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STATISTICAL EVALUATION OF THE EFFECTIVENESS OF FEDERAL MOTOR VEHICLE SAFETY STANDARD 222: SCHOOL BUS SEATING AND CRASH PROTECTION

Report No. 6 of 7

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FINAL REPORT

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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 222 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 on the statistical evaluation of Federal Motor Vehicle Safety Standard (FMVSS) 222: School Bus Seating and Crash Protection. It is one of seven statistical evaluations 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 222 is a death-and-injury reduction Standard which includes the structural strength of the seating system, padding and provision of restraining barriers. In the case of small buses under 10,000 lb gross vehicle weight, it requires passenger restraints for each seating position. This Standard became effective 1 April 1977.

A clinical analysis has been performed of 56 nonfatal and 26 fatal multidisciplinary school bus accident investigation (MDAI) reports spanning 1970 through 1978. Estimates of reductions in injury severity have been made by the Clinical Analysis Team. These reports were coupled with an analysis of National Safety Council information and 60 Fatal Accident Reporting System school bus accident reports for 1975-1978 to make the following estimate of the effectiveness of FMVSS 222.

- 65 percent of the injuries in the 2800 nonfatal school bus accidents annually would be reduced to no injury.
- 4 percent of the more severe injuries in nonfatal school bus accidents would be reduced by at least one Overall Abbreviated Injury Scale (OAIS) level.
- 7 percent of the fatalities would be averted in the average of 15 or so fatal school bus accidents annually.
- 17 percent of the fatal and injured passengers in fatal accidents would be reduced to no injury.
- 29 percent of the fatal and injured passengers in fatal accidents would have their injuries reduced at least one OAIS level (includes those reduced to No Injury).

In summary, when all school buses in the U.S. meet the requirements of FMVSS 222, it is estimated that about 69 percent of the 3900 injuries will be reduced in about 2800 nonfatal accidents/year and in the average 15 fatal accidents/year, about 29 percent of the 173 killed and injured will have their injuries reduced.

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METRIC CONVERSION FACTORS

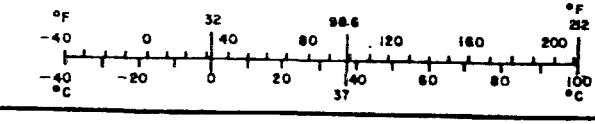
Approximate Conversions to Metric Measures

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	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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

Approximate Conversions from Metric Measures

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



EXECUTIVE SUMMARY

This is the final report of the statistical evaluation of the effectiveness of Federal Motor Vehicle Safety Standard (FMVSS) 222: School Bus Seating and Crash Protection.

FMVSS 222 is a death-and-injury-reduction Standard which includes the structural strength of the seating system, padding and provision of restraining barriers. In the case of small buses under 10,000 lb gross vehicle weight, it requires passenger restraints for each seating position. This Standard became effective 1 April 1977.

The objective of this analysis is to study fatality and injury mechanisms in a very limited set of reported accidents involving school buses. Detailed Multidisciplinary Accident Investigation (MDAI) reports on 82 school bus accidents have been clinically evaluated. In addition, 60 Fatal Accident Reporting System (FARS) school bus accidents have also been analyzed; National Safety Council data and 18 months of Connecticut school bus accident data (1007 cases) also have been used.

The purpose of the evaluation is to develop a better understanding of the characteristics of deaths and injuries in Pre-Standard school bus accidents reported by MDAI, and to infer the reductions in deaths and injuries that might occur in similar Post-Standard school bus accidents.

Reductions of death-and-injury due to FMVSS 222 are based on estimates made by a Clinical Analysis Team, rather than a statistical analysis of historical data. Within the restrictions of these caveats, estimates of the effectiveness of FMVSS 222 have been made separately for nonfatal and fatal school bus accidents.

The Clinical Analysis Team estimated reduction of injury severity for 56 nonfatal and 26 fatal MDAI school bus accident reports spanning 1970 through 1978. These results were coupled with an analysis of National Safety Council information covering 16 years and 60 FARS fatal school bus accident reports for 1975 through 1978 to make the following estimates of the effectiveness of FMVSS 222, assuming average annual conditions:

- 65 percent (2524) of the approximately 3900 injuries that occur in about 2800 nonfatal school bus accidents annually would be reduced to No Injury.

- 4 percent (168) of the more severe injuries in nonfatal school bus accidents would be reduced to less severe injuries by at least one OAIS level.
- Overall, 69 percent (2692) of the 3900 injuries in nonfatal school bus accidents would be reduced to a less severe injury or to No Injury.
- 7 percent (2) of the 27 fatalities would be averted in the 15 or so fatal school bus accidents that occur annually, on the average.
- 17 percent (30) of the average of 173 fatal and injured passengers in fatal accidents would be reduced to No Injury.
- Overall, 29 percent (51) of the 173 fatal and injured passengers in fatal accidents would have their injuries reduced at least one OAIS level (includes lives saved and reductions to No Injuries).

These effectiveness estimates are based on consideration of 719 passengers injured in 56 nonfatal MDAI school bus accidents and 83 passengers killed and 490 passengers injured in 26 fatal MDAI school bus accidents. From National Safety Council information, it has been estimated that annually there are about 3900 passengers injured in approximately 2800 passenger-injury nonfatal school bus acidents. About three-fourths of these accidents are believed to involve injury to only one passenger, and about 97 percent probably involve injury to three or less passengers. We estimate that about 89 percent of all injuries in nonfatal school bus acidents are OAIS 1 and about 10 percent are OAIS 2. In other words, serious injuries (OAIS 3, 4) in nonfatal school bus accidents are extremely rare events, occurring in less than one percent of such accidents. Conversely, about 99 percent of the injuries are presently minor or moderate (OAIS 1,2) and FMVSS 222 is most effective in reducing these. We estimate that about 69 percent (2692) of the estimated 3876 OAIS 1 and 2 annual injuries in nonfatal school bus accidents would be reduced to No Injury (65%) or from OAIS 2 to OAIS 1 (4%).

It is recognized that the above estimates show a large degree of effectiveness of FMVSS 222, and that these estimates are based on a small number of MDAI cases, and a strong assumption concerning the minor nature of most school bus accidents, inferred from very limited

National Safety Council information. To add further credibility to the findings of this study, CEM reviewed all of the 1007 hardcopy school bus accident reports in Connecticut, covering 1978 and the first half of 1979 (18 months). Of the 1007 school bus accidents in that 18-month period, only 46 involved injuries to passengers. In three cases, injury levels were not recorded, and in the other 43 cases, there were 126 C injuries and 82 B injuries. During the period reviewed, the passengers in injury-producing crashes sustained no serious (A-level)injuries or fatalities. No school bus passengers have been killed in Connecticut, since sometime prior to 1974. All buses involved in injury crashes were Pre-Standard, although all had limited amounts of add-on seat frame top padding, as required by Connecticut law.*

While recognizing that this detailed analysis of a limited sample of Connecticut school bus accidents is insufficient to draw a statistically significant conclusion about the correctness of the estimated distribution of passenger injury severity in nonfatal school bus accidents used in this study (Table 3-23), it can be stated that the findings of the analysis of 18 months of Connecticut school bus accidents strongly support the major assumption which led to the estimate, namely, the contention that only an extremely few school bus accidents produce serious injuries or fatalities. The analysis of Connecticut data lends an added degree of credibility to the estimates of the effectiveness of FMVSS 222.

Of the 26 fatal MDAI cases reviewed by the Clinical Analysis Team, 17 are also found among the 60 FARS cases for 1975 through 1978, which were analyzed by CEM. FARS contains 107 fatalities and 583 injuries among 969 passengers in 60 fatal school bus crashes, providing annual averages of 27 fatalities, 146 injured, and 70 uninjured passengers in 15 fatal school bus accidents per year. Comparative analysis of MDAI and FARS data indicated close correlation in the distribution of nonfatal injuries, indicating that clinical analysis estimates of injury reductions due to FMVSS 222 could be applied directly to FARS

*While all Connecticut school buses were pre-1977 models, and hence Pre-FMVSS 222, Connecticut school bus safety standards for seat frame padding were first imposed in 1974, and required retrofitting. In July 1977, Connecticut made its standards match FMVSS 222.

data (which are descriptive of fatal school bus accidents for the entire U.S.), with the effectiveness results indicated above. Because more than one-fourth of the FARS cases (17 of 60) had detailed MDAI reports which were also analyzed by the Clinical Analysis Team, it is judged that the extrapolation to national figures for fatal school bus accidents is quite credible.

This study shows that the seat back padding, higher seat backs, closer seats, stronger seat floor supports and seat frames, and the other requirements of FMVSS 222 are probably very effective (about 69 percent injury reduction) in the vast majority of school bus accidents, which usually involve minor damage to the bus, with at most a few passengers injured at the level of OAIS 1 or 2. In the few violent school bus accidents that produce fatalities, FMVSS 222 has lower effectiveness--about 29 percent injury reduction. The Standard has only limited effectiveness in the extremely small subset of very violent accidents involving rollover, crashes with trains, etc. where passengers are thrown into contact with each other, and/or forceably come into contact with broken glass, walls, roof, and other interior objects (which are not covered by the Standard), or are ejected from the bus. Due to the passenger restraints required by the Standard in vehicles under 10,000 lb, which are used as school buses, an estimated 2 lives per year will be saved, on average, assuming that all small school transportation vehicles have passenger restraints and they are used.

ACKNOWLEDGMENTS

The work being performed by CEM in evaluating the effectiveness of seven Federal Motor Vehicle Safety Standards is the product of an interdisciplinary team effort.

Dr. Philip Stent, Director of Ambulatory Services at St. Francis Hospital, Hartford, Connecticut, and Consultant to CEM, provided all medical judgments. Mr. Edward Sweeton, mechanical engineer and systems analyst, recreated crash dynamics, occupant kinematics,and hypothetically imposed required characteristics of FMVSS 222. Dr. Gaylord Northrop, Principal Investigator, developed the clinical analysis framework and participated in the judgment process. Ms. Kayla Costenoble assembled and analyzed the results.

We wish to gratefully acknowledge the other Study Team members who made contributions to this report. They are: Dr. Hans Joksch, Mr. Joseph Reidy, and Ms. Shirley Whyte. Mr. John O'Connell and Mr. Edward Prytko, of the Connecticut Department of Motor Vehicles, made available their school bus accident report files.

In addition, we note our appreciation to Ms. Grace Hazzard of NHTSA for her outstanding effort in providing MDAI and FARS data, and to Dr. Charles Kahane, the NHTSA Contract Technical Manager, for his guidance and assistance throughout this study. Any errors in analysis or interpretation of data and results are, of course, solely the responsibility of the authors of this report.

TABLE OF CONTENTS

TABLE OF CONTENTS

Appendixes

ABBREVIATIONS USED

CEM	The Center for the Environment and Man, Inc.
FMVSS	Federal Motor Vehicle Safety Standard
MDAI	Multidisciplinary Accident Investigation
NASS	National Accident Sampling System
HSRC	Highway Safety Research Center (University of North Carolina)
NHTSA	National Highway Traffic Safety Administration
GVWR	Gross Vehicle Weight Rating
OAIS	Overall Abbreviated Injury Scale
NCS	National Safety Council
FARS	Fatal Accident Reporting System

NF	Nonfatal
F	Fatal
BO	Bus Only
RE	Rear-End
FR	Front-Rear
FS	Front-Side
SS	Side-Swipe
SC	Side Coll
HO	Head-On
RO	Rollover

CEM-Devised Bus Accident Categories

(An "F" preceding these designations indicates that one of the school bus occupants [driver or passenger(s)] was fatally injured.)

1.0 INTRODUCTION

1.1 Background

This is the sixth in a series of reports of the statistical evaluation of the effectiveness of seven Federal Motor Vehicle Safety Standards (FMVSS). This work was 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 Seating Systems
- FMVSS 214: Side Door Beams
- FMVSS 222: School Bus Seating and Crash Protection
- FMVSS 301: Fuel System Integrity

The Final Report for FMVSS 222 (School Bus Seating and Crash Protection) is presented herein.

The School Bus Seating and Crash Protection Standard is one of a group of school bus Standards, which include FMVSS 220 (Rollover Protection) and FMVSS 221 (Body Joint Strength). These Standards were developed by NHTSA and first published in *The Federal Register* from February through October 1975, in response to the Congressional mandate of the Motor Vehicle and School Bus Safety Amendments of 1974. The scheduled effective date was 26 October 1976, but this was later revised to 1 April 1977. FMVSS 222 is a death-and-injury-reduction Standard which covers the structural strength of the seating system, spacing of seats, padding, and provision of restraining barriers; and, in the case of small buses, it requires passenger restraints for each sitting position, but relaxes the seat spacing requirement.

The requirements imposed by FMVSS 222 differ for buses over and under a Gross Vehicle Weight Rating (GVWR) of 10,000 pounds. All school buses manufactured after April 1, 1977, with a GVWR greater than 10,000 pounds must meet the following requirements.

- Passenger seats must face forward.
- Seat back height must be 20 inches and the seat back width must be at least 90 percent of the bench width.
- Under a specified forward force, the seat back forward deflection must not exceed 14 inches or not deflect to within 4 inches of another passenger or restraining barrier. The seat must not separate from the vehicle at any attachment point and the seat components must not separate from the seat at any attachment point.

- Under a specified rearward force, the seat must not deflect to within 8 inches of any part of another passenger seat; the seat must not separate from the vehicle at any attachment point; and the seat components will not separate from the seat at any attachment point.
- If the rear surface of another seat is not within 20 inches forward of any seating reference point, a restraining barrier within 20 inches of the reference point must be provided. Performance of this barrier under a specified load in a forward direction must be the same as the seat requirements.
- In a specified head protection zone, any contactable surface impacted by a head form at a specified velocity must not produce coaxial acceleration at the center of gravity of the head form greater than a specified maximum.
- In a specified knee protection zone, the impact of a knee form at a specified velocity on a seat back or barrier must not produce a resulting force of the impacted material greater than a specified maximum.

School buses with a GVWR less than 10,000 pounds must meet all of the above requirements except the 20 inch maximum distance between the seating reference point and seat back or barrier in front of it. In addition, these lighter buses must meet the requirements of those regulations on vehicle restraints: FMVSS 208 (Seat Belt Installations), FMVSS 209 (Seat Belt Assemblies) and FMVSS 210 (Seat Belt Assembly Anchorages). Compliance with these requirements is accomplished with either an automatic restraint system or a manual seat belt system. If a seat belt system is used, either lap or lap and shoulder belts may be used at the designated occupant seating positions other than the outboard positions in the front seat.

There are four general means of complying with the requirements of FMVSS 222 for buses with a GVWR of more than 10,000 pounds. They are:

- Repositioning seats so that the rear surface of another passenger seat is no more than 20 inches from the seating reference point.
- Installing a restraining barrier no more than 20 inches from the seating reference point.
- Installing additional seat padding.
- Redesigning seat support and seat structure to meet loading requirements.

1.2 Objective and Purpose

The objective of this analysis is to study fatality and injury mechanisms in a limited set of reported school bus accidents. Detailed Multidisciplinary Accident Investigation (MDAI) reports on school bus accidents have been clinically evaluated.

The purpose of the evaluation is to develop a clear understanding of the characteristics of deaths and injuries in Pre-Standard school bus accidents reported by MDAI, and to infer the reductions in deaths and injuries that might occur in similar Post-Standard school bus accidents. The study was undertaken in response to the complete evaluation program for FMVSS 222 which is described in References 1 and 2.

1.3 Scope

- This analysis of FMVSS 222 was limited to clinical analysis of detailed MDAI reports on accidents involving school buses.
- Because all of the available MDAI reports involve Pre-Standard school buses, the clinical analysis considered the characteristics of injury severity as a function of accident conditions in Pre-Standard school buses.
- The clinical analysis included subjective estimates ("extrapolations") made by the clinicians concerning the reduction in injury severity (if any) the school bus passengers would have incurred had the requirements of FMVSS 222 been met.
- The Task 2 Preliminary Report on FMVSS 222 concentrates on establishing the characteristics of injury severity in Pre-Standard and Post-Standard school buses.
- This Task 3 Final Report is based on clinical analysis of 82 MDAI school bus accident reports: 56 nonfatal school bus crashes involving 1688 passengers (719 injured) and 26 fatal school bus crashes involving 712 passengers (490 injured; 83 killed).
- To make an extrapolation of the clinical analysis results to the nation, school bus passenger injury information from *Accident Facts* has been used. To test the credibility of school bus passengers in injury distributions derived from the limited *Accident Facts* information, 1007 Connecticut school bus accident hard copy reports for 1978 and the first half of 1979 were reviewed and analyzed, resulting in the findings that only 46 cases (4.6 percent) involved passenger injury, and that among the 43 cases where injury levels were given, there were no fatalities or A injuries, and 82 B and 126 C injuries.
- FARS data for 1975, 1976, 1977 and 1978 has been analyzed to provide additional information for extrapolating the clinical analysis of fatal MDAI school bus accidents to the nation.

1.4 Approach

1.4.1 Data Source

Because of the comparatively recent effective date of FMVSS 222 (April 1, 1977), and because school bus accidents in which passengers are killed or injured are comparatively rare (about 2800 in the nation on the average in 1975, 1976, and 1977), there is a pronounced lack of Pre- and Post-Standard crash data which would allow the conventional "before *vs.* after" comparative analysis of the effect of implementing the Standard. Alternatively, since most of the crash data available involves vehicles manufactured prior to implementation of the Standard, it is necessary to use this information in a clinical fashion, where the individual deaths and injuries in each accident may be investigated and some relationship established between their causes and the requirements of the Standard, as demonstrated by the degree to which the involved school buses do or do not comply with these requirements. In order to conduct this type of investigation, a precisely detailed accident report is required which will provide the necessary information regarding the type of injuries and their probable causes, together with a reasonably accurate reconstruction of events during the crash.

Accident reports prepared by state and municipal police ordinarily do not contain this type of detail and, hence, are inadequate. The purpose of the Multidisciplinary Accident Investigation program of the National Highway Traffic Safety Administration is to conduct detailed, in-depth investigations of certain accidents which, to a limited degree, are representative of all accidents and provide the highway safety community more expert analysis and detailed information in these reports than can be found elsewhere. MDAI reports on school bus accidents comprise the data base used for this clinical evaluation of FMVSS 222. However, Fatal Accident Reporting System (FARS) and Connecticut school bus accident data have also been used in ancillary analyses.

1.4.2 Population of MDAI School Bus Accident Reports

Since the MDAI program began in 1969, there have been more than 20 special investigating teams located around the country. These teams have amassed more than 9,000 vehicle reports. Among these are approximately 120 reports on school bus accidents. All of these reports were ordered by CEM from a variety of sources. A preliminary investigation of the available reports revealed that only about 82 would be applicable for this analysis; these form the basis for this analysis. Thirty-eight of the 120 reports are considered inapplicable for the following reasons:

- No injuries or fatalities were involved.
- The bus driver was the only occupant killed or injured.
- No data were given on bus passengers because the bus was not the "case" vehicle or the data were simply missing.
- The bus essentially met all aspects of the Standard (one bus only).

To facilitate its analysis, CEM divided all MDAI school bus accidents into two categories: (1) those which involved nonfatal injuries only, and (2) those which involved both nonfatal injuries and fatalities.* In addition, accidents were ranked by type, with the "easier-to-analyze" accidents first. All bus accidents in each category are arranged as follows (easiest to most difficult to analyze).

• BO:	Bus Only	Bus is only moving vehicle involved.
• RE:	Rear-End	Bus hit in rear by another vehicle.
• FR:	Front-Rear	Bus hits another vehicle in the rear.
• FS:	Front-Side	But hits another vehicle in the side.
• SS:	Side-Swipe	Bus side-swiped by another vehicle.
• SC:	Side Collision	Bus hit in side by another vehicle
• HO:	Head-On.	Bus and another vehicle hit head-on.
• RO:	Rollover.	Bus rolls over.

*The reason for this division is to separate out those more violent accidents where the overall contributions of FMVSS 222 features may be small, relative to other injury-causing elements. A school bus accident was considered fatal if one or more passengers were killed, or the driver was killed and there were passengers on the bus. We did not analyze cases in which the driver was killed and was the only occupant of the school bus.

1.4.3 Clinical Analysis

After screening the MDAI reports for applicability, they were initially reviewed and terse one-to-two page accident summaries were prepared. Tables were prepared for all injured or killed occupants, summarizing in a common format all applicable detailed injury cause-and-effect information. Schematics of the accident and seating charts were extracted from the report. Thus, a clinical analysis "package" was prepared for each accident, which summarized the usually voluminous MDAI reports. A selected member of the three-person Clinical Analysis Team reviewed the MDAI reports, prominently flagging all applicable information. The Team then assembled; studied the summarized accident report; discussed the accident dynamics; reviewed photographs of the accident site, in-situ crashed vehicles, bus interior and other pertinent views; and then began the process of reviewing and analyzing the injuries and causes of injury suffered by each injured occupant. To familiarize themselves with the explicit characteristics of school bus interiors, the Clinical Analysis Team twice visited school bus operators who had both Pre-Standard and Post-Standard buses. Photographs of interiors were made and used for reference during the clinical analyses. (See Appendix A.)

The Team created a scenario of the crash events that each injured passenger underwent (bus drivers have been omitted from this analysis). At that point, the medical member of the Clinical Analysis Team, Dr. Philip Stent (CEM Consultant and Director of Ambulatory Services at St. Francis Hospital in Hartford, Connecticut), made two decisions. First, a decision was made concerning the degree of injury reduction that would have occurred, had the bus met the requirements of FMVSS 222; and, second, a decision was made concerning the quality of the estimate, in terms of Good, Fair, or Poor. In general, the estimates of injury reduction were on the conservative side. For example, where little information was available, the judgment usually was, "The OAIS remains the same, and the quality of the estimate is 'Poor.'" In the majority of instances where there was an estimated reduction in injury severity, the quality of the estimate was judged to be Good or Fair.

There was one assumption made in the case of van buses, which might be open to dispute. If the van was not already equipped with passenger restraints (such as lap belts), which are required by FMVSS 222, then it was assumed that had the van been Post-Standard, it would have been equipped with lap belts, and the belts would have been used. (If there were already belts in a van, and a

belt was not used, we made our judgment on the basis that the occupant elected not to use the existing belt.) This assumption is important, because in most of the van bus cases reviewed, unbelted occupants were ejected and severely injured or killed, and the assumption that Post-Standard van buses would have belts and the belts would be used produces significant injury reductions.

1.5 Limitations of the Study

This study was not expected to provide a statistically significant evaluation of the fatal-and-injury-reduction effectiveness of FMVSS 222. MDAI data have been investigated, and it appears there are only 82 MDAI cases that are readily applicable for this analysis. To provide additional insight, 60 FARS school bus passenger fatality cases for 1975, 1976, 1977 and 1978 have been analyzed. An argument is developed in Section 3 which suggests that the FMVSS 222 effectiveness estimated for nonfatal school bus accidents may be conservative. This argument is further supported in Section 3.9.2, based on analysis of 1007 Connecticut school bus accidents in 1978 and the first half of 1979, which resulted in no fatal and 43 passenger injury accidents. All of the MDAI, FARS and Connecticut cases involve Pre-Standard school buses.

1.6 Outline of the Report

Section 2 of this report summarizes the analyses performed for FMVSS 222. It includes a discussion of the measure of effectiveness; the estimated effectiveness of the Standard; overall success of the evaluation; credibility of the analysis; additional work which could be performed in the future; and comparison of results.

In Section 3, detailed analyses of MDAI data are described, and supporting analyses of FARS and Connecticut data are presented. Appendix A contains photographs comparing the interiors of Pre and Post-Standard school buses. The other Appendixes contained detailed supporting material for the analyses described in Section 3.

1.7 References for Section 1

1. Sweeton, E.R. and G.M. Northrop. *CEM Report 4229-599: Final Design and Implementation Plan for Evaluating the Effectiveness of FMVSS 220: School Bus Rollover Protection; FMVSS 221: School Bus Body Joint Strength; FMVSS 222: School Bus Seating and Crash Protection*, DOT HS 803 394, National Technical Information Service, Springfield, Virginia, 1978.

2. Northrop, G.M., J.T. Ball, D. Bancroft and J.C. Reidy. *CEM Report 4228/4229-600: Evaluation Methodologies for Nine Federal Motor Vehicle Safety Standards: FMVSS 105, 108, 202, 207, 213, 220, 221, 222*, DOT HS 803 388, National Technical Information Service, Springfield, Virginia, 1978.

3. Sweeton, E.R. and G.M. Northrop. *CEM Report 4254-637: Work Plan for the Statistical Evaluation of the Effectiveness of FMVSS 222: School Bus Seating and Crash Protection*, The Center for the Environment and Man, Inc., Hartford, Connecticut, December 1978. (Contract DOT-HS-8-02014).

2.0 SUMMARY OF ANALYSES PERFORMED FOR FMVSS 222

2.1 Measure of Effectiveness

The measure of effectiveness chosen for evaluating FMVSS 222 is reduction in fatalities and injury severity. These two aspects of the measure--reduction in injury severity in nonfatal school bus accidents and reduction in death and injuries in fatal school bus accidents--are treated separately in this report.

2.2 Estimated Effectiveness of FMVSS 222

FMVSS 222 sets standards for:

- Buses of Gross Vehicle Weight greater than 10,000 lb:
  - Padding of seats
  - Padding of stanchions and modesty shields
  - Seat backs and frame strength
  - Seat cushion/seat frame integrity
  - Spacing between seats
- Buses of Gross Vehicle Weight less than or equal to 10,000 lb:
  - Same as above, with the exception of spacing between seats, plus
  - Passenger restraints as required under FMVSS 208, 209 and 210.

Intuitively, one would anticipate that FMVSS 222 would be most effective in reducing minor injuries (OAIS 1 and 2)to lower levels, in instances where the school bus is large ($\geq$10,000 lb) and the school bus accident is not severe, and the bus remains upright. FMVSS 222 would not be particularly effective in reducing fatalities and less effective in reducing the severity of injuries in fatal school bus accidents, because the fatal accidents usually are quite violent and often involve rollover, which means the passengers are thrown about striking objects (walls, ceilings, etc.) that are not covered by FMVSS 222.

In the case of small buses(<10,000 lb)--especially van-type buses--intuition would suggest that the padding and seat strength characteristics in minor or moderate accidents might have slightly less effect, because there is not the added requirement of a maximum spacing (no more than 20 inches from the seating reference point to the near surface of another passenger seat). This can result in more space between seats, which affords more opportunity for passengers to slide over against walls, out into the aisle, or onto the floor between seats. Also, van vehicles are often relatively light and have high centers-of-gravity (particularly when loaded with passengers in seats), which increases skidding and rolling tendencies. However, since the Standard requires that small buses have restraints for passengers (at a minimum, lap belts), and assuming

these belts are used, it is clear that ejection from violent small bus accidents would be reduced and the Standard may be effective in reducing fatalities in small bus accidents.

2.3 Effectiveness of FMVSS 222 in Nonfatal School Bus Accidents

In this study, we have used the results of the clinical analysis of nonfatal school bus accidents as a basis for a set of approximate distributions of injury in nonfatal accidents where 1, 2, 3, 4, or 5 or more passengers are injured. The National Safety Council's annual *Accident Facts* suggests there were, on the average for 1975, 1976, and 1977, about 3900 passengers injured in about 2769 nonfatal school bus accidents, i.e., about 1.4 injured passengers per accident. For such a low accident rate, it follows that most nonfatal school bus accidents involve only one injured passenger (i.e., about 74 percent). This further suggests that most of the injuries are minor, because there is a high probability that the bus had more than one passenger, and it is unlikely that only one passenger of among 20 to 30 would be severely injured. We assumed the distribution of injury levels in the 56 nonfatal MDAI cases reviewed by the Clinical Analysis Team would fit those cases where 5 or more passengers were injured in an accident. Other national distributions were estimated for the situations in which 4, 3, 2, and 1 passengers are injured (see Table 3-23). While such assumptions may appear rash, in fact, they are not, because if 86 percent of the injuries are OAIS 1 in accidents where 5 or more passengers are injured, then somewhere between 86 percent and 100 percent must be OAIS 1 in accidents where only one passenger is injured, because there is a positive correlation between injury severity and number of passengers injured. Furthermore, if 86 percent of the injuries are OAIS 1 and 12 percent of the injuries are OAIS 2, and 1 percent are each OAIS 3 and OAIS 4 in nonfatal accidents where 5 or more passengers are injured, then some relationship such as 90 percent OAIS 1, 9.7 percent OAIS 2, and 0.3 percent OAIS 3 appears "rational," simply because we know the OAIS 1 portion must be greater than 86 percent and the OAIS 2 portion must be less than 12 percent, etc. There are an infinite set of numbers that would satisfy these distributions, even after constraints are applied, but none of them differs significantly from those chosen and shown in Table 3-23.

Once these distributions are selected, it is possible to determine on a national basis the approximate number of OAIS 1, 2, 3, and 4 injuries and apply the reductions in injury levels estimated by the Clinical Analysis Team. These calculations result in the following effectiveness factors for passengers injured in nonfatal school bus accidents.

- 65 percent of the Pre-Standard injuries would be reduced to No Injury (OAIS 0) in Post-Standard school buses.
- 4 percent (additional) of the Pre-Standard injuries would be reduced at least one OAIS level in Post-Standard school buses.

Thus, 69 percent of all passengers injured in Pre-Standard school buses in nonfatal accidents would derive some injury reduction benefit, if all school buses met the requirements of FMVSS 222. This amounts to about 2700 out of 3900 injured passengers per year who would benefit. Of these, nearly 2500 per year would receive no injury at all.

From this analysis, we conclude that FMVSS 222 is quite effective in most nonfatal school bus accidents, especially those in which three or fewer passengers are injured, which we estimate occurs in about 96 percent of the approximately 2800 nonfatal school bus accidents per year. The estimated number of passengers injured nationwide in nonfatal school bus accidents is shown in Table 2-1, assuming all buses are Pre-Standard or Post-Standard. It can be seen that 65 percent of the injuries would be prevented, if all school buses in the nation met the requirements of FMVSS 222. As noted above, an additional 4 percent of all injured passengers would have had their OAIS 2, 3, or 4 injuries reduced at least one OAIS level. Thus, a total of 69 percent of all injured passengers in nonfatal school bus accidents would benefit, if all school buses in the nation satisfied FMVSS 222.

TABLE 2-1

COMPARISON OF ESTIMATED PASSENGER INJURIES
IN NONFATAL SCHOOL BUS ACCIDENTS IN THE U.S.
ASSUMING ALL BUSES ARE PRE-STANDARD OR POST-STANDARD

OAIS Injury Level	Number of Injured Passengers		Number of Passengers Having Injuries Prevented
	All Buses Pre-Standard	All Buses Post-Standard	
1	3476	1280	2196
2	400	82	318
3	18	12	6
4	6	2	4
Total	3900	1376	2524
Percent of Pre-Standard	*100*	*35.3*	*64.7*

2.4 Effectiveness of FMVSS 222 in Fatal School Bus Accidents

In this analysis, a fatal school bus accident is defined as one involving the death of the driver and the presence of passengers and/or the death of one or more passengers. Accidents in which the driver is killed and is the only occupant are excluded. As part of this study, in addition to 26 fatal MDAI cases, we have analyzed the fatal school bus accidents available in FARS for 1975 through 1978--a total of 60 accidents.* On the average, there are annually throughout the U.S.:

- 15 fatal school bus accidents
- 242 passengers
- 27 fatalities
- 146 injuries

As was the case with nonfatal school bus accidents, the 26 fatal MDAI cases reviewed by the Clinical Analysis Team were, on the average, somewhat more violent than the fatal accidents in FARS. A comparison of killed, injured, and uninjured in MDAI and FARS fatal school bus accidents is shown in Table 2-2. Note that 17 of the 26 MDAI cases are included in the 60 FARS cases.

