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STATISTICAL EVALUATION OF THE EFFECTIVENESS OF FEDERAL MOTOR VEHICLE SAFETY STANDARD 108: SIDE MARKER LAMPS (ONLY)

Report No. 1 of 7

Jim C. Knoop
John T. Ball
Gaylord M. Northrop

The Center for the Environment and Man, Inc.
275 Windsor Street
Hartford, Connecticut 06120

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CONTRACT TECHNICAL MANAGER'S ADDENDUM

Prepared for the National Highway Traffic Safety Administration in support of a program to review existing regulations, as required by Executive Order 12044 and Department of Transportation Order 2100.5. Agency staff will perform and publish an official evaluation of Federal Motor Vehicle Safety Standard 108 based on the findings of this report as well as other information sources. The values of effectiveness and benefits found in this report may be different from those that will appear in the official Agency evaluation.

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16. Abstract

This is the Final Report for the statistical evaluation of the effectiveness of Federal Motor Vehicle Safety Standard (FMVSS) 108: Side Marker Lamps (Only). It is one of seven statistical evaluations to be conducted under this contract. The seven Standards are:

1. FMVSS 108: Side Marker Lamps (Only)
2. FMVSS 202: Head Restraints
3. FMVSS 207: Seat Back Locks (Only)
4. FMVSS 213: Child Restraints
5. FMVSS 214: Side Door Beams
6. FMVSS 222: School Bus Seating and Crash Protection
7. FMVSS 301: Fuel System Integrity

FMVSS 108 is an accident-avoidance Standard which mandates forward amber and rear red side marker lamps that are also reflective. The Standard became effective 1 January 1969. During 1969, the Standard could be met either by reflectors only, or by lamps with reflective covers. After 1 January 1970, lamps with reflective covers were required.

The objective of this study is to evaluate the effectiveness of FMVSS 108 side marker lamp requirements in reducing the frequency of angle collision accidents occurring during periods of reduced visibility. This required an analysis of subsets of mass accident data consisting of side collisions between two passenger vehicles approaching at an angle, occurring either at an intersection or driveway access. Evaluative statistics were based upon 98,811 accidents in Texas (1972, 1973 and 1974), 17,566 accidents in New York (1974), and 19,709 accidents in North Carolina (1973, 1974 and 1975). Contingency table data were subjected to log-linear modeling and adjustment to minimize potential confounding effects and to allow for direct comparison of angle collision frequencies between various lighting conditions and Pre- and Post-Standard configurations of vehicles. Single vehicle accidents were used as a control group to compensate for potentially different reduced light exposure risks for Pre- and Post-Standard passenger vehicles.

The results indicate that for all samples analyzed, there was, on the average, an overall significant reduction of 18 percent in the number of angle collisions occurring during periods of reduced lighting that can be attributed to both vehicles involved in a potential reduced light side collision situation satisfying the side marker lamp requirements of FMVSS 108. An analogous average reduction of 11 percent in the number of reduced lighting angle collisions in all three states was observed when only one of the vehicles in a potential reduced light side collision situation was equipped with side marker lamps.

On a nationwide basis, it is estimated that roughly 64,000 reduced light angle collisions were actually prevented by FMVSS 108 in 1974, when the numbers of Pre- and Post-Standard vehicles driven were approximately the same. Had all of the vehicles driven in 1974 been equipped with side marker lamps, however, an estimated 103,000 reduced light angle collisions could have been prevented by FMVSS 108.

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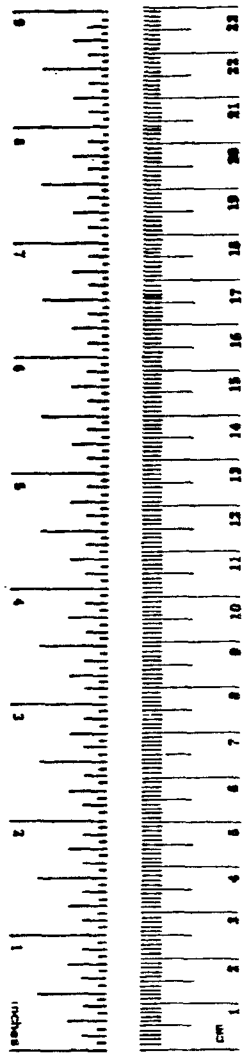
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

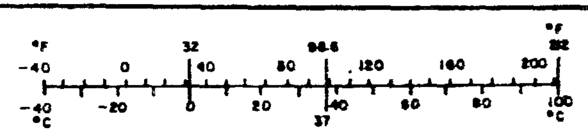
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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	0.96	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



EXECUTIVE SUMMARY

This is the Final Report of the statistical evaluation of the effectiveness of Federal Motor Vehicle Safety Standard 108: Side Marker Lamps (Only).

FMVSS 108 is an accident-avoidance Standard which mandates forward amber and rear red side marker lamps that are also reflective. The Standard became effective 1 January 1969. During 1969, the Standard could be met either by reflectors alone, or by lamps with reflective covers. After 1 January 1970, lamps with reflective covers were required.

The objective of this study is to statistically analyze a limited amount of mass accident data pertaining to angle collisions involving various configuration of Pre- and Post-Standard vehicles. Police-reported state accident data from Texas (1972-1974), New York (1974) and North Carolina (1973-1975) are statistically evaluated.

Since the purpose of the study is to evaluate the effectiveness of the FMVSS 108 side marker lamp requirements in reducing the frequency of angle collision accidents occurring during periods of reduced visibility, two distinct types of empirical estimates of side marker lamp effectiveness are derived. Estimates of *full* effectiveness represent the amount of accident avoidance realized when both vehicles involved in a potential reduced light angle collision situation satisfy the side marker lamp requirements of FMVSS 108. Thus, *full* effectiveness is defined as:

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

Estimates of *partial* effectiveness represent the amount of accident avoidance realized when only one of the vehicles in a potential reduced light angle collision situation is equipped with side marker lamps. Therefore, *partial* effectiveness is defined as:

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

Since the daylight and reduced light exposure risks of Pre- and Post-Standard vehicles are not necessarily the same in the population at large, the daylight-to-reduced light involvement ratios for Pre- and Post-Standard vehicles involved in single vehicle accidents are explicitly incorporated into the effectiveness estimation equations to control for any observed effects which are not due to FMVSS 108. In this sense, single vehicle accidents are treated as a control group, and represent measures of relative exposure risk. By inference, any observed reduction in the frequency of reduced light angle collisions involving Post-Standard vehicles, after controlling for relative exposure risk, are attributed to the effect of side marker lamps.

Accidents, rather than vehicles, are used as the unit of analysis, since Pre-Standard vehicles can also benefit from FMVSS 108, to the extent that they are able to avoid collisions with Post-Standard vehicles during periods of reduced lighting as a result of the greater conspicuity of the latter. Before either *full* or *partial* effectiveness values were computed, however, hierarchical, log-linear models were fit to contingency tables composed of Light Condition, Vehicle Configuration (Pre-with-Pre, Pre-with-Post and Post-with- Post) and selected control variables for each state-year of data. Modeling served the dual purpose of smoothing the data by removing random variability due to small cell frequencies, and of revealing the strength and pattern of various interactions among the variables comprising the contingency tables.

The smoothed data were then adjusted (standardized) to allow for the direct comparison of angle collision frequencies. Adjustment of the data was necessary in order to insure that the overall *full* and *partial* effectiveness estimates were not affected by different distributions of Pre-with-Pre, Pre-with-Post and Post-with-Post angle collisions occurring in daylight and reduced light periods across different levels of control variables. In most cases, the net impact of modeling and adjustment was to increase the value of effectiveness estimates by 1 to 3 percentage points, while slightly reducing the variability of these estimates.

Overall *full* and *partial* side marker lamp effectiveness values derived from smoothed, adjusted data (after controlling for relative exposure risk) are summarized in the following table for each sample. In the case of Texas and North Carolina, where multiple years of data were analyzed, weighted means of individual-year effectiveness values are also presented. Also, an overall weighted mean of all states' individual-year effectiveness values is presented. All effectiveness values are based upon the following number of accidents in each sample.

Texas		North Carolina	
1972:	34,011 cases	1973:	6,249 cases
1973:	34,255 cases	1974:	6,486 cases
1974:	30,545 cases	1975:	6,974 cases

New York	
1974:	17,566 cases

On the average, overall *full* effectiveness values for each of the three states range from 12 to 27 percent with an overall mean value of 18 percent for all states, and represent the amount of accident avoidance realized when both of the vehicles involved in a potential reduced lighting angle collision situation satisfy the side marker lamp requirements of FMVSS 108. All average *full* effectiveness values obtained are statistically significant.

Average *partial* effectiveness values obtained from Texas 1972-1974 and North Carolina 1973-1975 samples represent significant reductions in the number of reduced light angle collisions of 12 and 16 percent, respectively. These values can be interpreted as the amount of accident avoidance realized in each state when only one of the vehicles involved in a potential reduced light angle collision situation is equipped with side marker lamps. The *partial* effectiveness found for the New York 1974 sample was not statistically significant.

SUMMARY OF OVERALL FULL AND PARTIAL SIDE MARKER LAMP EFFECTIVENESS VALUES DERIVED FROM SMOOTHED, ADJUSTED STATE ACCIDENT DATA AFTER CONTROLLING FOR RELATIVE EXPOSURE RISK

State	Year	Full Effectiveness					Partial Effectiveness				
		Effectiveness	Standard Deviation	95% Confidence Interval From	95% Confidence Interval To	Is Effectiveness Significantly Different from Zero?	Effectiveness	Standard Deviation	95% Confidence Interval From	95% Confidence Interval To	Is Effectiveness Significantly Different from Zero?
Texas	1972	18.63	4.03	12.00	25.27	Yes	14.61	2.70	9.83	19.38	Yes
	1973	10.79	4.22	3.85	17.74	Yes	8.03	3.42	2.41	13.66	Yes
	1974	22.19	4.02	15.57	28.81	Yes	11.26	3.88	4.87	17.64	Yes
	1972-1974*	17.40	2.36	13.52	21.28	Yes	11.71	1.92	8.55	14.87	Yes
New York	1974	12.54	5.64	3.26	21.81	Yes	1.46	5.37	-7.37	10.28	No
North Carolina	1973	20.48	8.42	6.63	34.34	Yes	7.51	7.74	-5.22	20.25	No
	1974	36.38	6.90	25.03	47.73	Yes	25.56	6.83	14.32	36.80	Yes
	1975	15.45	9.69	-0.49	31.40	No	12.55	8.88	-2.06	27.16	No
	1973-1975*	26.61	4.67	18.93	34.29	Yes	16.38	4.44	9.08	23.68	Yes
All 3 States	All Years*	18.45	1.97	15.21	21.69	Yes	11.38	1.67	8.63	14.13	Yes

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

Partial effectiveness values in almost all cases were between one-fifth to two-thirds less than the corresponding *full* effectiveness values. The only exceptions to this involved the New York 1974 sample, where the *full* effectiveness estimate was roughly nine times greater than the *partial* effectiveness value.

When extrapolating from these findings to the entire nation, it is estimated that roughly 64,000 reduced light angle collisions were actually prevented by FMVSS 108 in 1974, when the numbers of Pre- and Post-Standard vehicles driven were approximately the same. Had all of the vehicles driven in 1974 been equipped with side marker lamps, however, it is estimated that more than 103,000 reduced light angle collisions could have been prevented by FMVSS 108.

ACKNOWLEDGMENTS

The work performed by CEM in statistically evaluating the effectiveness of seven Federal Motor Vehicle Safety Standards is the product of an inter-disciplinary team effort.

Dr. Gaylord Northrop is the Principal Investigator of this project, and participated in the development and implementation of the approach and the analyses of the results. Mr. Jim Knoop and Mr. John Ball are the principal authors of this report. Other members of the Study Team who contributed in various ways to the report include:

Ms. Kayla Costenoble
Mr. Thomas Bzik
Mr. Edward Sweeton
Mr. Joseph Reidy
Dr. Michael Sutherland

CEM is grateful for assistance provided by the Texas Highway Department, the New York Department of Motor Vehicles and the Highway Safety Research Center (University of North Carolina) in the acquisition and processing of their state's accident data. Mrs. Carmela Miller, Ms. Marjorie Wallace, Mrs. Teresa Mayer and Mrs. Arlene Bene also provided invaluable clerical support in the preparation of this report.

This study has benefitted throughout from the detailed reviews and constructive comments of the NHTSA Contract Technical Manager, Dr. Charles Kahane. Any errors in analysis or interpretation of data and results are, of course, solely the responsibility of the authors of this report.

ABBREVIATIONS USED

FMVSS	Federal Motor Vehicle Safety Standard
CEM	The Center for the Environment and Man, Inc.
HSRC	Highway Safety Research Center
HSRI	Highway Safety Research Institute
FARS	Fatal Accident Reporting System
NHTSA	National Highway Traffic Safety Administration
TAD	Traffic Accident Data Vehicle Damage Scale
KABCO	"K" Killed; "A", "B", "C" Injury Levels; "O" No Injury
LR	Likelihood Ratio
BMDP3F	Biomedical Computer Program 3F
df	Degrees of Freedom

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

This report is the first in a series of Final Reports of the statistical evaluation of the effectiveness of seven Federal Motor Vehicle Safety Standards (FMVSS). This work has been conducted under Contract DOT-HS-8-02014 by The Center for the Environment and Man, Inc. (CEM) and its subcontractor, the Highway Safety Research Center (HSRC) of the University of North Carolina. The seven FMVSS to be statistically evaluated are:

- FMVSS 108: Side Marker Lamps (Only)
- FMVSS 202: Head Restraints
- FMVSS 207: Seat Back Locks (Only)
- FMVSS 213: Child Restraints
- FMVSS 214: Side Door Strength
- FMVSS 222: School Bus Seating and Crash Protection
- FMVSS 301: Fuel System Integrity

The Final Report on the effectiveness of FMVSS 108 (Side Marker Lamps [Only]) is presented herein.

Side marker lamps are one of 15 separate lighting elements covered by FMVSS 108 (the formal title of this Standard is *Lamps, Reflective Devices and Assorted Equipment*). The overall purpose of the Standard is to prevent accidents by improving the driver's visual information during darkness or other conditions of reduced visibility. Side marker lamps are intended to help drivers notice the presence of, and judge the distance to, other vehicles when the vehicles are at an angle to one another during conditions of reduced visibility. FMVSS 108 was implemented in several phases, as outlined below.

- *Before January 1, 1969*, regular passenger vehicles were not required to have any side markers.

  However, due to styling considerations, some earlier models had various lights which were visible from the side.

- *Between January 1, 1969 and December 31, 1969*, passenger vehicles could satisfy the Standard with any combination of lamps or reflectors positioned front and rear as long as the colors were amber forward and red rear.

- *After January 1, 1970*, passenger vehicles had to have both lamps and reflectors for both forward and rear side markers. Some models achieved this by enlarging the front and/or rear lighting group so that it could be seen from the side; other models had totally separate side marker lamps. Usually, the lamp cover is both translucent and reflective.

1.2 Objective and Purpose

The objective of this study is to statistically analyze police-reported state accident data pertaining to angle collisions involving various configurations of Pre- and Post-Standard vehicles. Existing mass accident data from Texas (1972-1974), New York (1974) and North Carolina (1973-1975) were statistically evaluated.

The purpose of the study is to evaluate the effectiveness of the side marker lamp requirement of FMVSS 108 in reducing the frequency of side collisions during conditions of reduced visibility.

1.3 Scope

- This analysis involves the statistical analysis of state mass accident data concerning the frequency of side collisions occurring during conditions of reduced visibility in which either two Pre-Standard, two Post-Standard or one Pre- and one Post-Standard vehicles are involved.
- The mass accident data files used are those from Texas (1972-1974), New York (1974) and North Carolina (1973-1975).
- The analysis considers whether the incidence of side collision accidents under conditions of reduced visibility involving Post-Standard vehicles differs from the frequency of similar accidents involving Pre-Standard vehicles, after controlling for relevant vehicle, driver, highway and environmental factors; and taking into account the relative exposure risks of Pre- and Post-Standard vehicles during daylight or reduced light periods.

1.4 Approach

1.4.1 Background and Accident Data Populations

The statistical evaluation of the effectiveness of side marker lamps requires a large set of side collision accident data. Since the evaluation is based on a comparison of the incidence of side collision accidents involving Pre-Standard vehicles with the incidence of similar accidents involving Post-Standard vehicles, relatively old accident data bases are analyzed, in which numbers of Pre- and Post-Standard vehicles are roughly the same. Police-collected accident information from Texas, New York and North Carolina constitute the primary sources of evaluation statistics.

Table 1-1 below shows the size of the data bases used in the analyses. This population is described in greater detail in Section 3.2. In Table 1-1, the column labeled "Partial Data Base" contains the numbers of accidents which are applicable to the analysis of the effectiveness of side marker lamps--i.e., side collisions between two passenger vehicles approaching at an angle, occurring either at an intersection or driveway access.

TABLE 1-1

NUMBER OF ACCIDENTS AND VEHICLES IN DATA BASES USED FOR THE ANALYSIS OF FMVSS 108

State	Year	Variable	Full Data Base	Partial Data Base	Percentage
Texas	1972	Accidents Vehicles	432,997 744,697	34,637 69,274	8.0 9.3
	1973	Accidents Vehicles	464,225 800,543	35,019 70,038	7.5 8.8
	1974	Accidents Vehicles	434,193 747,832	31,049 62,098	7.2 8.3
	1972-1974 (pooled)	Accidents Vehicles	1,331,415 2,293,072	100,705 201,410	7.6 8.8
New York	1974	Accidents Vehicles	377,818 704,477	18,913 37,826	5.0 5.4
North Carolina	1973	Accidents Vehicles	129,150 232,825	6,312 12,624	4.9 5.4
	1974	Accidents Vehicles	121,568 218,506	6,584 13,168	5.4 6.0
	1975	Accidents Vehicles	129,013 232,180	7,053 14,106	5.5 6.1
	1973-1975 (pooled)	Accidents Vehicles	379,731 683,511	19,948 39,898	5.3 5.8

1.4.2 Analysis Approach

The basic hypothesis is that side marker lamps will prevent side collisions during periods of reduced visibility. Tests of this hypotheses will be conducted in reference to the primary table shown in Figure 1-1.

Since the final designation of which car is "struck" and which car is "striking" is in many instances determined during the last split second before a side collision accident occurs, no distinction is made between accidents in which Pre-Standard vehicles strike Post-Standard vehicles, or vice versa.

Vehicle Configuration	Light Condition	
	Daylight	Reduced Light
Pre with Pre		
Pre with Post		
Post with Post		

Figure 1-1. Primary table.

The analysis of the effectiveness of side marker lamps is carried out in the following steps.

1. Select the full mass accident data base.
2. Extract the partial data set to be used directly in evaluating the effectiveness of side marker lamps.
3. Define a set of potential control variables.
4. Select the variables to be used for modeling and adjustment purposes.
5. Fit a hierarchical, log-linear model to the contingency table composed of Vehicle Configuration, Light Condition and the control variables selected in Step 4.
6. Adjust the smoothed cell frequencies to allow for the direct comparison of reduced lighting angle collision frequencies.
7. Examine single vehicle accident frequencies to determine whether the exposure risk for Pre- and Post-Standard vehicles during reduced lighting periods is the same.
8. Compute effectiveness values and confidence intervals.
9. Extrapolate the results to the nation.

1.5 Limitations of the Study

The study is subject to several limitations. We do not know from mass accident data whether the vehicles' lights were on or whether there were any obstructions blocking the view of either driver. We also do not always know if the cars were approaching at an angle--only that they struck each other from front to side.

An additional limitation of the study is that the single vehicle accident data are not modeled or adjusted prior to their use in the effectiveness estimation procedure to control for differential exposure risk.

1.6 Outline of the Report

Section 2 of this report summarizes the analyses performed. It includes a discussion of the measure of effectiveness, the estimated effectiveness values and their confidence intervals, discussions of the overall success of the evaluation, the credibility of the analysis, and a comparison of results. Detailed analyses of the data are described in Section 3. Appendix A contains the fully cross-classified contingency tables derived from the state mass accident data bases. Appendix B summarizes the terms included in the various models fitted, along with their marginal associations. Appendix C contains a summary of all effectiveness values derived from both observed, unadjusted and smoothed, adjusted data.

2.0 SUMMARY OF ANALYSIS

2.1 Measures of Effectiveness

The effectiveness measures used in the statistical evaluation of FMVSS 108 are defined as follows.

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

Full effectiveness represents the amount of accident avoidance realized when both vehicles involved in a potential reduced light angle collision satisfy the side marker lamp requirements of FMVSS 108.

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

Partial effectiveness represents the amount of accident avoidance realized when only one of the vehicles in a potential reduced light angle collision situation is equipped with side marker lamps.

Since the daylight and reduced light exposure risks of Pre- and Post-Standard vehicles are not necessarily the same in the population at large--i.e., Post-Standard cars may in fact be less likely (or more likely) to be driven during periods of reduced lighting than Pre-Standard cars--the daylight-to-reduced light involvement ratios for Pre- and Post-Standard vehicles in single vehicle accidents are explicitly incorporated into the effectiveness measures to control for any observed "effect" that is not due to FMVSS 108. In this sense, single vehicle accidents are used as a control group. The overall magnitude of such "spurious" effects is negligible in all three years of Texas data, and approximately -4 percent in North Carolina for 1973 and 1975. However, in the case of both New York and North Carolina, single vehicle accident data reflect highly significant reductions in the number of reduced light angle collisions between Post-Standard vehicles of 6 and -16 percent, respectively, which cannot be attributed to FMVSS 108.

2.2 Estimated Effects of Side Marker Lamps

Tables 2-1 and 2-2 contain the *full* and *partial* effectiveness values obtained both prior to and after controlling for different exposure risks of Pre- and Post-Standard vehicles during periods of reduced lighting. Effectiveness values derived from both observed, unadjusted and smoothed, adjusted data are contained in these tables. Figure 2-1 places in perspective the various effectiveness values and their 95 percent confidence intervals.

The estimated overall effectiveness of side marker lamps in reducing the number of angle collisions occurring during periods of reduced lighting can be summarized as follows.

1. Full Effectiveness. After controlling for differential exposure risk, overall effectiveness values for the three states ranged, on the average, from 12 to 27 percent. This represents a 12 to 27 percent reduction in the number of reduced light angle collisions which can be attributed to both vehicles involved in a potential reduced light angle collision situation satisfying the side marker lamp requirements of FMVSS 108.

   The mean *full* effectiveness values obtained for all individual state-years of data was approximately 18 percent. All weighted averages of *full* effectiveness values obtained, moreover, were statistically significant.

2. Partial Effectiveness. Based upon weighted averages of overall *partial* effectiveness values (after controlling for differential exposure) derived from Texas 1972-1974 and North Carolina 1973-1975 samples, significant reductions in the number of reduced light angle collisions of 12 and 6 percent, respectively, were obtained when only one of the vehicles involved in a potential reduced light angle collision situation was equipped with side marker lamps. No significant *partial* effectiveness was found for the New York 1974 sample.

