear, or vice-versa, it was counted as being half equipped with SML--i.e., half of the sales for that make and model were counted as SML-equipped. Wraparound parking or taillights <u>were</u> counted as SML; reflectors without a lamp inside were <u>not</u>.

The percentages are, moreover, based on the assumptions that imported cars (which had only a small market share in those years) had about the same proportion SML equipped as domestic cars; that heavy trucks and buses initially received SML in 1968. Photographs indicated that light trucks and MPV's had neither SML nor reflectors in 1967 and earlier, but did have one or the other in 1968 and later. It is assumed that the proportion of light trucks that had only reflectors, as opposed to lamps, is the same as for cars.

Table 3-2 furnishes a detailed listing, by model year, of which models were equipped with SML.

In the contingency table analyses of Chapter 4, the objective is to compare the nighttime-to-daytime angle collision ratios of vehicles of the first model year "with" side marker lamps to those of the last model

TABLE 3-1

PERCENT OF NEW CARS, TRUCKS AND BUSES EQUIPPED
WITH SIDE MARKER LAMPS, BY MODEL YEAR

Model Year	Percent with Side Marker Lamps
1964	5
1965	8
1966	15
1967	13
1968	88
1969	85
1970 and subsequently	100

TABLE 3-2

SIDE MARKER LAMP EQUIPMENT ON DOMESTIC VEHICLES, BY MODEL YEAR, MAKE AND MODEL

1964: Buick Riviera and Cadillac--front lamp + wraparound taillight
Dodge Custom and Lincoln--wraparound taillight
Olds 98--front lamp

1965: AMC Classic, Mercury Comet, Plymouth Valiant and Pontiac Tempest--wraparound taillight
Buick Electra, Cadillac and Olds 98--front lamp
Lincoln and Mercury--wraparound parking and taillights

1966: AMC Ambassador & Classic, Chevrolet Impala, Chrysler, Plymouth Barracuda & Valiant--wraparound taillight
Buick Electra, Cadillac, Olds 98 & Toronado--front lamp
Mercury--wraparound parking and taillights

1967: AMC Classic--rear lamp
Buick Electra, Cadillac, Olds Toronado--front lamp
Chevrolet Chevelle and Plymouth Satellite--wraparound tailllight
Chrysler New Yorker--wraparound parking and taillight

1968: All cars and light trucks have front and rear SML or wraparound lights except Fords and Mercurys have them only in the front (in back--reflectors only)

Caveats: Some sources do not indicate any lamps on AMC American, Ford Fairlane or Mercury Comet.

1969: All cars and light trucks have front and rear SML or wraparound lights except

Chrysler (other than Imperial), Dodge Polara & Monaco--rear lamps and front reflectors

Dodge (other than Polara and Monaco), all Plymouths--reflectors only; no lamps

Caveats: Some sources do not indicate any lamps on AMC American; no front lamps on Ford Fairlane or Mercuty Comet

1970 and subsequent years: All vehicles have front and rear SML or wraparound lights.

year "without" SML. From the Table 3-1, it is clear that the appropriate comparison is MY 68 when 88 percent of new vehicles had SML vs. MY 67 when 87 percent did not have them. It is also evident that an analytic correction factor will have to be introduced in the results, to account for the fact that 13 percent of the MY 67 fleet had SML and 12 percent of the MY 68 fleet did not.

In the regression analyses of Chapter 5, there is one data point for each case vehicle model year MY in each calendar year of data CY. The dependent variable LOGODDS (MY, CY) is the log of the ratio of nighttime to daytime angle collision involvements, for cars of model year MY during calendar year CY. The most important independent variable is LAMP (MY, CY), which is the expected (or average) number of vehicles with side marker lamps in a 2-vehicle collision, during calendar year CY, in which the case vehicle is known to be of model year MY. The model year of the other vehicle is unknown, except to the extent that the distribution of vehicle registrations by model year in calendar year CY is known. LAMP (MY, CY) is a number between 0 and 2 and will reach 2 when every vehicle on the highway will be equipped with SML.

Why is the SML status of the other vehicle important? Because the presence of side marker lamps on either vehicle has the potential of helping prevent nighttime collisions; SML on both vehicles further increase that potential. Thus, for example, cars of model year 1968 should experience relatively fewer nighttime angle collisions in 1975 than in 1970 because thre is a greater likelihood that the other vehicle was also equipped with SML.

LAMP (MY, CY) is calculated in two steps:

$$\text{LAMP (MY, CY)} = \text{LAMPMY (MY)} + \text{LAMPCY (CY)}$$

where LAMPMY (MY) is the likelihood that the case vehicle of a certain model year has SML and is taken directly from Table 3-1 and

$$\text{LAMPCY (CY)} = \frac{\sum_{MY = 64}^{CY} \text{REG (MY, CY)} \quad \text{LAMPMY (MY)}}{\sum_{MY = 50}^{CY} \text{REG (MY, CY)}}$$

is the proportion of vehicles registered in calendar year CY that have SML. (Note that REG (MY, CY) is the number of vehicles of model year MY registered in calendar year CY and is given by Table 3-3, which is derived from "MVMA Motor Vehicle Facts and Figures '82" [20].) The proportion of registered vehicles with SML is shown in Table 3-4.

TABLE 3-3

REGISTERED CARS AND TRUCKS, BY MODEL YEAR, IN A GIVEN CALENDAR YEAR (000)

MODEL YEAR	CALENDAR YEAR										
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
PRE-1964	26221	20975	16489	13107	11013	9243	7656	6151	5617	5114	4638
1964	7763	6986	5968	4917	4118	3406	2705	2208	1818	1348	1100
1965	9469	8843	7923	6855	5910	4947	3945	3201	2623	2204	1800
1966	9754	9339	8696	7840	7052	6079	4983	4091	3366	2825	2433
1967	9170	8871	8456	7929	7386	6581	5545	4632	3820	3199	2752
1968	10298	10064	9737	9349	8951	8201	7126	6106	5110	4254	3634
1969	11152	10980	10706	10419	10118	9505	8608	7641	6493	5501	4717
1970	10624	10595	10321	10191	10009	9601	9022	8293	7344	6368	5575
1971	7120	10699	10468	10364	10279	9946	9505	8893	8074	7193	6367
1972	0	8806	12543	12543	12482	12218	11854	11367	10571	9707	8869
1973	0	0	9871	14098	14180	13929	13606	13240	12552	11760	10974
1974	0	0	0	8267	12502	12478	12283	12087	11593	11140	10617
1975	0	0	0	0	6010	9831	9586	9367	8996	8728	8468
1976	0	0	0	0	0	8365	12303	12226	11882	11650	11457
1977	0	0	0	0	0	0	9354	13622	13450	13263	13076
1978	0	0	0	0	0	0	0	9959	14240	14146	13923
1979	0	0	0	0	0	0	0	0	9690	14167	14053
1980	0	0	0	0	0	0	0	0	0	7230	11043
1981	0	0	0	0	0	0	0	0	0	0	6384

TABLE 3-4

PERCENT OF REGISTERED VEHICLES EQUIPPED WITH SIDE MARKER LAMPS, BY CALENDAR YEAR

Calendar Year	Percent of Registered Vehicles with SML
1971	40
1972	49
1973	58
1974	65
1975	71
1976	76
1977	80
1978	85
1979	87
1980	89
1981	91

CHAPTER 4

ANALYSES OF CONTINGENCY TABLES

Cars, trucks and buses of model year 1968--mostly equipped with side marker lamps--are shown to have 7 percent fewer nonfatal nighttime angle collision involvements than model year 1967 vehicles (mostly not equipped with side marker lamps). The finding is based on analyses of simple 2 by 2 tabulations of North Carolina and Texas angle collision involvements: by model year and light condition. No effect is found, however, in the crashes of the Fatal Accident Reporting System (FARS).

4.1 Method

Analyses are conducted on the following tabulation of vehicles involved in accidents:

	VEHICLES INVOLVED IN	
Model Year	Daytime Angle Collisions	Nighttime, Dawn or Dusk Angle Collisions
1967 - last model year before most vehicles had SML	N_{11}	N_{12}
1968 - first year that most vehicles had SML	N_{21}	N_{22}

The exact definition of "angle collision," "daytime," etc., depends on the data file and is given in Chapter 3. The ratio N_{21}/N_{11}

of daytime angle collisions is an indirect measure of the likelihood of post-standard vehicle accident involvements relative to pre-standard. It takes into account the differences in exposure and the effects of safety devices other than lamps (if any). If side marker lamps had no effect on nighttime collision risk, the expected number of nighttime collision involvements for model year 1968 would be $N_{12}\ (N_{21}/N_{11})$. Thus,

$$\mathcal{E} = 1 - \frac{N_{22}\ N_{11}}{N_{12}\ N_{21}}$$

is a measure of the collision-reducing effectiveness of equipping one vehicle with side marker lamps.

Two underlying assumptions are:

o Side marker lamps have little or no effect on daytime angle collision risk.

o The reduction in nighttime collision risk (relative to daytime) is due to side marker lamps, not other factors.

The first assumption seems acceptable. The validity of the second assumption is not nearly so clear and, as a minimum, requires further testing.

As noted above, the basic analysis is limited to a comparison of 1967 vs. 1968 model year vehicles. Thus, the age difference between the pre- and post-standard cars is just one year. That minimizes potential sources of bias such as the effect of changes in the vehicles other than side marker lamps or the effects related to differences in vehicle age. On the other hand, it raises a possibility that a result could be due to an anomaly in vehicles of model year 1967 or 1968, or a statistical mischance.

As a test, each basic analysis is repeated with an accident sample broadened to include 1966 and 1967 vehicles vs. 1968 and 1969 vehicles. Does the larger sample yield effectiveness estimates consistent with the basic analysis? As a further test, each analysis is again repeated with the sample broadened to include 1965-67 vs. 1968-70 vehicles and, finally, 1964-67 vs. 1968-71 vehicles. Do the effectiveness estimates from the 4 analyses (henceforth designated as $\pm$ 1 MY, $\pm$ 2 MY, $\pm$ 3 MY, $\pm$ 4 MY) show any trend of, say, effectiveness increasing as the span of model years increases? If so, it could indicate that the observed accident reduction is, at least in part, due to vehicle age differences because as the span of model years increases so does the average age difference between pre- and post-standard cars.

As a final test, the analyses are repeated in Section 4.5 using a control group of two-vehicle accidents that are not angle collisions. The exact definition of the control group varies from State to State and is given in Chapter 3. The main purpose of the control group analyses is to check if there are anomalies in the nighttime vs. daytime accident ratios for the two specific model years 1967 and 1968 which cannot be attributed to side marker lamps (because they are happening in crashes that are not angle collisions). A secondary purpose is to check for vehicle age-related trends in those ratios.

In all analyses, the statistical significance of the observed effect for side marker lamps is tested by taking the ordinary chi-square for the 2 x 2 table.

The analytic approach of this chapter was also used in NHTSA's evaluations of energy-absorbing steering assemblies [13] pp. 197-202, head restraints [14] pp. 161-170 and side door beams [15] pp. 143-157 as well as in the New York State study of side marker lamps (see Section 2.1).

4.2 Accidents of all severities

4.2.1 North Carolina

In Section 3.2, the accident sample for North Carolina was selected based on the variable "accident type" and included 2 vehicle crashes classified as "angle collision," "left turn across traffic" or "right turn across traffic." During 1971-80, there were 60,152 model year 1967 and 1968 vehicles involved in those types of crashes. Table 4-1 shows their distribution by light condition: daytime vs. nighttime (including dawn or dusk). There were 5,971 MY 1967 vehicles in nighttime angle collisions. Based on the ratio of MY 1968 to MY 1967 cars in daytime collisions, 5,971 (26,351/20,755) = 7,581 nighttime angle collision involvements are expected for the MY 1968 vehicles. In fact, only 7,075 occurred. This is a reduction of

$$1 - \frac{7,075 \cdot 20,755}{5,971 \cdot 26,351} = 7 \text{ percent}$$

in nighttime angle collision involvements for MY 1968 compared to MY 1967. Since the chi-square for the table is 12.08, the reduction is statistically significant ($\alpha = .05$).

TABLE 4-1

NORTH CAROLINA 1971-80: ANGLE COLLISION INVOLVEMENTS
BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nightime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	20,755	5,971		
1968 (first year with SML)	26,351	7,075	7**	12.08
1966-67 (last 2 yrs. w/o)	41,799	11,746		
1968-69 (first 2 yrs. with)	57,546	15,264	6**	17.36
1965-67 (last 3 yrs. w/o)	56,713	15,921		
1968-70 (first 3 yrs. with)	88,491	23,231	6**	33.36
1964-67 (last 4 yrs. w/o)	67,688	19,071		
1968-71 (first 4 yrs. with)	120,302	31,586	7**	46.45

* Includes dawn and dusk

**Statistically significant reduction for SML ($\alpha = .05$)

When the sample is expanded to include model years 1966-67 vs. 1968-69 (the $\pm$ 2 MY comparison), the result is nearly identical. Table 4-1 indicates a 6 percent reduction in nighttime angle collision involvements for model years 1968-69, which is again statistically significant (chi-square = 17.36). In the $\pm$ 3 MY comparison, the reduction is again 6 percent and in the $\pm$ 4 MY comparison it is 7 percent. The sequence of effectiveness estimates for the 4 consecutively larger samples - 7, 6, 6, 7 - shows little or no trend. It indicates that the ratio of nighttime to daytime angle collisions is more or less invariant across model years or vehicle ages except for a significant 7 percent reduction between MY 1967 and 68, the year that most cars received side marker lamps.

Dr. Chi of the Highway Safety Research Center expressed concern that the preceding definition of "angle collision" was perhaps too inclusive and extracted a subset which he called the "refined test group" (see Section 3.2). It is limited to crashes at intersections and driveway entrances and, in many cases, requires that one vehicle be damaged in the front and the other in the side. The refined test group is about 40 percent smaller than the basic sample, to a large extent because many cases are deleted due to unknown damage location.

Table 4-2 presents the analyses for the refined test group. In the $\pm$ 1 MY comparison, there is an 8 percent reduction in nighttime angle collision involvements for the MY 68 vehicles, which is

TABLE 4-2

NORTH CAROLINA "REFINED TEST GROUP" 1971-80: ANGLE COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nighttime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	12,325	3,450		
1968 (first year with SML)	15,327	3,929	8**	11.21
1966-67 (last 2 yrs. w/o)	24,834	6,763		
1968-69 (first 2 yrs. with)	33,301	8,424	7**	16.15
1965-67 (last 3 yrs. w/o)	33,959	9,261		
1968-70 (first 3 yrs. with)	50,909	12,807	8**	27.71
1964-67 (last 4 yrs. w/o)	40,775	11,190		
1967-71 (first 4 yrs. with)	68,819	17,327	8**	39.90

*Includes dawn and dusk

**Statistically significant reduction for SML ($\alpha = .05$)

statistically significant (chi-square = 11.21). It is also nearly the same as the 7 percent observed for the more inclusive sample of Table 4-1. For the $\pm$ 2, $\pm$ 3 and $\pm$ 4 year comparisons, the reductions are 7, 8 and 8 percent, respectively. In other words, there appears to be no vehicle-age related trend and the results are almost the same as for the more inclusive sample. Since the samples in Table 4-1 are nearly twice as large and since the results for the two tables are nearly identical, it is recommended that the results from Table 4-1 be given greater weight than those from the refined test group. It would also appear that the restrictions used in obtaining the refined test group were of limited utility in pinpointing those crashes where side marker lamps are most effective.

4.2.2 Texas

The accident sample for Texas consisted of cars, trucks and buses involved in 2-vehicle collisions in which one vehicle was frontally damaged and the other, in the side (based on the TAD classification of damage - see Section 3.3). During 1972-74, there were 83,395 model year 1967 and 1968 vehicles involved in those types of crashes. Table 4-3 shows their distribution by light condition. The MY 68 vehicles had a

$$1 - \frac{8,715 \cdot 30,324}{7,738 \cdot 36,618} = 7 \text{ percent}$$

reduction of nighttime angle collisions compared to MY 67. The reduction is statistically significant (chi-square = 15.97). Moreover,

TABLE 4-3

TEXAS 1972-74: ANGLE COLLISION INVOLVEMENTS
BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nighttime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	30,324	7,738		
1968 (first year with SML)	36,618	8,715	7**	15.97
1966-67 (last 2 yrs. w/o)	58,512	14,939		
1968-69 (first 2 yrs. with)	75,877	18,168	6**	27.07
1965-67 (last 3 yrs. w/o)	84,079	21,458		
1968-70 (first 3 yrs. with)	114,907	26,875	9**	72.97
1964-67 (last 4 yrs. w/o)	103,040	26,386		
1968-71 (first 4 yrs. with)	154,977	35,737	10**	133.96

*Includes dawn and dusk

**Statistically significant reduction for SML ($\alpha = .05$)

it is identical to the 7 percent effect observed in North Carolina (Table 4-1).

When the sample is expanded to include model years 1966-67 vs. 1968-69, the observed effect of SML drops very slightly to 6 percent, which is still a significant reduction (chi-square = 27.07). In the $\pm$ 3 MY comparison the effect increases, however, to 9 percent and it reaches 10 percent in the $\pm$ 4 MY comparison. The sequence of estimates--7, 6, 9, 10 percent--does not show a strong age-related trend. The estimates from the broader samples are compatible with the 7 percent reduction in the $\pm$ 1 MY comparison, which appears to be a good estimate of the effect of side marker lamps in MY 68 vehicles. (The regression analyses of Chapter 5 are an attempt to analyze possible trends in the data in more detail.)

The identical 7 percent estimates from the basic analyses of North Carolina and Texas data, both of which were statistically significant, suggest that this is a good figure for the effect of side marker lamps in model year 1968. In other words, MY 68 vehicles, 88 percent of which are equipped with SML, have 7 percent fewer nighttime angle collisions than MY 67 vehicles, only 13 percent of which are equipped with SML.

4.3 Injury accidents

The analyses of Tables 4-1, 4-2 and 4-3 are repeated with the data sets restricted to injury-producing accidents--in order to

TABLE 4-4

NORTH CAROLINA INJURY ACCIDENTS 1971-80: ANGLE COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nighttime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	6,303	2,240		
1968 (first year with SML)	7,835	2,554	8**	6.64
1966-67 (last 2 yrs. w/o)	12,644	4,463		
1968-69 (first 2 yrs. with)	17,016	5,498	8**	14.38
1965-67 (last 3 yrs. w/o)	17,485	6,059		
1968-69 (first 3 yrs. with)	26,338	8,378	8**	19.31
1964-67 (last 4 yrs. w/o)	21,035	7,248		
1968-71 (first 4 yrs. with)	35,802	11,418	7**	19.88

*Includes dawn and dusk

**Statistically significant reduction for SML ($\alpha = .05$)

check whether the 7 percent effect of side marker lamps found in all types of accidents also persists in accidents of higher severity. A vehicle is involved in an injury-producing accident if at least one person in the accident--not necessarily an occupant of the case vehicle--was injured or killed (see Section 3.1).

4.3.1 North Carolina

Table 4-4 shows that MY 68 vehicles were 8 percent less likely to be involved in injury-producing nighttime angle collisions than MY 67 vehicles in North Carolina during 1971-80. The reduction is statistically significant (chi-square = 6.64). It is also almost the same as the reduction in accidents of all severities (which was 7 percent in Table 4-1).

The reduction remains almost unchanged as the sample is broadened to include additional model years. It is 8 percent in the ± 2 MY comparison, 8 percent for ± 3 MY and 7 percent for ± 4 MY. All of those reductions are significant. The sequence of effectiveness estimates--8, 8, 8, 7--shows little or no trend and indicates that the 8 percent observed in the ± 1 MY comparison is probably a good, unbiased estimate.

Table 4-5 gives corresponding results for the "refined test group." The ± 1 MY comparison indicates a 13 percent accident reduction for SML, which is statistically significant. The reduction, however, drops to 11 percent in the ± 2 MY comparison and 10 percent in the ± 3 MY and ± 4 MY comparisons. There is little reason to believe that the

TABLE 4-5

NORTH CAROLINA INJURY ACCIDENTS, 1971-80, "REFINED TEST GROUP": ANGLE COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nighttime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	4,211	1,434		
1968 (first year with SML)	5,229	1,557	13**	10.20
1966-67 (last 2 yrs. w/o)	8,439	2,838		
1968-69 (first 2 yrs. with)	11,301	3,369	11**	16.97
1965-67 (last 3 yrs. w/o)	11,746	3,854		
1968-70 (first 3 yrs. with)	17,374	5,109	10**	20.09
1964-67 (last 4 yrs. w/o)	14,249	4,645		
1968-71 (first 4 yrs. with)	23,532	6,921	10**	22.42

*Includes dawn and dusk

**Statistically significant reduction for SML ($\alpha = .05$)

gradual dropoff is due to a vehicle age-related trend, since no such trend was seen in other tables. A more likely explanation is that the 13 percent estimate is somewhat overstated, by statistical mischance (in view of the reduced sample size of the refined test group) and that enlargement of the sample yields more precise values that are also more consistent with those seen in the other tables.

4.3.2 Texas

Table 4-6 shows that MY 68 vehicles experienced 8 percent lower risk of injury-producing nighttime angle collisions than MY 67 vehicles in Texas during 1972-74. The reduction is statistically significant (chi-square = 5.25) and identical to the one found in North Carolina.

Extending the sample to include additional model years hardly perturbs the results. The sequence of effectiveness estimates--8, 7, 7, 9 for the ± 1, 2, 3, 4 MY comparisons, respectively--indicates little or no trend and is virtually identical to the North Carolina sequence and the results for both States on accidents of all severities.

It would appear reasonable to conclude that side marker lamps are nearly equally effective in preventing injury accidents and property-damage accidents, with, perhaps, a slightly greater effect on injury accidents.

TABLE 4-6

TEXAS INJURY ACCIDENTS, 1972-74: ANGLE COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nighttime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	6,123	2,185		
1968 (first year with SML)	7,248	2,391	8**	5.25
1966-67 (last 2 yrs. w/o)	12,105	4,279		
1968-69 (first 2 yrs. with)	15,046	4,925	7**	10.09
1965-67 (last 3 yrs. w/o)	17,640	6,145		
1968-70 (first 3 yrs. with)	22,511	7,259	7**	14.86
1964-67 (last 4 yrs. w/o)	21,800	7,608		
1968-71 (first 4 yrs. with)	30,223	9,617	9**	27.14

*Includes dawn and dusk

**Statistically significant reduction for SML ($\alpha = .05$)

4.4 Fatal accidents

The accident sample extracted from the Fatal Accident Reporting System (FARS) consisted of cars, trucks and buses involved in fatal 2-vehicle collisions in which one vehicle was frontally damaged and the other, in the side (see Section 3.4). During 1975-81, there were 5,144 model year 1967 and 68 vehicles involved in those types of crashes. Table 4-7 shows their distribution by light condition. The smallest cell--nighttime involvements for MY 67-- is 965, which is about 1/6 as large as the comparable cell in North Carolina (Table 4-1) and 1/8 as large as in Texas (Table 4-3). Thus, estimates based on FARS are less precise than those for nonfatal crashes.