TABLE 2-2

COMPARISON OF MDAI AND FARS FATAL SCHOOL BUS ACCIDENTS

Passenger Injury Level	60 FARS Cases			26 MDAI Cases		
	Number	% Total	% K + I	Number	% Total	% K + I
K	107	*11*	*16*	83	*12*	*14*
A	203	*21*	*29*	178	*25*	*31*
B	257	*27*	*37*	221	*31*	*39*
C	123	*13*	*18*	91	*13*	*16*
0	279	*29*		139	*19*	
Total	969	*100*	*100*	712	*100*	*100*

The table above shows that the MDAI cases involve more killed and A level injuries, and fewer uninjured than are found in the FARS cases. However, an important feature of the table is the comparison of K, A, B, C proportions, based on K+I. Clearly, the distribution of injuries is very similar, suggesting that on the average, in fatal school bus accidents the distribution of injury levels is essentially constant, independent of the number of people killed.

In general, it is rare for more than three passengers to be killed in a school bus accident (see Table 3-18 and Figure 3-4). In FARS, 58 percent of the 60 fatal school bus accidents resulted in only one passenger death; 78 percent

*Actually, there were 59 fatal school bus accidents in FARS at the time of our analysis. We found one 1976 MDAI case which was not in FARS. We added it to our own FARS data, and informed Ms. Grace Hazzard of its omission from FARS. We expect it will soon be added to FARS.

involved three or fewer passenger deaths; and in 17 percent the driver was the only fatality although passengers were injured in 9 of the 10 cases in this category. This leaves about 5 percent (3 cases) of the accidents in which there were more than three passenger fatalities (they included 5, 8, and 29 deaths).

As further corroboration of this observation, in the MDAI cases, 85 percent involved three or fewer passenger fatalities, although there were proportionately more 2 and 3 fatality accidents than in FARS. The remaining 15 percent (4 cases), in which there were more than three passenger fatalities, involved 5,8,9, and 29 deaths. (The 8 and 29 death cases were common to both MDAI and FARS.) Appendix C illustrates these comments graphically.

The observation of close similarity between injury level distributions in FARS and MDAI suggests that FARS data can be used as a national basis, and the injury level reductions, estimated for the 26 MDAI cases by the Clinical Analysis Team, can be used directly on the average conditions based on FARS. The results are shown in Table 2-3 on the next page (which is a duplication of Table 3-32).

Table 2-3 combined with results derived from Table 3-7 indicates that in an average year, if all school buses met the requirements of FMVSS 222, then the effectiveness of FMVSS 222 in fatal school bus accidents would result in:

- 2 lives saved: a reduction in deaths of 7 percent. (This would be due to the use of seat belts in small school buses. One the average, one of the lives saved would be reduced to No Injury and the other to an OAIS 1 or 2.)
- 29 more uninjured passengers who would otherwise have been injured: an increase in uninjured passengers of 43 percent.
- 13 additional injured passengers would have their injuries reduced by one OAIS level: a reduction of one OAIS level for 9 percent of the injured persons.
- 7 additional injured passengers would have their injuries reduced by two or more OAIS levels: a reduction of at least two OAIS levels for 5 percent of the injured passengers.

Thus, out of an annual average of about 173 passengers killed or injured in fatal school bus accidents, a total of 51 (29 %) would benefit, if all school buses met the requirements of FMVSS 222. This 29 percent of the killed and injured in fatal school bus accidents who would benefit from FMVSS 222 requirements compares with the 69 percent of the injured estimated to benefit in nonfatal school bus accidents.

TABLE 2-3

AVERAGE ANNUAL LIVES SAVED AND INJURY REDUCTION IN FATAL SCHOOL BUS ACCIDENTS, ASSUMING ALL SCHOOL BUSES MEET FMVSS 222 REQUIREMENTS

Injury Level	Expected Passenger Deaths and Injuries						
	Pre-Standard			Post-Standard			
	No.	% Total	% K + I	No.	% Total	% K + I	
KABCO							
0	69	29		99	41		Uninjured
C	31	13	19	23	9	16	Injured
B	64	26	37	55	23	38	Injured
A	51	21	29	40	17	28	Injured
K	27	11	16	25	10	17	Killed
Total	242	100	100	242	100	100*	
OAIS							
0	69	29		99	41		Uninjured
1	82	34	47	69	28	48	Injured
2	30	12	17	25	10	17	Injured
3	20	8	12	14	6	10	Injured
4	9	4	5	6	2	4	Injured
5 NF	5	2	3	4	2	3	Injured
5 F	11	4	6	11	5	8	Killed
6	16	7	9	14	6	10	Killed
Total	242	100	100*	242	100	100	
Uninjured	69	28.5		99	40.9		
K + I	173	71.5		143	59.1		
Total	242	100		242	100		

*Percentages may not reconcile, due to rounding.

2.5 Evaluation of the Effectiveness Analysis

2.5.1 Limitations of the Nonfatal School Bus Accident Analysis

The analysis of nonfatal school bus accidents is limited by two factors:

- The MDAI nonfatal school bus cases tend to involve extremely severe accidents. For example, on the average, there were nearly 13 injured passengers per MDAI case, whereas the National Safety Council information reported in *Accident Facts* suggests that a rate of about 1.4 injuries per nonfatal school bus accidents is representative of the nation. We estimate that about 74 percent of all passenger injuries in nonfatal school bus accidents occur in situations in which only one passenger is injured. Further, we estimate that about 96 percent of the injuries are associated with nonfatal school bus accidents in which 1, 2, or 3 passengers are injured. However, only 14 of the 56 nonfatal MDAI cases (25 %) involve 3 or fewer injured passengers, and only 7 (12.5 %) involve only one injured passenger.

  Thus, we have had to speculate as to what the distribution of injury levels is in the most common nonfatal school bus accidents. While a set of "rational" assumptions has been made, they must be considered speculative until more detailed supporting analyses have been performed.

- The framework for extrapolating to the nation the injury reduction rates developed by the Clinical Analysis Team is based entirely on information extracted from the annual issues of *Accident Facts*, published by the National Safety Council. Certain well-delineated assumptions have been made to convert the information in *Accident Facts* to a form suitable for use with the MDAI clinical analysis.

While there is no firm, documented supporting evidence (of which we are aware) for the assumptions that have been made in order to extrapolate the clinical analysis results to determine the effectiveness of FMVSS 222 on a national basis, we believe that we have "zeroed in" on the "true" answer reasonably closely for the nonfatal school bus accidents which comprise at least 99 percent of all passenger-involved school bus accidents in which passengers or drivers are killed and/or passengers are injured. This tentative conclusion is supported, in part, by the analysis of 18 months of Connecticut school bus accident data, in which,out of 1007 accident cases, there were no passenger fatalities and only 46 school bus crashes in which passengers were injured.

2.5.2 Limitations of the Fatal School Bus Accident Analysis

By conducting an analysis of FARS fatal school bus accidents for 1975 through 1978 and developing KABCO-to-OAIS conversions that permitted direct comparison of the analysis of the 60 FARS cases with the analysis of the 26 fatal MDAI cases, we judge that the analysis of the effectiveness of FMVSS 222 in fatal school bus accidents is on relatively firm ground. In part, this is because 17 of the 26 MDAI cases are also in the 60 FARS cases. Thus, we have had available for clinical analysis a relatively large fraction (*28 %*) of the total FARS population. Although it is clear that the MDAI cases are biased toward larger numbers of fatalities per accident (see Table 3-28 and Figure 3-3), we have been able to demonstrate that the distribution of injury levels is very similar in the two data bases, thus demonstrating that, on the average, distribution of injury levels is essentially independent of the number of fatalities in the accident. In simple terms, an accident normally has to be quite violent in order to cause driver and/or passenger fatalities in passenger-involved school bus accidents. Once that level of violence is attained, on the average the distribution of injury levels (based on FARS) is relatively fixed at about:

- 11 percent killed
- 60 percent injured
  - 21 percent A
  - 27 percent B
  - 13 percent C

  } (sums to 61% because of rounding)
- 29 percent uninjured.

Based on the clinical analysis, we estimate that if all fatal school bus accidents occurred in vehicles meeting FMVSS 222 requirements, these levels would be:

- 10 percent killed
- 49 percent injured
- 41 percent uninjured.

These injury reductions are relatively modest and, on the average, would benefit only about 51 passengers per year, but we consider the extrapolation of the MDAI fatal school bus accidents clinical analysis to the national level to be on much more solid ground than that for nonfatal school bus accidents. The most crucial assumption involved in this analysis is that relating A, B, C injury levels to OAIS 1, 2, 3, 4, 5NF levels (see Table 3-29).

2.5.3 Credibility of the Analyses

In addition to the limitations discussed above, there remains the question of the accuracy of the judgments of the Clinical Analysis Team. In general, it can be said that the Team was conservative in making judgments, and was more prone to state that "OAIS stays the same" and indicate the Quality of Estimate to be "Poor" because there was inadequate information, rather than reduce the level of the injury and indicate the Quality of Estimate to be "Poor." Thus, it is probably more likely that judgments erred on the side of not reducing injury levels enough, rather than too much. This conservatism was not extreme, but it was deliberate on the part of the Clinical Analysis Team, to the degree to which it took place.

Because the Clinical Analysis Team classified the quality of each of the 1260 injury reduction estimates made into Good, Fair, and Poor estimates, it was possible to determine separately the effectiveness of FMVSS 222 for each of the quality of estimate categories, as well as combinations of "Good + Fair" (about 80 percent of the estimates) and "Good + Fair + Poor" (all available estimates). When applied to the nonfatal school bus accidents, the analysis showed that 94 percent of the 128 estimates classified Poor were estimates of "No Change" in injury level--a conservative decision made when the available information was considered inadequate. The remaining 6 percent of the Poor estimates involved injury reduction, and were usually so classified because it was considered that more injury reduction would probably occur than was estimated--again, a conservative decision.

The analysis further showed that if the Poor estimates were eliminated, the overall effectiveness of FMVSS 222 in reducing injuries in nonfatal school bus accidents would be about 81 percent, based on the Good + Fair estimates. This is an increase of 12 percentage points over the 69 percent found using the Good + Fair + Poor estimates (i.e., all appropriate estimates). In this study, CEM has chosen to use the more conservative overall effectiveness of 69 percent reduction in injury by at least one OAIS level, because there remains some uncertainty concerning the scenario of distribution of injuries per accident and the distribution of OAIS injury levels for accidents involving 1, 2, 3, 4, and 5 or more passengers per accident.

In general, CEM concludes that within the limited scope of a clinical analysis, the overall effectiveness value of 69 percent injury reduction in nonfatal accidents is probably accurate within $\pm$12 percentage points, and the overall effectiveness of 29 percent injury reduction in fatal accidents is probably accurate within $\pm$ 6 percentage points.

2.6 Additional Work

As proposed in References 1 and 2 of Section 1, as NASS data collection begins to develop on a large scale, it will be desirable to emphasize collection of data on Pre- and Post-Standard school bus accidents. This study reveals that overall effectiveness may be more accurately determined by placing emphasis on 1, 2, 3-passenger-injury accidents, rather than on accidents involving fatalities and/or large numbers of injuries, because the latter accidents are rare, and it is already reasonably well demonstrated herein that the effectiveness of FMVSS 222 in fatal accidents is less, and the number of individuals benefitted annually is quite small (i.e., of the order of 51 killed or injured passengers out of a total population of about 3900 killed and injured).* In addition, emphasis should be placed on NASS collection of accident data for vans and other small school transportation vehicles.

The objective of such an analysis would be to characterize the nature of school bus accidents. For example, according to FARS data, more fatal school bus accidents occur in April than in any other month. March, May and June are higher fatal accidents months than September, October and November. December is low for understandable reasons, but January is high and February is low. Why? Do nonfatal school bus accidents follow similar patterns? About one third of the fatal accidents in both FARS and the 26 MDAI cases occur in small buses or standard vehicles used as buses. Is this in proportion to the fraction of these vehicles in the total population of school bus vehicles? Or school bus miles driven (exposure)?

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*Of the annual average of 3900 passenger killed and injured, about 27 (*0.7 %*) are killed and the remainder (*99.3 %*; nearly all of the 3900) are injured.

2.7 Comparison of Results of Analyses

Understandably, the Clinical Analysis Team found it easier to make estimates of injury reductions for the nonfatal MDAI school bus accidents than for the fatal accidents. However, because the fatal MDAI school bus accidents were more representative of the total population of fatal school bus accidents, and more is known about that total population, we believe that the fatal extrapolations to the nation may be more accurate than the extrapolation to nonfatal accidents.

The estimate that FMVSS 222 will reduce injuries for 69 percent of the presently-injured passengers is believed to be a conservative estimate, because the Clinical Analysis Team was conservative in estimating injury reduction when there was little information available.

The estimate that FMVSS 222 would avert 7 percent of the fatalities (2 lives annually, on average, if all school buses met FMVSS 222) is conditioned on the assumption that small buses would have seat belts, and the belts would have a very high usage rate. If the belts are available but not used, then this estimate is unrealistically high, and essentially no fatalities would be averted by FMVSS 222.

The estimate that FMVSS 222 would provide about a 29 percent reduction in injuries in fatal school bus accidents is considered to be the most well founded of all the estimates contained herein.

2.8 Summary of Findings

We estimate that annually, on the average, there are approximately:

- 2800 nonfatal school bus accidents.
- 3900 injured passengers.

- 15 fatal school bus accidents.
- 27 fatally injured passengers.
- 146 injured passengers.

We estimate that meeting the requirements of FMVSS 222 will have the following results:

In nonfatal school bus accidents:

- 65 percent of the injured passengers will receive no injury.
- 4 percent of the more severely injured passengers will have their injuries reduced at least one OAIS level.

In fatal school bus accidents:

- 7 percent of the passenger fatalities might be averted, if all small school buses (vans, etc.) are equipped with seat belts, and they are used.
- 17 percent of the fatal and injured passengers will receive no injury.
- 29 percent of the fatal and injured passengers will have their injuries reduced at least one OAIS level (includes those reduced to No Injury).

The MDAI clinical analysis of 56 nonfatal and 26 fatal MDAI reports of school bus accidents, when coupled with National Safety Council information and FARS fatal school bus accident data, has provided a basis for extrapolating the injury reduction estimates of the CEM Clinical Analysis Team to national levels of effectiveness of FMVSS 222.

It appears that FMVSS 222 will have a large effectiveness in reducing injuries in nonfatal school bus accidents. It will have somewhat more than half the nonfatal accident effectiveness in fatal school bus accidents. However, fatal school bus accidents are rare events (i.e., about 15 out of 2800 total passenger injury school bus accidents per year,or about 0.5% of all such accidents).

3.0 ANALYSIS OF DATA

3.1 Sources of Multidisciplinary Accident Investigation Data

The Multidisciplinary Accident Investigation (MDAI) data obtained for clinical analysis stemmed from several sources. At the initiation of the study, CEM had microfiche for 36 MDAI school bus accidents. Additional reports were suggested by Ms. G. Hazzard (NHTSA) and Mr. R. Williams (NHTSA). A total of 67 MDAI reports were identified as potential data sources. Of these, 49 were used in the first phase of the clinical analysis. They comprise 28 nonfatal cases and 21 fatal cases in which at least one passenger or the driver was killed. The other 18 reports were rejected because:

- 10 involved no injuries or fatalities.
- 6 contained no data on the school bus occupants (the bus was not the MDAI case vehicle).
- 2 involved injury or death of the driver only.

During the course of collecting and screening the first 67 MDAI reports, an additional 51 MDAI reports were located. Thirty-three reports were judged useful for clinical analysis: 28 nonfatal cases and 5 fatal cases. Eighteen of the cases had insufficient information on injuries to allow performance of clinical analysis. This Final Report contains the analysis of all 82 MDAI reports.

In addition to MDAI reports, CEM has also made use of information on school bus accidents, fatalities and injuries found in *Accident Facts*, published annually by the National Safety Council. To place the clinical analysis of MDAI fatal school accident reports in a more comprehensive context, CEM has reviewed all fatal school bus accidents found in the Fatal Accident Report System (FARS) for 1975, 1976, 1977 and 1978--a total of 60 school bus accidents in which either the driver or at least one passenger was killed. (FARS contains 9 other cases where the driver was the only occupant and was killed; we are not considering such cases in this analysis.)

To add further credibility to the findings of this study, CEM reviewed 1007 hardcopy school bus accident reports, which cover all school bus accidents in Connecticut in 1978 and the first half of 1979 (18 months). Of these, only 46 involved injuries to passengers. During the period reviewed, the passengers in injury-producing school bus crashes sustained no serious (A-level) injuries or fatalities.

3.2 Framework for Clinical Analysis of Eighty-Two MDAI School Bus Accident Studies

To facilitate the clinical analysis of the 82 MDAI reports, they were categorized as follows:

- Nonfatal: No occupant fatalities.
- Fatal: At least one passenger or driver fatality.

Each of these categories was further divided into eight subcategories of crash types. The 56 nonfatal and 26 fatal studies subjected to clinical analysis are categorized as shown in Table 3-1.

TABLE 3-1

CATEGORIZATION OF 82 MDAI SCHOOL BUS ACCIDENTS

Description	Nonfatal		Fatal	
	Designation	No. Cases	Designation	No. Cases
1. Bus Only	BO	5	F-BO	5
2. Rear-End (Bus hit from rear)	RE	6	F-RE	0
3. Front-Rear (Bus strikes other vehicle in rear)	FR	5	F-FR	1
4. Front-Side (Bus strikes other vehicle in side)	FS	8	F-FS	0
5. Side-Swipe (Bus and other vehicle side-swipe)	SS	1	F-SS	2
6. Side-Collision (Bus struck in side by other vehicle)	SC	10	F-SC	4
7. Head-On (Bus and other vehicle collide head-on)	HO	4	F-HO	0
8. Rollover (Bus rolls over regardless of how accident initiates)	RO	17	F-RO	14
Total Cases		56		26

The categorization of MDAI cases, as shown in Table 3-1, was deliberately chosen to begin with the least violent, simplest cases (Nonfatal Bus Only) and to conclude with the most violent and complex cases (Fatal Rollover). The Clinical Analysis Team approached the MDAI studies in this order, gaining experience in the violence and complexity of school bus accident mechanics, kinematics, and injury causation. Before undertaking any clinical analyses, the Team visited a sizeable school bus operating firm to inspect the characteristics of school buses manufactured during 1967 through 1978. A second visit was made midway through this study. Photographs taken for reference while reviewing MDAI cases are shown in Appendix A.

The 82 MDAI reports were critically screened by CEM staff. Terse one-to-two page descriptions of the accidents were prepared in a common format. All pertinent accident diagrams were copied, and a table of the characteristics of each injured occupant was prepared, with space available in the table for a judgment of what the degree of injury would have been, had the bus met FMVSS 222 requirements. Tables 3-2 and 3-3 summarize the characteristics of the non-fatal and fatal MDAI reports clinically analyzed in the two phases of this study. Appendix B gives additional MDAI accident characteristics. Brief descriptions of all MDAI cases, including accident diagrams and the injury-reduction judgments of the Clinical Analysis Team,are found in the addendum to this report which is available from the National Highway Traffic Safety Administration:

CEM Report 4254-678:

Background Data for the Statistical Evaluation of Federal Motor Vehicle Safety Standard 222: School Bus Seating and Crash Protection.

One CEM member of the Clinical Analysis Team carefully reviewed and tabbed pertinent material in all original MDAI reports before the Team assembled. Once they had convened, the Team members reviewed the screened material and any available photographs and other pertinent written material in the original MDAI report. The crash dynamics were discussed, with significant points illustrated on the available blackboard. Occupant kinematics were agreed upon, and the analysis for each occupant was begun, making use of injury information and charts in the original MDAI reports. There was then a discussion of an occupant's injuries and the possible mitigation factors that would have been produced by FMVSS 222 requirements, such as:

- Effective seat back top and back padding.
- Higher seat backs.
- Stronger seat backs.
- Stronger seat frames.
- More effective attachment of seats to floor.
- More effective attachment of seat bottoms to seat frames.
- Reduced space between seats.
- Padding of vertical stanchions and modesty panels at front of bus.
- Passenger restraint systems in buses equal to or less than 10,000 lb GVW (i.e., compliance with FMVSS 208, 209, 210).

A decision was then made by Dr. P. Stent, CEM Consultant and Director of Ambulatory Services at St. Francis Hospital in Hartford, Connecticut, as to the

TABLE 3-2

SUMMARY CHARACTERISTICS OF 56 NONFATAL MDAI SCHOOL BUS ACCIDENT STUDIES

Study No.	Ident. Number	Investigating Organization	Total Occup.	Total Injuries		Description
				Passenger	Driver	
BO (Bus Only)						
BO-1	600-348	U.of Calif.	40	20	1	Bus roof struck rear end of boom on self-propelled crane.
BO-2	801-512	IRPS	16	13	1	Bus ran off road and struck fixed object.
BO-3	73-346	Calspan	46	6	1	Rear axle assembly ripped loose due to sudden braking. Bus came to abrupt halt.
BO-4	602-532	Calspan	3	2	1	Bus struck guardposts, bridge railings (frontal impacts).
BO-5	TOR 039-72	U.of Toronto, Canada	44	39	1	Bus lost steering control, crossed roadway; contacted bridge rail.
		Total	149	80	5	
RE [Rear-End (Bus Hit by Another Vehicle)]						
RE-1	SL 1-5	Dyn.Sci.,Inc.	14	4	1	Rear end of bus struck by garbage truck with failed brakes.
RE-2	600-722	Calspan	12	2		Rear end of stopped bus struck by stolen car.
RE-3	602-082	Calspan	47	1	1	Rear end of bus struck by truck.
RE-4	TOR OSI 52-74	Toronto, Canada	65	3		Rear end of stopped bus struck by pick-up truck.
RE-5	MGU 071-74	McGill Univ. Canada	15	6		Left rear corner of left-turning bus struck by car.
RE-6*	UNB 052-74	U.N.Brunswick, Canada	34	5	1	Stopped school bus hit in rear by a moving school bus.
		Total	187	21	3	
FR [Front-Rear (Bus Hits Another Vehicle)]						
FR-1	602-077	Calspan	48	3		Front of bus impacted rear of bus in front.
FR-2	602-711	Calspan	44	6	1	Front of bus impacted rear of stopped bus in front.
FR-3	600-836	U.New Mex.	45	12		Front of bus impacted rear of car in front, due to bus brake failure.
FR-4*	UNB 052-74	U.N.Brunswick, Canada	40	7	1	Rear end of stopped school bus hit in rear by a moving school bus.
FR-5	DTS 095-73	Trans.Minstry, Canada	52	46	1	Front of bus impacted rear of car which had rear-ended a stopped garbage truck.
		Total	229	74	3	

*This accident involved two school buses. The MDAI report gives detailed injury data for both the "case" vehicle and the "other" vehicle. They are presented separately as RE-6 and FR-4.

TABLE 3-2 (Continued)

Study No.	Ident. Number	Investigating Organization	Total Occup.	Total Injuries		Description
				Passenger	Driver	
FS [Front-Side (Bus Hits Another Vehicle in Side)]						
FS-1	010-72	U.Saskat., Canada	12	3	1	Front of bus struck car with U-haul trailer.
FS-2	802-056	IRPS	50	46	1	Front of bus struck garbage truck (acute oblique)[fog].
FS-3	TOR 056-74	U.of Toronto, Canada	18	13	1	Front of bus struck right side of car.
FS-4	DTS 107-75	Trans.Ministry Canada	56	15		Front of bus struck left side of flat bed truck.
FS-5	OK 74-03	HSRI	40	16	1	Front of bus struck out-of-control car; bus went into ditch.
FS-6	UNB 027-72	U.N. Bruns., Canada	55	30	1	Front of bus struck truck broadside at left rear wheels; truck unable to stop at intersection.
FS-7	054070	Utah Health Division	23	1	1	Front of bus struck right side of car which drove into its path.
FS-8	DTS 082-73	Trans.Ministry Canada	33	4		Stopped bus struck by speeding car which skidded and slid sideways into front of it.
		Total	287	128	6	
SS (Side Swipe)						
SS-1	600-367	U.of Calif.	18	3	1	Disabled bus sideswiped by truck auto carrier.
		Total	18	3	1	
SC [Side Collision (Bus Hit by Another Vehicle)]						
SC-1	600-726	Calspan	6	1		Bus (van)* struck in side by car at intersection
SC-2	603-139	Dyn.Sci.,Inc.	53	45		Bus struck in the side by truck auto carrier at intersection (fog).
SC-3	600-376	U.of Calif.	5	4	1	Bus struck in side by car at intersection.
SC-4	602-364	SwRI	47	7	1	Bus struck in side by station wagon previously hit by car at intersection.
SC-5	UOM 047-76	U.of Manitoba, Canada	15	11	1	Bus struck in side (intersection) by flatbed truck carrying tractor.
SC-6	602-766	U.S.Calif.	49	5	1	Bus brakes failed; stopped on highway; hit by car and tractor-trailer.
SC-7	DTS 094-73	Trans.Ministry Canada	57	12	1	Bus struck at intersection by car which failed to heed stop sign.
SC-8	DTS 096-73	Trans.Ministry Canada	26	23	1	Bus struck in side at intersection by truck (heavy fog).
SC-9	TOR 042-73	U.of Toronto Canada	4	1		Bus (van)* struck in side at intersection.
SC-10	UC-167	U.of Calif.	25	20	1	Bus making turn struck by truck; bus then hit car head-on.
		Total	287	129	7	

*Vehicle less than 10,000 lb.

TABLE 3-2 (Concluded)

Study No.	Ident. Number	Investigating Organization	Total Occup.	Total Injuries		Description
				Pass-enger	Dri-ver	
HO (Head-On)						
HO-1	600-367	U.of Calif.	21	3		Bus struck head-on by car (car underride).
HO-2	72-60A	Calspan	39	25	1	Bus struck head-on by car on curve.
HO-3	BRC 074-78	Traf.Acc.Rsrch. Canada	25	16	1	Bus struck right side of skidding car(ice) (car underride).
HO-4	TOR 080-77	U.of Toronto, Canada	10	7	1	Bus (van)*fishtailed; lost control; left front struck left front of car.
		Total	95	51	3	
RO (Rollover)						
RO-1	600-303	IRPS	34	31	1	Bus hit stump head-on and rolled 90° left.
RO-2	600-443	RTI	45	29		Bus brakes failed; bus rolled 90° left; struck tree and porch.
RO-3	72-231A	Calspan	69	8	1	Bus left road; hit curve warning sign; rolled 90° right.
RO-4	SI-1-8	Dyn.Sci.,Inc.	19	5	1	Bus skidded on icy road and rolled 90° right.
RO-5	NI-4-32	Dyn.Sci.,Inc.	42	41	1	Bus struck in rear by furniture van with failed brakes; rolled 90° left.
RO-6	601-570	HSRI	24	18	1	Bus and car collided at intersection; bus rolled 90° left.
RO-7	600-068	Ga.In.Tech.	57	1	1	Bus with failed brakes struck car at intersection and rolled over 90° right.
RO-8	602-706	Calspan	17	1		Bus had trouble steering over pot holes on muddy road and slid into ditch; bus rolled over 90° right.
RO-9	73-357	Calspan	16	8	1	Bus struck another bus; front to side impact; slid into ditch; rolled over 90° right.
RO-10	TOR 062-75	U.of Toronto, Canada	22	16	1	Bus left road; rolled over 90° left onto pavement,then slid off onto grass.
RO-11	TOR 059-75	U.of Toronto, Canada	39	16		Bus drove off roadway into ditch; rear wheel struck blockage; rolled over 90° right.
RO-12	TOR 048-73	U.of Toronto, Canada	2	1	1	Bus struck in front by van (ignored stop); rear wheel slid on ditch slope; rolled over 90° right.
RO-13	UNB 055-74	U.N. Bruns., Canada	6	5	1	Bus attempted to avoid stopped police car; skidded into ditch; rolled over 270° right.
RO-14	TOR 066-75	U.of Toronto, Canada	45	15	1	Bus left road, ran into ditch; rolled over 45° with right side tilted against ditch backslope.
RO-15	UOS 056-75	U.Saskat., Canada	25	20	1	Bus entered ditch and rolled over 90° left when drag link on steering separated.
RO-16	UOS 079-77	U.Saskat., Canada	14	13	1	Intersection collision of truck and bus; bus rolled over 90° left, rolled back onto wheels and then rolled over 90° right.
RO-17	TOR 071-76	U.of Toronto, Canada	16	5	1	Bus entered slippery ramp; fishtailed; rotated 180°; skidded into ditch while moving backwards; rolled over 45° with left rear corner tilted against ditch backslope.
56 (Total No.)		Total	492	233	14	
Total, All Nonfatal Studies			1744	719	42	

*Vehicle less than 10,000 lb.

TABLE 3-3

SUMMARY CHARACTERISTICS OF 26 FATAL MDAI SCHOOL BUS ACCIDENT STUDIES

Study Number	Ident. Number	Investigating Organization	Total Occup.	Total Injur.		Total Killed		Description
				Pass-enger	Dri-ver	Pass-enger	Dri-ver	
F-BO (Fatal - Bus Only)								
F-BO-1 *	603-000	HSRI	12	11			1	Bus (van)/ran off road and struck wall of drainage ditch head-on.
F-BO-2 *	603-028	SwRI	37			1		Bus struck fire hydrant and sideswiped utility pole.
F-BO-3 *	602-728	SwRI	9	3		2		Bus (van)/ran off road due to failed axle (3 occupants ejected).
F-BO-4	602-396	U.S. Calif.	11	9	1	1	1	Bus lost control; impacted marker,boulder; ended in irrigation ditch.
F-BO-5	UC-168	U. of Calif.	19	14	1	1		Bus left roadway; hit two wooden poles (separate impacts).
		Total	88	37	2	5	1	
F-FR (Fatal - Front-Rear [Bus Hits Another Vehicle])								
F-FR-1	TOR 055-74	U.of Toronto, Canada	33	32			1	Front of bus impacted rear of stopped tanker spray truck.
		Total	33	32			1	
F-SS (Fatal - Side Swipe)								
F-SS-1 *	603-059	Calspan	2			1	1	Bus sideswiped by tractor trailer in opposing lane; front impact and bus underride.
F-SS-2 *	603-138	Dy.Sci.Inc.	57	33	1	2		Bus sideswiped by dump truck.
		Total	59	33	1	3	1	
F-SC (Fatal - Side Collision [Bus Hit by Another Vehicle])								
F-SC-1 *	803-237	U.S.Calif.	41	29	1	3		Bus struck in side by train caboose.
F-SC-2 *	603-029	SwRI	17	8		8	1	Bus struck in side towards rear by train (rear panels separated; 16 occ.ejected).
F-SC-3 *	602-932	SwRI	36	15			1	Bus hit in side by trailer of tractor-trailer which had collided with a train.
F-SC-4 *	603-042	Calspan	41	20	1	1		Bus struck in side by logging truck (bus out of control in opposing lane).
		Total	135	72	2	12	2	

*Accident characteristics also found in the Fatal Accident Reporting System.

/Vehicle less than 10,000 lb.

