REPORT TO THE
COMMITTEE ON COMMERCE
UNITED STATES SENATE

BY THE COMPTROLLER GENERAL
OF THE UNITED STATES

Effectiveness, Benefits, And Costs Of Federal Safety Standards For Protection Of Passenger Car Occupants

National Highway Traffic Safety Administration
Department of Transportation

On the basis of North Carolina and New York motor vehicle accident data studies, GAO believes the crash survivability standards introduced through model year 1970 were effective in reducing deaths and serious injuries in accidents in those States. GAO found little, if any, further improvement resulting from standards introduced in 1971-73 model cars.

Benefits of lives saved and serious injuries avoided probably would be greater than the safety cost allocable to the 1966-70 crash survivability standards included in cars sold through 1974.

CED-76-121

JULY 7,1976

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-164497(3)

The Honorable Warren G. Magnuson
Chairman, Committee on Commerce
United States Senate

Dear Mr. Chairman:

In response to your request, we are submitting this report on effectiveness, benefits, and costs of Federal safety standards for protection of passenger car occupants.

The Department of Transportation's comments and our evaluations are included in the report.

We believe this report should be made available to the various House and Senate Committees concerned with motor vehicle safety; the Director, Office of Management and Budget; the Secretary of Transportation; and the Administrator, National Highway Traffic Safety Administration. We will be in contact with your office so that such distribution can be made.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

Contents

ABBREVIATIONS

ACIR	Automotive Crash Injury Research
FMVSS	Federal motor vehicle safety standards
GAO	General Accounting Office
GSA	General Services Administration
HSRC	Highway Safety Research Center
MDAI	Multidisciplinary Accident Investigation
NSC	National Safety Council
RECAT	Regulatory Effects on the Cost of Automotive Transportation

COMPTROLLER GENERAL'S REPORT TO THE COMMITTEE ON COMMERCE UNITED STATES SENATE

EFFECTIVENESS, BENEFITS, AND COSTS OF FEDERAL SAFETY STANDARDS FOR PROTECTION OF PASSENGER CAR OCCUPANTS

National Highway Traffic Safety Administration
Department of Transportation

D I G E S T

Federal motor vehicle safety standards for minimum performance are prescribed by the National Highway Traffic Safety Administration for passenger cars sold in the United States. This report analyzes costs and estimated benefits of those standards developed to provide better protection for passenger car occupants in accidents.

GAO's conclusions are based on analyses of information on over 2,000,000 cars involved in accidents in North Carolina and New York. GAO compared driver death and injury rates for model years of cars.

Many factors led to the adoption of safety features as standard equipment in passenger cars from the 1950s to 1966.

--State seatbelt laws.

--General Services Administration's requirements for cars bought by the Government.

--Initiative of manufacturers.

The first standards issued by the Safety Administration in 1967 and 1968 were for 1968 and 1969 model cars. Essentially, these were adapted from prior Government standards. (See pp. 9 to 11.)

Equalizing, as far as practical, conditions affecting accident severity for all model years of cars, GAO estimates that, in relation to pre-1966 model cars

--from 15 to 25 percent fewer deaths and serious injuries occurred in the 1966 to 1968 model cars;

--1969 and 1970 model cars had from 25 to 30 percent fewer deaths and serious injuries; and

--there was little, if any, further improvement in 1971 to 1973 model cars. (See pp. 12, 19, and 76.)

What implications might these results hold for the Nation? To find out, GAO estimated the value of the standards in terms of occupant lives saved. The following major assumptions had to be made.

--Data results from North Carolina are representative of the Nation.

--Drivers receive greater benefits from safety improvements than other occupants.

--All model years of cars are exposed to accidents in proportion to the number on the road.

--Value of human life as estimated by others.

Because of these assumptions, results or estimates of lives saved are offered only as approximations. The 1966-70 standards may have saved about 28,230 lives between 1966 and 1974. (See pp. 30 to 34.)

GAO could not estimate additional benefits to the Nation from a reduction in injuries, and injuries occur more often than fatalities. In North Carolina, reduced injuries accounted for one-third or more of the benefits. (See pp. 29 and 30.)

While safety is the overriding consideration in issuing standards, costs are also considered.

On the basis of manufacturers' data, GAO estimated total costs for complying with the crash survivability standards on 1966 through 1974 model cars at about $8.5 billion. These costs were for manufacturer-designed equipment such as seatbelts and shoulder harnesses, windshield mounting, energy-absorbing steering columns, reinforced roof and side doors, and other devices required by the Government. (See pp. 24 to 28.)

Estimated costs for the 1966-70 standards were about $7.2 billion for cars sold in 1966-74. The estimated value of lives saved and an indeterminate number of serious injuries avoided would probably be considered greater than the safety costs allocable to those years. (See pp. 27 and 35.)

Estimated costs for standards introduced in the 1971 through 1973 models were about $850 million. GAO found no important improvement in safety of these cars over the peak reached in the 1969 and 1970 models. (See pp. 27 and 36.)

To provide an additional dimension to its study, GAO also reviewed various research studies of the effectiveness of specific occupant protection standards and related benefit estimates. These studies and the divergent views of those concerned with motor vehicle safety are summarized in chapter 5. (See pp. 37 to 63.)

The Department of Transportation believes GAO's conclusion about recent model years needs to be more fully supported and that its report needs considerable refinement. GAO considers its conclusions justified on the basis of the evidence developed in the two States, giving full consideration to the stated assumptions. GAO considered all departmental questions and made necessary changes to the report. (See pp. 64 and app. IV.)

CHAPTER 1

INTRODUCTION

In August 1974 the Chairman, Senate Committee on Commerce, requested that we expand on the work we had recently completed for the Committee regarding benefit-cost analysis of Federal motor vehicle safety standards (FMVSS) promulgated by the National Highway Traffic Safety Administration. 1/

The Chairman was specifically interested in our identifying the probable factors responsible for changes in the annual accident trends in order to determine what effect safety standards have had on reducing accidents, deaths, and injuries. The Chairman also asked for an assessment of the range of possible safety benefits to be derived from the safety standards, based on our analysis of the benefit measurement data in our previous report, and our own assessment of safety benefits.

In addition the Chairman asked for (1) a companion evaluation of the cost of automobile safety during the same time period, (2) an overall benefit-cost evaluation, and (3) a comparison of evaluations of existing standards and our analysis of the results.

A credible nationwide evaluation of the effectiveness of motor vehicle safety standards cannot be made due to the present lack of adequate accident data. We therefore met with the Committee staff and agreed on the following three analyses to conform with limitations of reliable data available.

1. We agreed to develop accident trend information by model year from accident data of one or more States in an effort to show the effectiveness of motor vehicle safety standards. This approach does not deal with the frequency of accident occurrence. Rather, it is directed to determining whether vehicle occupants' chances of being killed or seriously injured in an accident are less when riding in late model vehicles as opposed to riding in earlier model vehicles. This approach is subject to two important limitations. First, the study was based on data from

---

1/Report to the Senate Committee on Commerce on "Need to Improve Benefit-Cost Analyses in Setting Motor Vehicle Safety Standards," B-164497(3), July 22, 1974.

selected States, so the results are not necessarily representative of the Nation. Second, an underlying assumption is that changes in the injury severity level are primarily attributable to motor vehicle safety standards, while highway safety standards and other improvements are primarily directed to accident avoidance.

2. We agreed to develop total costs to the consumer for the motor vehicle safety program from 1966 through 1974, based upon information which the major motor vehicle manufacturers would provide to us. For the standards to have been cost beneficial, the total benefits realized should at least equal this total cost. Using estimates of safety benefits included in our previous report, we agreed to determine, to the extent possible, whether these standards had been cost beneficial.

3. We also agreed to compare the similarities and differences of various effectiveness studies undertaken by researchers on four specific safety standards--head restraints, energy absorbing steering columns, side door reinforcements, and lap belt and shoulder harnesses. This work is intended to show the different results obtained as to the effectiveness of these four standards, highlighting the different assumptions, methods of study, accident data used, and criticisms of present designs.

NATIONAL TRAFFIC AND MOTOR VEHICLE SAFETY ACT OF 1966

Congressional concern over the increasing number of motor vehicle deaths led to the enactment of the National Traffic and Motor Vehicle Safety Act of 1966 (15 U.S.C. 1381), the purpose of which was to reduce motor vehicle accidents and the deaths and injuries resulting from such accidents.

The act specifies that the Secretary of Transportation shall establish appropriate Federal motor vehicle safety standards. According to the act, each standard shall be practical, shall meet the need for motor vehicle safety, and shall be stated in objective terms. In prescribing standards, the Secretary shall consider (1) relevant available motor vehicle safety data, (2) whether any such proposed standard is reasonable, practical, and appropriate for the particular type of motor vehicle or item of motor vehicle equipment for which it is prescribed, and (3) the extent to which such standards will contribute to carrying out the purposes of this act.

The National Highway Traffic Safety Administration issues these standards for the Department of Transportation. Through December 1975, 45 Federal motor vehicle safety standards have been issued. (See app. I.)

SCOPE OF REVIEW

We analyzed accident data from North Carolina for 1966 and 1968 through 1974 and from New York for 1971 through 1973. Data for calendar year 1967 was not available in machine-readable form. The analysis of North Carolina accident data was performed under contract by the Highway Safety Research Center, University of North Carolina, Chapel Hill, North Carolina. We analyzed the accident data from New York.

We reviewed trends in traffic accidents and fatalities and in automobile safety improvements. We also reviewed backup data and computations in support of the estimated costs of safety standards at the three major motor vehicle manufacturers' offices in Detroit, Michigan. We obtained, reviewed, and analyzed studies of individual safety standards at the Safety Administration's headquarters in Washington, D.C.

We also awarded a contract to the Center for The Environment and Man, Inc., Hartford, Connecticut, primarily for assistance in developing a method for evaluating the effectiveness of safety standards.

CHAPTER 2

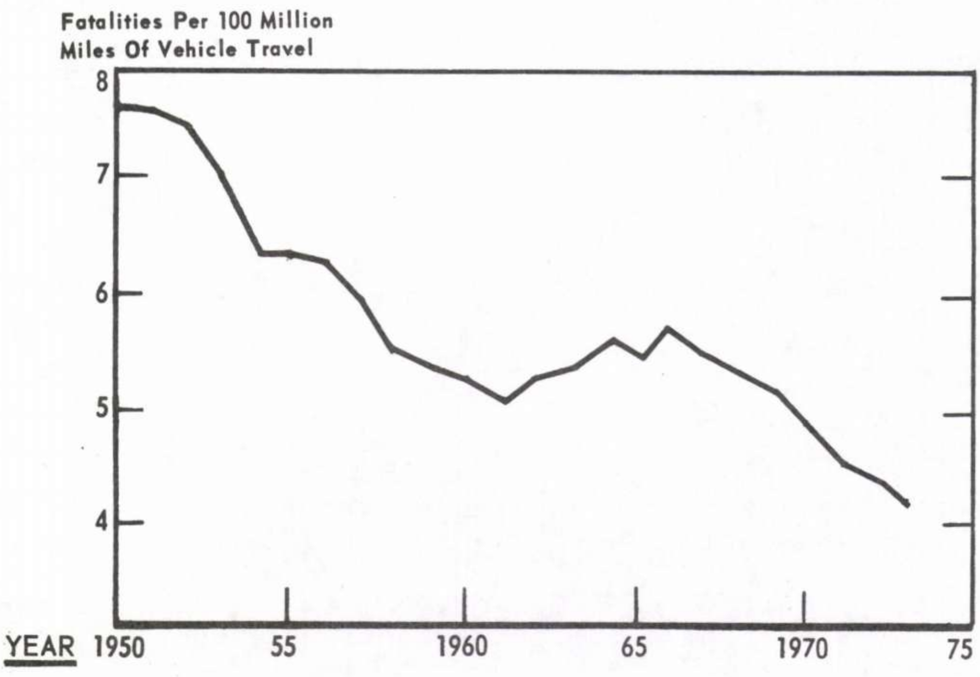
TRENDS IN TRAFFIC ACCIDENTS AND FATALITIES AND IN AUTOMOBILE SAFETY IMPROVEMENTS

The annual toll of deaths and injuries from traffic accidents demonstrated the need many years ago for safer highways, safer drivers, and safer motor vehicles. Traffic deaths exceeded 50,000 in every year from 1966 until the reduction to about 46,000 in 1974.

The trend in accidents from 1961 to 1974, some public efforts and other factors which reduced accidents and their human cost, and developments in automobile safety are summarized in this chapter.

CHANGES IN ACCIDENT, INJURY, AND FATALITY RATES

According to the National Safety Council's (NSC's) annual estimates of motor vehicle travel and fatalities, from the 1920s until 1961, miles of motor vehicle travel increased faster each year than fatalities from motor vehicle accidents. Thus, the rate of motor vehicle fatalities, customarily expressed as deaths per 100 million miles of travel, declined steadily. This trend was reversed after 1961, and annual fatalities and the fatality rate increased until 1967, when they again began to decline. (See graph below.)



The following estimates published by NSC show the magnitude of the accident problem for 3 key years.

Year	100 million miles of travel	Accidents	Motor vehicles involved	Injuries (note a)	Fatalities
		--------(000 omitted)-------			
1961	7,380	10,400	18,500	1,400	38,100
1966	9,300	13,600	24,300	1,900	53,000
1973	13,090	16,600	28,100	2,000	55,500

a/NSC's annual estimates of injuries resulting from accidents are approximations developed from special studies and should not be compared to indicate year-to-year changes or trends.

The number of vehicles involved in accidents in those years represented about one of every four registered vehicles in the United States (passenger cars, trucks, buses, and motorcycles). The total number of injured was about 1 out of every 100 residents, or even higher according to other estimates of total injuries. The number killed in motor vehicle accidents annually was about 1 out of every 4,000 residents.

We calculated the percent change in the rates of passenger cars involved in accidents and of passenger car occupants killed in accidents from estimates of NSC. Because the number of injuries to only passenger car occupants is not available, we calculated the average change in the rates of injuries in all motor vehicle accidents from four sources of estimates--NSC, the Federal Highway Administration, the Travelers Insurance Company, and the U.S. Public Health Service annual surveys. We found that from 1961 to 1966, both occupant fatalities and injuries increased at a greater rate than did passenger car accidents, showing that accidents increased in severity or that occupants were not as well protected, or both. The trend was reversed after 1966, when the fatality rate dropped more sharply than did either the accident or the injury rate. A number of factors contributed to the decreasing rates after 1966.

Some causes of reduced accident and fatality rates

Three important changes affecting accident and fatality rates from 1966 to 1973 were

--the proportion of women drivers to the total drivers increased from 40 to 44 percent;

--miles of travel in urban areas increased by 50 percent, while rural highway travel increased by only 30 percent; and

--travel on interstate highways increased from about 10 percent of total vehicle travel to about 16 percent.

Each of these contributed to a reduction in the Nation's accident and/or fatality rates because women drivers have only one-half the rate of involvement in fatal accidents as men; the average mileage fatality rate for all urban areas is less than one-third the rate in rural areas; and the interstate mileage rate of fatalities is about one-half the average rate for all other roads and streets.

At the same time, the rates of accidents and fatalities per 100 million miles of driving declined after 1966 for both men and women drivers, in both urban and rural areas, and on both interstate and noninterstate highways. Other factors obviously have had a bearing on the risks of motor vehicle travel.

Safety work on the Nation's roads and streets was accelerated by the Highway Safety Act of 1966 (23 U.S.C. 401). Under that act, the Federal Highway Administration established revised design standards for highway construction assisted by Federal funds.

In the Federal-Aid Highway Act of 1973 (87 Stat. 250), the Congress earmarked funds for specific highway safety programs. The results of the relatively few studies reported by certain States to the Federal Highway Administration generally indicate progress in implementing safety improvement programs. Because of limited time and scope, the studies did not estimate the overall effect on the Nation's highways.

The Highway Safety Act of 1966 also established Federal standards and provided grant funds to assist State and local governments to improve control of drivers and vehicles. The objective is to attain a minimum standard of performance in all States regarding driver education, the testing and licensing of drivers, periodic inspection of motor vehicles, enforcement of traffic regulations, and other nonhighway traffic problems. The effect of these efforts in terms of accidents, injuries, or fatalities is not currently measurable on any comprehensive basis.

Section 103 of the National Traffic and Motor Vehicle Safety Act of 1966 (15 U.S.C. 1392) pertains to motor vehicle safety standards. The safety features of motor vehicles are of two main types: those designed to enable drivers to avoid accidents and those to protect the occupants in the event of accidents. The former type includes improved braking, steering, lights, driver visibility, and the like. At present there is no reliable measure by which reductions in accidents can be related to developments in crash avoidance designs. The interaction of efforts under the Highway Safety Act and the construction of safer highways during the same time frame make it virtually impossible to isolate any influence of crash avoidance standards on the downward trend of the accident mileage rate since 1966.

Because the effect of crash avoidance standards cannot be measured, our study is limited to the effectiveness of occupant protection standards in reducing injuries and deaths when accidents occur.

The 55 mile per hour speed limit

Highway fatalities declined from about 55,500 in 1973 to 46,200 in 1974 and the fatalities per 100 million miles from 4.24 to 3.61 (about 15 percent). Much of this reduction has been attributed to establishment of the 55 mile per hour speed limit nationwide in January 1974. Several organizations estimated that the 55 mile per hour speed limit accounted for at least 25 percent of the reduced fatalities. The lower speed limit had a twofold effect: the risk of death or serious injury in an accident is less at a lower impact force, and traffic flowed more uniformly, reducing the chances of accidents.

Other factors commonly considered as significant in 1974 were a 2-percent reduction in overall driving and a reduction of driving in rural areas and at nights and on weekends.

Fatality-accident relationship--1961 to 1974

A rough approximation of the probability of passenger car occupants being killed in accidents is the ratio of total fatalities to the estimate of total passenger cars involved in accidents each year. Both of these figures are estimated for the Nation by NSC, on the basis of accident information furnished by the traffic authorities of certain States. Accident data generally is subject to a wide margin of error, and this is even true for nationwide projections from large samples. For that reason, the relationships shown in the table on p. 8 are to be considered only as indicators of an approximate order of magnitude and not precise measurements.