The MY 68 vehicles had a

$$1 - \frac{1292 \cdot 1255}{965 \cdot 1632} = 3 \text{ percent increase}$$

in the risk of fatal nighttime angle collisions compared to MY 67. The increase is not statistically significant (chi-square = 0.26).

When the sample is extended to include additional model years, the results become slightly worse: -7 percent for the $\pm$ 2 MY comparison and -6 percent for both the $\pm$ 3 MY and $\pm$ 4 MY comparisons. The sequence of estimates, however - -3, -7, -6, -6 - does not reveal any obvious trend. More importantly, none of the observed increases is statistically significant, even the one for $\pm$ 4 MY.

TABLE 4-7

U.S. FATAL ACCIDENTS, 1975-81: ANGLE COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Angle Collision Involvements		Nighttime* Reduction for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	1,255	965		
1968 (first year with SML)	1,632	1,292	-3	0.26
1966-67 (last 2 yrs. w/o)	2,440	1,818		
1968-69 (first 2 yrs. with)	3,594	2,861	-7	2.76
1965-67 (last 3 yrs. w/o)	3,334	2,481		
1968-70 (first 3 yrs. with)	5,765	4,532	-6	2.74
1964-67 (last 4 yrs. w/o)	3,976	2,927		
1968-71 (first 4 yrs. with)	8,075	6,276	-6	3.36

*Includes dawn and dusk

**Statistically significant change for SML ($\alpha = .05$)

From the data in Table 4-7 it is not possible to draw any conclusion on the effect of side marker lamps in fatal accidents. Other statistical analyses are needed and, if they do not resolve the issue, an engineering analysis.

4.5 Analyses for a control group of head-on and rear-end crashes

The preceding tabulations and analyses of angle collision involvements are reiterated for a control group of 2-vehicle crashes that are not angle collisions--viz., head-on and rear-end collisions. In those crashes, neither driver is likely to see the other vehicle from the side for a significant time period before the crash. Even if the driver does see the side of the other vehicle, it is probably at an angle where the front (headlights) or rear (brake or taillights) is also visible. In other words, side marker lamps should be of little or no value in preventing those collisions at night. Any significant "reduction" of nighttime collisions of MY 68 cars, relative to MY 67, in the control group is not likely due to side marker lamps and could indicate a bias in the basic analyses of angle collisions conducted in the preceding sections.

4.5.1 North Carolina

The control group for North Carolina was defined to be vehicles involved in 2-vehicle collisions that were specifically identified as head-on or rear-end (see Section 3.2). Table 4-8 shows their distribution

TABLE 4-8

NORTH CAROLINA, 1971-80: CONTROL GROUP COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Control Group Collision Involvements		Nighttime* "Reduction" for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	13,810	4,384		
1968 (first year with SML)	17,941	5,766	-1	0.29
1966-67 (last 2 yrs. w/o)	27,220	8,844		
1968-69 (first 2 yrs. with)	39,643	12,660	2	1.17
1965-67 (last 3 yrs. w/o)	36,610	12,169		
1968-70 (first 3 yrs. with)	61,584	19,430	5**	15.35
1964-67 (last 4 yrs. w/o)	43,330	14,512		
1968-71 (first 4 yrs. with)	85,771	26,571	8**	43.06

*Includes dawn and dusk

**Statistically significant "reduction" for SML ($\alpha = .05$)

by model year and light condition. The MY 68 vehicles experienced a 1 percent increase in nighttime control group collision risk, relative to MY 67. The increase is not significant (chi-square = 0.29).

When the control group sample is extended to include additional model years, there is a perfect linear trend in the "effectiveness" estimates: -1, 2, 5, 8 for the ± 1, ± 2, ± 3 and ± 4 MY comparisons, respectively. No trend like this was found in any of the analyses of angle collisions. Evidently, the biasing effect of vehicle age on the ratio of nighttime to daytime collisions is strong in the control group and virtually absent in the test group. That limits the usefulness of the control group as an analytic tool in this study. For example, it would not appear valid to do a 3 dimensional contingency table analysis of collision type (angle vs. control) x light condition x SML status. The best use of the control group is, as stated above, to search for specific anomalies in model years 67 and 68.

When the linear trend in the "effectiveness" estimates - -1, 2, 5, 8 - is extrapolated one year to the left, an estimate of -4 percent is obtained. The estimates -1, 2, 5, 8 are based on samples in which the average age difference of pre- and post-standard cars is 1, 2, 3, 4 years, respectively. The extrapolated estimate of -4 percent represents a condition where the age difference of pre- and post-standard cars is zero. In other words, after controlling for vehicle age differences, the "effect" of side marker lamps on the

TABLE 4-9

NORTH CAROLINA INJURY ACCIDENTS, 1971-80: CONTROL GROUP COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Control Group Collision Involvements		Nighttime* "Reduction" for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	4,037	1,680		
1968 (first year with SML)	5,188	2,207	-2	0.32
1966-67 (last 2 yrs. w/o)	8,069	3,474		
1968-69 (first 2 yrs. with)	11,244	4,806	1	0.07
1965-67 (last 3 yrs. w/o)	10,983	4,834		
1968-70 (first 3 yrs. with)	17,215	7,286	4	3.11
1964-67 (last 4 yrs. w/o)	13,169	5,778		
1968-71 (first 4 yrs. with)	23,617	9,868	5**	6.08

*Includes dawn and dusk

**Statistically significant "reduction" for SML ($\alpha = .05$)

control group is -4 percent. Certainly, then, the control group does not indicate a bias in favor of side marker lamps in the preceding analyses.

Table 4-9 is limited to injury producing control group accidents. The sequence of "effectiveness" estimates - -2, 1, 4, 5 percent - is nearly the same as in Table 4-8 and, again, does not indicate the presence of a bias in favor of side marker lamps.

4.5.2 Texas

The control group for Texas was defined to be cars, trucks and buses involved in 2-vehicle collisions in which the damage location was known for both vehicles and which were not front-to-side collisions (see Section 3.3). In part because of the inclusiveness of the definition, the Texas control group is more than 3 times as large as North Carolina's and will produce more statistically reliable results.

Table 4-10 presents the results for crashes of all severities. The "effectiveness" estimates for the $\pm$ 1, $\pm$ 2, $\pm$ 3 and $\pm$ 4 MY comparisons are on a straight line: 3, 6, 9 and 12 percent, respectively. When the line is extrapolated back to a "$\pm$ 0 MY comparison" the predicted effectiveness is zero. In other words, after controlling for vehicle age, side marker lamps have absolutely no effect on the nighttime to daytime ratio of crashes in the control group.

TABLE 4-10

TEXAS 1972-74: CONTROL GROUP COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Control Group Collision Involvements		Nighttime* "Reduction" for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	58,110	15,652		
1968 (first year with SML)	72,105	18,746	3**	8.45
1966-67 (last 2 yrs. w/o)	110,942	30,265		
1968-69 (first 2 yrs. with)	153,921	39,423	6**	53.83
1965-67 (last 3 yrs. w/o)	157,721	43,715		
1968-70 (first 3 yrs. with)	235,293	59,315	9**	178.77
1964-67 (last 4 yrs. w/o)	190,976	53,621		
1968-71 (first 4 yrs. with)	320,802	79,495	12**	394.53

*Includes dawn and dusk

**Statistically significant "reduction" for SML (α = .05)

Table 4-11 is limited to injury producing control group accidents. Again, the sequence of effectiveness estimates is perfectly linear, with a 3 percent increase for each additional year of age difference: 2, 5, 8, 11 percent. When the line is extrapolated to zero age difference, the "effect" of side marker lamps on the control group is -1 percent.

The control group results for North Carolina and Texas are remarkably consistent with one another and indicate that side marker lamps had no effect in property damage and injury crashes that are not angle collisions.

4.5.3 Fatal Accident Reporting System

The control group for FARS, as in Texas, consisted of cars, trucks and buses involved in 2-vehicle accidents that were not front-to-side impacts (see Section 3.4). The majority of these crashes on FARS, however, are head-on collisions whereas, among nonfatal accidents, rear-end collisions predominate. As a result, the FARS control group might be expected to behave differently from those of North Carolina and Texas.

Table 4-12 shows that MY 68 vehicles experienced a 10 percent increase in nighttime control group collision risk, relative to MY 67. The increase is statistically significant (chi-square = 4.76). Moreover, when the sample is extended to include additional model years, the increase persists without any vehicle age-related trend:

TABLE 4-11

TEXAS INJURY ACCIDENTS, 1972-74: CONTROL GROUP COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Control Group Collision Involvements		Nighttime* "Reduction" for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	7,673	3,304		
1968 (first year with SML)	9,061	3,817	2	0.60
1966-67 (last 2 yrs. w/o)	14,947	6,556		
1968-69 (first 2 yrs. with)	18,872	7,839	5**	7.41
1965-67 (last 3 yrs. w/o)	21,623	9,675		
1968-70 (first 3 yrs. with)	28,246	11,655	8**	24.23
1964-67 (last 4 yrs. w/o)	26,505	12,058		
1968-71 (first 4 yrs. with)	38,069	15,407	11**	64.62

*Includes dawn and dusk

**Statistically significant "reduction" for SML (α = .05)

-10, -10, -11, -11 percent effects for the $\pm$ 1, $\pm$ 2, $\pm$ 3, $\pm$ 4 MY comparisons, respectively.

The significant, persistent negative effect could be an unfortunate statistical mischance or it could represent a genuine effect of some change in MY 68 vehicles on control group accidents, either increasing nighttime fatalities or, just as likely, decreasing daytime fatalities.

It would appear reasonable not to attribute the effect to side marker lamps. A more plausible explanation of the effect could be:

o A trend toward lighter, brighter exterior paint colors for cars of the late 1960's [30], p. 106. That could have resulted in a reduction of daytime crashes by making cars more visible. It is hard to believe, however, that the reduction would be as large as 10 percent and concentrated in model year 68.

o Crashworthiness equipment installed in cars of the late 1960's might, perhaps, be more effective in daytime crashes than in nighttime crashes because the latter are more likely to involve alcohol and, as a result, extremely high speeds. Again, it is hard to believe that the differential effect would be as large as 10 percent and concentrated in MY 68.

In short, it is difficult to believe that the analysis creates a 10 percent bias against side marker lamps. But if such a

TABLE 4-12

U.S. FATAL ACCIDENTS, 1975-81: CONTROL GROUP COLLISION INVOLVEMENTS BY SIDE MARKER LAMP STATUS AND LIGHT CONDITION

Model Years	Control Group Collision Involvements		Nighttime* "Reduction" for SML (%)	Chi-Square
	Daylight	Nighttime*		
1967 (last year w/o SML)	1,623	1,938		
1968 (first year with SML)	1,946	2,564	-10**	4.76
1966-67 (last 2 yrs. w/o)	3,038	3,648		
1968-69 (first 2 yrs. with)	4,430	5,852	-10**	9.10
1965-67 (last 3 yrs. w/o)	4,226	4,980		
1968-70 (first 3 yrs. with)	7,107	9,278	-11**	15.29
1964-67 (last 4 yrs. w/o)	5,088	5,900		
1968-71 (first 4 yrs. with)	10,025	12,860	-11**	18.76

*Includes dawn and dusk

**Statistically significant "change" for SML ($\alpha = .05$)

bias is really there, it might explain the negative results obtained in the analyses of angle collisions on FARS (Table 4-7). In other words, it is conceivable that the -3 percent effect observed for SML in angle collisions could represent the sum of a 7 percent benefit for SML and a 10 percent bias against them--conceivable, but not too plausible.

Obviously, the contingency table analyses of this chapter do not give a clear indication of the effect of side marker lamps, if any, in fatal crashes. Further analyses are needed.

4.6 Discussion

The contingency table analyses of North Carolina and Texas data showed unambiguously that model year 1968 vehicles have a 7 or 8 percent lower risk of nighttime angle collision involvement than model year 1967 vehicles. A similar reduction was found in property damage crashes and injury-producing accidents (but not in fatal crashes).

The observed reduction, however, understates the net benefits of introducing side marker lamps in the entire vehicle fleet, for two reasons:

(1) 13 percent of model year 67 cars, trucks and buses were equipped with side marker lamps or wraparound parking or taillights; 88 percent of model year 68 vehicles were so equipped (see Section 3.5). As a result, the observed accident reduction measures the effect of a change from 13 percent to 88 percent SML installation. The effect of changing from 0 to 100 percent would be higher.

(2) More important, the analytic approach has been to consider the effect of changing one vehicle in a 2-vehicle collision from model year 1967 (unequipped) to MY 68 (SML equipped). The model year of the other vehicle was not specified. The effect of installing SML on both vehicles approaching at an angle should be close to double the effect of equipping just one of them.

These issues can be addressed more effectively by the regression analyses of Chapter 5 than by the approach of this chapter. The principal advantage of the contingency table analyses of this chapter, however, is that they demonstrated in a straightforward manner that side marker lamps reduce accident risk.

CHAPTER 5

REGRESSION ANALYSES

When a single car, truck or bus is equipped with side marker lamps, its risk of having a nighttime angle collision is reduced by 7-8 percent. When all cars, trucks and buses on the road have side marker lamps there will be 14-16 percent fewer nighttime angle collisions than if none of the vehicles had been so equipped. The finding is based on regressions of the ratio of nighttime to daytime angle collisions in North Carolina and Texas, as a function of side marker lamp installation, vehicle age and other factors (separate regressions for each State). It is close to the effectiveness obtained from the contingency table analyses of Chapter 4. No accident reduction, however, was found in the Fatal Accident Reporting System (FARS).

5.1 Method

In preparation for the regressions, involvements of cars, trucks and buses in 2 vehicle angle collisions are tabulated by calendar year of the accident (CY), model year of the vehicle (MY) and light condition, as follows (see Section 3.1):

Calendar Year (CY)	Model Year (MY)	Number of Angle Collision Involvements	
		Daytime	Nighttime
72	64	D(72,64)	N(72,64)
	65	D(72,65)	N(72,65)
	⋮	⋮	⋮
	72	D(72,72)	N(72,72)
73	64	D(73,64)	N(73,64)
	65	D(73,65)	N(73,65)
	⋮	⋮	⋮

Each applicable calendar year/model year combination will produce one data point for the regression. Calendar year ranges from 71 to 80 in North Carolina, 72-74 in Texas and 75-81 in FARS: The range of model years used in each of the analyses is 64-72, which corresponds to the period when side marker lamps were first introduced on a significant number of makes and models, then became standard on all vehicles.

The dependent variable is the logarithm of the ratio of nighttime to daytime angle collision involvement of cars of a given model year MY in a given calendar year CY:

$$\text{LOGODDS (CY, MY)} = \log\frac{N(CY, MY)}{D(CY, MY)}$$

where N(CY, MY) and D(CY, MY) are the counts of nightime and daytime angle collision involvements, respectively, from the preceding table.

The log of the odds ratio (nighttime to daytime) was selected as the dependent variable because it makes it especially simple to derive effectiveness estimates for side marker lamps from the regression equation, as will be shown below. Other statistics of N and D could have been used as the dependent variable but would have made it more complicated to derive effectiveness, while eventually producing almost the same results. This is because the relative variation of N/D is fairly small in the data sets used for this report: as a result, linear and log-linear models produce similar results. (By contrast, in NHTSA's evaluation of braking improvements, the brake failure rate increased enormously with vehicle age and the choice of a linear rather than log-linear model was critical [16], pp 40-43). In fact, all of the regressions in this chapter were duplicated using a linear model with N/D+N as the dependent variable and identical effectiveness estimates were obtained.

The independent variables are LAMP, AGE, AGE^2 and CY:

LAMP (MY, CY) is a measure of the combined availability of the side marker lamps of two vehicles involved in a collision during calendar year CY when one of the vehicles is known to be of model year MY and the other's model year is unknown.

LAMP (MY, CY) = LAMPMY (MY) + LAMPCY (CY)

LAMPMY (MY) is the proportion of vehicles of model year MY - the year of the case vehicle - that were equipped with side marker lamps. The values of LAMPMY are given by Table 3-1 and their derivation is explained in Section 3.5.

LAMPCY (CY) is the proportion of all vehicles on the road during calendar year CY that were equipped with side marker lamps -i.e., a best guess of the SML status of the "other" vehicle in the 2 vehicle accident. The values of LAMPCY are given by Table 3-4 and their derivation explained in Section 3.5.

LAMPMY (MY) ranges from 0.05 (in model year 1964) to 1.00 (in model year 1970 and beyond). LAMPCY (CY) ranges from 0.40 in 1971 to 0.91 in 1981. Thus, in the regressions of this chapter, LAMP ranges from LAMP (71, 64) = 0.45 to LAMP (81, 72) = 1.91.

AGE (CY, MY) = CY - MY, the age of the vehicle in years. AGE and AGE^2 are used to control for vehicle age-related trends in the ratio of nighttime to daytime accidents.

CY, the calendar year of the accident, is used as a categorical variable in the regression. Actually, it is a collection of independent variables. For example, North Carolina data are available from each year of 1971-80.

Let CY 71 = 1 if CY = 71, 0 otherwise

CY 72 = 1 if CY = 72, 0 otherwise

CY 79 = 1 if CY = 79, 0 otherwise

Note that CY 71 = ... = CY79 = 0 when CY=80.

Thus, CY71, ..., CY79 are a collection of nine independent variables that, together, denote the calendar year. They are needed for the regression because the nighttime-to-daytime accident ratio varies significantly from year to year. In general, it will be seen in Tables 5-1 through 5-12 that nighttime accidents were relatively less frequent during and after the economic recession of 1975.

Thus, the regression equation is

$$\log \frac{N(CY,\ MY)}{D(CY,\ MY)} = a_o + a_1\ LAMP + A_2\ AGE + a_3\ AGE^2 + a_4\ CY71 + \ldots + a_{12}\ CY79$$

for North Carolina. (The equations for Texas and FARS are the same except that the CY terms are changed to reflect the data years used.)

A weighted regression is run - each (CY, MY) data point is weighted by the total sample size of the collision involvements of vehicles of model year MY in calendar year CY, i.e., T(CY, MY) = N(CY,MY) + D(CY, MY). The runs were made by the General Linear Model procedure of the Statistical Analysis System (SAS), which allows weighted regressions with mixed linear and categorical variables [26].

The effectiveness of side marker lamps is derived from the regression equation. Note that the risk of a nighttime angle collision involvement for a given vehicle is

$$N = D \exp\ (a_o + a_1\ LAMP + a_2\ AGE + a_3\ AGE^2 + \ldots)$$

where D is the risk of a daytime angle collision involvement. Now, suppose that not a single car, truck or bus is equipped with side marker lamps -i.e. LAMP=0. Under those circumstances, the risk is

$$No = D \exp\ (a_o + \qquad a_2\ AGE + a_3\ AGE^2 + \ldots)$$

Suppose a single vehicle is then equipped with side marker lamps. For this vehicle, LAMPMY = 1.00. But since no other vehicle on the road has the lamps, LAMPCY = 0. Thus, for this single vehicle, LAMP = LAMPMY + LAMPCY = 1.00. Its nighttime angle collision risk is

$$N_1 = D \exp (a_o + a_1 (1.00) + a_2 \text{ AGE} + a_3 \text{ AGE}^2 + \ldots)$$

Thus, the reduction in nighttime angle collision risk for equipping one vehicle with side marker lamps is

$$\varepsilon_1 = 1 - \frac{N_1}{N_0} = 1 - \frac{D \exp (a_0 + a_1 (1.00) + a_2 \text{ AGE} + a_3 \text{ AGE}^2 + \ldots)}{D \exp (a_0 + a_2 \text{ AGE} + a_3 \text{ AGE}^2 + \ldots)}$$

$$= 1 - \exp (a_1)$$

Finally let every vehicle on the road be equipped with side marker lamps. At that point LAMPMY = LAMPCY = 1.00 and LAMP = 2.00. The nighttime angle collision risk becomes

$$N_2 = D \exp (a_0 + a_1 (2.00) + a_2 \text{ AGE} + a_3 \text{ AGE}^2 + \ldots)$$

The reduction of nighttime angle collision risk that occurs when every vehicle on the road has SML, relative to the situation where no vehicle on the road had them, is

$$\varepsilon_2 = 1 - \frac{N_2}{N_0} = 1 - \exp (2 a_1)$$

In other words, with the log-linear model, the effectiveness of equipping a single vehicle with SML, or all vehicles on the road with SML is a simple funtion of the regression coefficient for LAMP.

The statistical significance of the effectiveness estimates is determined by a t test on the regression coefficient for LAMP.

As in Chapter 4, the validity of the regression results for angle collisions is tested by performing identical regressions on control groups of crashes that are not angle collisions.

The analytic approach of this chapter was also used in NHTSA's evaluations of head restraints [14], pp. 170-174, side door beams [15], pp. 161-166 and, most extensively, braking improvements for passenger cars [16] , pp. 17-47.