TABLE 2-1
SUMMARY OF OVERALL FULL EFFECTIVENESS VALUES

State	Year	Prior to Controlling for Relative Exposure Risk				After Controlling for Relative Exposure Risk				
		Observed, Unadjusted Data		Smoothed, Adjusted Data		Smoothed, Adjusted Data				
		Effectiveness	Standard Deviation	Effectiveness	Standard Deviation	Effectiveness	Standard Deviation	95% Confidence Interval From	95% Confidence Interval To	Is Effectiveness Significantly Different from Zero?
Texas	1972	18.86	3.33	20.11	3.28	18.63	4.03	12.00	25.27	Yes
	1973	14.56	3.34	12.76	3.42	10.79	4.22	3.85	17.74	Yes
	1974	17.77	3.59	20.54	3.46	22.19	4.02	15.57	28.81	Yes
	1972-1974*	17.03	1.97	17.85	1.95	17.40	2.36	13.52	21.28	Yes
New York	1974	22.78	4.06	23.08	4.05	12.54	5.46	3.26	21.81	Yes
North Carolina	1973	10.44	8.01	13.25	7.75	20.48	8.42	6.63	34.34	Yes
	1974	16.59	7.56	14.74	7.75	36.38	6.90	25.03	47.73	Yes
	1975	5.08	9.29	7.75	8.99	15.45	9.69	-0.49	31.40	No
	1973-1975*	11.46	4.73	12.30	4.68	26.61	4.67	18.93	34.39	Yes
All 3 States	All Years*	17.30	1.66	18.03	1.64	18.45	1.97	15.31	21.69	Yes

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

TABLE 2-2

SUMMARY OF OVERALL PARTIAL EFFECTIVENESS VALUES

State	Year	Prior to Controlling for Relative Exposure Risk				After Controlling for Relative Exposure Risk				
		Observed, Unadjusted Data		Smoothed, Adjusted Data		Smoothed, Adjusted Data				
		Effectiveness	Standard Deviation	Effectiveness	Standard Deviation	Effectiveness	Standard Deviation	95% Confidence Interval From	95% Confidence Interval To	Is Effectiveness Significantly Different from Zero?
Texas	1972	14.57	2.65	15.39	2.63	14.61	2.90	9.83	19.38	Yes
	1973	10.49	3.10	9.05	3.16	8.03	3.42	2.41	13.66	Yes
	1974	8.42	3.82	10.32	3.72	11.26	3.88	4.87	17.64	Yes
	1972-1974*	11.88	1.78	12.23	1.78	11.71	1.92	8.55	14.87	Yes
New York	1974	6.69	4.78	7.59	4.73	1.46	5.37	-7.37	10.28	No
North Carolina	1973	1.76	7.77	3.40	7.61	7.51	7.74	-5.22	20.25	No
	1974	15.38	7.34	13.83	7.50	25.56	6.83	14.32	36.80	Yes
	1975	6.62	9.11	8.65	8.87	12.55	8.88	-2.06	27.16	No
	1973-1975*	8.36	4.60	8.68	4.58	16.38	4.44	9.08	23.68	Yes
All 3 States	All Years*	10.91	1.57	11.31	1.57	11.38	1.67	8.63	14.13	Yes

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

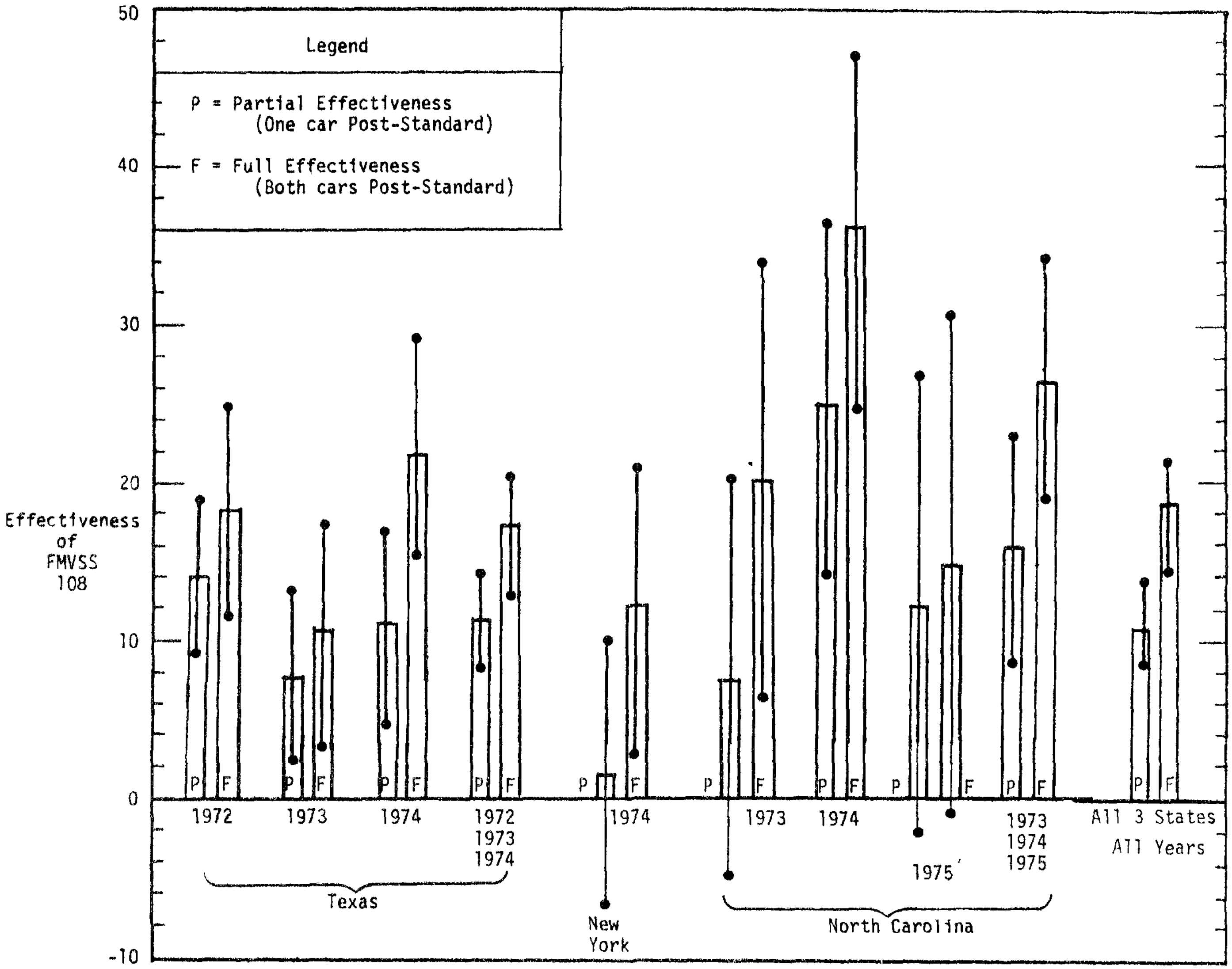


Figure 2-1. Summary of partial and full FMVSS 108 effectiveness values for two-car angle collisions in reduced light (smoothed, adjusted data, corrected for differential exposure risk).

As expected, these *partial* effectiveness values were in almost all cases between one-fifth to two-thirds less than the corresponding *full* effectiveness values. An overall average *partial* effectiveness value of 11 percent was obtained for all state-years of data analyzed, after controlling for exposure risk.

3. Impact of Adjustment of Data. Overall, the net impact of adjusting smoothed cell counts was to increase effectiveness values by roughly 1-3 percentage points, and to slightly reduce the variability of these estimates. However, in the case of Texas 1973 and North Carolina 1974 samples, smoothing and adjustment resulted in a decrease in effectiveness values of approximately 2 percentage points.

4. Impact of Controlling for Exposure Risk. In the case of North Carolina, where the analysis of single vehicle accidents revealed a significant over-representation of Post-Standard vehicles driven during periods of reduced lighting, *full* and *partial* effectiveness values were uniformly increased by an average of roughly 13 to 7 percentage points as a result of controlling for exposure risk. For the New York 1974 sample, where Post-Standard vehicles driven under reduced lighting conditions were under-represented in the population at large, *full* and *partial* effectiveness values were decreased by 10 to 5 percentage points, respectively. Controlling for exposure risk in the Texas samples, however, had no appreciable impact on effectiveness values, since both Pre- and Post-Standard cars driven during periods of reduced lighting were equally represented.

Using a weighted mean of 1974 effectiveness values for Texas, New York, and North Carolina to extrapolate to the nation, it is estimated that roughly 64,000 reduced light angle collisions were actually prevented by FMVSS 108 in 1974, when the numbers of Pre- and Post-Standard vehicles driven were approximately the same. Had all of the vehicles driven in 1974 been equipped with side marker lamps, however, it is estimated that more than 103,000 reduced light angle collisions could have been prevented by FMVSS 108.

2.3 Evaluation of the Analysis

2.3.1 Overall Success of the Analysis

The findings summarized in Tables 2-1 and 2-2 conclusively demonstrate the positive effectiveness of side marker lamps in preventing angle collisions occurring during periods of reduced lighting. The results of this analysis also indicate that, in many instances, side marker lamps are effective in preventing accidents even when only one vehicle in a potential reduced light collision situation satisfies the requirements of FMVSS 108.

2.3.2 Limitations of the Analysis

There are several potential limitations to this study which merit discussion. First, police-reported accident data are often lacking in detail and completeness. For example, we do not know from mass accident data whether the vehicle lights were on at the time of the accident. Furthermore, in New York, light condition information was not recorded in 1974, and had to be estimated from other information (county, time of day, month, etc.). Also, in New York, no record was made of whether the vehicles were approaching at an angle. However, information concerning the location of an accident (intersection or non-intersection), the vehicles' direction of travel, and the initial point of impact was available. The completeness of police accident reports was problematic insofar as many relevant accidents had to be excluded from the samples because information pertaining to vehicle model year, light condition or relevant control variables was unknown. In addition, a limitation which applies to the North Carolina data base concerns its relatively small sample size.

An additional limitation of the study is that the single vehicle accident data are not modeled or adjusted prior to their use in the effectiveness estimation procedure to control for differential exposure risk. Ideally, it would have been desirable to construct a Light Condition by Vehicle Configuration by Accident Type (angle collision or single vehicle) table stratified by relevant control variables for purposes of modeling, adjustment and computation of effectiveness values. Structural incompatibilities between the two groups of accidents, however, preclude this approach, as there is no vehicle configuration classification for single vehicles which is analogous to "Pre-with-Post."

2.3.3 Credibility of the Analysis

The results of the analysis of the effectiveness of side marker lamps are quite credible, given the overall size of the data bases, the general degree of consistency among the findings, the statistical significance of almost all effectiveness values obtained, and the straightforwardness of the analytic approach. The credibility of the analysis has been particularly enhanced by the use of single vehicle accidents as a control group.

3.0 ANALYSIS OF THE EFFECTIVENESS OF SIDE MARKER LAMPS

In this section, the effectiveness of side marker lamps in reducing the frequency of side collision accidents during periods of reduced lighting is empirically assessed, using police-reported state mass accident data. What follows is a brief description of CEM's approach for the analysis of side marker lamp effectiveness; a description of all relevant data bases used, along with information on how they were derived; a detailed presentation of the analysis; and finally, a summary of results.

3.1 Analysis Approach

The hypothetical impact of side marker lamps for three distinct scenarios of angle collisions occurring at intersections during periods of reduced lighting (night, dawn and dusk) is illustrated in Figure 3-1.* Since the purpose of the statistical evaluation of side marker lamp effectiveness is to test the hypothesis that side marker lamps reduce the frequency of reduced light angle collisions, this can be done by comparing the *observed* number of Post-Post

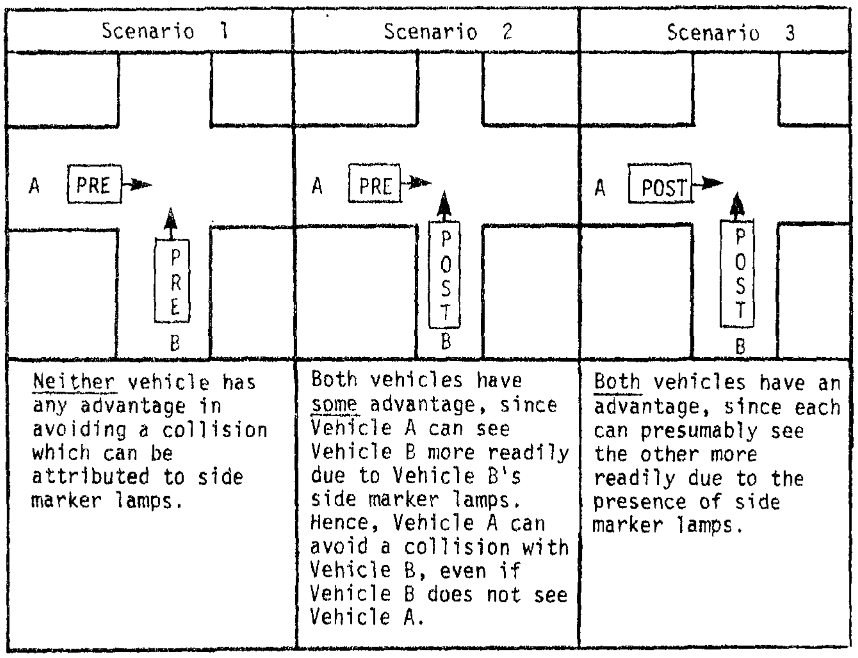


Figure 3-1. Hypothetical expectations for the impact of side marker lamps in various scenarios for reduced light angle collisions at intersections.

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*Although each scenario allows for two possible collision outcomes (A strikes B, or B strikes A), no distinction is made between the "struck" and "striking" vehicles, since in many instances this is determined during the last split second before a side collision occurs, and is not necessarily directly related to the presence or absence of side marker lamps.

collisions with the *expected* number of such accidents, after controlling for relative exposure risk. Additionally, the *observed* number of reduced light Pre-Post collisions can be compared with the *expected* number of such collisions to test the partial effectiveness of FMVSS 108, again after controlling for relative exposure risk. By inference, the percent difference between the expected and observed number of reduced light angle collisions in each case can be attributed to the effect of side marker lamps.

Accidents, rather than vehicles, are used as the unit of analysis, since Pre-Standard vehicles can also benefit from FMVSS 108, to the extent that they are able to avoid collisions with Post-Standard vehicles during periods of reduced lighting due to the greater conspicuity of the latter. Figure 3-2 depicts the basic Vehicle Configuration-by-Light Condition table central to the analyses, which is stratified by a set of control variables selected according to the procedures outlined in Section 3.3 Figure 3-2 also contains the basic Pre-Post-by-Light Conditions table for single vehicle accidents, from which measures of relative exposure risk are derived for control purposes. Cell

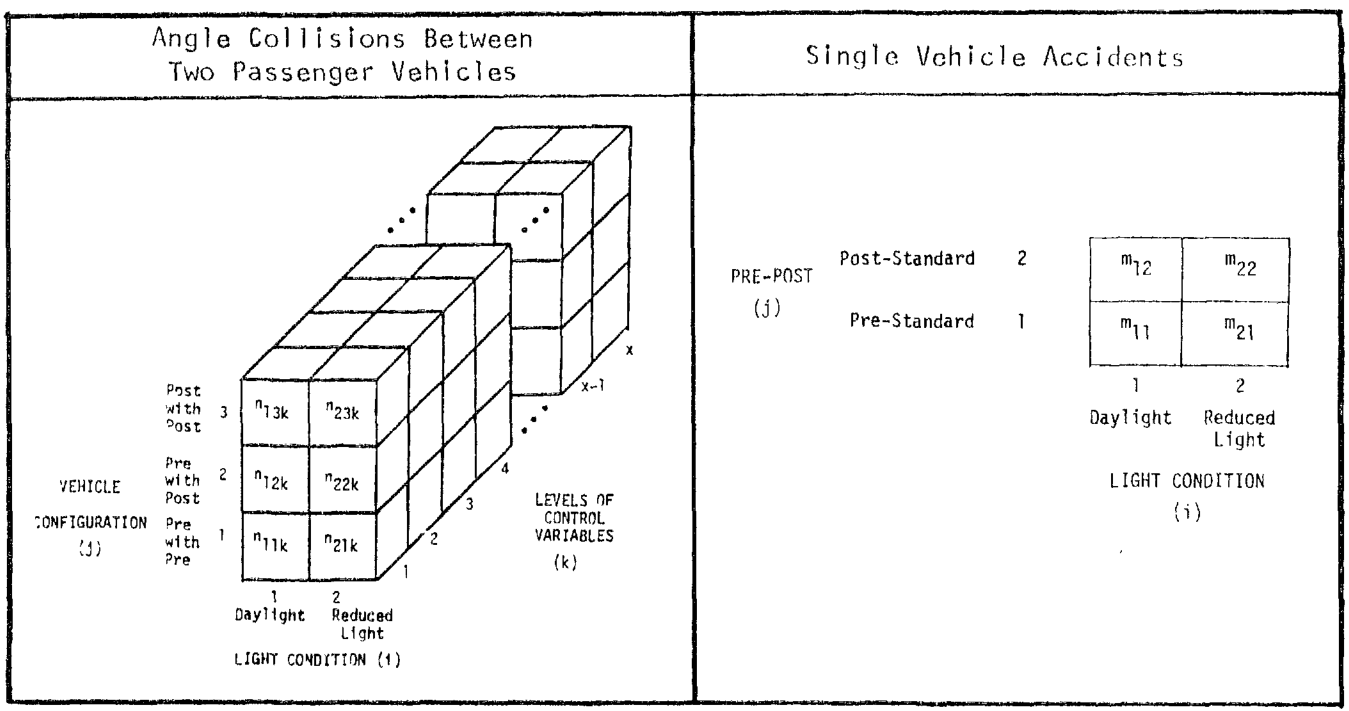

Figure 3-2. Basic contingency tables used to derive full and partial side marker lamp effectiveness estimates.

entries consist of observed counts (n_{ijk}'s and m_{ijk}'s), which are used to derive both "full" and "partial" effectiveness estimates. The former are based upon comparisons between Pre-Pre and Post-Post angle collision frequencies, after controlling for relative exposure risk, while the latter can be obtained by comparing the incidence of Pre-Pre and Pre-Post collisions across different light condition categories, again after controlling for relative exposure risk. Stated differently, *full* effectiveness represents the amount of accident avoidance realized when both vehicles in a potential reduced light angle collision satisfy the side marker lamp requirements of FMVSS 108, while *partial* effectiveness represents the amount of accident avoidance realized when only one of the vehicles satisfies FMVSS 108.

<u>Full effectiveness</u> can be defined as follows.

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

Using the notation in Figure 3-2, this can be expressed as:

$$E_{(Full)} = \left(1 - \left[\left(\frac{n_{11.}\ n_{23.}}{n_{13.}\ n_{21.}} \right) \Big/ \left(\frac{m_{11}\ m_{22}}{m_{21}\ m_{12}} \right) \right]^2 \right) \times 100$$

Partial effectiveness is defined as follows.

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

or:

$$E_{(\text{Partial})} = \left(1 - \left[\left(\frac{n_{11.}\ n_{22.}}{n_{12.}\ n_{21.}} \right) \Big/ \left(\frac{m_{11}\ m_{22}}{m_{21}\ m_{12}} \right) \right] \right) \times 100$$

Since the daylight and reduced light exposure risks of Pre- and Post-Standard vehicles are not necessarily the same in the population at large--i.e., Post-Standard cars may, in fact, be less likely (or more likely) to be driven during periods of reduced lighting than Pre-Standard cars--the daylight-to-reduced light involvement ratios for Pre- and Post-Standard vehicles in single vehicle accidents are explicitly incorporated into the preceding equations to control for any observed "effect" that is not due to FMVSS 108. In this sense, single vehicle accidents are used as a control group, and represent measures of relative exposure risk. In the case of the equation for estimating *full* effectiveness, it should be noted that the term $m_{11}m_{22}/m_{21}m_{12}$ in the denominator is squared. Since single vehicle accidents are used throughout the analysis as a measure of the reduced lighting exposure risk of Post-Standard vehicles relative to Pre-Standard vehicles, then the expectation (based upon exposure) of a reduced light angle collision between two Post-Standard vehicles can be expressed as the product of the expectations of each Post-Standard vehicle being involved in a reduced light angle collision--i.e., the square of $m_{11}m_{22}/m_{21}m_{12}$.

In addition to computing point estimates of effectiveness, an estimate of variability is necessary to generate the corresponding ranges of effectiveness (confidence intervals). Furthermore, in order to demonstrate that the observed effectiveness is significantly different from zero, one must reject the null hypothesis that there is no difference between the expected and observed incidence of angle collision accidents occurring under conditions of reduced lighting.

Prior to computing effectiveness values, however, the following preliminary treatment of the data must be carried out.

- Selection of a set of relevant control variables.
- Smoothing of the data to remove chance variation.
- Adjustment of the data to allow for direct comparison of angle collision accidents.

Each of these procedures is described in detail later in this section. In general, the evaluation of the effectiveness of side marker lamps is carried out in the following steps.

1. Select the full mass accident data base. The data bases analyzed are Texas 1972-1974, New York 1974 and North Carolina 1973-1975.

2. Extract the partial data set to be used directly in evaluating side marker lamp effectiveness. The partial data set consists of side collision accidents involving two passenger vehicles.

3. Define a set of variables to be considered for modeling and adjustment purposes. In addition to Vehicle Configuration and Lighting Condition, all available variables that might represent possible confounding effects are considered for modeling and adjustment.

4. Apply the variable selection procedure. This procedure consists of ranking all potential variables according to the strength of their interactions with Vehicle Configuration and Lighting Condition, and choosing those variables with the highest overall degree of interaction.

5. Fit a hierarchical, log-linear model to the contingency table composed of Vehicle Configuration, Lighting Condition and those variables selected in Step 4. The purpose of modeling is to smooth the data and to remove random variability due to small cell frequencies that occur when a large number of control variables are used. Modeling also reveals the strength of various interactions among the variables.

6. Adjust the smoothed cell frequencies to allow for the direct comparison of side collision accidents. Adjustment is necessary to insure that the overall effectiveness estimates will not be affected by different distributions of Pre-Pre, Pre-Post and Post-Post accidents in daylight and reduced lighting conditions across different levels of the control variables identified in Step 4.

7. <u>Examine single vehicle accident frequencies</u>. The daylight-to-reduced light ratios of Pre- and Post-Standard vehicles involved in single vehicle accidents provide the basis for determining the extent to which Post-Standard vehicles are either over- or under-represented during periods of reduced lighting in the population at large, relative to Pre-Standard vehicles.

8. <u>Compute effectiveness values and confidence intervals</u>. Values for both the full and partial effectiveness of side marker lamps are computed for each state-year of data, and an estimate made of their variances. Appropriate confidence intervals are determined, and the hypothesis that the obtained effectiveness values are significantly greater than zero is tested.

9. <u>Extrapolate the results</u>. A weighted mean of Texas 1972, 1973 and 1974 effectiveness values is used to extrapolate findings to a nationwide basis.

3.2 Data Characteristics

The data characteristics for each state are presented separately in this subsection. The generic tables that document each data set are the following.

- Relationship of partial data set to full data base.
- Univariate frequency distribution of relevant variables.
- Reduced lighting angle collision involvement rates for each level of vehicle configuration and relevant variables.

In each case, the data characteristics are discussed for three data sets:

- Texas 1972-1974
- New York 1974
- North Carolina 1973-1975.

The size of the partial data sets used in the analysis of side marker lamps relative to the entire state mass accident data bases can be characterized by noting the fraction of accidents and vehicles contained in the full data set as given in Table 3-1. All results are based on analyses of the partial data sets derived from the above listed police-reported mass accident data bases.

TABLE 3-1

NUMBER OF ACCIDENTS AND VEHICLES IN DATA BASES USED FOR THE ANALYSIS OF FMVSS 108

State	Year	Variable	Full Data Base	Partial Data Base	Percentage
Texas	1972	Accidents Vehicles	432,997 744,697	34,637 69,274	8.0 9.3
	1973	Accidents Vehicles	464,225 800,543	35,019 70,038	7.5 8.8
	1974	Accidents Vehicles	434,193 747,832	31,049 62,098	7.2 8.3
	1972-1974 (pooled)	Accidents Vehicles	1,331,415 2,293,072	100,705 201,410	7.6 8.8
New York	1974	Accidents Vehicles	377,818 704,477	18,913 37,826	5.0 5.4
North Carolina	1973	Accidents Vehicles	129,150 232,825	6,312 12,624	4.9 5.4
	1974	Accidents Vehicles	121,568 218,506	6,584 13,168	5.4 6.0
	1975	Accidents Vehicles	129,013 232,180	7,053 14,106	5.5 6.1
	1973-1975 (pooled)	Accidents Vehicles	379,731 683,511	19,948 39,898	5.3 5.8

As illustrated in Table 3-1, only a small subset of each state's yearly accident data base was used for the analysis of the effectiveness of side marker lamps. The criteria for the inclusion of accidents in the subsample for use in the analysis is the following.

- Accident type = Collision between motor vehicles.
- Manner of collision = Angle collision.
- Number of vehicles in accident = 2.
- Type of both vehicles in accident = Passenger car.
- Location of accident = Intersection or driveway access.
- Defects for both vehicles = None.
- Model year for both vehicles = Non-missing.
- Location of vehicle damage = One vehicle damaged in front, the other in the side.

The basic characteristics of the samples derived from Texas, New York and North Carolina can be seen from the univariate frequencies given in Tables 3-2, 3-3 and 3-4 of certain "key" variables used in the analysis of the effectiveness of side marker lamps. A critical variable in the analysis is Vehicle Configuration, which is classified relative to the Standard implementation date as Pre with Pre, Pre with Post or Post with Post. Texas accident data for 1972 through 1973 has the greatest representation of angle collisions in which both cars are Pre-Standard (25%); both New York (13% in 1974) and North Carolina (17% for 1973,1974,1975) have smaller rperesentations of accidents in which both cars are Pre-Standard. The most frequent combination in all samples is Pre with Post, which includes roughly one-half of all accidents analyzed.