TABLE 3-3 (Continued)

Study Number	Ident. Number	Investigating Organization	Total Occup.	Total Injur.		Total Killed		Description
				Passenger	Driver	Passenger	Driver	
F-RO (Fatal - Rollover)								
F-RO-1	600-353	Calspan	60	53	1	1		Bus struck in side by tractor-trailer; bus rolled 180° left.
F-RO-2 *	603-107	HSRI	19	17	1	1		Bus (van)† struck in side by car; bus rolled 450° left (6 occupants ejected).
F-RO-3 *	603-030	HSRI	15	13	1	1		Bus (van)† skidded on ice; ran off road into ditch; rolled 810° right (2 occupants ejected)
F-RO-4 *	603-060	HSRI	17	14		1	1	Bus (van)† struck in front and side by car; bus rolled 90° left.
F-RO-5 *	603-079	SwRI	12	9		2		Bus (van)† skidded on bleeding road surface: rotation; bus rolled 630° left (3 occupants ejected).
F-RO-6 *	603-061	HSRI	34	30		3		Bus struck guardrail; bridge parapet; bridge rail; rolled over bridge rail 180° right.
F-RO-7 *	603-140	Calspan	33	26	1	3		Bus struck from rear by tractor; bus rolled 90° right (1 occupant ejected).
F-RO-8	600-779	NHTSA	48	26	1	9		Bus (out of control) struck sign and rolled 900° right (39 occupants ejected).
F-RO-9 *	602-855	U.S.Calif.	20	17		2	1	Bus with failed brakes struck rear of car and guardrail; bus rolled 720° left (19 occupants ejected).
F-RO-10	601-348	U.of Kentucky	34	29	1	2		Bus struck overhanging tree limbs: ran into drainage ditch; hit tree trunk; rolled 90° right.
F-RO-11*	802-303	U.S.Calif.	52	22	1	29		Bus brakes failed on curving downgrade off-ramp: bus rolled over bridge rail 180° left and landed on roof.
F-RO-12	801-301	IRPS	12	8	1	2		Bus (van)† struck pavement, tree; rolled 90° right.
F-RO-13	801-202	IRPS	17	11	1	5		Bus struck at left rear axle by tractor-trailer; thrown into air; traveled 80 ft; rolled 90° right (1 occupant ejected).
F-RO-14	EPM 035/36-72	Poly.Inst., Canada	50	41	1	2		Bus hit another bus (entering intersection); lost steering control; hit truck; rolled 90° left (5 occupants ejected).
26 (Total No.)		Total	423	316	10	63	2	
Total, All Fatal Studies			738	490	15	83	7	

*Accident characteristics also found in the Fatal Accident Reporting System.

†Vehicle less than 10,000 lb.

level of injury reduction that in his medical judgment might have taken place, had the bus met the requirements of FMVSS 222. Next, a decision was made concerning the quality of the judgment (Good, Fair, Poor), which depended on the amount of information on the overall accident, and the crash conditions experienced by each injured occupant. The occupant injury table at the end of BO-2 (Figure 3-5, page 3-50) shows an example of the net results of the judgments involving injury reduction and quality of judgment.

Tables 3-4 and 3-5 give gross summaries of the results of the clinical analysis of 56 nonfatal and 26 fatal MDAI school bus accident reports. The tables show the original distribution of injuries, and the estimated reductions in injuries that (in the judgment of the Clinical Analysis Team) would have occurred, had the buses met the requirements of FMVSS 222. A more detailed discussion of these results is given in the next subsection.

TABLE 3-4

RESULTS OF THE CLINICAL ANALYSIS OF
56 NONFATAL MDAI SCHOOL BUS ACCIDENT STUDIES

Item	Number	Percent	
• Total Passengers	1688	100	
• Total Passengers Injured	719	42.6 *	
• Original OAIS			
- OAIS 0	969	57.4 *	
- OAIS 1	617	85.8 **	86.4#
- OAIS 2	82	11.4	11.5
- OAIS 3	8	1.1	1.1
- OAIS 4	7	1.0	1.0
- Unknown	5	0.7	
• Changes in OAIS Level			
- OAIS 1 to 0	304	42.6 #	
- OAIS 2 to 1	25	3.5	
- OAIS 2 to 0	22	3.1	
- OAIS 3 to 2	1	0.1	
- OAIS 3 to 1	4	0.6	
- OAIS 3 to 0	1	0.1	
- OAIS 4 to 3	2	0.3	
- OAIS 4 to 2	2	0.3	
- OAIS 4 to 1	2	0.3	
• OAIS Remains the Same			
- OAIS 1	313	43.8 #	
- OAIS 2	35	5.0	
- OAIS 3	2	0.3	
- OAIS 4	1	0.1	
• Quality of Estimates			
- Good	317	44.4 #	
- Fair	259	36.3	
- Poor	138	19.3	

*Percent based on 1688 passengers.

**Percent (flagged number, *et seq.*) based on 719 injured passengers.

#Percent (flagged number, *et seq.*) based on 714 clinical analysis judgments (excluding the five "Unknown" OAIS ratings).

TABLE 3-5

RESULTS OF THE CLINICAL ANALYSIS OF
26 FATAL MDAI SCHOOL BUS ACCIDENT STUDIES

Item	Number	Percent	
• Total Passengers	712	100	
• Total Passengers Injured	490	68.8 *	
• Total Passengers Killed	83	11.7 *	
• Original OAIS			
- OAIS 0	139	19.5*	
- OAIS 1	251	43.8**	47.4#
- OAIS 2	91	15.9	17.2
- OAIS 3	60	10.4	11.3
- OAIS 4	27	4.7	5.1
- OAIS 5 NF	17	3.0	3.2
- OAIS 5 F	34	5.9	6.4
- OAIS 6	49	8.6	9.3
- Unknown	44	7.7	
• Changes in OAIS Level			
- OAIS 1 to 0	82	15.4#	
- OAIS 2 to 1	31	5.8	
- OAIS 2 to 0	7	1.3	
- OAIS 3 to 2	8	1.5	
- OAIS 3 to 1	8	1.5	
- OAIS 4 to 2	7	1.3	
- OAIS 4 to 1	1	0.2	
- OAIS 5 NF to 4	1	0.2	
- OAIS 5 NF to 2	1	0.2	
- OAIS 5 NF to 1	2	0.4	
- OAIS 5 F to 1	1	0.2	
- OAIS 6 to 2	1	0.2	
- OAIS 6 to 1	3	0.6	
- OAIS 6 to 0	2	0.4	
• OAIS Remains the Same			
- OAIS 1	169	31.9#	
- OAIS 2	53	10.0	
- OAIS 3	45	8.5	
- OAIS 4	18	3.4	
- OAIS 5 NF	14	2.6	
- OAIS 5 F	34	6.4	
- OAIS 6	42	7.9	
• Quality of Estimates			
- Good	162	30.6#	
- Fair	190	35.8	
- Poor	178	33.6	

*Percent based on 712 total passengers.

**Percent (flagged number, *et seq.*) based on 573 killed and injured passengers.

#Percent (flagged number, *et seq.* based on 529 clinical analysis judgments (excluding the 44 "Unknown" OAIS ratings).

3.3 Overall Results of the Clinical Analysis of MDAI School Bus Accidents

In the 82 Multidisciplinary Accident Investigation Reports for which clinical analyses were performed, there were:

- 2400 passengers
- 1108 uninjured *(46 % of total passengers)*
- 1209 injured *(51 % of total passengers)*
- 83 killed *(3 % of total passengers)*

For the 1209 injured, OAIS ratings were:

- 868 OAIS 1 *(72 % of total injured)*
- 173 OAIS 2 *(14 % of total injured)*
- 68 OAIS 3 *(6 % of total injured)*
- 34 OAIS 4 *(3 % of total injured)*
- 17 OAIS 5 (NF)* *(1 % of total injured)*
- 49 Unknown *(4 % of total injured)*

For the 83 killed, OAIS ratings were:

- 34 OAIS 5 (F)* *(41 % of total killed)*
- 49 OAIS 6 ** *(59 % of total killed)*

Tables 3-6 and 3-7 give detailed results of the clinical analysis. The Clinical Analysis Team's judgments of reduction of injury severity and quality of each judgment for each individual injured or killed occupant in the 82 MDAI studies are given in the addendum to this report (see page 3-3). After completing the clinical analyses, and taking into account the judged effectiveness of FMVSS 222, there are:

- 2400 passengers
- 1526 uninjured *(63 % of total passengers)*
- 798 injured *(33 % of total passengers)*
- 76 killed *(3 % of total passengers)*

For the 798 injured, judged OAIS ratings are:

- 560 OAIS 1 *(70 % of total injured)*
- 107 OAIS 2 *(13 % of total injured)*
- 48 OAIS 3 *(6 % of total injured)*
- 21 OAIS 4 *(2 % of total injured)*
- 13 OAIS 5 (NF) *(2 % of total injured)*
- 49 Unknown *(6 % of total injured)*

For the 76 killed, judged OAIS ratings are:

- 33 OAIS 5 (F) *(43 % of total killed)*
- 43 OAIS 6 *(57 % of total killed)*

The above summarized results are illustrated graphically in Figure 3-1 for the nonfatal cases and in Figure 3-2 for the fatal cases. Additional data for fatal MDAI cases are found in Appendix C.

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*Of the total of 53 OAIS 5 injuries, 18 survived and 35 died. (The abbreviations "NF" and "F" mean "Nonfatal" and "Fatal," respectively).

**All MDAI OAIS ratings of 6 or above are lumped together under OAIS 6 in this report.

TABLE 3-6

SUMMARY OF THE CLINICAL ANALYSIS OF 56 NONFATAL MDAI SCHOOL BUS ACCIDENT STUDIES

CEM Case No.	Total Passengers	Total Pass. Inj.	Original OAIS (MDAI or CEM Estimate)						Changes in OAIS Levels								OAIS Remains the Same				Quality of Estimate		
			4	3	2	1	0	Unk Inj	4 to 3	4 to 2	4 to 1	3 to 2	3 to 1	3 to 0	2 to 1	2 to 0	1 to 0	4	3	2	1	Good	Fair	Poor
BO-1	39	20			2	18	19								1		6			1	12	11	6	3
BO-2	15	13			1	12	2								1		12					11	2	
BO-3	45	6				6	39										5				1	6		
BO-4	2	2			1	1										1					1	1	1	
BO-5	43	39	2		5	32	4		1	1					4	1	26				6	23	12	4
Total	144	80	2		9	69	64		1	1					6	2	49			1	20	52	21	7
RE-1	13	4				4	9										3				1	2	1	1
RE-2	11	2				2	9										1				1	2		
RE-3	46	1				1	45										1					1		
RE-4	64	3				3	61										3					2		1
RE-5	14	6				6	8										4				2	5	1	
RE-6	33	5			1	4	28									1	3				1	4		1
Total	181	21			1	20	160									1	15				5	16	2	3
FR-1	47	3			1	2	44								1		2					3		
FR-2	43	6				6	37										5				1	5	1	
FR-3	44	12				7	32	5									2				5	3	3	1
FR-4	39	7			3	4	32								1	2	1				3	4	2	1
FR-5	51	46				46	5										35				11	17	17	12
Total	224	74			4	65	150	5							2	2	45				20	32	23	14
FS-1	11	3				3	8										2				1	2	1	
FS-2	49	46	1	2	13	30	3			1			2		2	11	26				4	33	13	
FS-3	17	13				13	4										9				4	7	4	2
FS-4	55	15				15	40										11				4	7	6	2
FS-5	39	16				16	23										13				3	11	4	1
FS-6	54	30				30	24										23				7	18	9	3
FS-7	22	1				1	21														1			1
FS-8	32	4				4	28										4					4		
Total	279	128	1	2			151			1			2		2	11	88				24	82	37	9
SS-1	17	3			2	1	14								2						1			3
Total	17	3			2	1	14								2						1			3
SC-1	5	1				1	4										1					1		
SC-2	52	45	2	1	7	35	7		1				1		2	2	27	1		3	8	24	20	1
SC-3	4	4				4											1				3		4	
SC-4	46	7				7	39														7			7
SC-5	14	11		1	3	7	3								1		2		1	2	5	5	6	
SC-6	48	5				5	43														5		5	
SC-7	56	12			1	11	44									1	10				1	4	7	1
SC-8	25	23	2	1	6	14	2				2		1		5		8			1	6	12	11	
SC-9	3	1		1			2							1								1		
SC-10	24	20			1	19	4										10			1	9	12	7	1
Total	277	129	4	4	18	103	148		1		2		2	1	8	3	59	1	1	7	44	59	60	10
HO-1	20	3				3	17										2				1	2	1	
HO-2	38	25			5	20	13								1	2	9			2	11	8	10	7
HO-3	24	16				16	8										12				4	11	5	
HO-4	9	7				7	2										5				2	5	2	
Total	91	51			5	46	40								1	2	28			2	18	26	18	7
RO-1	33	31			4	27	2								1	1	5			2	22	9	14	7
RO-2	44	29			4	25	15								1		1			3	24		3	26
RO-3	68	8			1	7	60													1	7			8
RO-4	18	5			3	2	13													3	2		2	3
RO-5	41	41			2	39														2	39	4	8	29
RO-6	23	18			2	16	5								1					1	16	3	8	7
RO-7	56	1			1		55													1		1		
RO-8	16	1				1	15										1					1		
RO-9	15	8				8	7										2				6	2	6	
RO-10	21	16		1	1	14	5					1					2			1	12	3	13	
RO-11	38	16				16	22										1				15	8	7	1
RO-12	1	1				1															1	1		
RO-13	5	5		1	1	3													1	1	3	3	1	1
RO-14	44	15				15	29										3				12	7	7	1
RO-15	24	20			2	18	4													2	18	4	15	1
RO-16	13	13			9	4														8		4	9	
RO-17	15	5				5	10										5						5	
Total	475	233		2	30	201	242					1			4	1	20		1	25	181	50	98	85
Grand Total	1688	719	7	8	82	517	969	5	2	2	2	1	4	1	25	22	304	1	2	35	313	317	259	138

TABLE 3-7

SUMMARY OF THE CLINICAL ANALYSIS OF 26 FATAL MDAI SCHOOL BUS ACCIDENT STUDIES

CEM Case No.	Total Passengers	Total Passengers		Original OAIS (MDAI or CEM Estimate)									Changes in OAIS Levels											
		Inj.	K	6	5 (F)	5 (NF)	4	3	2	1	0	Unk Inj	6 to 2	6 to 1	6 to 0	5 to 4	5 to 2	5 to 1	4 to 2	4 to 1	3 to 2	3 to 1	2 to 1	2 to 0	1 to 0
F-BO-1	11	11	*			2			1	8								2NF					1		7
F-BO-2	36		1	1							35														
F-BO-3	8	3	2	2						3	3				2										3
F-BO-4	10	9	1	1				2	1	6			1								1	1	1		5
F-BO-5	18	14	1	1			1		6	7	3								1				1	5	7
Total	83	37	5	5		2	1	2	8	24	41		1		2			2NF	1		1	1	3	5	22
F-FR-1	32	32	*					1	2	29												1	2		20
Total	32	32						1	2	29												1	2		20
F-SS-1	1		1	1																					
F-SS-2	56	33	2		2	1	2	1	4	25	21												1		10
Total	57	33	3	1	2			1	4	25	21												1		10
F-SC-1	40	29	3		3	1	1	8	6	13	8										3		1		2
F-SC-2	15	8	8	8				3	5																
F-SC-3	35	15	*					3	7	5	20											3	4	2	4
F-SC-4	40	20	1		1				5	15	19												3		5
Total	131	72	12	8	4	1	1	14	23	33	47										3	3	8	2	11
F-RO-1	59	53	1	1				7	7	24	5	15									3		4		4
F-RO-2	18	17	1	1		1		1	5	10															
F-RO-3	14	13	1		1		1			12								1 F		1					
F-RO-4	16	14	1	1					2	11	1	1		1									2		4
F-RO-5	11	9	2	2				1	3	5				2								1	2		1
F-RO-6	33	30	3	2	1	2		4	9	15													1		
F-RO-7	32	26	3	2	1		1	2	1	22	3														
F-RO-8	47	26	9	9		4	3	8	6	5	12														
F-RO-9	19	17	2		2		3	3	2	9															
F-RO-10	33	29	2	2		2	5	4	9	9	2					1NF	1NF		4		1	2	7		5
F-RO-11	51	22	29	7	22	2	7	6	5	2															
F-RO-12	11	8	2	2			1	2		5	1														
F-RO-13	16	11	5	4	1	2	2	1		6									2						2
F-RO-14	49	41	2	2				3	5	5	6	28											1		3
Total	409	316	63	35	28	13	23	43	54	140	30	44		3		1NF	1NF	1 F	6	1	4	3	17		19
Grand Total	712	490	83	49	34	17	27	60	91	251	139	44	1	3	2	1NF	1NF	2NF 1 F	7	1	8	8	31	7	82

*The bus driver was the only fatality.

TABLE 3-7 (Continued)

CEM Case No.	OAIS Remains the Same							Quality of Estimate		
	6	5 (F)	5 (NF)	4	3	2	1	Good	Fair	Poor
F-BO-1							1	5	5	1
F-BO-2	1							1		
F-BO-3									5	
F-BO-4							1	10		
F-BO-5	1							14	1	
Total	2						2	30	11	1
F-FR-1							9	9	22	1
Total							9	9	22	1
F-SS-1	1							1		
F-SS-2		2	2	1	1	3	15	16	12	7
Total	1	2	2	1	1	3	15	17	12	7
F-SC-1		3	1	1	5	5	11		6	26
F-SC-2	8				3	5			16	
F-SC-3						1	1	12	1	2
F-SC-4		1				2	10	6	8	7
Total	8	4	1	1	8	13	22	18	31	35
F-RO-1	1				5	3	20		5	35
F-RO-2	1		1		1	5	10	7	6	5
F-RO-3							12	1	2	11
F-RO-4							7	1	3	10
F-RO-5						1	4		8	3
F-RO-6	2	1	2		4	8	15	3	1	29
F-RO-7	2	1		1	2	1	22		6	23
F-RO-8	9		4	3	8	6	5	9	26	
F-RO-9		2		3	3	2	9	18	1	
F-RO-10	2			1	1	2	4	2	19	10
F-RO-11	6	23	2	7	6	5	2	29	22	
F-RO-12	2			1	2		5	2	6	2
F-RO-13	4	1	2		1		4	14	2	
F-RO-14	2				3	4	2	2	7	6
Total	31	28	11	16	36	34	121	88	114	134
Grand Total	42	34	14	18	45	53	169	162	190	178

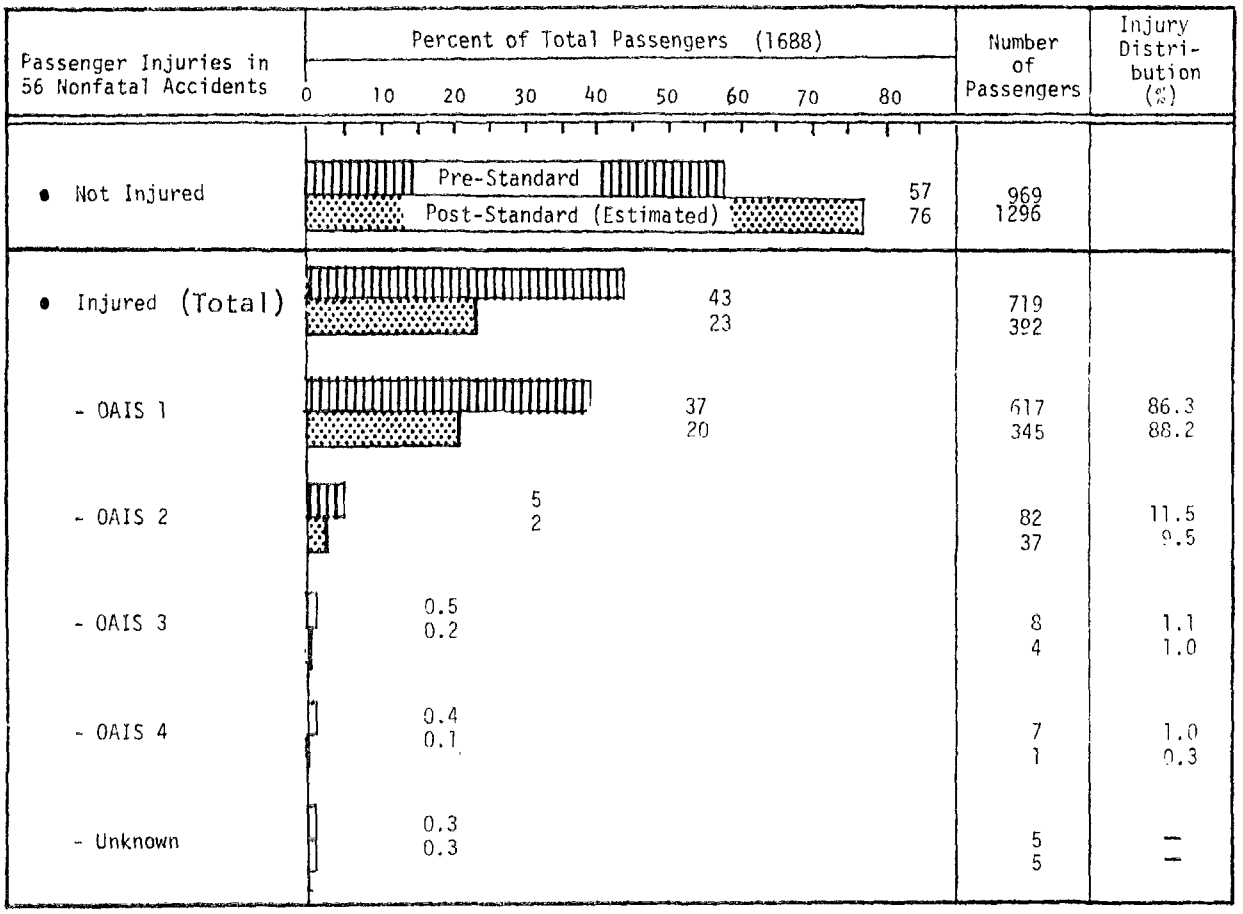

Figure 3-1. Summary of clinical analysis of 56 nonfatal MDAI school bus accident reports.

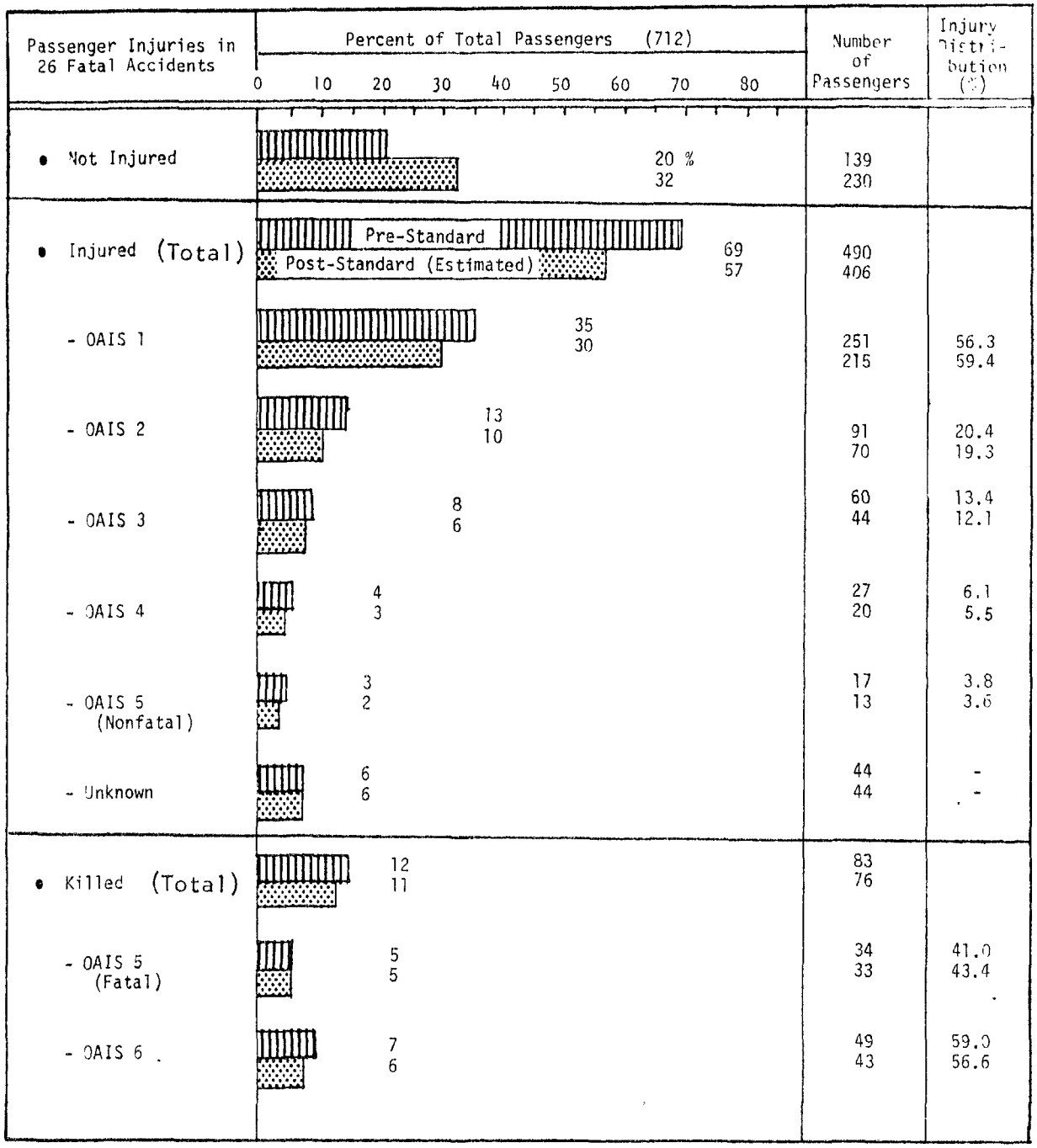

Figure 3-2. Summary of clinical analysis of 26 fatal MDAI school bus accident reports.

3.4 Effectiveness of FMVSS 222 in Reducing Injuries in Nonfatal School Bus Accidents

The Clinical Analysis Team reviewed 56 nonfatal school bus accidents. These involved a total of 1688 passengers (an average of 30.1 passengers/accident), of whom 719 (*42.6 %*) were injured (an average of 12.8 injured passengers/accident). In Section 3.6 , it is shown that for the nation, the average number of passengers injured in school bus accidents involving passenger injury is likely to be about 1.4 passengers/accident, based on information available in annual reports of the National Safety Council (NSC). This large difference (9-to-1) between the average number of passengers injured per accident in the MDAI results and the NSC information is probably due to the fact that school bus accidents are not investigated by MDAI teams unless they are relatively violent, and/or many people are injured. Two other points are also suggested:

- In about 74 percent or more of all school bus accidents nationwide, only one passenger is injured. This must be the case, if only 1.4 passengers are injured/accident. There is a very high likelihood that if only one passenger is injured, the bus accident is very minor, and the injured passenger receives only a minor injury (OAIS 1 or 2) in virtually every instance. Only rarely will more than 2 or 3 passengers be injured in a school bus accident, and only very rarely will there be OAIS 3 or 4 injuries.

- Conversely, the injury distributions developed from the 56 MDAI cases probably apply to less than 1 or 2 percent of all school bus accidents. For example, 17 of the 56 MDAI cases (30.4%) involve rollovers (ranging between about 45 and 90 degrees of rollover). Such school bus accidents are extremely rare, and it would not be correct to test the effectiveness of FMVSS 222 against a data set that is highly biased toward such an extremely rare event.

The above considerations led CEM to disaggregate into 12 categories the results of the estimates of injury reduction made by the Clinical Analysis Team, for each OAIS level of original injury. These categories are shown in Tables 3-8 through 3-11 for OAIS 1, 2, 3, and 4 injuries incurred in nonfatal school bus accidents. As can be seen from these tables, there is a significant deleterious impact that occurs from including rollover cases when computing reduction of OAIS 1 and OAIS 2 injuries. Conversely, OAIS 3 and 4 injuries occur in only 8 of the 56 nonfatal MDAI cases,* and of these ,

*OAIS 3 and/or 4 injuries occur in MDAI cases BO-5, FS-2, SC-2,5,8, and 9, and RO-10 and 13. See Table 3-6, page 3-13.

four involved side collisions where the bus was struck in the side at approximately a 90° angle. Such accidents usually produce considerable intrusion, and create dynamic forces that result in passenger contact with the sides of the bus. FMVSS 222 has no requirements involving padding of the interior sides of school buses and, therefore, there is little reason to expect that the Standard would be as effective under side collision crash conditions, as it would be under crash conditions where the passengers are thrown directly forward or to the rear.

TABLE 3-8

ESTIMATED INJURY REDUCTION OF OAIS 1 INJURIES
IN NONFATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 1	Estimated Change in OAIS			
			No Change		1 to 0	
			No.	%	No.	%
1. Bus Only (BO)	5	69	20	*29.0*	49	*71.0*
2. Rear End (RE)	6	20	5	*25.0*	15	*75.0*
3. Front-Rear (FR)	5	65	20	*30.8*	45	*69.2*
4. Front-Side (FS)	8	112	24	*21.4*	88	*78.6*
5. Side-Swipe (SS)	1	1	1	*100.0*		
6. Side Collision (SC)	10	103	44	*42.7*	59	*57.3*
7. Headon (HO)	4	46	18	*38.1*	28	*60.9*
8. Rollover (RO)	17	201	181	*90.0*	20	*10.0*
9. FR + HO	9	111	38	*34.2*	73	*65.8*
10. BO + RE + FR + SS + HO	21	201	64	*31.8*	37	*68.2*
11. All, except RO	39	416	132	*31.7*	284	*68.3*
12. All	56	617	313	*50.7*	304	*49.3*

TABLE 3-9

ESTIMATED INJURY REDUCTION OF OAIS 2 INJURIES
IN NONFATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 2	Estimated Change in OAIS					
			No Change		2 to 1		2 to 0	
			No.	%	No.	%	No.	%
1. Bus Only (BO)	5	9	1	11.1	6	66.7	2	22.2
2. Rear End (RE)	6	1	0		0		1	100.0
3. Front-Rear (FR)	5	4	0		2	50.0	2	50.0
4. Front-Side (FS)	8	13	0		2	15.4	11	84.6
5. Side-Swipe (SS)	1	2	0		2	100.0	0	
6. Side Collision (SC)	10	18	7	38.9	8	44.4	3	16.7
7. Headon (HO)	4	5	1	20.0	2	40.0	2	40.0
8. Rollover (RO)	17	30	25	83.3	4	13.3	1	33.3
9. FR + HO	21	9	1	11.1	4	44.4	4	44.4
10. BO + RE + FR + SS + HO	21	21	2	9.5	12	57.1	7	33.3
11. All, except RO	39	52	9	17.3	22	42.3	21	40.4
12. All	56	82	34	41.5	26	31.7	22	26.8

TABLE 3-10

ESTIMATED INJURY REDUCTION OF OAIS 3 INJURIES
IN NONFATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 3	Estimated Change in OAIS							
			No Change		3 to 2		3 to 1		3 to 0	
			No.	%	No.	%	No.	%	No.	%
1. Bus Only (BO)	5	0								
2. Rear End (RE)	6	0								
3. Front-Rear (FR)	5	0								
4. Front-Side (FS)	8	2	0		0		2	100.0		
5. Side-Swipe (SS)	1	0								
6. Side Collision (SC)	10	4	1	25.0	0		2	50.0	1	25.00
7. Headon (HO)	4	0								
8. Rollover (RO)	17	2	1	50.0	1	50.0				
9. FR + HO	9	0								
10. BO + RE + FR + SS + HO	21	0								
11. All, except RO	39	6	1	16.7	0		4	66.7	1	16.7
12. All	56	8	2	25.0	1	12.5	4	50.0	1	12.5

TABLE 3-11

ESTIMATED INJURY REDUCTION OF OAIS 4 INJURIES
IN NONFATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 4	Estimated Change in OAIS									
			No Change		4 to 3		4 to 2		4 to 1		4 to 0	
			No.	%	No.	%	No.	%	No.	%	No.	%
1. Bus Only (BO)	5	2	0		1		1					
2. Rear End (RE)	6	0										
3. Front-Rear (FR)	5	0										
4. Front-Side (FS)	8	1					1	100.0				
5. Side-Swipe (SS)	1	0										
6. Side Collision (SC)	10	4	1	25.0	1	25.0	0		2	50.0		
7. Headon (HO)	4	0										
8. Rollover (RO)	17	0										
9. FR + HO	9	0										
10. BO + RE + FR + SS + HO	21	2	0		1	50.0	1	50.0				
11. All, except RO	39	7	1	14.3	2	28.6	2	28.6	2	28.6		
12. All	56	7	1	14.3	2	28.6	2	28.6	2	28.6		

Summarizing Tables 3-8 through 3-11 gives the injury reduction rates shown in Table 3-12.