5.2 Accidents of all severities

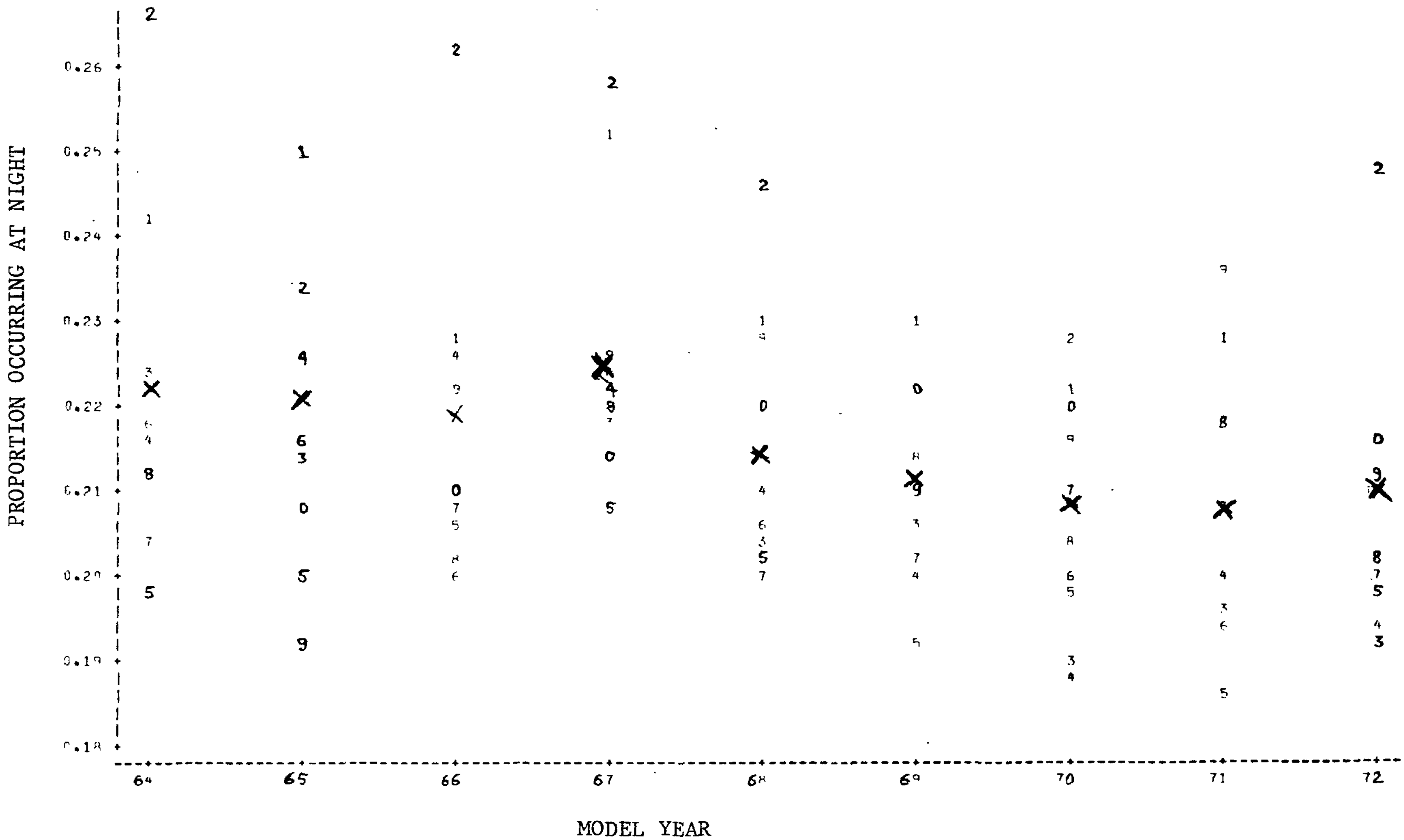
5.2.1 North Carolina

The accident sample for North Carolina consisted of vehicles involved in 2 vehicle collisions designated as "angle collision" or "turning across traffic" (see Section 3.2). Figure 5-1 is a graph of the proportion of those collisions occurring at night, by model year and calendar year. The model year (1964-72) is indicated on the horizontal axis; the calendar years (1971-80) are indicated, by their last digits, as numbered points on the graph. The "X's" mark the approximate center of the distribution of points, for each model year. Figure 5-1 appears to indicate a substantial reduction in nighttime accidents in model year 1968, when side marker lamps became standard on most vehicles. There may be small additional reductions in 1965-66, when SML became standard on some cars and 1970 when they became standard on all (see Section 3.5). It is not clear from Figure 5-1, however, whether these latter effects are due to SML or vehicle age trends. In Figure 5-2, the same points are graphed by vehicle age and calendar year. The figure indicates a strong calendar year effect: a much higher proportion of nighttime accidents in 1971-72, when a

FIGURE 5-1

NORTH CAROLINA: PROPORTION OF ANGLE COLLISIONS OCCURRING AT NIGHT,

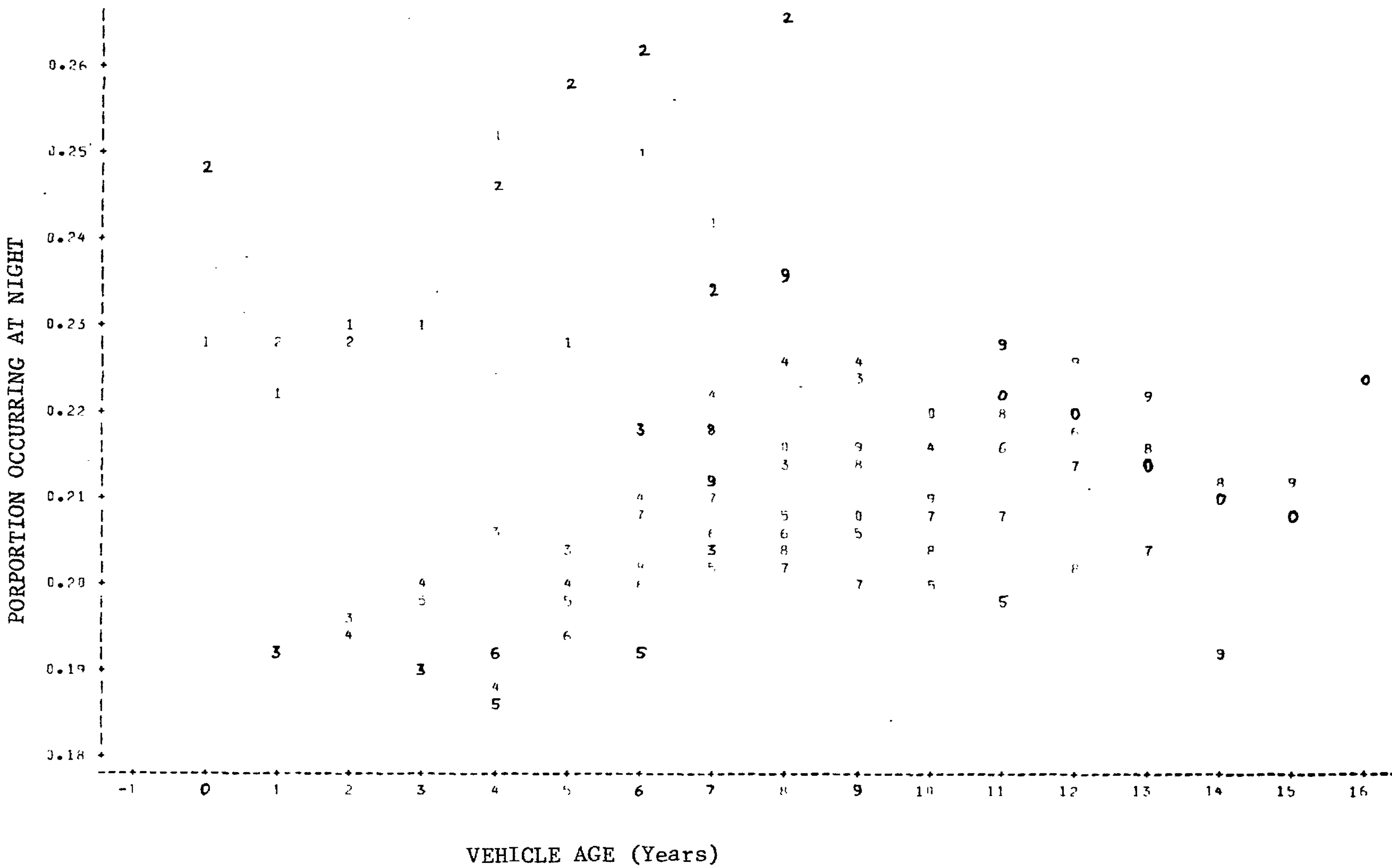
BY MODEL YEAR AND CALENDAR YEAR*



*Numbers on graph indicate last digit of calendar year (1971-80)

FIGURE 5-2

NORTH CAROLINA: PROPORTION OF ANGLE COLLISIONS OCCURRING AT NIGHT, BY VEHICLE AGE AND CALENDAR YEAR*



*Numbers on graph indicate last digit of calendar year (1971-80)

different definition of angle collision was used (see Section 3.2). Also, there appears to be a cancelling age effect: the proportion of nighttime accidents first increases and, for older cars, levels off or decreases as age increases. Thus, the net bias due to vehicle age effects is probably not large.

The results of the regression analysis mirror and clarify what was observed in the graphs. Table 5-1 shows that side marker lamps significantly reduced the risk of nighttime angle collisions: the coefficient for LAMP is -0.076 and its t-value is -2.70 (df=76, $p < .05$). The installation of s de marker lamps on a single vehicle reduces its risk of nighttime angle collisions by

$$\varepsilon_1 = 1 - \exp(-.076) = 7 \text{ percent relative to}$$

a vehicle without SML. The installation of SML on the entire vehicle fleet reduces the risk of nighttime angle collisions by

$$\varepsilon_2 = 1 - \exp(-.076 \times 2) = 14 \text{ percent relative to}$$

a fleet in which no vehicles have SML. Since North Carolina had 10 calendar years of data available and Texas only 3, the regression results from North Carolina should be considered more accurate.

AGE has a significant positive coefficient and AGE^2 has an equally significant negative coefficient. As Figure 5-2 suggested, the ratio of nighttime to daytime accidents first increases and eventually decreases with increasing vehicle age. The net marginal age effect is zero when

$$.025 - 2(.00161)\ AGE = 0$$

TABLE 5-1

NORTH CAROLINA: 1971-80 ANGLE COLLISIONS OF ALL SEVERITIES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	1938.72854238	161.56071184	23.84	0.0001	0.791109	210.1458
ERROR	76	515.01936402	6.77657058		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	88	2453.74790610			2.60318470		-1.3[illegible]064439

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	528.51075283	77.99	0.0001	1	49.55893319	7.31	0.0084
AGE	1	1.24413341	0.18	0.6695	1	89.74689145	13.24	0.0005
AGE*AGE	1	3.41489041	0.50	0.4800	1	109.08589537	16.10	0.0001
CY	9	1405.55876544	23.05	0.0001	9	1405.55876544	23.05	0.0001

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.24203416	B	-13.24	0.0001	0.09384075
LAMP		-0.07610308		-2.70	0.0084	0.02814144
AGE		0.02508547		3.64	0.0005	0.00689315
AGE*AGE		-0.00161611		-4.01	0.0001	0.00040131
CY	71	0.07173639	B	1.23	0.2236	0.05846935
	72	0.12828356	B	2.43	0.0177	0.05288629
	73	-0.10216281	B	-2.24	0.0278	0.04554268
	74	-0.08566211	B	-2.11	0.0383	0.04063311
	75	-0.13647927	B	-3.77	0.0003	0.03619079
	76	-0.10265516	B	-3.22	0.0019	0.03191345
	77	-0.08544732	B	-2.99	0.0038	0.02861645
	78	-0.05433298	B	-2.09	0.0400	0.02599851
	79	0.00799791	B	0.32	0.7530	0.02532352
	80	0.00000000	B	.	.	.

Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.076) = 7 percent
On the entire fleet: 1 - exp(-.076 x 2) = 14 percent

which is when the vehicles are 7.8 years old. In other words, for cars of approximately median age, the net age effect is close to zero.

Table 5-1 shows that, as expected, the calendar year effect is most strongly positive for 1971-72 and most strongly negative for the recession years 1975-76.

The results for Dr. Chi's "refined test group" (see Section 3.2) are nearly the same as for the more inclusive set of angle collisions. The t-values of the coefficients are a bit lower because the sample size of the underlying data tabulation is smaller, causing the dependent variable to have more residual error. Table 5-2 shows that side marker lamps significantly reduced nighttime angle collision risk ($t = -2.13$, $df = 76$) - by 8 percent when installed on a single vehicle and by 16 percent when installed on the entire vehicle fleet. The two estimates are just slightly higher than those of Table 5-1.

5.2.2 Texas

The accident sample for Texas consisted of cars, trucks and buses in 2 vehicle collisions in which one vehicle was frontally damaged and the other, in the side. Figure 5-3 is a graph of the proportion of those collisions occurring at night, by model year (1964-72) and calendar year (1972-74). The calendar years are indicated, by their last digit, as numbered points on the graph. The "X's" mark, for each model year, the approximate

TABLE 5-2

NORTH CAROLINA (REFINED TEST GROUP) 1971-80: ANGLE COLLISIONS OF ALL SEVERITIES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	1379.78525209	114.98210434	14.33	0.0001	0.693543	209.2025
ERROR	76	609.68898777	8.02222352		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	88	1989.47423986			2.83235300		-1.35388077

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	608.97672818	75.91	0.0001	1	36.37932428	4.53	0.0364
AGE	1	91.08457665	11.35	0.0012	1	40.22362382	5.01	0.0281
AGE*AGE	1	1.91610997	0.24	0.6264	1	54.95105350	6.85	0.0107
CY	9	677.80783729	9.39	0.0001	9	677.80783729	9.39	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.26506925 B	-9.32	0.0001	0.13569171
LAMP		-0.08581173	-2.13	0.0364	0.04029644
AGE		0.02156478	2.24	0.0281	0.00963057
AGE*AGE		-0.00148058	-2.62	0.0107	0.00056571
CY	71	0.05333799 B	0.64	0.5242	0.08335954
	72	0.13168896 B	1.75	0.0847	0.07538501
	73	-0.07528200 B	-1.13	0.2632	0.06678688
	74	-0.06173717 B	-1.03	0.3050	0.0597850
	75	-0.10488971 B	-1.95	0.0545	0.05370300
	76	-0.10253214 B	-2.14	0.0354	0.04785566
	77	-0.09761094 B	-2.23	0.0285	0.04344823
	78	-0.09421849 B	-2.36	0.0210	0.03997533
	79	-0.02945293 B	-0.75	0.4554	0.03925658
	80	0.00000000 B	.	.	.

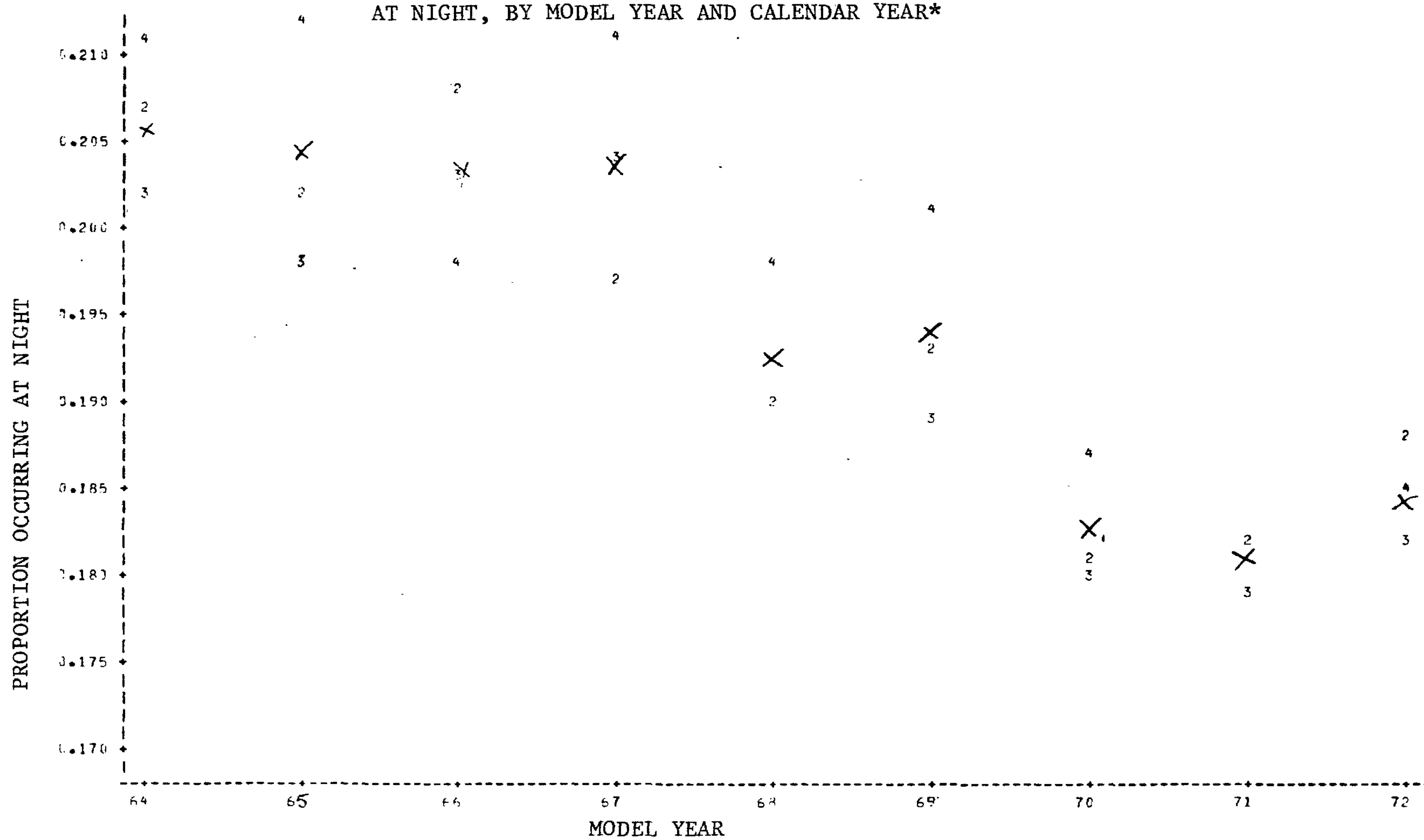
Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.086) = 8 percent
On the entire fleet: 1 - exp (-.086 x 2) = 16 percent

FIGURE 5-3

TEXAS: PROPORTION OF ANGLE COLLISIONS OCCURRING

AT NIGHT, BY MODEL YEAR AND CALENDAR YEAR*



*Numbers on graph indicate last digit of calendar year (1972-74)

average for the 3 calendar years of data available. Figure 5-3 indicates an obvious and substantial reduction of nighttime accidents in MY 68, when SML became standard equipment on most cars. There is, however, a second large reduction in MY 70, when they became standard on all cars. In Figure 5-4, the same points are graphed by vehicle age and calendar year. There may be some tendency, among the newer cars, for nighttime accidents to increase with vehicle age, but not among the older cars. The calendar effect does not appear to be strong.

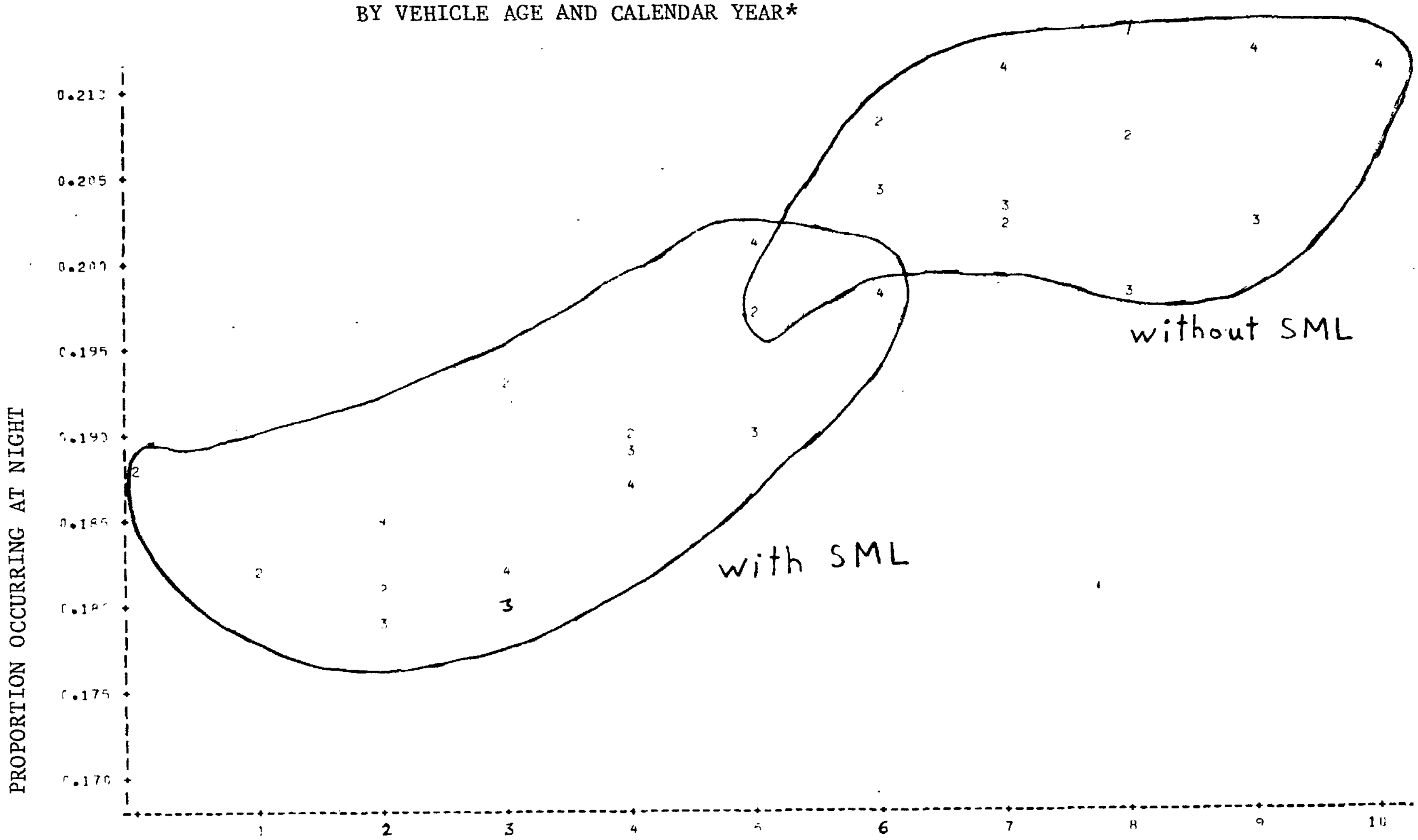
The regression results are consistent with what was observed in the graphs and generate a model not unlike the one in North Carolina. Table 5-3 shows that side marker lamps significantly reduced the risk of nighttime angle collisions: the coefficient of LAMP is -0.084 with t= -2.52, df=21, one-sided $p < .05$. The installation of side marker lamps on a single vehicle reduces its nighttime angle collision risk by 8 percent. The number of nighttime collisions when all vehicles on the road are equipped with SML is 16 percent lower than what would occur if none of them were so equipped. These effectiveness estimates are nearly the same as those in North Carolina (which were 7 and 14 percent, respectively).

The effects of vehicle age and calendar year are relatively weak.

FIGURE 5-4

TEXAS: PROPORTION OF ANGLE COLLISIONS OCCURRING AT NIGHT,

BY VEHICLE AGE AND CALENDAR YEAR*



*Numbers on graph indicate last digit of calendar year (1972-74)

TABLE 5-3

TEXAS 1972-74: ANGLE COLLISIONS OF ALL SEVERITIES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	5	1282.24955156	256.44991031	22.00	0.0001	0.839666	240.3881
ERROR	21	244.84516509	11.65929358		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	26	1527.09471665			3.41457077		-1.42044102

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	1057.93090132	90.74	0.0001	1	74.04199598	6.35	0.0199
AGE	1	158.88759148	13.63	0.0014	1	25.57340510	2.19	0.1535
AGE*AGE	1	0.12982555	0.01	0.9170	1	1.34962743	0.12	0.7371
CY	2	65.30123322	2.80	0.0835	2	65.30123322	2.80	0.0835

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.35729690 B	-19.51	0.0001	0.06956942
LAMP		-0.08449906	-2.52	0.0199	0.03353119
AGE		0.01252023	1.48	0.1535	0.00845384
AGE*AGE		-0.00029939	-0.34	0.7371	0.00087998
CY	72	-0.02079070 B	-1.00	0.3276	0.02074362
	73	-0.03604045 B	-2.25	0.0352	0.01601154
	74	0.00000000 B	.	.	.

Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.0845) = 8 percent
On the entire fleet: 1 - exp (-.845 x 2) = 16 percent

5.3 Injury accidents

The regressions of Tables 5-1, 5-2 and 5-3 are repeated with the data sets restricted to injury-producing accidents - in order to check whether the effect of SML found in all types of accidents persists in crashes of higher severity.