A second critical or "key" variable is Light Condition. The overall proportion of daylight accidents is 82 percent in Texas and 80 percent in North Carolina. In New York, 73 percent of all angle collisions occur in daylight. It is quite possible that there is a higher percentage of nighttime driving in New York. However, it should also be noted that Light Condition was a derived rather than an observed variable in New York. The proportion of accidents in Dawn/Dusk light conditions is 5.4 percent in New York compared with 2.4 percent in Texas and 4.2 percent in North Carolina. The proportion of accidents in dark conditions is 22 percent in New York compared with 16 percent in Texas and 15 percent in North Carolina.

TABLE 3-2

FREQUENCY DISTRIBUTIONS OF KEY VARIABLES FROM TEXAS 1972-1974 SAMPLES

Variable	Category	1972		1973		1974		Total: 1972-1974	
		Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known
Prepost	Pre with Pre	12,142	35.1	8,429	24.1	5,031	16.2	25,602	25.4
	Pre with Post	16,193	46.8	16,888	48.2	14,621	47.1	47,702	47.4
	Post with Post	6,302	18.2	9,702	27.7	11,397	36.7	27,401	27.2
Light Condition	Daylight	28,356	81.9	28,765	82.1	25,431	81.9	82,543	81.8
	Dawn	120	0.3	110	0.3	135	0.4	365	0.4
	Dusk	734	2.1	708	2.0	542	1.7	1,984	2.0
	Dark - Road Lit	1,724	5.0	1,868	5.3	1,792	5.8	5,384	5.4
	Dark - Road Unlit	3,703	10.7	3,568	10.2	3,149	10.1	10,420	10.4
Road Classification	U.S. State Highway	8,160	23.6	8,503	24.3	7,453	24.0	24,116	24.0
	County Road	526	1.5	481	1.4	428	1.4	1,435	1.4
	City Street	23,117	66.7	23,139	66.1	20,569	66.2	66,825	66.3
	Farm-to-Market	1,218	3.5	1,231	3.5	1,066	3.4	3,515	3.5
	Other	1,616	4.7	1,665	4.8	1,533	4.9	4,814	4.8
Road Surface Condition	Dry	28,129	81.2	27,562	78.7	24,803	79.9	80,494	80.0
	Wet	6,109	17.6	6,939	19.8	6,102	19.7	19,150	19.0
	Snow-Ice	394	1.2	511	1.4	134	0.4	1,039	1.0
	Other	5	0.0	7	0.0	10	0.0	22	0.0
Weather	Clear-Cloudy	29,768	85.9	29,410	84.0	26,235	84.5	85,413	84.3
	Rain	4,569	13.2	5,248	15.0	4,539	14.6	14,356	14.3
	Snow	110	0.3	188	0.5	48	0.2	346	0.3
	Fog	185	0.5	165	0.5	213	0.7	563	0.5
	Dust	5	0.0	8	0.0	14	0.0	27	0.0
Traffic Control	None	8,006	23.1	7,935	22.7	4,202	13.5	20,143	20.0
	Signal	8,258	23.8	8,701	24.8	8,537	27.5	25,496	25.3
	Stop Sign	15,162	43.8	15,256	43.6	13,005	41.9	43,423	43.1
	Flashing Light	657	1.9	635	1.8	612	2.0	1,904	1.9
	Yield Sign	1,793	5.2	1,723	4.9	1,486	4.8	5,002	5.0
	Center Stripe/ Divider	675	1.9	661	1.9	3,109	10.0	4,445	4.4
	Other	86	0.2	108	0.3	98	0.3	292	0.3
Location of Accident	Intersection	30,798	88.9	30,816	88.0	27,363	88.1	88,977	88.3
	Driveway Access	3,839	11.1	4,203	12.0	3,686	11.9	11,728	11.7
Severity of Accident	Property Damage Only	26,450	76.4	26,994	77.1	23,843	76.8	77,287	76.8
	Type C Injury	3,040	8.8	2,920	8.3	2,820	9.1	8,780	8.7
	Type B Injury	3,758	10.8	3,855	11.0	3,507	11.3	11,120	11.0
	Type A Injury	1,269	3.7	1,116	3.2	820	2.6	3,205	3.2
	Fatality	120	0.3	134	0.4	59	0.2	313	0.3
City Size	Less than 5,000	3,276	9.5	3,116	8.9	2,633	8.5	9,025	9.0
	5,000 - 9,999	1,503	4.3	1,543	4.4	1,331	4.3	4,377	4.4
	10,000 - 24,999	3,464	10.0	3,524	10.1	3,018	9.7	10,006	9.9
	25,000 - 49,999	2,197	6.3	2,371	6.8	2,197	7.1	6,765	6.7
	50,000 - 99,999	5,104	14.7	5,420	15.5	4,706	15.2	15,230	15.1
	100,000 - 249,999	2,709	7.8	2,864	8.2	2,759	8.9	8,332	8.3
	250,000 or More	16,384	47.3	16,181	46.2	14,405	46.4	46,970	46.6
Worst TAD in Accident	0-1	5,743	16.6	6,299	18.0	5,822	18.8	17,864	17.7
	2	11,009	31.8	11,686	33.4	10,512	33.9	33,207	33.0
	3	11,187	32.3	11,206	32.0	9,813	31.6	32,206	32.0
	4	3,943	11.4	3,564	10.2	3,185	10.3	10,692	10.6
	5	1,573	4.5	1,319	3.8	1,069	3.4	3,961	3.9
	6-7	1,182	3.4	945	2.7	648	2.1	2,775	2.8

TABLE 3-2 (continued)

Variable	Category	1972		1973		1974		Total: 1972-1974	
		Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known
Age of Driver of Striking Vehicle	15-24	12,687	37.4	12,789	37.3	11,724	38.6	37,200	37.6
	25-34	7,466	22.0	7,871	22.9	6,930	22.8	22,267	22.6
	35-54	8,340	24.6	8,280	24.1	7,027	23.1	23,647	24.0
	55 or Older	5,457	16.1	5,359	15.6	4,731	15.6	15,547	15.8
	Missing	687	--	720	--	637	--	2,044	--
Age of Driver of Struck Vehicle	15-24	11,684	34.4	12,148	35.3	10,929	35.8	34,761	35.0
	25-34	7,336	21.6	7,434	21.6	6,954	22.8	21,724	22.0
	35-54	8,855	26.0	8,685	25.2	7,261	23.8	24,801	25.1
	55 or Older	6,136	18.0	6,136	17.8	5,401	17.7	17,673	17.9
	Missing	626	--	616	--	504	--	1,746	--
Sex of Driver of Striking Vehicle	Male	21,176	61.4	21,306	61.1	18,520	59.9	61,002	60.8
	Female	13,318	38.6	13,559	38.9	12,403	40.1	39,280	39.2
	Missing	143	--	154	--	126	--	423	--
Sex of Driver of Struck Vehicle	Male	19,600	56.8	19,655	56.3	17,162	55.5	56,417	56.2
	Female	14,906	43.2	15,244	43.7	13,777	44.5	43,927	43.8
	Missing	131	--	120	--	110	--	361	--
Total Number of Cases		34,637	--	35,019	--	31,049	--	100,705	--

TABLE 3-3

FREQUENCY DISTRIBUTIONS OF KEY VARIABLES FROM NEW YORK 1974 SAMPLE

Variable	Category	Absolute Frequency	% of Known
Prepost	Pre with Pre	2,478	13.1
	Pre with Post	8,770	46.4
	Post with Post	7,665	40.5
Light Condition	Daylight	13,715	72.5
	Dawn/Dusk	1,011	5.4
	Dark	4,187	22.1
Road Classification	U.S.-State Highway	5,245	29.2
	County Road	2,169	12.1
	Town Road	2,359	13.1
	City Street	7,937	44.2
	Limited Access	255	1.4
	Missing	948	--
Road Surface Condition	Dry	12,463	66.2
	Wet	5,019	26.6
	Snow/Ice/Slush	1,307	6.9
	Other	49	0.3
	Missing	75	--
Weather	Clear	10,913	57.9
	Cloudy	3,751	19.9
	Rain	3,227	17.1
	Snow/Sleet	878	4.7
	Other	76	0.4
	Missing	68	--
Traffic Control	None	5,241	28.2
	Signal	5,680	30.5
	Stop Sign	6,676	35.9
	Flashing Light	399	2.1
	Yield Sign	387	2.1
	Other	222	1.2
	Missing	308	--
Location of Accident	Intersection	16,257	86.0
	Non-Intersection	2,656	14.0
Severity of Accident	Property Damage Only	6,331	33.5
	Personal Injury	12,527	66.2
	Fatality	55	0.3
Maximum Vehicle Damage	None	9	0.0
	Light	3,583	19.2
	Moderate	11,760	63.1
	Severe	3,185	17.1
	Demolished	88	0.5
	Missing	288	--

TABLE 3-3 (Continued)

Variable	Category	Absolute Frequency	% of Known
Number of Towaways	None Only One Vehicle Both Vehicles	11,090 4,571 3,252	58.6 24.2 17.2
Age of Driver of Striking Vehicle	15-24 25-34 35-54 55 or Older Missing	6,163 4,329 5,295 2,964 162	32.9 23.1 28.2 15.8 --
Age of Driver of Struck Vehicle	15-24 25-34 35-54 55 or Older Missing	5,525 4,249 5,521 3,468 150	29.4 22.6 29.4 18.5 --
Sex of Driver of Striking Vehicle	Male Female	12,643 6,270	66.8 33.2
Sex of Driver of Struck Vehicle	Male Female	11,909 7,004	63.0 37.0
Total Number of Cases		18,913	--

TABLE 3-4

FREQUENCY DISTRIBUTIONS OF KEY VARIABLES FROM NORTH CAROLINA 1973-1975 SAMPLES

Variable	Category	1973		1974		1975		Total: 1973-1975	
		Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known
Prepost	Pre with Pre	1,464	23.2	1,054	16.0	851	12.1	3,369	16.9
	Pre with Post	3,098	49.1	3,150	47.8	3,168	44.9	9,416	47.2
	Post with Post	1,750	27.7	2,380	36.1	3,034	43.0	7,164	35.9
Light Condition	Daylight	5,044	79.9	5,240	79.6	5,705	80.9	15,989	80.1
	Dawn	49	0.8	54	0.8	59	0.8	162	0.8
	Dusk	224	3.5	222	3.4	230	3.3	676	3.4
	Dark-Road Lit	670	10.6	741	11.3	759	10.8	2,170	10.9
	Dark-Road Unlit	325	5.1	327	5.0	300	4.3	952	4.8
Road Classification	U.S. Highway	887	14.2	822	12.5	834	11.9	2,543	12.8
	State Highway	512	8.2	462	7.0	543	7.7	1,517	7.6
	Rural Roads	717	11.4	729	11.1	746	10.6	2,192	11.0
	City Street	4,148	66.2	4,557	69.4	4,895	69.8	13,600	68.5
	Missing	48	--	14	--	35	--	97	--
Road Surface Condition	Dry	5,100	80.8	5,213	79.2	5,536	78.6	15,849	79.5
	Wet	1,074	17.0	1,350	20.5	1,475	20.9	3,899	19.6
	Snow-Ice	123	2.0	12	0.2	25	0.4	160	0.8
	Other	12	0.2	4	0.1	8	0.1	24	0.1
	Missing	3	--	5	--	9	--	17	--
Weather	Clear	4,267	68.1	4,281	65.2	4,626	65.8	13,174	66.3
	Cloudy	1,126	18.0	1,272	19.4	1,227	17.4	3,625	18.2
	Rain	787	12.6	943	14.4	1,102	15.7	2,832	14.3
	Snow/Sleet/Hail	53	0.8	15	0.2	22	0.3	90	0.4
	Fog	35	0.5	53	0.8	53	0.8	141	0.7
	Missing	44	--	20	--	23	--	87	--
Traffic Control	None	1,306	21.0	1,526	23.5	1,549	22.3	4,381	22.3
	Signal	1,525	24.5	1,690	26.0	1,904	27.4	5,119	26.0
	Stop Sign	3,108	50.0	2,995	46.0	3,165	45.5	9,268	47.1
	Flashing Light	125	2.0	146	2.2	137	2.0	408	2.1
	Yield Sign	122	2.0	106	1.6	141	2.0	369	1.9
	Other	34	0.5	42	0.7	58	0.8	134	0.6
	Missing	92	--	79	--	99	--	270	--
Location of Accident	Intersection	5,362	84.9	5,458	82.9	5,893	83.6	16,713	83.8
	Driveway Access	950	15.1	1,126	17.1	1,169	16.4	3,236	16.2
Investigating Agency	Municipal Police	4,461	70.7	4,818	73.2	5,169	73.3	14,448	72.4
	Highway Patrol	1,851	29.3	1,766	26.8	1,884	26.7	5,501	27.6
City Size	Less than 5,000	2,271	36.0	2,200	33.4	2,318	32.9	6,789	34.0
	5,000 - 9,999	406	6.4	420	6.4	439	6.2	1,265	6.3
	10,000 - 24,999	750	11.9	819	12.4	971	13.8	2,540	12.7
	25,000 - 49,999	822	13.0	825	12.5	860	12.2	2,507	12.6
	50,000 - 74,999	316	5.0	404	6.1	438	6.2	1,158	5.8
	Over 75,000	1,747	27.7	1,916	29.1	2,027	28.7	5,690	28.5
Severity of Accident	Property Damage	3,987	63.2	4,225	64.2	4,435	62.9	12,647	63.4
	Type C Injury	991	15.7	1,061	16.1	1,223	17.3	3,275	16.4
	Type B Injury	946	15.0	1,002	15.2	1,048	14.9	2,996	15.0
	Type A Injury	361	5.7	273	4.1	317	4.5	951	4.8
	Fatality	27	0.4	23	0.3	30	0.4	80	0.4

TABLE 3-4 (continued)

Variable	Category	1973		1974		1975		Total: 1973-1975	
		Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known	Absolute Frequency	% of Known
Maximum Vehicle Damage	Less than $250	1,123	17.8	1,080	16.4	1,088	15.4	3,291	16.5
	$250 - $499	2,212	35.0	2,365	35.9	2,340	33.2	6,917	34.7
	$500 - $699	1,129	17.9	1,109	16.8	1,265	17.9	3,503	17.6
	$700 - $999	853	13.5	886	13.5	962	13.6	2,701	13.5
	$1000 or More	995	15.8	1,144	17.4	1,398	19.8	3,537	17.7
Maximum Vehicle Speed	20 MPH or Less	1,275	21.0	1,354	21.2	1,343	19.5	2,972	20.5
	21 - 29 MPH	855	14.1	968	15.1	1,041	15.2	2,864	14.8
	30 - 40 MPH	2,821	46.5	3,031	47.4	3,342	48.6	9,194	47.5
	41 - 49 MPH	447	7.4	456	7.1	532	7.7	1,435	7.4
	50 MPH or More	671	11.0	589	9.2	613	8.9	1,873	9.7
	Missing	243	--	186	--	182	--	611	--
Age of Driver of Striking Vehicle	15 - 20	1,377	22.0	1,468	22.5	1,483	21.1	4,328	21.8
	21 - 25	1,084	17.3	1,191	18.2	1,218	17.3	3,493	17.6
	26 - 35	1,319	21.1	1,307	20.0	1,490	21.2	4,116	20.8
	36 - 55	1,467	23.4	1,523	23.3	1,678	23.9	4,668	23.6
	56 or Older	1,011	16.2	1,042	16.0	1,153	16.4	3,206	16.2
	Missing	54	--	53	--	31	--	138	--
Age of Driver of Struck Vehicle	15 - 20	1,355	21.7	1,438	22.0	1,459	20.8	4,252	21.5
	21 - 25	980	15.7	1,083	16.6	1,104	17.7	3,167	16.0
	26 - 35	1,227	19.6	1,260	19.3	1,492	21.3	3,979	20.1
	36 - 55	1,621	25.9	1,600	24.5	1,741	24.8	4,962	25.1
	56 or Older	1,066	17.1	1,156	17.7	1,222	17.4	3,444	17.4
	Missing	63	--	47	--	35	--	145	--
Sex of Driver of Striking Vehicle	Male	3,877	61.7	3,901	59.4	4,115	58.4	11,893	59.8
	Female	2,410	38.3	2,661	40.6	2,932	41.6	8,003	40.2
	Missing	25	--	22	--	6	--	53	--
Sex of Driver of Struck Vehicle	Male	3,634	57.7	3,736	56.9	3,909	55.4	11,279	56.6
	Female	2,663	42.3	2,828	43.1	3,142	44.6	8,633	43.4
	Missing	15	--	20	--	2	--	37	--
Total Number of Cases		6,312	--	6,584	--	7,053	--	19,949	--

Because of the importance of the Light Condition variable, it should be noted briefly how it was derived in New York. Using information on the County in which the accident occurred, the approximate latitude (LA) and longitude (LO) of the accident location was determined. The four relevant equations used for the computation of sunrise time (SRT) and sunset time (SST) are:

$$SRT = 12 - Y - ET - TZN + LO/15$$

$$Y = \frac{12}{\pi} \times \cos^{-1} (-\tan LA \times \tan \delta)$$

$$\delta = 23° \times \sin \left[\left(\frac{n-80}{370} \right) 360 \right]$$

$$SST = 24 - SRT$$

where ET is a correction time for time zone TZN = 5, i.e., Eastern Standard Time, δ is the declination, and n is the Julian Day. The values used for ET for each month are given in Table 3-5. It should also be noted that Daylight Savings Time was in effect from January 6, 1974, until the last Sunday of October in 1974. Light Condition was classified from the computations in the following manner.

- Daylight: Sunrise to sunset.
- Dawn: Forty minutes before sunrise to sunrise.
- Dusk: Sunset to 40 minutes after sunset.
- Dark: Forty minutes after sunset to 40 minutes before sunrise.

TABLE 3-5

MONTHLY VALUES USED FOR TIME CORRECTION

Month	ET Value (Hours)	Month	ET Value (Hours)
January	-.19	July	-.10
February	-.23	August	-.05
March	-.12	September	.11
April	.02	October	.26
May	.06	November	.23
June	-.03	December	.03

While the above computations may introduce some error to the Light Condition variable in New York, note that there are also some dissimilarities in the observed light conditions under which accidents occur in North Carolina and Texas. Basically, dawn/dusk appears to be considered a more extended period in North Carolina than in Texas. Also, a "night" accident is more likely than not to occur under a street light in North Carolina. The situation is reversed in the Texas samples.

Some additional comments on the univariate frequencies are listed briefly below.

- The percentages of Pre-Pre, Pre-Post and Post-Post accidents are roughly similar among matching years of Texas, New York and North Carolina data.
- Both North Carolina and Texas seem to experience similar weather conditions in terms of the percentage of accidents occurring for a given weather condition. In New York, a higher percentage of accidents occur in rain, and a far higher percentage (about five percent) of accidents occur in snow or sleet.
- In all three states, there is a greater proportion of male drivers in striking cars as compared to the proportion of male drivers in struck cars. There is also a tendency in all three states for younger drivers to be found in slightly higher proportions in striking cars as compared to struck cars.
- Also in all three states, about one-third or more of the drivers in striking cars and a similar fraction of drivers in struck cars were between 15 and 24 years of age (inclusive).

3.3 Variable Selection

The variable selection procedure is designed to select from a large group of potential variables a limited number that will be used to fit models to, and adjust, the data. The procedure, which is fairly straightforward, is detailed below.

1. For each potential variable, a three-variable saturated log-linear model containing Vehicle Configuration, Light Condition and Variable is fit.
2. Three likelihood ratio (LR) chi-square (χ^2) statistics are computed for the differences between the saturated model and three separate sub-models, the first of which differs from the saturated model only by the exclusion of the Variable x Vehicle Configuration interaction term, the second differing only by the exclusion of the Variable x Light Condition interaction term, and the third differing only by the exclusion of the Variable x Vehicle Configuration x Light Condition interaction term.
3. The harmonic mean of the three LR χ^2 statistics is computed.*
4. The variables are ordered according to the magnitude of the harmonic mean, and the highest ranked variables are selected for modeling and adjustment.

In addition to Vehicle Configuration and Light Condition, no more than five variables can be accommodated by the computer program used to fit hierarchical log-linear models to the data (BMDP: Biomedical Computer Program-P3F). Furthermore, to avoid problems of acute data sparsity in the contingency table to be modeled, the determination of the number of variables to be selected must take into account both the size of the sample from which the table is constructed and the number of categories characterizing each variable selected.

With regard to the latter, it should be emphasized that the choice of cutting points used to categorize a variable was not completely arbitrary. Whenever appropriate (and possible), several different "versions" of a given variable--each with different cutting points, and in many cases, with a different number of categories--were input into the variable selection procedure. Only one "version" of a variable, that with the highest harmonic mean of LRχ^2's, was used in subsequent analyses.

Figure 3-3 illustrates a typical example of the effort involved in determining the "optimal" cutting points of the variable "Age of Driver of Struck Vehicle" in the New York 1974 sample (the tetrachotomy is chosen).

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*The harmonic mean of a set of n values, a_i, is found from evaluating $n/\sum_{i=1}^{n} 1/a_i$.

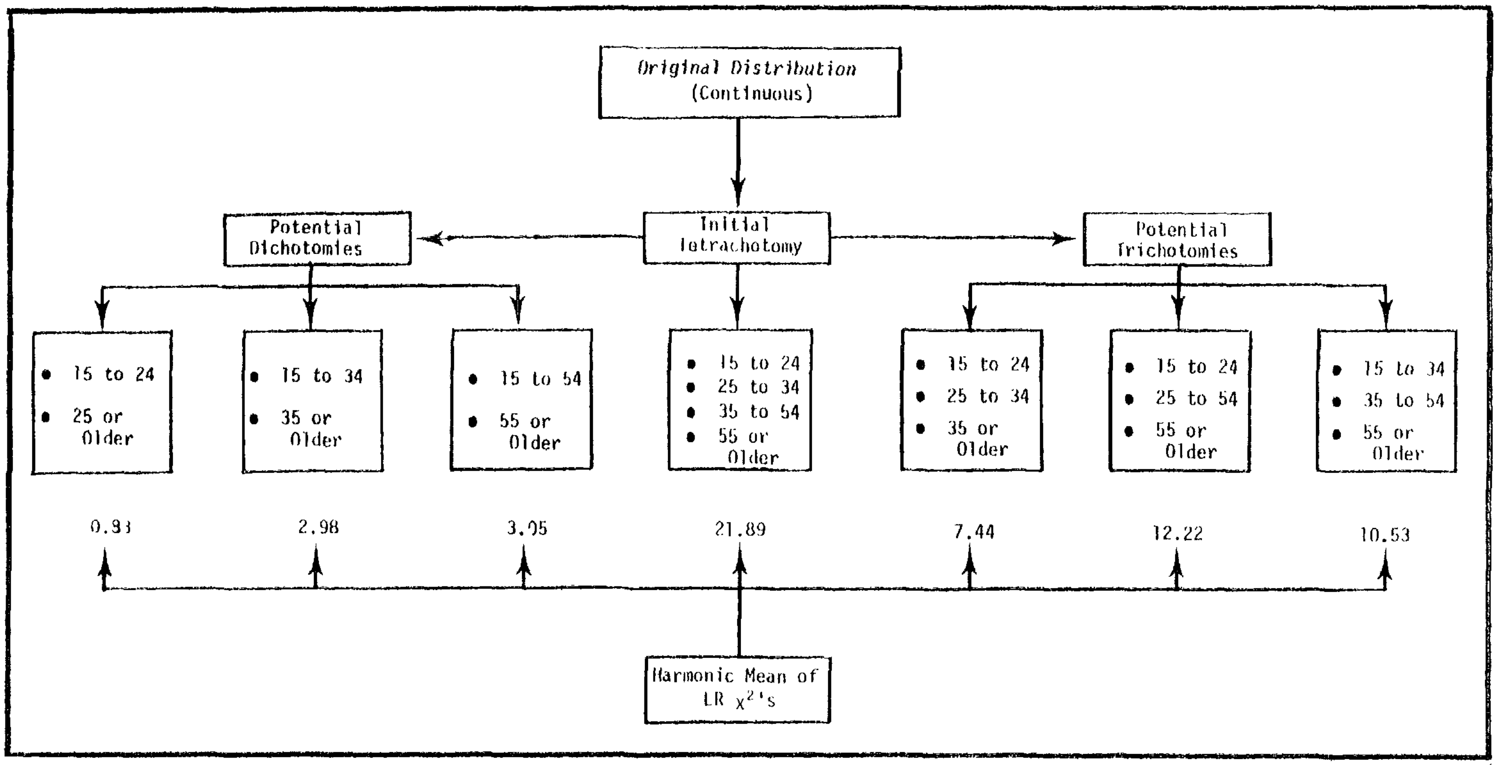

Figure 3-3. Example of determination of "optimal" cutting points of categorical variables.