In Table 3-12, injury reduction rates for OAIS 1 and 2 injuries are based on 39 MDAI cases, i.e., the 17 rollover cases are not considered. As noted above, only 8 nonfatal MDAI cases resulted in OAIS 3 and 4 injuries. Because of the small number of injuries, in the last three elements of Table 3-12, OAIS 3 and 4 injuries have been combined, and injury reduction rates for at least, one, two, and three OAIS levels computed. These reduction rates are probably much more meaningful than actual changes from one OAIS level to another, where at most the estimated reductions involve one, two, or four injured passengers.

TABLE 3-12

ESTIMATED INJURY REDUCTION RATES
IN NONFATAL SCHOOL BUS ACCIDENTS

(56 MDAI Cases)

Injury Reduction Condition	Original Number Injured	Estimated Rate of Injury Reduction Due to FMVSS 222
• OAIS 1 is reduced to OAIS 0*	416	68 %
• OAIS 2 is reduced to OAIS 1*	52	42 %
• OAIS 2 is reduced to OAIS 0*	52	40 %
• OAIS 3 is reduced to OAIS 2	8	12.5 %
• OAIS 3 is reduced to OAIS 1	8	50 %
• OAIS 3 is reduced to OAIS 0	8	12.5 %
• OAIS 4 is reduced to OAIS 3	7	29 %
• OAIS 4 is reduced to OAIS 2	7	29 %
• OAIS 4 is reduced to OAIS 1	7	29 %
• OAIS 3 and 4 injuries are reduced at least one OAIS level	15	80 %
• OAIS 3 and 4 injuries are reduced at least two OAIS levels	15	60 %
• OAIS 3 and 4 injuries are reduced at least three OAIS levels	15	20 %

*The OAIS 1 and 2 injury reduction rates are based on 39 MDAI cases, which exclude 17 rollovers. The OAIS 3 and 4 rates are based on all 56 MDAI cases.

3.5 Effectiveness of FMVSS 222 in Reducing Injuries in Fatal School Bus Accidents

There were 26 fatal MDAI school bus accident reports reviewed by the Clinical Analysis Team. In three of the accidents the driver was the only occupant killed. There were 712 passengers (an average of 27.4 passengers/accident), of whom 83 (*11.6 %*) were killed and 490 (*68.8 %*) were injured. There was an average of 22 passengers killed and injured/accident (80.5 % of all passengers). School bus accidents resulting in such high death-and-injury rates are necessarily very violent events; indeed, 14 of the 26 fatal MDAI cases involved rollovers, ranging from 90 to 900 degrees.

As discussed in greater detail in Section 3-7, 17 of the 26 fatal MDAI cases also occur in the FARS data base for 1975, 1976, 1977, and 1978. The remaining 9 MDAI cases either occurred prior to 1975 (7 cases) or the accident took place in Canada (2 cases). There are 60 fatal accidents in the four-year FARS data base, involving 107 passenger fatalities, for an average fatality rate of 1.8 passengers killed per accident. The fatality rate for the 26 fatal MDAI cases is 3.2 passengers killed/accident. This figure is high because MDAI cases are biased toward worst crashes, such as the one where 29 passengers were killed (F-RO-11). As was the situation with nonfatal MDAI cases, the fatal accidents selected for detailed multidisciplinary investigation were, understandably, considerably more violent than the actual norm--the fatality rate for MDAI cases is almost twice that of the FARS cases.

For comparison with the nonfatal data analysis immediately above, the same 12 categories of accidents are used. These categories are shown in Tables 3-13 through 3-19 for OAIS 1, 2, 3, 4, 5NF, 5F, and 6 injuries incurred in fatal school bus accidents. Tables 3-18 and 3-19 show clearly that the majority of the passenger fatalities (72 of 83, or *87 %*) occurred in side collisions and rollovers. Conversely, there were no fatalities in rearend, front-side, and headon accidents, in this set of 26 fatal MDAI investigations.

Not surprisingly, the majority of injuries occurring in these rare, complex, violent accidents are not affected by the interior safety features of FMVSS 222. Of the 446 known nonfatal injuries, 298 (*66.8 %*) were judged to remain unchanged by the Clinical Analysis Team. Only 7 (*8.4 %*) of the 83 fatalities were judged by the team to reduce to a lower level of nonfatal injury, and in each instance, this judgment took into account that 6 of 7 fatalities occurred in vans which did not have passenger seat belts. The team assumed that had the vans met the Standard, there would have been passenger

seat belts available and they would have been used. Five of these van deaths involved ejection, which a seat belt would have prevented, if used. The sixth van death occurred when a passenger was hurled against the unprotected metal back of the driver's seat. Here, too, the seat belt (assumed to be used) was judged to reduce the fatality to a minor injury. Had the seat belts not been available and used, these 6 fatalities would not have been prevented. Only in the case of one passenger fatality, who died as a result of massive abdominal damage stemming from contact with the top of an unpadded seat back frame in a conventional school bus, was the Team willing to judge that FMVSS 222 requirements would result in injuries of OAIS 2 or less. In this instance, the reduced spacing between seats, higher seat backs, and the broad padded seat back and top was estimated to produce the reduced injury level.

As a general observation, Tables 3-13 through 3-19 make clear that, in the judgement of the Clinical Analysis Team, FMVSS 222 is less than half as effective in fatal accidents, relative to nonfatal accidents. Estimated fatal accident injury reduction rates due to FMVSS 222 are summarized in Table 3-20, which can be compared with the nonfatal injury reduction rates found in Table 3-12. In particular, in nonfatal accidents 68 percent of the OAIS 1 and 40 percent of the OAIS 2 injuries are estimated to reduce to no injury, while in the fatal accidents the corresponding injury reductions are only 33 percent for OAIS 1 and 8 percent for OAIS 2. In addition, 42 percent of OAIS 2 injuries are estimated to reduce to OAIS 1 in nonfatal school bus accidents, but only 34 percent are similarly reduced in fatal accidents. There are so few OAIS 3 and 4 injuries in nonfatal school bus accidents that there is little basis for comparison with fatal accident injury reduction rates.

TABLE 3-13

ESTIMATED INJURY REDUCTION OF OAIS 1 INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 1	Estimated Change in OAIS			
			No Change		1 to 0	
			No.	%	No.	%
1. Bus Only (BO)	5	24	2	8.3	22	91.7
2. Rear End (RE)	0	0				
3. Front-Rear (FR)	1	29	9	31.0	20	69.0
4. Front-Side (FS)	0	0				
5. Side-Swipe (SS)	2	25	15	60.0	10	40.0
6. Side Collision (SC)	4	33	22	66.7	11	33.3
7. Headon (HO)	0	0				
8. Rollover (RO)	14	140	121	86.4	19	13.6
9. FR + HO	1	29	9	31.0	20	69.0
10. BO + RE + FR + SS + HO	6	78	26	33.3	52	66.7
11. All, except RO	12	111	48	43.2	63	56.8
12. All	26	251	169	67.3	82	32.7

TABLE 3-14

ESTIMATED INJURY REDUCTION OF OAIS 2 INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 2	Estimated Change in OAIS					
			No Change		2 to 1		2 to 0	
			No.	%	No.	%	No.	%
1. Bus Only (BO)	5	8	0		3	37.5	5	62.5
2. Rear End (RE)	0	0						
3. Front-Rear (FR)	1	2	0		2	100		
4. Front-Side (FS)	0	0						
5. Side-Swipe (SS)	2	4	3	75	1	25	1	
6. Side Collision (SC)	4	23	13	56.5	8	34.8	2	8.7
7. Headon (HO)	0	0						
8. Rollover (RO)	14	54	37	68.5	17	31.5		
9. FR + HO	1	2	0		2	100		
10. BO + RE + FR + SS + HO	6	14	3	21.4	6	42.9	5	35.7
11. All, except RO	12	37	16	43.2	14	37.8	7	18.9
12. All	26	91	53	58.2	31	34.1	7	7.7

TABLE 3-15

ESTIMATED INJURY REDUCTION OF OAIS 3 INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 3	Estimated Change in OAIS					
			No Change		3 to 2		3 to 1	
			No.	%	No.	%	No.	%
1. Bus Only (BO)	5	2	0		1	50	1	50
2. Rear End (RE)	0	0						
3. Front-Rear (FR)	1	1	0		0		1	100
4. Front-Side (FS)	0	0						
5. Side-Swipe (SS)	2	1	1	100				
6. Side Collision (SC)	4	14	8	57.1	3	21.4	3	21.4
7. Headon (HO)	0	0						
8. Rollover (RO)	14	42	35	83.3	4	9.5	3	7.1
9. FR + HO	1	1	0		0		1	100
10. BO + RE + FR + SS + HO	6	4	1	25.0	1	25.0	2	50.0
11. All, except RO	12	18	9	50.0	4	22.2	5	27.7
12. All	26	60	44	73.3	8	13.3	8	13.3

TABLE 3-16

ESTIMATED INJURY REDUCTION OF OAIS 4 INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 4	Estimated Change in OAIS					
			No Change		4 to 2		4 to 1	
			No.	%	No.	%	No.	%
1. Bus Only (BO)	5	1			1	100		
2. Rear End (RE)	0	0						
3. Front-Rear (FR)	1	0						
4. Front-Side (FS)	0	0						
5. Side-Swipe (SS)	2	2	2	100				
6. Side Collision (SC)	4	1	1	100				
7. Headon (HO)	0	0						
8. Rollover (RO)	14	23	16	69.6	6	26.1	1	4.3
9. FR + HO	1	0						
10. BO + RE + FR + SS + HO	6	3	2	66.7	1	33.3		
11. All, except RO	12	4	3	75.0	1	25.0		
12. All	26	27	19	70.4	7	25.9	1	3.7

TABLE 3-17

ESTIMATED INJURY REDUCTION OF OAIS 5(NF) INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 5(NF)	Estimated Change in OAIS							
			No Change		5 NF to 4		5 NF to 2		5 NF to 1	
			No.	%	No.	%	No.	%	No.	%
1. Bus Only (BO)	5	2	0		0		0		2	*100*
2. Rear End (RE)	0	0								
3. Front-Rear (FR)	1	0								
4. Front-Side (FS)	0	0								
5. Side-Swipe (SS)	2	1	1	*100*						
6. Side Collision (SC)	4	1	1	*100*						
7. Headon (HO)	0	0								
8. Rollover (RO)	14	13	11	*84.6*	1	*7.7*	1	*7.7*		
9. FR + HO	1	0								
10. BO + RE + FR + SS + HO	6	3	1	*33.3*					2	*66.7*
11. All, except RO	12	4	2	*50.0*					2	*50.0*
12. All	2	17	13	*76.5*	1	*5.9*	1	*5.9*	2	*11.8*

TABLE 3-18

ESTIMATED INJURY REDUCTION OF OAIS 5(F) INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 5(F)	Estimated Change in OAIS			
			No Change		5F to 1	
			No.	%	No.	%
1. Bus Only (BO)	5	0				
2. Rear End (RE)	0	0				
3. Front-Rear (FR)	1	0				
4. Front-Side (FS)	0	0				
5. Side-Swipe (SS)	2	2	2	*100*		
6. Side Collision (SC)	4	4	4	*100*		
7. Headon (HO)	0	0				
8. Rollover (RO)	14	28	27	*96.4*	1	*3.6*
9. FR + HO	1	0				
10. BO + RE + FR + SS + HO	6	2	2	*100*		
11. All, except RO	12	6	6	*100*		
12. All	26	34	33	*97.1*	1	*2.9*

TABLE 3-19

ESTIMATED INJURY REDUCTION OF OAIS 6 INJURIES
IN FATAL SCHOOL BUS ACCIDENTS

Accident Type	No. of MDAI Cases	Original No. of Injuries of OAIS 6	Estimated Change in OAIS							
			No Change		6 to 2		6 to 1		6 to 0	
			No.	%	No.	%	No.	%	No.	%
1. Bus Only (BO)	5	5	2	*40.0*	1	*20.0*			2	*40.0*
2. Rear End (RE)	0	0								
3. Front-Rear (FR)	1	0								
4. Front-Side (FS)	0	0								
5. Side-Swipe (SS)	2	1	1	*100*						
6. Side Collision (SC)	4	8	8	*100*						
7. Headon (HO)	0	0								
8. Rollover (RO)	14	35	32	*91.4*	0		3	*8.6*		
9. FR + HO	1	0								
10. BO + RE + FR + SS + HO	6	6	3	*50.0*	1	*16.7*			2	*33.3*
11. All, except RO	12	14	11	*78.6*	1	*7.1*			2	*14.3*
12. All	26	49	43	*87.8*	1	*2.0*	3	*6.1*	2	*4.1*

TABLE 3-20

ESTIMATED INJURY REDUCTION RATES IN FATAL SCHOOL BUS ACCIDENTS
(26 MDAI Cases)

Injury Reduction Condition	Original Number Injured or Killed	Estimated Rate of Injury Reduction Due to FMVSS 222
• OAIS 1 is reduced to OAIS 0	169	33 %
• OAIS 2 is reduced to OAIS 1	91	34 %
• OAIS 2 is reduced to OAIS 0	91	8 %
• OAIS 3 is reduced to OAIS 2	60	13 %
• OAIS 3 is reduced to OAIS 1	60	13 %
• OAIS 4 is reduced to OAIS 2	27	26 %
• OAIS 4 is reduced to OAIS 1	27	4 %
• OAIS 5 NF is reduced to OAIS 4	17	6 %
• OAIS 5 NF is reduced to OAIS 2	17	6 %
• OAIS 5 NF is reduced to OAIS 1	17	12 %
• OAIS 5 F is reduced to OAIS 1	34	3 %
• OAIS 6 is reduced to OAIS 2	34	2 %
• OAIS 6 is reduced to OAIS 1	34	6 %
• OAIS 6 is reduced to OAIS 0	49	4 %
• Nonfatal injury is reduced at least one OAIS level	446	33 %
• Nonfatal injury is reduced at least two OAIS levels	446	6 %
• Fatal injury is reduced to nonfatal injury	83	8 %

3.6 Extrapolation of Clinical Analysis Results to the Nationwide Effectiveness of FMVSS 222 (Nonfatal School Bus Accidents)

The results of the effectiveness of FMVSS 222 in reducing injuries and fatalities in school bus accidents, presented in the previous subsections, are based solely on the analysis of 82 MDAI reports.

It is emphasized that the estimates of effectiveness in the previous figures and tables do not apply to the nation. Furthermore, the sample size--in terms of numbers of accidents--is extremely small for nonfatal accidents. We have reviewed 56 nonfatal accidents (*∿0.16 %*) out of a total of possibly 30,000 to 40,000 which occurred during the eleven years represented by the nonfatal MDAI reports. For the fatal accidents, we have a small sample, but a larger fraction of the total accidents: 26 accidents (*∿13 %*) in which there was at least one occupant fatality, out of a total of about 150 to 250 accidents that we estimate have occurred during the nine years for which we have fatal MDAI reports. In this subsection, we modify the clinical analysis results to ameliorate their assumed bias towards (a) accidents in which many students are injured, or (b) the more violent school bus accidents in which at least one occupant was killed.

We have reviewed the information available in the annual editions of *Accident Facts*, published by the National Safety Council. While their information on passengers injured and killed in school bus accidents is in the form of estimates, it is the best available at this time, to our knowledge. Table 3-21 shows this information.

Table 3-21 suggests that of the pupils killed, on the average, about 30 to 40 percent are killed in the bus, and the remainder are killed outside the bus. For pupils injured, there is no comparable breakdown, but averaging the National Safety Council information for 1975, 1976, and 1977 gives about:

- 4000 school bus accidents in which injuries occur.
- 4300 pupils injured.
- 2600 non-pupils injured.

We will arbitrarily assume that 15% of the accidents (i.e., 600) involved the bus hitting one pedestrian, and that two-thirds of these involved the bus hitting one pupil (i.e., 400 pupils), and one third involved the bus hitting one non-pupil (i.e., 200 non-pupils). In both cases, we assume no one else was injured.

TABLE 3-21

A SUMMARY OF SCHOOL BUS ACCIDENT CHARACTERISTICS

(Source: *Accident Facts*, 1963 through 1977 Editions)

Year	Total Vehicles (000s)	Annual Bus Mileage (millions)	Pupils Transp. Daily (millions)	Injury Accidents	Persons Injured		Estimated Pupils Killed		
					Pupils	Total	Total	Pass-engers	Pedes-trians
1962	191	1649	13.3	2859	2906	4262	49	17	32
1963	192	1675	15.1	2984	3533	4599	41	11	30
1964	200	1700	16.0	3400	3700	4800	50	15	35
1965	220	1750	16.0	4000	3700	5000	50	15	35
1966	225	1800	16.5	4000	3800	5000	50	15	35
1967	250	1900	17.2	3000	3200	4000	60	25	35
1968	260	1950	18.0	3000	3600	5000	75	25	50
1969	275	2150	19.0	2000	3900	5400	75	25	50
1970	285	2200	19.5	5000	3900	5400	75	25	50
1971	290	2300	20.0	6000	4200	5600	85	35	50
1972	310	2400	20.5	5000	4500	6000	100	35	65
1973	310	2500	21.0	4000	4500	6000	125	60	65
1974	340	2400	21.5	4000	4700	6500	90	35	55
1975	350	2500	22.0	4000	4500	6300	90	35	55
1976	380	2600	22.2	5000	4300	7200	105	55	50
1977	380	2900	22.2	3000	4100	7200	95	30	65

Under these assumptions, we would have:

- 3400 school bus injury accidents, excluding pedestrians injured.
- 3900 pupils injured while in the bus.
- 2400 non-pupils injured.

We now arbitrarily assume that in the accidents where only non-pupils were injured, the injury rate for each accident was 1.3 non-pupils/accident. Further, we assume that two-thirds of the accidents involving non-pupils caused injuries only to non-pupils. We then have 1231 accidents which involved only non-pupils:

$$\left(2400 \times \frac{2}{3}\right) / 1.3 = 1231$$

This leaves:

- 2769 school bus injury accidents in which pupils were injured.
- 3900 pupils injured.
- 1.4 pupils injured/accident (average) as passengers.*

Figure 3-1 indicates that there were 1688 passengers in the 56 nonfatal MDAI school bus accidents assessed by the Clinical Analysis Team. Thus, there was an average of 30.1 passengers/school bus. There were 719 (*42.6 %*) passengers injured and 969 (*57.4 %*) not injured. This implies about 13 passengers injured per accident. If we apply these statistics to the conditions above, we would have:

2769 x 30.1 x 0.426 = 35,506 injured passengers.

Obviously, the MDAI cases are much more violent (factor of 9) than the norm--assuming the National Safety Council (NSC) figures are at least "in the ball park." The average number of school bus passengers injured per accident (*∿1.4*) implies that in the vast majority of accidents, no more than one passenger is injured. A possible distribution of number of passengers injured per accident might be as shown in Table 3-22.

TABLE 3-22

A HYPOTHETICAL DISTRIBUTION OF SCHOOL BUS PASSENGERS INJURED/ACCIDENT WHICH SATISFIES THE NATIONAL SAFETY COUNCIL ESTIMATES
(Based on average conditions for 1975, 1976, 1977)

Passengers Injured Per Accident	Percent of Total Accidents	Number of Accidents	Number of Passengers Injured
1	73.5	2035	2035
2	17.2	476	952
3	5.7	158	474
4	2.6	72	288
5 or more	1.0	28	151
Total	100	2769	3900

While Table 3-22 is an artificial construct, it is safe to say that any other combination of percentages of accidents in which the number of students injured is 1, 2, 3, 4, and 5 or more must be very close to the values shown, assuming that the percentages must be of descending magnitude, and that the bounds (1.4 injured passengers per accident; 2769 accidents; 3900 passengers injured) are preserved.

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*In a private communication (May 1977), Mr. J. Recht of the National Safety Council staff concurred that 1.4 pupils injured/accident was "a reasonable estimate."

It is reasonable to assume that both accident severity and the highest level of injury severity increase in proportion to the number of passenger injured per accident. A possible distribution of accident severity as a function of number of passengers injured per accident might be as shown in Table 3-23. This is an arbitrarily derived distribution, which has been made internally consistent by iteration, so that the distribution for cases for 5 or more injured passengers conforms to results from the MDAI cases. The other distributions are consistent with this baseline.

TABLE 3-23

ESTIMATED DISTRIBUTION OF PASSENGER INJURY SEVERITY IN NONFATAL SCHOOL BUS ACCIDENTS

Number of Passengers Injured in Accident	Estimated Distribution of Injury Severity (%)			
	OAIS 1	OAIS 2	OAIS 3	OAIS 4
1	90	9.7	0.3	-
2	89	10.5	0.4	0.1
3	88	11.1	0.6	0.3
4	87	11.4	0.9	0.7
5 or more	86.3	11.6	1.1	1.0

The distribution of injury severity for accidents in which five or more passengers are injured is based on the clinical analysis (see Figure 3-1). The other distributions are rational estimates.

Combining Tables 3-22 and 3-23 gives the estimated injury severity of passengers in school bus accidents in 1976, as shown in Table 3-24 below.

TABLE 3-24

ESTIMATED INJURY SEVERITY OF PASSENGERS IN PRE-FMVSS 222 NONFATAL SCHOOL BUS ACCIDENTS IN 1976

Passengers Injured Per Accident	Estimated Number of Injured (1976)	Estimated Injury Severity			
		OAIS 1	OAIS 2	OAIS 3	OAIS 4
1	2035	1832	197	6	-
2	952	847	100	4	1
3	474	417	53	3	1
4	288	250	33	3	2
5 or more	151	130	17	2	2
Total	3900	3476	400	18	6
% of Total	*100*	*89.1*	*10.3*	*0.5*	*0.1*

Source: *Accident Facts*, National Safety Council, and CEM estimates.

The injury reductions resulting from the clinical analysis (shown in Table 3-8 through Table 3-12) for nonfatal MDAI school bus accidents indicate the following:

- 68 % of OAIS 1 injuries would be reduced to No Injury.
- 42 % of OAIS 2 injuries would be reduced to OAIS 1.
- 40 % of OAIS 2 injuries would be reduced to No Injury.

The above injury reduction estimates are based on clinical analysis of 39 MDAI cases which exclude bus rollover accidents. There are not sufficient number of OAIS 3 and 4 injuries in the MDAI nonfatal cases to arrive at a conclusive estimate for reduction. For this scenario, we use as a conservative estimate:

- 51 % of OAIS 3 injuries would be reduced to at least OAIS 2.
- 51 % of OAIS 4 injuries would be reduced to at least OAIS 3.

Based on these injury reductions that are estimated to result from FMVSS 222, Table 3-24 becomes:

TABLE 3-25

ESTIMATED AVERAGE ANNUAL INJURY SEVERITY OF PASSENGERS IN NONFATAL SCHOOL BUS ACCIDENTS, ASSUMING ALL BUSES MET FMVSS 222 REQUIREMENTS IN 1975/1976/1977

Passengers Injured In Original Accident	Estimated Number Injured (Pre-Standard)	Previously Injured Estimated Not Injured (Post-Standard)		Estimated Injury Severity (Post-Standard)			
				OAIS 1	OAIS 2	OAIS 3	OAIS 4
1	2035	1325	(65 %)	669	38	3	
2	952	616	(65 %)	313	20	3	0
3	474	305	(64 %)	155	12	2	0
4	288	183	(64 %)	94	8	2	1
5 or more	151	95	(63 %)	49	4	2	1
Total	3900	2524	(65 %)	1280	82	12	2
Percent of Pre-Standard Total	*100*	*64.7*		*32.8*	*2.1*	*0.3*	*0.05*

Table 3-25 suggests that at least 34 percent (1325/2769) of all Pre-Standard accidents would not have been classified as passenger injury accidents, had all the buses met FMVSS 222 requirements. That is, 1325 of the 2035 accidents involving only one injured passenger would have resulted in no injury. About 65 percent of the 3900 injured students would not have been injured, and about 4 percent (168/3900) would have had their OAIS 2, 3, or 4 injury reduced at least one OAIS level. Thus, 69 percent of the passengers would have been better off, on the average, had all the school buses involved in passenger accidents in 1975/1976/1977 met the requirements of FMVSS 222.

3.7 Extrapolation of Clinical Analysis Results to the Nationwide Effectiveness of FMVSS 222 (Fatal School Bus Accidents)

Considering that more than 22 million school pupils are transported about 3 billion miles annually, by about 300,000 vehicles, it is indeed remarkable that on the average there are probably no more than about 20 accidents a year in which the driver and/or one or more passengers are killed. (We exclude from this discussion the case where the driver is killed and is the only occupant of the school bus.)

In this study, 26 fatal school bus MDAI cases have been reviewed by the Clinical Analysis Team. There were 18 cases involving school buses weighing 10,000 lb or more; one case involving an 8600 lb "mini-bus" (i.e.,conventional school bus configuration); and 7 van cases in which the vehicle weight was less than 10,000 lb. An overview of the results (taken from Table 3-7) is shown in Table 3-26.

To place the clinical analyses of the 26 MDAI cases in perspective, all data available in the NHTSA Fatal Accident Reporting System (FARS) for 1975 through 1978 was requested from Ms. Grace Hazzard, and analyzed. Summary results of the FARS analysis are shown in Table 3-27. Detailed, case-by-case summaries for both the MDAI and FARS data are found in Appendix C.

In general, as has been noted previously, the accidents investigated by Multidisciplinary Accident Investigation teams are usually the more violent ones. This is exemplified by Table 3-28, which shows the frequency of passengers killed/accident in the MDAI and FARS cases. This table clearly indicates the following:

- Relative to FARS, the MDAI cases involve only about half as many accidents where:
  - The driver is killed, but no passengers are killed.
  - Only one passenger is killed.
- Relative to FARS, the MDAI cases involve nearly three times as many accidents where:
  - Two passengers are killed.
  - More than three passengers are killed.

These points and others are illustrated in Figure 3-3, which makes obvious that in approximately 75 percent of the FARS cases, there is one (*58 %*) or no (*17 %*) passenger fatalities. These data illustrate that--perhaps contrary to some popular opinions--not only are fatal school bus accidents rare events, but the probability that more than one passenger will be killed is small (~*25 %*), and the probability of more than three passengers being killed is very small (~*5 %*).*

*In the previous subsection, it was shown that there are about 2800/year school bus accidents in which someone is killed or injured. FARS data indicate that the number of fatal accidents is about 15/year, or less than 0.6 percent, which is also the approximate probability of an individual being killed in a school bus accident involving passenger death or injury. Thus, the probability of more than three passengers being killed in a school bus injury accident is of the order one in three thousand, or about 0.0003.

TABLE 3-26

SCHOOL BUS FATALITIES
(Source: 26 Fatal MDAI School Bus Reports: 1970-1977)

Vehicle Type	Number of Accidents	Total Passengers	Killed		Injured		Uninjured		Killed Plus Injured	Killed	Injured
			No.	%*	No.	%*	No.	%*		% of K + Inj.	% of K + Inj.
School Bus	19	623	74	*12*	415	*67*	134	*21*	489	*15.1*	*84.9*
Van	7	89	9	*10*	75	*84*	5	*6*	84	*10.7*	*89.3*
Total	26	712	83	*12*	490	*69*	139	*19*	573	*14.5*	*85.5*

*Percentage based on Total Passengers in category.

TABLE 3-27

SCHOOL BUS FATALITIES
(Source: FARS: 1975-1978)

Year • Vehicle Type	No. of Acc.	Total Passengers	Killed		Injured		Uninjured		Killed Plus Injured	Killed	Injured
			No.	%*	No.	%*	No.	%*		% of K + Inj.	% of K + Inj.
1975											
• School Bus	8	113	9	*8*	57	*50*	47	*42*	66	*14*	*86*
• Van, Other	6	28	6	*21*	18	*64*	4	*14*	24	*25*	*75*
• Total	14	141	15	*11*	75	*53*	51	*36*	90	*17*	*83*
1976											
• School Bus	11	293**	51	*17*	187	*64*	54	*18*	238	*21*	*79*
• Van, Other	7	42	5	*12*	37	*88*	0	*0*	42	*12*	*88*
• Total	18	335	56	*17*	224	*67*	54	*16*	280	*20*	*80*
1977											
• School Bus	11	201	14	*7*	91	*45*	96	*48*	105	*13*	*87*
• Van, Other	5	40	5	*12*	31	*78*	4	*10*	36	*14*	*86*
• Total†	16	241	19	*8*	122	*51*	100	*41*	141	*14*	*86*
1978											
• School Bus	10	247	16	*7*	159	*64*	72	*29*	175	*9*	*91*
• Van, Other	2	6	1	*17*	3	*50*	2	*33*	4	*25*	*75*
• Total	12	253	17	*7*	162	*64*	74	*29*	179	*10*	*90*
4-Year Total											
• School Bus	40	844**	90	*11*	494	*58*	269	*31*	584	*15*	*85*
• Van, Other	20	116	17	*15*	89	*77*	10	*9*	106	*16*	*84*
• Total	60	970**	107	*11*	583	*60*	279	*29*	690	*16*	*84*

*Percent of Total Passengers.

**Includes one (1) Unknown.

†Omits two fatal accidents in which students were passengers on municipal transit buses.

TABLE 3-28

COMPARISON OF SCHOOL BUS PASSENGERS KILLED/ACCIDENT

No. of Passengers Killed/Acc.	MDAI Cases		FARS Cases									
			1975		1976		1977		1978		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0*	3	11	3	21	3	17	1	6	3	25	10	17
1	9	35	7	50	10	55	12	75	6	50	35	58
2	7	27	4	29			2	12			6	10
3	3	11			3	17	1	6	2	16	6	10
4												
5	1	4							1	8	1	2
6												
7												
8	1	4			1	6					1	2
9	1	4										
29	1	4			1	6					1	2
Total No. Cases	26	100	14	100	18	100	16	100	12	100	60	100

*Driver killed, but no passengers killed. However, passengers were in the school bus. In only one case (FARS Case 1976/0799) was the driver killed, but no passengers were injured.

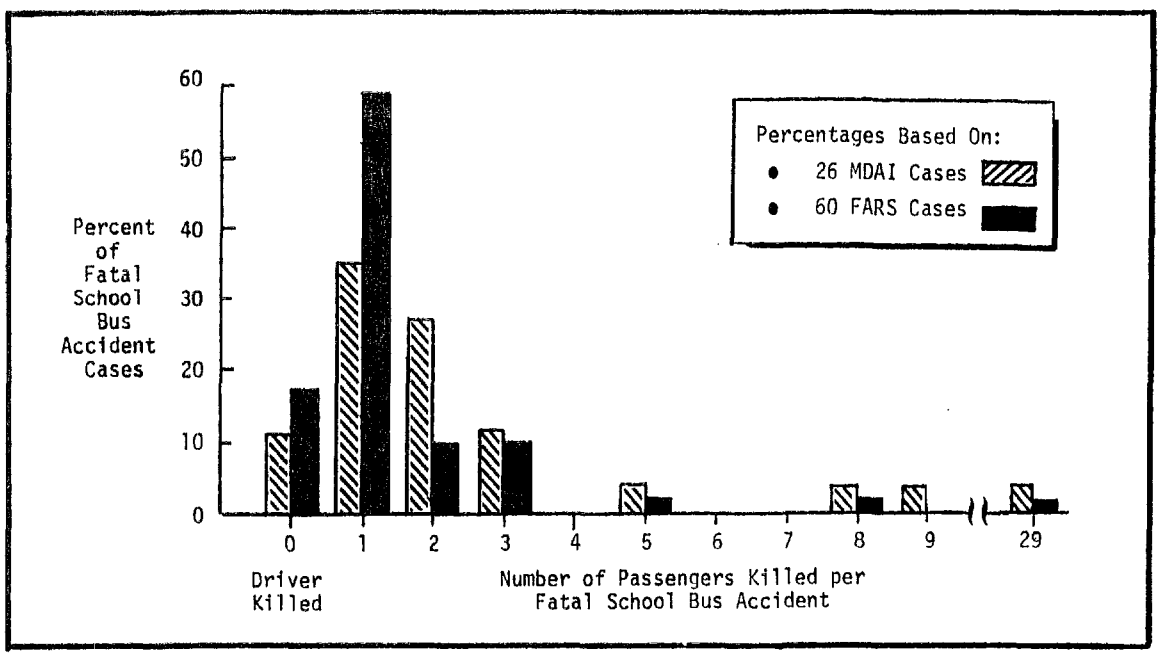

Figure 3-3. Comparison of number of passengers killed/fatal school bus accidents in MDAI and FARS cases.