5.3.1 North Carolina

Table 5-4 indicates that side marker lamps significantly reduced the risk of being involved in an injury-producing nighttime angle collision in North Carolina. The t-value for the coefficient of LAMP is -2.98, df=76. The effectiveness estimate for installing SML on a single vehicle is 12 percent. The accident reduction for installing them in all vehicles on the road is 23 percent. The estimates are higher than those obtained in accidents of all severities (Table 5-1 - the estimates were 7 and 14 percent) although not significantly higher (based on the standard errors of the regression coeffients for LAMP in Tables 5-1 and 5-4). The regression equation for injury accidents shows effects for vehicle age and calendar year that are reasonably similar to the effects in accidents of all severities.

In Dr. Chi's refined test group, the effectiveness estimates are 16 percent for equipping a single vehicle and 30 percent for the entire vehicle fleet - a significant reduction according to Table 5-5. These anomalously high estimates, as well as the negative rather than positive coefficient for AGE, may have been caused by a statistical mischance - an unreasonably high reduction in nighttime crashes for MY 68 relative to MY 67 - which in turn is

TABLE 5-4

NORTH CAROLINA 1971-80: INJURY-PRODUCING ANGLE COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS1
WEIGHT: N1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	627.09977600	52.25831467	10.10	0.0001	0.614636	205.6762
ERROR	76	393.17785813	5.17339287		STD DEV		LOGODDS1 MEAN
CORRECTED TOTAL	88	1020.27763413			2.27450937		-1.10586896

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	182.03199514	35.19	0.0001	1	45.95154849	8.88	0.0039
AGE	1	3.61491701	0.70	0.4058	1	1.31002340	0.25	0.6163
AGE*AGE	1	1.81572127	0.35	0.5553	1	12.09197972	2.34	0.1305
CY	9	439.63714258	9.44	0.0001	9	439.63714258	9.44	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.83161644 B	-5.66	0.0001	0.14694215
LAMP		-0.13083819	-2.98	0.0039	0.04390078
AGE		0.00538815	0.[illegible]	0.6163	0.0107075
AGE*AGE		-0.00094353	-1.5[illegible]	0.1305	0.00061715
CY	71	-0.02949184 B	-0.3[illegible]	0.7471	0.09113505
	72	0.00380403 B	0.05	0.9631	0.08203659
	73	-0.15044406 B	-2.11	0.0384	0.07138073
	74	-0.12492064 B	-1.96	0.0535	0.06367970
	75	-0.23943949 B	-4.[illegible]	0.0001	0.05660875
	76	-0.12538500 B	-2.51	0.0142	0.04994244
	77	-0.07485781 B	-1.67	0.0992	0.04484675
	78	-0.05096752 B	-1.25	0.2159	0.04084363
	79	-0.01701486 B	-0.43	0.6679	0.03953136
	80	0.00000000 B	.	.	.

Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.131) = 12 percent
On the entire fleet: 1 - exp (-.131 x 2) = 23 percent

TABLE 5-5

NORTH CAROLINA (REFINED TEST GROUP) 1971-80: INJURY-PRODUCING ANGLE COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS1
WEIGHT: N1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	694.73571519	57.89464293	9.84	0.0001	0.608380	203.3804
ERROR	76	447.20869168	5.88432489		STD DEV		LOGODDS1 MEAN
CORRECTED TOTAL	88	1141.94440687			2.42576274		-1.19272205

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	300.02834120	50.99	0.0001	1	55.44464543	9.42	0.0030
AGE	1	108.30962296	18.41	0.0001	1	0.09728100	0.02	0.8980
AGE*AGE	1	2.77273367	0.47	0.4945	1	8.26172630	1.40	0.2397
CY	9	283.62501735	5.36	0.0001	9	283.62501735	5.36	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.78022572 B	-3.99	0.0001	0.19542704
LAMP		-0.17799854	-3.07	0.0030	0.05798758
AGE		-0.00178322	-0.13	0.8980	0.01386881
AGE*AGE		-0.00095273	-1.18	0.2397	0.00080405
CY	71	-0.04612161 B	-0.38	0.7014	0.11985222
	72	-0.00537058 B	-0.05	0.9605	0.10801583
	73	-0.17795003 B	-1.85	0.0676	0.09597020
	74	-0.15097493 B	-1.76	0.0828	0.08588883
	75	-0.22318378 B	-2.90	0.0048	0.0768544
	76	-0.15639521 B	-2.29	0.0248	0.06829457
	77	-0.15779028 B	-2.54	0.0130	0.06205754
	78	-0.09156328 B	-1.60	0.1131	0.05711883
	79	-0.04890559 B	-0.88	0.3811	0.05551569
	80	0.00000000 B	.	.	.

Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.178) = 16 percent
On the entire fleet: 1 - exp(-.178 x 2) = 30 percent

due to the relatively small cell sample sizes (see Table 4-5).

5.3.2 Texas

Table 5-6 indicates that injury-producing nighttime angle collisions were significantly reduced in Texas, too. The t-value for the coefficient of LAMP is -1.89, df = 21, one-sided $p < .05$. The effectiveness estimate for installing SML on a single vehicle is 10 percent; for equipping the entire vehicle fleet, 19 percent. These estimates are a bit higher than the ones obtained from Texas data for accidents of all severities (6 and 12 percent, respectively) but a bit lower than the results for North Carolina injury crashes (12 and 23 percent, respectively).

In the regression model, the effects of vehicle age and calendar year are relatively weak, similar to those in the analysis of Texas accidents of all severities.

In all 3 regressions (North Carolina, "refined" North Carolina, Texas) the effectiveness estimate for injury-producing crashes was higher than the estimate for crashes of all severities, but not significantly higher.

5.4 Fatal accidents

The accident sample from FARS consisted of cars, trucks and buses in 2 vehicle collisions in which one vehicle was frontally damaged and the other, in the side (see Section 3.4). Figure 5-5 is a graph of the proportion of those collisions occurring at night, by model year (1964-72) and calendar year (1975-81). (The

TABLE 5-6

TEXAS 1972-74: INJURY-PRODUCING ANGLE COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS1
WEIGHT: N1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	5	259.06128768	51.81225754	7.41	0.0004	0.638359	239.5781
ERROR	21	146.76839841	6.98897135		STD DEV		LOGODDS1 MEAN
CORRECTED TOTAL	26	405.82968603			2.64366627		-1.10346735

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	155.61862195	22.27	0.0001	1	24.96617922	3.57	0.0726
AGE	1	48.53042768	6.94	0.0155	1	6.07011890	0.87	0.3620
AGE*AGE	1	0.86013670	0.12	0.7292	1	4.06220502	0.58	0.4543
CY	2	54.05210136	3.87	0.0372	2	54.05210136	3.87	0.0372

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.96508770 B	-8.29	0.0001	0.11640617
LAMP		-0.10555325	-1.89	0.0726	0.05584735
AGE		0.01326895	[illegible]	0.3620	0.01423781
AGE*AGE		-0.00110928	-0.76	0.4543	0.00145502
CY	72	-0.06930732 B	[illegible]	0.0585	0.03463459
	73	-0.07429237 B	-2.78	0.0113	0.02675399
	74	0.00000000 B	.	.	.

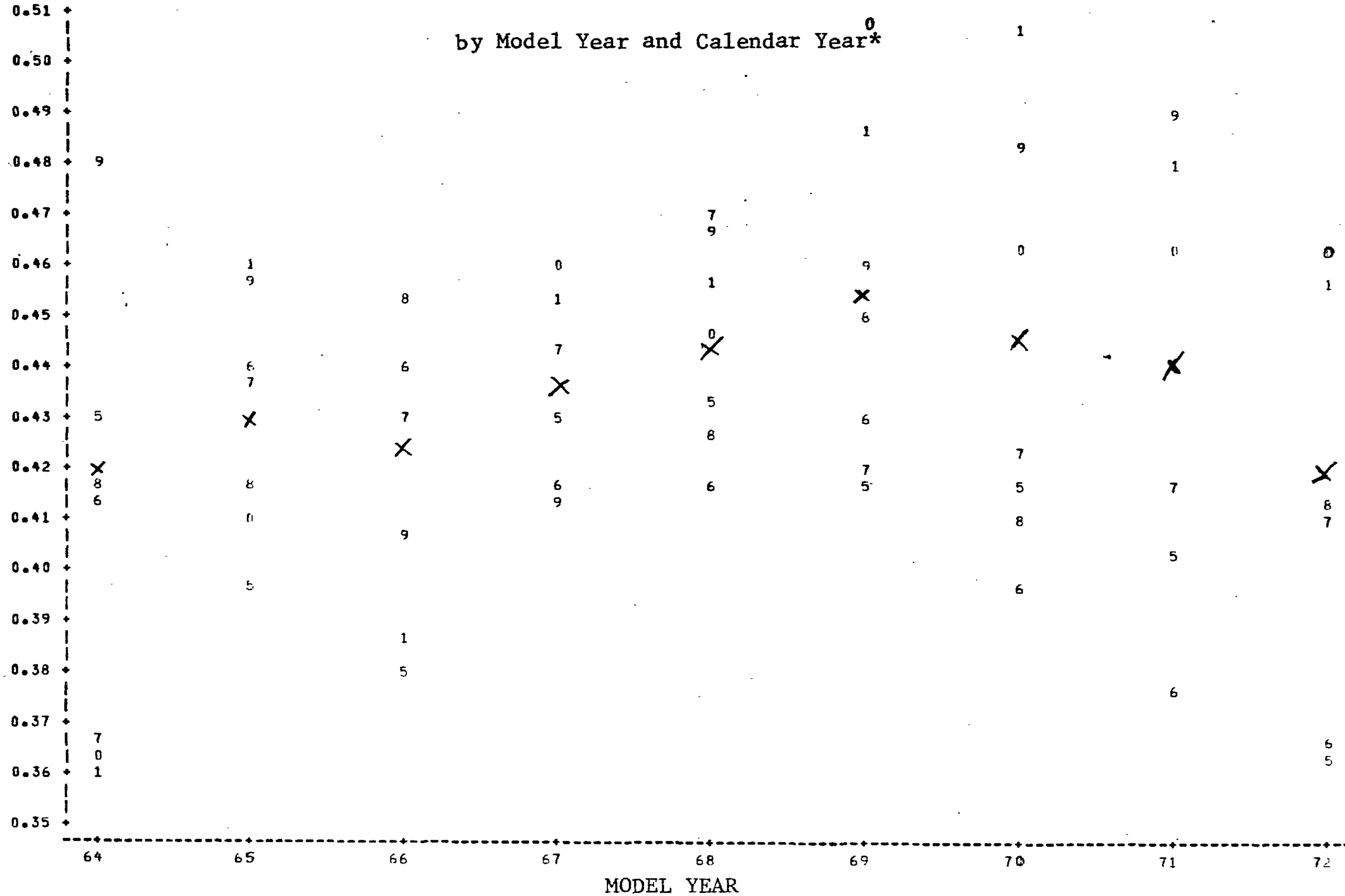
Effectiveness of side marker lamps:

On a single vehicle: 1 - exp(-.106) = 10 percent
On the entire fleet: 1 - exp(-.106 x 2) = 19 percent

FIGURE 5-5

FARS: PROPORTION OF FATAL ANGLE COLLISIONS OCCURRING AT NIGHT,

by Model Year and Calendar Year*



*Numbers on graph indicate last digit of calendar year (1975-81)

numbered points on the graph indicate the last digit of the calendar year.) The "X's" mark, for each model year, the approximate average for the 7 calendar years of data available. Figure 5-5 certainly does not indicate a reduction of nighttime accidents in MY 68, when SML became standard equipment. In fact, the pattern of the X's is more less a parabola - lowest in 1964 and 1972 and attaining a broad peak in 1968-70. That suggests a strong role for vehicle age, with a positive coefficient for AGE and a negative one for AGE^2 (nighttime fatal accidents first increase as cars get older and then eventually decrease). Finally, the nighttime accident risk is consistently highest for the most recent calendar years, 1979-81, when the largest proportion of registered vehicles was SML-equipped. That is probably not a cause-and-effect relationship, but since the regression sees no evidence of positive SML effectiveness in the model year trend, it is likely to attribute this relationship to LAMP rather than CY, with unpleasant consequences for the effectiveness estimate.

As Table 5-7 shows, the regression attributes a statistically significant adverse effect to side marker lamps ($t = +1.90$, df=53). Based on the model, the installation of SML on a single vehicle increases its nighttime fatal angle collision risk by 13 percent; on the entire vehicle fleet, by 28 percent. The regression model behaves in the manner predicted from observation of the graphed data points: there is a large significant positive coefficient for AGE, negative for AGE^2. The effect of the calendar year terms is not significant ($F = 1.67$, df = 6, 53), suggesting that the nighttime accident increase in later calendar years has been,

TABLE 5-7

FARS 1975-81: FATAL ANGLE COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	349.51684513	38.83520501	12.75	0.0001	0.683979	625.1644
ERROR	53	161.48809165	3.04694513		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	62	511.00493678			1.74555009		-0.27921459

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	8.76846643	[illegible]	0.0957	1	11.01078876	3.61	0.0627
AGE	1	234.24160978	76.88	0.0001	1	130.84188353	42.94	0.0001
AGE*AGE	1	76.06243468	24.96	0.0001	1	88.83053838	29.15	0.0001
CY	6	30.44433424	1.67	0.1478	6	30.44433424	1.67	0.1478

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.04901198	B	-4.83	0.0001	0.21718739
LAMP		0.12176944		1.90	0.0627	0.064056[illegible]
AGE		0.13068260		6.[illegible]	[illegible]	0.01994237
AGE*AGE		-0.00566582		-5.4[illegible]	0.0001	0.00108638
CY	75	-0.0575707[illegible]	B	-0.70	0.4888	0.08258428
	76	-0.11619006	B	-1.59	0.1176	0.07304043
	77	-0.07581080	B	-1.17	0.2464	0.06468445
	78	-0.11100075	B	-1.94	0.0577	0.05721201
	79	-0.02572211	B	-0.49	0.6286	0.05287580
	80	-0.01288707	B	-0.25	0.8015	0.05100068
	81	0.00000000	B	.	.	.

Effect of side marker lamps:

On a single vehicle: 1 - exp (.122) = -13 percent
On the entire fleet: 1 - exp (.122 x 2) = -28 percent

to a large extent, charged against SML.

It is fair to argue, then, that the significant negative effect found in the regression is largely spurious. Further evidence for this is that nearly the same thing happens in the regression for a control group of head-on and rear-end collisions on FARS (see Table 5-12).

5.5 Analyses for a control group of head-on and rear-end crashes

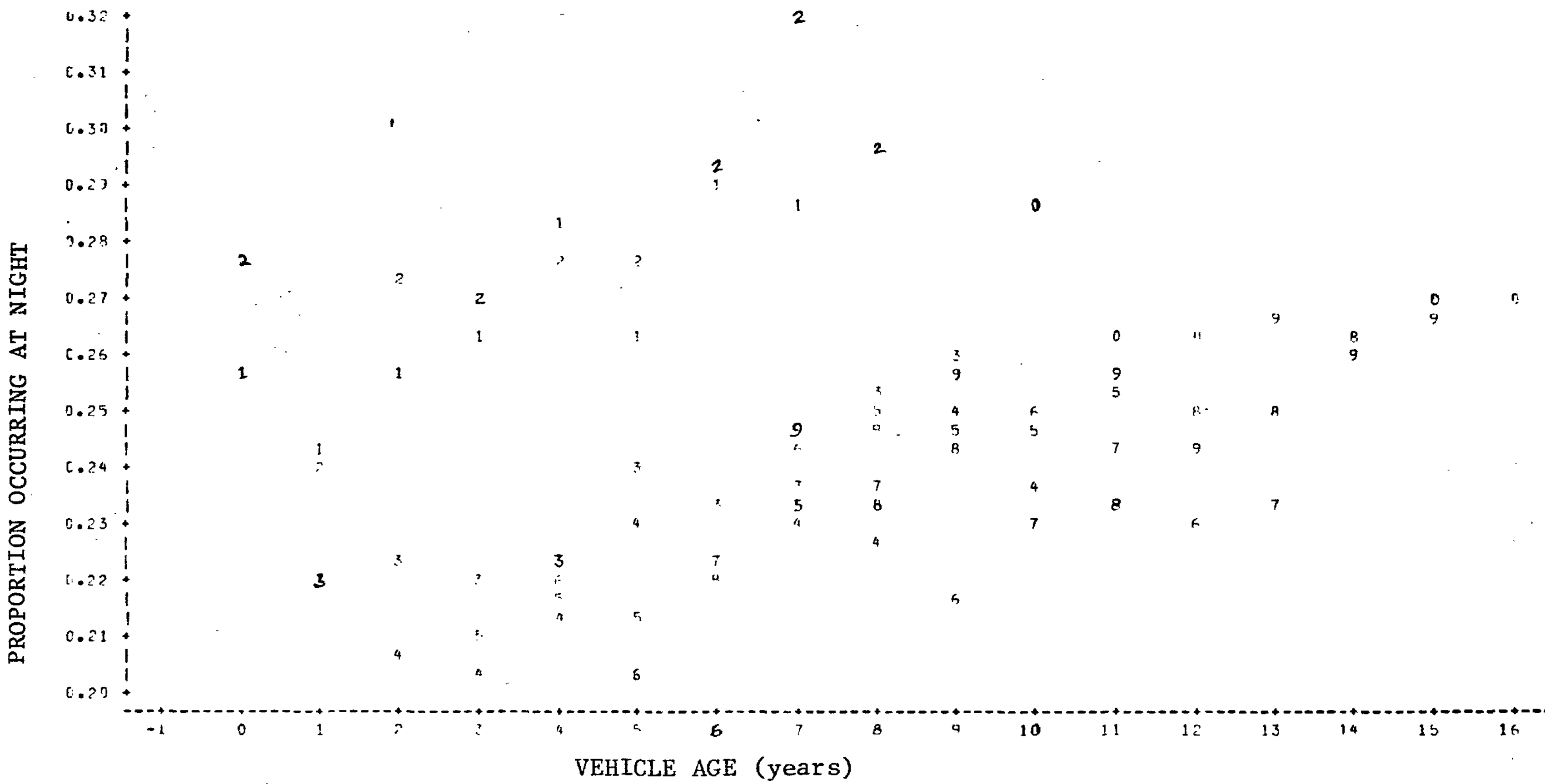
The preceding regressions are reiterated for a control group of 2 vehicle crashes that are not angle collisions - viz., head-on and rear-end collisions. Side marker lamps should be of little or no value in preventing those collisions at night. Any significant "reduction" of nighttime control group collisions attributed to SML by the regression could indicate a bias in the preceding analyses of angle collisions.

5.5.1 North Carolina

The control group for North Carolina was defined to be vehicles involved in 2 vehicle collisions that were specifically identified as head-on or rear-end (see Section 3.2). The definition used for calendar years 1971-72 differed from 1973-80, because of changes in the accident report form. Figure 5-6 is a graph of the proportion of control group collisions occurring at night, by vehicle age and calendar year. (The numbers on the graph indicate the last digit of the calendar year.) Figure 5-6 appears to indicate

FIGURE 5-6

NORTH CAROLINA CONTROL GROUP: PROPORTION OF HEAD-ON AND REAR-END CRASHES OCCURRING AT NIGHT, BY VEHICLE AGE AND CALENDAR YEAR



*Numbers on graph indicate last digit of calendar year (1971-80)

a nearly linear vehicle age effect for the points from CY 1971-72 and another nearly linear effect for the points from CY 1973-80. The two straight lines seem to explain most of the variation among the data points.

The regression, Table 5-8, confirms what was observed in the graph. The linear effect of vehicle AGE and the calendar year effect (especially 1971-72 versus all others) explain most of the variance. Side marker lamps do not have a statistically significant "effect" on nighttime collision risk - in fact, a nonsignificant increase in the risk was observed (4 percent on a single vehicle and 9 percent if SML are installed on the entire vehicle fleet).

When the North Carolina data are restricted to injury-producing accidents, the results are almost identical. Table 5-9 indicates that side marker lamps did not have a significant effect in the control group. The observed "effectiveness" estimates were -2 percent (on a single vehicle) and -3 percent (on the entire fleet).

5.5.2 Texas

Figure 5-7 is a graph of the proportion of accidents occurring at night, by vehicle age and calendar year, for the Texas control group (which was defined in Section 3.3). Thanks to the very large sample cell sizes it shows an even stronger relationship between vehicle age and the dependent variable than did the North Carolina data. The "effect" of side marker lamps is obviously negligible.

TABLE 5-8

NORTH CAROLINA CONTROL GROUP 1971-80: HEAD-ON AND REAR-END COLLISIONS OF ALL SEVERITIES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	2311.60512856	192.63376071	34.31	0.0001	0.844170	211.1179
ERROR	76	426.71228570	5.61463534		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	88	2738.31741426			2.36952218		-1.12236908

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	476.36855953	84.84	0.0001	1	11.46201934	2.04	0.1572
AGE	1	216.85176312	38.62	0.0001	1	217.98576564	38.82	0.0001
AGE*AGE	1	13.28550305	2.37	0.1281	1	36.65836454	6.53	0.0126
CY	9	1605.09930286	31.76	0.0001	9	1605.09930286	31.76	0.0001

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.45868508	B	-14.51	0.0001	0.10052010
LAMP		0.04348983		1.43	0.1572	0.03043813
AGE		0.04547945		6.23	0.0001	0.00729898
AGE*AGE		-0.00110997		-2.56	0.0126	0.00043440
CY	71	0.26705074	B	4.27	0.0001	0.06254932
	72	0.30757939	B	5.41	0.0001	0.05685723
	73	0.03000484	B	0.62	0.5378	0.04848012
	74	-0.05617557	B	-1.30	0.1991	0.04336197
	75	-0.04635014	B	-1.20	0.2329	0.03854434
	76	-0.08642975	B	-2.53	0.0133	0.03410637
	77	-0.09514062	B	-3.07	0.0030	0.03102265
	78	-0.09892447	B	-3.57	0.0006	0.02773566
	79	-0.02923493	B	-1.08	0.2841	0.02710117
	80	0.00000000	B	.	.	.