Relationship of

Passenger Car Fatalities to Accidents

(National Safety Council estimates)

1961-74

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Passenger cars involved in accidents (000's)	16,150	16,550	17,350	18,650	20,460	20,960	21,020	22,435	22,990	23,690	23,990	24,680	23,470	20,750
Occupant fatalities	24,700	26,800	28,900	31,500	32,500	34,800	34,800	36,200	36,800	34,800	34,200	35,200	33,700	26,800
Fatalities/1,000 accidents average	1.53	1.62	1.67	1.69	1.59	1.66	1.66	1.61	1.60	1.47	1.43	1.43	1.44	1.29
Fatalities at average rate for 1961-66 (note a)							34,260	36,570	37,475	38,615	39,100	40,230	38,260	33,520
Difference between Fatalities at 1961-66 Average and actual (note b)							-540	370	675	3,815	4,900	5,030	4,560	7,080

a/Average rate for 1961-66 is 1.63.

b/If the number of passengers killed per 1,000 accidents had continued at the 1961-66 average rate, the highway death toll for passenger car occupants would have been much higher. The differences between fatalities at the 1961-66 rate and actual fatalities, summarized above, gives some idea of lives saved by a variety of causes, including improvements in auto safety.

TRENDS IN VOLUNTARY AND MANDATORY SAFETY IMPROVEMENTS IN AUTOMOBILES

Automobile manufacturers faced considerable public pressure since at least 1960 to improve the safety of their products. The principal legislative results of the public's concern were the following:

--State laws requiring installation of front seatbelts in all cars sold after a specified date. Illinois was the first State to adopt such legislation, applicable to the 1961 model year. By the 1966 model year about 30 other States had enacted similar laws.

--Public Law 88-515, adopted in 1964, by which the Congress directed the Administrator of the General Services Administration (GSA) to set safety standards for cars purchased by the United States Government. In June 1965 the Administrator issued 17 standards to be required on the 1967 model-year cars the Administration would purchase.

Prior to these laws, American automobile manufacturers generally offered certain safety features as optional equipment at extra cost to the buyer. Principal among these features were front seatbelts and the padded dash available from the mid- or late 1950s. Some safety features, such as safety door locks and impact-absorbing steering wheels, were incorporated as standard equipment in certain models.

In 1962 manufacturers began to install seatbelt anchorages at the factory, which made the seatbelt option less costly to the buyer than the complete installation by dealers. In January 1964 all American manufacturers made front seatbelts standard equipment in all cars.

In June 1965 American manufacturers announced that they would incorporate most of the GSA standards in all 1966 models produced and the remainder would be incorporated in the 1967 model with certain exceptions. The principal occupant protection features achieved by these requirements were performance standards for the strength and quality of seatbelts and anchorages, safety glass, impact-absorbing steering column and its rearward displacement in a frontal collision, safety door latches and hinges, recessed dash instruments and knobs, and padded dash and visors. Standards pertaining to the avoidance of accidents included performance requirements for brakes, tire tread, lights, windshield washers and wipers, and other features. Automobile standards for performance and uniform testing developed by organizations such as the Society of Automotive Engineers, the USA Standards Institute, and the National Bureau of Standards were instrumental in formulating many of GSA's standards.

Initial motor vehicle safety standards of the National Highway Traffic Safety Administration

The National Traffic and Motor Vehicle Safety Act, approved by the President on September 9, 1966, specified that initial Federal motor vehicle safety standards for all new vehicles sold in the United States be issued by January 31, 1967. The report on the bill by the Senate Committee on Commerce pointed out that such standards must be based on existing standards.

In less than 4 months the new National Highway Safety Bureau, now the National Highway Traffic Safety Administration, completed the administrative procedures required to issue formal rules on January 31, 1967, establishing the first Federal motor vehicle safety standards (FMVSS). Most of the standards became effective on January 1, 1968, and were generally met at the beginning of the 1968 model year. Because of the short time available, nearly all of the passenger car standards were adopted directly from updated GSA standards for 1968 models. A few standards were taken from voluntary industry standards recommended by the Society of Automotive Engineers and the National Bureau of Standards.

The occupant protection standards were issued as a 200 numerical series. The Safety Administration made an addition to the GSA Standards regarding interior padding and recessed instruments, knobs, and handles (FMVSS 201). The Safety Administration also issued a seatbelt standard based on State laws requiring seatbelts in front outboard (driver and right front) positions, effective in 32 States. This new standard required shoulder belts in both front outboard positions and lap belts for all positions.

The only postcrash safety standard issued with the initial set, FMVSS 301, regarding control of fuel leakage from the fuel tank and pipes, is primarily for protection of occupants. The Safety Administration adopted the GSA standard for 1968 models, adding a requirement for integrity of fuel tank connections.

The occupant protection and postcrash safety standards are referred to in this report as the crash survivability standards.

Crash survivability standards and amendments issued after 1967

In February 1968 the Safety Administration issued FMVSS 202 effective in January 1969 requiring head restraints for the outboard seating positions. This issuance was a postponement of a GSA standard for the same purpose, which was to have been effective on 1968 model cars bought for the Government.

In August 1968 the Safety Administration issued FMVSS 212 effective in January 1970, setting performance requirements for the security of windshield mountings.

In March 1970 the Safety Administration issued FMVSS 213, setting performance requirements for child seating systems offered as optional equipment. Inasmuch as these items are not standard equipment in passenger cars, we have not considered their cost or effectiveness in this study.

In October 1970 the Safety Administration issued FMVSS 214 effective in January 1973, requiring strengthened side doors to better resist side impacts.

In December 1971 the Safety Administration issued FMVSS 216 effective in September 1973, specifying a crush resistance standard for vehicle roofs for better protection of occupants in cases of rollovers.

FMVSS 208, covering lap and shoulder belts, was amended several times. The principal amendments required a warning light and buzzer for the 1972 model cars and the ignition interlock system for the 1974 model cars. The interlock system was eliminated on cars after February 1975, retaining an intermittent light and buzzer.

In April 1971 the Safety Administration issued FMVSS 215 effective in 1972 requiring the front and rear bumpers to absorb a specific impact without damage to the body, or safety devices required by other standards. The standard's main purpose was not to protect occupants so we have not considered its cost or effectiveness in this study.

In December 1970 the Administration issued the second postcrash standard, FMVSS 302 effective in September 1972, to limit the flammability of materials used in car interiors.

CHAPTER 3

EFFECTIVENESS OF THE

CRASH SURVIVABILITY STANDARDS

Analyses of information on over 2,000,000 automobile accidents in North Carolina and New York State show a clear trend of improvement in safety to the drivers. These improvements appear to have begun with the 1962 model and continued to the 1970 model. The greatest improvement occurred between model years 1966 and 1970 when chances of surviving an accident increased by 25 percent or more. Some of the data after the 1970 model year is conflicting, but most of our analyses showed little or no improvements in the 1971 through 1973 models over the 1970 model.

The premise of our analyses is that safety features can be evaluated by how often passengers involved in accidents are killed or injured in different model-year cars. This approach does not consider the frequency of accidents or the fact that accidents may have been avoided. In this study we measure the effectiveness of all crash survivability safety features whether or not mandated by the Government. We did not isolate the effects of any particular standard except for a separate analysis of seatbelts, described in this chapter.

Our analyses of accidents were limited to the fates of the drivers because the number of other uninjured occupants involved in an accident is often not reported, or is misstated.

On the basis of discussions with auto safety officials and from our own evaluation of the relative accuracy, completeness, and consistency, we selected North Carolina accident data for analyses. To compare these analyses with accident statistics from a more urban State, we also selected New York State accident data, which we considered to be reasonably good.

To determine the relative similarities or differences among accidents across the country with those occurring in North Carolina or New York, we developed a series of indicators. For instance, the percent of motor vehicle deaths occurring in rural areas was 67.4 for the entire United States and 84.5 for North Carolina. To express the relationship between North Carolina and the Nation we set the U.S. index at 100 and this results in a North Carolina index of 125. Thus, North Carolina's proportion of fatalities in rural areas is 25 percent higher than the U.S. index. The following table compares the two State indices for various fatal accident characteristics and the related averages.

	North Carolina	New York	Index Average
	(U.S. = 100)		
Rural location	125	92	109
Nighttime	99	107	103
Wet/slippery road conditions	87	114	101
Multicar	89	76	82
Male driver	104	101	103
Driver under 25	107	86	96
Motor vehicle deaths per registration	122	99	111
Pedestrian as a proportion of all motor vehicle deaths	93	127	110

Although differences exist between the two States' indices, most accident characteristics show a resemblance to the U.S. index. More importantly, the table shows that the North Carolina and New York accident experience is not too different from the rest of the country.

Two types of analysis were performed on the data. The first involved raw, or unadjusted, statistics. A second, more complicated series of analyses were performed to adjust for factors--such as speed or weight of vehicles--which can cause the raw statistics to be misleading.

ANALYSIS OF RAW DATA

The North Carolina data base was divided into two independent groups because of changes in its accident-reporting system in 1973. The data groups used in our analysis are presented below.

	North Carolina		New York
Calendar years in which accidents occurred (note a)	b/1966-72	1973-74	1971-73
Number of cars involved in accidents	1,020,000	424,000	861,000
Earliest model-year group	pre-1961		1965

a/Using the two short-term data files tends to reduce the effects of changes in the driving environment. On the other hand, the long-term file tends to reduce the effects of vehicle aging.

b/1967 calendar year data is not included because it was not readily accessible in the file.

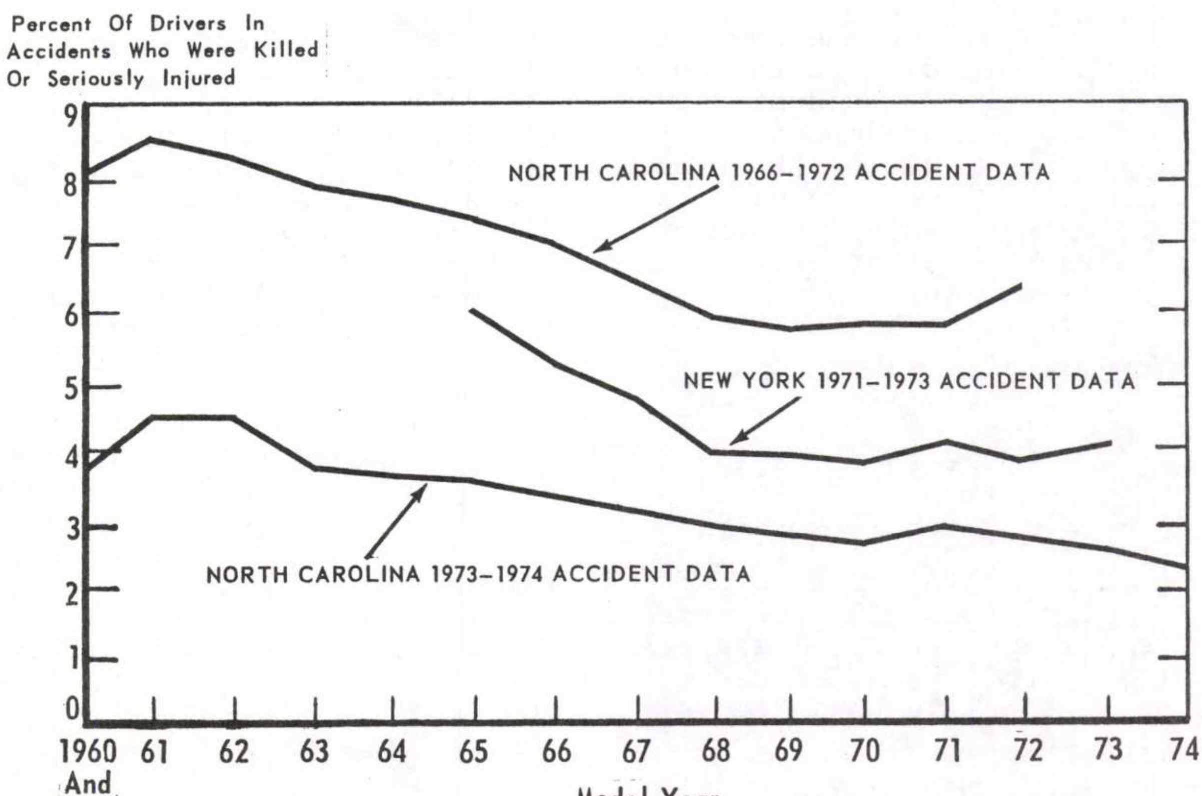
Figure 1 below is a graph of the unadjusted statistics from the three data groups. This figure shows the percent of drivers killed or seriously injured in accidents. In both States the safety of cars showed a continuing improvement in model years until the 1969-70 model. New York showed a greater improvement than did North Carolina. Fluctuations in the last model year for each data base are the result, we believe, of fewer observations for the most current year rather than any real change in safety. The next section discusses how we adjust for possible distortions in the raw data.

We believe the three files show different percentages of drivers killed or seriously injured because of different definitions of a serious injury and also because New York has a different environment and different types of accidents.

The results shown in figure 1 are a combination of fatalities and serious injuries. The separate results given on p. 15 show that fatalities are few in comparison with serious injuries, and are even less frequent occurrences in comparison with all injuries. Generally, the standards were as effective in reducing serious injuries as in saving lives.

FIGURE 1

FATALITIES AND SERIOUS INJURIES BY MODEL YEAR



Percent of Drivers in Accidents Who Were
Killed or Injured in North Carolina, 1973-74

Model year	Fatalities	Serious injuries	All injuries
pre-1961	0.38	3.47	20.1
1961	0.46	4.02	20.6
1962	0.56	3.90	19.1
1963	0.54	3.29	19.3
1964	0.42	3.28	19.2
1965	0.46	3.23	18.7
1966	0.40	3.05	18.1
1967	0.33	2.88	17.5
1968	0.37	2.58	16.5
1969	0.36	2.50	15.9
1970	0.34	2.47	16.2
1971	0.34	2.67	16.5
1972	0.34	2.45	16.0
1973	0.36	2.33	16.3
1974 (note a)	0.31	2.11	15.4

a/ Some of the reduction noted for model year 1974 may be attributable to the effects of the energy crisis.

ADJUSTED DATA

We adjusted the raw data to compensate for factors which may possibly distort the model-year results. For example, severity of an accident depends primarily on the force of impact. Force of impact, in turn, depends on many factors, such as speed, weight of the vehicles, and point of impact. Less apparent factors are also related to accident severity, such as a single-vehicle crash compared to two or more vehicles colliding, whether drivers involved are inebriated or sober, time of accident, accidents on high-speed rural highways compared to those on the dense traffic of cities, and driver's sex.

If the cars of one model year were involved in a higher proportion of severe accidents than the average for other model years, that model year would show a higher rate of fatalities and serious injuries. Drivers in single-car accidents, for example, have about four to five times the rate of death and serious injuries as those in multiple-car accidents. Unless the proportions of such accidents and other severity factors are equalized for all model years, the relative safety of each model year of cars cannot be demonstrated. To equalize the factors, we used "regression analysis"--a statistical technique for measuring the relationship among variables.

The variables considered for use in the regression analyses depended on what variables were available in the States' accident data files and on the judgment of our staff and consultants. The table below lists the initial variables marked with an "X" which were considered in each of the three data files. Some of them were eventually eliminated by statistical tests and further analysis.

Variables	North Carolina 1966-72 data file	North Carolina 1973-74 data file	New York 1971-73 data file
Driver injury level	X	X	X
Calendar years	X	X	X
Time of day	X	X	X
Road defects	X	X	
Weather conditions	X	X	
Locality	X	X	
Number of violations	X	X	
Type of accident (single or multiple vehicle)	X	X	X
Region of impact	X	X	X
Speed	X	X	
Driver's age	X	X	X
Driver's sex	X	X	X
Sobriety	X	X	X
Model year	X	X	X
Vehicle weight	X	X	X
Seatbelt usage		X	X
Vehicle damage index		X	
Road system			X
Population class			X

The analyses of North Carolina data were performed under contract by the Highway Safety Research Center of the University of North Carolina using categorical regression procedures. Our staff performed the analyses of the New York accident data using multiple stepwise regression. (See app. II for discussion of these specific regression procedures.)

One special factor we investigated was vehicle age. Are old model cars less safe because of their lack of safety features or just because of their age? The vehicle age might affect how well safety features operate, the frequency and accuracy of accident reporting, and the type of accidents in which the cars are involved. However, in North Carolina special analysis of the age effect was made and no major effects due to aging were noted.

To assure better statistical measurement in the regression procedures, we combined the accident statistics in two major ways: (1) deaths and serious injuries were usually combined together to form one safety indicator and (2) several model years were grouped together.

To thoroughly investigate the relationship between model years and crash survivability, 11 different analyses were performed using different data, files, variables, etc. The table on page 18 summarizes four of these analyses. Roman numerals correspond to those of the analyses in appendix II.

To compare the results of the analyses, a safety index was developed using the rate of survivability in prestandard models as the base. The base year selected could greatly influence the results. It is difficult to know which one to use because of the evolutionary way in which safety features were implemented since the early 1960s, as discussed in chapter 2. In one of our analyses we considered prestandard cars to be the average of model years 1965 and earlier, while in others we included 1966 models among those considered prestandard.

The safety index is the reduction, by model year, in the percent of drivers (1) killed, or (2) killed or seriously injured in accidents, as compared to the prestandard cars. Stated another way, the index represents improvements in one's chances of walking away from an accident. For example, the table below, which summarizes the results from the four analyses, shows for analysis XI that a driver of a 1967 or 1968 model car has about a 23-percent better chance of surviving in an accident than the driver of a prestandard car (in this case a 1965 or 1966 car) while a driver of a 1969 or 1970 car has a 29-percent better chance of surviving. The table also shows the raw or unadjusted data for the same cases used in the adjusted analyses.

Percent Improvement in Safety
by Model Year for Four Analyses

Model year (note a)	I Raw data	I Adjusted data	IV Raw data	IV Adjusted data	V Raw data	V Adjusted data	XI Raw data	XI Adjusted data
1966	-	-	6.0		-	-	-	-
1967	16.7		15.6	15.3	12.2	17.7	15.2	23.0
1968	22.0	18.7	22.3		21.5		29.3	
1969	25.3		27.0	26.9	12.2	21.3	29.3	29.0
1970	24.9		27.4		35.3		31.1	
1971	24.6	24.0	26.4		35.3		25.8	
1972	17.7		15.2	26.9	28.4	26.7	31.1	30.6
b/1973	36.0		44.3		(c)		27.6	

a/Data in successive years is cumulative.

b/We believe the North Carolina 1972-73 raw data reductions are due more to fewer observations than to changes in safety.

c/Not shown due to small number of observations.