The MDAI cases suggest that more school bus fatalities occur in rollovers than in any of the other accident classifications: of 83 MDAI passenger fatalities 63 (*76 %*) occurred in rollovers. Even if the major California school bus rollover in which 29 passengers perished (CEM's F-RO-11; FARS 1976/1401) is excluded, of the remaining 54 fatalities, 44 (*82 %*) occurred in rollovers.

As has been noted earlier in this report (Section 2), the Clinical Analysis Team concluded that FMVSS 222 has little effectiveness in preventing fatalities in school bus accidents, because the fatalities occur in the more physically violent accidents, and in numerous cases result from rollovers and/or passenger ejection, or severe physical damage to the bus, as occurs when a portion of a truck or train or some other massive structure intrudes the interior of the bus. The major exception to this statement involves the FMVSS 222 requirement that vans and other small vehicles used as buses must meet the restraint system requirements of FMVSS 208, 209 and 210--usually done by means of a lap or lap-and-shoulder belt. Assuming that belts installed in small buses are used by the passengers, it is likely that FMVSS 222 would be highly effective in reducing both death and injury in these vehicles, even when involved in the complex, violent accidents that presently result in fatalities. According to the FARS data in Table 3-27, 15 percent of both deaths and injuries in fatal school bus accidents occur in small school transportation vehicles. In the MDAI cases (Table 3-26), 11 percent of the deaths and 15 percent of the injuries occurred in vans. Assuming an annual average of 27 fatalities and 146 injured passengers in fatal school bus accidents, the use of seat belts in small buses would, at most, have some effect on 4 deaths and 22 injuries per year, based on data in Table 3-27. If the passengers use the belts, it is judged that about 50 percent of the deaths in small transportation vehicles would be prevented, and over half of the injuries would be reduced at least one OAIS level. Obviously, we are discussing an impact on only about 30 school bus passengers, on a national basis.*

Table 3-27 (FARS data) indicates there is an average of about 15 fatal school bus accidents per year, involving a total of 27 passenger fatalities and 146 passenger injuries. The clinical analyses of injury reduction due to FVMSS 222 are shown in Tables 3-5 and 3-7. Since FARS data are given in the form of KABCO, rather than OAIS, the approximations in Table 3-29 are used to convert the

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*At this time, we have no basis for developing the injury level reductions that would occur in nonfatal small bus accidents, if all the passengers used seat belts.

results of the MDAI clinical analysis to a form that will permit use of the FARS data, as shown.

The OAIS-to-KABC conversions in Table 3-29 are combined with the appropriately adjusted uninjured values from Table 3-7 to give the results shown in Table 3-30.

TABLE 3-29

CONVERSIONS OF OAIS TO KABC

(Source: CEM Report 4250-641)[/]

OAIS Level	Distribution to KABC	Original MDAI OAIS Injuries*	OAIS to KABC Conversion				MDAI Injuries Reduced by FMVSS 222 **	OAIS to KABC Conversion			
			C	B	A	K		C	B	A	K
1	33 % to A	276	91				231	76			
	60 % to B			166					139		
	7 % to A				19					16	
2	55 % to B	100		55			75		41		
	45 % to A				45					34	
3	100 % to A	66			66		47			47	
4	100 % to A	30			30		21			21	
5 NF	100 % to A	18			18		14			14	
5 F	100 % to K	34				34	33				33
6	100 % to K	49				49	43				43
Totals		573	91	221	178	83	464	76	180	132	76
Percent		*100*	*16*	*39*	*31*	*14*	*100*	*16*	*39*	*29*	*16*

*The 44 injured passengers with unknown injury levels are included. They are distributed in the same proportions as the 446 passengers with known injury levels. (See Figure 3-2.)

**The 44 injured passengers with unknown injury levels have been distributed in the same proportions as the 636 injured and uninjured passengers, after injury reduction due to FMVSS 222. (See Figure 3-2.)

/ CEM Report 4250-641: *Design of Field Passive Restraint Evaluation (Interim Report)*, H. Joksch and J. Reidy, February 1979, Contract DOT-HS-8-02109.

TABLE 3-30

MDAI FATAL SCHOOL BUS CLINICAL ANALYSIS RESULTS IN KABCO FORM

Injury Level	Passenger Injury Distributions in MDAI Fatal School Bus Accidents					
	Original Injury Levels		Estimated Injury Levels with FMVSS 222		Reduction in Injuries Due to FMVSS 222	
	No.	Col.%	No.	Col.%	No.	Row %
K	83	*11.6*	76	*10.7*	7	*8.4*
A	178	*25.0*	132	*18.5*	46	*25.8*
B	221	*31.0*	180	*25.3*	41	*18.6*
C	91	*12.8*	76	*10.7*	15	*16.5*
O	139	*19.5*	248	*34.8*	-109	*-78.4*
Totals	712	*100*	712	*100*		

Of prime importance, the table suggests for the MDAI cases implementation of FMVSS 222 would result in:

- A reduction of 8 percent of the passenger deaths.
- A reduction from 0.8 to 0.65 in the conditional probability of being killed or injured, given that one is a passenger in a fatal school bus accident.

The basic FARS data in Appendix C are combined in Table 3-31 and compared with the MDAI results from Table 3-30.

TABLE 3-31

COMPARISON OF FARS AND ORIGINAL MDAI KABCO DATA FOR FATAL SCHOOL BUS ACCIDENTS

FARS YEAR	Total Passengers	Passenger Injury Level				
		K	A	B	C	O
1975	141	15	24	34	17	51
1976	334*	56	111	87	26	54
1977	241	19	22	58	42	100
1978	253	17	46	78	38	74
FARS Total	969*	107	203	257	123	279
% of Total	*100***	*11*	*21*	*27*	*13*	*29*
% of K+I		*16*	*29*	*37*	*18*	
MDAI Total	712	83	178	221	91	139
% of Total	*100*	*12*	*25*	*31*	*13*	*19*
% of K+I	*100*	*14*	*31*	*39*	*16*	

*The one Unknown has been omitted.

**Total percent does not reconcile because of rounding.

The comparison of FARS and MDAI results suggests two conclusions:

- On the average, the MDAI cases are only slightly different than "real world" fatal school bus accidents, as represented by FARS data.
- The distribution of injury levels in the MDAI cases is (fortuitously) essentially the same as the distribution of injury levels in "real world" fatal school bus accidents. [This conclusion is conditioned on the accuracy of the OAIS-to-KABC conversions in Table 3-19, which in turn are simplifications of results taken from CEM Report 4250-641, *Design of Field Passive Restraint Evaluation*.]

Assuming the validity of these conclusions, it would then follow that the death and injury reductions due to FMVSS 222 determined for the MDAI cases could be conservatively applied to the FARS results. Of particular importance, because of the close equivalence of FARS and MDAI distributions for the killed and injured

(K+A+B+C), to a first approximation, one can observe that the FARS K+I has the same OAIS distribution (45 %) as the MDAI cases. Under this assumption, we can determine from FARS the average annual number of killed plus injured, and convert this to OAIS levels, using the same proportions found in Table 3-7 , where the total adjusted MDAI K+I is 469. We can then directly apply the reductions in OAIS levels estimated by the Clinical Analysis Team for the MDAI fatal school bus cases.

The FARS data indicate annual averages of 27 passengers killed and 146 injured in fatal school bus accidents, for a total national annual average K+I of 173 out of 242 passengers. Table 3-32 shows the expected lives that would be saved and the OAIS and KABCO injury levels that would be reduced annually, assuming all school buses meet FMVSS 222 requirements. It is noted that lives saved in this analysis occur under the assumption that vans and other small school buses will have at least seat belts, and these will be used, for the most part. The caveat occurs because the clinical analysis included some vans with seat belts which were not used. When those instances of deliberate lack of use of available belts occurred, the Clinical Analysis Team's estimates of injury reduction due to FMVSS 222 were not based on the assumption that the passenger would have been restrained, and in those instances (especially when the passenger was ejected), the impact of FMVSS 222 was usually judged small or zero. Thus, the MDAI clinical analysis includes to some degree the pessimistic impact of lack of use of some of the available seat restraints.

Table 3-32 incorporates the results derived from the tables of estimated injury reduction for fatal school bus accidents (see Section 3.5). It indicates that in an average year, if all school buses met the requirements of FMVSS 222, then the effectiveness of FMVSS 222 in fatal school bus accidents would result in:

- 2 lives saved: a reduction of 7 percent. (This would be due to the use of seat belts in small school buses. On the average, one of these fatalities would be reduced to No Injury and one to a nonfatal OAIS injury level.)
- 29 more uninjured passengers: an increase in uninjured passengers of 43 percent.
- 13 additional injured passengers would have their injuries reduced by one OAIS level: a reduction of one OAIS level for 9 percent of the injured-only passengers.
- 7 additional injured passengers would have their injuries reduced by two or more OAIS levels: a reduction of at least two OAIS levels for 5 percent of the injured passengers.

Thus, out of an annual average of 173 passengers killed or injured in fatal school bus accidents, a total of 51 (29 %) would benefit, if all school buses met the requirements of FMVSS 222. This 29 percent reduction in killed and injured in fatal school bus accidents compares with the 69 percent reduction in injuries estimated to occur in nonfatal school bus accidents.

TABLE 3-32

AVERAGE ANNUAL LIVES SAVED AND INJURY REDUCTION IN FATAL SCHOOL BUS ACCIDENTS, ASSUMING ALL SCHOOL BUSES MEET FMVSS 222 REQUIREMENTS

Injury Level	Expected Passenger Deaths and Injuries					
	Pre-Standard			Post-Standard		
	No.	% Total	% K + I	No.	% Total	% K + I
KABCO						
0	69	*29*		99	*41*	
C	31	*13*	*18*	23	*9*	*16*
B	64	*26*	*37*	55	*23*	*38*
A	51	*21*	*29*	40	*17*	*28*
K	27	*11*	*16*	25	*10*	*17*
Total	242	*100*	*100*	242	*100*	*100**
OAIS						
0	69	*29*		99	*41*	
1	82	*34*	*47*	69	*28*	*48*
2	30	*12*	*17*	25	*10*	*17*
3	20	*8*	*12*	14	*6*	*10*
4	9	*4*	*5*	6	*2*	*4*
5 NF	5	*2*	*3*	4	*2*	*3*
5 F	11	*4*	*6*	11	*5*	*8*
6	16	*7*	*9*	14	*6*	*10*
Total	242	*100*	*100**	242	*100*	*100*
Uninjured	69	*28.6*		99	*40.9*	
K + I	173	*71.6*		143	*59.1*	
Total	242	*100*		242	*100*	

*Percentages may not reconcile, due to rounding.

3.8 Credibility of the Clinical Analyses

3.8.1 Background

The Clinical Analysis Team which analyzed the 82 MDAI reports of school bus accidents consisted of three people: Dr. Philip Stent (CEM Consultant and Director of Ambulatory Services at St. Francis Hospital in Hartford, Connecticut); Dr. Gaylord M. Northrop (Principal Investigator and an engineer by original training); and Mr. Edward Sweeton (mechanical engineer and automotive safety systems analyst). The Team was chosen to provide a balanced view of crash dynamics, injury causation and injury reduction, due to the safety features in the interiors of school buses which meet the standards set by FMVSS 222.

To prepare for the clinical analysis task, the Team visited a professional school bus leasing firm and physically inspected buses that ranged from 1967 (no longer in use) to 1978. At a later point, two members of the Team visited the bus farm of the town which has Connecticut's largest municipally-owned school bus fleet, and took a series of color photographs of interior and exterior school bus safety features.* These photographs were mounted on a single panel and used by the Clinical Analysis Team as a ready reference for drawing distinctions between the physical differences between Pre-Standard and Post-Standard school buses. The field trip experience and photographs were valuable aids in helping the Team arrive at conclusions concerning the degree of injury reduction that would take place, had the children involved in the MDAI accidents been in Post-Standard school buses (all of the MDAI accidents involved Pre-Standard vehicles).

3.8.2 Classification of Injury Reduction Estimates

Prior to beginning the clinical analyses, it was recognized that not all estimates of injury reduction would be of equal validity. Partly, this would be due to the nature of the accident or the injuries, or both. And, partly, it would be due to the amount of information available in the MDAI reports. For these reasons, it was decided to classify the quality of estimate for injury-reduction as "Good," "Fair," or "Poor." The interpretation of these terms by the Team was as follows:

- Good: The understanding of accident dynamics and injury causation is clear and unambiguous, and the nature of injury reduction, if any was judged to take place (typically, due to higher seat backs, seats closer together, well-padded seat backs--especially the tops and sides of seat backs--and stronger seat backs and floor fastenings, along with padded horizontal bars, vertical stanchions, and modesty shields at the front of the bus), is also well perceived by the Team. To satisfy the

*Black-and-white copies of the color photographs are found in Appendix A.

requirements for a "Good" estimate, the MDAI report had to be thorough, explicit, and complete. Usually, this meant that the MDAI report had a good description of the accident, including pictures of the accident location, and the vehicle(s) involved, along with an analysis of the crash dynamics (including the effect of dynamic forces in causing passenger injuries), estimates of points of contact that caused injuries (structural or other passengers), seating charts and trajectories of passengers to final resting places.

- Fair: The understanding of accident dynamics and injury causation is reasonably clear, but there may be some vital information missing and/or some ambiguity involved--possibly due to the complexity of the crash.

- Poor: This quality of estimate classification was used in two distinct ways:

  Poor (No Change in Injury): When the Team had inadequate information to make a judgment concerning injury reduction, the OAIS level was not changed, and the quality of estimate was classified as "Poor." Had more information been available, at least some of these "No Change" decisions might have become decisions that the injury would have been reduced to a lower OAIS level.

  Poor (Injury Reduced): There were instances when the Clinical Analysis Team was convinced that at least a certain level of injury reduction would take place, and there was a substantial probability that even more injury reduction might be judged to occur, had more information been available. In such instances, the more conservative injury reduction was selected, but the estimate was classified as Poor, because of the lack of information. There were other instances, when the limited information available indicated to the Clinical Analysis Team that an injury reduction was probable, but it was recognized that had more information been available, the Team might have decided upon No Change or reduction to a higher injury level. (Only in a very few instances did the Team classify a reduction in injury judgment as Poor.)

3.8.3 Overall Results

An overview of the quality of estimates of injury reduction made by the Clinical Analysis Team is shown in Table 3-33. Detailed computer analyses from which these data were obtained are shown in Appendix D and summarized in Appendix E.

TABLE 3-33
QUALITY OF ESTIMATES OF INJURY REDUCTION

Accident Type	Quality of Estimate						
	Good		Fair		Poor		Row Totals
	No Change	Injury Reduced	No Change	Injury Reduced	No Change	Injury Reduced	
Nonfatal	72	242	147	112	131	10	714*
	10.1	*33.9*	*20.6*	*15.7*	*13.4*	*1.4*	*100 %*
Fatal	102	57	118	77	154	21	529**
	19.3	*10.8*	*22.3*	*14.6*	*29.1*	*1.4*	*100 %*
Total	174	299	265	189	285	31	1243
	14.0	*24.1*	*21.3*	*15.2*	*22.9*	*2.5*	*100 %*
Grand Total	473		454		316		1243
	38.1		*36.5*		*25.4*		*100 %*

*Omits 5 injured, whose injury levels were unknown.
**Omits 44 injured (only), whose injury levels were unknown.

The table indicates several important points, as follows.

- In the clinical analysis of nonfatal accidents, about 20 percent of the injury estimates were classified as Poor. Of these 141 Poor estimates, 93 percent were judgments of No Change, usually because there was insufficient information to make a valid estimate. Had more information been available, many of these 131 estimates of No Change might have become Fair or Good estimates of Injury Reduction.
- Of the 1243 injuries considered by the Clinical Analysis Team, only 31 (2.5 %) estimates of Injury Reduction were judged Poor. In most cases, these judgments were made when the Clinical Analysis Team was convinced that there would be an injury level reduction of at least one OAIS level, but there were strong indications that the injury reduction might be greater than estimated.
- In the clinical analysis of fatal accidents, slightly more than 30 percent of the estimates were classified as Poor. Of these 175 Poor estimates, 88 percent were estimates of No Change, again usually because there was inadequate information available.

- In the nonfatal accidents there were 147 estimates (*20.6 %*) of No Change that were classified Fair. There were 118 similar estimates (*22.3 %*) associated with the fatal accidents. This implies that there is some reasonable probability that, had more information been available, some of the No Changes would have been judged to be Injury Reductions.
- Over 45 percent of the judgments of injuries in nonfatal accidents, and over 30 percent of the judgments in fatal accidents were classified as Good. This means that in the judgment of the Clinical Analysis Team, there was little doubt that there would be No Change in injury,or buses that meet the requirements of FMVSS 222 would have provided a safer environment, thus producing injury reduction.

In general, it was the policy of the Clinical Analysis Team to be prudent in their judgments of injury reduction, and conservative about making judgments of No Change--that is, in the absence of adequate information, we preferred to judge there would be No Change and classify the quality of the estimate as Poor, rather than make an injury reduction estimate that might have been open to challenge.

It is noted that Dr. Philip Stent (M.D.) made the final decision concerning the level of injury reduction of No Change, as well as the classification of the quality of estimate. Dr. Northrop or Mr. Sweeton primarily provided a description of the accident dynamics, and suggestions of how the physical features of a Post-Standard bus might have prevented or ameliorated injuries. However, it should also be noted that if one member of the Team had a reason for changing an injury reduction estimate or a quality of estimate classification, the issue was always thoroughly discussed until a consensus of opinions was achieved. As noted earlier, the Team's personal inspection of Pre-Standard and Post-Standard school buses, and the color photographs of Pre/Post bus interiors was very important in helping to resolve differences of opinion. In all instances, if the Clinical Analysis Team erred, it was intentionally on the side of conservatism.

The reader might question: "How can a group of three people decide that an injury would be reduced, had the bus met the requirements of FMVSS 222?" This is, perhaps, best answered by giving some background of how the Team operated, and how the decisions were made. First, all MDAI reports were screened by two CEM staff members, and an abbreviated description of the accident prepared in a common format. All available pertinent information on the nature of each injured passenger was transcribed onto a form used by the Clinical Analysis Team to make their decision. (See Figure 3-5 for a complete example.) All members of the Team were provided with copies of the accident and injury summaries, after they

were quality checked by Dr. Northrop. Second, Dr. Northrop or Mr. Sweeton reviewed each MDAI report to highlight and flag photographs and other pertinent material not included in the summary. Third, the Team assembled for an afternoon of work, beginning with a review of the MDAI report and a "blackboard analysis" of the crash dynamics and the dynamic forces that would have acted upon passengers in various locations in a bus. When the Team was satisfied that the dynamics of the crash were thoroughly understood, Dr. Stent began reviewing the characteristics of the injuries incurred by passengers. The cause of injury was often given in the MDAI report. In the great majority of cases, the MDAI report provided a seating diagram, showing where each passenger was located prior to the crash. In many instances, the crash-caused trajectory of passengers was also shown. The injury description often provided the cause of injury. Consider one of the MDAI cases, such as FR-1 (see Table 3-2). While "mild" by standards for selecting MDAI cases, this is probably a medium-to-severe nonfatal accident by national standards, because 3 of the 47 passengers were injured. This accident occurred 27 February 1974 in New York, about 3:45 p.m. on a two-lane pavement intersection under good weather and road conditions. One school bus was stopped at the intersection, and a following school bus (the "case" bus) ran into the rear of the stopped bus at a ΔV of about 8-12 miles per hour, because the driver failed to apply adequate brake pressure.

The injury and accident causal mechanisms are shown in Figure 3-4, below, which is a direct copy of the Injury Description Form used by the Clinical Analysis Team. As can be clearly seen, the MDAI team has concluded that the injuries to all

Accident Description: FR-1: Front of bus impacted rear of bus in front.							Occupants: 48	Killed: 0 Injured: 3			Applicability for Analysis			
Code No.	Local Designator	M	F	Age	Wt.	Description of Injury/Fatality	Contact Points and/or Cause		AIS	Body Diagram	Good	Fair	Poor	AIS With Padding
FR-1-1	1		X	12		3/4" laceration, lower lip, sutured (window seat near front of bus)	Backrest (definite)		2	Yes	X			1
FR-1-2	2	X		12		Fracture, right index finger	Backrest (definite)		1		X			0
						Contusion and soft tissue swelling, right index finger (window seat near rear of bus)	Backrest (definite)		1		X			0
FR-1-3	3		X	12		Pain, right knee (seating position unknown)	Backrest (definite)		1		X			0
						Note: • CPIR Report on passenger compartments indicates that seat back tops were padded and that the rear of the seat backs were unpadded metal.								

Figure 3-4. Example of Clinical Analysis Team injury reduction judgment process.

passengers were caused by the metal backrests. In this instance, it was judged that the OAIS 2 injury to the first passenger (a cut lower lip) would have been reduced to an OAIS 1 injury (i.e., probably a bruised lip, had the bus met the Standard). It is quite possible that there would have been no injury at all. However, the Team took the more conservative choice of reduction of one OAIS level, rather than two. The fracture and contusion of the right index finger of the second passenger probably occurred when the passenger put his right hand against the seatback in front of him, and them jammed the right index finger up against the top of the pipe frame to which the seatback was attached (the common construction practice for Pre-Standard seats). A Post-Standard bus seatback would be completely padded, and all stiff structural parts are totally surrounded by padding. Therefore, it was judged that this OAIS 1 injury would not have occurred. The pain in the right knee suffered by the third passenger was also judged to occur because the knee struck the metal seatback and/or the vertical part of the pipe frame to which the Pre-Standard seatback attaches. Again, the well-padded Post-Standard seatback was judged to be capable of absorbing the energy without causing pain or trauma. All of these estimates were classified as Good, because there was considerable information available (e.g., the MDAI report was emphatic about the seatback being the cause of injury, and there were concise descriptions of injuries), and the accident dynamics were relatively simple. For example, when the front of the moving bus struck the rear of the stopped bus, much of the impact energy was absorbed by moving the stopped bus forward slightly, and through deformation of the rear of the stopped bus and the grill of the moving bus. Only three of the 47 passengers were injured. The highest injury level was an OAIS 2.

This example is considered to be illustrative of the type of decision process which the Clinical Analysis Team followed. Of course, it must be recognized that this was one of the least complex of the 82 MDAI cases. Being simple, it is probably more comparable to the vast majority of injury-producing school bus accidents than most of the MDAI cases which the Clinical Analysis Team reviewed.

As a further example illustrating the forms used to summarize MDAI reports, the next three pages reproduce in its entirety the summarized information for BO-2, an MDAI case in which, due to brake failure, a bus with 15 passengers ran off the road in an Indianapolis residential area, and glanced off a pole and struck a tree. Thirteen of the 15 passengers were injured; there were one OAIS 2 and 12 OAIS 1 injuries. As can be seen from the "AIS with Padding"

column at the right side of the third page of the summary, the Clinical Analysis Team estimated that all injured passengers would have had their injuries reduced one OAIS level. Thus, the OAIS 1 contusions, abrasions and lacerations were judged to be reduced to No Injury, due to more padding, higher seat backs and closer seats required by the Standard. The OAIS 2 injury was judged to be reduced to an OAIS 1. Based on the available information, 11 of the 13 judgments were considered to be "Good" and two were judged "Fair."

CEM

Case No. BO-2

Title						HS: 801-512 PB: 241-236
Bus only: Bus ran off road and struck fixed object.						
Reporting Organization					Accident Date: October 16, 1974	
Institute for Research in Public Safety Indiana University					Report Date: April 1975	
Occupants	Killed	Injured	Bus Type			
16	0	13 Passengers + Driver	1967 Ford B600 Superior Coach, 54 passenger			
Day	Time	State	County	City	Locale	
Wednesday	3:40p.m.	Indiana		Indianapolis	Residential	
Highway Type	Sixteenth Street: arterial 40' wide, 4 lanes, no median. Wallace Ave: local, 30' wide, 2 lanes, no median. Both concrete surfaces in traveled condition, straight and level.			Road Condition	Visibility	
				Drv	Clear	
Other Pertinent Information	Padding: 1.5" wide padded strip above boarding door, 4" wide padded strip just below the windows					

Accident Description

As eastbound bus was approaching T-intersection on four lane street, van truck at intersection turned right into same street. Bus driver reduced speed slightly. However, van truck stopped in midst of turn. Bus driver applied moderate, then firm pressure, left rear wheel cylinder failed, resulting in total loss of brake pressure. Driver attempted to steer off road just past intersection, between light pole and tree. Driver lost control when bus bounced over 6 inch curb, and bus glanced off pole, then struck tree. One passenger suffered broken nasal bone; twelve others and driver incurred minor injuries. Investigation revealed that incorrect maintenance by school mechanic led to failure.

Report conclusion: Injuries probably resulted from facial contact with unpadded seat backs and frames. Padding or seat belts might have prevented or mitigated these injuries.

Figure 3-5. Example of forms for MDAI report summaries.

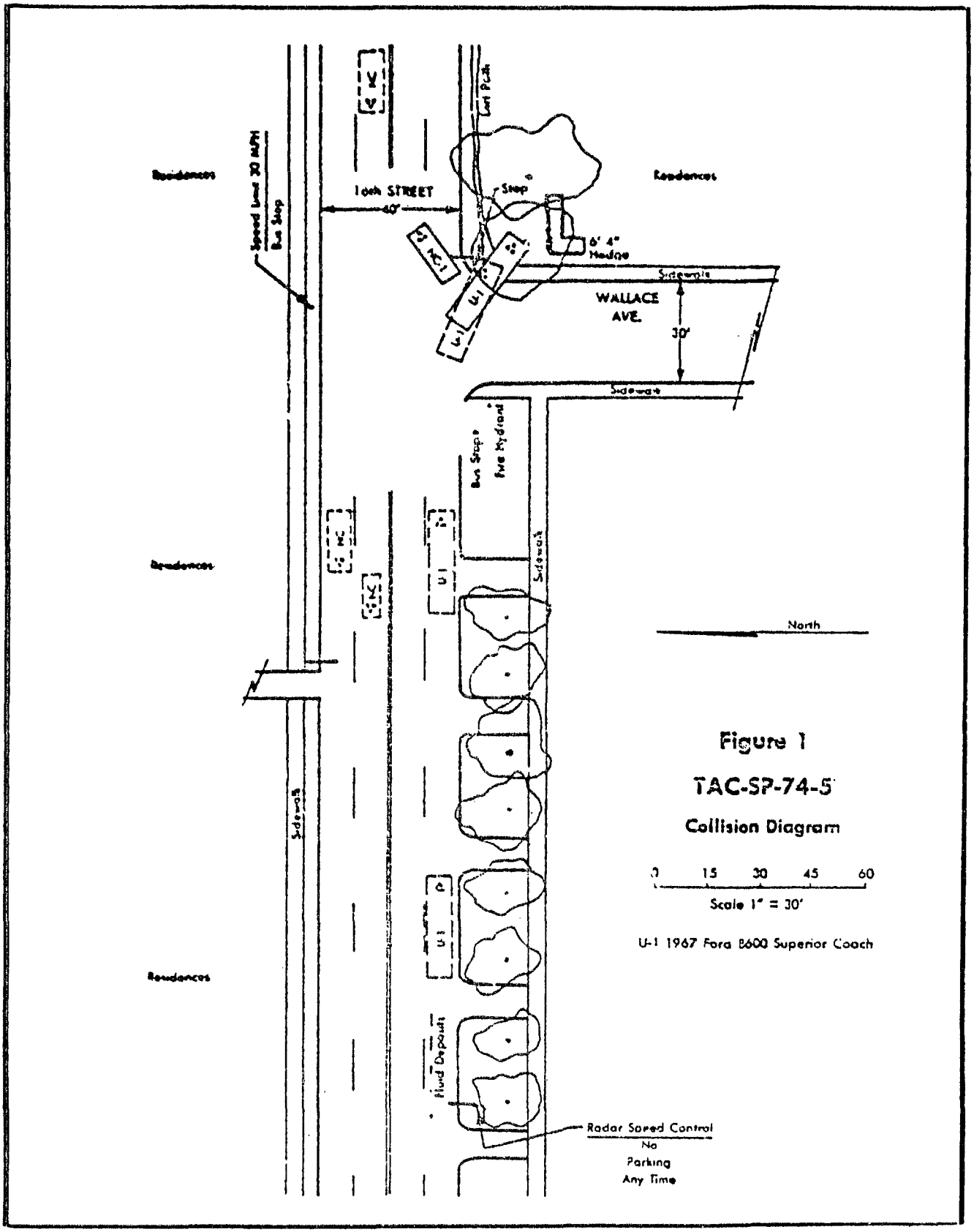

Figure 3-5. Example of forms for MDAI report summaries (continued).

Accident Description:	BO-2: Bus only. Bus ran off road and struck fixed object.						Occupants: 16	Killed: 0 Injured: 14			Applicability for Analysis			
Code No.	Local Designator	M	F	Age	Wt.	Description of Injury/Fatality	Contact Points and/or Cause	AIS	Body Diagram	Good	Fair	Poor	AIS With Padding
BO-2-1	1		X	5	NA	Facial abrasions	"All of the injuries sustained in this accident were minor, probably resulting from facial contact with the unpadded seat backs and seat frames of the seats immediately ahead of the injured pupils. Better padding or seat belts might have prevented or mitigated these injuries."(p.7) Reference to padding: "1.5" wide padded strip above boarding door, 4" wide padded strip running length of each side of bus just below the windows." (p.2)	1	No	X			0
BO-2-2	2		X	5		Small lacerations of inside upper lip		1		X			0
BO-2-3	3		X	5		Fracture of nasal bone		2		X			1
BO-2-4	4	X		5		Contusion of left jaw		1		X			0
BO-2-5	5		X	6		Complaint of pain in neck		1			X		0
BO-2-6	6		X	6		Contusions of both knees		1		X			0
BO-2-7	7		X	7		Laceration of mouth		1		X			0
BO-2-8	8	X		7		Abrasion of right cheek		1		X			0
BO-2-9	9		X	8		Abrasions to chin and right knee		1		X			0
BO-2-10	10		X	8		Complaint of pain in neck		1			X		0
BO-2-11	11	X		8		Blunt trauma to nose(no fracture)		1		X			0
BO-2-12	12	X		8		Contusion of right mandible		1		X			0
BO-2-13	13	X		9		Contusion of right side of face		1		X			0
BO-2-14	Driver	X		24	150	Complaint of pain in left hand		1					

Note:

- Seating positions not known. Passengers ordered by chronological age.

Figure 3-5. Example of forms for MDAI report summaries (concluded).

3.8.4 Credibility of the Injury Reduction Estimates

Sections 3.6 and 3.7 suggest that if all school buses in the nation met the requirements of FMVSS 222, there would be annual reductions of injuries resulting in approximately the following improvements:

- Nonfatal Accidents
  - 1300 accidents in which one passenger is injured at present would reduce to accidents in which no passengers are injured.
  - 2500 passengers presently being injured would not be injured.
  - 168 of the 400 passengers who presently incur OAIS 2, 3, and 4 injuries would have their injuries reduced at least one OAIS level.
- Fatal Accidents
  - Of the average of 242 passengers injured and killed in an average of 15 fatal school bus accident annually, 30 passengers presently being injured would not be injured.
  - 13 additional injured passengers would have their OAIS 2 and higher injuries reduced at least one OAIS level. In part, this reduction depends on the use of seat belts in the vans and other small school transportation vehicles.
  - 2 lives,of an average of 27 deaths, would be saved. This reduction is totally dependent on the use of seat belts in vans and other small school transportation vehicles.