"Effectiveness" of side marker lamps:

On a single vehicle: 1 - exp(.043) = -4 percent
On the entire fleet: 1 - exp(.043 x 2) = -9 percent

TABLE 5-9

NORTH CAROLINA CONTROL GROUP 1971-80: INJURY PRODUCING HEAD-ON AND REAR-END COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS1
WEIGHT: N1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	806.79671851	67.23305988	12.82	0.0001	0.66926	274.4672
ERROR	76	398.70871913	5.24616736		STD DEV		LOGODDS1 MEAN
CORRECTED TOTAL	88	1205.50543764			2.29045134		-0.83450816

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	74.43297398	14.19	0.0003	1	0.42160953	0.08	0.7776
AGE	1	15.32935776	2.92	0.0915	1	56.33837776	10.74	0.0016
AGE*AGE	1	2.44237986	0.47	0.4971	1	31.29679895	5.97	0.0169
CY	9	714.59200690	15.13	0.0001	9	714.59200690	15.13	0.0001

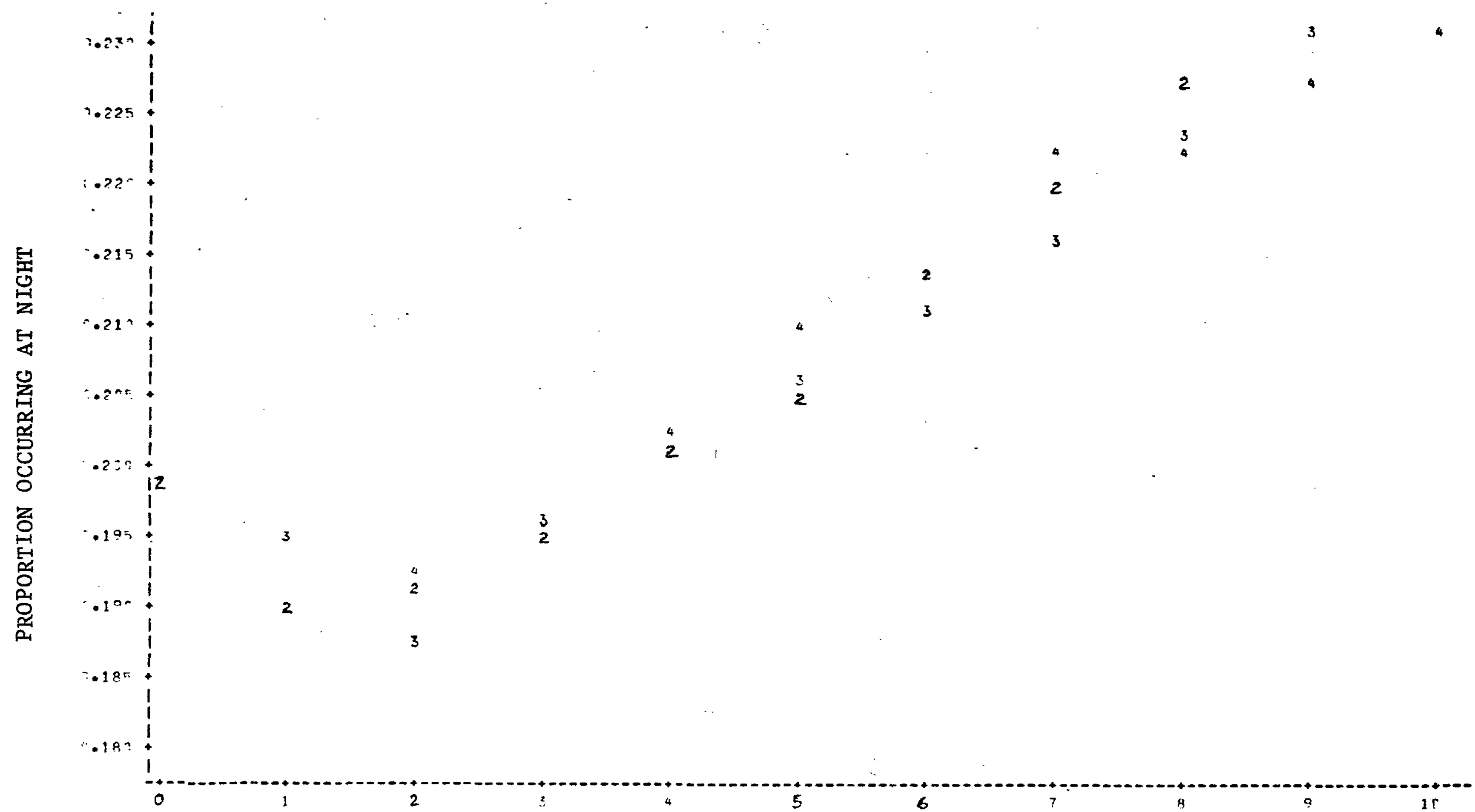
PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.99007410 B	-5.63	0.0001	0.17588969
LAMP		0.01503631	0.28	0.7776	0.05304043
AGE		0.04231991	3.28	0.0016	0.01291409
AGE*AGE		-0.00184665	-2.44	0.0169	0.00075676
CY	71	0.20304562 B	1.85	0.0686	0.10993143
	72	0.21947804 B	2.21	0.0300	0.09924668
	73	-0.06413405 B	-0.76	0.4503	0.08451414
	74	-0.15251577 B	-2.02	0.0470	0.07553852
	75	-0.17808052 B	-2.66	0.0095	0.06687760
	76	-0.18294427 B	-3.11	0.0027	0.05891893
	77	-0.15258634 B	-2.85	0.0056	0.05345122
	78	-0.13695612 B	-2.87	0.0054	0.04779505
	79	-0.03567503 B	-0.77	0.4453	0.04649967
	80	0.00000000 B	.	.	.

"Effectiveness" of side marker lamps:

On a single vehicle: 1 - exp (.015) = -2 percent
On the entire fleet: 1 - exp (.015 x 2) = -3 percent

FIGURE 5-7

TEXAS CONTROL GROUP: PROPORTION OF HEAD-ON AND REAR-END CRASHES OCCURRING AT NIGHT, BY VEHICLE AGE AND CALENDAR YEAR*



*Numbers on graph indicate last digit of calendar year (1972-74)

The regression analysis confirms what was observed in the graphs. Table 5-10 shows that the accident "reduction" attributed to side marker lamps is not statistically significant (t = -0.86) and amounts to 2 percent, when SML are installed on a single vehicle or 4 percent, when installed in the entire fleet. Most of the variation in the data points is explained by the vehicle age variables.

Similarly, Table 5-11 shows that side marker lamps had no significant effect on injury-producing nighttime control group crashes (t = -0.10). The observed "effectiveness" of SML is less than 1/2 percent, on a single vehicle, and 1 percent when they are installed in the entire fleet.

The control group results for North Carolina and Texas are consistent with one another. None of them produced a significant effect for side marker lamps. All of the analyses of angle collisions from those States showed significant benefits for SML. Thus, the control group analyses do not indicate any bias in the analyses of angle collisions.

5.5.3 Fatal Accident Reporting System

In the analysis of fatal angle collisions (Section 5.3) the regression attributed a significant 13 percent increase in nighttime collision risk to the installation of SML on a single vehicle. It was argued that this was undoubtedly a spurious result, possibly because the regression attributed calendar year effects to SML.

TABLE 5-10

TEXAS CONTROL GROUP 1972-74: HEAD-ON AND REAR-END COLLISIONS OF ALL SEVERITIES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	5	3913.22352678	782.64470536	52.09	0.0001	0.925385	290.0942
ERROR	21	315.52864546	15.02517359		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	26	4228.75217224			3.87623188		-1.33619779

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	2750.16057960	183.04	0.0001	1	11.17908166	0.74	0.3981
AGE	1	1022.11862917	68.03	0.0001	1	12.46556541	0.83	0.3727
AGE*AGE	1	132.02078763	8.79	0.0074	1	116.67175841	7.77	0.0111
CY	2	8.92353038	0.30	0.7461	2	8.92353038	0.30	0.7461

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.39687981 B	-25.16	0.0001	0.05551278
LAMP		-0.02333127	-0.86	0.3981	0.02704861
AGE		0.00605130	0.91	0.3727	0.00664359
AGE*AGE		0.00197930	2.79	0.0111	0.00071030
CY	72	-0.00862737 B	-0.52	0.6057	0.01646331
	73	-0.00973272 B	-0.77	0.4495	0.01262921
	74	0.00000000 B	.	.	.

"Effectiveness" of side marker lamps:

On a single vehicle: 1 - exp (-.023) = 2 percent
On the entire fleet: 1 - exp (-.023 x 2) = 4 percent

TABLE 5-11

TEXAS CONTROL GROUP 1972-74: INJURY-PRODUCING HEAD-ON AND REAR-END COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS1
WEIGHT: N1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	5	579.52284450	115.90456890	27.20	0.0001	0.866237	242.3673
ERROR	21	89.48897320	4.26137968		STD DEV		LOGODDS1 MEAN
CORRECTED TOTAL	26	669.01181770			2.06431094		-0.85172842

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	347.25964736	81.49	0.0001	1	0.03974433	0.01	0.9240
AGE	1	170.23736226	39.95	0.0001	1	8.75771209	2.06	0.1664
AGE*AGE	1	7.42678349	1.74	0.2010	1	8.12478128	1.91	0.1819
CY	2	54.59905138	6.41	0.0067	2	54.59905138	6.41	0.0067

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.97499264 B	-12.41	0.0001	0.07858940
LAMP		-0.00364932	-0.10	0.9240	0.03778764
AGE		0.01375509	1.43	0.1664	0.00959496
AGE*AGE		0.00135361	1.39	0.1819	0.00098031
CY	72	-0.00057359 B	-0.02	0.9807	0.02341489
	73	0.04693986 B	2.62	0.0161	0.01794248
	74	0.00000000 B	.	.	.

Effectiveness" of side marker lamps:

On a single vehicle: $1 - \exp(-.004) = 0$
On the entire fleet: $1 - \exp(-.004 \times 2) = 1$ percent

Table 5-12 shows that almost the same thing happened in the control group. The model attributed a statistically significant (t = 2.19) increase in nighttime head-on and rear-end collision to SML. The observed increase is 14 percent, when the lamps are installed on a single vehicle and 29 percent, when installed on the entire fleet.

The fact that the angle collision and control group regressions produced nearly identical spurious, negative results could, perhaps, be viewed as evidence that side marker lamps have little or no effect in preventing fatal angle collisions. But it is not very convinving evidence. More analyses of FARS are needed.

TABLE 5-12

FARS CONTROL GROUP 1975-81: FATAL HEAD-ON AND REAR-END COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	661.14762057	73.46084673	19.02	0.0001	0.763537	878.0814
ERROR	53	204.75364455	3.86327631		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	62	865.90126511			1.96552189		0.22384278

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	133.73733883	34.62	0.0001	1	18.52676067	4.80	0.0330
AGE	1	392.35220465	101.56	0.0001	1	79.01936568	20.45	0.0001
AGE*AGE	1	50.84656825	13.16	0.0006	1	63.44146888	16.42	0.0002
CY	6	84.21150883	3.63	0.0043	6	84.21150883	3.63	0.0043

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.26094973	B	-1.32	0.1932	0.19800987
LAMP		0.12676364		2.19	0.0330	0.05788591
AGE		0.08216356		4.52	0.0001	0.0181673[illegible]
AGE*AGE		-0.00396279		-4.05	0.0002	0.00097789
CY	75	-0.18268968	B	-2.44	0.0180	0.07481079
	76	-0.15979077	B	-2.42	0.0191	0.06607465
	77	-0.11156759	B	-1.91	0.0611	0.05830334
	78	-0.11869175	B	-2.32	0.0243	0.05118275
	79	-0.03382603	B	-0.72	0.4756	0.04708293
	80	0.07253155	B	1.60	0.1166	0.04546580
	81	0.00000000	B	.	.	.

"Effect" of side marker lamps:

On a single vehicle: 1 - exp (.127) = -14 percent
On the entire fleet: 1 - exp (.127 x 2) = -29 percent

CHAPTER 6

FATAL INVOLVEMENTS PER 1000 VEHICLE YEARS

The rate of involvement in fatal nighttime angle collisions, per 1000 vehicle exposure years, does not appear to have decreased as a result of side marker lamps.

6.1 Method and exposure data sources

The contingency table analyses of Chapter 4 and regressions of Chapter 5 provided clear, consistent evidence that side marker lamps prevent nonfatal collisions, but did not provide corresponding results for fatal crashes. Both chapters relied on comparing the number of nighttime and daytime crash involvements. It is possible that the FARS results (which are based on the smallest samples) were thrown off by unanticipated variations in the number of daytime crashes. It would be desirable to analyze FARS by another approach which does not require information on daytime crashes.

Rather than calculating the risk of nighttime relative to daytime crashes, calculate the absolute risk: the number of fatal nighttime angle collision involvements per 1000 vehicle exposure years. The number of vehicles, of a particular model year MY, involved in nighttime angle collisions, is identified for a specific calendar year CY of FARS. This number is divided by the quantity of cars, trucks and buses of model year MY that were still on the road in the United States in calendar year CY - a quantity given by Table 3-3 of this report and derived from "MVMA Motor Vehicle Facts and Figures '82 " [20]. The analysis is feasible because FARS is a national fatality census.

Thus, an accident rate is obtained for each CY, MY combination; CY ranges from 1975 to 1981, the years for which FARS data were available; MY ranges from 1964 to 1972. These CY, MY accident rates, or their logarithms, can be used as observations of the dependent variable in a regression, using the same independent variables as in Chapter 5. But a simpler approach is to calculate the average accident rate for a model year MY by summing accidents and exposure across the 7 calendar years of FARS:

$$R(MY) = \frac{\sum_{CY=75}^{81} \text{Accidents }(CY, MY)}{\sum_{CY=75}^{81} \text{Vehicle years }(CY, MY)}$$

Both approaches for analyzing exposure-based accident rates were used in NHTSA's evaluations of head restraints [14], pp. 175-177 and side door beams [15], pp. 167-179.

6.2 Tabulation of accident rates

Table 6-1 indicates the number of fatal nighttime angle collision involvements per 1000 vehicle exposure years, by model year, during 1975-81. Cars, trucks and buses of model year 1967 were involved in 965 nighttime angle collisions on FARS during 1975-81. They accumulated 33,915,000 vehicle exposure years during that time. That is a rate of .0285 accidents per 1000 vehicle years. Cars, trucks and buses of model year 1968 had 1292 accidents and 43,382,000 vehicle exposure years in 1975-81: a rate of .0298 accidents per 1000 years. In other words, MY 68 vehicles, most of which were equipped

TABLE 6-1

U.S. FATAL ACCIDENTS, 1975-81: NIGHTTIME ANGLE COLLISION INVOLVEMENTS PER 1000 VEHICLE YEARS, BY SIDE MARKER LAMP STATUS

Model Years	Exposure 1975-81 (1000 Vehicle Years)	Nighttime* Angle Collision Involvements	Accident Rate	Reduction for SML (%)
1967 (last year w/o SML)	33,915	965	.0285	
1968 (first year w. SML)	43,382	1292	.0298	-5
1966-67	64,744	1818	.0281	-6**
1968-69	95,965	2861	.0298	
1965-67	89,374	2481	.0278	-7**
1968-70	152,177	4532	.0298	
1964-67	106,077	2927	.0276	-7**
1968-71	212,434	6276	.0295	

*Includes dawn and dusk

**Statistically significant accident increase (one-sided $\alpha = .05$)

with SML, had a 5 percent higher risk of fatal nighttime angle collisions than MY 67 vehicles most of which were not equipped. The increase. however, is not statistically significant because

$$Z = \frac{\frac{1,292}{43,382} - \frac{965}{33,915}}{\left(\frac{1,292}{43,382^2} + \frac{965}{33,915^2}\right)^{1/2}} = 1.08$$

When the sample is expanded to include model years 1966-67 vs. 1968-69 (the $\pm$ 2 MY comparison), the result is slightly more unfavorable to side marker lamps. Table 6-1 indicates that the MY 68-69 vehicles had a 6 percent higher accident rate than MY 66-67 - a statistically significant increase because

$$Z = \frac{\frac{2,861}{95,965} - \frac{1,818}{64,744}}{\left(\frac{2,861}{95,965^2} + \frac{1,818}{64,744^2}\right)^{1/2}} = 2.01$$

In the $\pm$ 3 MY and $\pm$ 4 MY comparisons, the increase in the accident rate for SML-equipped vehicles is 7 percent.

At first glance, the results do not show any evidence of a beneficial effect of side marker lamps in fatal crashes and even leave open the possibility that they increased accident risk. On closer inspection, though, the sequence of effectiveness estimates for the 4 consecutively broader samples - -5,-6, -7, -7 - shows a modest trend, probably due to the increasing difference in the age of the pre and post-standard vehicles. Similarly, the accident rate for the pre-standard cars decreases as more and more older cars are added to the sample: .0285, .0281, .0278, .0276 in Table 6-1. This decrease is not attributable to side marker lamps and could be creating an unfavorable bias in the SML effectiveness estimate.

A regression analysis is perhaps more suitable to deal with these vehicle age-related trends.

6.3 Regression of accident rates

The method for regression of accident rates per 1000 years is virtually the same as for nighttime/daytime accident ratios. Each applicable CY/MY combination yields one data point for the regression, where CY ranges from 75 to 81 and MY from 64 to 72. The dependent variable is the logarithm of the nighttime fatal accident rate

$$\text{LOGR}(\text{CY}, \text{MY}) = \log \frac{\text{N}(\text{CY}, \text{MY})}{\text{EXPO}(\text{CY}, \text{MY})}$$

where N(CY, MY) is the count of nighttime angle collision involvements of vehicles of model year MY on the FARS file for year CY and EXPO (CY, MY) is the number of vehicles of model year MY that are still on the road during CY (from Table 3-3).

The independent variables are LAMP, AGE, AGE^2 and CY, which are defined in Section 5.1. LAMP is a measure of the combined availability of the side marker lamps of two vehicles involved in an accident during calendar year CY, one of which is known to be of model year MY. AGE = CY - MY. CY is treated as a categorical variable.

A weighted regression is run, with EXPO (CY,MY) as the weight variable, using the General Linear Models procedure of SAS.

As explained in Section 5.1, LAMP = 0 when none of the vehicles on the road have side marker lamps. If a single vehicle is equipped with side marker lamps, but no others are, LAMP = 1 in calculations of the accident risk for this vehicle. If every vehicle on the road is equipped with SML, LAMP = 2. Let a_1 be the calculated regression coefficient for LAMP. Then, if a single vehicle is equipped with SML, its nighttime angle collision risk is reduced by

$$\mathcal{E}_1 = 1 - \exp(a_1)$$

When all vehicles on the road have SML, the angle collision risk per 1000 vehicle years is

$$\mathcal{E}_2 = 1 - \exp(2\, a_1)$$

lower than if no vehicles have SML.

Table 6-2 indicates that side marker lamps had no statistically significant effect on the rate of fatal nighttime angle collisions per 1000 vehicle years. The t value for the regression coefficient for LAMP is 0.39, df=53. The estimated effect of installing side marker lamps on a single vehicle is that the accident rate would increase by 2 percent: this estimate is closer to zero than the results obtained in the preceding section. The regression assigns a substantial negative coefficient to AGE^2, indicating that, for older cars, the accident rate decreases as vehicle age increases. This is a bias against side marker lamps which produced excessively unfavorable results in the preceding section.

TABLE 6-2

FARS 1975-81: FATAL NIGHTTIME ANGLE COLLISIONS PER 1000 VEHICLE YEARS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGR
WEIGHT: EXPO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	2540.46383096	282.27375900	8.77	0.0001	0.598277	159.4231
ERROR	53	1705.83298492	32.18552802		STD DEV		LOGR MEAN
CORRECTED TOTAL	62	4246.29681588			5.67322906		-3.55860019

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	599.08661962	18.61	0.0001	1	5.00209418	0.16	0.6950
AGE	1	223.86504179	6.96	0.0109	1	477.70525442	14.84	0.0003
AGE*AGE	1	950.63461492	29.54	0.0001	1	647.57233415	20.12	0.0001
CY	6	766.87755463	3.97	0.0024	6	766.87755463	3.97	0.0024

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-3.77771483 B	-20.45	0.0001	0.18470947
LAMP		0.02133228	0.39	0.6950	0.05411175
AGE		0.06434155	3.85	0.0003	0.01670097
AGE*AGE		-0.00402810	-4.49	0.0001	0.00089802
CY	75	-0.11326822 B	-1.62	0.1103	0.06974237
	76	-0.06077915 B	-0.99	0.3279	0.06155684
	77	0.02093658 B	0.38	0.7025	0.05452447
	78	0.04224688 B	0.88	0.3836	0.04808557
	79	0.05268848 B	1.20	0.2361	0.04396481
	80	-0.00493772 B	-0.12	0.9060	0.04162033
	81	0.00000000 B	.	.	.

Effect of side marker lamps:

On a single vehicle: 1 - exp (.021) = -2 percent
On the entire fleet: 1 - exp (.021 x 2) = -4 percent

The standard deviation of the regression coefficient for LAMP is 0.054, while the coefficient itself is 0.21. A lower confidence bound (one-sided α = .05) for the effect of installing SML on a single vehicle is

$$1 - \exp (.021 + 1.674 \times .054) = -12 \text{ percent}$$

(where 1.674 is the 90th percentile of a t distribution with 53 df). The upper bound is

$$1 - \exp (.021 - 1.674 \times .054) = 7 \text{ percent}$$

In short, the best estimate from the regression is that side marker lamps had little or no effect on fatal nighttime angle collisions, but the confidence bounds indicate a fair amount of statistical uncertainty about this result. Based on statistical analyses, alone, it cannot be firmly concluded that side marker lamps have no effect on fatalities.

6.4 Analyses for a control group of head-on and rear-end crashes

As in Chapter 4 and 5, it is desirable to repeat the analyses for a control group of 2 vehicle crashes that are not angle collisions - viz., head-on and rear-end collisions. If side marker lamps appear to have the same "effects" in the control group and in angle collisions, it would reinforce a conclusion that SML have little or no effect in fatal angle collisions.

Table 6-3 indicates the number of fatal nighttime accident involvements, in the control group, per 1000 vehicle years. The results are virtually identical to the ones for angle collisions (Table 6-1). The accident rate for MY 68 cars is a nonsignificant 3 percent

TABLE 6-3

U.S. FATAL ACCIDENTS, 1975 - 81: NIGHTTIME HEAD-ON AND REAR-END COLLISION INVOLVEMENTS, PER 1000 VEHICLE YEARS, BY SIDE MARKER LAMP STATUS

Model Years	Exposure 1975-81 (1000 Vehicle Years)	Nighttime* Control Gp. Involvements	Accident Rate	Reduction for SML (%)
1967 (last year w/o SML)	33,915	1938	.0571	
1968 (first year w. SML)	43,382	2564	.0591	-3
1966-67	64,744	3648	.0563	
1968-69	95,965	5852	.0609	-8**
1965-67	89,374	4980	.0557	
1968-70	152,177	9278	.0610	-9**
1964-67	106,077	5900	.0556	
1968-71	212,434	12,860	.0605	-9**

*Includes dawn and dusk

**Statistically significant accident increase (one-sided α = .05) higher in the control group than for MY 67 cars (it was a nonsignificant 5 percent higher in the angle collisions). The sequence of "effectiveness" estimates in the control group, for progressively broader samples, is -3, -8, -9, -9. It was -5, -6, -7, -7 in the angle collisions. Given the relatively small sample sizes from FARS, the two sequences may be considered equivalent. In other words, Table 6-3 helps support a conclusion that side marker lamps had little effect in fatal crashes. (Contrast this to the situation in Chapter 4, where the control group and angle collisions behaved differently, possibly due to confounding effects on daytime fatal accidents, and left more doubt about the effect of SML.)

A regression analysis for the control group is carried out in Table 6-4. Just as in both FARS regressions of Chapter 5, the results are not meaningful because the model assigns a large negative effect to side marker lamps, possibly confusing it with the calendar year effect. It is not appropriate to compare the results to Table 6-2, the regression on angle collision rates, which appeared to have modeled the data points properly.