FOUR ANALYSES

	I	IV	V	XI
STATE	NORTH CAROLINA	NORTH CAROLINA	NORTH CAROLINA	NEW YORK
ACCIDENT YEARS	1966–1972	1966–1972	1966–1972	1971–1973
NUMBER OF CASES (Note a)	876,000	514,000	514,000	861,000
SAFETY INDICATOR	KILLED OR SERIOUSLY INJURED	KILLED OR SERIOUSLY INJURED	KILLED ONLY	KILLED OR SERIOUSLY INJURED
VARIABLES USED	SPEED; SOBRIETY; TYPE OF ACCIDENT; DRIVER'S SEX; LOCALITY; WEATHER; AND TIME	WEIGHT; SPEED; IMPACT SITE; TYPE OF ACCIDENT DRIVER'S AGE	WEIGHT; SPEED; IMPACT SITE; TYPE OF ACCIDENT DRIVER'S AGE	MOST VARIABLES INCLUDED IN I AND II EXCEPT SPEED
TYPE OF REGRESSION	CATEGORICAL	CATEGORICAL	CATEGORICAL	MULTIPLE STEP WISE
PRESTANDARD CARS	1966 AND EARLIER	1965 AND EARLIER	1966 AND EARLIER	1965 AND 1966
POST STANDARD CAR GROUPING	1967–1969 1970–1972	1966–1968 1969–1970 1971–1972	1967–1968 1969–1970 1971–1972	1967–1968 1969–1970 1971–1973

NOTE a

EACH ANALYSIS INCLUDED ONLY THE CASES WHICH HAD COMPLETE INFORMATION ON THE VARIABLES USED. THUS, THE NUMBER OF CASES INCLUDED IN EACH ANALYSIS IS DIFFERENT EVEN THOUGH THE SAME DATA FILE WAS USED.

Most of the adjusted data analyses (see app. II), show a reduction of 25 percent or more in the percentage killed or seriously injured in the most current models as compared to prestandard cars. This same general trend is produced no matter whether raw or adjusted data is used, what variables are used, or what other changes were considered. The raw data indicate that most of this reduction came in the early model years (1966-70) with little if any additional reduction in 1971-73 models. Some of the adjusted analyses differ with these results. For example, analysis V, dealing only with fatalities, shows a continuing improvement through 1972. Most of the 11 analyses, however, show a leveling in improvements in recent models.

THE EFFECT OF KEY VARIABLES

During our analyses, some important facts became apparent about many of the variables. The effects of key variables that have policy implications with respect to auto safety are discussed below. The variables include speed, sobriety, seatbelts, and vehicle weight.

Speed

Figure 2 on page 22 is based on analysis I for 1966-72 data and compares chances of being killed or seriously injured at different speeds, given an accident has occurred, for three model-year groupings. In recent model cars, the chances of surviving an accident are improved. For example, the chances of being killed or seriously injured when driving at high speeds are 27 percent in a 1966 and earlier model car and only 22 percent in a 1970-73 car. While this represents a 20-percent improvement, greater improvement can be had by reducing speed. For example, the chances of being killed or seriously injured in recent model cars can be reduced from 22 percent at high speed to about 8 percent at medium speed. This represents more than a 60-percent improvement.

Sobriety

Figure 3 on page 23 is based on analysis I for 1966-72 data and compares, in three model-year groupings, one's chances of being killed or seriously injured in an accident, whether drinking or not drinking. The chances of being killed or seriously injured are less in recent model cars. For example, the drinker's chance is reduced from 19 percent in 1966 and earlier cars to 14 percent in 1970-73 model cars. This represents about a 28-percent improvement. However, the chances of surviving an accident appear even greater if one is not drinking. In recent model cars the drinking driver's chance of being killed or seriously injured is about

14 percent as compared to the nondrinking driver whose chance is only 5 percent. This represents a 64-percent improvement.

Seatbelts

We found that a larger percent of North Carolina drivers involved in accidents wore seatbelts in more recent model cars, as follows:

Model year	Percent of drivers involved in accidents and wearing seatbelts
pre-1967	4.9
1967-70	11.1
1971-75	22.7

Increased belt usage in the 1967-70 models over the earlier models may be due to the large proportion of cars in operation equipped with belts. A further increase in the 1971-75 model groups may also be due to the buzzer and warning light system required in 1972.

We also considered seatbelt effectiveness in relation to the extent of damage to the vehicle in the 1973-74 raw data from North Carolina.

The following table shows that drivers wearing seatbelts have less than one-half the chance of being killed or seriously injured as compared to drivers not wearing them.

Percent of Drivers Killed or Seriously Injured in Accidents When Wearing or Not Wearing Seatbelts

Vehicle damage index (note a)	Wearing belts	Not wearing belts	Improvement belt vs. no belt
Minor	0.26	0.69	62
Moderate	1.49	3.78	61
Severe	9.14	18.13	50
Average	1.89	4.44	57

a/See p. 71, analysis VI.

Vehicle weight

The effect of vehicle weight on driver safety was also examined by reviewing the raw data. The schedule below shows that drivers of lighter cars involved in accidents are always more likely to be killed or seriously injured than drivers of heavier cars. Also, with respect to model years, driver safety has improved most noticeably in the light and heavy weight cars.

Percent of Drivers in Accidents Killed or Seriously Injured in Different Weights of Vehicles

Model year	Light	Medium	Heavy
pre-1967	6.96	4.69	4.41
1967-70	5.75	4.03	3.07
1971-75	4.17	4.16	2.69

FIGURE 2

PERCENT OF DRIVERS KILLED OR SERIOUSLY INJURED IN ACCIDENTS BY SPEED

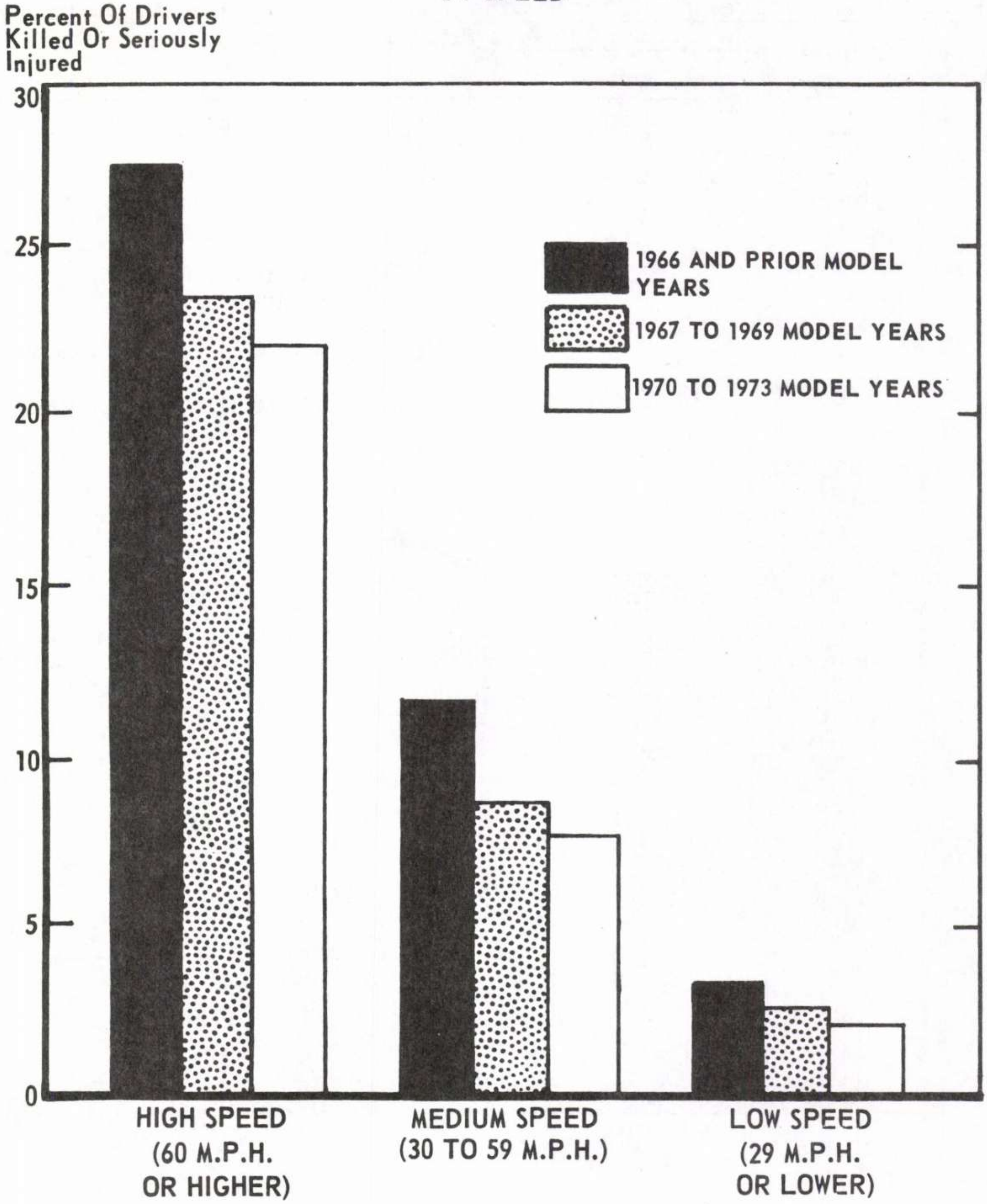
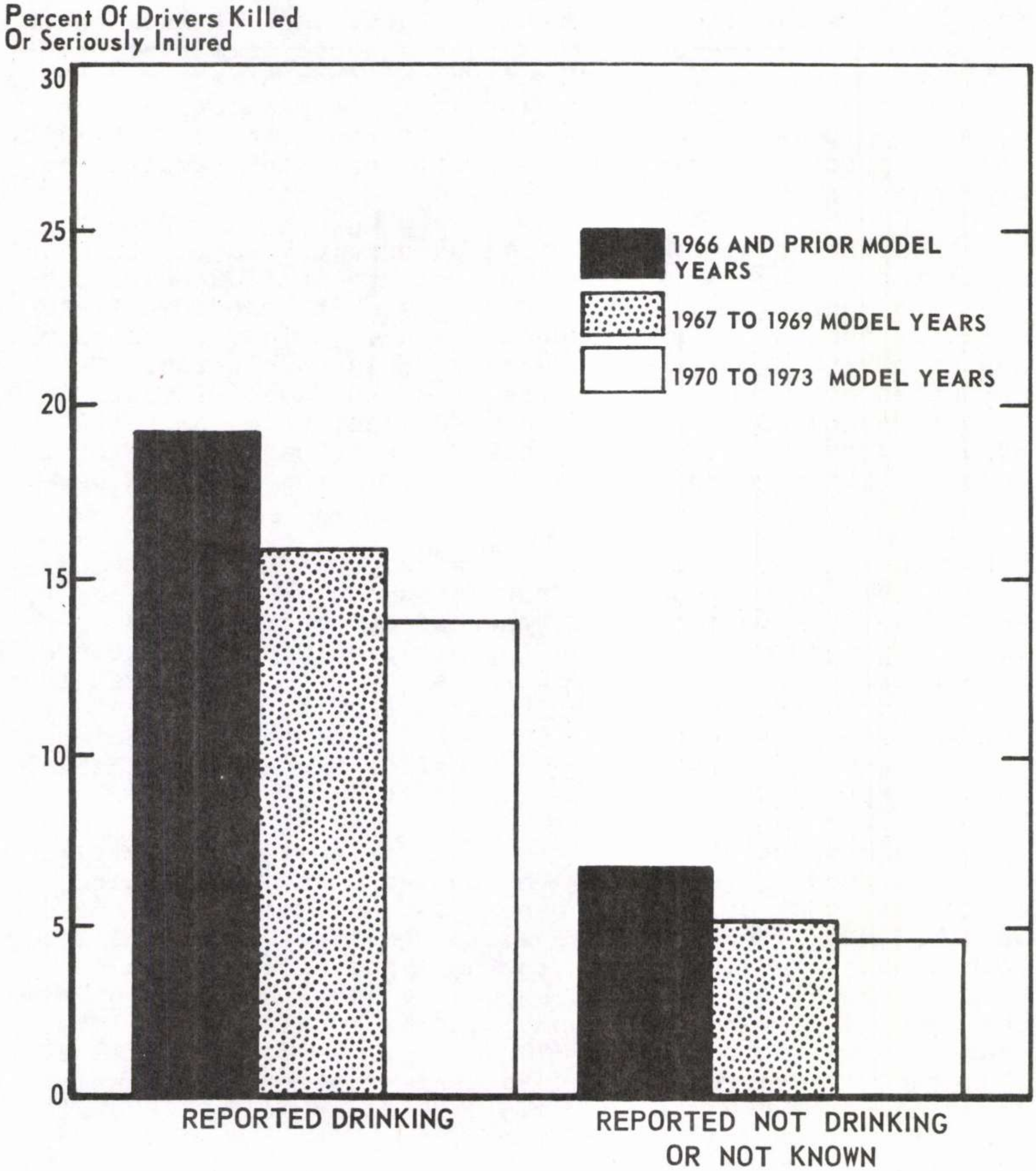


FIGURE 3

PERCENT OF DRIVERS KILLED OR SERIOUSLY INJURED IN ACCIDENTS BY INFLUENCE OF ALCOHOL



CHAPTER 4

ESTIMATED COSTS AND BENEFITS OF THE CRASH SURVIVABILITY SAFETY STANDARDS

In reporting on proposed legislation which became the National Traffic and Motor Vehicle Safety Act of 1966, both the Senate Commerce Committee and the House Committee on Interstate and Foreign Commerce stated that safety was to be the overriding consideration in issuing a standard. Both Committees pointed out, however, that the motoring public's cost to purchase and maintain safety equipment required by a standard also should be considered.

Measured only by our estimates of lives saved, the cumulative effect of safety improvements introduced through the 1970 model-year car appears to be cost beneficial. Additional benefits from a reduction in injuries, although not measurable, would add confidence to this conclusion. The estimated costs per car for the crash survivability standards prescribed by GSA and the Safety Administration amounted to about $99 through the 1970 model years of cars. The total costs of these features on all cars sold through 1974 were about $7.2 billion.

The analyses described in the prior chapter show that by the 1970 model year, the rate of death or serious injury for drivers in accidents was reduced by about 25 to 30 percent compared to the average for all pre-1966 model-year cars. We estimate that about 28,230 lives may have been saved from 1966 through 1974 because of these safety features. At all but the lowest valuation of the cost of a death to society, we estimate the value of these benefits exceeds the cost of the safety standards.

The cumulative unit costs of additional crash survivability standards (excluding the bumper standard) required in model-year cars of 1971-73 were about $31, or a total of about $850 million for these additional features on all cars sold through 1974. Most of the analyses of accidents in North Carolina and New York showed no important change in the rate of driver deaths and injuries for these model years, compared to the 1966-70 period. We conclude therefore that these model years offer the same protection as their immediate predecessors, but yield no important additional protection from death or serious injury for the additional $31 of safety requirements.

About $47 of occupant protection changes were added to the 1974 model. That model was involved in too few of the accidents analyzed to draw inferences, except to note a slight improvement that may be attributable to increased use of seatbelts because of the belt-ignition interlock system.

Passenger car buyers paid about $14.5 billion for all safety requirements included in the prices of the 1966-74 models. For crash survivability standards only, the estimated total costs in these model years of cars sold are about $8.5 billion.

COST OF SAFETY STANDARDS

Federally mandated safety features have been incorporated in about 86 million passenger cars sold in the United States--from 1966 through 1974 models. Because Federal standards specify minimum performance requirements, vehicle manufacturers design their own equipment to comply with the standards. The estimated average cost per car of complying with each Federal standard (including changes) was provided by the three major American automobile manufacturers for each model year. We weighted each set of unit costs by the volume of cars reported sold or produced each year by each manufacturer to compute an average unit cost for the industry. The table on p. 26 shows that the average estimated unit cost of all standards rose from about $40 on the 1966 model to about $368 on the 1974 model, and that the estimate for crash survivability standards--exclusive of bumper protection--rose from about $22 to about $177.

We reviewed estimating procedures of the three major American manufacturers for the above costs, and compared estimates of selected cost elements with records of actual costs for several standards in later models. The procedures were consistent with normal systems of these firms for estimating the costs of other planned model-year changes. The estimates represented the incremental cost in a model year of introducing a new standard or modifying an existing standard to comply with an amended standard. The estimates appeared to present a reasonable approximation of the manufacturers' costs of providing the safety features required by the Federal standards.

We also received cost estimates from two foreign automobile manufacturers for some of the Federal standards. These costs did not vary greatly from the American estimates. Therefore, we have used the weighted average unit costs reported by the three major American manufacturers to apply to the total estimated passenger cars sold in the United States by all firms to arrive at a total estimated cost for the Federal motor vehicle safety standards.

Estimated Average Cost per Car

Federal Motor Vehicle Safety Standards

Standards	1966	1967	1968	1969	1970	1971	1972	1973	1974
	Model year								
Accident avoidance:									
Total	$18	$31	$41	$48	$55	$55	$55	$55	$55
Crash survivability:									
201 Occupant protection on interior impact	$ 7	$10	$20	$19	$19	$19	$19	$19	$19
202 207 Head restraints and seating systems		3	5	19	19	18	18	19	19
203 204 Steering column protection and displacement		13	17	17	17	17	17	17	17
205 Glazing materials	3	3	4	4	3	3	3	3	3
206 211 Door locks, wheel nuts, discs, etc.	1	1	1	2	2	2	2	2	2
208 209 210 Occupant crash protection, seatbelt assemblies, etc.	11	13	32	32	32	32	45	50	94
212 Windshield mounting	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
214 Side door strength				5	7	9	10	15	15
215 Exterior protection (bumpers)							5	61	136
216 Roof crush resistance									3
301 302 Fuel system integrity and flammability of materials	—	—	—	1	1	1	1	5	5
Total (note b)	$22	$43	$79	$97	$99	$101	$120	$191	$313
Total-all standards	$40	$74	$120	$145	$154	$156	$175	$246	$368
Yearly increase		34	46	25	9	2	19	71	122
Crash survivability less bumper standard	$22	$43	$79	$97	$99	$101	$116	$130	$177

a/Less than $1.

b/Totals may not add due to rounding.