In brief, FMVSS 222 would beneficially help about 69 percent of the passengers being injured in nonfatal school bus accidents, and about 26 percent of the passengers being injured or killed in fatal school bus accidents.

How credible are these effectiveness estimates? The answer is: they are actually based on relatively conservative estimates, because the Poor estimates are primarily No Change. To substantiate this statement, CEM separated the injury reduction estimates for each MDAI case into three groups, by quality of estimate (Good, Fair, and Poor). We then used a computer program to process them in groups:

- Group #1: Good + Fair + Poor
- Group #2: Good + Fair
- Group #3: Good
- Group #4: Fair
- Group #5: Poor

As with all of the CEM analyses in this study, fatal and nonfatal MDAI cases were treated separately. All detailed computer results are given in Appendix D, with a summary contained in Appendix E.

The overall results for nonfatal accidents are shown in Table 3-34, which tabulates the number of injured passengers in each indicated category, and Table 3-35, which converts the numbers to appropriate percentages, as was done in Section 3.4 and 3.5. Note that results are shown only for "Good + Fair + Poor,"

TABLE 3-34

INJURY REDUCTIONS IN NONFATAL SCHOOL BUS ACCIDENTS, CATEGORIZED BY QUALITY OF ESTIMATE

Injury Reduction Condition (OAIS Level Change)	Quality of Estimate					
	Good + Fair + Poor		Good + Fair		Poor	
	No. of Injured		No. of Injured		No. of Injured	
	All Accident Types	All Except Rollover	All Accident Types	All Except Rollover	All Accident Types	All Except Rollover
1 to 0	304	284	296	276	8	8
No Change	313	132	193	88	120	44
Orig. Total Inj.	617	416	489	364	128	52
2 to 1	26	22	24	20	2	2
2 to 0	22	21	22	21	0	0
No Change	34	9	24	8	10	1
Orig. Total Inj.	82	52	70	49	12	3
3 to 2	1	0	1	0	0	0
3 to 1	4	4	4	4	0	0
3 to 0	1	1	1	1	0	0
No Change	2	1	2	1	0	0
Orig. Total Inj.	8	6	8	6	0	0
4 to 3	2	2	2	2	0	0
4 to 2	2	2	2	2	0	0
4 to 1	2	2	2	2	0	0
4 to 0	0	0	0	0	0	0
No Change	1	1	0	0	1	1
Orig. Total Inj.	7	7	6	6	1	1

TABLE 3-35

PERCENT INJURY REDUCTIONS IN NONFATAL SCHOOL BUS ACCIDENTS, CATEGORIZED BY QUALITY OF ESTIMATE
(Based on Values in Table 3-34)

Injury Reduction Condition (OAIS Level Change)	Quality of Estimate					
	Good + Fair + Poor		Good + Fair		Poor	
	Percent of Injured		Percent of Injured		Percent of Injured	
	All Accident Types	All Except Rollover	All Accident Types	All Except Rollover	All Accident Types	All Except Rollover
1 to 0	49.3	68.3	60.5	75.8	6.2	15.4
No Change	50.7	31.7	39.5	24.2	93.8	84.6
2 to 1	31.7	42.3	34.3	40.8	16.7	66.7
2 to 0	26.8	40.4	31.4	42.9	0	0
No Change	41.5	17.3	34.3	16.3	83.3	33.3
3 to 2	12.5	0	12.5	0	0	0
3 to 1	50.0	66.7	50.0	66.7	0	0
3 to 0	12.5	16.7	12.5	16.7	0	0
No Change	25.0	16.7	25.0	16.7	0	0
4 to 3	28.6	28.6	33.3	33.3	0	0
4 to 2	28.6	28.6	33.3	33.3	0	0
4 to 1	28.6	28.6	33.3	33.3	0	0
4 to 0	0	0	0	0	0	0
No Change	14.3	14.3	0	0	100	100

"Good + Fair," and "Poor." Doing so illustrates the important point that elimination of the "Poor" estimates--which have been shown in Table 3-33 to be primarily No Change--leaves the remaining group of "Good + Fair" estimates showing a notably higher effectiveness of FMVSS 222 in achieving injury reduction, as best seen in Table 3-35. These two tables show results both for all accident types, and for all accident types except rollovers. This was done because the injury reduction estimates shown in Table 3-12 for reductions from OAIS 1 and 2 injuries use the 39 non-rollover nonfatal MDAI cases. The estimates from Table 3-12 were used at the end of Section 3.6, to convert Table 3-24 into Table 3-25.

For comparative purposes, the same conditions used in preparing Table 3-12 are invoked in Table 3-36, which uses selected information from Tables 3-34 and 3-35. Clearly, had only the clinical analysis results deemed Good and Fair by the Clinical Analysis Team been used, it is likely that the effectiveness of FMVSS 222, extrapolated to the national scale, would have been about 10 percent higher than the results indicated at the end of Section 3.6. Approximately, we would probably have concluded that about 77 percent of those passengers injured in nonfatal school bus accidents would have benefitted, rather than the 69 percent, which was obtained by including the injury reduction estimates judged Poor. This would occur because eliminating the Poor estimates significantly reduces the number of injured passengers estimated to incur No Change in injury status, as a consequence of the Standard. To be on the conservative side, we prefer to use the lower injury reduction rates based on all appropriate estimates, regardless of their quality.

TABLE 3-36

COMPARISON OF ESTIMATED INJURY REDUCTION RATES, CATEGORIZED BY QUALITY OF ESTIMATE

Injury Reduction Condition (OAIS Level Change)	Quality of Estimate					
	Good + Fair + Poor		Good + Fair		Poor	
	Orig. No. Inj.	Injury Reduction Rate	Orig. No. Inj.	Injury Reduction Rate	Orig. No. Inj.	Injury Reduction Rate
1 to 0 *	416	68 %	364	76 %	52	15 %
2 to 1 *	52	42	49	41	3	67
2 to 0 *	52	40	49	43	3	0
3 to 2	8	12.5	8	12.5	0	0
3 to 1	8	50	8	50	0	0
3 to 0	8	12.5	8	12.5	0	0
4 to 3	7	29	6	33	1	0
4 to 2	7	29	6	33	1	0
4 to 1	7	29	6	33	1	0

*The OAIS 1 and 2 injury reduction rates are based on 39 MDAI cases, which exclude 17 rollover cases. The OAIS 3 ane 4 rates are based on all 56 MDAI cases.

3.9 Credibility of the Estimate of Nationwide Effectiveness of FMVSS 222

3.9.1 Analysis of Additional FARS Data for Nonfatal School Bus Crashes

The extrapolation of the clinical analysis results for nonfatal school bus accidents (Section 3.6) was accomplished by analyzing National Safety Council figures for 1975, 1976, and 1977, and using certain "reasonable" assumptions concerning the number of school bus passengers injured per accident, and the distribution of (nonfatal) injuries incurred by those passengers.

To shed some light on the credibility of these important assumptions, CEM undertook two ancillary analyses. First, data were obtained and analyzed for all FARS cases involving two (or more) vehicle school bus crashes, but in which neither the bus driver nor any school bus passengers were killed. There were 107 FARS cases (an average of about 27 accidents per year) that met the conditions stated. In these 107 "other-vehicle-fatal" crashes, the injury levels of the school bus passengers are as shown in Table 3-37. The distribution of injuries as a function of number of passengers injured, and the distribution of number of passengers injured per accident are given in Table 3-38.

TABLE 3-37

INJURY LEVELS FOR SCHOOL BUS PASSENGERS
IN OTHER-VEHICLE-FATAL CRASHES

Year	Injury Level						Total Injured	
	C		B		A			
	No.	Row %	No.	Row %	No.	Row %	No.	Col. %
1975	65	36.9	98	55.7	13	7.4	176	21.5
1976	36	24.5	91	61.9	20	13.6	147	18.0
1977	109	41.1	139	52.5	17	6.4	265	32.4
1978	104	45.4	110	48.0	15	6.5	229	28.0
Total Injured	314	38.4	438	53.6	65	8.0	817	100

It is apparent from the tables that these 107 FARS cases are too few to draw significant conclusions. At best, the results only support the contention that even in severe multiple-vehicle school bus crashes--in which someone in another vehicle is killed--only a small fraction (8 percent) of the injured passengers receive severe (A level) injuries.

TABLE 3-38

DISBRIBUTION OF INJURY LEVELS AND NUMBER OF PASSENGERS INJURED PER ACCIDENT FOR SCHOOL BUS PASSENGERS IN OTHER-VEHICLE-FATAL CRASHES

(Source: FARS: 1975 - 1978)

No. of School Bus Passengers Injured in Accident	Injury Level						Total	Distribution of Number Injured	Cases	
	C		B		A					
	No.	Row %	No.	Row %	No.	Row %	No.	Col. %	No.	%
1	6	31.5	9	47.4	4	21.1	19	2.3	19	17.8
2	1	5.5	13	72.2	4	22.2	18	2.2	9	8.4
3	18	46.2	18	46.2	3	7.7	39	4.8	13	12.1
4	11	30.5	21	58.3	4	11.0	36	4.4	9	8.4
5	12	30.0	22	55.0	6	15.0	40	4.9	8	7.5
Subtotal (1-5)	48	20.8	83	54.6	21	13.8	152	18.6	58	54.2
6	22	61.1	14	38.9			36	4.4	6	5.6
7	1	4.8	14	66.7	6	28.6	21	2.6	3	2.8
8	27	56.3	16	33.3	5	10.4	48	5.9	6	5.6
9	15	33.3	28	62.2	2	4.4	45	5.5	5	4.7
10	5	25.0	13	65.0	2	10.0	20	2.4	2	1.9
Subtotal (6-10)	70	41.2	85	50.0	15	8.8	170	20.8	22	20.6
1-5	48	20.8	83	54.6	21	13.8	152	18.6	58	54.2
6-10	70	41.2	85	50.0	15	8.8	170	20.8		20.6
11-15	82	42.3	91	46.9	21	10.8	194	23.7	15	14.0
16-20	21	38.2	34	61.8			55	6.7	3	2.8
21-25	93	67.4	43	31.2	2	1.4	138	16.9	6	5.6
26-30										
31-40			102	94.4	6	5.5	108	13.2	2	2.8
> 40										
Total	314	38.4	438	53.6	65	8.0	817	100	107	100

The results also show that in these more severe, highly biased crashes,* there is an average of 7.6 passengers injured per accident, and 38.4 percent receive C injuries; while 53.6 percent receive B injuries, and 8 percent receive A injuries. The number of cases is too few for these values to have statistical significance.

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*These FARS data are highly biased because they comprise the very small subset of all school bus accidents in the nation where the school bus was involved in an accident in which at least one bus passenger was injured, but no passengers were killed, and at least one person was killed in another vehicle involved in the crash.

3.9.2 Analysis of School Bus Accidents in Connecticut

At about the time that it became apparent that the analysis of the biased FARS data described in Section 3.9.1 could not be applied to the assumptions in Section 3.6, it was learned that staff of the Connecticut Motor Vehicle Department receive copies of reports of all motor vehicle accidents involving school buses.* Accident reports are available for 730 cases in 1978 and 277 cases for the first half of 1979, for a total of 1007 cases. Of these, only 46 (4.6 percent) involved injury to passengers. In 31 cases, the school bus passenger injury levels were estimated by the police officer submitting the accident report. In 12 cases, injury levels were not specified, but the reporting officer described the injuries in sufficient detail to permit CEM to estimate the level of injury. In three cases. the passenger injury levels are unknown, and no injury information is given, other than the total number of injured. It is clear there were no fatalities in these accidents because that information would have been reported, and it is virtually certain there were no serious (A level) injuries, from the description of the accident. However, in these three cases, the distribution of B and C injuries is not given.

Table 3-39 summarizes the characteristics of the Connecticut school bus accidents. In these 46 school buses in crashes,** there were 227 injured passengers, or about one-fifth of all passengers. This is an average of 4.9 passengers injured per school bus involved in an injury-producing crash. This figure is higher (by a factor of about three) than the 1.4 passengers injured per crash, estimated from National Safety Council data in Section 3.6 However, it is less than the 7.6 passengers injured per accident,indicated by the 107 nonfatal FARS cases in Section 3.9.1. It is much less than the average of 13 passengers injured per accident in the 56 nonfatal MDAI accidents.

Of the 208 injured passengers for whom injury levels were given or could be estimated from injury descriptions, there were 126 C-injuries (60.6 percent) and 82 B-injuries (39.4 percent).

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*Until 1 October 1979, school bus accident reports had to be filed only if total damage in the accident was $400 or more, or someone was injured in the accident. However, during that period, some reports in which there were no injuries and damage was less than $400 were filed "to get them into the record." After 1 October 1979, a new Connecticut law requires that motor vehicle accident reports be filed if a school bus is involved in the accident, regardless of the extent of damage.

**One crash involved one school bus skidding on ice into the rear of another school bus, as they were carrying children home in the afternoon.

TABLE 3-39

SUMMARY CHARACTERISTICS OF 46 CONNECTICUT SCHOOL BUS ACCIDENTS INVOLVING PASSENGER INJURIES (JANUARY 1978-JUNE 1979)

Source: Connecticut Department of Motor Vehicles

Case No.	Date	Number of Passengers	Injury Level				Total Number Injured	Un-injured	No. of Vehicles in Acc.	Bus Model Year	Comments
			K	A	B	C					
	1978										
1	9 Jan	18			1*		1	17	1	1974	Ran off road. Hit tree. Ice.
2	9 Jan	"Several"			1*		1	Unk	1	1974	Icy conditions.
3	17 Jan	54			5	16	21	33	2	1972	Icy conditions. Struck from rear. One bus skidded into other. Ran into bus in front.
4	17 Jan	40			3	6	9	31	2	1970	
5	30 Jan	12				1	1	11	2	1974	Van.
6	1 Mar	6			5	1	6	0	2	1974	Van, turning left, hit in left side by passing vehicle(snow).
7	1 Mar	4		Unknown			4	0	1	1974	Van skidded off road (to right) & hit building (snow).
8	3 Mar	14				2	2	12	2	1975	Struck headon on curve; vehicles going slowly (snow).
9	17 Mar	1				1	1	0	2	1976	Struck headon on downhill curve; vehicles going slowly (snow).
10	20 Mar	12			1	2	3	9	2	1973	Struck from side(front left) in intersection. Bus ran stop sign.
11	22 Mar	12			1*		1	11	2	1974	Struck from side in intersection.
12	6 Apr	27				1	1	26	3	1970	Struck from rear after abrupt braking.
13	18 Apr	29				4	4	25	2	1974	Struck on left side in intersection by car running stop sign.
14	8 May	5				1	1	4	2	Unk	Bus braked abruptly to avoid collision at intersection.
15	13 June	8				3	3	5	2	1972	Struck in left side while leaving curb.
16	20 June	Unk.				3	3	Unk	2	1972	Struck in front right (90°) in intersection. Bus ran stop sign.
17	22 June	34				2	2	32	2	1973	Forced off road to right, hit tree
18	16 Aug	Unk.		Unknown			10	Unk	1	1968	Brakes failed while being pushed. Struck tree.
19	21 Aug	14			1*		1	13	3	1974	Struck from rear.
20	14 Sept	24			4	12	16	8	2	1974	Struck in front by passing car. Bus was stopped.
21	28 Sept	5				4	4	1	2	1976	Station wagon. Struck in left side, running stop light.
22	24 Oct	15				3	3	12	2	1975	Struck in right side by car leaving private driveway.
23	24 Oct	34			1		1	33	2	1976	Struck from rear by another bus.
24	1 Nov	13			3	1	4	9	1	1974	Ran off road into tree.
25	2 Nov	32				1	1	31	4	1973	Struck from rear while stopped.
26	21 Nov	25				3*	3	22	2	1972	Struck headon on curve by oncoming car (wet).
27	19 Dec	6			3	3	6	0	2	1972	Bus struck car which ran red light.
1978 Totals		444	0	0	29	70	113	345			

*Injury level assigned by CEM, based on police officer's written description of injury.

TABLE 3-39 (Continued)

Case No.	Date	Number of Passengers	Injury Level				Total Number Injured	Un-injured	No. of Vehicles in Acc.	Bus Model Year	Comments
			K	A	B	C					
	1979										
28	3 Jan	7			1		1	6	2	1971	Sideswiped on right by car whose brakes failed.
29	11 Jan	29				3	3	26	2	1976	Struck from rear.
30	18 Jan	30			3*	3*	6	24	1	1975	Ice. Skidded off road, knocked down 8 small trees (right side).
31	22 Jan	4				1	1	3	2	1973	Ice. Struck in front left by skidding car.
32	30 Jan	38			1	1	2	36	2	1974	Struck in left rear by passing car.
33	5 Feb	Unk	Unknown				5	Unk	2	1974	Struck in right rear.
34	8 Feb	Unk			1		1	Unk	2	1973	Struck in front left, right angle.
35	8 Feb	Unk				1	1	Unk	1	1972	Skidded off road. Hit pole, right rear.
36	2 Mar	Unk				1	1	Unk	2	1971	Struck headon (while stopped) by speeding car.
37	16 Mar	Unk				1	1	Unk	2	1972	Struck front left fender by on-coming car, on curve.
38	19 Mar	41			13*	8*	21	20	2	1974	Struck front left fender from side (90°) at intersection, by dump truck.
39	2 Apr	21				1	1	20	2	1970	Struck from rear while waiting for passengers.
40	27 Apr	42			7*	5*	12	30	2	1972	Hit in rear by second bus.
41	27 Apr	15			4*	4*	8	7	2	1972	Struck stopped bus (waiting for passengers) in rear.
42	30 Apr	Unk				1*	1	0	2	1971	Struck car making u-turn.
43	8 May	27				5	5	22	2	1973	Struck car(bus right side to car left rear) while making left turn.
44	10 May	45			18*	19*	37	8	2	1973	Struck oncoming car on right rear, then went off road to right; hit tree.
45	24 May	5				2	2	3	2	1976	Struck in right side by left-turning car at intersection.
46	20 June	26			5*		5	21	1	1972	Ran off road to right; struck pole front right.
1979 Totals		330	0	0	53	56	114	226			
Total:** 1978 and 1979		774	0	0	82	126	227	571			

*Injury level assigned by CEM, based on police officer's written description of injury.

**All buses in this table are Pre-FMVSS 222. However, in 1974, Connecticut imposed limited seat padding requirements on all school buses, thus necessitating retrofitting. Three-and-two across seating was required in all new school buses purchased in Connecticut after 1 September 1974.

Table 3-34 suggests that approximately 89 percent of injuries in nonfatal school bus accidents are OAIS 1, and 10 percent are OAIS 2; less than one percent of the injuries are OAIS 3 or 4. Using the conversions for OAIS to KABCO given in Table 3-29, these relationships convert to approximately 30 percent C-injuries, and 60 percent B-injuries, with about 10 percent A-injuries. The Connecticut sample (60.6 percent C; 39.4 percent B; no A) does not conform to these relationships, but this could be caused by reporting procedures or by the statistically insignificant size of the sample. The Connecticut sample, converted to OAIS levels, would be about 80 percent OAIS 1 and 20 percent OAIS 2. (All of the C-injuries would be OAIS 1, and about half of the B-injuries would convert to OAIS 1 and the other half to OAIS 2.) While these Connecticut injury levels do not correspond exactly to the assumption used in Table 3-23, they are close. As with FARS, the small size of the Connecticut sample precludes associating any statistical significance with the derived results.

In Table 3-22, a distribution of number of school bus accidents involving 1, 2, 3, 4, and 5 or more injured passengers is assumed. In brief, it is suggested that 99 percent of all passenger-injury-producing school bus accidents (about 2900 per year) involve 4 or fewer injured passengers. Table 3-38 indicates that from the nonfatal FARS data, only 46.7 percent of the injury-producing accidents involved 4 or fewer injured passengers. Table 3-40 shows that in the 18-month period in Connecticut, 72.2 percent of the injury-producing accidents involved 4 or fewer injured passengers. Figure 3-5 compares the frequency of number of accidents as a function of number of passengers injured. It is cautioned that the nonfatal FARS data represent a highly biased subset, and the Connecticut data represent a very small sample that may also be highly biased, relative to the entire nation, because of severe winter conditions and high population density in Connecticut. The most significant results from the Connecticut data appear to be the demonstration that in a state containing 1.4 percent of the nation's population, an 18-month period can exist when no school bus accident produces a serious or fatal passenger injury.* This supports the contention that the great majority of injury-causing school bus accidents involving Pre-Standard buses produce only minor injuries, which the Clinical Analysis has judged would be very effectively reduced by the requirements of FMVSS 222.

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*In Connecticut, the period of no school bus passenger fatalities is at least 4.5 years long, of which only the last 1.5 years of detailed accident reports were available for this analysis.

TABLE 3-40

DISTRIBUTION OF INJURY LEVELS AND NUMBER INJURED PER ACCIDENT FOR CONNECTICUT (JANUARY 1978-JUNE 1979)
Source: Connecticut Department of Motor Vehicles

No. of School Bus Passengers Injured in Accident	Injury Level					Total		Cases	
	C		B		A				
	No.	Row %	No.	Row %		No.	Col. %	No.	%
1	11	61.1	7	38.9	0	18	8.7	18	41.9
2	7	87.5	1	12.5	0	8	3.9	4	9.3
3	17	94.4	1	5.6	0	18	8.7	6	14.0
4	9	75.0	3	25.0	0	12	5.8	3	7.0
5	5	50.0	5	50.0	0	10	4.8	2	4.7
Sub-Total (1-5)	49	71.9	19	28.1	0	68	32.7	33	76.9
6	7	38.9	11	60.1	0	18	8.7	3	7.0
7	0	0	0	0	0	0	0	0	0
8	4	50.0	4	50.0	0	8	3.9	1	2.3
9	6	66.7	3	66.7	0	9	4.3	1	2.3
10	0	0	0	0	0	0	0	0	0
Sub-Total (6-10)	17	48.6	18	51.4	0	35	16.8	4	11.6
1-5	49	71.9	19	28.1	0	78	32.7	33	76.9
6-10	17	48.6	18	51.4	0	35	16.8	4	11.6
11-15	5	41.7	7	58.3	0	12	5.8	1	2.3
16-20	12	75.0	4	25.0	0	16	7.7	1	2.3
21-25	24	57.1	18	42.9	0	42	20.2	2	4.7
26-30	0	0	0	0	0	0	0	0	0
31-40	19	51.4	18	48.6	0	37	17.8	4	2.3
>40	0	0	0	0	0	0	0	0	0
Total	126	60.6	82	38.4	0	208	100	43	100

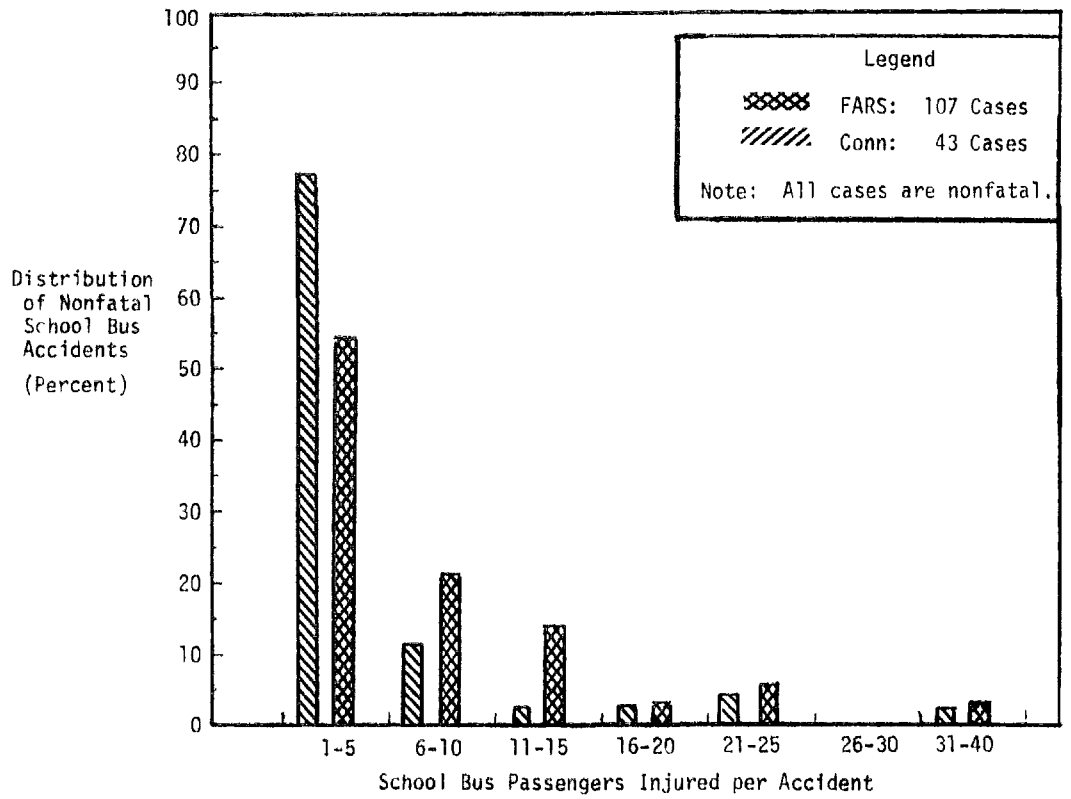


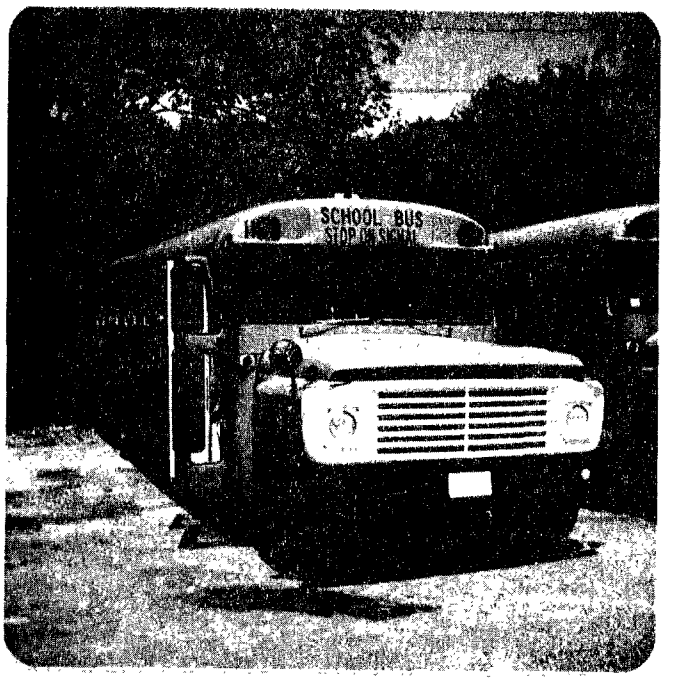
Figure 3-5. Comparison of frequencies of number of nonfatal school bus accidents as a function of number of passenger injured.

APPENDIX A

PHOTOGRAPHS COMPARING CHARACTERISTICS OF PRE-STANDARD AND POST-STANDARD SCHOOL BUSES

CEM

PRE-STANDARD



- 1971 Ford
- Superior body and seats
- II Rows of seats
- Total capacity:
  - 66 children (6th grade or lower)
  - 44 7th-12th graders on field trips

POST-STANDARD

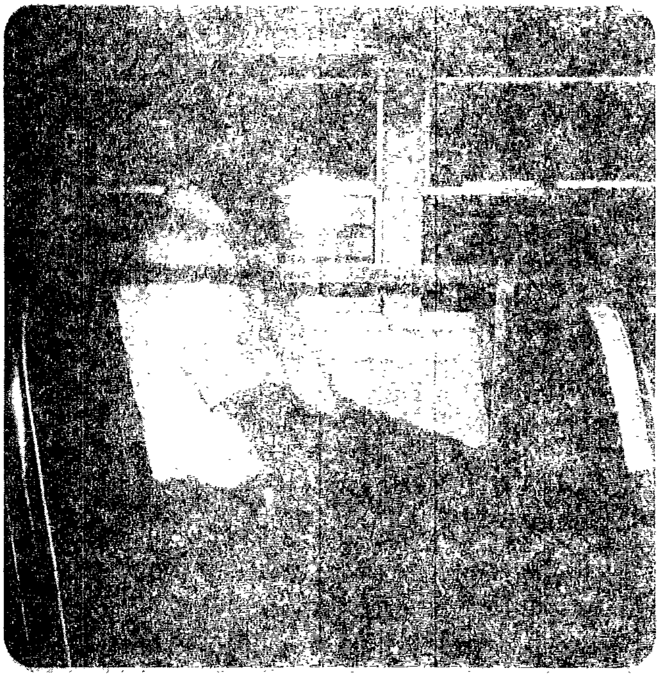
- 1979 Ford
- Thomas body and seats
- II Rows of seats
- Total capacity:
  - 54: three-two seating except two-two seating in rear row

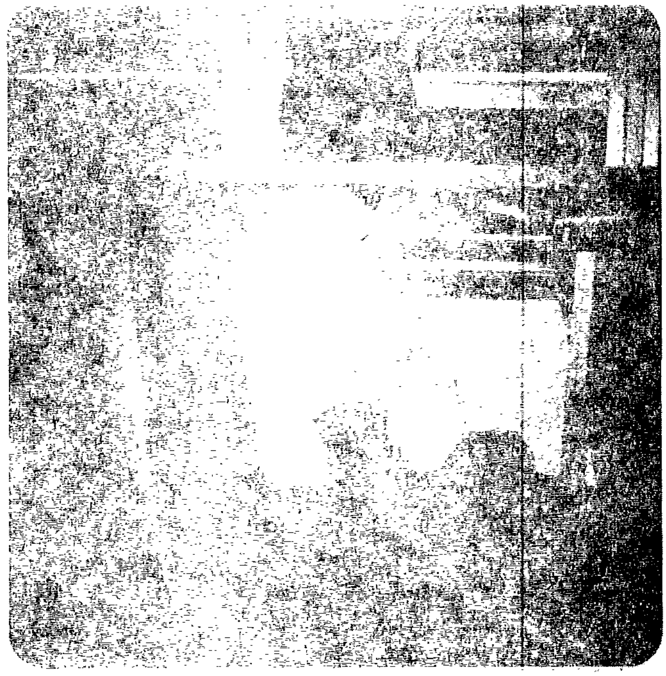
There is apt to be very little difference in the outward appearance of Pre-Standard school buses and those that meet FMVSS 222--the major exception being that the height of windows in Pre-Standard buses is 28.5 inches, while the height of windows in Post-Standard buses is 22.5 inches. In both Pre- and Post-Standard buses, the base of the windows is 32 inches above the floor.

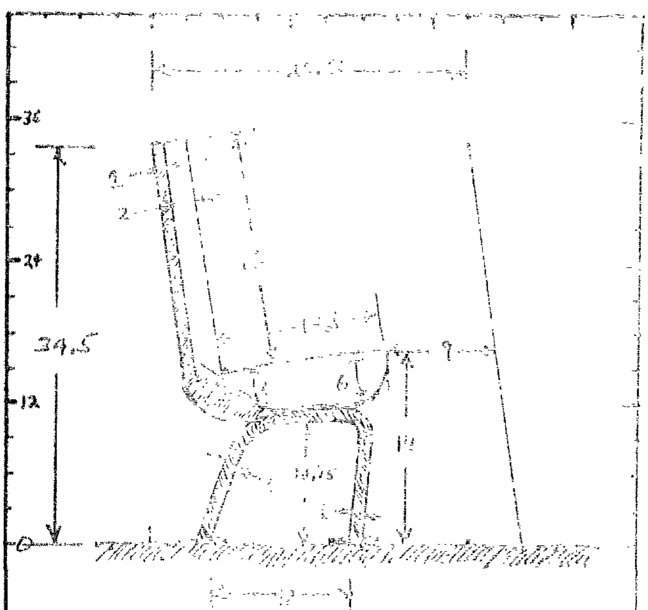
Note: All photographs and dimensional information was obtained through the courtesy of the Glastonbury, Connecticut, Board of Education. Glastonbury operates the largest municipally-owned school bus fleet in Connecticut.