TABLE 6-4

FARS CONTROL GROUP 1975-81: FATAL NIGHTTIME HEAD-ON AND REAR-END COLLISIONS PER 1000 VEHICLE YEARS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGR
WEIGHT: EXPO

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	9	2883.22167988	320.35796443	17.49	0.0001	0.748114	150.2523
ERROR	53	970.76540148	18.31632833		STD DEV		LOGR MEAN
CORRECTED TOTAL	62	3853.98708136			4.27975798		-2.84838118

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	513.61788804	28.04	0.0001	1	114.37968431	6.24	0.0156
AGE	1	822.45342581	44.90	0.0001	1	637.44058880	34.80	0.0001
AGE*AGE	1	809.65629066	44.20	0.0001	1	522.56616699	28.53	0.0001
CY	6	737.49407536	6.71	0.0001	6	737.49407536	6.71	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-3.38757704 B	-24.31	0.0001	0.13934072
LAMP		0.10200834	2.50	0.0156	0.04082070
AGE		0.07432439	5.90	0.0001	0.01259884
AGE*AGE		-0.00361849	-5.34	0.0001	0.00067745
CY	75	0.00943328 B	0.18	0.8584	0.05261210
	76	-0.00749272 B	-0.16	0.8724	0.04643711
	77	0.07123024 B	1.73	0.0891	0.04113205
	78	0.11770484 B	3.24	0.0020	0.03627468
	79	0.10257683 B	3.09	0.0032	0.03316607
	80	0.06920187 B	2.20	0.0319	0.03139745
	81	0.00000000 B	.	.	.

"Effect" of side marker lamps:

On a single vehicle: 1 - exp (.102) = -11 percent
On the entire fleet: 1 - exp (.102 x 2) = -23 percent

CHAPTER 7

"BEST" ESTIMATES OF SIDE MARKER LAMP EFFECTIVENESS

Regressions on the combined North Carolina and Texas data sets provide good estimates of the effectiveness of side marker lamps in preventing nonfatal crashes. It is estimated that installation of side marker lamps reduces a vehicle's nighttime angle collision risk by 8 percent (11 percent for injury-producing crashes). When all vehicles on the road have side marker lamps, there will be 16 percent fewer nighttime angle collisions (21 percent fewer injury-producing crashes) than if none of them had the lamps. It is also concluded that side marker lamps have little or no effect on fatal collision risk. The conclusion is based on the statistical results of Chapter 6 and an analysis of sighting and stopping distances to be carried out in this chapter.

7.1 Effectiveness estimates from Chapters 4-6

Table 7-1 recapitulates the effectiveness estimates for side marker lamps obtained by various methods and data sources in Chapters 4-6. In the regression analyses, the effect of installing SML on a single vehicle is shown rather than that of installing them on the whole vehicle fleet, because the former is more comparable to the reduction from MY67 to MY68.

The 6 results for accidents of all severities are extremely consistent, varying only between 7 and 8 percent. All 6 reductions are statistically significant.

TABLE 7-1

SUMMARY OF EFFECTIVENESS ESTIMATES

FOR SIDE MARKER LAMPS IN CHAPTERS 4 - 6

	Nighttime Angle Collision Reduction (%)		
Analysis Procedure →	Contingency Table Analysis	Regression	
Basis for Comparison →	MY 68 vs. MY 67	Install SML on a Single Veh.	
Computation Method →	Nighttime/Daytime	Nighttime/Daytime	Nighttime/1000yrs.
ACCIDENTS OF ALL SEVERITIES			
North Carolina	7*	7*	
North Carolina (refined)	8*	8*	
Texas	7*	8*	
INJURY-PRODUCING ACCIDENTS			
North Carolina	8*	12*	
North Carolina (refined)	13*	16*	
Texas	8*	10*	
FATAL ACCIDENTS			
FARS	-3	-13**	-2

* statistically significant effect

** analysis suspected of major biases

The 6 results for injury producing accidents are also consistent with one another and slightly higher than the preceding ones, varying between 8 and 16 percent. Again, all 6 reductions are statistically significant. Two of the 3 results for fatal crashes are close to zero. The third is based on a regression which was suspected of having confused calendar year differences in the data with the effect of side marker lamps (see Section 5.4).

It should be noted that the results based on comparison of MY68 and MY67 are not exactly comparable to the regressions. Since 13 percent of MY67 cars already had SML, while 12 percent of MY68 cars did not yet have them, the change from MY67 to 68 is not quite as drastic as from a vehicle without SML to one with SML. Let R^+ be the nighttime angle collision risk with SML, R^- without them. Since, in North Carolina and Texas

$$.07 = 1 - \frac{R68}{R67} = 1 - \frac{.88R^+ + .12R^-}{.13R^+ + .87R^-}$$

$$1 - \frac{R^+}{R^-} = .09$$

In other words, a 7 percent accident reduction from MY 67 to MY 68 is equivalent to an 9 percent reduction for equipping a single vehicle with SML.

Thus, the results from Chapter 4 (comparison of MY67 and 68) need to be augmented by about 2/7 to make them directly comparable to the regression results. That should be kept in mind in a review of Table 7-1. After the contingency table analysis estimates are augmented, they are still close to the regression results, especially so for injury crashes.

7.2 "Best" estimates for nonfatal crashes

The North Carolina and Texas data sets obviously produced compatible results. It would be desirable to combine the data files, somehow, to produce a single, statistically precise effectiveness estimate. The estimate should be formulated as follows: the percent reduction of nighttime angle collisions when all vehicles on the road have side marker lamps, relative to a situation where no vehicles on the road have SML. An estimate of this form can be obtained only by regression, not contingency table analysis. In other words, the regressions of Chapter 5 should be performed on a combined North Carolina-Texas data set. There is good reason to believe that the approach will be successful because, in Chapter 5, not only the effectiveness estimates but the entire regression equations were reasonably similar for the 2 States.

In the combined regression, each permissible combination of State/Calendar Year/Model Year yields one data point. In other words, the original 89 data points from North Carolina and 27 points from Texas are left unchanged and pooled to provide a total of 116 data points. The dependent variable, weight factor and independent variables LAMP, AGE and AGE^2 are the same as before. Only the independent variable CY is changed to a new categorical variable STATECY which contains one category for each calendar year of data from each State: NC71, NC72, ..., NC80, TX72, TX73, TX74.

7.2.1 Accidents of all severities

Table 7-2 shows that side marker lamps significantly reduced the risk of nighttime angle collisions: the coefficient for LAMP had t value -4.40, df = 100. The regression fit the combined data set very well (R^2 = .87). It attributed a significant positive coefficient to AGE and an equally significant negative coefficient to AGE^2, consistent with the trends observed in graphs of both States' data points.

When side marker lamps are installed in every vehicle on the road, the number of nighttime angle collisions will be

$$1 - \exp(-.088 \times 2) = 6 \text{ percent lower than if none}$$

of the vehicles on the road had SML (The regression coefficient for LAMP is -.088; see Section 5.1 on the derivation of the effectiveness estimate.) Confidence bounds (one-sided α = .05) for this estimate can be obtained by noting that the standard deviation of the regression coefficient for LAMP is .020. The confidence bounds are

$$1 - \exp(-.088 \pm (1.661 \times .020) \times 2)$$
$$= 10 \text{ to } 22 \text{ percent}$$

(Note that 1.661 is the 90th percentile of a t distribution with 100 df.)

Similarly, the installation of side marker lamps on a single vehicle reduces its nighttime angle collision risk by 8 percent (confidence bounds: 5 to 11 percent). This result is almost exactly in the middle of the 6 earlier estimates summarized on Table 7-1, after the estimates based on contingency tables are augmented as described in Section 7.1.

TABLE 7-2

NORTH CAROLINA AND TEXAS, COMBINED: ANGLE COLLISIONS OF ALL SEVERITIES

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS
WEIGHT: N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	15	5165.15846154	344.34389740	43.82	0.0001	0.867953	211.0027
ERROR	100	785.81018863	7.85810189		STD DEV		LOGODDS MEAN
CORRECTED TOTAL	115	5950.96864968			2.80323062		-1.32852809

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	858.03377284	109.19	0.0001	1	151.88029169	19.33	0.0001
AGE	1	1153.00832935	146.73	0.0001	1	181.62703039	23.11	0.0001
AGE*AGE	1	31.41762440	4.00	0.0483	1	155.23514741	19.75	0.0001
STATECY	12	3122.69873446	33.12	0.0001	12	3122.69873446	33.12	0.0001

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-1.36316485	B	-31.63	0.0001	0.04310205
LAMP		-0.08783102		-4.40	0.0001	0.01997819
AGE		0.02153884		4.81	0.0001	0.00448013
AGE*AGE		-0.00140235		-4.44	0.0001	0.00031552
STATECY	NC71	0.21254141	B	7.97	0.0001	0.02668283
	NC72	0.27143415	B	11.41	0.0001	0.02378294
	NC73	0.04377632	B	2.54	0.0125	0.01720833
	NC74	0.06273076	B	3.62	0.0005	0.01731250
	NC75	0.01388565	B	0.76	0.4471	0.01819152
	NC76	0.04930058	B	2.56	0.0121	0.01929540
	NC77	0.06766681	B	3.12	0.0024	0.02167602
	NC78	0.09967251	B	4.03	0.0001	0.02473285
	NC79	0.16218799	B	5.65	0.0001	0.02872747
	NC80	0.15412636	B	4.61	0.0001	0.03344377
	TX72	-0.02265858	B	-1.54	0.1255	0.01466691
	TX73	-0.03751977	B	-3.03	0.0031	0.01238670
	TX74	0.00000000	B	.	.	.

Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.088) = 8 percent
On the entire fleet: 1 - exp (-.088 x 2) = 16 percent

7.2.2 Injury accidents

Table 7-3 indicates that side marker lamps significantly reduced the number of injury-producing nighttime angle collisions: the coefficient for LAMP had t = 3.67. The other regression coefficients were similar to those obtained when the analysis was performed on the States separately (Tables 5-4 and 5-6).

When side marker lamps are installed in every vehicle on the road, the number of injury-producing nighttime angle collisions will be

$$1 - \exp(-.120 \times 2) = 21 \text{ percent}$$

lower then if none of the vehicles on the road had SML. The confidence bounds for this estimate are 12 to 29 percent. The installation of SML on a single vehicle reduces the risk by 11 percent (confidence bounds: 6 to 16 percent). This result is, again, almost exactly in the middle of the 6 estimates obtained earlier in the study (see Table 7-1).

The "best" estimate is that side marker lamps are slightly more effective in preventing accidents of a severity likely to cause injuries than in eliminating property damage accidents (21 vs. 16 percent, for the whole fleet; 11 vs. 8 percent for a single vehicle). Since the best estimate of all-severity accident reduction is within the confidence bounds for injury reduction, however, it cannot be firmly concluded that the latter is higher than the former. A more appropriate conclusion is that injury reduction is as high or slightly higher than overall accident reduction.

TABLE 7-3

NORTH CAROLINA AND TEXAS, COMBINED: INJURY-PRODUCING ANGLE COLLISIONS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGODDS1
WEIGHT: N1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	15	888.69010233	59.24600682	10.93	0.0001	0.621127	210.6433
ERROR	100	542.08001100	5.42080011		STD DEV		LOGODDS1 MEAN
CORRECTED TOTAL	115	1430.77011333			2.32826118		-1.10531996

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
LAMP	1	338.98964549	62.53	0.0001	1	72.82513710	13.43	0.0004
AGE	1	3.95231472	0.73	0.3952	1	10.49698941	1.94	0.1671
AGE*AGE	1	4.63637823	0.86	0.3573	1	27.75783462	5.12	0.0258
STATECY	12	541.11176390	8.32	0.0001	12	541.11176390	8.32	0.0001

PARAMETER		ESTIMATE		T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		-0.93022215	B	-13.08	0.0001	0.07112386
LAMP		-0.11971630		-3.67	0.0004	0.03266212
AGE		0.01027336		1.39	0.1671	0.00738264
AGE*AGE		-0.00111204		-2.26	0.0258	0.00049143
STATECY	NC71	0.04470493	B	1.10	0.2743	0.04066712
	NC72	0.07518693	B	2.13	0.0356	0.03528628
	NC73	-0.08302349	B	-3.04	0.0030	0.02733714
	NC74	-0.06134247	B	-2.25	0.0266	0.02726339
	NC75	-0.17927146	B	-6.33	0.0001	0.02830350
	NC76	-0.06833666	B	-2.25	0.0264	0.03032099
	NC77	-0.02058563	B	-0.60	0.5521	0.03450605
	NC78	0.00081375	B	0.02	0.9836	0.03946684
	NC79	0.03279164	B	0.72	0.4731	0.04553399
	NC80	0.04808657	B	0.91	0.3640	0.05273454
	TX72	-0.07723596	B	-3.04	0.0030	0.02539089
	TX73	-0.07828204	B	-3.57	0.0006	0.02194814
	TX74	0.00000000	B	.	.	.

Effectiveness of side marker lamps:

On a single vehicle: 1 - exp (-.120) = 11 percent
On the entire fleet: 1 - exp (-.120 x 2) = 21 percent

7.3 "Best" estimates for fatal crashes

7.3.1 Statistical results

The statistical analyses of fatal crashes appear to indicate that the effect of side marker lamps is close to zero. The statistical approach that, perhaps, did the best job modeling the data and yielded the most precise results was the regression of nighttime fatal crashes per 1000 vehicle exposure years (Section 6.3). It yielded a point estimate that the installation of current side marker lamps on a single vehicle raises the risk of a fatal nighttime angle collision by 2 percent. The increase was not statistically significant. Moreover, the confidence bounds (one-sided $\alpha = .05$) for effectiveness ranged from -12 to +7 percent.

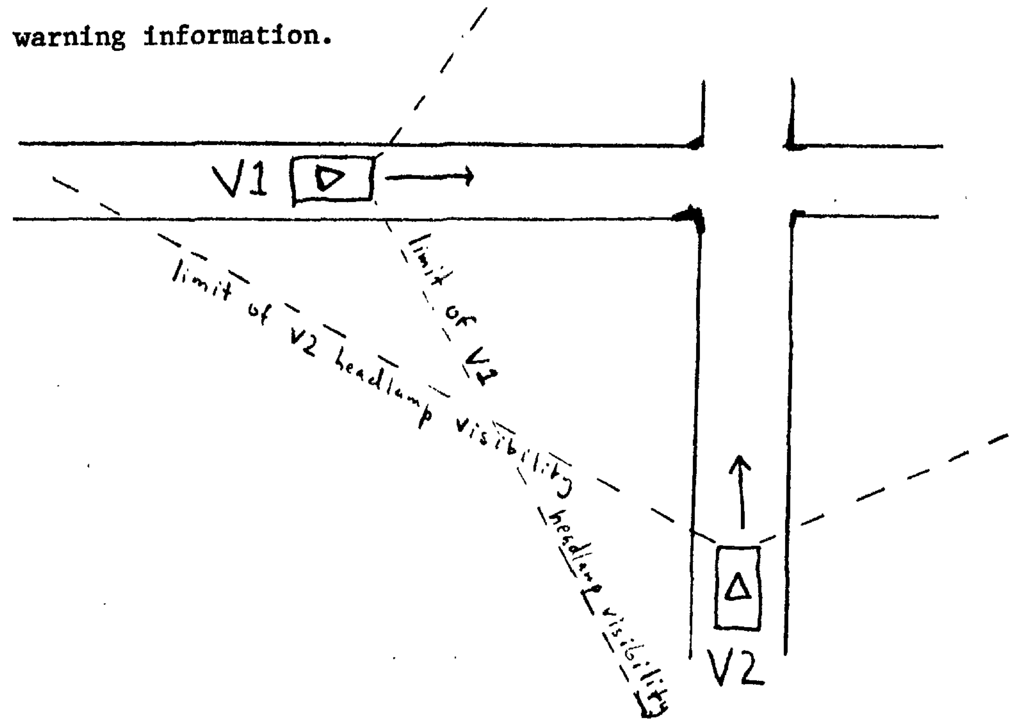
In other words, the statistical analyses would certainly support a hypothesis that the effect of side marker lamps on fatal crashes is negligible, but they are also compatible with possibilities that SML have moderately large negative or positive effects.

7.3.2 Analysis of travelling speeds in fatal crashes

Another approach is to analyze the distribution of pre-crash travelling speeds of vehicles in angle collisions and to identify groups of crashes for which side marker lamps would have little or no potential for preventing a collision or significantly reducing its severity. Specifically, there are two situations where, based on pre-crash travelling speeds alone, it can be inferred that SML would have been of limited utility:

(1) One of the vehicles is travelling so fast that the driver is unable to see and react to the SML of the other vehicle in time to stop or significantly reduce speed.

(2) Both vehicles are travelling at moderately high speeds prior to the collision. Under these circumstances, the sighting angle from one vehicle to the other is wide enough that each driver should be able to see the other vehicle's headlights much more clearly than the SML (see the illustration below). Thus, the latter provide little or no additional warning information.

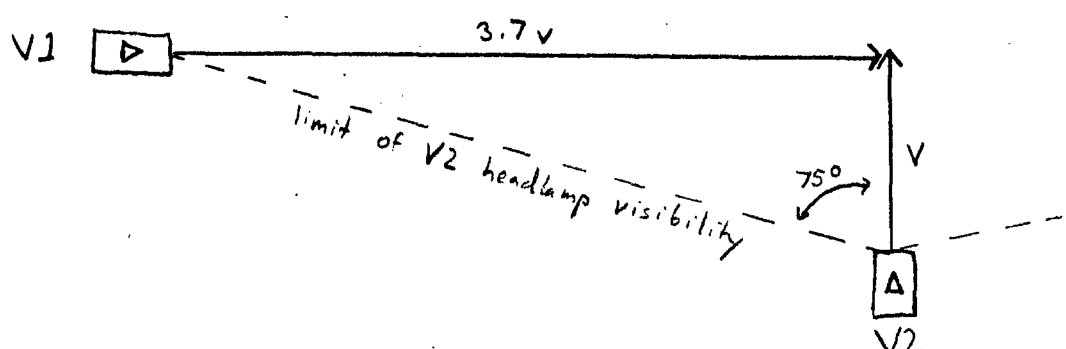


Data from the Multidisciplinary Accident Investigation File will indicate that approximately 87 percent of fatal accidents are in one of the preceding categories and are unlikely to be significantly affected by side marker lamps. Only 57 percent of nonfatal collisions are in those categories--leaving a much higher proportion of collisions that can potentially be mitigated by SML.

Extensive laboratory test experience by B. L. Cole and others with lighting and signal systems has demonstrated that side marker lamps typical of American practice (close to 0.25 candela for red and 0.62

candela for amber [23]) have an effective range of 100 meters [5], p. 5.13. By "effective range" is meant the distance at which drivers with average eyesight, under dark, clear conditions, will notice and respond to the lamps even while they are preoccupied with the task of steering a car. The effective range of 100 meters is designed to give drivers travelling up to 50 miles per hour sufficient advance warning to react to the lamps and come to a stop or slow down significantly. Thus, side marker lamps will be of limited utility in collision situations where one of the vehicles is travelling over 50 miles per hour--situation (1) in the preceding discussion. (Incidentally, Cole believed that the effective range of American side marker lamps was insufficient to prevent fatal accidents and recommended that Australia require lamps that would be 10-100 times as intense [5].)

A vehicle's headlamps can be plainly seen for some distance to the front and side of a vehicle as well as directly in front of it. Ford's letter to NHTSA regarding the compliance of 1972-74 Mercury Capris with Standard 108 indicates that the headlamps of a "representative" car can be seen up to 75 degrees to the side [18], Illustration No. 2. Under those circumstances, when two vehicles approach one another at right angles, each driver would more easily see the other vehicle's headlamps than the side marker lamps, unless one of the vehicles is travelling at least 3.7 times as fast as the other (see the picture below).



Thus, side marker lamps will be of limited utility if $V_1 < 3.7V_2$ and $V_2 < 3.7V_1$ - situation (2) in the preceding discussion.

The Multidisciplinary Accident Investigation data file contains records of 144 angle collisions in which the precrash travelling speeds of both vehicles were known and in which someone in the struck vehicle suffered a fatal or critical injury. There are 524 cases where nobody in the struck vehicle suffered more than a minor injury. The travelling speeds of the vehicles are distributed as follows:

	Fatal and Critical Injuries	Minor Injuries
(1) Percent with one car over 50 miles per hour	45	10
(2) Percent with $V_1 < 3.7V_2$ and $V_2 < 3.7V_1$ (both vehicles $<$ 50 mph)	42	47
Percent in which SML have limited or no potential	87	57
Percent in which SML have potential to be effective	13	43

Thus, based on travelling speeds, SML have the potential to provide an adequate warning in 13 percent of fatal collisions and 43 percent of non-fatal injury collisions. (Of course, in many crash situations, the lamps are not seen due to other vision obstructions, driver inattention, etc., so the actual effectiveness of SML is well below 13 percent in fatal crashes and 43 percent in nonfatal crashes.) In other words, based on speed distributions alone, the potential benefit of SML in fatal crashes is, at best, 1/3 as large as in nonfatal crashes.

Finally, alcohol is another factor that could reduce the effectiveness of side marker lamps in fatal crashes. Approximately 60 percent of fatal nighttime multivehicle collisions involve at least one intoxicated driver [3]. The inattention or unsafe actions by that person could nullify the potential benefits of side marker lamps.

When the effect of alcohol is added to that of speeds that exceed SML sighting distances or make the headlamps visible to both drivers, it can be concluded that the potential benefit of side marker lamps in preventing fatal crashes or reducing their severity to a nonfatal level is, at best, 1/4 as large as in nonfatal crashes--i.e., at best a 2 percent reduction when the lamps are installed on a single vehicle. That reduction is well within the confidence bounds obtained in the statistical analysis of fatal crashes, which ranged from -12 to +7 percent effectiveness. Since

o None of the statistical analyses showed a positive effect for side marker lamps (but only nonsignificant negative effects on the order of -2 to -5 percent),

o The preceding analysis of sighting and stopping distances indicates that the benefit in fatal crashes, if any, is unlikely to exceed 2 percent,

- There is no intuitive basis for believing that side marker lamps would increase the risk of fatal angle collisions,

it is concluded that side marker lamps have little or no effect in preventing fatal angle collisions or reducing their severity to a level where no fatalities occur.

CHAPTER 8

COSTS AND BENEFITS

One of the goals of the evaluation is to estimate the actual benefits and actual costs of side marker lamps in a manner that allows a meaningful comparison of benefits and costs.

The benefits of side marker lamps are the number of injuries and the value of property damage that will be prevented annually when all cars, trucks and buses on the road have side marker lamps -- relative to a baseline case where none of the vehicles on the road have any side marker lamps.

Similarly, the cost of SML is the average annual fleetwide cost of lamps that were installed in vehicles during 1970-83, a period during which all new cars, trucks and buses were equipped with SML -- relative to a baseline case of vehicles that have no side marker lamps at all. The cost includes the increase in the initial purchase price of a vehicle, the incremental fuel consumption due to the weight and electrical consumption of the equipment and any growth in repair and maintenance costs. All costs are expressed in 1982 dollars.