Estimated Costs of Auto Safety Standards

Model year introduced	All standards: Unit cost of standards	Model years to which applicable	Total cars sold	Total cost of standards	Crash survivability standards: Unit cost of standards	Total cost of standards	Amortized 1966-74 (note a)
			(000 omitted)	(000,000 omitted)		(000,000 omitted)	(000,000 omitted)
1966	$ 40	1966-74	86,288	$ 3,447.2	$ 22	$1,915.6	$ 928.2
1967	34	1967-74	77,164	2,664.5	21	1,629.0	709.3
1968	46	1968-74	68,629	3,100.0	36	2,413.0	941.3
1969	25	1969-74	59,358	1,523.1	18	1,113.0	380.3
1970	9	1970-74	49,789	431.7	2	98.6	28.8
Subtotal	154			$11,166.5	$ 99	$7,169.2	$2,987.9
1971	2	1971-74	40,594	81.2	2	78.0	19.1
1972	19	1972-74	31,980	621.1	15	468.5	95.2
1973	71	1973-74	21,450	1,515.6	14	299.9	46.7
Subtotal	$ 92			$ 2,217.9	$ 31	$ 846.4	161.0
1974	122	1974	9,520	1,159.4	47	445.2	44.5
Total	$368			$14,543.8	177	a/8,460.8	$3,193.4

a/Total costs of each model year change amortized at 10 percent per year over the approximate life of an average car. Thus, costs in the 1966 car are amortized over 9 years (1966-74), the 1967 car over 8 years (1967-74), etc. See appendix III for an example of how the amortized costs were computed by model year.

Amortized Costs

Model year in which standard or change was introduced	Calendar year									
	1966	1967	1968	1969	1970	1971	1972	1973	1974	Total
	(000,000 omitted)									
1966	$20.3	$39.2	$ 59.8	$ 81.0	$101.4	$120.5	$143.9	$170.4	$191.7	$ 928.2
1967		18.0	37.6	57.8	77.2	95.4	117.6	142.8	162.9	709.3
1968			32.6	66.2	98.6	128.9	165.9	207.8	241.3	941.3
1969				17.9	35.2	51.3	71.1	93.5	111.3	380.3
1970					1.8	3.5	5.6	8.0	9.9	28.8
Subtotal	20.3	57.2	130.0	222.9	314.2	399.6	504.1	622.5	717.1	2,987.9
1971						1.7	3.7	5.9	7.8	19.1
1972							15.4	32.9	46.9	95.2
1973								16.7	30.0	46.7
Subtotal	-	-	-	-	-	1.7	19.1	55.5	84.7	161.0
1974	-	-	-	-	-	-	-	-	44.5	44.5
Total	$20.3	$57.2	$130.0	$222.9	$314.2	$401.3	$523.2	$678.0	$846.3	$3,193.4

ESTIMATED BENEFITS OF SAFETY STANDARDS

For the purpose of estimating the benefits derived from crash survivability safety features, the effects on both fatalities and injuries should be measured. We believe, however, that the probable reduction of fatalities is the only effect that can be reasonably measured on a nationwide basis for comparison with costs.

The use of injury data for that purpose is complicated by two factors. The serious injuries that were grouped with fatalities in the analyses of North Carolina and New York accidents are not defined for reporting in the same terms in all States and are subject to interpretation and judgment of the investigating officer at each accident. Also, the broad term "serious injury" is not consistent in the several studies available on the estimated cost to society of automobile injuries. Because of the importance of reduced injuries in computing benefits, however, we have attempted to provide some measure of their effects in North Carolina.

A North Carolina automobile

Our first approach was to estimate the benefits and costs that occur over the useful lives of different model-year cars in North Carolina. The benefits of preventing fatalities and injuries are the product of (1) the number of fatalities and injuries prevented per accident, (2) the number of accidents a car is expected to be involved in over its life, and (3) the societal cost of a fatality or injury.

The number of fatalities and injuries prevented was calculated from the North Carolina raw data of 1973 and 1974 on page 15. The number of fatalities or injuries for model years after 1965 was subtracted from the average number of fatalities or injuries that occurred in pre-1966 cars. The prestandard rates used (weighted averages of cases) were 0.45 percent for fatalities and 19.5 percent for injuries.

On the basis of our review of actual accident data in North Carolina and our discussions with auto safety experts, we assumed that a car will be in one reportable accident in its lifetime. The number of accidents to the average car is critical to the analysis, because the benefits vary in direct proportion to it. This number will vary widely among States depending on the driving environment and the States' criteria and method of reporting accidents. Also, as the chances of being in an accident are reduced through highway safety standards or other means, the benefits of crash survivability standards are also reduced.

The societal costs of deaths and injuries used in the computations are given on page 35.

An ad hoc committee of the Office of Science and Technology reported on the "Cumulative Regulatory Effects on the Cost of Automotive Transportation." (RECAT) 1/ A benefit-cost comparison by model year using their benefit measurement data follows. (Similar computations using Safety Administration values about double the benefit-cost ratios, while the NSC values would decrease them by about one-third.)

Model year	Benefits of fatalities and injuries prevented: Fatalities	Injuries	Total	Unit cost of standard	Benefit-cost ratio
1966	$ 70	$ 38	$108	$ 22	4.9 /1
1967	168	54	222	43	5.2 /1
1968	112	83	195	79	2.5 /1
1969	126	98	224	97	2.3 /1
1970	154	91	245	99	2.5 /1
1971	154	83	237	101	2.4 /1
1972	154	95	249	116	2.2 /1
1973	126	87	213	130	1.6 /1

These computations are based only on driver fatalities and injuries prevented per accident. Total fatalities and injuries prevented for all occupants may produce higher benefit-cost ratios. Reduced injuries account for about 36 percent of the benefits when RECAT values are used, about 52 percent when Safety Administration values are used, and about 64 percent when NSC values are used.

Benefits of driver and occupant fatality reduction

Because of the problems discussed earlier in estimating injury reduction on a nationwide basis, this section deals only with benefits of fatality reduction. In this section we have included benefits to other occupants.

For estimating a measure of safety improvements nationwide, the North Carolina results are probably more appropriate than the New York results. Considerably more analysis of various conditions affecting severity of accidents was possible and all model years of cars were identified in the North Carolina accidents back to those of pre-1961. The New York accident reports lacked some information, such as the identification of model years earlier than 1965. We have proceeded

1/The committee report of Feb. 28, 1972.

with North Carolina rates of improvement, therefore, as having a somewhat higher confidence factor and being more conservative.

We cannot assert with any degree of reliability that North Carolina accidents are representative of the Nation, although we do not believe they are very different. (See pp. 12 and 13.) We have used North Carolina fatality and injury data and national vehicle registration data as a base so that we could obtain a rough measure of the magnitude of benefits to the Nation. This was then used for drawing a benefit-cost relationship. This method required several important assumptions.

- --North Carolina data represents a reasonable base for these estimates.
- --Improvements for passenger safety are only one-half those for drivers.
- --All model-year cars are exposed to accidents in proportion to the number on the road, regardless of vehicle age.

On the basis of North Carolina analyses described in the previous chapter, we have used analysis IV with the following percent reductions for drivers killed or seriously injured in accidents by model-year groups, with pre-1966 as the base.

Percent Reduction in Drivers Killed or Seriously Injured
(model-year groups)

pre-1966	1966-68	1969-70	1971-73
-	15.3	26.9	27.5

Are the improvements in drivers' safety equally applicable to other occupants? Of all passenger car occupants killed in accidents, about 65 percent were drivers and 35 percent were other occupants. The fatalities and serious injuries combined for other occupants in the data base show approximately the same trend as the drivers' fate by model year. Therefore, we believe that a reasonable assumption for benefit analysis is to consider that improvements in passenger safety are only one-half those attained for drivers.

Thus, a composite occupant percentage would be derived from the formula, (driver improvement percentage X 65 percent) plus (50 percent of driver improvement X 35 percent).

Below is the composite percentage for drivers and passengers in the later model-year cars compared to occupants in pre-1966 model cars for the same number and types of accidents.

Model-year cars	Relative percent change under same accident condition: Killed	Not killed
Average pre-1966	100	-
Average 1966-68	87	13
Average 1969-70	78	22
Average 1971-73	77	23

If the relative percents of occupants killed are applied to the proportions of the respective model-year cars among the total cars registered each year, the result is an approximate index of how much safer the total mix of cars became each year through the introduction of safer cars beginning in 1966. The percent of total registrations represented by each model year from 1966 to 1974 is shown in the following table.

Percent of Total Cars Registered by Model Year at July 1 (note a)

Model-year group	1966	1967	1968	1969	1970	1971	1972	1973	1974
pre-1966	91.2	79.9	69.3	58.9	49.2	41.0	32.8	25.3	19.4
1966-68	8.8	20.1	30.7	32.9	31.4	30.0	27.8	25.3	22.7
1969-70				8.2	19.4	21.9	20.8	19.5	18.5
1971-74						7.1	18.6	29.9	39.4
Total	100	100	100	100	100	100	100	100	100

a/Based on data obtained from Automotive News (1975 Almanac Issue), a weekly newspaper of the industry.

The registration percents multiplied by the relative safety percent of each model year are summarized in the following table.

Relative Index of Auto Safety for All Cars Registered

Model-year group (percent)	1966	1967	1968	1969	1970	1971	1972	1973	1974
	Registration year								
pre-1966 (100)	91.2	79.9	69.3	58.9	49.2	41.0	32.8	25.3	19.4
1966-68 (87)	7.7	17.5	26.7	28.6	27.3	26.1	24.2	22.0	19.8
1969-70 (78)				6.4	15.1	17.1	16.2	15.2	14.4
1971-74 (77)	____	____	____	____	____	5.5	14.3	23.0	30.3
Total (Safety Index)	98.9	97.4	96.0	93.9	91.6	89.7	87.5	85.5	83.9

The relative safety indices calculated by this procedure carry the assumption that all model years of cars are exposed to accidents in proportion to the number on the road, regardless of the age of cars. Older cars are driven less on the average than are newer cars. The procedure tends, therefore, to understate the effect of safety improvements in reducing fatalities over this period and again introduces a more conservative element into benefit estimates.

One method of estimating lives saved by the use of these indices would be to apply them to the annual fatalities calculated at the average rate of fatalities per 1,000 accidents for the high-rate years 1961-66. These calculations are shown in the table on page 8. This method, however, has several problems affecting reliability of the results. One is that no allowance is made for relative severity of accidents from year to year. An obvious illustration of that factor is in 1974, when the reduced speed limit considerably lowered impact severity for all models of cars. Another problem of the method is that it is highly dependent on estimates of how many cars were involved in accidents each year; these estimates are subject to more error than are estimates of passenger car fatalities.

In our opinion, a better approximation of how many passenger car fatalities might have occurred from 1966 to 1974, if safety improvements had not been introduced, can be derived by starting with the National Safety Council's estimates of passenger car occupant fatalities. Dividing the annual fatalities by the annual safety indices from the table above provides an estimate of possible deaths without the safety improvements. The difference between how many might have been killed and the estimates of actual fatalities represents an approximation of lives saved by introduction of safety improvements from 1966 to 1970 models. Results of these calculations are summarized in the following table.

Calendar year	Passenger car occupant fatalities	Safety index	Estimated fatalities without improvement (note a)	Estimated lives saved (note b)
1966	34,800	98.9	35,190	390
1967	34,800	97.4	35,730	930
1968	36,200	96.0	37,710	1,510
1969	36,800	93.9	39,190	2,390
1970	34,800	91.6	37,990	3,190
1971	34,200	89.7	38,130	3,930
1972	35,200	87.5	40,230	5,030
1973	33,700	85.5	39,420	5,720
1974	26,800	83.9	31,940	5,140
Total	307,300		335,530	28,230

a/"Estimated fatalities without improvement" is equal to passenger car occupant fatalities divided by the safety index.

b/"Estimated lives saved" is equal to estimated fatalities without improvement less number of passenger car occupant fatalities.

Estimated lives saved continued to increase by calendar year because it has taken several years for the effective improvements introduced through 1970 to be incorporated in a large number of cars and to replace those on the road without the improvements.

Estimated cost to society of an auto fatality and injury

Costs to society from motor vehicle accidents have been estimated by the Safety Administration, the RECAT Committee, and the National Safety Council. All three estimates are based on price levels of approximately 1970-71. Their estimates vary greatly, depending on assumptions and the exclusion or inclusion of such factors as lost wages, days of hospitalization, cost of pain and suffering, and other factors. 1/ The three organizations estimated the cost to society of a fatality and an injury as follows.

1/See footnote 1, p. 1.

	Fatality	Injury
National Safety Council	$ 52,000	$3,100
RECAT Committee	140,000	2,750
Safety Administration	200,700	7,300

Rather than judging which of the above estimates is most appropriate, one might consider the benefits acceptable if the cost to save one life is within that range.

BENEFIT-COST COMPARISONS

On the basis of the three estimates of the cost of a traffic fatality to society, the estimated lives saved through 1974 by safety improvements introduced in the 1966-70 models would be valued as follows, given the assumptions stated on p. 31.

Estimated lives saved	28,230
Value at:	
$ 52,000	$1,468.0 million
140,000	3,952.2 million
200,700	5,665.8 million

The estimated amortized costs of the 1966-70 standards in all 1966 and later models over the same period are about $2,988 million. (See p. 27.) Thus, the estimated benefit-cost ratios are:

At $ 52,000	$\frac{\$1,468.0}{\$2,987.9} = 0.5\ /1$
At $140,000	$\frac{\$3,952.2}{\$2,987.9} = 1.3\ /1$
At $200,700	$\frac{\$5,665.8}{2,987.9} = 1.9\ /1$

Inasmuch as the benefit-cost ratio is more than one-to-one ~~half~~ for the medium estimate of life value, as well as for the Safety Administration's higher value, the costs of safety standards introduced in those years (1966-70) appear to be beneficial. Additional benefits from a definite reduction in serious injuries, although not measurable on a national basis, add confidence to that conclusion.

We have not attributed any benefits to 1971-73 safety standards because our study showed little, if any, improvement from these model cars. The total estimated costs of these requirements are over $800 million in the model years 1971-73. (See table on p. 27.)

We have not attempted to estimate benefits for the 1974 occupant safety requirements, because there were insufficient accidents to analyze in which this model was involved.

CHAPTER 5

DISCUSSION OF OTHERS' ANALYSES OF EFFECTIVENESS AND SAFETY BENEFITS OF INDIVIDUAL STANDARDS

There are considerable differences in the motor vehicle safety community--among advocates, regulators, and manufacturers--as to the effectiveness of individual safety standards and the number of lives saved and injuries avoided or reduced by the safety devices. The primary cause of such differences is lack of a national accident data system which would provide representative and uniform data with which to measure the effectiveness of existing safety devices and provide support for the development and implementation of new and revised standards.

In our report of July 22, 1974, we recommended that the Secretary of Transportation explore with the Safety Administration ways to expedite development of an authoritative accident cause data system. As of January 1976, the Safety Administration had completed plans for a National Accident Sampling System and expected the system to become operational by fiscal year 1980. According to the Safety Administration, the system is designed to provide accurate and detailed national data on various aspects of accidents--their causes and consequences--and will provide a valid basis for assessing proposed and existing safety standards.

In spite of the existing deficiency, decisions about motor vehicle safety are being continuously made. These decisions are usually based upon a study of available accident data. Government, industry, and other interested parties commission research organizations and individuals to determine how well safety devices on motor vehicles have been performing. These researchers use their own accident data or seek others' files.

Many effectiveness studies have been made of the same safety device, especially the more important crash protection devices. These studies involve the analyses of accident samples in which the percent of fatalities and injuries in crashed vehicles with safety devices is compared to the percent of fatalities and injuries in crashed vehicles without safety devices. The difference is the percent of effectiveness. A comparison of the studies usually shows a consensus as to the effectiveness of a safety device and the range of agreement or disagreement. They do not show the estimated reduction in deaths and injuries attributable to a particular safety device. The Safety Administration and some motor vehicle manufacturers have made such estimates for head restraints, steering columns, side door strength, and seatbelts. Their estimates are detailed in this chapter. They are estimates of annual safety benefits, based on the assumption that all cars on the road were equipped with the safety device, and are not comparable to the aggregate estimates of lives saved, which we discussed in a previous chapter. Estimated annual safety benefits can, however, be valued with the benefit measurement data of the National Safety Council, the RECAT Committee, and the Safety Administration and compared with the annual amortized cost of equipping all cars on the road in 1974 with the safety device. The following benefit-cost ratios are then obtained.

Safety device and cost and source of estimated fatalities and injuries avoided	Fatalities and injuries avoided	Benefit-cost ratios (note a)		
		NSC estimate (note b)	RECAT estimate (note b)	Safety Administration estimate (note b)
Head restraints, $132.5 million:				
Safety Administration	0/186,200	4.36 to 1	3.86 to 1	10.26 to 1
Ford	0/ 3,300	0.08 to 1	0.07 to 1	0.18 to 1
General Motors	0/ 38,750	0.91 to 1	0.80 to 1	2.13 to 1
Steering columns, $153 million:				
Ford	1,800/1,860	0.65 to 1	1.68 to 1	2.45 to 1
Side door strength, $136 million:				
Safety Administration	67/26,800	0.64 to 1	0.61 to 1	1.53 to 1
Ford	0/12,400	0.28 to 1	0.25 to 1	0.66 to 1
Seatbelts, $870 million:				
Safety Administration	7,000/340,000	1.63 to 1	2.20 to 1	4.47 to 1
Ford	17,200/503,000	2.82 to 1	4.36 to 1	8.21 to 1
General Motors	5,150/336,000	1.50 to 1	1.89 to 1	4.01 to 1

a/Represents fatalities or injuries avoided at the three different estimates, divided by the cost. For example, the Safety Administration's estimate of 186,200 injuries avoided by head restraints at $3,100 as the average cost of an injury produces a benefit of $577 million, divided by the head restraint cost of $132.5 million to give the benefit-cost ratio of 4.36 to 1.

b/See p. 35.

To better understand the divergent views of those concerned with motor vehicle safety, we reviewed and compared studies of the foregoing safety devices. Two main elements were involved in assessing the effectiveness and benefits of these safety standards.

--An estimate of how effectively the safety device has actually performed.

--An estimate of the annual fatalities and injuries which occurred or would have occurred without the safety device.

The resulting differences or net savings were sometimes large. For example, estimates of injuries avoided by the head restraint ranged from 3,300 to 186,200. For seatbelts the estimates of fatalities avoided ranged from 5,000 to 17,000. Differences in the types of data used provided some reasons for varying results. One file contains data on late-model vehicles, another concentrates only on severe crashes, some have data only on urban accidents, and others include both urban and rural accident data. Other important reasons for differences are the geographic location from which the samples were taken, the size of the sample used, and different definitions of injury. Different methods of analysis and subjective interpretations of data also contribute to the problem. None of the sources provide nationally representative, uniform accident data.