Tables 3-2, 3-3 and 3-4 contain the variables which were candidates for selection in the Texas, New York and North Carolina samples. Reduced Lighting angle collision involvement rates, along with the number of angle collisions in each Vehicle Configuration category, are presented separately for each variable in Tables 3-6 through 3-12 for Texas 1972, 1973, 1974; New York 1974; and North Carolina 1973, 1974, 1975 samples, respectively.

As noted previously, the overall reduced lighting angle collision rates for Texas, New York and North Carolina are 18.2 percent, 27.5 percent and 19.9 percent, respectively. These figures can be kept in mind in the brief discussion below.

In the Texas sample, reduced lighting angle collision rates range from a high of 36.6 percent in 1974 collisions between Pre-Standard vehicles with at least one TAD between 5-7, to a low of 8.2 percent in collisions in the same year between Post-Standard vehicles when at least one driver was 55 years of age or older. Reduced lighting angle collision rates tend to be higher for accidents involving at least one young driver, at least one male driver, accidents involving injuries or fatalities and accidents with a high TAD for at least one of the vehicles. Reduced lighting angle collision rates tend to be lower for accidents occurring on

TABLE 3-6

PERCENT OF ANGLE COLLISIONS OCCURRING DURING PERIODS OF REDUCED LIGHTING FOR TEXAS 1972 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Road Classification (N = 34,637)	City Street U.S. State Highway Other	17.9 24.4 22.5	15.6 20.7 22.0	15.5 18.6 19.0	8,262 2,802 1,078	10,747 3,839 1,607	4,108 1,519 675
Age of Driver of Struck Vehicle (N = 34,011)	15-24 25-54 55 or Older	24.1 20.2 11.1	21.5 17.2 10.4	21.6 15.7 10.3	4,252 5,332 2,304	5,428 7,671 2,818	2,004 3,188 1,014
City Size (N = 34,637)	Less than 100,000 100,000 or More	17.7 21.8	15.7 18.8	15.9 17.2	5,740 6,402	7,213 8,980	2,591 3,711
Age of Driver of Striking Vehicle (N = 33,950)	15-24 25-54 55 or Older	22.9 20.8 10.6	20.3 18.1 9.1	20.3 16.4 9.6	4,622 5,182 2,057	5,972 1,335 2,529	2,093 530 871
Sex of Driver of Struck Vehicle (N = 34,506)	Male Female	23.7 14.1	21.7 11.6	21.0 11.5	7,090 4,996	9,124 7,011	3,386 2,899
Location of Accident (N = 34,637)	Intersection Driveway Access	19.5 23.0	17.3 19.0	16.7 16.2	10,911 1,231	14,368 1,825	5,519 783
Road Surface Condition (N = 34,637)	Dry Other	19.3 22.2	16.8 20.3	16.5 17.3	9,876 2,266	13,114 3,079	5,139 1,163
Sex of Driver of Striking Vehicle (N = 34,494)	Male Female	23.8 12.9	20.9 11.8	20.3 11.2	7,600 4,477	9,865 6,268	3,711 2,573
Worst TAD in Accident (N = 34,637)	0-2 3-4 5-7	17.0 21.0 30.3	14.6 19.0 26.2	14.8 16.9 26.5	5,872 5,310 960	7,828 7,061 1,304	3,052 2,759 491
Severity of Accident (N = 34,637)	Property Damage Only Injury or Fatality	18.2 24.8	15.8 22.7	15.4 21.3	9,096 3,046	12,403 3,790	4,951 1,351
Traffic Control Sign/Signal/Device Present? (N = 34,637)	Yes No	20.0 19.3	17.8 16.5	17.0 15.5	8,933 3,209	12,210 3,983	4,766 1,536
Weather (N = 34,637)	Clear-Cloudy Other	19.5 21.9	17.1 19.6	16.5 17.6	10,455 1,687	13,895 2,295	5,418 384

TABLE 3-7

PERCENT OF ANGLE COLLISIONS OCCURRING
DURING PERIODS OF REDUCED LIGHTING
FOR TEXAS 1973 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Sex of Driver of Striking Vehicle (N = 34,865)	Male Female	23.2 11.9	20.9 12.4	20.5 11.9	5,412 2,961	10,261 6,558	5,633 4,040
Road Classification (N = 35,019	City Street U.S. State Highway Other	17.4 24.4 20.4	16.1 20.5 21.2	15.5 19.6 20.0	5,707 2,002 720	11,146 4,127 1,615	6,286 2,374 1,042
Age of Driver of Striking Vehicle (N = 34,299)	15-24 25-54 55 or Older	21.9 20.3 10.6	20.6 17.9 9.7	20.5 16.6 9.3	3,275 3,544 1,392	6,171 7,755 2,629	3,343 4,852 1,338
Worst TAD in Accident (N = 35,019)	0-2 3-4 5-7	15.9 21.5 33.2	14.9 19.6 27.2	14.4 19.2 22.9	4,299 3,621 509	8,693 4,090 1,105	4,993 4,059 650
City Size (N = 35,019)	Less than 100,000 100,000 or More	16.7 21.8	16.0 19.1	15.4 18.1	4,104 4,325	7,772 9,116	4,098 5,604
Traffic Control Signal/Sign/Device Present? (N = 35,019)	Yes No	19.5 18.8	17.8 17.2	18.0 13.7	6,287 2,142	12,737 4,151	7,336 2,366
Age of Driver of Struck Vehicle (N = 34,403)	15-24 25-54 55 or Older	23.4 19.8 10.6	21.8 17.6 9.6	21.0 16.6 9.7	3,106 3,498 1,651	5,849 7,758 2,990	3,193 4,863 1,495
Sex of Driver of Struck Vehicle (N = 34,899)	Male Female	24.0 12.5	21.8 12.0	21.4 11.7	4,893 3,498	9,566 7,268	5,196 4,478
Severity of Accident (N = 35,019)	Property Damage Only Injury or Fatality	17.7 23.9	16.2 22.7	15.9 21.0	6,299 2,130	13,036 3,852	7,659 2,043
Road Surface Condition (N = 35,019)	Dry Other	18.7 21.7	17.3 18.9	16.3 19.3	6,607 1,822	13,304 3,584	7,651 2,051
Weather (N = 35,019	Clear-Cloudy Other	18.8 22.2	17.3 19.6	16.5 19.6	7,085 1,344	14,198 2,690	8,127 1,575
Location of Accident (N = 35,019)	Intersection Driveway Access	19.2 20.7	17.5 19.1	17.4 14.3	7,548 881	14,891 1,997	8,377 1,325

TABLE 3-8

PERCENT OF ANGLE COLLISIONS OCCURRING DURING PERIODS OF REDUCED LIGHTING FOR TEXAS 1974 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Age of Driver of Struck Vehicle (N = 30,545)	15-24 25-54 55 or Older	24.4 20.4 10.4	22.3 18.4 11.1	21.7 16.1 8.2	1,825 2,094 1,014	5,252 6,461 2,655	3,852 5,660 1,732
Worst TAD in Accident (N = 31,049)	0-2 3-4 5-7	16.5 21.5 36.6	15.6 20.9 27.1	14.4 18.4 30.1	2,510 2,237 284	7,723 6,060 838	6,101 4,701 595
Road Classification (N = 31,049)	City Street U.S. State Highway Other	17.6 24.8 25.4	16.7 22.4 20.8	15.6 19.0 19.2	3,489 1,152 390	9,683 3,547 1,391	7,397 2,754 1,246
City Size (N = 31,049)	Less than 100,000 100,000 or More	16.9 22.5	16.4 20.2	15.6 17.8	2,365 2,666	6,770 7,851	4,750 6,647
Age of Driver of Striking Vehicle (N = 30,412)	15-24 25-54 55 or Older	23.1 20.7 10.7	21.8 18.7 8.9	20.6 16.3 9.0	1,967 2,016 933	5,613 6,420 2,298	4,144 5,521 1,500
Traffic Control Signal/Sign/Device Present? (N = 31,049)	Yes No	20.7 17.3	19.1 16.2	17.1 16.0	3,783 1,248	11,201 3,420	8,713 2,684
Weather (N = 31,049)	Clear-Cloudy Other	18.9 25.5	17.6 23.4	16.2 20.1	4,273 758	12,386 2,235	9,576 1,821
Sex of Driver of Striking Vehicle (N = 30,923)	Male Female	23.9 12.6	22.1 12.4	20.7 11.7	3,147 1,862	8,873 5,682	6,500 4,859
Severity of Accident (N = 31,049)	Property Damage Only Injury or Fatality	17.9 25.3	17.0 23.0	15.5 22.0	3,709 1,322	11,174 3,447	8,960 2,437
Road Surface Condition (N = 31,049)	Dry Other	18.8 24.0	17.4 22.7	16.0 20.1	4,027 1,004	11,723 2,898	9,053 2,344
Sex of Driver of Struck Vehicle (N = 30,939)	Male Female	24.1 13.4	22.9 12.5	21.3 11.8	2,943 2,062	8,187 8,376	6,032 5,339
Location of Accident (N = 31,049)	Intersection Driveway Access	19.6 21.7	18.5 17.8	16.9 16.8	4,505 526	12,945 1,676	9,913 1,484

TABLE 3-9

PERCENT OF ANGLE COLLISIONS OCCURRING
DURING PERIODS OF REDUCED LIGHTING
FOR NEW YORK 1974 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Age of Driver of Struck Vehicle (N = 18,763)	15-24	35.3	33.4	29.7	811	2,635	2,079
	25-34	32.0	29.1	27.6	506	1,912	1,831
	35-54	31.2	29.0	23.5	673	2,571	2,277
	55 or Older	18.1	19.8	18.5	465	1,573	1,430
Road Classification (N = 17,710)	State Highway	33.2	29.9	27.2	632	2,320	2,293
	County Roads	30.4	26.9	21.4	299	973	897
	Town Roads	24.1	21.8	20.6	365	1,127	867
	City Streets	31.8	21.6	26.7	1,044	3,802	2,091
Number of Towaways (N = 18,913)	None	28.8	26.3	24.0	1,514	5,118	4,458
	One Vehicle Only	30.0	30.7	26.8	527	2,157	1,887
	Both Vehicles	35.9	34.0	27.2	437	1,495	1,320
Maximum Vehicle Damage (N = 18,625)	None-Light	27.2	25.4	24.2	419	1,622	1,551
	Moderate	29.8	28.4	25.0	1,583	5,476	4,701
	Severe-Demolished	34.3	32.6	26.9	440	1,544	1,289
Age of Driver of Striking Vehicle (N = 18,751)	15-24	33.9	31.8	29.0	912	2,997	2,254
	25-34	33.4	33.0	28.2	515	1,982	1,832
	35-54	28.5	27.4	24.5	666	2,394	2,235
	55 or Older	21.2	17.5	15.5	354	1,324	1,286
Road Surface Condition (N = 18,838)	Dry	28.6	26.6	24.3	1,596	5,764	5,103
	Other	33.1	32.8	27.1	875	2,971	2,529
Sex of Driver of Struck Vehicle (N = 18,913)	Male	34.7	32.4	29.5	1,637	5,600	4,672
	Female	21.8	22.1	18.5	841	3,170	2,993
Traffic Control Signal/Sign/Device Present (N = 18,605)	No	26.6	25.8	23.6	698	2,496	2,263
	Yes	31.6	30.0	25.9	1,751	6,128	5,269
Weather (N = 18,845)	Clear-Cloudy	29.2	27.4	24.5	1,884	6,788	5,992
	Other	33.8	33.2	28.0	589	1,948	1,644
Location of Accident (N = 18,913)	At Intersection	30.0	28.7	24.9	2,155	7,556	6,546
	Non-Intersection	32.5	28.8	27.3	323	1,214	1,119
Severity of Accident (N = 18,813)	Property Damage Only	24.5	23.7	21.3	695	2,796	2,840
	Injury or Fatality	32.6	31.0	27.5	1,783	5,974	4,825
Sex of Driver of Striking Vehicle (N = 18,913)	Male	33.8	32.1	28.9	1,758	5,979	4,906
	Female	21.7	21.3	18.6	720	2,791	2,759

TABLE 3-10

PERCENT OF ANGLE COLLISIONS OCCURRING DURING PERIODS OF REDUCED LIGHTING FOR NORTH CAROLINA 1973 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Age of Driver of Struck Vehicle (N = 6,249)	15-25	25.0	24.1	25.0	532	1,162	641
	26-55	20.4	19.4	16.0	629	1,368	851
	56 or Older	13.2	14.8	13.4	280	540	246
City Size (N = 6,312)	Less than 50,000	20.9	19.6	17.3	1,063	2,104	1,082
	50,000 or More	20.4	21.7	22.3	401	994	668
Maximum Vehicle Damage (N = 6,312)	Less than $350	18.1	19.6	18.3	652	1,103	529
	$350 - $899	22.3	20.4	19.0	668	1,400	785
	$900 or More	25.7	21.3	20.6	144	595	436
Road Surface Condition (N = 6,309)	Dry	19.4	18.5	18.6	1,163	2,501	1,436
	Other	26.2	27.7	22.0	301	595	313
Age of Driver of Striking Vehicle (N = 6,258)	15-25	24.0	24.0	22.2	550	1,237	674
	26-55	21.1	20.2	19.6	630	1,323	833
	56 or Older	13.7	11.6	9.33	270	516	225
Severity of Accident (N = 6,312)	Property Damage	18.2	19.2	17.8	889	1,966	1,132
	Injury or Fatality	24.7	22.1	21.8	575	1,132	618
Weather (N = 6,268)	Clear-Cloudy	19.4	19.2	19.0	1,251	2,628	1,514
	Other	28.1	25.5	21.3	203	447	225
Road Classification (N = 6,247)	U.S. State Highway	23.7	24.9	21.4	317	694	388
	City Street	20.0	18.7	19.2	957	2,041	1,150
	Rural Paved Road	19.9	20.2	14.6	171	331	198
Maximum Vehicle Speed (N = 6,111)	Less than 30 MPH	16.3	15.9	17.0	509	1,051	612
	30-49 MPH	21.6	22.1	19.8	749	1,617	902
	50 MPH or More	28.3	26.5	21.6	152	325	194
Sex of Driver of Striking Vehicle (N = 6, 287)	Male	23.3	23.0	22.6	927	1,921	1,029
	Female	16.1	15.8	14.1	528	1,167	715
Sex of Driver of Struck Vehicle (N = 6,297)	Male	24.2	23.4	22.6	900	1,757	977
	Female	15.1	16.1	14.9	562	1,334	767
Traffic Control Signal/Sign/Device Present? (N= 6,220)	No	19.3	21.7	22.8	296	650	360
	Yes	21.2	19.8	18.3	1,149	2,398	1,367
Location of Accident (N = 6,312)	Intersection	21.3	20.1	19.3	1,265	2,622	1,475
	Driveway Access	17.6	21.0	18.5	199	476	275
Investigating Agency (N = 6,312)	Municipal Police	20.1	19.4	18.9	1,035	2,191	1,235
	Highway Patrol	22.4	22.3	20.0	429	907	515

TABLE 3-11

PERCENT OF ANGLE COLLISIONS OCCURRING DURING PERIODS OF REDUCED LIGHTING FOR NORTH CAROLINA 1974 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Age of Driver of Struck Vehicle (N = 6,537)	15-25 26-55 56 or Older	26.6 23.6 14.3	25.3 18.6 11.4	21.8 20.7 12.4	414 416 217	1,221 1,341 569	886 1,103 370
Road Classification (N = 6,555)	U.S. State Highway City Street Rural Paved Road	26.1 20.1 33.9	23.3 19.2 20.4	24.1 18.9 16.1	211 712 127	617 2,159 363	456 1,686 224
Sex of Driver of Striking Vehicle (N = 6,562)	Male Female	24.8 19.3	23.9 14.1	22.7 15.8	673 379	1,877 1,262	1,351 1,020
Investigating Agency (N = 6,584)	Municipal Police Highway Patrol	20.1 30.1	18.9 23.1	19.3 21.0	755 299	2,283 867	1,780 600
Maximum Vehicle Damage (N = 6,584)	Less than $350 $350 - $899 $900 or More	20.6 23.3 31.7	19.2 18.0 26.4	18.0 18.3 24.2	461 489 104	1,092 1,441 617	768 988 624
Sex of Driver of Struck Vehicle (N = 6,564	Male Female	25.6 18.0	22.7 16.3	24.0 14.8	669 383	1,786 1,352	1,281 1,093
City Size (N = 6,584)	Less than 5,000 5,000 or More	27.2 20.6	21.0 19.6	20.1 19.6	379 675	1,091 2,059	730 1,650
Severity of Accident (N = 6,584)	Property Damage Injury or Fatality	20.1 28.3	17.2 25.0	18.1 22.8	683 371	1,995 1,155	1,547 833
Age of Driver of Striking Vehicle (N = 6,531)	15-25 26-55 56 or Older	27.3 22.4 14.6	24.3 19.9 11.0	23.3 19.2 9.5	429 420 199	1,253 1,321 547	977 1,089 296
Road Surface Condition (N = 6,579)	Dry Other	21.0 31.6	18.4 26.5	17.6 27.9	858 196	2,481 665	1,874 505
Traffic Control Signal/Sign/Device Present? (N = 6,505)	No Yes	22.0 23.3	18.3 20.5	16.7 20.7	246 791	705 2,418	575 1,770
Maximum Vehicle Speed (N = 6,415)	Less than 30 MPH 30-49 MPH 50 MPH or More	17.8 25.4 31.6	15.8 20.2 33.3	16.8 20.7 25.4	381 551 95	1,108 1,676 285	850 1,260 209
Weather (N = 6,564)	Clear-Cloudy Other	21.6 29.6	18.8 26.6	18.2 27.8	898 152	2,655 489	2,000 370
Location of Accident (N = 6,584)	Intersection Driveway Access	23.3 21.4	20.4 18.1	20.4 16.8	881 173	2,637 513	1,940 440

TABLE 3-12

PERCENT OF ANGLE COLLISIONS OCCURRING DURING PERIODS OF REDUCED LIGHTING FOR NORTH CAROLINA 1975 SAMPLE

Variable	Category	Angle Collision Rate for Reduced Lighting Conditions (Percent)			Number of Angle Collisions		
		Pre with Pre	Pre with Post	Post with Post	Pre with Pre	Pre with Post	Post with Post
Age of Driver of Striking Vehicle (N = 7,022)	15-25 26-55 56 or Older	24.5 21.2 9.3	24.0 18.3 8.8	25.1 17.0 11.0	323 354 172	1,241 1,369 536	1,137 1,445 445
Road Classification (N = 7,005)	U.S. State Highway City Street Rural Paved Road	24.3 18.0 23.0	20.9 18.5 18.0	21.3 19.0 15.1	181 567 100	623 2,165 355	573 2,163 278
Severity of Accident (N - 7,053)	Property Damage Injury or Fatality	18.2 22.9	16.8 22.4	19.1 19.0	528 323	1,967 1,201	1,940 1,094
Sex of Driver of Struck Vehicle (N = 7,051)	Male Female	23.0 15.2	22.0 14.7	23.9 13.9	521 330	1,818 1,349	1,570 1,463
Age of Driver of Struck Vehicle (N = 7,018)	15-25 26-55 56 or Older	24.6 20.4 11.5	22.6 18.8 12.4	23.2 18.7 10.5	301 358 183	1,139 1,432 582	1,123 1,443 457
Maximum Vehicle Speed (N = 6,887)	Less than 30 MPH 30-49 MPH 50 MPH or More	15.2 23.6 19.2	16.2 20.2 22.4	16.4 20.0 24.7	295 449 78	1,089 1,743 272	1,016 1,682 263
Maximum Vehicle Damage (N = 7,053)	Less than $350 $350 - $899 $900 or More	19.0 20.6 21.4	17.2 18.5 22.2	18.3 18.6 20.6	378 384 89	1,024 1,431 713	878 1,327 829
Road Surface Condition (N = 7,044)	Dry Other	19.5 21.5	17.5 24.1	17.1 26.1	673 177	2,499 665	2,364 666
City Size (N = 7,053)	Less than 75,000 75,000 or More	19.6 21.3	18.8 19.2	18.2 20.9	673 178	2,315 853	2,038 996
Weather (N = 7,030)	Clear-Cloudy Other	20.1 19.4	18.0 23.4	17.7 25.5	713 134	2,632 526	2,508 517
Investigating Agency (N = 7,053)	Municipal Police Highway Patrol	18.7 23.0	18.7 19.4	18.9 19.7	603 248	2,294 874	2,272 762
Sex of Driver of Striking Vehicle (N = 7,047)	Male Female	22.2 16.2	21.9 14.7	22.4 14.7	537 314	1,856 1,309	1,722 1,309
Traffic Control Signal/Sign/Device Present? (N = 6,954)	No Yes	24.4 18.2	19.1 19.1	19.6 18.8	193 648	681 2,439	675 2,318
Location of Accident (N = 7,053)	Intersection Driveway Access	18.5 27.5	18.9 19.0	19.0 19.4	713 138	2,652 516	2,528 506

city streets, involving at least one older driver, at least one female driver, and involving no personal injuries and minimal vehicle damage.

In the New York sample, reduced lighting angle collision rates range from a high of 35.9 percent in towaway accidents in which both cars are Pre-Standard to a low of 15.5 percent for collisions in which both cars are Post-Standard and the age of at least one driver is 55 years or older. Rates tend to be higher when young drivers and male drivers are involved, and when accidents occur on state highways, involve an injury or fatality, result in extensive vehicle damage, result in both vehicles being towed, and occur when the environmental condition is other than dry.

In the North Carolina sample, reduced lighting angle collision rates range from a high of 33.9 percent for collisions between Pre-Standard cars on rural paved roads in 1974, to a low of 8.8 percent for collisions between one Pre-Standard and one Post-Standard car in 1975 in which the age of at least one driver is 56 years or older. Higher reduced lighting angle collision rates are associated with young drivers, male drivers, high speed accidents, precipitating conditions and wet surfaces, high dollar amounts of vehicle damage and accidents involving injuries or fatalities.

The information used in the variable selection procedure to determine those variables selected for modeling and adjustment purposes in the Texas, New York and North Carolina samples is given in Tables 3-13 through 3-19. In each table, the variables analyzed are listed in descending order of the magnitude of the harmonic mean of the $LR\chi^2$'s of the partial association of the following three interaction terms: Variable x Vehicle Configuration, Variable x Light Condition, and Variable x Vehicle Configuration x Light Condition. For the convenience of the reader, the variables selected in each sample are listed below in the same order as they appear in the tables.

Texas 1972

- Road Classification
- Age of Driver of Struck Vehicle

Texas 1973

- Sex of Driver of Striking Vehicle
- Road Classification
- Age of Driver of Striking Vehicle
- Worst TAD in Accident

Texas 1974

- Age of Driver of Struck Vehicle
- Worst TAD in Accident
- Road Classification

North Carolina 1973

- Age of Driver of Struck Vehicle
- City Size
- Maximum Vehicle Damage

North Carolina 1974

- Age of Driver of Struck Vehicle
- Road Classification
- Sex of Driver of Striking Vehicle

North Carolina 1975

- Age of Driver of Striking Vehicle
- Road Classification
- Severity of Accident

New York 1974

- Age of Driver of Struck Vehicle
- Road Classification
- Number of Towaways

Thus, the most frequently used variables for modeling and adjustment are Road Classification, Age of Driver, Worst TAD in Accident (or Maximum Vehicle Damage), and Sex of Driver.

TABLE 3-13

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE TEXAS 1972 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR x^2	df	LR x^2	df	LR x^2	df	
Road Classification	27.24	4	137.23	2	6.23*	4	14.67
Age of Driver of Struck Vehicle	78.25	4	407.33	2	5.01*	4	13.96
City Size	68.96	2	56.33	1	3.93*	2	10.46
Age of Driver of Striking Vehicle	125.47	4	386.60	2	3.50*	4	10.13
Sex of Driver of Struck Vehicle	31.54	2	566.28	1	2.70*	2	7.43
Location of Accident	23.84	2	8.04	1	3.85*	2	7.04
Road Surface Condition	1.24*	2	28.07	1	3.12*	2	2.58
Sex of Driver of Striking Vehicle	20.48	2	544.51	1	0.90*	2	2.58
Worst TAD in Accident	0.80*	4	249.12	2	4.15*	4	2.01
Severity of Accident	27.27	2	177.76	1	0.55*	2	1.61
Traffic Control	15.65	2	5.51	1	0.58*	2	1.52
Weather	0.66*	2	13.79	1	0.60*	2	0.92

*$p > 0.05$

Note: The variables above the heavy line were selected for modeling.