8.1 Costs

A 1979 study performed under contract to NHTSA gave estimates of the purchase price increase and weight added to passenger cars by side marker lamps [10]. Estimates were obtained for a representative sample of 16 cars of model year 1970. The lamps in MY 1970 cars are quite similar to those in subsequent model years and those of current (1983) design. The study sample did not include any light trucks but their side marker lamps are similar to cars'. Nor did it include heavy trucks and buses, whose lamps are likewise similar to cars' except for the possible inclusion of a third lamp at the vehicle's midpoint. Their sales are small relative to cars and light trucks and therefore have little effect on the fleetwide average cost of the lamps. Thus, the average cost of SML per model year 1970 passenger car is close to the average current cost per car, truck or bus.

Table 8-1 indicates, for each of the 16 models, the total cost and weight of SML in 1970. It is the total for all 4 lamps on the car. In this evaluation, the "baseline" vehicle has no SML at all--i.e., zero cost and weight--so the figures in Table 8-1 represent the incremental cost and weight for SML. (It should be noted that the contractor's analysis uses as "baseline" the SML of cars of MY 1968 and 69 and subtracts their cost from those of MY 70. That results in a much lower incremental cost, but one which is inconsistent with the method by which benefits are calculated in this evaluation--i.e., relative to no SML at all.) The "cost" in Table 8-1, which is meant to approximate the purchase price increase, includes materials, labor, tooling, assembly, overhead, manufacturer's and dealer's markups and taxes. The cost is expressed in 1982 dollars, whereas the contractor report on which it is based used 1979 dollars. The cost has been converted to 1982 dollars by

TABLE 8-1

COST AND WEIGHT ADDED BY SIDE MARKER LAMPS
(1982 dollars)

Specimen Vehicle	1970 Sales (000)	Side Marker Lamp Cost	Side Marker Lamp Weight
70 AMC Gremlin	23	$14.01	1.36 pounds
70 Plymouth Valiant	242	17.43	1.74
70 Plymouth Satellite	161	17.88	1.92
70 Plymouth Fury	268	16.93	1.77
70 Ford Maverick	211	21.19	2.64
70 Ford Fairlane	329	21.15	3.20
70 Ford Galaxie	807	21.27	3.64
70 Mercury Cougar	72	18.03	3.35
70 Chevrolet Nova	315	15.64	1.31
70 Chevrolet Malibu	394	12.41	0.97
70 Chevrolet Impala	891	10.66	0.95
70 Chevrolet Camaro	125	11.18	0.97
70 Buick Electra	403	12.68	1.13
70 Cadillac DeVille	215	23.90	3.92
70 Toyota Corona	35	33.37	1.65
70 Volkswagen Beetle	400	20.00	1.59
	SALES-WEIGHTED AVERAGE	$16.76	2.00 pounds

multiplying by the ratio of the Consumer Price Index for automobiles, which was 159.8 in 1979 and 198.1 in 1982.

Thus, according to Table 8-1, the average purchase price increase for side marker lamps is $16.76 per vehicle.

Table 8-1 also indicates that SML added an average of 2.0 pounds to the weight of a car. Each incremental pound of weight results in the consumption of an average of one additional gallon of fuel over the lifetime of a car [9], pp. VII-43-46. Table VII-16 of [9] calculates the discounted present value of consuming an additional gallon of fuel over the lifetime of a car. When the costs in that table are changed to reflect 1982 fuel prices ($1.21 per gallon in February [19], p. 82), it is found that each incremental pound of weight adds $1.00 to the discounted lifetime cost of owning and operating a car. Since SML add 2 pounds, the weight-related fuel penalty is $2.00.

Lamps also add to fuel consumption because they use electricity which is supplied by the battery which, in turn, is recharged by applying a drag on the engine. The type 194 bulb, which is widely used for side marker lamps (see Chilton's Auto Repair Manual, 1970), runs on 14 volts and .27 amperes -- i.e., 3.78 watts [23], p. 21.25. With 4 SML to a car, that is 15.12 watts. Over its lifetime, the average car is driven 28,000 miles at night (derived from the mileage-based fatality rates in "Accident Facts, 1979"[1], p. 50). Under the assumption of an average speed of 25 miles per hour, that amounts to 1120 hours with the lamps on, over the life of a car. Thus, the electrical power consumption by the lamps is

15.12 watts x 1120 hours = 16.9 kilowatt hours

Finally, assume that the process by which the engine and alternator convert motor fuel to electricity is 20 percent efficient and that the combustion of a gallon of fuel produces 38.68 kilowatt hours of energy [24]. It takes, then, 2.19 gallons of fuel to produce 16.9 kilowatt hours of electricity. The net present value of the fuel needed to power the lamps, over the life of the car, is $2.19.

Side marker light bulbs can burn out and must be occasionally replaced. The Hunter service job analysis indicates that 82 million small light bulbs of all types are replaced annually [27]. The average motor vehicle contains 30 small bulbs, 4 of which are side marker lamps (based on light bulb information in Chilton's Auto Repair Manual, 1970). Under the assumption that bulbs of different types are replaced at about the same rate, it is estimated that 10.9 million SML bulbs are replaced per year (i.e., 4/30 of 82 million). Since 12.3 million cars, trucks and buses are sold per year, it means there is a probability of .89 = 10.9/12.3 that an SML bulb will be replaced sometime during the life of a vehicle. Typically, replacement could occur in the vehicle's 8th year. Since this is 7 years after purchase, the cost should be discounted by .478, assuming a 10 percent discount rate. Finally, inquiries to parts shops in the Washington area indicated an average price of 63 cents for the bulbs. Thus, the discounted cost of replacement bulbs per motor vehicle is

.89 x .478 x 63 = 27 cents

The total consumer cost per vehicle for side marker lamps is

purchase price increase + fuel (weight) + fuel (electricity) + replacements = \$16.76 + 2.00 + 2.19 + 0.27 = \$21.22 (in 1982 dollars)

Since 12.3 million cars, trucks and buses are sold annually in the United States, the total cost of side marker lamps is about \$261 million.

8.2 Benefits

The best estimates of effectiveness (from Section 7.2) were that if all cars, trucks and buses were equipped with side marker lamps of current design, there would be 16 percent fewer nighttime angle collisions than if none of the vehicles had SML (confidence bounds: 10 to 22 percent). There would be 21 percent fewer injury-producing nighttime angle collisions (confidence bounds: 12 to 29 percent). Benefits are calculated by applying these reductions to the number of nighttime angle collisions that would occur annually if no vehicles on the road had SML and to the number of injuries and amount of damages that would occur in these crashes.

For example, according to National Accident Sampling System (NASS) data, there are 6,773,000 police-reported motor vehicle accidents per year [25]. What percentage of them would have occurred in nighttime angle collisions? The most reliable information source is the National Accident Summary (NAS), which is a census of police-reported and encoded accidents from 39 States in 1971. The file contains records of 3,964,469 accidents of which 375,642 are nighttime angle collisions. Note, however, that the data were collected in 1971, when 40 percent of cars, trucks and buses on the road were equipped with SML (see Section 3.5). Thus, the number of nighttime angle collisions on NAS must be augmented by the number which was already eliminated by the SML in vehicles on the road in 1971:

$$\frac{375,642}{1 - .40\varepsilon_A} = \frac{375,642}{1 - .40 \times .16} = 401,327$$

(where ε_A = accident-reducing effectiveness of side marker lamps). Also only 97 percent of the vehicles involved in angle collisions on NAS are cars, trucks and buses; the 3 percent that are other vehicle types must be removed from the total.

The appropriate formula, then, for accidents avoided by side marker lamps is

$$A_{Benefit} = NAC_{us} \cdot \varepsilon_A$$

$$= A_{NASS} \cdot P_{NAC} \cdot \varepsilon_A$$

$$= A_{NASS} \left(\frac{NAC_{NAS} / (1 - L_{71} \varepsilon_A)}{OC_{NAS} + \frac{NAC_{NAS}}{1 - L_{71} \varepsilon_A}} CTB_{NAS} \right) \varepsilon_A$$

where

$A_{Benefit}$ = accidents avoided (annual benefit)

NAC_{us} = nighttime angle collisions in the U.S. if no vehicles have SML

ε_A = accident reducing effectiveness of SML = .16 (confidence bounds: .10 - .22)

A_{NASS} = total number of police-reported accidents, based on NASS = 6,773,000

P_{NAC} = proportion of crashes that are nighttime angle collisions

NAC_{NAS} = nighttime angle collisions on NAS = 375,642

OC_{NAS} = other crashes on NAS = 3,588,827

L_{71} = proportion of registered vehicles with SML in 1971 = .40

CTB_{NAS} = proportion of vehicles involved in angle collisions on NAS that are cars, trucks or buses = .97

Thus

$$P_{NAC} = .0976$$

$$NAC_{us} = .0976 \times 6,773,000 = 661,000$$

$$A_{Benefit} = 6,773,000 \times .0976 \times .16$$

$$= 661,000 \times .16$$

$$= 106,000 \text{ police-reported crashes avoided annually}$$

Confidence bounds for the number of accidents avoided can be computed by substituting the lower and upper confidence bounds for $\mathcal{E}_A$, respectively, for the point estimate, in the 3 places where $\mathcal{E}_A$ appears in the formula for $A_{Benefit}$. The lower confidence bound (one-sided $\alpha = .05$) for accident avoidance is 65,000; the upper bound is 149,000 crashes avoided per year.

Similarly, the total amount of property damage that occurs in motor vehicle accidents is $22,200 million per year, according to NHTSA's study of "The Economic Cost to Society of Motor Vehicle Accidents" [7], p. I-4 (converted from 1980 to 1982 dollars, using the Consumer Price Index for automobiles). As calculated above, P_{NAC} = 9.76 percent of all crashes would be nighttime angle collisions, in the absence of side marker lamps. It is assumed that nighttime angle collisions, likewise, account for 9.76 percent of all property damage. Finally, side marker lamps eliminate 16 percent of those 9.76 percent:

$$PD_{Benefit} = PD{-}NAC_{us} \cdot \mathcal{E}_A$$

$$= PD_{tot} \cdot P_{NAC} \cdot \mathcal{E}_A$$

where

$PD_{Benefit}$ = property damage avoided (annual benefit)

$PD{-}NAC_{US}$ = property damage in nighttime angle collisions in the U.S. if no vehicles have SML

$\mathcal{E}_A$ = accident reducing effectiveness of SML = .16 (confidence bounds: .10 -.22)

PD_{tot} = property damage in all motor vehicle accidents = \$22,200 M

P_{NAC} = proportion of crashes that are nighttime angle collisions (formula provided above)

Thus

$PD{-}NAC_{US}$ = .0976 x \$22,200M = \$2,167M

$PD_{Benefit}$ = \$2167M x .16 = \$347 million property damages avoided annually

Confidence bounds for property damage avoidance can be computed by using the confidence bounds for $\mathcal{E}_A$ in the formulas for $PD_{Benefit}$ and P_{NAC}. The lower confidence bound for damage savings is \$213 million; the upper bound is \$488 million saved per year.

The calculation of the number of injuries avoided is similar to the computation of crash avoidance, except that

o the injury reducing effectiveness of SML (21%) is slightly higher than the overall accident reducing effectiveness (16 percent)

o The proportion of injury producing crashes that are nighttime angle collisions (11.02 percent) is slightly higher than P_{NAC}, the corresponding proportion for crashes of all severities (9.76 percent) - as will be calculated below.

Thus, a somewhat larger proportion of the 4,000,000 motor vehicle crash injuries that occur annually in the United States (according to NHTSA's societal cost study [7], p. II-2) are eliminated by side marker lamps.

The appropriate formula for injury avoidance is

$$I_{Benefit} = I\text{-}NAC_{US} \cdot \varepsilon_I$$

$$= I_{tot} \cdot P_{NAC-I} \cdot \varepsilon_I$$

$$= I_{tot} \left(\frac{I\text{-}NAC_{NAS} / (1 - L_{71}\,\varepsilon_I)}{OI_{NAS} + \dfrac{I\text{-}NAC_{NAS}}{1 - L_{71}\,\varepsilon_I}} \; CTB_{NAS} \right) \varepsilon_I$$

where

$I_{Benefit}$ = injuries avoided (annual benefit)

$I\text{-}NAC_{US}$ = injuries in nighttime angle collisions in the U.S. if no vehicles have SML

ε_I = injury-reducing effectiveness of SML = .21 (confidence bounds: .12 –.29)

I_{tot} = total number of persons injured in crashes in the U.S. per year = 4,000,000

P_{NAC-I} = proportion of crash injuries that occur in nighttime angle collisions

$I\text{-}NAC_{NAS}$ = nighttime angle collision injuries on NAS = 213,381

OI_{NAS} = other injuries on NAS = 1,817,954

L_{71} = proportion of registered vehicles with SML in 1971 = .40

CTB_{NAS} = proportion of vehicles involved in angle collisions in NAS that are cars, trucks or buses = .97

Thus

P_{NAC-I} = .1102

$I\text{-}NAC_{US}$ = .1102 x 4,000,000 = 440,800

$I_{Benefit}$ = 4,000,000 x .1102 x .21

= 440,800 x .21

= 93,000 injuries avoided per year

Confidence bounds for the number of injuries avoided can be computed by substituting the boundary values for ε_I for the point estimate in the 3 places where $\mathcal{E}_I$ appears in the formula for $I_{Benefit}$. The lower confidence bound is 51,000; the upper bound is 132,000 injuries avoided per year.

Table 8-2 summarizes the benefits of side marker lamps.

8.3 Cost-effectiveness

Safety equipment designed for crash avoidance has the potential to produce a variety of benefits. Specifically, side marker lamps have been shown to reduce both property damage and nonfatal injuries. Separate measures of cost-effectiveness will be given for the two types of benefits. The two measures will not be combined into a single figure in this report, but will be discussed together for a qualitative assessment of whether side marker lamps are cost-effective.

o Damage reduction: side marker lamps annually save $347 million in property damage because they prevent accidents (confidence bounds: $213-488 million) while costing consumers $261 million. In other words, by this benefit alone, they are providing consumers an estimated annual net saving of $86 million (confidence bounds: -48 to +227 million dollars).

o Injury reduction: side marker lamps prevent 93,000 injuries and cost $261 million per year. In other words they eliminate

$$\frac{93,000}{261} = 360 \text{ injuries per million dollars of cost}$$

TABLE 8-2

BENEFITS OF SIDE MARKER LAMPS

	Annual Occurrences in the United States		Annual Benefits of Side Marker Lamps	
	In All Types of Crashes	In Nighttime Angle Collisions	Best Estimate	Confidence Bounds
Police-reported crashes	6,773,000[1]	661,000	106,000	65,000 - 149,000
Value of property damage (1982 dollars)	$22,200M[2]	$2,167M	$347M	$213 - 488M
Injuries (nonfatal)	4,000,000[2]	441,000	93,000	51,000 - 132,000

[1] Source: NASS [25]

[2] Source: NHTSA Societal Cost Study [7]

Since the confidence bounds for injury prevention were 51,000 - 132,000, the confidence bounds for this measure of cost-effectiveness are 200 - 500 injuries per million dollars. The severity of these injuries is unknown. The majority of them are minor but the lamps may also prevent a substantial number of moderate or severe injuries which can occur in side impacts of low severity [15], p. 86. But probably few if any of them are life-threatening, because the lamps have little effect in crashes severe enough to produce fatalities or life-threatening injuries. Nevertheless, these figures compare very favorably with automotive head restraints which prevent 64,000 injuries, almost all of them minor whiplash, and cost $324 million per year--i.e., eliminate 200 minor injuries per million dollars of cost.

Since side marker lamps eliminate a large number of injuries while more than likely paying for themselves in property damage reduction alone, it is obvious that they are a cost-effective safety device.

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APPENDIX A

Tabulations of North Carolina, Texas and Fatal Accidents

Contents: Angle collisions

ERRATUM - The values of LAMP shown in this Appendix were not used in the report. The correct values are obtained by adding the percentages in Tables 3-1 and 3-4 of the report.

TABULATION OF NORTH CAROLINA ANGLE COLLISIONS

CY=75

MY	Crash Involvements Day	Crash Involvements Night	P(night)	Injury Crash Involvements Day	Injury Crash Involvements Night	P(night)	AGE	LAMP
64	1286	319	0.1988	395	120	0.2330	11	0.73
65	1727	432	0.2001	577	161	0.2182	10	0.76
66	2524	651	0.2050	783	244	0.2376	9	0.82
67	2539	668	0.2083	803	249	0.2367	8	0.80
68	3148	793	0.2012	938	273	0.2254	7	1.50
69	3639	863	0.1917	1091	299	0.2151	6	1.56
70	3472	854	0.1974	1098	280	0.2032	5	1.63
71	3532	810	0.1865	1092	280	0.2041	4	1.63
72	4493	1108	0.1978	1346	397	0.2278	3	1.64

CY=76

MY							AGE	LAMP
64	1129	314	0.2176	360	132	0.2683	12	0.78
65	1634	450	0.2159	505	164	0.2451	11	0.81
66	2514	631	0.2006	779	236	0.2325	10	0.87
67	2449	705	0.2235	779	259	0.2495	9	0.85
68	3324	861	0.2057	970	314	0.2445	8	1.55
69	3983	1028	0.2051	1144	366	0.2424	7	1.61
70	3878	970	0.2001	1179	340	0.2238	6	1.68
71	3902	935	0.1933	1152	344	0.2299	5	1.68
72	4935	1172	0.1919	1480	455	0.2351	4	1.69

CY=77

MY							AGE	LAMP
64	993	253	0.2030	286	98	0.2552	13	0.82
65	1403	383	0.2144	448	141	0.2394	12	0.85
66	2081	545	0.2075	626	213	0.2539	11	0.91
67	2260	595	0.2084	644	233	0.2657	10	0.89
68	3142	790	0.2009	923	280	0.2328	9	1.59
69	3742	942	0.2011	1086	320	0.2276	8	1.65
70	3944	1049	0.2101	1143	380	0.2495	7	1.72
71	3958	1037	0.2076	1136	375	0.2482	6	1.72
72	4999	1245	0.1994	1398	449	0.2431	5	1.73

CY=78

MY							AGE	LAMP
64	816	220	0.2124	266	75	0.2199	14	0.86
65	1134	312	0.2158	338	115	0.2539	13	0.89
66	1946	496	0.2011	517	188	0.2667	12	0.95
67	2011	570	0.2208	611	194	0.2410	11	0.93
68	2766	707	0.2036	795	242	0.2334	10	1.63
69	3376	915	0.2135	959	334	0.2583	9	1.69
70	3695	943	0.2033	1066	343	0.2434	8	1.76
71	4052	1133	0.2185	1157	413	0.2631	7	1.76
72	5239	1327	0.2021	1515	450	0.2290	6	1.77

TABULATION OF NORTH CAROLINA ANGLE COLLISIONS

CY=71

MY	Crash Involvements			Injury Crash Involvements			AGE	LAMP
	Day	Night	P(night)	Day	Night	P(night)		
64	1305	418	0.2426	440	160	0.2667	7	0.43
65	1472	490	0.2497	502	199	0.2839	6	0.46
66	1852	549	0.2287	579	229	0.2834	5	0.52
67	1607	543	0.2526	528	193	0.2677	4	0.50
68	1826	547	0.2305	577	215	0.2715	3	1.20
69	1880	561	0.2298	608	215	0.2612	2	1.26
70	1872	534	0.2219	577	222	0.2778	1	1.33
71	1357	400	0.2277	420	156	0.2708	0	1.33

CY=72

MY							AGE	LAMP
64	1081	393	0.2666	407	158	0.2796	8	0.52
65	1427	438	0.2349	502	168	0.2507	7	0.55
66	1650	586	0.2621	562	245	0.3036	6	0.61
67	1521	530	0.2584	477	225	0.3205	5	0.59
68	1692	552	0.2460	593	212	0.2634	4	1.29
69	1966	586	0.2296	679	241	0.2620	3	1.35
70	1768	520	0.2273	633	204	0.2437	2	1.42
71	1831	540	0.2278	594	215	0.2658	1	1.42
72	1666	549	0.2479	556	233	0.2953	0	1.43

CY=73

MY							AGE	LAMP
64	1872	543	0.2248	612	197	0.2435	9	0.61
65	2588	703	0.2136	830	270	0.2455	8	0.64
66	3335	854	0.2039	970	318	0.2469	7	0.70
67	3070	853	0.2174	914	317	0.2575	6	0.68
68	3623	930	0.2043	1009	344	0.2542	5	1.38
69	3998	1031	0.2050	1074	369	0.2557	4	1.44
70	3703	865	0.1894	1078	317	0.2272	3	1.51
71	3789	925	0.1962	1097	325	0.2286	2	1.51
72	5003	1193	0.1925	1372	405	0.2279	1	1.52

CY=74

MY							AGE	LAMP
64	1469	406	0.2165	463	139	0.2309	10	0.68
65	2006	589	0.2270	617	224	0.2663	9	0.71
66	2778	815	0.2268	828	301	0.2666	8	0.77
67	2693	765	0.2212	780	302	0.2791	7	0.75
68	3296	871	0.2090	969	309	0.2418	6	1.45
69	3793	943	0.1991	1076	329	0.2342	5	1.51
70	3593	835	0.1886	1019	292	0.2227	4	1.58
71	3358	842	0.2005	997	309	0.2366	3	1.58
72	4567	1093	0.1931	1279	389	0.2332	2	1.59

TABULATION OF NORTH CAROLINA ANGLE COLLISIONS

MY	Crash Involvements Day	Crash Involvements Night	Crash Involvements P(night)	Injury Crash Involvements Day	Injury Crash Involvements Night	Injury Crash Involvements P(night)	AGE	LAMP
CY=79								
64	629	170	0.2128	214	64	0.2302	15	0.89
65	917	219	0.1928	309	90	0.2256	14	0.92
66	1367	388	0.2211	400	139	0.2579	13	0.98
67	1496	439	0.2269	438	164	0.2724	12	0.96
68	2047	604	0.2278	625	209	0.2506	11	1.66
69	2824	748	0.2094	867	269	0.2368	10	1.72
70	2783	766	0.2158	834	260	0.2377	9	1.79
71	3371	1037	0.2353	1029	374	0.2666	8	1.79
72	4588	1229	0.2113	1312	432	0.2477	7	1.80
CY=80								
MY							AGE	LAMP
64	395	114	0.2240	107	46	0.3007	16	0.91
65	606	159	0.2078	213	64	0.2310	15	0.94
66	997	266	0.2106	297	110	0.2703	14	1.00
67	1109	303	0.2146	329	104	0.2402	13	0.98
68	1487	420	0.2202	436	156	0.2635	12	1.68
69	2000	572	0.2224	597	202	0.2528	11	1.74
70	2237	631	0.2200	695	242	0.2583	10	1.81
71	2661	696	0.2073	790	249	0.2397	9	1.81
72	3821	1047	0.2151	1130	353	0.2380	8	1.82

TABULATION OF NORTH CAROLINA REFINED TEST GROUP

CY=71

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	1199	360	0.2309	419	143	0.2544	7	0.43
65	1334	430	0.2438	466	176	0.2741	6	0.46
66	1694	477	0.2197	547	212	0.2793	5	0.52
67	1448	482	0.2497	485	180	0.2707	4	0.50
68	1664	472	0.2210	540	202	0.2722	3	1.20
69	1702	462	0.2135	569	190	0.2503	2	1.26
70	1707	456	0.2108	546	194	0.2622	1	1.33
71	1240	328	0.2092	400	145	0.2661	0	1.33