HEAD RESTRAINTS

Federal motor vehicle safety standard No. 202 specifies requirements for head restraints to reduce the frequency and severity of neck injury in rear end impact accidents and other collisions. Since January 1, 1969, head restraints have been required at each front outboard seating position.

In 1973 the Safety Administration made a preliminary benefit-cost analysis of head restraints which indicated that a large number of neck injuries were being sustained in rear end impact accidents. Considerably fewer neck injuries were later reported in studies by Ford 1/ when

---

1/Ford Motor Company, "Highway and Vehicle Safety Standards," May 17, 1974.

results of its assessment of numerous safety standards were made known and by General Motors 1/ when it submitted information to the Federal Energy Administration on passenger car fuel economy.

Estimates from these three sources and a discussion of underlying differences follow.

Source of study	Injuries without head restraints	Percent effective	Neck injuries avoided
Safety Administration	1,330,000	0.14	186,200
Ford	16,500	0.20	3,300
General Motors	193,750	0.20	38,750

Injuries without head restraints

The Safety Administration based its estimate of neck injuries on a study by O'Neill and others. 2/ O'Neill concluded, on the basis of insurance claims, that there may be as many as 1 million neck injuries each year to drivers involved in rear end impacts. The Safety Administration adjusted the estimated 1 million neck injuries to eliminate the effects of existing head restraints. Using vehicle registrations, they assumed that 25 percent of the cars on the road were equipped with head restraints which were 100 percent effective. The Safety Administration used this information to compute an estimate of 1,330,000 neck injuries if there had been no head restraints.

Both Ford and General Motors used total injured occupants as their starting point. Ford calculated that there would

---

1/Comments by General Motors Corporation to the Federal Energy Administration on "Passenger Car Fuel Economy," August 1974, volume II, pp. C-33 through C-39.

2/Brian O'Neill, William Haddon, Jr., Albert B. Kelley, and Wayne W. Sorenson, "Automobile Head Restraints--Frequency of Neck Injury Claims in Relation to the Presence of Head Restraints," The American Journal of Public Health, vol. 62, no. 3, March 1972, pp. 399-406.

be 1.7 million passenger car occupant injuries in 1974 had the accident rates prevailing in the mid-1960s continued. 1/ Ford estimated that 1.2 million of the injuries were minor--the category which includes neck injuries--and that 50,000 of them resulted from rear impact accidents. The 50,000 injuries were based on a 4-to-5-percent rear impact injury estimate reported by Garrett and Morris 2/ in their evaluation of head restraint performance. Another researcher, Kihlberg, 3/ reported that the overall incidence of neck injuries among occupants in rear impact accidents was about 33 percent. Ford thus concluded that one-third of the rear impact injuries, or 16,500, would be neck injuries occurring in 1974 if there had been no head restraints.

General Motors took a different approach and began with an estimated 2.3 million occupant injuries in 1974. This estimate was based on an assumed 100 million cars exposed to accidents each year, an assumed 15-percent accident rate, an assumed 10-percent injury rate, and a Motors Insurance Corporation 4/ rate for 1972 and 1973 of 1.56 injured occupants per accident (100,000,000 x 0.15 x 0.10 x 1.56 = 2,340,000). Motors Insurance Corporation data also revealed that 6.6 percent were front seat occupants incurring neck injuries from rear impact accidents. General Motors applied the 6.6-percent rate to the number of total injured occupants in determining that 155,000 neck injuries would occur in 1974 with existing head restraints, which it said could be off by ± 50 percent. General Motors estimated there would have been 193,750 neck injuries without any head restraints.

1/See Ford estimates, pp. 48 and 49.

2/J. W. Garrett and D. F. Morris, "Performance Evaluation of Automobile Head Restraints," Society of Automotive Engineering Congress Presentation, January 1972, 14 pp.

3/J. K. Kihlberg, "Flexion-Torsion Neck Injury in Rear Impacts, Cornell Aeronautical Laboratory, Report VJ-2721 R-2, Apr. 1969.

4/The Motors Insurance Corporation file data is obtained by insurance adjusters while they are investigating claims involving an injury-producing accident in a current model General Motors vehicle. About 25,000 accidents are reported each year--10 percent, or 2,500 of which are injury producing. A detailed file is maintained by General Motors on all injury-producing accidents.

Effectiveness of head restraints

After estimating the number of neck injuries that would occur if there were no head restraints, each organization selected an effectiveness rate to use in arriving at an estimate of the number of neck injuries that would be avoided by head restraints in motor vehicles. The Safety Administration's effectiveness rate--14 percent--was taken from a study by States and Balcerak. 1/ Ford and General Motors used an effectiveness rate of 20 percent based on their analyses of published data including that of Garrett and Morris, O'Neill, and States and Balcerak.

To see why researchers' conclusions differed, we reviewed six studies pertaining to the effectiveness of head restraints, including those previously mentioned. Each study was based on a sample of actual accidents, yet the conclusions ranged from no apparent reduction of injuries to a 30-percent reduction of injuries. The percent reduction in injuries represents the difference between the rate of neck injuries in rear-impacted cars with head restraints and the rate of neck injuries in rear-impacted cars without head restraints. Some conclusions related to only the driver position, some related to both the driver and the front passenger, and others related to total results. Some studies reported that female occupants received greater benefits from head restraints. Some researchers defined the injury they were studying; others did not.

The studies involved the use of many different types of accident data from different geographical areas and accident samples ranging from 200 to almost 7,000. Some of the files used included the Automotive Crash Injury Research (ACIR) and the Multidisciplinary Accident Investigations (MDAI) files. (See p. 44.) Following is a comparison of these variables and a discussion of some of the apparent reasons for differences. It was impossible, however, to quantify the effects which the variables have on the study results.

1/J. D. States and J. C. Balcerak, "The Effectiveness of Head Restraints in Rear End Impacts," University of Rochester School of Medicine, Contract DOT-HS-167-2-261, June 1973 65 pp.

Date of report	Researchers, type of data, and location	Accident period included in sample	Sample size: Rear impacts	Sample size: Occupants	General conclusion
Jan. 72	Garrett and Morris				
	ACIR (note a) files--31 States' Trilevel accident study files western New York State	1953-71 (only accidents involving 1960-71 model cars)	961	1,342	A decrease (unspecified) in the frequency of nondangerous cervical injury
Mar. 72	O'Neill	Jan.-Sept. 1970 (only accidents involving 1966-70 model cars)	6,833	5,663	18% effective for drivers
	Insurance claim files				
Dec. 72	Fell (note b)				
	MDAI (note c) files--various	1968-72	200	353	No apparent reduction in injuries
June 73	States and Balcerak				
	Police accident reports supplemented by telephone interviews and mail questionnaires--Rochester, N.Y.	Jan.-Apr. 1972	769	906	14% effective
(undated)	McLean (note d)				
	Police accident reports in North Carolina supplemented by additional data and telephone interviews with occupants	Apr.-Aug. 1971	950	750	Appear to reduce the frequency and severity of injury in more severe rear end impacts

Date of report	Researchers, type of data, and location	Accident period included in sample	Sample size: Rear impacts	Sample size: Occupants	General conclusion
Dec. 73	Joksch (note e) State of Texas accident records	1971-72	Not stated		Betweem 10 and 30%--most likely 15 to 20% effective

a/The ACIR (Automotive Crash Injury Research) file of about 85,000 injury-producing motor vehicle accidents was developed from a study conducted by the Cornell Aeronautical Laboratory, Inc. (now Calspan, Inc.), in 31 participating States between 1953 and 1969. The trilevel files have been developed from a study in an eight-county area of western New York since 1969.

b/James C. Fell, "Data Relevant to the Performance of Head Restraints in Collisions," Research Institute, National Highway Traffic Safety Administration, Department of Transportation, December 1972, 11 pp.

c/Multidisciplinary Accident Investigations, a major detailed accident and injury data file sponsored by the Safety Administration and the Motor Vehicle Manufacturers Association, covering a small number of accidents. Teams of specialists--including medical, legal, and engineering disciplines--make indepth studies of selected accidents to obtain precrash, crash, and postcrash accident data on the occupant, the vehicle, and the environment.

d/A. J. McLean, "Collection and Analysis of Collision Data for Determining the Effectiveness of Some Vehicle Systems," Motor Vehicle Manufacturers Association of the United States, Inc., undated, pp. 1-94.

e/H. Joksch, "Evaluation of Motor Vehicle Safety Standards," The Center for the Environment and Man, Inc., Contract DOT-HS-246-2-433, December 1973, pp. 40-72.

Type of data and location

There were considerable differences in the type of accident data used and the locations from which the data was obtained.

No matter what source is used and how the data is analyzed, it contains some biases. The ACIR and trilevel files used by Garrett and Morris tend to emphasize the more severe, injury-producing accidents. The O'Neill study recognized that insurance claim files may be biased because some injury claims are probably false. Those injuries which could be ascertained at the accident site would tend to be the more severe ones. An injury such as whiplash, for example, is not always apparent at the time of an accident, so police reports made at the site would show no record of the minor or moderate injury. The technique of supplementing police accident reports with telephone interviews and mail questionnaires is also subject to bias because, as Griffith has reported, 1/ a person whose injury is so minor that he normally would not report it, if asked, would say that he had been injured.

The geographic location from which the sample is taken could influence results and conclusions drawn from it. Researchers agree that there are different accident and injury characteristics between urban and rural areas, especially the degree of severity. For this reason, it is reasonable to expect O'Neill's conclusions, which were based on a sample from the highly urbanized Los Angeles area, to differ somewhat from McLean's conclusions, which were based on a sample from the primarily rural State of North Carolina. One can only guess how the results of the samples may also be influenced by different climatic conditions, terrain, and other local characteristics.

These comments are generally applicable to studies we reviewed on other safety devices discussed in this chapter.

Sample size

The variety of accident conditions could have considerable influence on conclusions drawn if the sample size

---

1/Lindsay I. Griffith III, "Analysis of the Benefits Derived from Certain Presently Existing Motor Vehicle Safety Devices: A Review of the Literature," Highway Safety Research Center, University of North Carolina, Chapel Hill, N.C., December 1973, p. 33.

is very small. In only one report were the conclusions stated to be statistically significant. The other studies' results were either not statistically significant or the reports did not comment on significance. Generally, results were not statistically significant because the difference between the frequency of injuries in vehicles equipped with head restraints and those not equipped with head restraints was not large in relation to sample size.

These comments are generally applicable to studies we reviewed on other safety devices discussed in this chapter.

Injury definition

The injury definition can also be responsible for differences in researchers' conclusions. Varying definitions of injury result in one researcher considering injuries that another researcher would not consider; researchers using stricter injury definitions considered only more serious injuries than those researchers using a more liberal definition. We noted variations in definitions of whiplash injury in the studies reviewed.

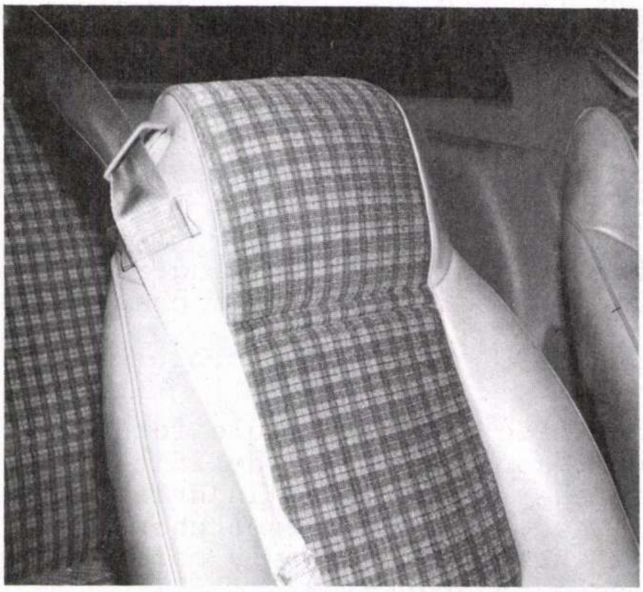
Three studies provided a definition and they differed not so much in the characteristics of whiplash injuries, but in the disability required for the injury to be counted as such. Garrett and Morris defined "whiplash" as any fracture, sprain, or complaint of pain associated with hyperextension or hyperflexion of the neck, without regard to disability. States and Balcerak used a similar definition, but excluded injuries which did not cause great disability as evidenced by loss of time at work or loss of ability to perform necessary activities of daily living.

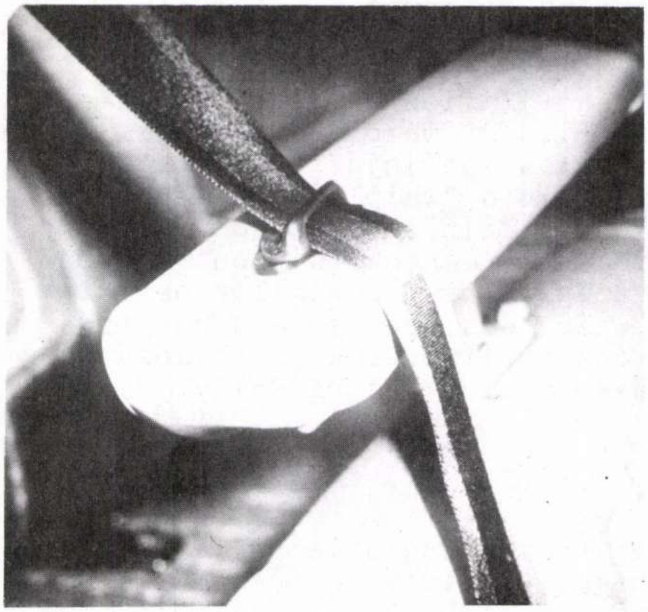
Design of head restraints

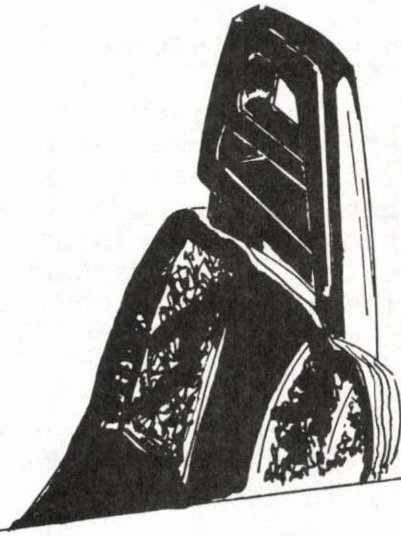
Head restraints can be either adjustable or fixed, although there seems to have been a preference by manufactures for the adjustable type. The adjustable head restraint is an "active" safety device which must be properly positioned by an occupant for it to perform effectively in an accident.

Five of the foregoing researchers studied the positioning of adjustable head restraints and reported that from 59 to 84 percent of the occupants had not adjusted them. Several researchers attributed the low percent of effectiveness to this.

VARIOUS TYPES OF HEAD RESTRAINTS







In March 1974 the Safety Administration proposed an amendment to this safety standard. As of January 1976, this amendment had not been made effective. The amendment would require head restraints be of such height that, even in their lowest permissible position, both outboard occupants in the front seat would be adequately protected. Adjustment of the right front seat head restraint would be retained to overcome an objection to fixed head restraints--restricted visibility. Some manufacturers, however, have essentially overcome the visibility problem by providing open spaces in "oval" or "ladder" shaped fixed head restraints.

Recently, Huelke and O'Day 1/ recommended laboratory and field studies on neck injury mechanisms with high-back seats before concluding that high-back seats will decrease the frequency of whiplash injury.

STEERING COLUMN

Federal motor vehicle safety standards 203 and 204, effective since January 1, 1968, specify energy-absorbing and rearward displacement requirements for steering control systems that will minimize chest, neck, and facial injuries to the driver as a result of impact. Little has been reported about the numbers of fatalities and injuries avoided by the presence of energy-absorbing steering columns. In May 1974 Ford Motor Company reported on the potential reductions due to this safety device. Its estimates and a discussion of their bases follow.

	Fatalities	Serious injuries
Fatalities or injuries without energy-absorbing steering column	8,150	8,400
Effectiveness rate	x .222	x .222
Fatalities or injuries avoided	1,800	1,860

Fatalities and injuries without the improved steering column

Using National Safety Council historical accident data, Ford Motor Company calculated there would have been 1.7 million

---

1/D. F. Huelke and James O'Day, "The Federal Motor Vehicle Safety Standards: Recommendations for Increased Occupant Safety," July 1975, p. 5.

passenger car occupant injuries in 1974 if there had been no safety improvements whatsoever. They used ACIR accident data and distributed the injuries by severity as follows:

Fatal	46,000
Serious	77,000
Moderate	415,000
Minor	1,170,000
Total	1,708,000

Ford conducted a study 1/ and concluded that, of all passenger car occupant fatalities, 38.4 percent were drivers involved in frontal crashes and 73.2 percent were in non-rollover-related-type accidents. From another study, conducted by Calspan Inc., 2/ Ford determined that 63 percent of the dangerous-to-life and fatal injuries to drivers in frontal impacts involved steering assembly contact. Thus, the number of steering-assembly-related driver fatalities in non-roll-over frontal impacts is about 8,150 (46,000x 0.384x0.732x0.63 = 8,150). The number and degree of injuries to drivers were determined in a similar manner, using injury distribution data from a study by Anderson. 3/

Effectiveness of energy-absorbing steering columns

Ford also determined from a study by Levine and Campbell and others 4/ that energy-absorbing steering columns reduced dangerous and fatal driver injuries in frontal

---

1/E. S. Grush, S. E. Henson, and O. R. Ritterling, "Restraint System Effectiveness," Report No. S-71-40, Ford Motor Company, Sept. 21, 1971.

2/Cornell Aeronautical Laboratory, Inc., "Research in Impact Protection of Automobile Occupants," Transportation Research Department, CAL Report No. VJ-2672-V-1, July 1969.

3/T. E. Anderson, "Analysis of Vehicle Injury Sources," Cornell Aeronautical Laboratory, Inc., Contract DOT-HS-053-1-109, September 1972.

4/D. N. Levine and B. J. Campbell, "Effectiveness of Lap Seat Belts and the Energy Absorbing Steering System in the Reduction of Injuries," Highway Safety Research Center, University of North Carolina, Chapel Hill, N.C. November 1971.

crashes by 22.2 percent. Levine and Campbell indicated no important reduction for less severe injuries, so Ford assigned no savings to drivers incurring moderate and minor injuries.

We reviewed five studies of actual accidents, to see what degree of effectiveness was being reported for the energy-absorbing steering columns. Only Levine and Campbell reported a reduction of about 14 percent in serious injuries due to the energy-absorbing steering columns. The remaining four studies reported only that energy-absorbing steering columns were effective in reducing driver injuries.