TABLE 3-14

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE
TEXAS 1973 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR χ^2	df	LR χ^2	df	LR χ^2	df	
Sex of Driver of Striking Vehicle	70.66	2	498.16	1	5.38*	2	14.85
Road Classification	32.01	4	120.51	2	5.96*	4	14.47
Age of Driver of Striking Vehicle	111.03	4	353.25	2	3.49*	4	10.06
Worst TAD in Accident	5.83*	4	273.20	2	8.02*	4	10.00
City Size	81.18	2	70.89	1	3.47*	2	9.54
Traffic Control	3.16*	2	11.58	1	13.50	2	4.36
Age of Driver of Struck Vehicle	141.63	4	443.30	2	1.28*	4	3.80
Sex of Driver of Struck Vehicle	36.79	2	625.09	1	1.26*	2	3.65
Severity of Accident	41.77	2	148.05	1	0.99*	2	2.88
Road Surface Condition	0.57*	2	20.39	1	1.84*	2	1.28
Weather	0.57*	2	24.40	1	0.71*	2	0.94
Location of Accident	44.70	2	0.06*	1	11.92	2	0.18

*p >0.05

Note: The variables above the heavy line were selected for modeling.

TABLE 3-15

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE
TEXAS 1974 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR χ^2	df	LR χ^2	df	LR χ^2	df	
Age of Driver of Struck Vehicle	137.70	4	396.45	2	7.07*	4	19.84
Worst TAD in Accident	19.12	4	257.67	2	9.51	4	18.60
Road Classification	55.38	4	115.41	2	6.15*	4	15.85
City Size	71.83	2	64.42	1	5.73*	2	14.71
Age of Driver of Striking Vehicle	147.04	4	387.80	2	4.41*	4	12.70
Traffic Control	4.61*	2	21.80	1	2.84*	2	4.88
Weather	4.10*	2	70.69	1	1.78*	2	3.66
Sex of Driver of Striking Vehicle	51.18	2	492.91	1	1.14*	2	3.34
Severity of Accident	44.23	2	146.98	1	0.84*	2	2.46
Road Surface Condition	2.99*	2	75.63	1	0.41*	2	1.08
Sex of Driver of Struck Vehicle	45.24	2	539.57	1	0.18*	2	0.54
Location of Accident	26.34	2	0.01*	1	1.64*	3	0.03

*$p > 0.05$

Note: The variables above the heavy line were selected for modeling.

TABLE 3-16

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE
NEW YORK 1974 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR χ^2	df	LR χ^2	df	LR χ^2	df	
Age of Driver of Struck Vehicle	39.96	6	197.41	3	9.35*	6	21.89
Road Classification	55.43	6	74.54	3	5.55*	6	14.18
Number of Towaways	14.46	4	50.14	2	6.18*	4	11.96
Maximum Vehicle Damage	15.78	4	25.09	2	3.39*	4	7.53
Age of Driver of Striking Vehicle	64.22	6	240.62	3	2.37*	6	6.79
Road Surface Condition	3.45*	2	44.95	1	4.08*	2	5.38
Sex of Driver of Struck Vehicle	20.02	2	271.00	1	1.93*	3	5.25
Traffic Control	2.56*	2	23.87	1	1.60*	2	2.84
Weather	4.67*	2	35.23	1	1.18*	2	2.75
Location of Accident	4.62*	2	2.22*	1	1.51*	2	2.26
Severity of Accident	79.51	2	103.28	1	0.34*	2	1.01
Sex of Driver of Striking Vehicle	44.80	2	251.32	1	0.24*	2	0.72

*$p > 0.05$

Note: The variables above the heavy line were selected for modeling.

TABLE 3-17

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE NORTH CAROLINA 1973 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR χ^2	df	LR χ^2	df	LR χ^2	df	
Age of Driver of Struck Vehicle	21.17	4	57.99	2	4.23*	4	9.97
City Size	43.53	2	5.17	1	3.40*	2	5.88
Maximum Vehicle Damage	153.17	4	4.76	2	2.72*	4	5.14
Road Surface Condition	3.38*	2	29.49	1	2.88*	2	4.43
Age of Driver of Striking Vehicle	26.63	4	69.12	2	1.42*	4	3.98
Severity of Accident	5.73*	2	14.84	1	1.78*	2	3.68
Weather	2.29*	2	15..0	1	1.99*	2	2.98
Road Classification	1.29*	4	14.17	2	4.01*	4	2.18
Maximum Vehicle Speed Prior to Impact	0.99*	4	35.14	2	2.99*	4	2.18
Sex of Driver of Striking Vehicle	7.64	2	54.61	1	0.55*	2	1.52
Sex of Driver of Struck Vehicle	11.51	2	60.13	1	0.49*	2	1.40
Traffic Control	0.46*	2	1.93*	1	3.38*	2	1.00
Location of Accident	3.32*	2	0.17*	1	1.47*	2	0.44
Investigating Agency	0.02*	2	4.01	1	0.37*	2	0.06

* $p > 0.05$

<u>Note:</u> The variables above the heavy line were selected for modeling.

TABLE 3-18

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE
NORTH CAROLINA 1974 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR χ^2	df	LR χ^2	df	LR χ^2	df	
Age of Driver of Struck Vehicle	22.46	4	76.21	2	5.70	4	12.87
Road Classification	8.98*	4	14.51	2	10.95	4	11.05
Sex of Driver of Striking Vehicle	13.86	2	65.64	1	3.72*	2	8.42
Investigating Agency	4.95*	2	14.06	1	4.92*	2	6.30
Maximum Vehicle Damage	145.27	4	32.76	2	2.21*	4	6.12
Sex of Driver of Struck Vehicle	26.10	2	58.08	1	1.72*	2	4.71
City Size	13.05	2	3.49*	1	3.35*	2	4.53
Severity of Accident	2.01*	2	42.02	1	1.87*	2	2.84
Age of Driver of Striking Vehicle	38.76	4	89.12	2	0.95*	4	2.75
Road Surface Condition	4.54*	2	54.60	1	0.72*	2	1.85
Traffic Control	2.88*	2	5.38	1	0.91*	2	1.84
Maximum Vehicle Speed Prior to Impact	0.65*	4	56.16	2	5.41*	4	1.72
Weather	1.16*	2	35.72	1	0.43*	2	0.93
Location of Accident	4.91*	2	4.42	1	0.35*	2	0.91

p >0.05

Note: The variables above the heavy line were selected for modeling.

TABLE 3-19

INTERACTION TERMS EVALUATED IN VARIABLE SELECTION PROCEDURE
NORTH CAROLINA 1975 SAMPLE

Variable	Interaction Terms from the 3-Variable Saturated Model Containing Prepost, Light Condition and Variable						Harmonic Mean of Interaction Terms
	Variable x Prepost		Variable x Light Condition		Variable x Prepost x Light Condition		
	LR x^2	df	LR x^2	df	LR x^2	df	
Age of Driver of Striking Vehicle	23.96	4	128.03	2	4.28*	4	10.59
Road Classification	12.95	4	6.60	2	4.15*	4	6.39
Severity of Accident	2.57*	2	9.97	1	7.94	2	4.88
Sex of Driver of Struck Vehicle	33.18	2	83.31	1	1.61*	2	4.52
Age of Driver of Struck Vehicle	25.35	4	76.74	2	1.18*	4	3.33
Maximum Vehicle Speed Prior to Impact	1.51*	4	24.20	2	3.66*	4	3.07
Maximum Vehicle Damage	143.66	4	7.89	2	1.16*	4	3.01
Road Surface Condition	1.07*	2	36.84	1	3.45*	2	2.40
City Size	56.49	2	2.38*	1	1.03*	2	2.04
Weather	0.86*	2	19.95	1	3.93*	2	2.04
Investigating Agency	7.74	2	1.32*	1	1.09*	2	1.66
Sex of Driver of Striking Vehicle	10.83	2	59.57	1	0.38*	2	1.05
Traffic Control	0.71*	2	0.94*	1	2.70*	2	1.05
Location of Accident	0.21*	2	1.00*	2	4.55*	2	0.50

*$p > 0.05$

Note: The variables above the heavy line were selected for modeling.

3.4 Analysis of Mass Accident Data

Following completion of the variable selection procedure, the analytical steps that remain are modeling, adjustment of data, computation of effectiveness values, error estimation, and extrapolation of results to the nation. Each of these steps, along with the results, is described in the following subsections.

3.4.1 Modeling

The basic purpose of modeling as it is applied to the evaluation of side marker lamp effectiveness is twofold:

1. To "smooth" the data--i.e., remove random variation due to small cell counts.
2. To compensate for the uneven distribution of data across cells, especially the sparsity of data which characterizes the reduced light categories for certain subpopulations.

CEM used the log-linear modeling routine (BMDP3F) of the Biomedical Computer Program's P-Series to generate smoothed or "fitted" cell frequencies. The BMDP3F program, which is based on an iterative proportional fitting (IPF) algorithm, was chosen for the number of dimensions in contingency tables (up to seven) which it can handle, as well as for its model screening capability.

The fitting of log-linear models to the data involves several steps. First, fully cross-classified contingency tables--i.e., containing no missing data for any of the variables--were constructed, using Lighting Condition, Vehicle Configuration and all variables selected by the procedure discussed in Section 3.3. Appendix A contains complete listings of each of these contingency tables.

Next, a description of the relationships among variables (or "effects") was obtained, consisting of a test of the significance of the main effects and of the various interactions between these effects.* This provided a basis for ordering the interaction terms by their importance (significance). Using this information, a model was fit according to the following iterative procedure:

1. As many significant effects as required were first specified in an attempt to derive a model with an optimal fit. Optimal fit refers to the situation in which the magnitude of the model's LR chi-square is roughly similar to its number of degrees of freedom.
2. Effects were either deleted or added to the model in a stepwise fashion until the deletion of any one effect would result in a significant worsening of the fit, whereas the addition of any single effect would not significantly improve the model's fit.

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*The terminology used here (main effects, interaction terms, etc.) is analogous to that used in an Analysis of Variance model. A major difference involves the fact that in the log-linear modeling approach, it is the *logarithm* of the expected cell frequency which is an additive function of both main effects and interaction terms.

This approach represents a compromise of sorts between the two considerations of parsimony and goodness-of-fit. In all cases, residuals were examined to detect possible systematic patterns in the error terms, which might necessitate the respecification of the model.

Tables 3-20 to 3-22 summarize the models fit to data from Texas, New York and North Carolina samples. The likelihood ratio (LR) chi-square values were derived from tests of marginal association for each effect, in which the cell counts for the complete contingency table were summed over all unspecified margins, after which the effect (interaction term) was tested to be zero, using a LR chi-square statistic.

Since the log-linear models fitted are hierarchical models, the specification of a given effect forces all lower-order effects which are subsets of the effect into the model. For example, if a "Vehicle Configuration x Light Condition x Road Type" effect is specified, the following additional terms are hierarchically included:

- Vehicle Configuration x Light Condition
- Vehicle Configuration x Road Type
- Light Condition x Road Type
- Vehicle Configuration
- Light Condition
- Road Type

Therefore, Tables 3-20 to 3-22 contain the LR χ^2 values and significant levels of the directly specified effects only. A complete enumeration of both specified and hierarchically included model effects can be found in Appendix B. Chi-square values marked with an asterisk in Appendix B represent effects which were specified. All other chi-square values denote those effects which were included due to the hierarchical nature of the log-linear models.

3.4.2 Adjustment of Data

Prior to computing the actual effectiveness values, the smoothed (or "fitted") data were adjusted to allow for the direct comparison of angle collision frequencies. Such adjustment is necessary to insure that the overall effectiveness estimate will not be affected by a potentially different distribution of Pre-with-Pre, Pre-with-Post and Post-with-Post collisions across all levels of the pre-crash control variables identified by the variable selection procedure (described in Section 3.3).

TABLE 3-20

SUMMARY OF TESTS OF MARGINAL ASSOCIATION OF DIRECTLY SPECIFIED MODEL EFFECTS FOR TEXAS 1972-1974 SAMPLE

Effect *	Texas 1972			Texas 1973			Texas 1974		
	LR χ^2	df	Prob.	LR χ^2	df	Prob.	LR χ^2	df	Prob.
Veh Mix x Light Cond	36.28	2	0.000	17.15	2	0.000	22.12	2	0.000
Veh Mix x Road Type	24.54	4	0.000	30.61	4	0.000	49.90	4	0.000
Veh Mix x Dr Age	76.26	4	0.000	108.97	4	0.000	133.23	4	0.000
Light Cond x Road Type	134.56	2	0.000	123.57	2	0.000	114.06	2	0.000
Light Cond x Dr Age	405.35	2	0.000	349.91	2	0.000	391.95	2	0.000
Road Type x Dr Age	126.87	4	0.000	73.42	4	0.000	39.79	4	0.000
Road Type x Max TAD	-	-	-	338.29	4	0.000	247.97	4	0.000
Max TAD x Dr Age	-	-	-	56.42	4	0.000	18.47	4	0.001
Veh Mix x Dr Age x Dr Sex	-	-	-	19.28	4	0.001	-	-	-
Veh Mix x Light Cond x Max TAD	-	-	-	-	-	-	9.40	4	0.052
Light Cond x Max TAD x Dr Age	-	-	-	10.60	4	0.032	-	-	-
Light Cond x Max TAD x Dr Sex	-	-	-	8.38	2	0.015	-	-	-
Light Cond x Dr Age x Dr Sex	-	-	-	21.54	2	0.000	-	-	-
Light Cond x Road Type x Dr Age	-	-	-	-	-	-	9.18	4	0.057
Road Type x Dr Age x Dr Sex	-	-	-	13.35	4	0.010	-	-	-
Max TAD x Dr Age x Dr Sex	-	-	-	9.76	4	0.045	-	-	-
SUMMARY OF MODEL	36.28	28	0.138	260.81	256	0.405	125.97	112	0.173

*For the Texas 1972 and 1974 models, driver characteristics refer to drivers of the struck vehicles, whereas for the Texas 1973 model, they refer to drivers of the striking vehicle.

TABLE 3-21

SUMMARY OF TESTS OF MARGINAL ASSOCIATION OF DIRECTLY SPECIFIED MODEL EFFECTS FOR NEW YORK 1974 SAMPLE

Effect *	New York 1974		
	LR χ^2	df	Prob.
Vehicle Mix x Light Condition	37.04	2	0.000
Vehicle Mix x Dr Age x Towaways	21.65	12	0.042
Vehicle Mix x Road Type x Towaways	40.63	12	0.000
Light Condition x Dr Age x Road Type	13.99	9	0.123
Light Condition x Dr Age x Towaways	21.10	6	0.002
Light Condition x Road Type x Towaways	25.80	18	0.104
Dr Age x Road Type x Towaways	172.60	166	0.347
SUMMARY OF MODEL			

* Driver Age refers to drivers of struck vehicles.

TABLE 3-22

SUMMARY OF TESTS OF MARGINAL ASSOCIATION OF DIRECTLY SPECIFIED MODEL EFFECTS FOR NORTH CAROLINA 1973-1975 SAMPLE

Effect *	North Carolina 1973			North Carolina 1974			North Carolina 1975		
	LR χ^2	df	Prob.	LR χ^2	df	Prob.	LR χ^2	df	Prob.
Veh Mix x Light Cond	1.96	2	0.376	4.46	2	0.107	0.49	2	0.782
Veh Mix x Dr Age	20.72	4	0.000	21.77	4	0.000	22.83	4	0.000
Veh Mix x City Size	41.76	2	0.000	-	-	-	-	-	-
Veh Mix x Damage	147.83	4	0.000	-	-	-	-	-	-
Veh Mix x Road Type	-	-	-	9.72	4	0.045	13.39	4	0.010
Light Cond x City Size	4.36	1	0.037	-	-	-	-	-	-
Light Cond x Dr Age	57.53	2	0.000	70.30	2	0.000	126.72	2	0.000
Dr Age x City Size	16.14	2	0.000	-	-	-	-	-	-
Dr Age x Road Type	-	-	-	19.18	4	0.001	19.01	4	0.001
City Size x Damage	9.30	2	0.010	-	-	-	-	-	-
Light Cond x Dr Age x Damage	12.11	4	0.016	-	-	-	-	-	-
Light Cond x Road Type x Severity	-	-	-	-	-	-	6.81	2	0.033
Dr Age x Road Type x Dr Sex	-	-	-	10.29	4	0.036	-	-	-
Veh Mix x Light Cond x Severity	-	-	-	-	-	-	7.85	2	0.020
Veh Mix x Light Cond x Road Type x Dr Sex	-	-	-	20.74	4	0.000	-	-	-
SUMMARY OF MODEL	68.11	70	0.542	49.49	54	0.649	73.24	72	0.437

* For the North Carolina 1973 and 1975 models, driver characteristics refer to the drivers of the struck and striking vehicles, respectively. For the North Carolina 1974 model, Age refers to drivers of struck vehicles, while Sex refers to drivers of striking vehicles.

Each smoothed cell count (n_{ijk}) was adjusted to yield a corresponding smoothed, adjusted cell count (n'_{ijk}) as follows (notation is presented in Figure 3-4).

$$n'_{ijk} = n_{ijk} \left[\frac{n_{..k}}{n_{...}} \times \frac{n_{.j.}}{n_{.jk}} \right]$$

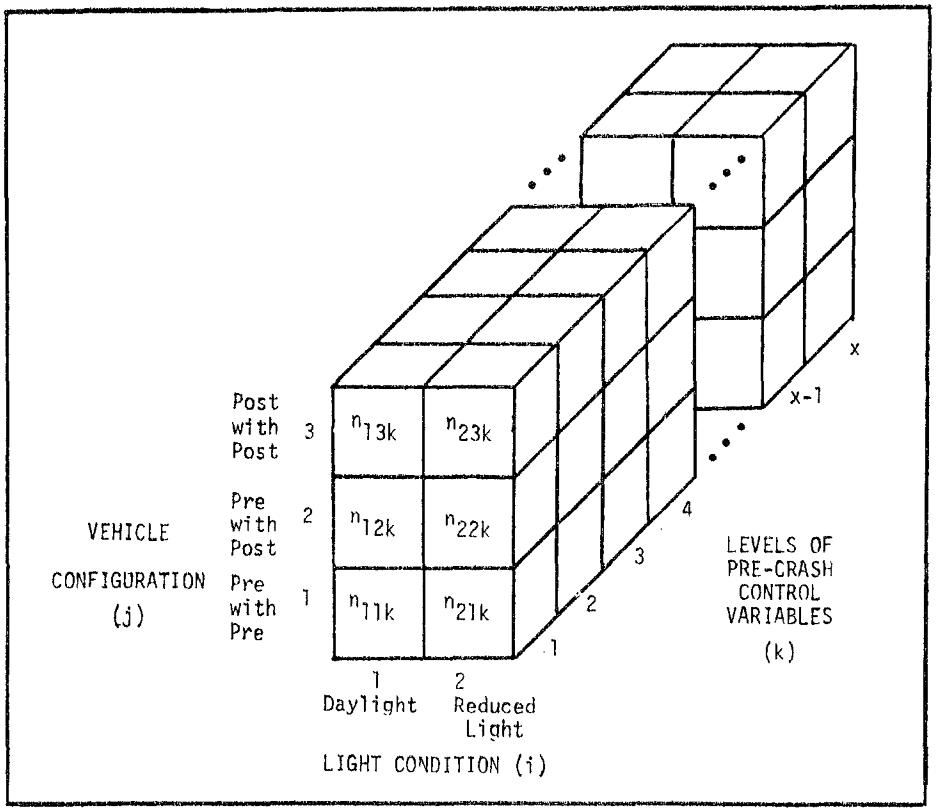

Figure 3-4. Summary of notation used to describe the data adjustment procedure.

By adjusting cell counts in this manner, the total sample size remains the same--i.e., $n'_{...} = n_{...}$. Additional relations between adjusted and unadjusted cell counts are as follows:

(1) $n'_{i..} = n_{i..}$

(2) $n'_{.j.} = n_{.j.}$

(3) $n'_{..k} = n_{..k}$

(4) $n'_{i.k} = n_{i.k}$

(5) $n'_{ij.} = n_{ij.}$

In other words, the total number of accidents in each light condition category does not change, nor does the total number of accidents in each vehicle configuration or within each level of every control variable change.

It should be noted, however, that within each combination of Vehicle Configuration (j) and Level of Control Variables (k), the adjusted count will not equal the unadjusted count:

$$n'_{.jk} = n_{.jk}\left[\frac{(n_{.j.})(n_{..k})}{n_{...}}\right]$$

However, even under these conditions, the cross-product ratios that serve as a basis for computing both *full* and *partial* effectiveness values remain unchanged:

$$\frac{n'_{11k}\,n'_{23k}}{n'_{21k}\,n'_{13k}} = \frac{n_{11k}\,n_{23k}}{n_{21k}\,n_{13k}} \quad (\textit{full}\ \text{effectiveness})$$

$$\frac{n'_{11k}\,n'_{22k}}{n'_{21k}\,n'_{12k}} = \frac{n_{11k}\,n_{22k}}{n_{21k}\,n_{12k}} \quad (\textit{partial}\ \text{effectiveness})$$

After all cell counts were adjusted, the data were aggregated over all levels of all control variables, resulting in a simple Light Condition x Vehicle Configuration table for each sample. These tables served as the basis for all subsequent effectiveness computations and error estimations.

By way of summary, Table 3-23 contains the pre-crash variables which, in conjunction with Light Condition and Vehicle Configuration, were used in adjusting the smoothed cell counts.

TABLE 3-23

PRE-CRASH CONTROL VARIABLES USED
IN DATA ADJUSTMENT PROCEDURE

State	Year	Variables	Categories
Texas	1972	Road Type	City Street U.S./State Highway Other
		Age of Driver of Struck Vehicle	15 to 24 25 to 54 55 or Older
	1973	Road Type	City Street U.S./State Highway Other
		Age of Driver of Striking Vehicle	15 to 24 25 to 54 55 or Older
		Sex of Driver of Striking Vehicle	Male Female
	1974	Road Type	City Street U.S./State Highway Other
		Age of Driver of Struck Vehicle	15 to 24 25 to 54 55 or Older
New York	1974	Age of Driver of Struck Vehicle	15 to 24 25 to 34 35 to 54 55 or Older
		Road Type	State Highway County Road Town Road City Street
North Carolina	1973	Age of Driver of Struck Vehicle	15 to 25 26 to 55 56 or Older
		City Size	LT 50,000 50,000 or More
	1974	Age of Driver of Struck Vehicle	15 to 25 26 to 55 56 or Older
		Road Type	U.S./State Highway City Street Rural Road
		Sex of Driver of Striking Vehicle	Male Female
	1975	Road Type	U.S./State Highway City Street Rural Road

3.4.3 Effectiveness and Error Estimation

Estimation of Effectiveness Values

As noted previously, the overall effectiveness of side marker lamps (E) in preventing angle collisions during periods of reduced lighting, after controlling for differential exposure risk, can be expressed as:

$$E_{(Full)} = \left(1 - \left[\left(\frac{n_{11.}\ n_{23.}}{n_{13.}\ n_{21.}} \right) \bigg/ \left(\frac{m_{11}\ m_{22}}{m_{21}\ m_{12}} \right)^{2} \right] \right) \times 100 \quad \text{, and}$$

$$E_{(Partial)} = \left(1 - \left[\left(\frac{n_{11.}\ n_{22.}}{n_{12.}\ n_{21.}} \right) \bigg/ \left(\frac{m_{11}\ m_{22}}{m_{21}\ m_{12}} \right) \right] \right) \times 100 \quad ,$$

using the notation depicted in Figure 3-5. The n_{ijk}'s represent smoothed adjusted counts, while the m_{ij}'s consist of observed, unadjusted frequencies.