CY=72

MY	Day	Night	P(night)	Day	Night	P(night)	AGE	LAMP
64	992	335	0.2524	382	146	0.2765	8	0.52
65	1308	375	0.2228	481	146	0.2329	7	0.55
66	1482	522	0.2605	523	227	0.3027	6	0.61
67	1388	465	0.2509	441	199	0.3109	5	0.59
68	1550	492	0.2409	557	193	0.2573	4	1.29
69	1828	516	0.2201	638	216	0.2529	3	1.35
70	1610	459	0.2218	586	180	0.2350	2	1.42
71	1684	476	0.2204	559	198	0.2616	1	1.42
72	1504	479	0.2416	506	208	0.2913	0	1.43

CY=73

MY	Day	Night	P(night)	Day	Night	P(night)	AGE	LAMP
64	1064	304	0.2222	392	113	0.2238	9	0.61
65	1496	404	0.2126	536	164	0.2343	8	0.64
66	1923	458	0.1924	618	182	0.2275	7	0.70
67	1784	488	0.2148	596	211	0.2615	6	0.68
68	2028	524	0.2053	645	217	0.2517	5	1.38
69	2289	590	0.2049	710	228	0.2431	4	1.44
70	2063	480	0.1888	694	192	0.2167	3	1.51
71	2150	533	0.1987	696	201	0.2241	2	1.51
72	2877	637	0.1813	883	221	0.2002	1	1.52

CY=74

MY	Day	Night	P(night)	Day	Night	P(night)	AGE	LAMP
64	853	234	0.2153	300	89	0.2288	10	0.68
65	1132	332	0.2268	393	140	0.2627	9	0.71
66	1591	435	0.2147	531	165	0.2371	8	0.77
67	1562	407	0.2067	505	174	0.2563	7	0.75
68	1887	482	0.2035	629	183	0.2254	6	1.45
69	2156	517	0.1934	694	195	0.2193	5	1.51
70	2[illegible]26	458	0.1644	651	178	0.2147	4	1.58
71	1[illegible]37	479	0.2[illegible]68	637	185	0.2251	3	1.58
72	2563	606	0.1912	817	235	0.2234	2	1.59

TABULATION OF NORTH CAROLINA REFINED TEST GROUP

MY	Crash Involvements Day	Crash Involvements Night	Crash Involvements P(night)	Injury Crash Involvements Day	Injury Crash Involvements Night	Injury Crash Involvements P(night)	AGE	LAMP
CY=75								
64	685	175	0.2035	248	72	0.2250	11	0.73
65	972	231	0.1920	362	92	0.2026	10	0.76
66	1320	333	0.2015	465	146	0.2390	9	0.82
67	1384	346	0.2000	511	142	0.2175	8	0.80
68	1704	423	0.1989	593	164	0.2166	7	1.50
69	1952	435	0.1822	682	181	0.2097	6	1.56
70	1869	466	0.1996	658	169	0.2044	5	1.63
71	1872	419	0.1829	664	155	0.1893	4	1.63
72	2399	590	0.1974	842	244	0.2247	3	1.64
CY=76								
64	601	158	0.2082	223	76	0.2542	12	0.78
65	847	218	0.2047	303	84	0.2171	11	0.81
66	1309	312	0.1925	473	141	0.2296	10	0.87
67	1311	375	0.2224	476	156	0.2468	9	0.85
68	1721	413	0.1935	618	155	0.2005	8	1.55
69	2068	503	0.1956	706	211	0.2301	7	1.61
70	2029	499	0.1974	729	194	0.2102	6	1.68
71	2089	462	0.1811	729	180	0.1980	5	1.68
72	2597	575	0.1813	907	266	0.2268	4	1.69
CY=77								
64	514	117	0.1854	181	52	0.2232	13	0.82
65	715	190	0.2099	269	77	0.2225	12	0.85
66	1048	272	0.2061	375	113	0.2316	11	0.91
67	1114	290	0.2066	385	121	0.2391	10	0.89
68	1591	352	0.1812	553	140	0.2020	9	1.59
69	1918	435	0.1849	638	158	0.1985	8	1.65
70	1958	494	0.2015	682	191	0.2188	7	1.72
71	2002	518	0.2056	701	201	0.2228	6	1.72
72	2600	577	0.1816	864	228	0.2088	5	1.73
CY=78								
64	403	108	0.2114	160	39	0.1960	14	0.86
65	564	146	0.2056	192	58	0.2320	13	0.89
66	944	219	0.1883	287	95	0.2487	12	0.95
67	1001	253	0.2018	353	101	0.2225	11	0.93
68	1420	293	0.1710	473	118	0.1997	10	1.63
69	1703	443	0.2064	567	184	0.2450	9	1.69
70	1830	423	0.1877	646	187	0.2245	8	1.76
71	2043	516	0.2016	693	221	0.2418	7	1.76
72	2647	609	0.1870	897	222	0.1984	6	1.77

TABULATION OF NORTH CAROLINA REFINED TEST GROUP

CY=79

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	328	80	0.1961	148	34	0.1868	15	0.89
65	445	100	0.1835	178	45	0.2018	14	0.92
66	687	166	0.1946	226	69	0.2339	13	0.98
67	757	203	0.2115	257	94	0.2678	12	0.96
68	1033	283	0.2150	369	112	0.2328	11	1.66
69	1384	343	0.1986	507	141	0.2176	10	1.72
70	1408	337	0.1931	483	127	0.2082	9	1.79
71	1676	474	0.2205	632	204	0.2440	8	1.79
72	2304	557	0.1947	799	227	0.2212	7	1.80

CY=80

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	177	58	0.2468	50	27	0.3506	16	0.91
65	312	72	0.1875	127	34	0.2112	15	0.94
66	511	119	0.1889	183	54	0.2278	14	1.00
67	576	141	0.1967	202	56	0.2171	13	0.98
68	729	195	0.2110	252	73	0.2246	12	1.68
69	974.	251	0.2049	361	108	0.2303	11	1.74
70	1108	311	0.2192	398	128	0.2433	10	1.81
71	1317	315	0.1930	447	122	0.2144	9	1.81
72	1877	500	0.2103	654	200	0.2342	8	1.82

TABULATION OF TEXAS ANGLE COLLISIONS

CY=72

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	7856	2049	0.2069	1785	615	0.2562	8	0.53
65	10217	2588	0.2021	2209	729	0.2481	7	0.56
66	10715	2810	0.2078	2239	790	0.2608	6	0.62
67	11371	2784	0.1967	2236	791	0.2613	5	0.60
68	13524	3176	0.1902	2683	810	0.2319	4	1.34
69	14196	3388	0.1927	2823	913	0.2444	3	1.38
70	14262	3145	0.1807	2730	870	0.2417	2	1.43
71	14564	3247	0.1823	2821	868	0.2353	1	1.43
72	13076	3020	0.1876	2510	780	0.2371	0	1.44

CY=73

MY							AGE	LAMP
64	6475	1639	0.2020	1399	483	0.2566	9	0.61
65	8927	2206	0.1981	1873	625	0.2502	8	0.64
66	9837	2503	0.2028	2091	745	0.2627	7	0.70
67	10475	2686	0.2041	2114	725	0.2554	6	0.68
68	12657	2960	0.1895	2445	862	0.2607	5	1.42
69	13588	3174	0.1894	2704	801	0.2285	4	1.46
70	13393	2946	0.1803	2574	745	0.2245	3	1.51
71	13866	3026	0.1791	2642	772	0.2261	2	1.51
72	17594	3911	0.1819	3374	1047	0.2368	1	1.52

CY=74

MY							AGE	LAMP
64	4630	1240	0.2112	976	365	0.2722	10	0.68
65	6423	1725	0.2117	1453	512	0.2606	9	0.71
66	7636	1888	0.1982	1652	559	0.2528	8	0.77
67	8478	2268	0.2111	1773	669	0.2740	7	0.75
68	10437	2579	0.1981	2120	719	0.2533	6	1.49
69	11475	2891	0.2012	2271	820	0.2653	5	1.53
70	11375	2616	0.1870	2161	719	0.2497	4	1.58
71	11640	2589	0.1820	2249	718	0.2420	3	1.58
72	14071	3193	0.1850	2672	862	0.2439	2	1.59

TABULATION OF FARS ANGLE COLLISIONS

CY=75

MY	Crash Involvements Day	Night	P(night)	AGE	LAMP
64	153	116	0.4312	11	0.73
65	233	153	0.3964	10	0.76
66	289	177	0.3798	9	0.82
67	261	198	0.4314	8	0.80
68	314	239	0.4322	7	1.50
69	381	274	0.4183	6	1.56
70	401	287	0.4172	5	1.63
71	407	275	0.4032	4	1.63
72	503	288	0.3641	3	1.64

CY=76

MY				AGE	LAMP
64	126	89	0.4140	12	0.78
65	175	137	0.4391	11	0.81
66	231	182	0.4407	10	0.87
67	266	190	0.4167	9	0.85
68	334	238	0.4161	8	1.55
69	381	287	0.4296	7	1.61
70	404	265	0.3961	6	1.68
71	394	239	0.3776	5	1.68
72	604	349	0.3662	4	1.69

CY=77

MY				AGE	LAMP
64	118	68	0.3656	13	0.82
65	153	119	0.4375	12	0.85
66	192	145	0.4303	11	0.91
67	207	165	0.4435	10	0.89
68	254	225	0.4697	9	1.59
69	362	262	0.4199	8	1.65
70	394	289	0.4231	7	1.72
71	391	280	0.4173	6	1.72
72	550	380	0.4086	5	1.73

CY=78

MY				AGE	LAMP
64	84	60	0.4167	14	0.86
65	122	87	0.4163	13	0.89
66	160	132	0.4521	12	0.95
67	185	147	0.4428	11	0.93
68	264	196	0.4261	10	1.63
69	308	251	0.4490	9	1.69
70	326	226	0.4094	8	1.76
71	385	276	0.4175	7	1.76
72	550	387	0.4130	6	1.77

TABULATION OF FARS ANGLE COLLISIONS

CY=79

MY	Crash Involvements Day	Night	P(night)	AGE	LAMP
64	62	57	0.4790	15	0.89
65	81	68	0.4564	14	0.92
66	131	90	0.4072	13	0.98
67	134	95	0.4148	12	0.96
68	191	168	0.4680	11	1.66
69	219	187	0.4606	10	1.72
70	265	248	0.4834	9	1.79
71	291	281	0.4913	8	1.79
72	495	350	0.4142	7	1.80

CY=80

MY				AGE	LAMP
64	49	28	0.3636	16	0.91
65	75	52	0.4094	15	0.94
66	104	78	0.4286	14	1.00
67	116	99	0.4605	13	0.98
68	149	120	0.4461	12	1.68
69	170	175	0.5072	11	1.74
70	223	193	0.4639	10	1.81
71	241	208	0.4633	9	1.81
72	333	287	0.4629	8	1.82

CY=81

MY				AGE	LAMP
64	50	28	0.3590	17	0.92
65	55	47	0.4608	16	0.95
66	78	49	0.3858	15	1.01
67	86	71	0.4522	14	0.99
68	126	106	0.4569	13	1.69
69	141	133	0.4854	12	1.75
70	158	163	0.5078	11	1.82
71	201	185	0.4793	10	1.82
72	340	286	0.4569	9	1.83

TABULATION OF NORTH CAROLINA CONTROL GROUP

CY=71

MY	Crash Involvements Day	Crash Involvements Night	Crash Involvements P(night)	Injury Crash Involvements Day	Injury Crash Involvements Night	Injury Crash Involvements P(night)	AGE	LAMP
64	794	319	0.2866	227	124	0.3533	7	0.43
65	950	387	0.2895	261	155	0.3726	6	0.46
66	1127	404	0.2639	279	146	0.3435	5	0.52
67	932	369	0.2836	211	133	0.3866	4	0.50
68	1230	440	0.2635	312	149	0.3232	3	1.20
69	1333	459	0.2561	332	144	0.3025	2	1.26
70	1364	435	0.2418	308	151	0.3290	1	1.33
71	1018	353	0.2575	221	114	0.3403	0	1.33

CY=72

MY							AGE	LAMP
64	579	243	0.2956	205	103	0.3344	8	0.52
65	779	367	0.3202	228	151	0.3984	7	0.55
66	974	402	0.2922	262	136	0.3417	6	0.61
67	902	343	0.2755	230	136	0.3716	5	0.59
68	1097	419	0.2764	292	160	0.3540	4	1.29
69	1239	457	0.2695	340	155	0.3131	3	1.35
70	1201	451	0.2730	333	156	0.3190	2	1.42
71	1298	407	0.2387	312	153	0.3290	1	1.42
72	1211	466	0.2779	292	175	0.3747	0	1.43

CY=73

MY							AGE	LAMP
64	1276	448	0.2599	424	183	0.3015	9	0.61
65	1693	578	0.2545	533	233	0.3042	8	0.64
66	2327	715	0.2350	700	292	0.2944	7	0.70
67	2216	679	0.2345	632	257	0.2891	6	0.68
68	2745	859	0.2383	779	336	0.3013	5	1.38
69	3177	914	0.2234	849	344	0.2883	4	1.44
70	3087	864	0.2187	734	318	0.3023	3	1.51
71	3133	908	0.2247	792	303	0.2767	2	1.51
72	4190	1176	0.2192	1040	386	0.2707	1	1.52

CY=74

MY							AGE	LAMP
64	952	297	0.2378	306	119	0.2800	10	0.68
65	1351	454	0.2515	431	195	0.3115	9	0.71
66	1936	566	0.2262	582	249	0.2996	8	0.77
67	1931	578	0.2304	568	210	0.2699	7	0.75
68	2374	721	0.2330	645	274	0.2982	6	1.45
69	2733	810	0.2286	742	283	0.2761	5	1.51
70	2720	741	0.2141	751	270	0.2644	4	1.58
71	2815	718	0.2032	722	245	0.2534	3	1.58
72	3728	967	0.2060	946	338	0.2632	2	1.59

TABULATION OF NORTH CAROLINA CONTROL GROUP

CY=75

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	761	256	0.2517	245	91	0.2708	11	0.73
65	1163	383	0.2477	360	159	0.3064	10	0.76
66	1668	550	0.2480	487	205	0.2962	9	0.82
67	1707	571	0.2507	514	219	0.2988	8	0.80
68	2241	688	0.2349	679	264	0.2800	7	1.50
69	2685	820	0.2340	770	310	0.2870	6	1.56
70	2613	712	0.2141	721	250	0.2575	5	1.63
71	2752	766	0.2177	752	252	0.2510	4	1.63
72	3541	945	0.2107	911	324	0.2623	3	1.64

CY=76

MY	Day	Night	P(night)	Day	Night	P(night)	AGE	LAMP
64	735	221	0.2312	258	93	0.2650	12	0.78
65	1052	355	0.2523	357	135	0.2744	11	0.81
66	1485	492	0.2489	484	184	0.2754	10	0.87
67	1744	487	0.2183	559	208	0.2712	9	0.85
68	2311	673	0.2255	693	273	0.2826	8	1.55
69	2679	857	0.2424	783	351	0.3095	7	1.61
70	2660	808	0.2330	730	284	0.2801	6	1.68
71	3045	784	0.2048	799	285	0.2629	5	1.68
72	3769	1059	0.2193	991	368	0.2708	4	1.69

CY=77

MY	Day	Night	P(night)	Day	Night	P(night)	AGE	LAMP
64	546	167	0.2342	183	65	0.2621	13	0.82
65	750	226	0.2316	236	96	0.2892	12	0.85
66	1215	393	0.2444	371	175	0.3205	11	0.91
67	1376	408	0.2287	427	150	0.2600	10	0.89
68	1820	594	0.2461	582	229	0.2824	9	1.59
69	2280	707	0.2367	658	282	0.3000	8	1.65
70	2432	751	0.2359	654	274	0.2953	7	1.72
71	2674	775	0.2247	728	303	0.2939	6	1.72
72	3523	959	0.2140	970	363	0.2723	5	1.73

CY=78

MY	Day	Night	P(night)	Day	Night	P(night)	AGE	LAMP
64	493	177	0.2642	162	78	0.3250	14	0.86
65	721	240	0.2497	225	98	0.3034	13	0.89
66	1140	383	0.2515	341	179	0.3442	12	0.95
67	1281	388	0.2325	380	160	0.2963	11	0.93
68	1736	536	0.2359	503	186	0.2700	10	1.63
69	2392	770	0.2435	676	309	0.3137	9	1.69
70	2555	776	0.2330	748	287	0.2773	8	1.76
71	3019	923	0.2341	827	347	0.2956	7	1.76
72	3825	1070	0.2186	1015	376	0.2703	6	1.77

TABULATION OF NORTH CAROLINA CONTROL GROUP

CY=79

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	331	121	0.2677	93	56	0.3758	15	0.89
65	511	179	0.2594	149	86	0.3660	14	0.92
66	849	310	0.2675	292	128	0.3048	13	0.98
67	973	313	0.2434	282	116	0.2915	12	0.96
68	1377	473	0.2557	425	188	0.3067	11	1.66
69	1778	596	0.2511	488	227	0.3175	10	1.72
70	1805	626	0.2575	559	243	0.3030	9	1.79
71	2431	803	0.2483	681	312	0.3142	8	1.79
72	3312	1076	0.2452	871	416	0.3232	7	1.80

CY=80

MY							AGE	LAMP
64	253	94	0.2709	83	32	0.2783	16	0.91
65	420	156	0.2708	134	52	0.2796	15	0.94
66	689	245	0.2623	234	100	0.2994	14	1.00
67	748	248	0.2490	234	91	0.2800	13	0.98
68	1010	363	0.2644	278	148	0.3474	12	1.68
69	1406	504	0.2639	418	194	0.3170	11	1.74
70	1504	606	0.2872	433	247	0.3632	10	1.81
71	2002	704	0.2602	568	268	0.3206	9	1.81
72	2790	919	0.2478	774	387	0.3333	8	1.82

TABULATION OF TEXAS CONTROL GROUP

CY=72

MY	Crash Involvements Day	Night	P(night)	Injury Crash Involvements Day	Night	P(night)	AGE	LAMP
64	13448	3961	0.2275	1929	938	0.3272	8	0.53
65	18283	5153	0.2199	2611	1184	0.3120	7	0.56
66	20046	5433	0.2132	2770	1201	0.3024	6	0.62
67	21182	5453	0.2047	2758	1118	0.2884	5	0.60
68	25975	6529	0.2009	3313	1283	0.2792	4	1.34
69	29319	7130	0.1956	3470	1388	0.2857	3	1.38
70	29092	6892	0.1915	3312	1287	0.2798	2	1.43
71	30844	7210	0.1895	3518	1295	0.2691	1	1.43
72	28304	7009	0.1985	3123	1199	0.2774	0	1.44

CY=73

MY							AGE	LAMP
64	11395	3423	0.2310	1667	823	0.3305	9	0.61
65	16124	4646	0.2237	2224	1105	0.3319	8	0.64
66	18375	5070	0.2163	2519	1165	0.3162	7	0.70
67	20345	5468	0.2118	2625	1194	0.3126	6	0.68
68	25010	6490	0.2060	3085	1350	0.3044	5	1.42
69	28466	7164	0.2011	3350	1411	0.2964	4	1.46
70	28085	6871	0.1966	3293	1334	0.2883	3	1.51
71	29596	6826	0.1874	3398	1334	0.2819	2	1.51
72	38231	9290	0.1955	4291	1759	0.2907	1	1.52

CY=74

MY							AGE	LAMP
64	8412	2522	0.2307	1286	622	0.3260	10	0.68
65	12372	3651	0.2279	1641	830	0.3107	9	0.71
66	14411	4110	0.2219	1985	886	0.3086	8	0.77
67	16583	4731	0.2220	2290	992	0.3023	7	0.75
68	21120	5727	0.2133	2663	1184	0.3078	6	1.49
69	24031	6383	0.2099	2991	1223	0.2902	5	1.53
70	24195	6129	0.2021	2769	1195	0.3015	4	1.58
71	25069	6144	0.1968	2907	1123	0.2787	3	1.58
72	32047	7659	0.1929	3618	1426	0.2827	2	1.59

TABULATION OF FARS CONTROL GROUP

CY=75

MY	Crash Involvements Day	Night	P(night)	AGE	LAMP
64	221	213	0.4908	11	0.73
65	304	318	0.5113	10	0.76
66	346	371	0.5174	9	0.82
67	359	408	0.5319	8	0.80
68	404	500	0.5531	7	1.50
69	501	567	0.5309	6	1.56
70	504	537	0.5159	5	1.63
71	508	504	0.4980	4	1.63
72	646	644	0.4992	3	1.64

CY=76

MY				AGE	LAMP
64	171	189	0.5250	12	0.78
65	220	247	0.5289	11	0.81
66	260	327	0.5571	10	0.87
67	342	358	0.5114	9	0.85
68	367	440	0.5452	8	1.55
69	474	585	0.5524	7	1.61
70	489	531	0.5206	6	1.68
71	461	532	0.5358	5	1.68
72	569	598	0.5124	4	1.69

CY=77

MY				AGE	LAMP
64	149	154	0.5083	13	0.82
65	189	229	0.5478	12	0.85
66	237	294	0.5537	11	0.91
67	264	341	0.5636	10	0.89
68	339	424	0.5557	9	1.59
69	439	565	0.5627	8	1.65
70	432	573	0.5701	7	1.72
71	495	538	0.5208	6	1.72
72	547	666	0.5491	5	1.73

CY=78

MY				AGE	LAMP
64	127	126	0.4980	14	0.86
65	178	175	0.4958	13	0.89
66	219	247	0.5300	12	0.95
67	232	268	0.5360	11	0.93
68	285	392	0.5790	10	1.63
69	399	541	0.5755	9	1.69
70	417	548	0.5679	8	1.76
71	524	579	0.5249	7	1.76
72	519	729	0.5841	6	1.77

TABULATION OF FARS CONTROL GROUP

CY=79

MY	Crash Involvements Day	Night	P(night)	AGE	LAMP
64	89	98	0.5241	15	0.89
65	134	158	0.5411	14	0.92
66	161	194	0.5465	13	0.98
67	202	225	0.5269	12	0.96
68	240	345	0.5897	11	1.66
69	271	421	0.6084	10	1.72
70	365	492	0.5741	9	1.79
71	374	580	0.6080	8	1.79
72	451	619	0.5785	7	1.80

CY=80

MY				AGE	LAMP
64	57	79	0.5809	16	0.91
65	90	108	0.5455	15	0.94
66	103	147	0.5880	14	1.00
67	115	198	0.6326	13	0.98
68	166	279	0.6270	12	1.68
69	219	350	0.6151	11	1.74
70	251	423	0.6276	10	1.81
71	298	469	0.6115	9	1.81
72	416	579	0.5819	8	1.82

CY=81

MY				AGE	LAMP
64	48	61	0.5596	17	0.92
65	73	97	0.5706	16	0.95
66	89	130	0.5936	15	1.01
67	109	140	0.5622	14	0.99
68	145	184	0.5593	13	1.69
69	181	259	0.5886	12	1.75
70	219	322	0.5952	11	1.82
71	258	380	0.5956	10	1.82
72	381	569	0.5989	9	1.83