Some of the studies contained conflicts as to what injuries are avoided and how the reduction is accomplished. For example, one study concluded that severe driver injuries are reduced by 30 percent in medium-speed frontal impacts (30-49 miles per hour). Another study reported that the risk of serious driver injury is reduced only for high-speed frontal impacts (over 50 m.p.h.) One study reported that there were no additional injury reductions for seatbelt-restrained drivers due to the presence of energy-absorbing steering columns, while another study concluded that the energy-absorbing steering columns further reduced the overall injury risk for belted drivers. When considering the type of injury--head or chest--two different studies by the same researcher showed that energy-absorbing steering columns reduced head injuries, but had either little influence or a negative influence on chest injuries.

In addition to giving different considerations to the variables previously mentioned, the five studies also used different types of accident data from different geographical areas and accident samples ranging from about 4,900 to 21,000 incidents. (See p. 51.)

Design of steering assemblies

Both Garrett and Hendricks 1/ in the United States and Gloyns and Mackay 2/ in England found that steering columns

---

1/J. W. Garrett and D. L. Hendricks, "Factors Influencing the Performance of the Energy-Absorbing Steering Column in Accidents," Calspan Corporation, Fifth International Technical Conference on Experimental Safety Vehicles, London, June 1974.

2/P. F. Gloyns and G. M. Mackay, "Impact Performance of Some Designs of Steering Assembly in Real Accidents and Under Test Conditions." Paper 741176, Proceedings of the Eighteenth Stapp Car Crash Conference, Ann Arbor, Michigan, December 1974.

Date of report	Researchers, type of data, and location	Accident period included in sample	Sample size (frontal impacts)	General conclusions
Nov. 71	Levine and Campbell Police-reported accidents in North Carolina	1966 and 1968	21,047 (includes "car-ran-off-the-road" collisions)	Reduction of serious and fatal injuries by about 4 percent.
Sept. 72	Anderson ACIR Files--31 States; trilevel accident study files western New York State	1953-71 (only accidents involving 1960-71 model cars)	4,903 (injured drivers)	Reduction of fatalities and injuries only in severe accidents.
Jan. 73	New York State (note a) New York State Departmentment of Motor Vehicles accident data file--Police reported	1968 and 1969	7,171 (vehicles involved in head-on frontal impacts)	Reduction of injury severity, especially when seatbelts not worn.
(undated)	McLean (note b) North Carolina State Police accident reports supplemented by special report forms	Apr. 1971-Oct. 1972	6,550	Steering columns in certain models appear to provide substantial protection.
Oct. 74	Anderson (note c) Same as above	1953-73 (only accidents involving 1960-73 model cars)	6,241	Reduction of serious injury only in severe accidents.

a/"VSDSS Research Studies", New York State Department of Motor Vehicles, Contract DOT-FH-11-6799, January 1973.

b/See footnote d, p.44.

c/T. E. Anderson, "The Effects of Automobile Interior Design Changes on Injury Risk," Calspan Corporation, Contract DOT-HS-053-3-619, October 1974.

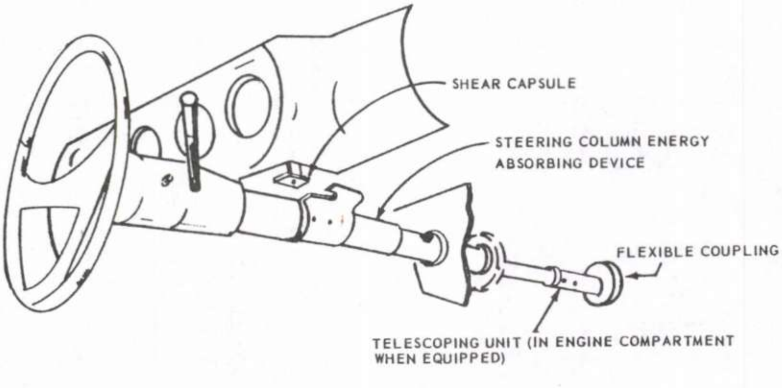
of certain designs do not collapse as intended upon impact in crashes.

Garrett and Hendricks found that steering assemblies performed best when the driver squarely contacted the steering wheel in a crash, and, as the driver's contact with the steering wheel became "angular" rather than "head-on", the energy-absorbing device compressed less. They attributed this lack of compression to "binding" of the column's telescoping elements because of crash-induced movement of the column and the driver. They recommended that compliance test procedures be reviewed.

Gloyns and Mackay reported that steering columns which comply with Federal standards were essentially ineffective in preventing serious chest and abdominal injuries. They also reported that column bending, when the driver hit the steering wheel, was the major cause of "locking" or "binding." Gloyns recommended that testing techniques be modified to better predict actual performance of steering assemblies.

The Safety Administration plans to amend the current standard to require a chest-wheel alinement mechanism and a larger padded wheel hub, to spread the impact force over a greater area of the chest.

COLLAPSIBLE STEERING COLUMN



SIDE DOOR STRENGTH

Federal motor vehicle safety standard No. 214 specifies requirements for side door strength of passenger cars to minimize the safety hazard caused by intrusion into the passenger compartment in a side impact accident. Strengthened side doors were used in some American cars as early as the

1967 model year, although the safety standard was not effective until January 1, 1973. Most manufacturers chose to strengthen doors by using a low-weight, high-strength steel beam positioned horizontally in the door. In addition, they reinforced the supporting body structures of the door areas to complement the action of the side door beam. (See diagram on p. 55.)

In August 1972 the Safety Administration 1/ used side door strength as an example for performing benefit analysis and estimated that the standard would avoid about 67 fatalities 2/ and 26,800 injuries annually. The Ford Motor Company estimated in May 1974 3/ that strengthened side doors avoided about 12,400 minor injuries annually.

The Safety Administration used 3.8 million annual injuries. This figure was derived from a 1969 National Health Survey adjusted to 1971. These injuries were then adjusted by (1) the number of passenger car occupants injured in angle (side) collisions, (2) accidents at speeds under 30 miles per hour (on the assumption that strengthened side doors are not effective at higher speeds), and (3) the contribution of door structures to injuries, to arrive at 26,800 annual injuries avoided by side door beams.

Ford concluded from several research studies that side door beams were beneficial in reducing only minor injuries of about 1.2 million (see p. 49), and the 10.8-percent contribution of side door impacts to injuries reported by Anderson 4/ yielded about 124,000 minor door-related injuries for 1974. Ford used an effectiveness rate of 10 percent, which was reported by McLean, 5/ to estimate there were 12,400 minor injuries avoided in 1974 by the presence of side door beams.

A comparison of several effectiveness studies follows.

1/National Highway Traffic Safety Administration Staff Report, "Benefit and Cost Analysis Methodology--MVP Rulemaking Programs," August 1972, pp. 10 and 11.

2/Fatalities are not separately discussed because similar methods and bases were used for both fatalities and injuries.

3/See footnote 1, p. 39.

4/See footnote c, p. 51.

5/See footnote d, p. 44.

Date of report	Researcher, type of data, and location	Accident period included in sample	Sample size	General Conclusion
Sept. 1973	Preston and Shortridge (note a) Police accident reports-Denver County, Colorado	1972	517 drivers and right front passengers	
	Collision Performance and Injury Report Revision 3 (note b)	1970-73	253 drivers and right front passengers	No statistically significant differences were noted between presence or absence of side door beams and reduction of injury severity.
	Police accident reports for the State of Texas	1972	353 drivers and right front passengers	
(undated)	McLean (note c) Police accident reports in the State of North Carolina	1970-72	4,288 cars involved in left side impacts; 4,288 drivers	Major reduction in injury risk to driver in right side impacts. Less major injuries in left side impacts.
Dec. 1973	Joksch (note d) State of Texas accident records	1971-72	Not stated	No conclusions were drawn on the effects of strengthened side doors because sample was not statistically valid.

a/F. Preston and R. Shortridge, "An Evaluation of the Effectiveness of Side Door Beams Based on Accident Exposure," University of Michigan Highway Safety Research Institute, Report UM-HSRI-SA-73-8, September 1973.

b/Includes accident reports prepared primarily on insurance claims filed with the Motors Insurance Corporation and generally based on police and medical reports, witnesses' statements, and other sources.

c/See footnote d, p. 44.

d/See footnote e, p. 44.

Designs for side door strength

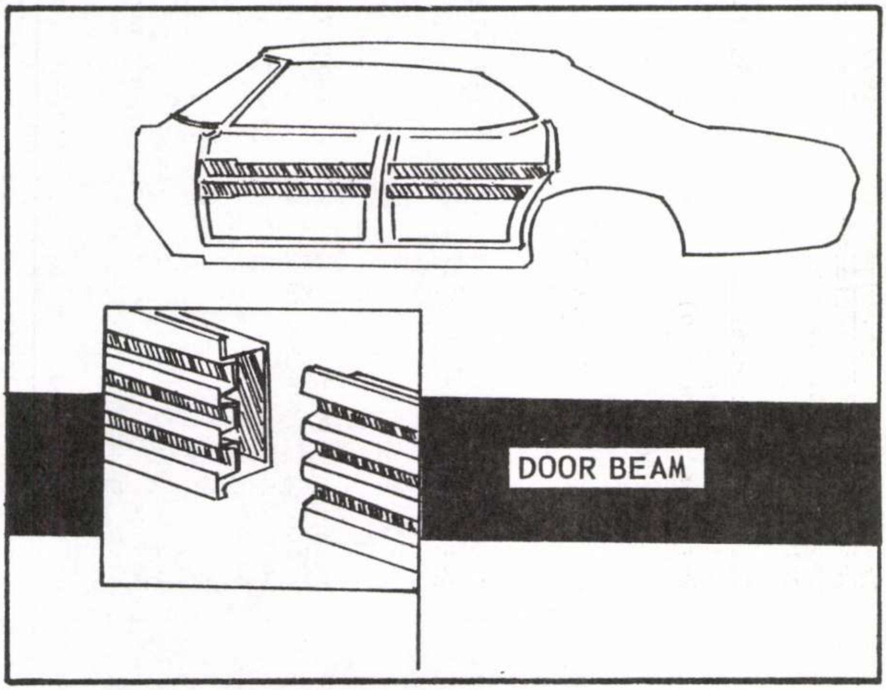
Most automobiles use a side impact system which consists of intrusion beams located at approximately each door midline in conjunction with reinforced body pillars, hinges, and door locks.

General Motors, the initiator of side door beams, has recently claimed that the current standard inadvertently perpetuated designs that were not the most efficient means of providing occupant protection with the least weight and cost. Furthermore, it contends that current Federal requirements restrict designers in their efforts to provide other forms of protective side structure because tests were tailored around designs using a beam.

Researchers have pointed out that new designs are being developed which meet all the Federal requirements and add only 15 to 20 pounds to each vehicle without a cost penalty.

Future experience by automotive manufacturers will be instrumental in changing or modifying existing designs.

SIDE DOOR BEAMS



SEATBELTS

Federal motor vehicle safety standard No. 208 establishes requirements for seatbelt installations in motor vehicles to protect occupants against death and injury in accidents. Seatbelts were installed voluntarily as standard equipment by all manufacturers in 1964 model vehicles and as optional equipment by manufacturers in many earlier model cars. Effective January 1, 1968, however, standard 208 required lap and shoulder belts in the front outboard seating positions and lap belts in the other positions of all passenger cars. The primary function of lap belts is ejection prevention, while the shoulder harness restrains the upper torso from striking the vehicle interior.

Since 1968, seatbelt requirements have undergone modifications directed primarily toward improving seatbelt use rather than performance. Beginning January 1, 1972, light and buzzer reminder systems were required, followed by the addition of an ignition interlock system and nondetachable lap-shoulder belts effective September 1, 1973. The interlock requirement was prohibited by law as of October 28, 1974. Since February 25, 1975, vehicles have been required only to be equipped with a simplified light and buzzer reminder system.

Most authorities agree that seatbelts, when used, offer considerable protection against death and injury and provide overall benefits which compare favorably with total seatbelt costs. The results of various studies, however, disclose considerable disagreement on the degree of protection and the level of benefits provided.

In August 1974 the Safety Administration reported 1/ on its analysis of effectiveness and resulting benefits of seatbelts and air cushion restraint systems. Subsequent comments on the Safety Administration's position by Ford 2/

1/"Analysis of Effects of Proposed Changes to Passenger Car Requirements of MVSS 208," National Highway Traffic Safety Administration and Transportation System Center, August 1974.

2/"Comments of Ford Motor Company on Analysis of Effects of Proposed Changes to Passenger Car Requirements of MVSS 208," Oct. 9, 1974.

and General Motors 1/ show the range of differences among the three parties as to the effectiveness and benefits of the interlock system, the required safety device at the time of the studies.

	Safety Administration	Ford Motor Company	General Motors
Annual fatalities and injuries without protection:			
Fatalities	38,000	46,000	35,000
Injuries	2,800,000	1,662,000	1,400,000
Net effectiveness rate:			
Fatalities	.18	.37	.15
Injuries	.12	.30	.24
Number saved annually (note a)			
Fatalities	7,000	17,200	5,150
Injuries	340,000	503,000	336,000

a/Figures do not compute due to rounding.

Fatalities and injuries without seatbelts

The Safety Administration based its estimate of fatalities on a projection of the trend in the growth of occupant deaths with no protection. Projected injuries were not explained.

The bases for Ford's estimated fatalities and injuries are presented on pp. 48 and 49 of this report. General Motors reported that its estimate began with the 2.2 million traffic injuries quoted by the RECAT Committee in its February 1972 report. This value, adjusted to vehicle occupants only, became 1.4 million and according to General Motors established a 40-to-1 ratio between injuries and the 35,000 annual occupant fatalities 2/ which was consistent with its injury file and a Volvo accident file.

1/"Comments of General Motors Corporation with respect to the NHTSA Report Entitled Analysis of Effects of Proposed Changes to Passenger Car Requirements of MVSS 208," General Motors Corporation USG1172, Oct. 4, 1974.

2/This estimate is consistent with accident data published by the National Safety Council for 1972.

Overall effectiveness rates

Effectiveness estimates for each of the three safety devices previously discussed involved a specific type of collision--frontal, rear, or side--and were generally based on actual accidents. Estimating seatbelt effectiveness was quite different in that all types of collisions had to be considered and the estimates were based, for the most part, upon "expected" performance rather than "actual" performance in accidents.

The Safety Administration's estimate of seatbelt effectiveness in avoiding fatalities/injuries in frontal impacts was based upon laboratory and accident data and technical judgment. From this information it estimated the occupants' survival chances at various speeds and correlated them with the frequency of fatalities and injuries at those speeds. Effectiveness in avoiding fatalities and injuries for the other types of collisions was generally based on seatbelt studies of actual accidents.

Ford took an approach similar to the Safety Administration in estimating seatbelt effectiveness in preventing fatalities and injuries in frontal impacts. Its estimates for the other types of collisions were based on accident data and the assumption that seatbelts prevented fatalities and injuries associated with occupant ejection.

General Motors' estimate of the effectiveness of seatbelts in avoiding fatalities in all of the types of collisions was based on an analysis of a small number of fatal accidents. This data was used to estimate the occupants' chances of survival if seatbelts had been worn. Seatbelt effectiveness in reducing injuries was primarily based on a study by Bohlin. 1/

Seatbelt effectiveness in frontal collision fatalities, which represent about one-half of all fatalities, was heavily emphasized and documented in the Safety Administration and Ford studies. The performance of lap-shoulder belts in frontal collisions is of particular importance for comparison with the air cushion restraint system, since this system was designed primarily for frontal collision protection. For these reasons,

---

1/Bohlin, N., "A Statistical Analysis of 28,000 Accident Cases with Emphasis on Occupant Restraint Value, SAE Paper No. 670925, presented at 11th Stapp Car Crash Conference, Anaheim, California, October 1967.

E R R A T A

To recipients of the Comptroller General's report to the Senate Committee on Commerce entitled "Effectiveness, Benefits, and Costs of Federal Safety Standards For Protection Of Passenger Car Occupants" (CED-76-121):

On page 35, paragraph 4, lines 1 and 2, "one-half" should read "one-to-one."

and to simplify matters, we are confining our comparisons and discussions to fatalities only, as they relate to the lap and shoulder belt interlock system (front outboard occupants) in frontal collisions.

	Safety Administration	Ford	General Motors
Effectiveness--frontal impacts	a/0.37	b/0.80	0.37
Probability of fatality occurrence	x.44	x.42	x.32
	.16	.34	.12
Lap-shoulder belt use--interlock	x.50	x.60	x.50
Net effectiveness--frontal impacts	c/ .08	.20	.06

a/This estimate was later raised to 0.50.

b/See note b, p. 61.

c/These values are part of the net effectiveness estimates shown on p. 57.

Effectiveness--frontal impacts

The Safety Administration determined that lap-shoulder belts provide protection against death at an average frontal impact speed of 30 miles per hour. In effect, the chances of survival were established at 100 percent for fatalities occurring under 30 miles per hour and 0 percent for those occurring over 30 miles per hour. The Safety Administration assumed that any survivals at speeds over 30 miles per hour would generally offset fatalities at speeds under 30 miles per hour. The 30 mile per hour protection level was based on the results of various studies of both accidents and simulated crash tests. The frequency of fatalities at various impact speeds, which was correlated with the survival chances at corresponding speeds, was based on 1,244 frontal fatalities included in the ACIR files.1/ Using the Grush, et al., study 2/ Ford estimated the belted occupants' chances of survival for 72 different frontal crash configurations and correlated them with the corresponding frequency of fatalities occurring for these configurations.

1/See footnote a, p. 44.

2/See footnote 1, p. 49.

The 72 configurations covered 2 basic types of frontal collisions, 3 specific frontal impact directions, 6 levels of severity (speed), and the 2 front outboard seating positions. The chance-of-survival estimates were determined by relating occupant impact forces recorded in simulated crashes with the impact forces found to be tolerable by humans. A computerized mathematical model developed by the Cornell Aeronautical Laboratory was used to simulate frontal crashes and obtain measures of potential impact force on the head and chest at various speeds. Measures of human tolerance to impact forces on the head and chest were based on the results of experiments with subhuman primates conducted by the Highway Safety Research Institute of the University of Michigan. The frequency of fatalities at various impact speeds was based on 790 frontal fatalities in the ACIR files involving 1960 through 1969 model cars.

A comparison of the differences between the Safety Administration and Ford estimates is shown on the following page.