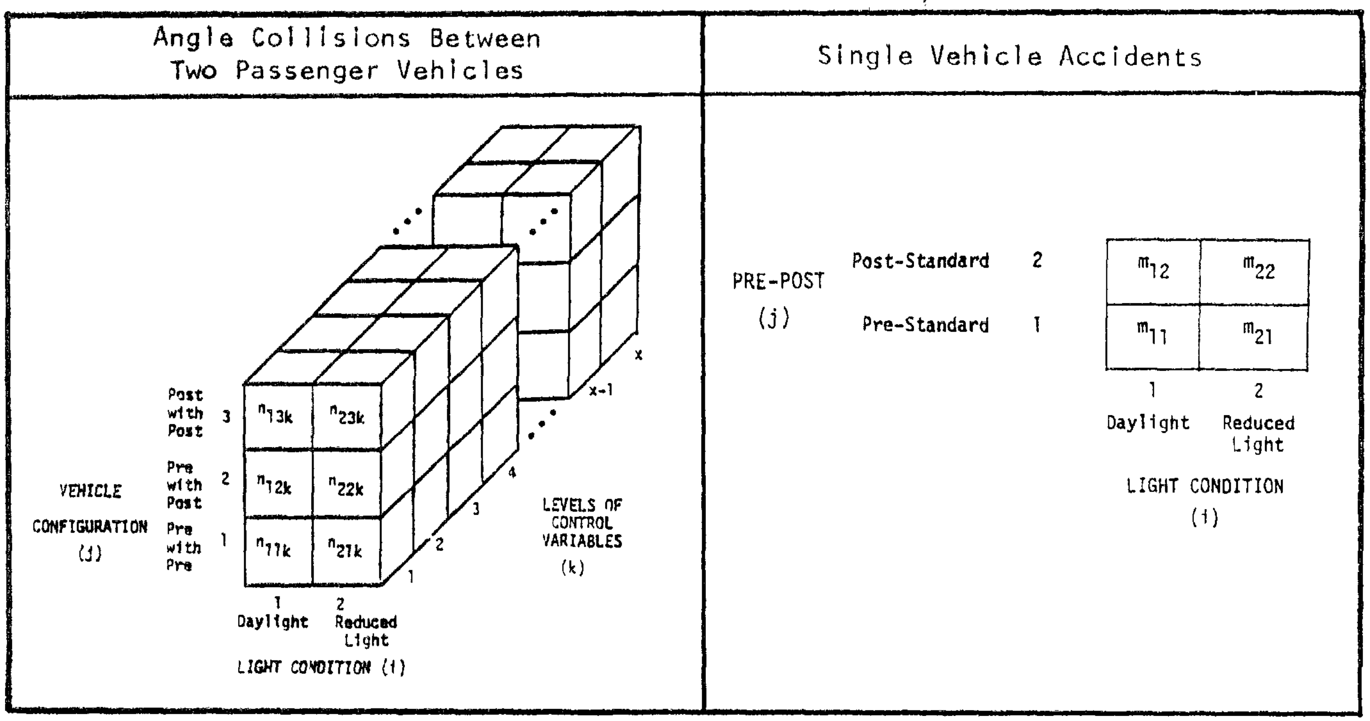

Figure 3-5. Summary of notation used to describe the effectiveness and error estimation procedures.

Data

For purposes of reference, Tables 3-24 to 3-30 contain the daylight and reduced light frequencies of angle collisions between two Pre-Standard vehicles, between two Post-Standard vehicles, and between one Pre- and one Post-Standard vehicle (smoothed, adjusted), as well as the daylight and reduced light distributions of single vehicle accidents (neither smoothed nor adjusted) for each sample. Tables 3-24 to 3-26 summarize this information for Texas 1972, 1973 and 1974 samples, respectively. Table 3-27 pertains to the New York 1974 sample. Finally, Tables 3-28 to 3-30 correspond to North Carolina 1973, 1974 and 1975 samples, respectively.

TABLE 3-24

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR TEXAS 1972 SAMPLE (Total Cases = 34,011)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	9513	28.0	13141	38.6	5174	15.2	27828	81.8
REDUCED LIGHT	2375	7.0	2776	8.2	1032	3.0	6183	18.2
COLUMN TOTALS	11888	35.0	15917	46.8	6206	18.2	34011	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	26287	29.6	15985	18.0	42272	47.6
REDUCED LIGHT	29023	32.7	17488	19.7	46511	52.4
COLUMN TOTALS	55310	62.3	33473	37.7	88783	100.0

TABLE 3-25

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR TEXAS 1973 SAMPLE (Total Cases = 34,255)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	6637	19.4	13619	39.8	7900	23.1	28156	82.2
REDUCED LIGHT	1562	4.6	2915	8.5	1622	4.7	6099	17.8
COLUMN TOTALS	8199	23.9	16534	48.3	9522	27.8	34255	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	22912	25.1	20303	22.2	43215	47.3
REDUCED LIGHT	25619	28.1	22450	24.6	48069	52.7
COLUMN TOTALS	48531	53.2	42753	46.8	91284	100.0

TABLE 3-26

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR TEXAS 1974 SAMPLE (Total Cases = 30,545)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	3937	12.9	11711	38.3	9362	30.6	25010	81.9
REDUCED LIGHT	996	3.3	2657	8.7	1882	6.2	5535	18.1
COLUMN TOTALS	4933	16.1	14368	47.0	11244	36.8	30545	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	17515	20.9	20980	25.1	38495	46.0
REDUCED LIGHT	20438	24.4	24740	29.6	45178	54.0
COLUMN TOTALS	37953	45.4	45720	54.6	83673	100.0

TABLE 3-27

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR NEW YORK 1974 SAMPLE (Total Cases = 17,566)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	1603	9.1	5769	32.8	5287	30.1	12659	72.1
REDUCED LIGHT	715	4.1	2378	13.5	1814	10.3	4907	27.9
COLUMN TOTALS	2318	13.2	8147	46.4	7101	40.4	17566	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	9778	19.9	16532	33.7	26310	53.6
REDUCED LIGHT	8805	17.9	13961	28.4	22766	46.4
COLUMN TOTALS	18583	37.9	30493	62.1	49076	100.0

TABLE 3-28

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR NORTH CAROLINA 1973 SAMPLE (Total Cases = 6,249)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	1139	18.2	2444	39.1	1413	22.6	4996	79.9
REDUCED LIGHT	302	4.8	626	10.0	325	5.2	1253	20.1
COLUMN TOTALS	1441	23.1	3070	49.1	1738	27.8	6249	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	4301	21.5	4447	22.2	8748	43.7
REDUCED LIGHT	5429	27.1	5863	29.3	11292	56.3
COLUMN TOTALS	9730	48.6	10310	51.4	20040	100.0

TABLE 3-29

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR NORTH CAROLINA 1974 SAMPLE (Total Cases = 6,487)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	808	12.5	2491	38.4	1875	28.9	5174	79.8
REDUCED LIGHT	233	3.6	619	9.5	461	7.1	1313	20.2
COLUMN TOTALS	1041	16.0	3110	47.9	2336	36.0	6487	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	3460	18.0	4517	23.5	7977	41.5
REDUCED LIGHT	4479	23.3	6769	35.2	11248	58.5
COLUMN TOTALS	7939	41.3	11286	58.7	19225	100.0

TABLE 3-30

DISTRIBUTION OF SMOOTHED, ADJUSTED ANGLE COLLISION FREQUENCIES AND OBSERVED, UNADJUSTED SINGLE VEHICLE ACCIDENT FREQUENCIES FOR NORTH CAROLINA 1975 SAMPLE (Total Cases = 6,974)

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	674	9.7	2531	36.3	2434	34.9	5639	80.9
REDUCED LIGHT	172	2.5	590	8.5	573	8.2	1335	19.1
COLUMN TOTALS	846	12.1	3121	44.8	3007	43.1	6974	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	2926	15.1	5166	26.6	8092	41.7
REDUCED LIGHT	3974	20.5	7329	37.8	11303	58.3
COLUMN TOTALS	6900	35.6	12495	64.4	19395	100.0

Effectiveness Values Prior to Controlling for Exposure Risk

In terms of the amount of accident avoidance realized when both vehicles in a potential reduced light angle collision are equipped with side marker lamps (*full* effectiveness), Table 3-31 indicates that, before controlling for differential exposure risk, estimates of the percent reduction in the number of reduced light angle collisions due to FMVSS 108 on the average range from 12 percent in the 1973-1975 North Carolina samples to 23 percent in the New York 1974 sample, with the overall Texas 1972-1974 effectiveness value falling roughly midway between these extremes (18 percent). Table 3-32, on the other hand, contains estimates of the percent reduction in the number of reduced light angle collisions realized when only one of the vehicles involved in a potential reduced light angle collision situation is equipped with side marker lamps (*partial* effectiveness)—again prior to controlling for differential exposure risks of Pre- and Post-Standard vehicles during periods of reduced lighting. On the average, the overall values of *partial* effectiveness range from 8 and 9 percent in New York and North Carolina, respectively, to 12 percent in Texas. These *partial* effectiveness values are in all cases less than the corresponding *full* effectiveness values, which conforms to intuitive expectations that the effectiveness of FMVSS 108 in preventing reduced light angle collisions is lessened when only one accident-involved vehicle is equipped with side marker lamps.

TABLE 3-31

SUMMARY OF OVERALL FULL EFFECTIVENESS VALUES PRIOR TO CONTROLLING FOR RELATIVE EXPOSURE RISK

State	Year	Observed, Unadjusted Data					Smoothed, Adjusted Data				
		Effectiveness	Standard Deviation	95% Confidence Interval		Is Effectiveness Significantly Different from Zero?	Effectiveness	Standard Deviation	95% Confidence Interval		Is Effectiveness Significantly Different from Zero?
				From	To				From	To	
Texas	1972	18.86	3.33	13.38	24.34	Yes	20.11	3.28	14.71	25.51	Yes
	1973	14.56	3.34	9.06	20.06	Yes	12.76	3.42	7.14	18.38	Yes
	1974	17.77	3.59	11.86	23.68	Yes	20.54	3.46	14.84	26.23	Yes
	1972-1974*	17.03	1.97	13.79	20.27	Yes	17.85	1.95	14.64	21.06	Yes
New York	1974	22.78	4.06	16.09	29.47	Yes	23.08	4.05	16.42	29.73	Yes
North Carolina	1973	10.44	8.01	-2.73	23.61	No	13.25	7.75	0.50	26.01	Yes
	1974	16.59	7.56	4.15	29.02	Yes	14.74	7.75	1.99	27.48	Yes
	1975	5.08	9.29	-10.20	20.37	No	7.75	8.99	-7.03	22.54	No
	1973-1975*	11.46	4.73	3.68	19.24	Yew	12.30	4.68	4.60	20.00	Yes

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

TABLE 3-32

SUMMARY OF OVERALL PARTIAL EFFECTIVENESS VALUES PRIOR TO CONTROLLING FOR RELATIVE EXPOSURE RISK

State	Year	Observed, Unadjusted Data					Smoothed, Adjusted Data				
		Effectiveness	Standard Deviation	95% Confidence Interval		Is Effectiveness Significantly Different from Zero?	Effectiveness	Standard Deviation	95% Confidence Interval		Is Effectiveness Significantly Different from Zero?
				From	To				From	To	
Texas	1972	14.57	2.65	10.21	18.94	Yes	15.39	2.63	11.07	19.70	Yes
	1973	10.49	3.10	5.38	15.59	Yes	9.05	3.16	3.85	14.25	Yes
	1974	8.42	3.82	2.14	14.70	Yes	10.32	3.72	4.20	16.44	Yes
	1972-1974*	11.88	1.78	8.95	14.81	Yes	12.33	1.78	9.30	15.16	Yes
New York	1974	6.69	4.78	-1.17	14.55	No	7.59	4.73	-0.19	15.37	No
North Carolina	1973	1.76	7.77	-11.02	14.53	No	3.40	7.61	-9.13	15.92	No
	1974	15.38	7.34	3.30	27.45	Yes	13.83	7.50	1.49	26.16	Yes
	1975	6.62	9.11	-8.37	21.61	No	8.65	8.87	-5.94	23.24	No
	1973-1975*	8.36	4.60	0.79	15.93	Yes	8.68	4.58	1.15	16.21	Yes

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

To obtain the effectiveness estimates in Table 3-31 and 3-32 <u>without</u> controlling for differential exposure risk, simplified versions of the previously defined effectiveness measures were applied, as follows.

$$\hat{E}_{(Full)} = \left[1 - \left(\frac{n_{11.} \; n_{23.}}{n_{13.} \; n_{21.}} \right) \right] \times 100 \quad \text{, and}$$

$$\hat{E}_{(Partial)} = \left[1 - \left(\frac{n_{11.} \; n_{22.}}{n_{12.} \; n_{21.}} \right) \right] \times 100 \quad ,$$

using the notation depicted in Figure 3-5.

Given the stochastic nature of the phenomenon under study, the effectiveness values computed prior to controlling for differential exposure risk ($\hat{E}$) can be written to explicitly include an error term (χ) as

$$\hat{E}'_{(Full)} = 100 \times \left[1 - \left(\frac{N_{23.}N_{11.}}{N_{21.}N_{13.}} \quad \frac{(1+\chi_{23.})\ (1+\chi_{11.})}{(1+\chi_{21.})\ (1+\chi_{13.})} \right) \right] \quad \text{and}$$

$$\hat{E}'_{(Partial)} = 100 \times \left[1 - \left(\frac{N_{22.}N_{11.}}{N_{21.}N_{12.}} \quad \frac{(1+\chi_{22.})\ (1+\chi_{11.})}{(1+\chi_{21.})\ (1+\chi_{12.})} \right) \right]$$

where the $N_{ij.}$ are the expected values of the $n_{ij.}$.

It is assumed that the observed frequencies $n_{ij.}$ are independent and Poisson-distributed with expected values of $N_{ij.}$, and further assumed that the Poisson distribution can be approximated by a normal distribution. In other words, $n_{ij.}$ is assumed to be approximately normally-distributed with mean $N_{ij.}$ and $\sigma_{ij.} = \sqrt{N_{ij.}}$. Therefore, $\chi_{ij.} = \frac{n_{ij.} - N_{ij.}}{N_{ij.}}$ is normally distributed with mean 0 and $\sigma_{(\chi_{ij.})} = \frac{1}{\sqrt{N_{ij}}}$.

Using $\hat{E}'_{(Full)}$ as an example, the term

$$r = \frac{(1+\chi_{23.})\ (1+\chi_{11.})}{(1+\chi_{21.})\ (1+\chi_{13.})}$$

can be approximated by expanding the fraction in power series $\chi_{21.}$ and $\chi_{13.}$. These series expressions hold only if $|\chi_{ij.}| < 1$, a restriction which is violated only by a minimal fraction of all cases.

An expansion of r up to secord order terms is

$$r = 1 + \chi_{23.} + \chi_{11.} - \chi_{21.} - \chi_{13.} + \chi_{23.}\ \chi_{11.} - \chi_{23.}\ \chi_{21.} - \chi_{23.}\ \chi_{13.}$$
$$- \chi_{11.}\chi_{21.} - \chi_{11.}\chi_{13.} + \chi_{21.}\chi_{13.} + \chi_{21.}^{\ 2} + \chi_{13.}^{\ 2}.$$

Taking expectations (independence among the $\chi_{ij.}$ was assumed), one obtains

$$E(r) = 1 + E(\chi_{21.}^{\ 2}) + E(\chi_{13.}^{\ 2}) ,$$

which can be written as

$$\bar{r} = 1 + \frac{1}{N_{21.}} + \frac{1}{N_{13.}} .$$

Squaring the difference between r and $\bar{r}$, and taking expectations, one obtains

$$E(r - \bar{r})^2 = E(\chi_{23.}{}^2) + E(\chi_{11.}{}^2) + E(\chi_{21.}{}^2) + E(\chi_{13.}{}^2) + \left(\frac{1}{N_{21.}} + \frac{1}{N_{13.}}\right)^2 ,$$

or

$$E(r - \bar{r})^2 = \frac{1}{N_{23.}} + \frac{1}{N_{11.}} + \frac{1}{N_{21.}} + \frac{1}{N_{13.}} + \left(\frac{1}{N_{21.}} + \frac{1}{N_{13.}}\right)^2 .$$

Since $\sigma_r^2 = E(r-\bar{r})^2$, then the variance of $\hat{E}'_{(Full)}$ is

$$\sigma^2_{\hat{E}'_{(Full)}} = \left(\frac{N_{23.}\ N_{11.}}{N_{21.}\ N_{13.}}\right)^2 \sigma_r^2 .$$

The above can be easily adapted to the measure of partial effectiveness (prior to controlling for exposure risk) by substituting the terms $N_{22.}$, $n_{22.}$ and $\chi_{22.}$ for $N_{23.}$, $n_{23.}$, and χ_{23}; and the terms $N_{12.}$, $n_{12.}$ and $\chi_{12.}$ for $N_{13.}$, $n_{13.}$ and $\chi_{13.}$, respectively.

Effectiveness Values After Controlling for Exposure Risk

Table 3-33 contains estimates of the extent to which Post-Standard vehicles driven during periods of reduced light are either over-represented (negative value) or under-represented(positive value) in the population at large. Essentially, these estimates represent the percent difference between the daylight-to-reduced light ratio of accident-involved Pre-Standard vehicles and the corresponding ratio for accident-involved Post-Standard vehicles. Stated differently, these estimates represent the percent reduction in the number of reduced light angle collisions which cannot be attributed to FMVSS 108, since they are derived from single vehicle accident data.

From Table 3-33, it can be seen that differences in the reduced light exposure risks for Pre- and Post-Standard vehicles are negligible in all three years of Texas data, and approximately -4 percent in North Carolina for 1973 and 1975. However, in the case of both New York 1974 and North Carolina 1974, the estimated differences in reduced light exposure risks between Pre- and Post-Standard vehicles are highly significant, and represent values of 6 and -16 percent, respectively.

TABLE 3-33

ESTIMATED DIFFERENCES IN REDUCED LIGHTING EXPOSURE RISKS
FOR PRE- AND POST-STANDARD VEHICLES
DERIVED FROM OBSERVED SINGLE-VEHICLE ACCIDENT DATA

State	Year	Daylight				Reduced Light				Total Number of Cases	Differential Exposr. Risk	Standard Deviation
		Pre		Post		Pre		Post				
		Number	%	Number	%	Number	%	Number	%			
Texas	1972	26,287	29.6	15,985	18.0	29,023	32.7	17,488	19.7	88,783	0.91	1.37
	1973	22,912	25.1	20,303	22.2	25,619	28.1	22,450	24.6	91,284	1.11	1.31
	1974	17,515	20.9	20,980	25.1	20,438	24.4	24,740	29.6	83,673	-1.06	1.41
North Carolina	1973	4,301	21.5	4,447	22.2	5,429	27.1	5,863	29.3	20,040	-4.45	2.98
	1974	3,460	18.0	4,517	23.5	4,479	23.3	6,769	35.2	19,225	-15.76	3.44
	1975	2,926	15.1	5,166	26.6	3,974	20.5	7,329	37.8	19,395	-4.46	3.18
New York	1974	9,778	19.9	16,532	33.7	8,805	17.9	13,961	28.4	49,076	6.22	1.75

Table 3-34 contains the *full* and *partial* effectiveness values obtained after controlling for different exposure risks of Pre- and Post-Standard vehicles during periods of reduced lighting. On the average, *full* effectiveness values derived from smoothed, adjusted data range from 12 and 17 percent in New York and Texas , to 27 percent in North Carolina. Individual effectiveness values for the three years of Texas data are roughly the same for the 1972 and 1974 samples (19 vs. 22 percent), although for the 1973 sample, the *full* effectiveness value is almost one-half of these values (11 percent). On the other hand, effectiveness values for individual years of North Carolina data vary considerably, from 20 to 36 to 15 percent for 1972, 1973 and 1974 samples, respectively. With the exception of the North Carolina 1975 sample, however, all *full* effectiveness values reported in Table 3-34 are statistically significant.

Table 3-34 also summarizes the overall *partial* effectiveness values obtained after controlling for differential exposure risk. On the average, the overall reduction in the number of reduced light angle collisions realized when only one vehicle involved in a potential reduced light angle collision situation was equipped with side marker lamps was 12 percent for Texas samples and 16 percent for North Carolina samples. In the case of the New York 1974 sample, the amount of *partial* effectiveness was negligible and most likely due to chance (1.5 percent). Again, all *partial* effectiveness values obtained after controlling for differential exposure risk were less than the corresponding *full* effectiveness values.

TABLE 3-34

SUMMARY OF OVERALL FULL AND PARTIAL EFFECTIVENESS VALUES
DERIVED FROM SMOOTHED, ADJUSTED DATA
AFTER CONTROLLING FOR RELATIVE EXPOSURE RISK

State	Year	Full Effectiveness					Partial Effectiveness				
		Effectiveness	Standard Deviation	95% Confidence Interval From	95% Confidence Interval To	Is Effectiveness Significantly Different from Zero?	Effectiveness	Standard Deviation	95% Confidence Interval From	95% Confidence Interval To	Is Effectiveness Significantly Different from Zero?
Texas	1972	18.63	4.03	12.00	25.27	Yes	14.61	2.70	9.83	19.38	Yes
	1973	10.79	4.22	3.85	17.74	Yes	8.03	3.42	2.41	13.66	Yes
	1974	22.19	4.02	15.57	28.81	Yes	11.26	3.88	4.87	17.64	Yes
	1972-1974*	17.40	2.36	13.52	21.28	Yes	11.71	1.92	8.55	14.87	Yes
New York	1974	12.54	5.64	3.26	21.81	Yes	1.46	5.37	-7.37	10.28	No
North Carolina	1973	20.48	8.42	6.63	34.34	Yes	7.51	7.74	-5.22	20.25	No
	1974	36.38	6.90	25.03	47.73	Yes	25.56	6.83	14.32	36.80	Yes
	1975	15.45	9.69	-0.49	31.40	No	12.55	8.88	-2.06	27.16	No
	1973-1975*	26.61	4.67	18.93	34.29	Yes	16.38	4.44	9.08	23.68	Yes
All 3 States	All Years*	18.45	1.97	15.21	21.69	Yes	11.38	1.67	8.63	14.13	Yes

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

The variance of values of $E_{(Full)}$ and $E_{(Partial)}$ obtained <u>after</u> controlling for relative exposure risk were obtained as follows (see Figure 3-5 for notation).

$$\sigma^2_{E_{(Full)}} = \left(\frac{\dfrac{n_{11.} n_{23.}}{n_{13.} n_{21.}}}{\left[\dfrac{m_{11}\ m_{22}}{m_{21}\ m_{12}}\right]^2} \right)^2 \left(\frac{1}{n_{11.}} + \frac{1}{n_{23.}} + \frac{1}{n_{13.}} + \frac{1}{n_{21.}} + \frac{4}{m_{11}} + \frac{4}{m_{21}} + \frac{4}{m_{22}} + \frac{4}{m_{12}} \right), \text{ and}$$

$$\sigma^2_{E_{(Partial)}} = \left(\frac{\dfrac{n_{11.} n_{22.}}{n_{12.} n_{21.}}}{\dfrac{m_{11}\ m_{22}}{m_{21}\ m_{12}}} \right)^2 \left(\frac{1}{n_{11.}} + \frac{1}{n_{12.}} + \frac{1}{n_{22.}} + \frac{1}{n_{21.}} + \frac{1}{m_{11}} + \frac{1}{m_{21}} + \frac{1}{m_{22}} + \frac{1}{m_{12}} \right).$$

These equations are based on the assumption that the $m_{11}m_{22}/m_{21}m_{12}$ term is close to 1, with a relatively small error.

Having derived σ^2_E, 95 percent confidence intervals were computed as follows.

$$\text{Lower Limit} = E - 1.64\sigma_E$$

$$\text{Upper Limit} = E + 1.64\sigma_E$$

Furthermore, separate tests of the hypothesis that the obtained level of effectiveness is significantly greater than zero were also carried out, since interval estimation and hypothesis testing are generally not equivalent. In an attempt to reject the null hypothesis that the observed effectiveness values are equal to zero in the population, the following test statistic was used:

$$t = \frac{E - 0}{s.e._E}$$

where E represents a given effectiveness value. A one-tailed test required a t-value greater than 1.64 in order to reject the null hypothesis, since without exception the number of cases (and hence, degrees of freedom) exceeded 120 by a considerable margin.

By way of summary, the following conclusions can be drawn from the preceding findings.

1. Full Effectiveness. After controlling for differential exposure risk, overall effectiveness values for the three states ranged, on the average, from 12 to 27 percent. This represents a 12 to 27 percent reduction in the number of reduced light angle collisions which can be attributed to both vehicles involved in a reduced light angle collision situation satisfying the side marker lamp requirement of FMVSS 108.

   The average *full* effectiveness value obtained for all individual state-years of data was approximately 18 percent.* Furthermore, all mean *full* effectiveness values obtained were statistically significant.

2. Partial Effectiveness. Based upon weighted averages of overall *partial* effectiveness values (after controlling for differential exposure risk) derived from Texas 1972-1974 and North Carolina 1973-1975 samples, significant reductions in the number of reduced light angle collisions of 12 and 16 percent, respectively, were obtained when only one of the vehicles involved in a potential reduced light angle collision situation was equipped with side marker lamps. No significant *partial* effectiveness was found for the New York 1974 sample.

   As expected, these *partial* effectiveness values were in almost all cases between one-fifth to two-thirds less than the corresponding *full* effectiveness values. An overall average *partial* effectiveness value of 11 percent was obtained for all state-years of data analyzed, after controlling for exposure risk.*

3. Impact of Adjustment of Data. Overall, the net impact of adjusting smoothed cell counts was to increase effectiveness values by roughly 1 to 3 percentage points, and to slightly reduce the variability of these estimates. However, in the case of Texas 1973 and North Carolina 1974 samples, smoothing and adjusting resulted in a decrease in effectiveness values of approximately 2 percentage points.