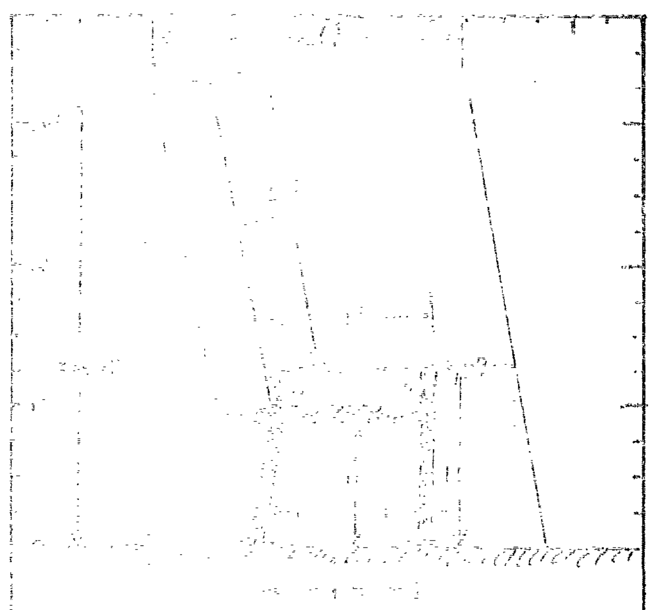
PRE-STANDARD

[illegible]









Dimensions in inches

Pre-Standard seats have exposed back frames and solid wooden or metal backs, which create areas where fingers can be jammed and bruises, contusions, lacerations and broken teeth and bones can occur.*

Post-Standard seats are closer together and have higher backs and no exposed metal back frames. [illegible] absorbing material is used for seat padding. The potential for bruises, concussions, lacerations and broken teeth and bones [illegible] reduced.

*Note that Connecticut instituted [illegible] bus seating standards in 1974, involving [illegible] on stanchions. Connecticut anticipated FMVSS 222 by requiring three-and-two padded seating in [illegible] 1976.

CEM

PRE-STANDARD

If a Pre-Standard bus stops or slows abruptly, passengers can be thrown forward, with face striking the hard seat back frame; knees striking the hard seat back; shins slipping under the hard seat back frame; and fingers jamming into the right angle formed by the metal seat back frame and the hard wood or metal seat back. The low height (34 inches) of the seat back makes it easy for passengers to be catapulted forward, over the seat backs(s) into the seat(s) in front of them, sometimes causing collisions with other passengers.

(Note: Passenger shown above is 5' 11".)

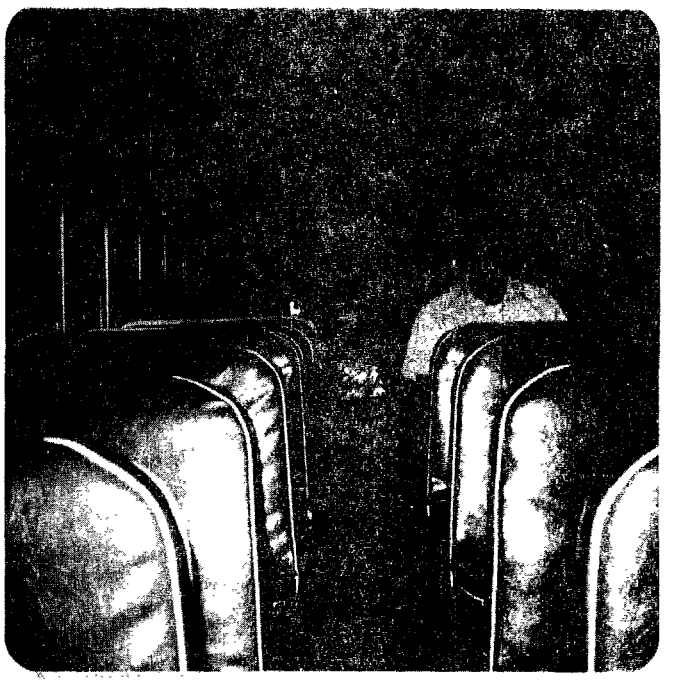
POST-STANDARD

If a Post-Standard bus stops or slows abruptly, a passenger thrown forward encounters a smooth vinyl-covered seat back covering approximately 2 inches of stiff, energy absorbing foam material on both the front and rear of an enclosed metal seat back. The higher seat back (39.5 inches) and closer seats (26.5 inches, back-to-back) reduce the opportunity for passengers being catapulted over the seat back(s) in front of them. The higher seat backs also reduce the possibility for whiplash, which could occur if the bus is struck from behind, or as a second-phase injury from a sudden stop.

(Note: Passenger shown above is 5' 11".)

PRE-STANDARD

POST-STANDARD



Interior views, emphasizing the Post-Standard reduction in potential injuries due to passengers falling into aisles, and incurring bruises, contusions, lacerations, and broken bones, due to striking metal seat frames. Also, note reduced potential for whiplash in Post-Standard seats.

Note: Passenger shown above is 5' 11".

CEM

PRE-STANDARD

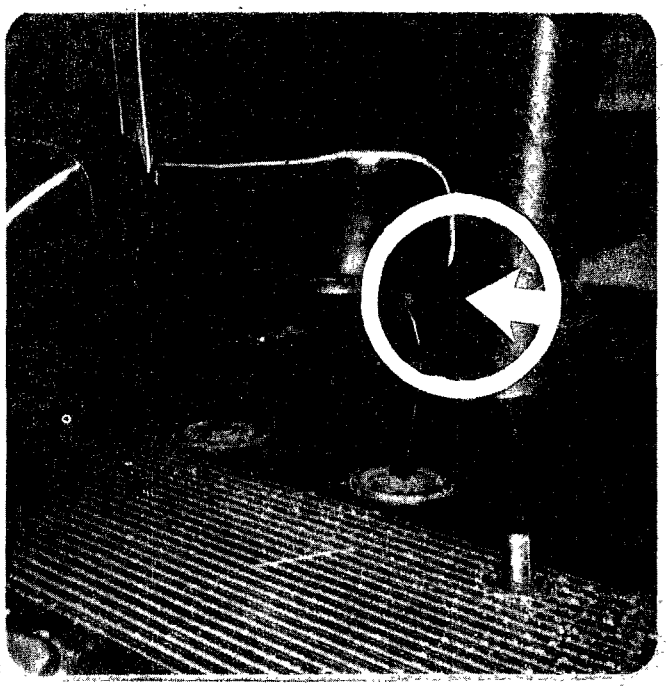
POST-STANDARD

Interior views, emphasizing the Post-Standard reduction in injury potential for passengers sitting in the seat immediately behind the driver. In the Post-Standard bus, the horizontal bar and vertical stanchion (padded, per Connecticut Law) are replaced by a full, padded seat back (or, modesty panel), which prevents passengers from being hurled against the driver's seat back, or into the left side of the driver's compartment.

Note: Pre-Standard horizontal bar height is 36 inches; Post-Standard seat back (modesty panel) height is 36 inches.

CEM

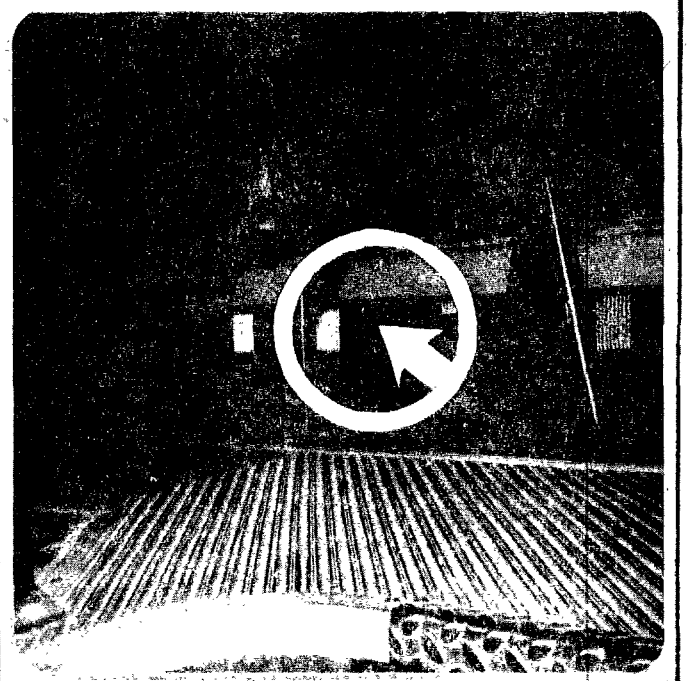
PRE-STANDARD



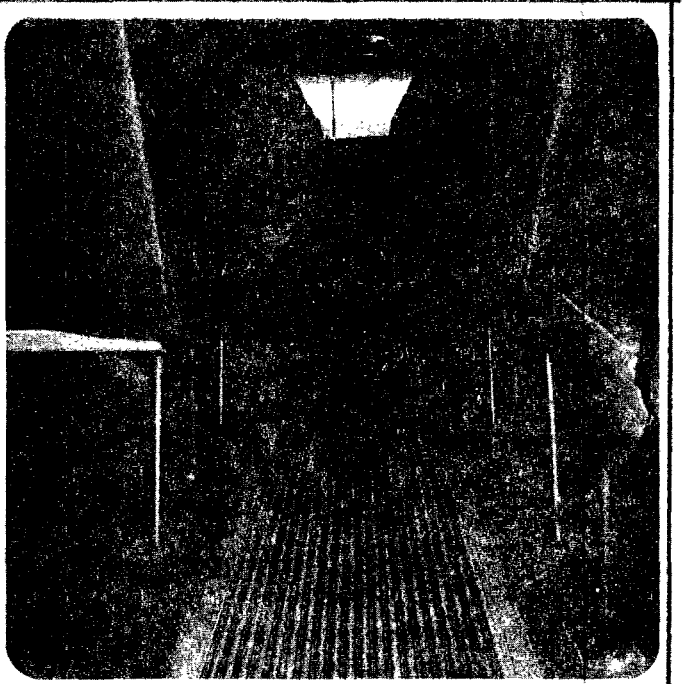
Pre-Standard seats do not have gusset plates to resist collapse of legs to side, due to side impact.

In Pre-Standard buses, passengers thrown into aisles can be hurt on exposed seat end frames.

POST-STANDARD



Post-Standard seats have gusset plates, connecting legs to seat bottom frame, which resist collapse of legs to side.



In Post-Standard buses, seat ends are padded, thus protecting passengers who fall into aisles.

APPENDIX B

DISTRIBUTION OF PASSENGERS INVOLVED IN MDAI SCHOOL BUS ACCIDENT CASES

No.	Study Number	Passengers Injured	Total Passengers	% Passengers Injured	Driver Injured	Capacity of Bus
1.	BO-1	20	39	51	X	55
2.	-2	13	15	87	X	54
3.	-3	6	45	13	X	60
4.	-4	2	2	100	X	16
5.	-5	39	43	91	X	73
6.	RE-1	4	13	31	X	55
7.	-2	2	11	18		54
8.	-3	1	46	2	X	66
9.	-4	3	64	5		72
10.	-5	6	14	43		55
11.	-6	5	33	15	X	66
12.	FR-1	3	47	6		60
13.	-2	6	43	14	X	60
14.	-3	12	44	27		44
15.	-4	7	39	18	X	66
16.	-5	46	51	90	X	72
17.	FS-1	3	11	27	X	36
18.	-2	46	49	94	X	66
19.	-3	13	17	76	X	37
20.	-4	15	55	27		66
21.	-5	16	39	41	X	66
22.	-6	30	54	56	X	44
23.	-7	1	22	5	X	40
24.	-8	4	32	12		78
25.	SS-1	3	17	18	X	72
26.	SC-1 (Van)	1	5	20		12
27.	-2	45	52	87		91
28.	-3	4	4	100	X	20
29.	-4	7	46	15	X	72
30.	-5	11	14	79	X	44
31.	-6	5	48	10	X	72
32.	-7	12	56	21	X	78
33.	-8	23	25	92	X	66
34.	-9 (Van)	1	3	33		12
35.	-10	20	24	83	X	n.a.
Subtotals		435	1122	39	25	1900

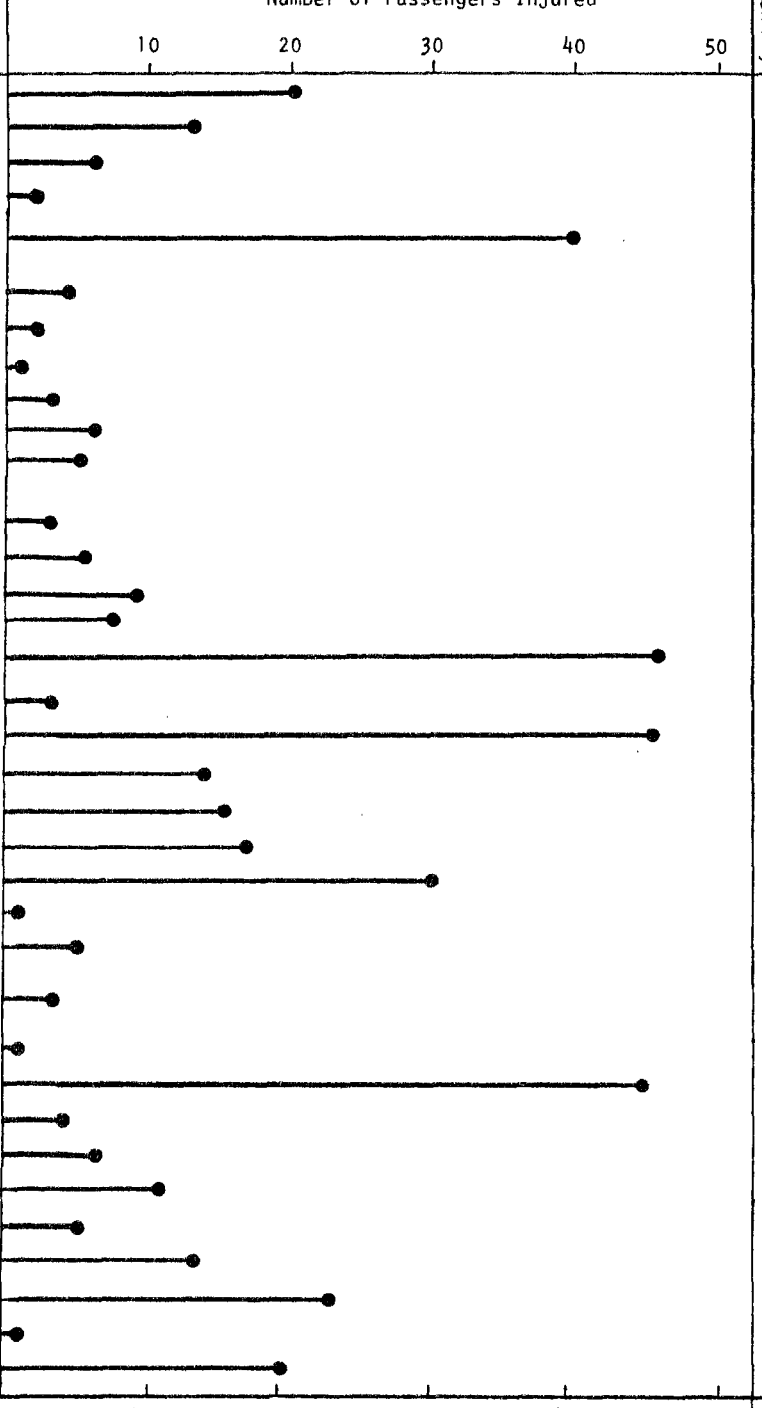
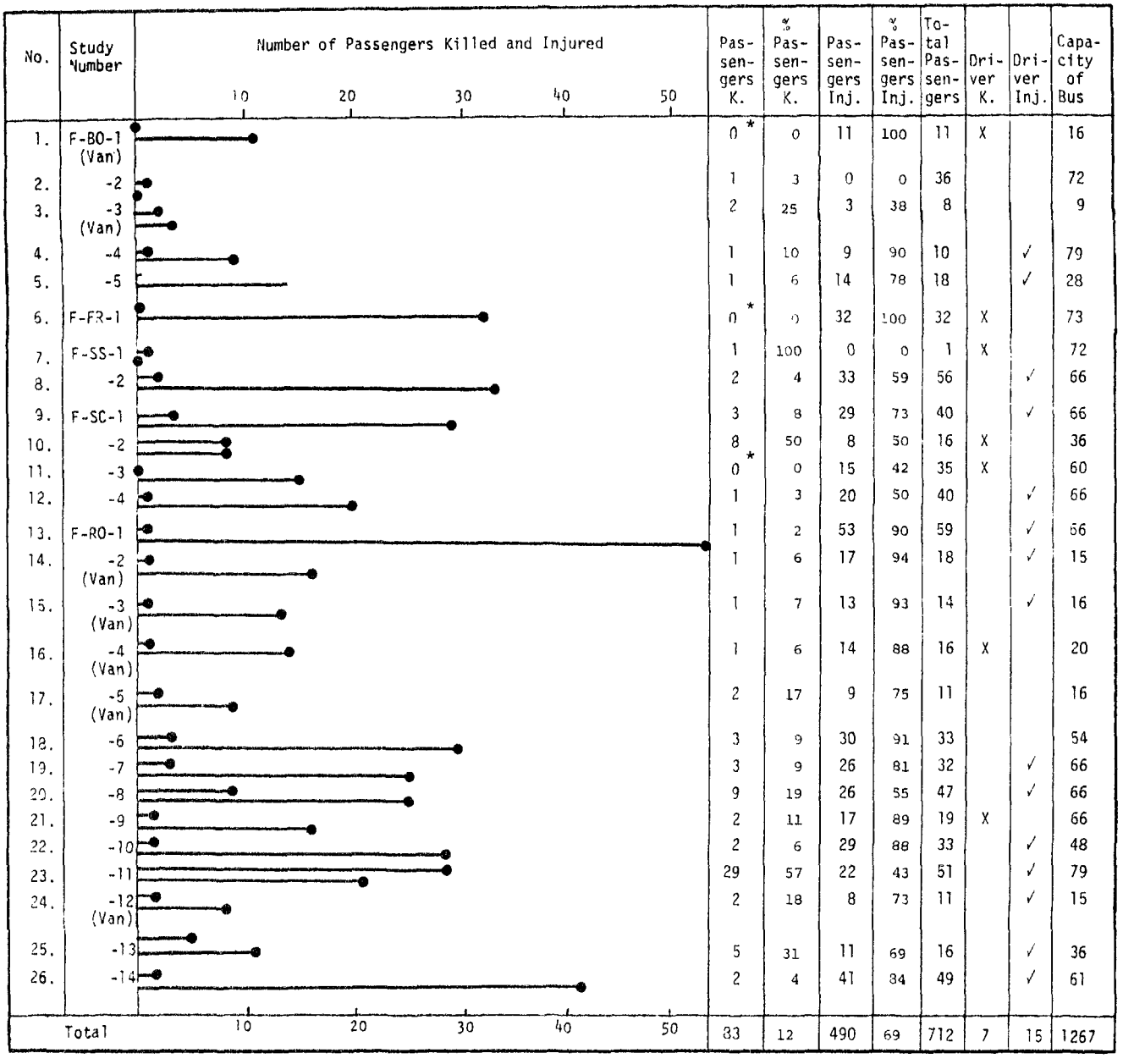


Figure B-1. Distribution of passengers injured in 56 MDAI nonfatal school bus accidents.

No.	Study Number	Number of Passengers Injured (10 20 30 40 50)	Passengers Injured	Total Passengers	% Passengers Injured	Driver Injured	Capacity of Bus
36.	HO-1		3	20	15		60
37.	HO-2		25	38	66	X	60
38.	HO-3		16	24	67	X	42
39.	HO-4		7	9	78	X	10
40.	RO-1		31	33	94	X	54
41.	-2		29	44	66		48
42.	-3		8	68	12	X	72
43.	-4		5	18	28	X	66
44.	-5		41	41	100	X	66
45.	-6		18	23	78	X	66
46.	-7		1	56	2	X	66
47.	-8		1	16	6		66
48.	-9		8	15	53	X	60
49.	-10		16	21	76	X	60
50.	-11		16	38	42		66
51.	-12		1	1	100	X	45
52.	-13		5	5	100	X	45
53.	-14		15	44	34	X	66
54.	-15		20	24	83	X	36
55.	-16		13	13	100	X	36
56.	-17		5	15	33	X	36
	Subtotals		284	566	50	17	1126
	Grand Total		719	1688	43	42	3026

Figure B-1. (continued).



No.	Study Number	Passengers K.	% Passengers K.	Passengers Inj.	% Passengers Inj.	Total Passengers	Driver K.	Driver Inj.	Capacity of Bus
1.	F-BO-1 (Van)	0 *	0	11	100	11	X		16
2.	-2	1	3	0	0	36			72
3.	-3 (Van)	2	25	3	38	8			9
4.	-4	1	10	9	90	10		✓	79
5.	-5	1	6	14	78	18		✓	28
6.	F-FR-1	0 *	0	32	100	32	X		73
7.	F-SS-1	1	100	0	0	1	X		72
8.	-2	2	4	33	59	56		✓	66
9.	F-SC-1	3	8	29	73	40		✓	66
10.	-2	8	50	8	50	16	X		36
11.	-3	0 *	0	15	42	35	X		60
12.	-4	1	3	20	50	40		✓	66
13.	F-RO-1	1	2	53	90	59		✓	66
14.	-2 (Van)	1	6	17	94	18		✓	15
15.	-3 (Van)	1	7	13	93	14		✓	16
16.	-4 (Van)	1	6	14	88	16	X		20
17.	-5 (Van)	2	17	9	75	11			16
18.	-6	3	9	30	91	33			54
19.	-7	3	9	26	81	32		✓	66
20.	-8	9	19	26	55	47		✓	66
21.	-9	2	11	17	89	19	X		66
22.	-10	2	6	29	88	33		✓	48
23.	-11	29	57	22	43	51		✓	79
24.	-12 (Van)	2	18	8	73	11		✓	15
25.	-13	5	31	11	69	16		✓	36
26.	-14	2	4	41	84	49		✓	61
Total		83	12	490	69	712	7	15	1267

*The bus driver was the only fatality in the accident.

Figure B-2. Distribution of passengers killed and passengers injured in 26 MDAI fatal school bus accidents.

APPENDIX C

DETAILED SUMMARIES OF FARS AND MDAI FATAL SCHOOL BUS ACCIDENT REPORTS

TABLE C-1

FARS SCHOOL BUS ACCIDENT REPORTS: 1975

CEM Number	FARS Case No.	State	Acc. Date (1975)	Type Veh.	Passengers		Passengers Killed or Injured					% K	% Inj.	Driver				No. of Other Veh.
					Total	Eject.	K	A	B	C	O			Age	Sex	K	Inj.	
School Buses																		
1	0426	Penn	4-11	School Bus	1	0	1					100	-	58	M	-	-	-
2	1320	Ohio	11-11		13	2	2	2	9			15	85	42	F		A	-
3	0314	Ark	9-11		34	-		2	2	10	20		41	55	M	K		1
4	0614	Texas	3-6		1	1	1					100	-	32	F	-	-	-
5	1429	Calif	6-23		10	1	1		5	4		10	90	23	F		B	1
6	0012	Alaska	3-27		30	-	1	4			25	3	13	63	M	-	-	1
7	0019	Alaska	4-21		5	-	1		2	2		20	80	24	M		A	2
8	0137	Oregon	5-9		19	18	2	12	3		2	11	79	40	F	K[e]		1
		Totals			113 14.1 avg. occ.	22 19%	9	20	21 57	16	47	8	50 58%	42.1 avg. age		2	3	
Vans, etc.																		
9	0163	NY	2-13	Van	1	-	1					100		60	M		B	-
10	0170	Tenn	3-21	Van	4	4	1		3			25	75	63	M	-	-	-
11	1326	Mich	11-6	Van	11	5		3	8			27	73	37	F	K		-
12	0248	Miss	5-8	Van	8	3	2		2		4	25	25	23	F	-	-	-
13	0145	Ariz	4-21	Van	1	?		1					100	34	F	K[e]		-
14	0390	Ohio	5-2	4-dr Sedan	3	1 1 Par.	2			1		67	33	18	F		C	4
		Totals			28 4.7 avg. occ.	14 50%	6	4	13 18	1	4	21	64 85%	39.2 avg. age		2	2	
Driver Only																		
15	1464	NY	9-30	Pick Up	0									36	F	K		1
16	0073	Ind	2-21	School Bus	0									57	M	K		1
17	0822	Ind	11-6	School Bus	0									52	M	K		-
		Totals												48.3 avg. age		3		
Totals: School Buses & Vans					141 10.1 avg. occ.	36 26%	15	24	34 75	17	51	11	53 64%	40.9 avg. age				

TABLE C-2

FARS SCHOOL BUS ACCIDENT REPORTS: 1976

CEM Number	FARS Case No.	State	Acc. Date (1976)	Type Veh.	Passengers		Passengers Killed or Injured					% K	% Inj.	Driver				No. of Other Veh.
					Total	Eject.	K	A	B	C	O			Age	Sex	K	Inj.	
School Buses																		
1	0799	NY	6-20	School Bus	1	-					1	-	-	32	M	K[e]		-
2	0282	Penn	3-16		1	-	1					100		39	F	K		1
3	0255	Fla	2-16		51	1	3	48				6	94	51	M	K[e]		1
4	0074	NCar	1-28		17	-	1				16	6	-	19	M	-	-	-
5	0589	Ohio	6-8		16	-	1		15			6	94	56	F	K[pe]		1
6	0879	Texas	5-11		36	-	1				35	3	-	51	F	-	-	-
7	0369	Iowa	3-6		33	-	3	15	14		1 unk	9	88	39	F		A	-
8	0485	Iowa	9-24		31	-	1	5	25			3	97	41	F		A	1
9	1401	Calif	5-21		51	-	29	18	4			57	43	50	M		A	-
10	0367	Oreg	9-8		40	-	3		17	18	2	8	88	54	M		A	-
11	0192	Neb	8-8		16	16	8	5	3			50	50	44	M	K[e]		1
		Totals			293 26.6 avg. occ.	17 6%	51	91	78 187	18	54 & 1 unk	17 81%	64	43.2 avg. age		5	4	
Vans, etc.																		
12	0086	Rh.I.	4-13	Sta.Wag.	5	1	1			4		20	80	43	M		C	1
13	0567	NY	5-13	Sta.Wag.	5	-	1	4				20	80	52	M	K		1
14	0138	Penn	1-19	Sta.Wag.	10	-	1	8		1		10	90	38	M		A	1
15	0483	Penn	4-30	Van	2	-		2					100	37	F	K		1
16	0175	Ill.	1-12	Van	14	2	1	1	9	3		7	93	33	M		B	-
17	1161	Ohio	9-9	Van	4	3	1	3				25	75	67	F		A[e]	1
18	0156	Neb	7-14	Van	2	-		2					100	23	F	K		1
		Totals			42 6.0 avg. occ.	6 14%	5	20 37	9	8	0	12 100%	88	41.9 avg. age		3	4	
Driver Only																		
19	0277	Penn	3-15	Sch.Bus										21	F	K		1
20	0309	Neb	12-13											31	F	K[e]		-
		Totals												25 avg. age		2		
Totals: School Buses & Vans					335 18.6 avg. occ.	23 7%	56	111 224	87	26	54& 1 unk	17 84%	67	42.7 avg. age				

TABLE C-3

FARS SCHOOL BUS ACCIDENT REPORTS: 1977

CEM Number	FARS Case No.	State	Acc. Date (1977)	Type Veh.	Passengers		Passengers Killed or Injured					% K	% Inj.	Driver				No. of Other Veh.
					Total	Eject.	K	A	B	C	O			Age	Sex	K	Inj.	
School Buses																		
1	2038	NY	12-14	School Bus	29	1	1		1		27	3	3	29	F	-	-	-
2	0112	Virg	3-8		32	-	3	2	15	12		9	91	57	F		A	1
3	0420	Ala	6-27		1	1	1					100		42	M	-	-	-
4	1377	Fla	10-29		23	1	1				22	4	-	36	M	-	-	-
5	0172	Ga	3-18		1	-	1					100		29	F	-	-	-
6	0019	S.Car.	1-19		11	1	1				10	9	-	19	M	-	-	-
7	0084	Tenn	2-10		1	-	1					100		21	M	-	-	-
8	0130	N.Mex.	4-26		5	1	1				4	20	-	21	M	-	-	-
9	0710	Calif	3-22		1	-	1					100		41	F	-	-	-
10	0202	Idaho	10-17		57	-	2	7	18	16	14	4	28	40	M		B	1
11	F-SC-4 (not in FARS)	Ver	1-13		40	-	1	3	12	5	19	3	50	26	M	-	C	1
		Totals			201 18.3 avg.occ.	5 2.5%	14	12	46	33	96	7	45	32.8 avg. age		-	3	
									91			52%						
Vans, etc.																		
12	0830	NY	6-18	Sta.Wag.	8	-	1	1	3	3		13	87	21	M	-	-	-
13	0124	N.Mex.	4-19	Van	10	1, 2 par.	2	2		2	4	20	40	26	M	-	-	-
14	1359	Texas	6-1	Sta.Wag.	2	1	1	1				50	50	27	F		A	1
15	0028	Iowa	1-24	Van	1	-		1		1			100	22	M	K[e]		1
16	0406	Mich	4-29	Van	18	5	1	5	9	3		6	94	23	F		C	1
		Totals			40 8.0 avg. occ.	9 22%	5	10	12	9	4	13	77	23.8 avg. age		1	2	
									31			90%						
Totals: School Buses & Vans					241 16.1 avg. occ.	14 6%	19	22	58	42	100	8	51	30.0 avg. age				
									122			59%						

TABLE C-4

FARS SCHOOL BUS ACCIDENT REPORTS: 1978

CEM Number	FARS Case No.	State	Acc. Date (1978)	Type Veh.	Passengers		Passengers Killed or Injured					% K	% Inj.	Driver				No. of Other Veh.
					Total	Eject.	K	A	B	C	O			Age	Sex	K	Inj.	
School Buses																		
1	1462-b	Penn	10-27	School Bus	14	-			3	11			100	46	F	K		1
2	0303	Ga.	4-11		33	-	3	30				9	91	24	F		A	-
3	3532	Miss	4-20		11	-	1				10	9	-	45	M	-	-	1
4	0870	N.Car.	9-15		38	-	1			1	36	3	3	17	M	-	-	-
5	1547	Ill.	10-30		48	-	1		47			2	98	40	F		A	-
6	0172	Minn	4-28		19	-	1			4	14	5	21	20	M	-	-	-
7	4071	Ohio	12-7		15	-			3		12	-	20	51	F	K[e]		1
8	0100	Texas	1-16		24	-	1		3	20		4	96	28	M		A	1
9	3773	Texas	12-8		23	1	5	13	4	1		22	78	43	M		A	1
10	0907	Miss	11-13		22	-	3	3	16			14	86	21	M	-	-	2
		Totals			247	1	16	46	76	37	72	6	64	33.5 avg. age		2	4	
					24.7 avg. occ.	1%			159			70%						
Vans, etc.																		
11	0679	Penn	6-13	Van	5	-			2	1	2	-	60	18	F	K[pe]		-
12	0320	N.Car.	4-11	Van	1	1	1					100		23	F	-	-	-
		Totals			6	1	1		2	1	2	17	50	20.5 avg. age		1	0	
					3 avg. occ.	17%			3			67%						
Driver Only																		
12	1462-a	Penn	10-27	Sta.Wag.										47	F	K		1
13	0162	S.Car.	3-2	Sc.Bus										40	F	K		2
14	3057	Kan.	11-29	Van										50	F	K		2
		Totals												45.7 avg. age		3		
Totals: School Buses & Vans					253	2	17	46	78	38	74	7	64	31.3 avg. age				
					21.1 avg. occ.	1%			162			71%						

TABLE C-5

MDAI FATAL SCHOOL BUS ACCIDENT REPORTS: 1970-1977

No.	CEM MDAI Designation	State	Accident Date	Passengers		Passengers Killed or Injured									% K	% Inj	Driver				No. Other Veh.
				Total	Eject.	6	5 F	5 NF	4	3	2	1	0	Unk			Age	Sex	K	OAIS	
School Buses																					
1	F-RO-1	Idaho	1970	59	-	1				7	7	24	5	15	2	64	18	M		4	1
2	F-RO-8	Col	9-11-71	47	39	9		4	3	8	6	5	12		19	55	23	M		5[e]	-
3	F-RO-14	Canada	12-72	49	5	2				3	5	5	6	28	4	27	unknown			X	1
4	F-RO-10	S.Car	5-23-73	33	-	2		2	5	4	9	9	2		6	88	16	F		1	-
5	F-RO-13	Ind	10-31-73	16	1	4	1	2	2	1		6			31	69	27	M		3	1
6	F-FR-1	Canada	6-74	32	-					1	2	29			-	100	67	M	K		1
7	F-BO-4	Calif	10-8-74	10	-	1				2	1	6			10	90	36	M		1	-
8	F-RO-9	Ore	5-9-75 *	19	18		2		3	3	2	9			10	90	40	F	K[e]		1
9	F-SC-3	Ark	9-11-75 *	35	-					3	7	5	20		-	43	55	M	K		1
10	F-SS-1	Penn	3-16-76 *	1	-	1									100		39	F	K		1
11	F-BO-2	Texas	5-11-65 *	36	-	1							35		3	-	52	F	-	-	-
12	F-RO-11	Calif	5-21-76 *	51	-	7	22	2	7	6	5	2			57	43	50	M		4	-
13	F-RO-6	Iowa	8-6-76 *	33	-	2	1	2		4	9	15			9	91	39	F		2	-
14	F-SC-2	Neb	8-8-76 *	16	15	8				3	5				50	50	44	M	K[e]		Train
15	F-SC-1	Calif	9-8-76 *	40	-		3	1	1	8	6	13	8		7	73	53	M		3	Train
16	F-SC-4	Vt	1-13-77 *	40	-		1				5	15	19		2	50	26	M		1	1
17	F-RO-7	Va	3-8-77 *	32	1	2	1		1	2	1	22	3		9	81	57	F		1	-
18	F-SS-2	Idaho	10-17-77 *	56	-		2	1	2	1	4	25	21		4	59	40	M		1	1
Totals:				605	79	40	33	14	24	56	74	190	125	43	12	59	40.1 avg. age		5	12	
					13%					358					71%						
Vans, Small Trans. Vehicles																					
19	F-BO-5	Calif	1-28-66	18	-	1			1		6	7	3		6	78	42	F		2	-
20	F-RO-12	Ill	7-29-74	11	-	2			1	2		5	1		18	73	51	M		3	-
21	F-BO-3	Mo	5-8-75 *	8	3	2						3	3		25	38	23	F	-	-	-
22	F-BO-1	Mich	11-6-75 *	11	-			2			1	8				100	37	F	K		-
23	F-RO-3	Ill	1-12-76 *	14	2		1		1			12			7	93	33	M		1	-
24	F-RO-4	Ohio	6-8-76 *	16	-	1					2	11	1	1	6	81	56	F	K		1
25	F-RO-5	N.Mex	4-19-77 *	11	3	2				1	3	5			18	82	26	M	-	-	-
26	F-RO-2	Mich	4-29-77 *	18	6	1		1		1	5	10			6	94	23	F		1	1
Totals:				107	14	9	1	3	3	4	17	61	8	1	9	82	36.4 avg. age		2	3	
					16%	10				88					91%						
Totals: School Buses, Vans & Small Transportation Vehicles				712	93	49	34	17	27	60	91	251	133	44	10	63	38.9 avg. age		7	17	
					13%	74				446					73%						

* Indicates the MDAI case is in FARS.