General Motors used a different approach to develop its effectiveness estimate. It analyzed 706 fatal accidents in detail to determine the unique series of circumstances and resulting hazards to occupants in each fatal accident.

The fatal accidents were selected from MDAI files 1/ and collision performance and injury reports prepared primarily in connection with insurance claims filed with the Motors Insurance Corporation of General Motors. 2/ A panel of four General Motors engineers, experienced in seatbelt design, development, and performance, judged each occupant's expected chance of survival in frontal accidents if seatbelts had been worn. They considered factors such as the extent of intrusion into the vehicle interior; the severity of the crash; and the age, size, and health of the occupant. The effectiveness rate was determined by adding the individual chance of survival estimates for each fatality and dividing by the number of fatalities.

Other factors

The probabability of a fatality occurring--derived from different accident data by each organization--represents the product of the percent of fatalities occurring in frontal impacts and the percent of fatalities to the driver and right front seat passenger.

1/See footnote c, p. 44.

2/See footnote 4, p. 41.

Barrier impact speed (miles per hour)	Chance of survival: Safety Administration (note a)	Chance of survival: Ford (note b)	Frequency of fatalities: Safety Administration (note a)	Frequency of fatalities: Ford (note b)	Effectiveness: Safety Administration	Effectiveness: Ford
	(percent)					
0 - 15	100	100	3	3	3	3
16 - 25	100	98	17	8	17	8
26 - 30	100	91	17	c/17	17	15
Total (0 to 30)	d/100	d/ 94	37	28	37	26
31 - 35	0	91	19	c/18	0	16
36 - 45	0	70	30	54	0	38
46 - 55	0	30	11	0	0	0
56 and over	0	d/ 0	3	0	0	0
Total (over 30)	d/ 0	d/ 75	63	72	0	54
Total (all speeds)	d/ 37	d/ 80	100	100	37	80

a/Determined on the basis of data included in the Safety Administration study. (See footnote 1, p. 56.)

b/Based on data included in Grush, *et al.*, study (see footnote 1, p. 49) covering single impact frontal collision. According to Ford Motor Company representatives the rates for multiimpact frontal collisions would be about the same.

c/For comparison, Ford study fatality rate for the 26 to 35 mile per hour speed was divided about equally between the 26 to 30 and the 31 to 35 mile per hour speeds used in the schedule.

d/Represents average and not total of preceding percents.

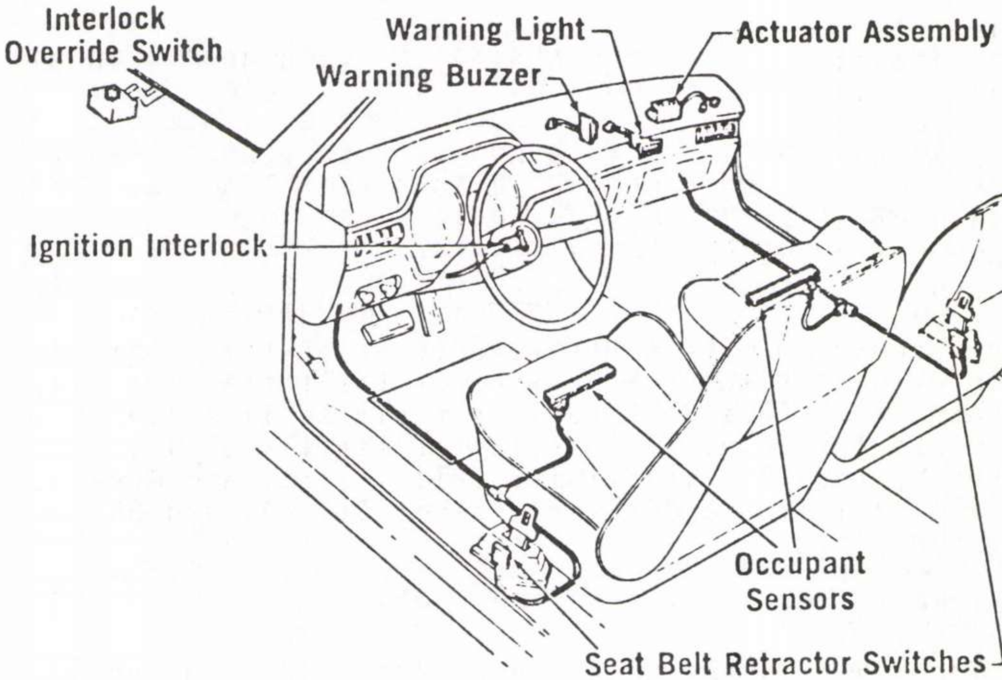
	Safety Administration	Ford	General Motors
Fatalities in frontal impact	0.51	0.48	0.37
Fatalities of driver and right front passenger	x.87	x.87	x.87
Probability of fatality occurring	0.44	0.42	0.32

Estimates of seatbelt use were based on the interlock system in effect at the time. None of the three organizations stated the specific basis for their estimates, but they were similar to actual results of earlier surveys undertaken by the Safety Administration, Ford, and General Motors, which disclosed "driver" use of 51, 63, and 55 percent, respectively.

Design of seatbelts

In January 1975 the Safety Administration requested major automobile manufacturers to cooperate in counteracting the impending reduction of seatbelt use, brought about by abolishing the interlock system, by making more convenient seatbelt systems available as soon as possible. They were provided with results of a study that showed a large number of drivers preferred a seatbelt system designed for optimum comfort and convenience rather than the various 1974 seatbelt systems available.

1974 SAFETY BELT SYSTEM



CHAPTER 6

AGENCY COMMENTS AND OUR EVALUATIONS

The Department of Transportation agreed in principle with our findings concerning present limitations of accident data, which preclude a credible nationwide estimate of motor vehicle safety standards effectiveness. For this reason, the Department said our conclusion that recent models showed little, if any, improvement over prior year models needs to be more fully supported in the report.

Our conclusions about all of the model years are based on data analyses of over 2 million cars involved in accidents in North Carolina and New York. Most of the analyses disclosed a large initial improvement to driver safety and then a leveling off--which indicates to us that the model-year effect is quite strong regardless of the analytical factors and data used. After fully considering our stated assumptions, the care exercised in analyzing the data, and the overwhelming evidence developed in these two States as to the program's effectiveness, we feel our conclusions are justified.

When we use this State data to estimate the value of standards in terms of lives saved by safer cars, we realize it is not necessarily representative of the Nation and that results are offered only as approximations intended to illustrate relationships. So that estimates are not misleading or misinterpreted, we have highlighted our assumptions.

The Department believed that the report needed considerable refinement and, therefore, presented a page-by-page interrogation on points of potential misinterpretation, confusion, or apparent contradiction which it believed should be answered prior to completing the report.

The entire Department reply to our draft report and our comments to questions are included as appendix IV. We carefully considered every question and made appropriate changes in the report.

FEDERAL MOTOR VEHICLE SAFETY STANDARDS

FOR PASSENGER CARS

Standard number	Title	Effective date
100 Series-Accident Avoidance		
101	Control Location, Identification, and Illumination	1-1-68
102	Transmission Shift Lever Sequence, Starter Interlock, and Transmission Braking Effect	1-1-68
103	Windshield Defrosting and Defogging Systems	1-1-68
104	Windshield Wiping and Washing Systems	1-1-68
105	Hydraulic Brake--Passenger Cars	1-1-68
106	Hydraulic Brake Hoses	9-1-74
107	Reflecting Surfaces	1-1-68
108	Lamps, Reflective Devices, and Associated Equipment	1-1-68
109	New Pneumatic Tires	1-1-68
110	Tire Selection and Rims	4-1-68
111	Rearview Mirrors	1-1-68
112	Headlamp Concealment Devices	1-1-69
113	Hood Latch Systems	1-1-69
114	Theft Protection	1-1-70
115	Vehicle Identification Number	1-1-69
116	Hydraulic Brake Fluids	3-1-72
117	Retreaded Pneumatic Tires	1-1-72
118	Power-Operated Window Systems	2-1-71
119	Tires for Vehicles Other Than Passenger Cars	9-1-74

Standard number	Title	Effective date
121	Air Brake Systems--Trucks, Buses, and Trailers	9-1-74
122	Motorcycle Brake Systems	1-1-74
123	Motorcycle Controls and Displays	9-1-74
124	Accelerator Control Systems	9-1-73
125	Warning Devices	1-1-74
126	Truck-Camper Loading	1-1-73
200 and 300 Series-Crash Survivability		
201	Occupant Protection in Interior Impact	1-1-68
202	Head Restraints	1-1-69
203	Impact Protection for the Driver from the Steering Control System	1-1-68
204	Steering Control Rearward Displacement	1-1-68
205	Glazing Materials	1-1-68
206	Door Locks and Door Retention Components	1-1-68
207	Seating Systems	1-1-68
208	Occupant Crash Protection--Passenger Cars	1-1-68
209	Seatbelt Assemblies	3-1-67
210	Seatbelt Assembly Anchorages	1-1-68
211	Wheel Nuts, Wheel Discs, and Hub Caps	1-1-68
212	Windshield Mounting	1-1-70
213	Child Seating Systems	4-1-71
214	Side Door Strength	1-1-73
215	Exterior Protection	9-1-72

Standard number	Title	Effective date
216	Roof Crush Resistance	8-15-73
217	Bus Window Retention and Release	9-1-73
218	Motorcycle Helmets	3-1-74
301	Fuel System Integrity	1-1-68
302	Flammability of Interior Materials	9-1-72

TECHNICAL ANALYSES

The effectiveness estimate of crash survivabililty standards was based on accident information from 2 States, 3 data files, 2 different regression procedures, and 11 groups of analyses. This wide variety of approaches was taken to minimize the potential for biased results due to quality or source of data, methodology employed, or other factors.

The North Carolina data base was split into two files to accommodate a January 1973 change in the definition of serious injury. A more appropriate data base was also provided for examining the question of calendar year effects. Variables considered in the analyses are shown in table I (pp. 77 and 78).

Regression procedures

We analyzed the New York data using a traditional multiple stepwise regression analysis. This enabled us to estimate, by various model-year categories, the change in probability of a driver involved in an accident being seriously injured or killed. This change is estimated after considering the effects of other important factors, such as weight of the car, region of impact, or the road system. For a complete list see table I.

In contrast, the North Carolina data was analyzed by the Highway Safety Research Center (HSRC), University of North Carolina. The analytic method used is somewhat different from the method used on the New York analysis and therefore requires some explanation. The majority of the data used in the study was categorical in nature (i.e., male or female, day or night, drinking or not drinking), and thus, the statisticians at HSRC preferred categorical regression analysis, a technique developed to analyze this type of data. Two fundamental differences exist between multiple and categorical regression analysis.

1. In multiple regression, the dependent variable, as well as most of the independent variables, would be expressed as 0's or 1's. In categorical regression, the dependent variable is expressed as a probability--the probability of driver death or serious injury--while the independent variables are expressed as 0's or 1's.

2. The categorical regression procedure uses a modified chi square technique to select variables to be used in the equation, while multiple regression uses the "F to enter" statistic. The categorical regression procedure is similar to a forward stepwise regression procedure.

Using the categorical regression procedure, we screen variables to select those which explain the greatest amount of variation in driver fatality or injury. Then, a categorical regression model is fitted to the variables selected to determine the effect of the model-year variable on driver fatality or serious injury.

To determine which independent variable is most highly related to driver fatality or injury (the dependent variable), contingency tables are constructed for all the independent variables relative to driver fatality or injury. Chi square statistics are computed for all contingency tables and the variable with the largest chi square statistic is the first variable selected. Once this variable has been selected, three-way contingency tables are constructed showing the relations of all possible independent variables to the chosen dependent variable. Again, chi square statistics are computed for all contingency tables, and the variable with the largest chi square statistic is the second variable selected. Additional variables are selected on the basis of the chi square statistic for four-way, five-way, etc., contingency tables.

The selection of independent variables divides data into a number of cells. For example, if the following variables were selected, the number of cells would equal 48 (2x2x2x2x3) in a multidimensional contingency table.

Variable selected	Number of categories
Driver's sex	2
Locality	2 (town or country)
Weather	2 (good or bad)
Time of day	2 (day or night)
Model year	3 (old, medium, or new)

The probability of being killed or seriously injured is computed for each of these 48 cells. Each cell then becomes an observation and these probabilities are modeled using a regression by weighted least squares with the dependent variable expressed as the probability and the independent variables expressed as 0's or 1's.

Once the modeling is complete, it is then possible to test model fit, again using chi-square (X^2) statistics. Finally, a measure of explained variation, similar to the R^2 in multiple regression analysis, can be computed as follows:

$$"R^2" = \frac{X^2 \text{ due to model}}{X^2 \text{ due to error} + X^2 \text{ due to model}}$$

The reader interested in a more technical discussion of categorical regression techniques is referred to the Grizzle, Starmer, and Koch article. (See p. 83.)

Description of analyses

Using either standard or categorical regression procedures, we conducted 11 different analyses. The important elements of each are outlined in table II and the distinguishing characteristics are summarized below (pp. 79 and 80).

Analysis

I Analysis I used the largest data base and control for variables selected for their statistical relationship to driver death or injury. In contrast, most remaining North Carolina analyses controlled for the potential effect of factors which have a physical relationship to driver death or injury.

II This was similar to analysis I, but in order to expand the model-year variable to four categories, it was necessary to omit data on drinking drivers.

III This is similar to analysis II, except that drunk drivers were included and control variables were selected on the basis of physical rather than statistical criteria. Independent variables were defined as:

	Weight	≤2,500 lbs., 2,520-3,500, 3,520-6,000
	Speed	0-59 m.p.h., above 60 m.p.h.
	Age	≤54,≥55 (one-car accidents only)
	Impact area	Front and left, right and rear (multiple-car accidents only)
	Model year	Pre-1967, 1967-68, 1969-70, 1971-73
	Type	One-car, multiple-car accident
IV	Analysis III was duplicated except that prestandard cars were redefined as pre-1966 model year.	
V	This analysis considers the changing probability of fatality only by model year and is similar to analysis III except for the changed dependent variable. The later three model-year groups were combined across all categories for one-car accidents and were collapsed for right side and rear end multiple-car accidents.	
VI	The data base for this analysis consisted of calendar years 1973 and 1974 passenger car drivers involved in accidents in North Carolina. Control variables included seatbelt use, locality, and vehicle damage rating. (Damage to vehicle--minor, 1 and 2; moderate, 3 and 4; and severe, 5 to 7.)	
VII	This analysis is similar to the previous one except vehicle weight (2,500 lbs. and under, 2,520-3,500, lbs. 3,520-6,000 lbs.) replaced seatbelt use as a controlling variable.	
VIII	This is similar to analysis VII except that locality was not considered and the vehicle damage rating was redefined.	
IX	The analysis focuses on single-car accidents in New York State using standard stepwise regression procedures. Similar to analysis I, the criterion for selecting control variables was a strong statistical rather than physical relation to the dependent variable.	
X	This is similar to analysis IX but for multiple-car accidents.	
XI	This combines, on a weighted basis, the results of analyses IX and X.	

<u>Categorical Regression Results-North Carolina (Analyses I through VIII)</u>

Table III (pp. 81 and 82) shows--by analysis and for each module within--the change in driver's fate attributed to each model-year group.

The coefficients for model-year group 2 represent a decrease in the probability of fatality, or fatality and serious injury, from that experienced by drivers of prestandard cars. The coefficients for model-year group 3 represent a further change from the earlier experience. Thus analysis I indicates a fatality and serious injury rate of 7.67 percent for pre-1967 models. Model-year group 2 shows a reduction of 1.43 percent for a net fatality or serious injury rate of 6.24 percent. Model-year group 3 reflects a further reduction of 0.4 percent.

Model-year groupings vary by analysis and are defined in table II (pp. 79 and 80). The "R^2" was computed for each module of analyses I and II. Similar statistics were not computed for the analyses that followed as the model predictors closely estimated observed data; that is, the sum of squares due to error was small.

Stepwise Regression Results--
New York (Analyses IX through XI)

Analysis IX was a stepwise regression performed on 92,000 drivers in one-car accidents. The dependent variable was defined as "drivers killed and seriously injured versus all other." The F value for entry and removal was specified to allow the maximum number of variables to enter and remain in the equation. All variables did, in fact, enter and remain in the equation. The following table lists the variables in the order in which they entered the equation (i.e., the first variable entering contributes most to explaining driver death and injury, the second variable entering can best explain driver death and injury given variable one as part of the equation, and so on).

Step	Variable entered
1	Driver's sobriety
2	Region of impact (rollover)
3	Region of impact (front end)
4	Population class
5	Time of day
6	Weight
7	Model year 1971-73
8	Model year 1969-70
9	Model year 1967-68
10	Road system (parkway and limited access)
11	Road system (thruway and Northway)
12	Region of impact (left-side impact)
13	Region of impact (right-side impact)
14	Road system (interstate)
15	Road system (State highways, country roads, and town roads)
16	Driver's sex
17	Driver's age

The basic equation indicates a reduction in death and serious injury of about 34 percent to the driver when 1971-73 cars are compared with 1964-65 cars.

Model year	Percent killed or seriously injured	Percent change from 1965-66
1965-66	20.85	-
1967-68	16.68	20.00
1969-70	14.68	29.59
1971-73	13.79	33.86

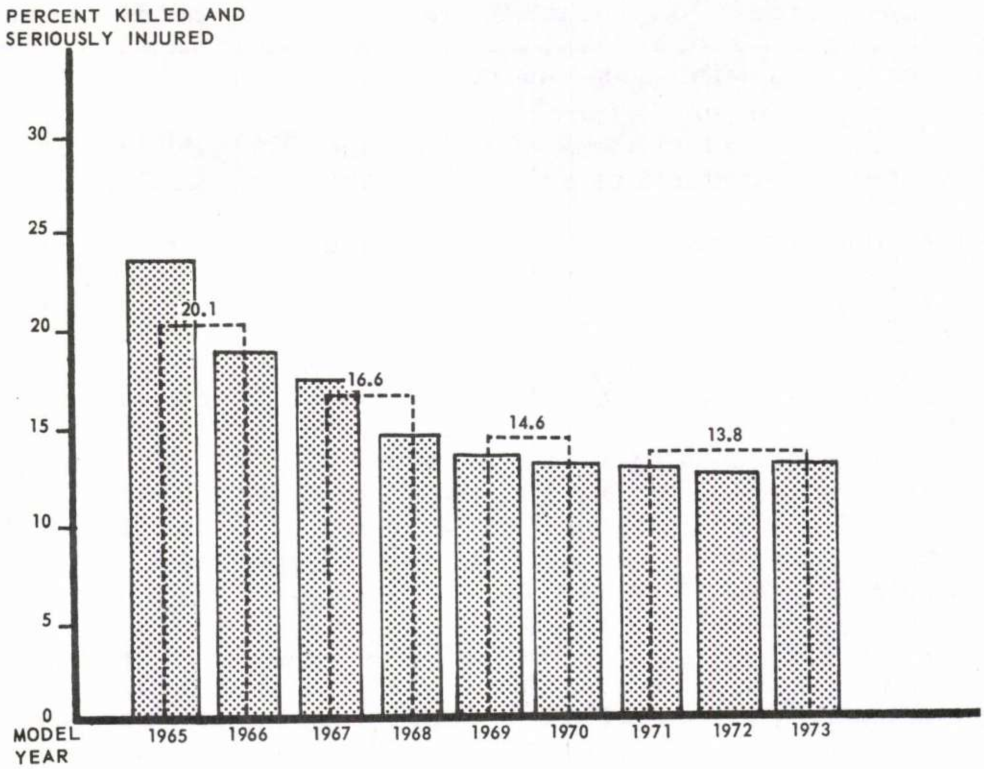
The coefficients of the basic equation were subjected to hypothesis testing to determine if a statistical difference between the coefficients exists. In other words, is the percentage reduction in death and serious injury between 1965-66 cars and 1967-68 cars statistically significant ? The difference between coefficients (or percentage change) and model years was found to be statistically significant. (See p. 76.)