4. Impact of Controlling for Exposure Risk. In the case of North Carolina, where the analysis of single vehicle accidents revealed a significant over-representation of Post-Standard vehicles driven during periods of reduced lighting, *full* and *partial* effectiveness values were uniformly increased by an average of roughly 13 and 7 percentage points as a result of controlling for exposure risk. For the New York 1974 sample, where Post-Standard vehicles driven under reduced lighting conditions were under-represented in the population at large, *full* and

*Weighted mean, using the inverse of the variance of each year as a weighting factor.

partial effectiveness values were decreased by 10 and 5 percentage points, respectively. Controlling for exposure risk in the Texas samples, however, had no appreciable impact on effectiveness values, since both Pre- and Post-Standard cars driven during periods of reduced lighting were equally represented.

While interpreting these and other findings, the reader should keep in mind the various limitations of the analysis discussed in Sections 1.5 and 2.3.

3.4.4 Extrapolation to the Nation

Using a weighted mean of the 1974 side marker lamp effectiveness values for Texas, New York and North Carolina, it is possible (for heuristic purposes) to extrapolate to the nation, although the resulting estimates are obviously approximate. No single state was used for extrapolation purposes, since the relationship between light condition and traffic density in either Texas or New York is not representative of the nation at large. Furthermore, North Carolina sample sizes are smaller than the other two states. Hence, a combination of all three states' effectiveness values was used. The year 1974 was chosen as a basis for extrapolating to the nation for the simple reason that it is the only year common to all three state data bases used in the analysis. During 1974, moreover, the numbers of Pre- and Post-Standard vehicles driven were approximately equal.

In order to derive estimates of the total number of reduced light angle collisions which were actually prevented nationwide in 1974, along with the number which could have potentially been prevented had all vehicles been equipped with side marker lamps, extrapolations were carried out in the following steps.

1. The total number of motor vehicle accidents [N] occurring nationwide in 1974 was estimated, along with the number of these which were angle collisions occurring during periods of reduced lighting [N'].

2. Three-state averages of the proportions of all reduced light angle collisions involving Pre with Pre, Pre with Post, and Post with Post vehicle configurations were computed ($\bar{r}_j$'s).

3. Weighted means for Texas, New York and North Carolina 1974 effectiveness values were computed, after controlling for differential exposure risk ($E_{(Full)}$ and $E_{(Partial)}$.

4. Based on the preceding information, extrapolated values were derived for the number of reduced light angle collisions:

- Expected if no vehicles had been equipped with side marker lamps [$X_{(None)}$].
- Expected if all vehicles had side marker lamps [$X_{(All)}$].
- Actually prevented by FMVSS 108 [$S_{(Actual)}$].
- Potentially prevented by FMVSS 108 at full implementation [$S_{(Potential)}$].

Since available estimates of the total number of motor vehicle accidents in 1974 vary considerably, accident statistics from 13 states were used as a basis for approximating the national total. From Table 3-35 it can be seen that these 13 states account for 45 percent of both the total number of fatalities and the total number of motor vehicle registrations recorded in 1974.

TABLE 3-35

ESTIMATION OF THE NUMBER OF REDUCED LIGHTING ANGLE COLLISIONS NATIONWIDE IN 1974, BASED UPON DATA FROM 13 STATES

State (1974)	Number Of Reported Accidents	Angle Collisions Occurring During Periods of Reduced Lighting		Number of Fatalities[b]	Number of Motor Vehicle Registrations[c]
		Percent	Number		
California	496,577	*9.89*[a]	*49,132*	4,019	13,684,399
Illinois	486,812	*6.38*	*31,085*	2,007	6,174,102
Michigan	296,936	*5.98*	*17,745*	1,875	5,400,904
Missouri	30,406	*1.98*	*600*	1,042	2,825,461
New Hampshire	18,520	*13.81*	*2,558*	166	490,303
New Mexico	39,741	*5.97*	*2,371*	540	763,452
New York	377,818	*6.62*	*25,014*	2,620	7,457,802
North Carolina	121,568	*5.46*	*6,633*	1,580	3,569,769
Oregon	45,476	*7.44*	*3,384*	670	1,579,736
Tennessee	10,302	*6.94*	*714*	1,285	2,568,381
Texas	434,194	*5.98*	*25,968*	3,046	8,053,269
Virginia	144,537	*5.10*	*7,366*	1,050	3,171,744
Washington	106,242	*7.30*	*7,761*	759	2,444,446
13-State Total	2,609,129	*6.91*	*180,331*	20,659	58,183,768
Nationwide Total	*5,798,064*	*6.91*	*400,736*	46,200	129,893,311

a. Numbers in *italics* are *estimates* derived from reports of state authorities.

b. Source: *Accident Facts, 1975*, National Safety Council.

c. Source: *Highway Statistics 1974*, U.S. Department of Transportation, Federal Highway Administration.

Therefore, by inflating the 13-state accident totals by a factor of 2.22, one obtains a national estimate of 5,798,064 (=N) accidents in 1974, of which 400,736 (=N') were angle collisions under reduced light conditions.

The formulas used to carry out Step 4 above are:

$$X_{(None)} = N' \left[\bar{r}_1 + \frac{\bar{r}_2}{1-[E_{(Partial)}/100]} + \frac{\bar{r}_3}{1-[E_{(Full)}/100]} \right]$$

$$X_{(All)} = N' \left[\bar{r}_1 \left(1-E_{(Full)}/100]\right) + \bar{r}_2 \left(\frac{1-[E_{(Full)}/100]}{1-[E_{(Partial)}/100]} \right) + \bar{r}_3 \right]$$

$$S_{(Actual)} = X_{(None)} - N'$$

$$S_{(Potential)} = X_{(None)} - X_{(All)}$$

Using the notation depicted in Figure 3-6, $\bar{r}_i = \dfrac{n_{2i}}{n_{21} + n_{22} + n_{23}}$.

LIGHT CONDITION (i)	VEHICLE CONFIGURATION (j): Pre with Pre (1)	Pre with Post (2)	Post with Post (3)
Daylight (1)	n_{11}	n_{12}	n_{13}
Reduced Light (2)	n_{21}	n_{22}	n_{23}

Figure 3-6. Summary of notation used in extrapolation to the nation.

Also, N' refers to the national estimate of reduced light angle collisions for 1974 (N' = 400,736). Values for $\bar{r}_i$ can be found in Table 3-36, whereas values for $E_{(Full)}$ and $E_{(Partial)}$ are contained in Table 3-37. By substituting these values in the above equations, one finds that in 1974, when the numbers of

Pre- and Post-Standard vehicles driven were roughly the same, approximately 64,000 reduced light angle collisions were actually prevented by the side marker lamp requirement of FMVSS 108. At this time, had the Standard been fully implemented--i.e., had all vehicles driven been equipped with side marker lamps--it is estimated that almost twice as many reduced light angle collisions (~103,000) would have been prevented. These extrapolations of both the actual and potential numbers of accidents prevented by FMVSS 108 are summarized in Table 3-38.

TABLE 3-36

PROPORTIONS OF ALL REDUCED LIGHT ANGLE COLLISIONS CORRESPONDING TO EACH VEHICLE CONFIGURATION CATEGORY (1974)

Vehicle Configuration (j)	Texas		New York		North Carolina		All Three States	
	n_{2j}	r_j	n_{2j}	r_j	n_{2j}	r_j	n_{2j} (Pooled)	$\bar{r}_j$
Pre with Pre (1)	966	0.18	715	0.15	233	0.18	1914	0.17
Pre with Post (2)	2657	0.48	2378	0.48	619	0.47	5654	0.48
Post with Post (3)	1882	0.34	1814	0.37	461	0.35	4157	0.35

TABLE 3-37

SUMMARY OF 1974 SIDE MARKER LAMP EFFECTIVENESS VALUES USED FOR EXTRAPOLATIONS

State (1974)	Effectiveness Values Corrected for Bias			
	Full		Partial	
	$\hat{E}$	s.d.	$\hat{E}$	s.d.
Texas	22.19	4.02	11.26	3.88
New York	12.54	5.64	1.46	5.37
North Carolina	36.38	6.90	25.56	6.83
All Three States*	22.14	2.96	10.99	2.86

*Weighted mean, using the inverse of the variance as a weighting factor.

TABLE 3-38

ESTIMATED NUMBER OF REDUCED LIGHT ANGLE COLLISIONS ACTUALLY AND POTENTIALLY PREVENTED NATIONWIDE IN 1974 BY SIDE MARKER LAMPS

Expected Number of Reduced Light Angle Collisions If No Vehicles Had Side Marker Lamps	Actual Number of Reduced Light Angle Collisions	Expected Number of Reduced Light Angle Collisions If All Vehicles Had Side Marker Lamps	Estimated Actual Number of Reduced Light Angle Collisions Prevented By FMVSS 108	Potential Number of Reduced Light Angle Collisions Prevented By FMVSS 108 at Full Implementation
464,369	400,736	361,558	63,633	102,811

APPENDIX A

FULLY CROSS-CLASSIFIED CONTINGENCY TABLES DERIVED FROM STATE MASS ACCIDENT DATA BASES

TABLE A-1

FULLY CROSS-CLASSIFIED TABLE OF
TEXAS 1972 RAW DATA

DRVAGE2 A	ROADTYPE R	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
15-24	CITY	DAYLIGHT	2319	2996	1039
		REDUCED	634	728	267
	US-STATE	DAYLIGHT	625	872	356
		REDUCED	291	294	121
	OTHER	DAYLIGHT	282	392	176
		REDUCED	101	146	45
25-54	CITY	DAYLIGHT	3017	4303	1829
		REDUCED	674	758	300
	US-STATE	DAYLIGHT	866	1419	580
		REDUCED	295	386	130
	OTHER	DAYLIGHT	370	629	277
		REDUCED	110	176	72
55 +	CITY	DAYLIGHT	1308	1614	544
		REDUCED	145	164	63
	US-STATE	DAYLIGHT	576	696	286
		REDUCED	88	105	31
	OTHER	DAYLIGHT	164	215	80
		REDUCED	23	24	10

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 34011

TABLE A-2

FULLY CROSS-CLASSIFIED TABLE OF TEXAS 1973 RAW DATA

DRVSEX X	DRVAGE A	MAXTAU T	ROADTYPE R	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
MALE	15-24	0-2	CITY	DAYLIGHT	620	1092	540
				REDUCED	152	241	119
			US-STATE	DAYLIGHT	159	279	138
				REDUCED	59	89	55
			OTHER	DAYLIGHT	66	132	66
				REDUCED	16	41	22
		3-4	CITY	DAYLIGHT	516	867	420
				REDUCED	173	257	147
			US-STATE	DAYLIGHT	162	328	167
				REDUCED	79	142	60
			OTHER	DAYLIGHT	74	117	57
				REDUCED	24	57	35
		5-7	CITY	DAYLIGHT	57	119	58
				REDUCED	33	52	17
			US-STATE	DAYLIGHT	29	44	38
				REDUCED	26	36	19
			OTHER	DAYLIGHT	9	24	17
				REDUCED	9	14	10
	25-54	0-2	CITY	DAYLIGHT	596	1245	783
				REDUCED	136	250	153
			US-STATE	DAYLIGHT	179	418	256
				REDUCED	57	116	66
			OTHER	DAYLIGHT	52	172	123
				REDUCED	28	36	18
		3-4	CITY	DAYLIGHT	420	915	523
				REDUCED	167	280	149
			US-STATE	DAYLIGHT	190	378	265
				REDUCED	87	145	93
			OTHER	DAYLIGHT	76	143	90
				REDUCED	23	62	42
		5-7	CITY	DAYLIGHT	34	104	73
				REDUCED	27	57	21
			US-STATE	DAYLIGHT	29	93	49
				REDUCED	25	45	21
			OTHER	DAYLIGHT	16	33	17
				REDUCED	7	16	10
	55 +	0-2	CITY	DAYLIGHT	283	510	245
				REDUCED	33	60	17
			US-STATE	DAYLIGHT	115	211	99
				REDUCED	19	24	14
			OTHER	DAYLIGHT	32	67	47
				REDUCED	5	6	5
		3-4	CITY	DAYLIGHT	190	357	179
				REDUCED	22	36	23
			US-STATE	DAYLIGHT	88	174	88
				REDUCED	17	24	11
			OTHER	DAYLIGHT	32	46	29
				REDUCED	2	9	8
		5-7	CITY	DAYLIGHT	17	28	16
				REDUCED	4	8	2
			US-STATE	DAYLIGHT	11	37	16
				REDUCED	5	6	3
			OTHER	DAYLIGHT	2	14	7
				REDUCED	1	1	0

TABLE A-2 (Continued)

DRVSEX1 X	DRVAGE1 A	MAXTAD T	ROADTYPE R	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
FEMALE	15-24	0-2	CITY	DAYLIGHT	354	749	442
				REDUCED	37	120	62
			US-STATE	DAYLIGHT	70	194	119
				REDUCED	13	34	22
			OTHER	DAYLIGHT	43	68	60
				REDUCED	7	19	15
		3-4	CITY	DAYLIGHT	253	524	307
				REDUCED	50	97	49
			US-STATE	DAYLIGHT	67	169	106
				REDUCED	20	33	25
			OTHER	DAYLIGHT	28	75	56
				REDUCED	4	14	9
		5-7	CITY	DAYLIGHT	21	57	43
				REDUCED	8	9	9
			US-STATE	DAYLIGHT	16	39	17
				REDUCED	6	8	4
			OTHER	DAYLIGHT	8	15	7
				REDUCED	0	8	3
	25-54	0-2	CITY	DAYLIGHT	506	1084	720
				REDUCED	44	107	73
			US-STATE	DAYLIGHT	120	312	180
				REDUCED	17	47	20
			OTHER	DAYLIGHT	31	129	93
				REDUCED	7	19	14
		3-4	CITY	DAYLIGHT	362	790	485
				REDUCED	46	101	62
			US-STATE	DAYLIGHT	103	275	178
				REDUCED	21	47	27
			OTHER	DAYLIGHT	50	131	95
				REDUCED	11	20	11
		5-7	CITY	DAYLIGHT	40	87	57
				REDUCED	8	16	14
			US-STATE	DAYLIGHT	13	39	33
				REDUCED	4	17	8
			OTHER	DAYLIGHT	6	14	19
				REDUCED	1	2	4
	55 +	0-2	CITY	DAYLIGHT	180	383	179
				REDUCED	14	32	14
			US-STATE	DAYLIGHT	70	134	62
				REDUCED	15	10	3
			OTHER	DAYLIGHT	21	31	18
				REDUCED	0	2	2
		3-4	CITY	DAYLIGHT	125	220	117
				REDUCED	4	20	12
			US-STATE	DAYLIGHT	43	85	61
				REDUCED	4	7	6
			OTHER	DAYLIGHT	12	28	19
				REDUCED	0	4	0
		5-7	CITY	DAYLIGHT	10	24	19
				REDUCED	0	2	1
			US-STATE	DAYLIGHT	13	16	10
				REDUCED	2	3	3
			OTHER	DAYLIGHT	1	6	2
				REDUCED	0	1	0

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 34255

TABLE A-3

FULLY CROSS-CLASSIFIED TABLE OF TEXAS 1974 RAW DATA

DRVAGE2 A	MAXTAD T	ROADTYPE R	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
15-24	0-2	CITY	DAYLIGHT	536	1565	1172
			REDUCED	111	303	224
		US-STATE	DAYLIGHT	129	426	346
			REDUCED	42	150	97
		OTHER	DAYLIGHT	44	197	156
			REDUCED	19	38	49
	3-4	CITY	DAYLIGHT	424	1158	765
			REDUCED	133	333	220
		US-STATE	DAYLIGHT	132	359	275
			REDUCED	70	170	112
		OTHER	DAYLIGHT	49	181	151
			REDUCED	25	64	49
	5-7	CITY	DAYLIGHT	39	114	80
			REDUCED	23	67	45
		US-STATE	DAYLIGHT	12	61	44
			REDUCED	13	35	27
		OTHER	DAYLIGHT	14	22	28
			REDUCED	10	9	12
25-54	0-2	CITY	DAYLIGHT	670	2094	1806
			REDUCED	116	347	286
		US-STATE	DAYLIGHT	168	603	565
			REDUCED	49	146	100
		OTHER	DAYLIGHT	62	239	250
			REDUCED	16	61	50
	3-4	CITY	DAYLIGHT	485	1363	1212
			REDUCED	122	326	236
		US-STATE	DAYLIGHT	161	498	490
			REDUCED	64	149	108
		OTHER	DAYLIGHT	49	207	233
			REDUCED	15	69	50
	5-7	CITY	DAYLIGHT	43	138	98
			REDUCED	22	41	41
		US-STATE	DAYLIGHT	20	98	72
			REDUCED	17	38	27
		OTHER	DAYLIGHT	9	31	21
			REDUCED	6	13	15

TABLE A-3 (Continued)

DRVAGE2 A	MAXTAD T	ROADTYPE R	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
55 +	0-2	CITY	DAYLIGHT	317	856	586
			REDUCED	39	85	36
		US-STATE	DAYLIGHT	104	308	187
			REDUCED	7	35	18
		OTHER	DAYLIGHT	30	104	62
			REDUCED	2	13	6
	3-4	CITY	DAYLIGHT	283	578	403
			REDUCED	28	70	47
		US-STATE	DAYLIGHT	108	292	202
			REDUCED	11	52	25
		OTHER	DAYLIGHT	27	85	72
			REDUCED	5	15	10
	5-7	CITY	DAYLIGHT	24	61	38
			REDUCED	5	12	2
		US-STATE	DAYLIGHT	13	60	19
			REDUCED	8	8	5
		OTHER	DAYLIGHT	3	17	11
			REDUCED	0	4	3

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 30545

TABLE A-4

FULLY CROSS-CLASSIFIED TABLE OF NEW YORK 1974 RAW DATA

NUMTOWED T	ROADTYPE R	DRVAGE2 A	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
NONE	STATE	15-24	DAYLIGHT	47	269	266
			REDUCED	37	111	97
		25-34	DAYLIGHT	54	161	201
			REDUCED	17	68	68
		35-54	DAYLIGHT	52	265	269
			REDUCED	28	75	82
		55 +	DAYLIGHT	56	189	189
			REDUCED	12	38	52
	COUNTY	15-24	DAYLIGHT	46	129	98
			REDUCED	15	56	31
		25-34	DAYLIGHT	20	73	84
			REDUCED	8	23	18
		35-54	DAYLIGHT	26	110	131
			REDUCED	11	27	25
		55 +	DAYLIGHT	20	60	82
			REDUCED	4	19	19
	TOWN	15-24	DAYLIGHT	60	169	103
			REDUCED	12	53	34
		25-34	DAYLIGHT	34	105	84
			REDUCED	7	21	22
		35-54	DAYLIGHT	50	151	131
			REDUCED	15	28	27
		55 +	DAYLIGHT	27	88	64
			REDUCED	5	13	11
	CITY STR	15-24	DAYLIGHT	138	378	317
			REDUCED	69	232	131
		25-34	DAYLIGHT	113	444	336
			REDUCED	57	179	154
		35-54	DAYLIGHT	137	484	437
			REDUCED	74	231	150
		55 +	DAYLIGHT	111	348	276
			REDUCED	31	86	59

TABLE A-4 (continued)

NUMTOWED T	ROADTYPE R	DRVAGE2 A	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
ONE ONLY	STATE	15-24	DAYLIGHT	35	125	110
			REDUCED	21	61	58
		25-34	DAYLIGHT	14	78	75
			REDUCED	11	45	38
		35-54	DAYLIGHT	29	106	122
			REDUCED	10	60	46
		55 +	DAYLIGHT	21	97	91
			REDUCED	9	36	26
	COUNTY	15-24	DAYLIGHT	20	44	40
			REDUCED	14	23	20
		25-34	DAYLIGHT	12	36	39
			REDUCED	9	11	16
		35-54	DAYLIGHT	13	52	58
			REDUCED	4	27	14
		55 +	DAYLIGHT	10	48	35
			REDUCED	5	10	3
	TOWN	15-24	DAYLIGHT	28	69	53
			REDUCED	7	21	18
		25-34	DAYLIGHT	7	50	43
			REDUCED	1	13	11
		35-54	DAYLIGHT	15	63	58
			REDUCED	11	25	18
		55 +	DAYLIGHT	9	27	23
			REDUCED	2	8	2
	CITY STR	15-24	DAYLIGHT	43	146	128
			REDUCED	23	93	67
		25-34	DAYLIGHT	23	145	149
			REDUCED	11	72	58
		35-54	DAYLIGHT	31	166	151
			REDUCED	13	96	59
		55 +	DAYLIGHT	37	144	123
			REDUCED	3	30	29

TABLE A-4 (Concluded)

NUMTOWED T	ROADTYPE R	DRVAGE2 A	LIGHTINGI L I	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
BOTH	STATE	15-24	DAYLIGHT	32	95	72
			REDUCED	25	86	58
		25-34	DAYLIGHT	19	50	68
			REDUCED	13	32	32
		35-54	DAYLIGHT	23	100	105
			REDUCED	22	56	40
		55 +	DAYLIGHT	32	75	87
			REDUCED	3	22	25
	COUNTY	15-24	DAYLIGHT	8	58	38
			REDUCED	14	23	21
		25-34	DAYLIGHT	6	27	24
			REDUCED	5	15	14
		35-54	DAYLIGHT	13	40	43
			REDUCED	1	19	8
		55 +	DAYLIGHT	13	27	29
			REDUCED	1	9	2
	TOWN	15-24	DAYLIGHT	16	53	44
			REDUCED	12	26	11
		25-34	DAYLIGHT	7	24	25
			REDUCED	4	15	8
		35-54	DAYLIGHT	10	49	33
			REDUCED	6	16	9
		55 +	DAYLIGHT	13	27	25
			REDUCED	4	6	7
	CITY STR	15-24	DAYLIGHT	16	80	80
			REDUCED	21	60	32
		25-34	DAYLIGHT	17	81	91
			REDUCED	14	42	40
		35-54	DAYLIGHT	22	86	78
			REDUCED	8	50	28
		55 +	DAYLIGHT	21	72	82
			REDUCED	3	16	13

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 17566

TABLE A-5

FULLY CROSS-CLASSIFIED TABLE OF NORTH CAROLINA 1973 RAW DATA

MAXDAMAG D	CITYSIZE C	DRVAGE2 A	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
$0-349	LT 50K	15-25	DAYLIGHT	129	199	86
			REDUCED	37	55	22
		26-55	DAYLIGHT	147	271	127
			REDUCED	38	57	25
		56 +	DAYLIGHT	91	115	41
			REDUCED	10	16	3
	50K +	15-25	DAYLIGHT	56	114	52
			REDUCED	10	32	15
		26-55	DAYLIGHT	68	120	103
			REDUCED	17	45	26
		56 +	DAYLIGHT	34	59	23
			REDUCED	5	10	6
$350-899	LT 50K	15-25	DAYLIGHT	128	282	144
			REDUCED	48	94	51
		26-55	DAYLIGHT	176	334	194
			REDUCED	49	76	21
		56 +	DAYLIGHT	81	143	60
			REDUCED	12	29	14
	50K +	15-25	DAYLIGHT	48	118	79
			REDUCED	19	42	28
		26-55	DAYLIGHT	63	175	123
			REDUCED	11	34	25
		56 +	DAYLIGHT	16	50	33
			REDUCED	5	9	4
$900 +	LT 50K	15-25	DAYLIGHT	30	120	82
			REDUCED	13	37	22
		26-55	DAYLIGHT	29	141	111
			REDUCED	8	35	20
		56 +	DAYLIGHT	16	70	46
			REDUCED	3	11	6
	50K +	15-25	DAYLIGHT	8	49	38
			REDUCED	6	20	22
		26-55	DAYLIGHT	18	61	57
			REDUCED	5	19	19
		56 +	DAYLIGHT	5	23	10
			REDUCED	2	5	0