TABLE C-6

IDENTIFICATION NUMBERS FOR MDAI AND FARS
FATAL SCHOOL BUS ACCIDENT REPORTS

CEM Number	FARS Case Number	CEM Number	FARS Case Number
F-BO-1	1975/1326	F-RO-2	1977/0406
F-BO-2	1976/0879	F-RO-3	1976/0175
F-BO-3	1975/0248	F-RO-4	1976/0589
F-SS-1	1976/0282	F-RO-5	1977/0124
F-SS-2	1977/0202	F-RO-6	1976/0369
F-SC-1	1976/0367	F-RO-7	1977/0112
F-SC-2	1976/0192	F-RO-9	1975/0137
F-SC-3	1975/0314	F-RO-11	1976/1401
F-SC-4	Included in Fars Analysis but not in FARS		

APPENDIX D

DETAILED COMPUTER ANALYSES OF INJURY REDUCTION ESTIMATES, BY QUALITY OF ESTIMATE

56 Fatal and 26 Nonfatal School Bus Accidents

Quality of Estimates

- Good + Fair + Poor
- Good + Fair
- Good
- Fair
- Poor

TABLE D-1

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR ALL NON FATAL ACCIDENT INJURIES AND ALL QUALITY OF ESTIMATES (GOOD + FAIR + POOR)

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL O A I S	NONFATAL	969	617	82	8	7	0			1683	1683	= ALL PASSENGERS	
	FATAL							0	0	0	714	= INJURED ONLY	
OAIS UNCHANGED													
	1		313							313		50.7	
	2			34						34		41.5	
	3				2					2		25.0	
	4					1				1	350	14.3	49.0
	5N						0			0		0.0	
	5F							0		0		0.0	
	6								0	0		0.0	
QUALITY OF ESTIMATE	GOOD		61	9	2	0	0	0	0	72		10.1	
	FAIR		132	15	0	0	0	0	0	147	350	20.6	49.0
	POOR		120	10	0	1	0	0	0	131		18.3	
OAIS CHANGES													
1 TO 0		304								304		49.3	
2 TO 1			26							26		31.7	
2 TO 0		22								22		26.8	
3 TO 2				1						1		12.5	
3 TO 1			4							4		50.0	
3 TO 0		1								1		12.5	
4 TO 3					2					2		28.6	
4 TO 2				2						2		28.6	
4 TO 1			2							2		28.6	
4 TO 0		0								0	364	0.0	51.0
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				0						0		0.0	
5N TO 1			0							0		0.0	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			0							0		0.0	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				0						0		0.0	
6 TO 1			0							0		0.0	
6 TO 0		0								0		0.0	
TOTAL CHANGES		327	32	3	2	0	0						
QUALITY OF ESTIMATE	GOOD	225	16	1	0	0	0			242		33.9	
	FAIR	94	14	2	2	0	0			112	364	15.7	51.0
	POOR	8	2	0	0	0	0			10		1.4	
PRE-STD.DIST.(%)		57.6	36.7	4.9	0.5	0.4	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)		0.0	86.4	11.5	1.1	1.0	0.0	0.0	0.0	100.0	= INJURED ONLY		
NEW OAIS TOTALS		1296	345	37	4	1	0	0	0	1683			
POST-STD.DIS.(%)		77.0	20.5	2.2	0.2	0.1	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
POST-STD.DIS.(%)		0.0	89.1	9.6	1.0	0.3	0.0	0.0	0.0	100.0	= INJURED ONLY		

TABLE D-2

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR NON FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE GOOD + FAIR

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL O A I S	NONFATAL	699	489	70	8	6	0			1272	1272	= ALL PASSENGERS	
	FATAL							0	0	0	573	= INJURED ONLY	
OAIS UNCHANGED													
	1		193							193		39.5	
	2			24						24		34.3	
	3				2					2		25.0	
	4					0				0	219	0.0	38.2
	5N						0			0		0.0	
	5F							0		0		0.0	
	6								0	0		0.0	
QUALITY OF ESTIMATE	GOOD		61	9	2	0	0	0	0	72		12.6	
	FAIR		132	15	0	0	0	0	0	147	219	25.7	38.2
	POOR		0	0	0	0	0	0	0	0		0.0	
OAIS CHANGES													
1 TO 0		296								296		60.5	
2 TO 1			24							24		34.3	
2 TO 0		22								22		31.4	
3 TO 2				1						1		12.5	
3 TO 1			4							4		50.0	
3 TO 0		1								1		12.5	
4 TO 3					2					2		33.3	
4 TO 2				2						2		33.3	
4 TO 1			2							2		33.3	
4 TO 0		0								0	354	0.0	61.8
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				0						0		0.0	
5N TO 1			0							0		0.0	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			0							0		0.0	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				0						0		0.0	
6 TO 1			0							0		0.0	
6 TO 0		0								0		0.0	
TOTAL CHANGES		319	30	3	2	0	0						
QUALITY OF ESTIMATE	GOOD	225	16	1	0	0	0			242		42.2	
	FAIR	94	14	2	2	0	0			112	354	19.5	61.8
	POOR	0	0	0	0	0	0			0		0.0	
PRE-STD.DIST.(%)		55.0	38.4	5.5	0.6	0.5	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)		0.0	85.3	12.2	1.4	1.0	0.0	0.0	0.0	100.0	= INJURED ONLY		
NEW OAIS TOTALS		1018	223	27	4	0	0	0	0	1272			
POST-STD.DIS.(%)		80.0	17.5	2.1	0.3	0.0	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
POST-STD.DIS.(%)		0.0	87.8	10.6	1.6	0.0	0.0	0.0	0.0	100.0	= INJURED ONLY		

TABLE D-3

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR NON FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE GOOD

O A I S LEVELS	0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL NONFATAL	467	274	32	6	2	0			781	781	= ALL PASSENGERS	
O A I S FATAL							0	0	0	314	= INJURED ONLY	
OAIS UNCHANGED												
1		61							61		22.3	
2			9						9		28.1	
3				2					2		33.3	
4					0				0	72	0.0	22.9
5N						0			0		0.0	
5F							0		0		0.0	
6								0	0		0.0	
QUALITY GOOD		61	9	2	0	0	0	0	72		22.9	
OF FAIR		0	0	0	0	0	0	0	0	72	0.0	22.9
ESTIMATE POOR		0	0	0	0	0	0	0	0		0.0	
OAIS CHANGES												
1 TO 0	213								213		77.7	
2 TO 1		12							12		37.5	
2 TO 0	11								11		34.4	
3 TO 2			0						0		0.0	
3 TO 1		3							3		50.0	
3 TO 0	1								1		16.7	
4 TO 3				0					0		0.0	
4 TO 2			1						1		50.0	
4 TO 1		1							1		50.0	
4 TO 0	0								0	242	0.0	77.1
5N TO 4					0				0		0.0	
5N TO 3				0					0		0.0	
5N TO 2			0						0		0.0	
5N TO 1		0							0		0.0	
5N TO 0	0								0		0.0	
5F TO 4					0				0		0.0	
5F TO 3				0					0		0.0	
5F TO 2			0						0		0.0	
5F TO 1		0							0		0.0	
5F TO 0	0								0		0.0	
6 TO 5N						0			0		0.0	
6 TO 4					0				0		0.0	
6 TO 3				0					0		0.0	
6 TO 2			0						0		0.0	
6 TO 1		0							0		0.0	
6 TO 0	0								0		0.0	
TOTAL CHANGES	225	16	1	0	0	0						
QUALITY GOOD	225	16	1	0	0	0			242		77.1	
OF FAIR	0	0	0	0	0	0			0	242	0.0	77.1
ESTIMATE POOR	0	0	0	0	0	0			0		0.0	
PRE-STD.DIST.(%)	59.8	35.1	4.1	0.8	0.3	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)	0.0	87.3	10.2	1.9	0.6	0.0	0.0	0.0	100.0	= INJURED ONLY		
NEW OAIS TOTALS	692	77	10	2	0	0	0	0	781			
POST-STD.DIS.(%)	88.6	9.9	1.3	0.3	0.0	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
POST-STD.DIS.(%)	0.0	86.5	11.2	2.2	0.0	0.0	0.0	0.0	100.0	= INJURED ONLY		

TABLE D-4

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR NON FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE FAIR

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL O A I S	NONFATAL	232	215	38	2	4	0			491	491	= ALL PASSENGERS	
	FATAL							0	0	0	259	= INJURED ONLY	
OAIS UNCHANGED													
	1		132							132		61.4	
	2			15						15		39.5	
	3				0					0		0.0	
	4					0				0	147	0.0	56.8
	5N						0			0		0.0	
	5F							0		0		0.0	
	6								0	0		0.0	
QUALITY OF ESTIMATE	GOOD		0	0	0	0	0	0	0	0		0.0	
	FAIR		132	15	0	0	0	0	0	147	147	56.8	56.8
	POOR		0	0	0	0	0	0	0	0		0.0	
OAIS CHANGES													
1 TO 0		83								83		38.6	
2 TO 1			12							12		31.6	
2 TO 0		11								11		28.9	
3 TO 2				1						1		50.0	
3 TO 1			1							1		50.0	
3 TO 0		0								0		0.0	
4 TO 3					2					2		50.0	
4 TO 2				1						1		25.0	
4 TO 1			1							1		25.0	
4 TO 0		0								0	112	0.0	43.2
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				0						0		0.0	
5N TO 1			0							0		0.0	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			0							0		0.0	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				0						0		0.0	
6 TO 1			0							0		0.0	
6 TO 0		0								0		0.0	
TOTAL CHANGES		94	14	2	2	0	0						
QUALITY OF ESTIMATE	GOOD	0	0	0	0	0	0			0		0.0	
	FAIR	94	14	2	2	0	0			112	112	43.2	43.2
	POOR	0	0	0	0	0	0			0		0.0	
PRE-STD.DIST.(%)		47.3	43.8	7.7	0.4	0.8	0.0	0.0	0.0	100.0		= ALL PASSENGERS	
PRE-STD.DIST.(%)		0.0	83.0	14.7	0.8	1.5	0.0	0.0	0.0	100.0		= INJURED ONLY	
NEW OAIS TOTALS		326	146	17	2	0	0	0	0	491			
POST-STD.DIS.(%)		66.4	29.7	3.5	0.4	0.0	0.0	0.0	0.0	100.0		= ALL PASSENGERS	
POST-STD.DIS.(%)		0.0	88.5	10.3	1.2	0.0	0.0	0.0	0.0	0.0		= INJURED ONLY	

TABLE D-5

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR NON FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE POOR

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL O A I S	NONFATAL	238	128	12	0	1	0			379	379	= ALL PASSENGERS	
	FATAL							0	0	0	141	= INJURED ONLY	
OAIS UNCHANGED													
1			120							120		93.8	
2				10						10		83.3	
3					0					0		0.0	
4						1				1	131	100.0	92.9
5N							0			0		0.0	
5F								0		0		0.0	
6									0	0		0.0	
QUALITY OF ESTIMATE	GOOD		0	0	0	0	0	0	0	0		0.0	
	FAIR		0	0	0	0	0	0	0	0	131	0.0	92.9
	POOR		120	10	0	1	0	0	0	131		92.9	
OAIS CHANGES													
1 TO 0		8								8		6.3	
2 TO 1			2							2		16.7	
2 TO 0		0								0		0.0	
3 TO 2				0						0		0.0	
3 TO 1			0							0		0.0	
3 TO 0		0								0		0.0	
4 TO 3					0					0		0.0	
4 TO 2				0						0		0.0	
4 TO 1			0							0		0.0	
4 TO 0		0								0	10	0.0	7.1
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				0						0		0.0	
5N TO 1			0							0		0.0	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			0							0		0.0	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				0						0		0.0	
6 TO 1			0							0		0.0	
6 TO 0		0								0		0.0	
TOTAL CHANGES		8	2	0	0	0	0						
QUALITY OF ESTIMATE	GOOD	0	0	0	0	0	0			0		0.0	
	FAIR	0	0	0	0	0	0			0	10	0.0	7.1
	POOR	8	2	0	0	0	0			10		7.1	
PRE-STD.DIST.(%)		62.8	33.8	3.2	0.0	0.3	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)		0.0	90.8	8.5	0.0	0.7	0.0	0.0	0.0	100.0	= INJURED ONLY		
NEW OAIS TOTALS		246	122	10	0	1	0	0	0	379			
POST-STD.OIS.(%)		64.9	32.2	2.6	0.0	0.3	0.0	0.0	0.0	100.0	= ALL PASSENGERS		
POST-STD.OIS.(%)		0.0	91.7	7.5	0.0	0.8	0.0	0.0	0.0	100.0	= INJURED ONLY		

TABLE D-6

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR ALL FATAL ACCIDENT INJURIES AND ALL QUALITY OF ESTIMATES (GOOD + FAIR + POOR)

O A I S LEVELS	0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL NONFATAL	139	251	91	60	27	17			585	668	= ALL PASSENGERS	
O A I S FATAL							34	49	83	529	= INJURED ONLY	
OAIS UNCHANGED												
1		169							169		67.3	
2			53						53		58.2	
3				44					44		73.3	
4					19				19	374	70.4	70.7
5N						13			13		76.5	
5F							33		33		97.1	
6								43	43		87.8	
QUALITY GOOD		25	7	5	5	4	27	29	102		19.3	
OF FAIR		41	24	22	11	6	3	11	118	374	22.3	70.7
ESTIMATE POOR		103	22	17	3	3	3	3	154		29.1	
OAIS CHANGES												
1 TO 0	82								82		32.7	
2 TO 1		31							31		34.1	
2 TO 0	7								7		7.7	
3 TO 2			8						8		13.3	
3 TO 1		8							8		13.3	
3 TO 0	0								0		0.0	
4 TO 3				0					0		0.0	
4 TO 2			7						7		25.9	
4 TO 1		1							1		3.7	
4 TO 0	0								0	155	0.0	29.3
5N TO 4					1				1		5.9	
5N TO 3				0					0		0.0	
5N TO 2			1						1		5.9	
5N TO 1		2							2		11.8	
5N TO 0	0								0		0.0	
5F TO 4					0				0		0.0	
5F TO 3				0					0		0.0	
5F TO 2			0						0		0.0	
5F TO 1		1							1		2.9	
5F TO 0	0								0		0.0	
6 TO 5N						0			0		0.0	
6 TO 4					0				0		0.0	
6 TO 3				0					0		0.0	
6 TO 2			1						1		2.0	
6 TO 1		3							3		6.1	
6 TO 0	2								2		4.1	
TOTAL CHANGES	91	46	17	0	1	0						
QUALITY GOOD	36	16	5	0	0	0			57		10.8	
OF FAIR	48	23	6	0	0	0			77	155	14.6	29.3
ESTIMATE POOR	7	7	6	0	1	0			21		4.0	
PRE-STD.DIST.(%)	20.8	37.6	13.6	9.0	4.0	2.5	5.1	7.3	100.0		= ALL PASSENGERS	
PRE-STD.DIST.(%)	0.0	47.4	17.2	11.3	5.1	3.2	6.4	9.3	100.0		= INJURED ONLY	
NEW OAIS TOTALS	230	215	70	44	20	13	33	43	668			
POST-STD.DIS.(%)	34.4	32.2	10.5	6.6	3.0	1.9	4.9	6.4	100.0		= ALL PASSENGERS	
POST-STD.DIS.(%)	0.0	49.1	16.0	10.0	4.6	3.0	7.5	9.8	100.0		= INJURED ONLY	

TABLE D-7

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE GOOD + FAIR

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL NONFATAL		120	141	62	37	24	13			397	474	= ALL PASSENGERS	
O A I S FATAL								31	46	77	354	= INJURED ONLY	
OAIS UNCHANGED													
1			66							66		46.8	
2				31						31		50.0	
3					27					27		73.0	
4						16				16	220	66.7	62.1
5N							10			10		76.9	
5F								30		30		96.8	
6									40	40		87.0	
QUALITY OF ESTIMATE	GOOD		25	7	5	5	4	27	29	102		28.8	
	FAIR		41	24	22	11	6	3	11	118	220	33.3	62.1
	POOR		0	0	0	0	0	0	0	0		0.0	
OAIS CHANGES													
1 TO 0		75								75		53.2	
2 TO 1			24							24		38.7	
2 TO 0		7								7		11.3	
3 TO 2				2						2		5.4	
3 TO 1			8							8		21.6	
3 TO 0		0								0		0.0	
4 TO 3					0					0		0.0	
4 TO 2				7						7		29.2	
4 TO 1			1							1		4.2	
4 TO 0		0								0	134	0.0	37.9
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				1						1		7.7	
5N TO 1			2							2		15.4	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			1							1		3.2	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				1						1		2.2	
6 TO 1			3							3		6.5	
6 TO 0		2								2		4.3	
TOTAL CHANGES		84	39	11	0	0	0						
QUALITY OF ESTIMATE	GOOD	36	16	5	0	0	0			57		16.1	
	FAIR	48	23	6	0	0	0			77	134	21.8	37.9
	POOR	0	0	0	0	0	0			0		0.0	
PRE-STD.DIST.(%)		25.3	29.7	13.1	7.8	5.1	2.7	6.5	9.7	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)		0.0	39.8	17.5	10.5	6.8	3.7	8.8	13.0	100.0	= INJURED ONLY		
NEW OAIS TOTALS		204	105	42	27	16	10	30	40	474			
POST-STD.DIS.(%)		43.0	22.2	8.9	5.7	3.4	2.1	6.3	8.4	100.0	= ALL PASSENGERS		
POST-STD.DIS.(%)		0.0	38.9	15.6	10.0	5.9	3.7	11.1	14.8	100.0	= INJURED ONLY		

TABLE D-8

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE GOOD

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL O A I S	NONFATAL	59	54	25	11	8	4			161	218	= ALL PASSENGERS	
	FATAL							27	30	57	159	= INJURED ONLY	
OAIS UNCHANGED													
1			25							25		46.3	
2				7						7		28.0	
3					5					5		45.5	
4						5				5	102	62.5	64.2
5N							4			4		100.0	
5F								27		27		100.0	
6									29	29		96.7	
QUALITY OF ESTIMATE	GOOD		25	7	5	5	4	27	29	102		64.2	
	FAIR		0	0	0	0	0	0	0	0	102	0.0	64.2
	POOR		0	0	0	0	0	0	0	0		0.0	
OAIS CHANGES													
1 TO 0		29								29		53.7	
2 TO 1			11							11		44.0	
2 TO 0		7								7		28.0	
3 TO 2				1						1		9.1	
3 TO 1			5							5		45.5	
3 TO 0		0								0		0.0	
4 TO 3					0					0		0.0	
4 TO 2				3						3		37.5	
4 TO 1			0							0		0.0	
4 TO 0		0								0	57	0.0	35.8
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				0						0		0.0	
5N TO 1			0							0		0.0	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			0							0		0.0	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				1						1		3.3	
6 TO 1			0							0		0.0	
6 TO 0		0								0		0.0	
TOTAL CHANGES		36	16	5	0	0	0						
QUALITY OF ESTIMATE	GOOD	36	16	5	0	0	0			57		35.8	
	FAIR	0	0	0	0	0	0			0	57	0.0	35.8
	POOR	0	0	0	0	0	0			0		0.0	
PRE-STD.DIST.(%)		27.1	24.8	11.5	5.0	3.7	1.8	12.4	13.8	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)		0.0	34.0	15.7	6.9	5.0	2.5	17.0	18.9	100.0	= INJURED ONLY		
NEW OAIS TOTALS		95	41	12	5	5	4	27	29	218			
POST-STD.DIS.(%)		43.6	18.8	5.5	2.3	2.3	1.8	12.4	13.3	100.0	= ALL PASSENGERS		
POST-STD.DIS.(%)		0.0	33.3	9.8	4.1	4.1	3.3	22.0	23.6	100.0	= INJURED ONLY		

TABLE D-9

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE FAIR

O A I S LEVELS		0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL O A I S	NONFATAL	61	87	37	26	16	9			236	256	= ALL PASSENGERS	
	FATAL							4	16	20	195	= INJURED ONLY	
OAIS UNCHANGED													
1			41							41		47.1	
2				24						24		64.9	
3					22					22		84.6	
4						11				11	118	68.8	60.5
5N							6			6		66.7	
5F								3		3		75.0	
6									11	11		68.8	
QUALITY OF ESTIMATE	GOOD		0	0	0	0	0	0	0	0		0.0	
	FAIR		41	24	22	11	6	3	11	118	118	60.5	60.5
	POOR		0	0	0	0	0	0	0	0		0.0	
OAIS CHANGES													
1 TO 0		46								46		52.9	
2 TO 1			13							13		35.1	
2 TO 0		0								0		0.0	
3 TO 2				1						1		3.8	
3 TO 1			3							3		11.5	
3 TO 0		0								0		0.0	
4 TO 3					0					0		0.0	
4 TO 2				4						4		25.0	
4 TO 1			1							1		6.3	
4 TO 0		0								0	77	0.0	39.5
5N TO 4						0				0		0.0	
5N TO 3					0					0		0.0	
5N TO 2				1						1		11.1	
5N TO 1			2							2		22.2	
5N TO 0		0								0		0.0	
5F TO 4						0				0		0.0	
5F TO 3					0					0		0.0	
5F TO 2				0						0		0.0	
5F TO 1			1							1		25.0	
5F TO 0		0								0		0.0	
6 TO 5N							0			0		0.0	
6 TO 4						0				0		0.0	
6 TO 3					0					0		0.0	
6 TO 2				0						0		0.0	
6 TO 1			3							3		18.8	
6 TO 0		2								2		12.5	
TOTAL CHANGES		48	23	6	0	0	0						
QUALITY OF ESTIMATE	GOOD	0	0	0	0	0	0			0		0.0	
	FAIR	48	23	6	0	0	0			77	77	39.5	39.5
	POOR	0	0	0	0	0	0			0		0.0	
PRE-STD.DIST.(%)		23.8	34.0	14.5	10.2	6.3	3.5	1.6	6.3	100.0	= ALL PASSENGERS		
PRE-STD.DIST.(%)		0.0	44.6	19.0	13.3	8.2	4.6	2.1	8.2	100.0	= INJURED ONLY		
NEW OAIS TOTALS		109	64	30	22	11	6	3	11	256			
POST-STD.DIS.(%)		42.6	25.0	11.7	8.6	4.3	2.3	1.2	4.3	100.0	= ALL PASSENGERS		
POST-STD.DIS.(%)		0.0	43.5	20.4	15.0	7.5	4.1	2.0	7.5	0.0	= INJURED ONLY		

TABLE D-10

SUMMARY AND ANALYSIS OF INJURY REDUCTION ESTIMATES MADE BY THE CEM CLINICAL ANALYSIS TEAM FOR FATAL ACCIDENT INJURIES FOR WHICH QUALITY OF ESTIMATES ARE POOR

O A I S LEVELS	0	1	2	3	4	5NF	5F	6	SUB TOTAL	TOTAL	FREQ OF NO CHANGE AND CHANGE (%)	CHANGE IN INJURED(%)
ORIGNAL NONFATAL	14	110	29	23	3	4			183	189	= ALL PASSENGERS	
O A I S FATAL							3	3	6	175	= INJURED ONLY	
OAIS UNCHANGED												
1		103							103		93.6	
2			22						22		75.9	
3				17					17		73.9	
4					3				3	154	100.0	88.0
5N						3			3		75.0	
5F							3		3		100.0	
6								3	3		100.0	
QUALITY GOOD		0	0	0	0	0	0	0	0		0.0	
OF FAIR		0	0	0	0	0	0	0	0	154	0.0	88.0
ESTIMATE POOR		103	22	17	3	3	3	3	154		88.0	
OAIS CHANGES												
1 TO 0	7								7		6.4	
2 TO 1		7							7		24.1	
2 TO 0	0								0		0.0	
3 TO 2			6						6		26.1	
3 TO 1		0							0		0.0	
3 TO 0	0								0		0.0	
4 TO 3				0					0		0.0	
4 TO 2			0						0		0.0	
4 TO 1		0							0		0.0	
4 TO 0	0								0	21	0.0	12.0
5N TO 4					1				1		25.0	
5N TO 3				0					0		0.0	
5N TO 2			0						0		0.0	
5N TO 1		0							0		0.0	
5N TO 0	0								0		0.0	
5F TO 4					0				0		0.0	
5F TO 3				0					0		0.0	
5F TO 2			0						0		0.0	
5F TO 1		0							0		0.0	
5F TO 0	0								0		0.0	
6 TO 5N						0			0		0.0	
6 TO 4					0				0		0.0	
6 TO 3				0					0		0.0	
6 TO 2			0						0		0.0	
6 TO 1		0							0		0.0	
6 TO 0	0								0		0.0	
TOTAL CHANGES	7	7	6	0	1	0						
QUALITY GOOD	0	0	0	0	0	0			0		0.0	
OF FAIR	0	0	0	0	0	0			0	21	0.0	12.0
ESTIMATE POOR	7	7	6	0	1	0			21		12.0	
PRE-STD.DIST.(%)	7.4	58.2	15.3	12.2	1.6	2.1	1.6	1.6	100.0		= ALL PASSENGERS	
PRE-STD.DIST.(%)	0.0	62.9	16.6	13.1	1.7	2.3	1.7	1.7	100.0		= INJURED ONLY	
NEW OAIS TOTALS	21	110	28	17	4	3	3	3	189			
POST-STD.DIS.(%)	11.1	58.2	14.8	9.0	2.1	1.6	1.6	1.6	100.0		= ALL PASSENGERS	
POST-STD.DIS.(%)	0.0	65.5	16.7	10.1	2.4	1.8	1.8	1.8	100.0		= INJURED ONLY	

APPENDIX E

SUMMARIES OF QUALITY OF INJURY REDUCTION ESTIMATES

TABLE E-1

SUMMARY OF QUALITY OF INJURY REDUCTION ESTIMATES
FOR 56 NONFATAL MDAI CASES

Nonfatal Accidents (56 Cases)	Number	Quality of Estimate		
		Good	Fair	Poor
OAIS Remains the Same				
OAIS 1	313	61	132	120
OAIS 2	34	9	15	10
OAIS 3	2	2		
OAIS 4	1			1
Total	350	72	147	131
OAIS Changes				
OAIS 1 to 0	304	213	83	8
OAIS 2 to 1	26	12	12	2
OAIS 2 to 0	22	11	11	
OAIS 3 to 2	1		1	
OAIS 3 to 1	4	3	1	
OAIS 3 to 0	1	1		
OAIS 4 to 3	2		2	
OAIS 4 to 2	2	1	1	
OAIS 4 to 1	2	1	1	
Total	364	242	112	10
Grand Total	714	314	259	141

TABLE E-2

SUMMARY OF QUALITY OF INJURY REDUCTION ESTIMATES
FOR 26 FATAL MDAI CASES

Fatal Accidents (26 MDAI Cases)	Number	Quality of Estimate		
		Good	Fair	Poor
OAIS Remains the Same				
OAIS 1	169	25	41	103
OAIS 2	53	7	24	22
OAIS 3	44	5	22	17
OAIS 4	19	5	11	3
OAIS 5 (NF)	13	4	6	3
OAIS 5 (F)	33	27	3	3
OAIS 6	43	29	11	3
Total	374	102	118	154
OAIS Changes				
OAIS 1 to 0	82	29	46	7
OAIS 2 to 1	31	11	13	7
OAIS 2 to 0	7	7		
OAIS 3 to 2	8	1	1	6
OAIS 3 to 1	8	5	3	
OAIS 4 to 2	7	3	4	
OAIS 4 to 1	1		1	
OAIS 5 (NF) to 4	1			1
OAIS 5 (NF) to 2	1		1	
OAIS 5 (NF) to 1	2		2	
OAIS 5 (F) to 1	1		1	
OAIS 6 to 2	1	1		
OAIS 6 to 1	3		3	
OAIS 6 to 0	2		2	
Total	155	57	77	21
Grand Total	529	159	195	175