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 6249

TABLE A-6

FULLY CROSS-CLASSIFIED TABLE OF NORTH CAROLINA 1974 RAW DATA

DRVSEX1 X	ROADTYPE R	DRVAGE2 A	LIGHTING1 L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
MALE	US-STATE	15-25	DAYLIGHT	39	125	52
			REDUCED	18	52	35
		26-55	DAYLIGHT	39	112	94
			REDUCED	21	35	38
		56 +	DAYLIGHT	23	75	38
			REDUCED	7	8	8
	CITY STR	15-25	DAYLIGHT	122	322	280
			REDUCED	39	135	78
		26-55	DAYLIGHT	144	427	337
			REDUCED	33	129	97
		56 +	DAYLIGHT	80	200	129
			REDUCED	15	32	21
	RURAL RD	15-25	DAYLIGHT	24	70	43
			REDUCED	18	35	8
		26-55	DAYLIGHT	20	67	48
			REDUCED	10	16	12
		56 +	DAYLIGHT	10	16	11
			REDUCED	3	2	2
FEMALE	US-STATE	15-25	DAYLIGHT	16	60	59
			REDUCED	3	23	14
		26-55	DAYLIGHT	24	72	74
			REDUCED	6	18	12
		56 +	DAYLIGHT	15	24	26
			REDUCED	0	4	2
	CITY STR	15-25	DAYLIGHT	88	284	221
			REDUCED	24	53	43
		26-55	DAYLIGHT	79	345	276
			REDUCED	23	40	64
		56 +	DAYLIGHT	52	158	106
			REDUCED	5	15	12
	RURAL RD	15-25	DAYLIGHT	14	47	34
			REDUCED	7	7	8
		26-55	DAYLIGHT	11	61	38
			REDUCED	3	10	4
		56 +	DAYLIGHT	5	26	11
			REDUCED	1	4	1

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 6486

TABLE A-7

FULLY CROSS-CLASSIFIED TABLE OF NORTH CAROLINA 1975 RAW DATA

ACCSEV I	ROADTYPE R	DRVAGE1 A	LIGHTING L	STATUS (S) PRE-PRE	PRE-POST	POSTPOST
K+A+B+C	US-STATE	15-25	DAYLIGHT	18	71	53
			REDUCED	8	21	19
		26-55	DAYLIGHT	29	105	90
			REDUCED	7	26	24
		56 +	DAYLIGHT	15	26	32
			REDUCED	0	4	5
	CITY STR	15-25	DAYLIGHT	59	211	212
			REDUCED	28	91	76
		26-55	DAYLIGHT	71	277	327
			REDUCED	21	77	52
		56 +	DAYLIGHT	37	140	99
			REDUCED	4	16	14
	RURAL RD	15-25	DAYLIGHT	7	45	19
			REDUCED	2	19	5
		26-55	DAYLIGHT	8	37	39
			REDUCED	3	10	11
		56 +	DAYLIGHT	5	11	6
			REDUCED	1	1	0
NONE	US-STATE	15-25	DAYLIGHT	31	112	101
			REDUCED	10	41	38
		26-55	DAYLIGHT	26	122	134
			REDUCED	14	31	29
		56 +	DAYLIGHT	18	55	40
			REDUCED	5	7	7
	CITY STR	15-25	DAYLIGHT	102	409	395
			REDUCED	24	105	130
		26-55	DAYLIGHT	121	488	517
			REDUCED	21	91	120
		56 +	DAYLIGHT	73	226	196
			REDUCED	4	16	20
	RURAL RD	15-25	DAYLIGHT	27	87	67
			REDUCED	7	18	15
		26-55	DAYLIGHT	23	82	82
			REDUCED	8	13	9
		56 +	DAYLIGHT	7	27	22
			REDUCED	2	3	2

**FOR ANALYSIS, 0.001 IS ADDED TO EACH CELL ABOVE

THE TOTAL FREQUENCY IS 6974

APPENDIX B

SUMMARY OF THE MARGINAL ASSOCIATION OF MODEL EFFECTS

TABLE B-1

SUMMARY OF TESTS OF MARGINAL ASSOCIATIONS OF MODEL EFFECTS
TEXAS 1972-1974 SAMPLE

Effect†	Texas 1972			Texas 1973			Texas 1974		
	LR χ^2	df	Prob.	LR χ^2	df	Prob.	LR χ^2	df	Prob.
Veh Mix x Light Cond	36.28	2	0.000	17.15	2	0.000	22.12*	2	0.000
Veh Mix x Road Type	24.54	4	0.000	30.61	4	0.000	49.90	4	0.000
Veh Mix x Dr Age	76.26	4	0.000	108.97*	4	0.000	133.23	4	0.000
Veh Mix x Dr Sex	-	-	-	73.59*	2	0.000	-	-	-
Veh Mix x Max TAD	-	-	-	-	-	-	19.87*	4	0.000
Light Cond x Road Type	134.56	2	0.000	123.57	2	0.000	114.06*	2	0.000
Light Cond x Dr Age	405.35	2	0.000	349.91*	2	0.000	391.95*	2	0.000
Light Cond x Max TAD	-	-	-	271.82*	2	0.000	265.06*	2	0.000
Light Cond x Dr Sex	-	-	-	512.37*	1	0.000	-	-	-
Road Type x Dr Age	126.87	4	0.000	73.42*	4	0.000	39.79*	4	0.000
Road Type x Max TAD	-	-	-	338.29	4	0.000	247.97	4	0.000
Road Type x Dr Sex	-	-	-	66.25*	2	0.000	-	-	-
Max TAD x Dr Age	-	-	-	56.42*	4	0.000	18.47	4	0.001
Max TAD x Dr Sex	-	-	-	52.66*	2	0.000	-	-	-
Dr Age x Dr Sex	-	-	-	99.15*	2	0.000	-	-	-
Veh Mix x Dr Age x Dr Sex	-	-	-	19.28	4	0.001	-	-	-
Veh Mix x Light Cond x Max TAD	-	-	-	-	-	-	9.40	4	0.052
Light Cond x Max TAD x Dr Age	-	-	-	10.60	4	0.032	-	-	-
Light Cond x Max TAD x Dr Sex	-	-	-	8.38	2	0.015	-	-	-
Light Cond x Dr Age x Dr Sex	-	-	-	21.54	2	0.000	-	-	-
Light Cond x Road Type x Dr Age	-	-	-	-	-	-	9.18	4	0.057
Road Type x Dr Age x Dr Sex	-	-	-	13.35	4	0.010	-	-	-
Max TAD x Dr Age x Dr Sex	-	-	-	9.76	4	0.045	-	-	-
SUMMARY OF MODEL	36.20	28	0.138	260.81	256	0.405	125.97	112	0.173

†For the Texas 1972 and 1974 models, driver characteristics refer to drivers of the struck vehicles, whereas for the Texas 1973 model, they refer to drivers of the striking vehicle.

*Effect is specified directly in the model.

TABLE B-2

SUMMARY OF TESTS OF MARGINAL ASSOCIATIONS OF MODEL EFFECTS
NEW YORK 1974 SAMPLE

Effect ≠	New York 1974		
	LR χ^2	df	Prob.
Vehicle Mix x Light Condition	37.04	2	0.000
Vehicle Mix x Dr Age	38.98*	6	0.000
Vehicle Mix x Road Type	52.40*	6	0.000
Vehicle Mix x Towaways	13.04*	4	0.011
Light Condition x Dr Age	210.91*	3	0.000
Light Condition x Road Type	71.75*	3	0.000
Light Condition x Towaways	44.86*	2	0.000
Dr Age x Road Type	135.81*	9	0.000
Dr Age x Towaways	15.79*	6	0.015
Road Type x Towaways	260.51*	6	0.000
Vehicle Mix x Dr Age x Towaways	21.65	12	0.042
Vehicle Mix x Road Type x Towaways	40.63	12	0.000
Light Condition x Dr Age x Road Type	13.99	9	0.123
Light Condition x Dr Age x Towaways	13.83	6	0.032
Light Condition x Road Type x Towaways	21.10	6	0.002
Dr Age x Road Type x Towaways	25.80	18	0.104
SUMMARY OF MODEL	172.60	166	0.347

≠Driver Age refers to drivers of struck vehicles.

*Effect is specified directly in the model.

TABLE B-3

SUMMARY OF TESTS OF MARGINAL ASSOCIATIONS OF MODEL
NORTH CAROLINA 1973-1975 SAMPLE

Effect	North Carolina 1973			North Carolina 1974			North Carolina 1975		
	LR χ^2	df	Prob.	LR χ^2	df	Prob.	LR χ^2	df	Prob.
Veh Mix x Light Cond	1.96	2	0.376	4.46*	2	0.107	0.49*	2	0.782
Veh Mix x Dr Age	20.72	4	0.000	21.77	4	0.000	22.83	4	0.000
Veh Mix x City Size	41.76	2	0.000	-	-	-	-	-	-
Veh Mix x Damage	147.83	4	0.000	-	-	-	-	-	-
Veh Mix x Road Type	-	-	-	9.72*	4	0.045	13.39	4	0.010
Veh Mix x Dr Sex	-	-	-	14.60*	2	0.001	-	-	-
Veh Mix x Severity	-	-	-	-	-	-	3.16*	2	0.206
Light Cond x Dr Age	57.53*	2	0.000	70.30	2	0.000	126.72	2	0.000
Light Cond x City Size	4.36	1	0.037	-	-	-	-	-	-
Light Cond x Damage	3.71*	2	0.156	-	-	-	-	-	-
Light Cond x Road Type	-	-	-	14.88*	2	0.001	6.66*	2	0.036
Light Cond x Dr Sex	-	-	-	65.30*	1	0.000	-	-	-
Light Cond x Severity	-	-	-	-	-	-	9.22*	1	0.002
Dr Age x City Size	16.14	2	0.000	-	-	-	-	-	-
Dr Age x Damage	6.27*	4	0.180	-	-	-	-	-	-
Dr Age x Road Type	-	-	-	19.18*	4	0.001	19.01	4	0.001
Dr Age x Dr Sex	-	-	-	0.25*	2	0.883	-	-	-
City Size x Damage	9.30	2	0.010	-	-	-	-	-	-
Road Type x Dr Sex	-	-	-	16.78*	2	0.000	-	-	-
Road Type x Severity	-	-	-	-	-	-	16.29*	2	0.000
Light Cond x Dr Age x Damage	12.11	4	0.016	-	-	-	-	-	-
Light Cond x Road Type x Dr Sex	-	-	-	0.44*	2	0.803	-	-	-
Light Cond x Road Type x Severity	-	-	-	-	-	-	6.81	2	0.033
Veh Mix x Light Cond x Road Type	-	-	-	10.81*	4	0.029	-	-	-
Veh Mix x Light Cond x Dr Sex	-	-	-	4.46*	2	0.108	-	-	-
Veh Mix x Road Type x Dr Sex	-	-	-	6.32*	4	0.177	-	-	-
Veh Mix x Light Cond x Severity	-	-	-	-	-	-	7.85	2	0.020
Dr Age x Road Type x Dr Sex	-	-	-	10.29	4	0.036	-	-	-
Veh Mix x Light Cond x Road Type x Dr Sex	-	-	-	20.74	4	0.000	-	-	-
SUMMARY OF MODEL	68.11	70	0.542	49.49	54	0.649	73.24	72	0.437

ƒFor the North Carolina 1973 and 1975 models, driver characteristics refer to the drivers of the struck and striking vehicles,respectively. For the North Carolina 1974 model, Age refers to drivers of struck vehicles, while Sex refers to drivers of striking vehicles.

*Effect is specified directly in the model.

APPENDIX C

SUMMARY OF EFFECTIVENESS RESULTS FOR OBSERVED, UNADJUSTED STATE MASS ACCIDENT DATA

TABLE C-1

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING TEXAS 1972 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 34,011

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	9527	28.0	13136	38.6	5167	15.2	27830	81.8
REDUCED LIGHT	2361	6.9	2781	8.2	1039	3.1	6181	18.2
COLUMN TOTALS	11888	35.0	15917	46.8	6206	18.2	34011	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	26287	29.6	15985	18.0	42272	47.6
REDUCED LIGHT	29023	32.7	17488	19.7	46511	52.4
COLUMN TOTALS	55310	62.3	33473	37.7	88783	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT)							
	BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE				AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE			
	EFFECTIVENESS		95% CONFIDENCE INTERVAL		EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	18.86	3.33	13.38	24.34	17.36	4.09	10.63	24.09
PARTIAL	14.57	2.65	10.21	18.94	13.79	2.93	8.96	18.61

TABLE C-2

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING TEXAS 1973 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 34,255

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	6620	19.3	13625	39.8	7910	23.1	28155	82.2
REDUCED LIGHT	1579	4.6	2909	8.5	1612	4.7	6100	17.8
COLUMN TOTALS	8199	23.9	16534	48.3	9522	27.8	34255	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	22912	25.1	20303	22.2	43215	47.3
REDUCED LIGHT	25619	28.1	22450	24.6	48069	52.7
COLUMN TOTALS	48531	53.2	42753	46.8	91284	100.0

TYPE OF EFFECTIVE-NESS	EFFECTIVENESS VALUES (PERCENT)							
	BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE				AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE			
	EFFECTIVENESS		95% CONFIDENCE INTERVAL		EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	14.56	3.34	9.06	20.06	12.63	4.13	5.83	19.43
PARTIAL	10.49	3.10	5.38	15.59	9.48	3.36	3.96	15.01

TABLE C-3

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING TEXAS 1974 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 30,545

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	3955	12.9	11715	38.4	9344	30.6	25014	81.9
REDUCED LIGHT	978	3.2	2653	8.7	1900	6.2	5531	18.1
COLUMN TOTALS	4933	16.1	14368	47.0	11244	36.8	30545	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	17515	20.9	20980	25.1	38495	46.0
REDUCED LIGHT	20438	24.4	24740	29.6	45178	54.0
COLUMN TOTALS	37953	45.4	45720	54.6	83673	100.0

TYPE OF EFFECTIVE-NESS	EFFECTIVENESS VALUES (PERCENT)							
	BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE				AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE			
	EFFECTIVENESS		95% CONFIDENCE INTERVAL		EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	17.77	3.59	11.86	23.68	19.48	4.17	12.62	26.34
PARTIAL	8.42	3.82	2.14	14.70	9.38	3.98	2.83	15.93

TABLE C-4

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NEW YORK 1974 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 17,566

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	PRE WITH PRE %	PRE WITH POST N	PRE WITH POST %	POST WITH POST N	POST WITH POST %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	1606	9.1	5763	32.8	5290	30.1	12659	72.1
REDUCED LIGHT	712	4.1	2384	13.6	1811	10.3	4907	27.9
COLUMN TOTALS	2318	13.2	8147	46.4	7101	40.4	17566	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	PRE-STANDARD %	POST-STANDARD N	POST-STANDARD %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	9778	19.9	16532	33.7	26310	53.6
REDUCED LIGHT	8805	17.9	13961	28.4	22766	46.4
COLUMN TOTALS	18583	37.9	30493	62.1	49076	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	22.78	4.06	16.09	29.47	12.20	5.66	2.88	21.51
PARTIAL	6.69	4.78	-1.17	14.55	0.90	5.42	-8.41	9.42

TABLE C-5

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NORTH CAROLINA 1973 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 6,249

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	1143	18.3	2444	39.1	1409	22.5	4996	79.9
REDUCED LIGHT	298	4.8	626	10.0	329	5.3	1253	20.1
COLUMN TOTALS	1441	23.1	3070	49.1	1738	27.8	6249	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	4301	21.5	4447	22.2	8748	43.7
REDUCED LIGHT	5429	27.1	5863	29.3	11292	56.3
COLUMN TOTALS	9730	48.6	10310	51.4	20040	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE				AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE			
	EFFECTIVENESS		95% CONFIDENCE INTERVAL		EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	10.44	8.01	-2.73	23.61	17.91	8.70	3.60	32.22
PARTIAL	1.76	7.77	-11.02	14.53	5.94	7.90	-7.05	18.93

TABLE C-6

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NORTH CAROLINA 1974 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 6,486

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	PRE WITH PRE %	PRE WITH POST N	PRE WITH POST %	POST WITH POST N	POST WITH POST %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	805	12.4	2491	38.4	1877	28.9	5173	79.8
REDUCED LIGHT	236	3.6	618	9.5	459	7.1	1313	20.2
COLUMN TOTALS	1041	16.0	3109	47.9	2336	36.0	6486	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	PRE-STANDARD %	POST-STANDARD N	POST-STANDARD %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	3460	18.0	4517	23.5	7977	41.5
REDUCED LIGHT	4479	23.3	6769	35.2	11248	58.5
COLUMN TOTALS	7939	41.3	11286	58.7	19225	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	16.59	7.56	4.15	29.02	37.76	6.74	26.67	48.84
PARTIAL	15.38	7.34	3.30	27.45	26.90	6.69	15.89	37.91

TABLE C-7

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NORTH CAROLINA 1975 DATA (OBSERVED, NOT ADJUSTED)

Total Cases = 6,974

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	PRE WITH PRE %	PRE WITH POST N	PRE WITH POST %	POST WITH POST N	POST WITH POST %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	677	9.7	2531	36.3	2431	34.9	5639	80.9
REDUCED LIGHT	169	2.4	590	8.5	576	8.3	1335	19.1
COLUMN TOTALS	846	12.1	3121	44.8	3007	43.1	6974	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	PRE-STANDARD %	POST-STANDARD N	POST-STANDARD %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	2926	15.1	5166	26.6	8092	41.7
REDUCED LIGHT	3974	20.5	7329	37.8	11303	58.3
COLUMN TOTALS	6900	35.6	12495	64.4	19395	100.0

TYPE OF EFFECTIVE-NESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	5.08	9.29	-10.20	20.37	13.01	10.01	-3.45	29.47
PARTIAL	6.62	9.11	-8.37	21.61	10.60	9.12	-4.40	25.61

TABLE C-8

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING TEXAS 1972 DATA (SMOOTHED, ADJUSTED)

Total Cases = 34,011

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	9513	28.0	13141	38.6	5174	15.2	27828	81.8
REDUCED LIGHT	2375	7.0	2776	8.2	1032	3.0	6183	18.2
COLUMN TOTALS	11888	35.0	15917	46.8	6206	18.2	34011	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	26287	29.6	15985	18.0	42272	47.6
REDUCED LIGHT	29023	32.7	17488	19.7	46511	52.4
COLUMN TOTALS	55310	62.3	33473	37.7	88783	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS		95% CONFIDENCE INTERVAL		AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	20.11	3.28	14.71	25.51	18.63	4.03	12.00	25.27
PARTIAL	15.39	2.63	11.07	19.70	14.61	2.90	9.83	19.38

TABLE C-9

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING TEXAS 1973 DATA (SMOOTHED, ADJUSTED)

Total Cases = 34,255

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	PRE WITH PRE %	PRE WITH POST N	PRE WITH POST %	POST WITH POST N	POST WITH POST %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	6637	19.4	13619	39.8	7900	23.1	28156	82.2
REDUCED LIGHT	1562	4.6	2915	8.5	1622	4.7	6099	17.8
COLUMN TOTALS	8199	23.9	16534	48.3	9522	27.8	34255	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	PRE-STANDARD %	POST-STANDARD N	POST-STANDARD %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	22912	25.1	20303	22.2	43215	47.3
REDUCED LIGHT	25619	28.1	22450	24.6	48069	52.7
COLUMN TOTALS	48531	53.2	42753	46.8	91284	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	12.76	3.42	7.14	18.38	10.79	4.22	3.85	17.74
PARTIAL	9.05	3.16	3.85	14.25	8.03	3.42	2.41	13.66

TABLE C-10

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING TEXAS 1974 DATA (SMOOTHED, ADJUSTED)

Total Cases = 30,545

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	3937	12.9	11711	38.3	9362	30.6	25010	81.9
REDUCED LIGHT	996	3.3	2657	8.7	1882	6.2	5535	18.1
COLUMN TOTALS	4933	16.1	14368	47.0	11244	36.8	30545	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	17515	20.9	20980	25.1	38495	46.0
REDUCED LIGHT	20438	24.4	24740	29.6	45178	54.0
COLUMN TOTALS	37953	45.4	45720	54.6	83673	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT)							
	BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE				AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE			
	EFFECTIVENESS		95% CONFIDENCE INTERVAL		EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	20.54	3.46	14.84	26.23	22.19	4.02	15.57	28.81
PARTIAL	10.32	3.72	4.20	16.44	11.26	3.88	4.87	17.64

TABLE C-11

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NEW YORK 1974 DATA (SMOOTHED, ADJUSTED)

Total Cases = 17,566

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	%	PRE WITH POST N	%	POST WITH POST N	%	ROW TOTALS N	%
DAYLIGHT	1603	9.1	5769	32.8	5287	30.1	12659	72.1
REDUCED LIGHT	715	4.1	2378	13.5	1814	10.3	4907	27.9
COLUMN TOTALS	2318	13.2	8147	46.4	7101	40.4	17566	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	%	POST-STANDARD N	%	ROW TOTALS N	%
DAYLIGHT	9778	19.9	16532	33.7	26310	53.6
REDUCED LIGHT	8805	17.9	13961	28.4	22766	46.4
COLUMN TOTALS	18583	37.9	30493	62.1	49076	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	23.08	4.05	16.42	29.73	12.54	5.64	3.26	21.81
PARTIAL	7.59	4.73	-0.19	15.37	1.46	5.37	-7.37	10.28

TABLE C-12

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NORTH CAROLINA 1973 DATA (SMOOTHED, ADJUSTED)

Total Cases = 6,249

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	%	PRE WITH POST N	%	POST WITH POST N	%	ROW TOTALS N	%
DAYLIGHT	1139	18.2	2444	39.1	1413	22.6	4996	79.9
REDUCED LIGHT	302	4.8	626	10.0	325	5.2	1253	20.1
COLUMN TOTALS	1441	23.1	3070	49.1	1738	27.8	6249	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	%	POST-STANDARD N	%	ROW TOTALS N	%
DAYLIGHT	4301	21.5	4447	22.2	8748	43.7
REDUCED LIGHT	5429	27.1	5863	29.3	11292	56.3
COLUMN TOTALS	9730	48.6	10310	51.4	20040	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	13.25	7.75	0.50	26.01	20.48	8.42	6.63	34.34
PARTIAL	3.40	7.61	-9.13	15.92	7.51	7.74	-5.22	20.25

TABLE C-13

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NORTH CAROLINA 1974 DATA (SMOOTHED, ADJUSTED)

Total Cases = 6,487

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS: PRE WITH PRE N	PRE WITH PRE %	PRE WITH POST N	PRE WITH POST %	POST WITH POST N	POST WITH POST %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	808	12.5	2491	38.4	1875	28.9	5174	79.8
REDUCED LIGHT	233	3.6	619	9.5	461	7.1	1313	20.2
COLUMN TOTALS	1041	16.0	3110	47.9	2336	36.0	6487	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS: PRE-STANDARD N	PRE-STANDARD %	POST-STANDARD N	POST-STANDARD %	ROW TOTALS N	ROW TOTALS %
DAYLIGHT	3460	18.0	4517	23.5	7977	41.5
REDUCED LIGHT	4479	23.3	6769	35.2	11248	58.5
COLUMN TOTALS	7939	41.3	11286	58.7	19225	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT) — BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO	AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE: EFFECTIVENESS VALUE	STD. DEV.	95% CONFIDENCE INTERVAL FROM	TO
FULL	14.74	7.75	1.99	27.48	36.38	6.90	25.03	47.73
PARTIAL	13.83	7.50	1.49	26.16	25.56	6.83	14.32	36.80

TABLE C-14

SUMMARY OF FMVSS 108 EFFECTIVENESS STUDY USING NORTH CAROLINA 1975 DATA (SMOOTHED, ADJUSTED)

Total Cases = 6,974

LIGHT CONDITION	DISTRIBUTION OF ANGLE COLLISIONS — PRE-POST MIX OF VEHICLES IN ACCIDENTS							
	PRE WITH PRE		PRE WITH POST		POST WITH POST		ROW TOTALS	
	N	%	N	%	N	%	N	%
DAYLIGHT	674	9.7	2531	36.3	2434	34.9	5639	80.9
REDUCED LIGHT	172	2.5	590	8.5	573	8.2	1335	19.1
COLUMN TOTALS	846	12.1	3121	44.8	3007	43.1	6974	100.0

LIGHT CONDITION	DISTRIBUTION OF SINGLE VEHICLE ACCIDENTS					
	PRE-STANDARD		POST-STANDARD		ROW TOTALS	
	N	%	N	%	N	%
DAYLIGHT	2926	15.1	5166	26.6	8092	41.7
REDUCED LIGHT	3974	20.5	7329	37.8	11303	58.3
COLUMN TOTALS	6900	35.6	12495	64.4	19395	100.0

TYPE OF EFFECTIVENESS	EFFECTIVENESS VALUES (PERCENT)							
	BEFORE CONTROLLING FOR SINGLE VEHICLE EXPOSURE				AFTER CONTROLLING FOR SINGLE VEHICLE EXPOSURE			
	EFFECTIVENESS		95% CONFIDENCE INTERVAL		EFFECTIVENESS		95% CONFIDENCE INTERVAL	
	VALUE	STD. DEV.	FROM	TO	VALUE	STD. DEV.	FROM	TO
FULL	7.75	8.99	-7.03	22.54	15.45	9.69	-0.49	31.40
PARTIAL	8.65	8.87	-5.94	23.24	12.55	8.88	-2.06	27.16