The basic equation was tested for stability by eliminating key variables. The coefficients of the model-year variables remained relatively stable in every instance. The following table shows the model-year coefficients for each equation.

Equation (note a)	1967-68	1969-70	1971-73
Basic equation	-0.042	-0.062	-0.071
Eliminating time of day and sobriety	-0.046	-0.067	-0.076
Eliminating population and road system (for speed variable)	-0.040	-0.059	-0.069
Eliminating population and impact site (for speed variable)	-0.042	-0.063	-0.073

a/1965-66 was the dummy variable.

The following graph summarizes the analysis of single-vehicle accidents by presenting the percent of drivers killed and seriously injured within model-year categories (regression results) superimposed over the percent of drivers killed and seriously injured by model year (raw data).



Analysis X was similar to the previous one except that the data base contained 770,000 drivers in multiple-car accidents in New York State during calendar years 1971 to 1973.

The dummy stepwise regression resulted in the following variables entering the equation in the order listed.

Step	Variable entered
1	Driver's sobriety
2	Car weight squared
3	Population squared
4	Front impact
5	Left-side impact
6	Right-side impact
7	Time of day
8	Rollover
9	Road system (State highways and country and town roads)
10	Interstate highway
11	Model years 1969-70
12	Model years 1971-73

Step	
13	Model years 1967-68
14	Driver's sex
15	Road system--parkway and limited access roads
16	Road system--thruway and Northway

Following are the results as they related to vehicle model year.

Model year	Percent killed and seriously injured	Percent change from 1965-66
1965-66	3.90	-
1967-68	2.89	25.90
1969-70	2.75	29.49
1971-73 (note a)	2.79	28.46

a/No statistically significant change from prior period.

The model-year coefficients were tested for statistical differences among groups. No difference could be discerned between the 1969-70 group and the 1971-73 group. The model-year coefficients were also tested for stability by eliminating key variables from the equation. On the basis of results listed in the following table, the model-year coefficients appear to be relatively stable.

Equation (note a)	Model years		
	1967-68	1969-70	1971-73
Basic equation	-0.010	-0.012	-0.011
Eliminating sobriety and age	-0.010	-0.012	-0.012
Eliminating time of day, age, and sobriety	-0.011	-0.012	-0.012
Eliminating age and road system	-0.010	-0.011	-0.011
Eliminating age and impact site	-0.010	-0.012	-0.011

a/1965-66 was the dummy variable.

Analysis XI simply combined the results, on a weighted basis, of analyses IX and X to reflect the total model-year effect of the New York data.

The statistical significance for the New York analysis is as follows:

	Model-year changes	Significance
Multiple-vehicle accident	1967-68 vs. 1969-70	p = 0.12
	1969-70 vs. 1971-73	not significant
Single-vehicle accident	1967-68 vs. 1969-70	p = 0.002
	1969-70 vs. 1971-73	p = 0.100

Summary of Results

The figure below summarizes results from all the analyses. It shows safety improvement by model-year groups. For example, in analysis I there is an 18.7-percent reduction in the rate of drivers killed or seriously injured in accidents for 1967-69 models as compared with the prestandard pre-1967 models. The 1970-73 models provide a 24-percent reduction as compared to the pre-1967 models.

Summary of Results - Percent Reduction in Drivers Killed and Seriously Injured in Accidents--or Killed Only--by Model Year of Car (note a)

Model year

Analysis	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
I			18.7			24.0				
II		19.7		24.6		b/24.0				
III		16.9		25.0		24.9				
c/IV	15.3			26.9		b/27.5				
V		17.7		21.3		26.7				
VI		20.2						16.4		
VII		27.4						30.8		
VIII		28.8						b/30.7		
IX		20.0		29.6		33.9				
X		25.9		29.5		b/28.5				
XI		23.0		29.0		30.6				

a/Data is a comparison to prestandard rate.

b/No statistically significant change from prior period.

c/Base year is 1965 for analysis IV.

TABLE I

DATA FILES AND VARIABLES USED IN EFFECTIVENESS ANALYSIS

	North Carolina 1966-72 (note a)	North Carolina 1973-74	New York 1971-73
Driver injury	Killed Seriously injured Other Not injured	Same as 1966-72 file	Killed or seriously injured Other
Time of day	5:00 am to 4:59 pm 5:00 pm to 4:59 am	do.	Same as North Carolina
Road defects	None or not stated Defects	do.	(b)
Weather	Clear, cloudy, or not stated Other conditions	do.	(b)
Locality	Business, residential, or school area Open country	do. do.	(b)
Population class	(b)	do.	New York City Population over 50,000 Villages with populations to 50,000 Rural areas
Number of violations	None One More than one	do.	(b)
Accident type	Single-car accident Multiple-car accident	do.	Same as North Carolina
Region of impact	Front Right Left Rear Not stated/other	do.	do.
Approximate speed before accident	0 to 29 m.p.h. 30 to 59 m.p.h. Above 60 m.p.h.	do.	(b)

	North Carolina 1966-72 (note a)	North Carolina 1973-74	New York 1971-73
Driver's age	24 or under 25 to 54 55 or over	do.	24 or under 25 or over
Driver's sex	Male Female	do.	Same as North Carolina
Sobriety	Not drinking or not stated Drinking	do.	do.
Model year	1960-73 combined in various analyses	pre-1967 1967-70 1971-75	1965-66 1967-68 1971-73
Vehicle weight	0 to 2,500 lbs. 2,520 to 3,500 lbs. 3,520 to 6,000 lbs.	Same as 1966-72 file	1,000 to 2,499 lbs. 2,500 to 2,999 lbs. 3,000 to 3,499 lbs. 3,500 to 3,999 lbs. 4,000 to 5,749 lbs.
Seatbelt use	Lap and/or shoulder belts used Not used, not stated, no belts	do.	(b)
Vehicle damage rating scale	(b)	1 2 3 4 5, 6, and 7	(b)
Road system	(b)	(b)	State highway, county, and town roads Parkway and limited access Thruway and Northway interstate highways

a/1967 excluded.

b/Not available.

TABLE II

IMPORTANT ELEMENTS OF EFFECTIVENESS ANALYSES

Analysis	State	Cases	Dependent variable safety indicator	Variables used	Type of regression	Prestandard cars (note a)	Poststandard car grouping
I	N. Carolina	876,000	Driver killed or seriously injured	Speed, sobriety, type of accident, driver's sex, locality, weather, time of day	Categorical	Pre-1967	b/ 1967-69 c/ 1970-73
II	do.	788,000	do.	Same as I excluding data on drinking drivers	do.	pre-1967	b/ 1967-68 c/ 1969-70 d/ 1971-73
III	do.	514,000	do.	Weight, speed, driver age, impact area type	do.	pre-1967	b/ 1967-68 c/ 1969-70 d/ 1971-73
IV	do.	514,000	do.	do.	do.	pre-1966	b/ 1966-68 c/ 1969-70 d/ 1971-73
V	do.	514,000	Driver killed	do.	do.	pre-1967	b/ 1967-68 c/ 1969-70 d/ 1971-73
VI	do.	145,000	Driver killed or seriously injured	Type, vehicle damage rating, belt use, locality	do.	pre-1967	b/ 1967-70 c/ 1971-75
VII	do.	101,000	do.	Type, vehicle damage rating (3), weight, locality	do.	pre-1967	b/ 1967-70 c/ 1971-75

Analysis	State	Cases	Dependent variable safety indicator	Variables used	Type of regression	Prestandard cars (note a)	Poststandard car grouping
VIII	do.	102,000	do.	Type, vehicle damage rating (5), weight	do.	pre-1967	b/ 1967-70 c/ 1971-75
IX	New York	92,000	do.	(e)	Standard multiple stepwise	1965-66	b/ 1967-68 c/ 1969-70 d/ 1971-73
X	do.	770,000	do.	(f)	do.	1965-66	b/ 1967-68 c/ 1969-70 d/ 1971-73
XI	do.	862,000	do.	Combination of analyses	do.	1965-66	b/ 1967-68 c/ 1969-70 d/ 1971-73

a/Model-year group 1 for the analysis.

b/Model-year group 2 for the analysis.

c/Model-year group 3 for the analysis.

d/Model-year group 4 for the analysis.

e/See p. 72 .

f/See pp. 74 and 75 .

TABLE III

Categorical Regression Results by Analysis and Module

Analysis	Variable: Type (note a)	Speed (note b)	Sobriety (note c)	Model-year group 2 (note d): Change from base	Variance	Model-year group 3 (note d): Change from group 2	Variance	Model-year group 4 (note d): Change from group 3	Variance	R^2
I	Mu	L	S	0.00463	0.1849x10^{-6}	0	0			0.9854
	Mu	L	D	.01628	.1221x10^{-4}	0.00865	0.4669x10^{-5}			.8253
	Mu	M	S	.01347	.1149x10^{-5}	.00283	.8032x10^{-6}			.9764
	Mu	M	D	.03228	.2108x10^{-4}	.00536	.1882x10^{-5}			.9413
	Mu	H	S	.03909	.4401x10^{-4}	.02195	.5043x10^{-4}			.7178
	Mu	H	D	.02336	.1651x10^{-3}	.02634	.4294x10^{-5}			.9479
	Si	L	S	.02675	.3549x10^{-4}	.00703	.6637x10^{-5}			.9000
	Si	L	D	.00945	.3025x10^{-3}	.08401	.3308x10^{-3}			.9817
	Si	M	S	.04316	.6563x10^{-5}	.00516	.5228x10^{-5}			.9595
	Si	M	D	.04309	.3801x10^{-4}	.05000	.6413x10^{-4}			.8981
	Si	H	S	.03298	.4162x10^{-4}	.02242	.5762x10^{-4}			.8842
	Si	H	D	.04709	.5408x10^{-4}	0	0			.7707
Overall pre-1967 = .0767				.01431		.00409				
Standard error					.000529		.000428			
II	Mu	L		.00574	.1850x10^{-6}	.000988	.6428x10^{-7}	(-).000988	.6428x10^{-7}	.9819
	Mu	M		.01239	.1449X10^{-5}	.005325	.1817x10^{-5}	(-).004063	.7021x10^{-6}	.9678
	Mu	H		.03640	.3532x10^{-4}	.006956	.3006x10^{-3}	.000537	.1702x10^{-4}	.7951
	Si	L		.01450	.2943x10^{-4}	.01438	.4086x10^{-4}	.08541	.2892x10^{-3}	.9375
	Si	M		.04492	.6355x10^{-5}	0	0	0	0	.9589
	Si	H		.02290	.4962x10^{-4}	.02632	.3582x10^{-3}	.005889	.7843x10^{-5}	.8857
Overall pre-1967 = .0627				.01234		.003101		(-).00042		
Standard error					.00053		.00072		.000377	
								0		
III	Mu			.00666	.6062x10^{-6}	.00519	.5196x10^{-6}	(-).00054	.1354x10^{-9}	
	Si			.04123	.8494x10^{-5}	.00983	.7813x10^{-5}	0	0	
Overall pre-1967 = .0736				.0124		.00597		(-).000045		
Standard error					.00081		.00076		.000012	
IV	Mu			.005797	.7653x10^{-5}	.00746	.6299x10^{-5}	(-).00056	.1381x10^{-5}	
	Si			.039444	.4748x10^{-6}	.01444	.1082x10^{-5}	0	0	
Overall pre-1966 = .0745				.0114		.00863		h/.00047		
Standard error					.00074		.00096		.00097	
								.00028	.4826x10^{-8}	
V	Mu			.000529	.0190x10^{-6}	.000185	.1646x10^{-7}	0	0	
	Si			.00196	.1996x10^{-6}	0	0	.000233		
Overall pre-1967 = .0043				.000768		.000154	(note e)		.000058	
Standard error					.000137		.000107			

Categorical Regression Results by Analysis and Module

Analysis	Variable: Type (note a)	Variable: Speed (note b)	Variable: Sobriety (note c)	Model-year group 2 (note d): Change from base	Model-year group 2 (note d): Variance	Model-year group 3 (note d): Change from group 2	Model-year group 3 (note d): Variance	Model-year group 4 (note d): Change from group 3	Model-year group 4 (note d): Variance	R^2
VI	Mu			.00365	$.9178 \times 10^{-6}$	0	0			
	Si			.03527	$.1652 \times 10^{-4}$	(-).00944	$.0605 \times 10^{-4}$			
Overall pre-1967 = .0492				.00995		(-).00188	(note f)			
Standard error					.00112		.00049			
VII	Mu			.00622	$.0161 \times 10^{-4}$	.001944	$.00430 \times 10^{-4}$			
	Si			.04139	$.2637 \times 10^{-4}$	.00417	$.1524 \times 10^{-4}$			
Overall pre-1967 = .04766				.01304		.001648	(note g)			
Standard error					.00143		.000923			
VIII	Mu			.00698	$.1675 \times 10^{-5}$	.001488	$.5060 \times 10^{-6}$			
	Si			.04171	$.2600 \times 10^{-4}$	(-).001499	$.1448 \times 10^{-4}$			
Overall pre-1967 = .04764				.01372		h/0.0091				
Standard error					.001438		.00093			

a/Mu=multiple-car accidents
Si=Single-car accidents

b/L=low speed
M=medium speed
H=high speed

c/S=sober
D=drinking

d/See footnotes, p.80.

e/Significant at .08.

f/While the rate change is significant overall and negative, it was nonsignificant for all combinations except single vehicle with the highest (vehicle damage) rating.

g/Significant at .075.

h/Not significant.

REFERENCES

Clarke, S. and Koch, G G. "What Determines Whether Persons Arrested for Burglary and Larceny Go to Prison?" Unpublished technical report, 1974 -- submitted to Journal of Criminal Law and Criminology.

Grizzle, Starmer, and Koch. "Analysis of Categorical Data by Linear Models," Biometrics, 489-504, 1969.

Lahnen, Robert G. and Koch, Gary G. "A Comparison of Conventional and Categorical Regression Techniques in Political Analysis," The American Political Science Association, 1973.

Stewart, J. Richard "An Analysis of Automobile Accidents to Determine Which Variables Are Most Strongly Associated With Driver Injury," Highway Safety Research Center, University of North Carolina, Chapel Hill, December 1975.

Amortized Cost of Standards

Introduced in Model Year 1966

Model year to which applicable	Estimated sales		Unit cost	Total cost	Amortized at 10 percent a year 1966	1967	1968	1969	1970	1971	1972	1973	1974	Total
	(000 omitted)			(000 omitted)	(millions)									
1966	9,124	x	$22.20	$ 220,553	$20.3	$20.3	$20.3	$20.3	$ 20.3	$ 20.3	$ 20.3	$ 20.3	$ 20.3	$182.7
1967	8,535	x	22.20	189.477		18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	151.2
1968	9,271	x	22.20	205.816			20.6	20.6	20.6	20.6	20.6	20.6	20.6	144.2
1969	9,569	x	22.20	212,432				21.2	21.2	21.2	21.2	21.2	21.2	127.2
1970	9,195	x	22.20	204,129					20.4	20.4	20.4	20.4	20.4	102.0
1971	8,614	x	22.20	191,230						19.1	19.1	19.1	19.1	76.4
1972	10,530	x	22.20	233,766							23.4	23.4	23.4	70.2
1973	11,930	x	22.20	264,846								26.5	26.5	53.0
1974	9,520	x	22.20	211,344									21.3	21.3
Total	86,288			$1,915,593	$20.3	$39.2	$59.8	$81.0	$101.4	$120.5	$143.9	$170.4	$191.7	$928.2

APPENDIX III

APPENDIX IV

This appendix contains the response of the Assistant Secretary for Administration, Department of Transportation, to our report. Our comments are indented immediately after each question.

OFFICE OF THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

ASSISTANT SECRETARY
FOR ADMINISTRATION

May 5, 1976

Mr. Henry Eschwege
Director
Resources and Economic Development
Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Eschwege:

This is in response to your letter of March 23, 1976, requesting the Department's comments on the General Accounting Office's (GAO) draft report on the effectiveness and costs of Federal motor vehicle safety standards.

The GAO concluded that a creditable nationwide estimate of the effectiveness of motor vehicle safety standards cannot be made due to the present limitations of accident data. The National Highway Traffic Safety Administration (NHTSA) agrees in principle with the GAO findings regarding the present limitations of accident data, which precludes a creditable nationwide estimate of the effectiveness of motor vehicle safety standards. For this reason, NHTSA believes that the definitive conclusion by GAO that 1970 to 1973 models showed little, if any, additional improvement over prior year models needs to be more fully supported in the report.

NHTSA believes that before the report can be accepted as a contributing research document in the field of evaluation, considerable refinement will be required. To this end, our reply is being presented in the form of a page by page interrogatory on points of potential misinterpretation, confusion, or apparent contradiction which we believe should be answered prior to finalization of the report. This form of reply was discussed with GAO representatives who participated in the review, and they consider it an appropriate presentation.

I have enclosed two copies of the Department's reply.

Sincerely,

William S. Heffelfinger

Enclosure
(two copies)

DOT REPLY TO

GAO DRAFT REPORT TO THE COMMITTEE ON COMMERCE

UNITED STATES SENATE

ON

EFFECTIVENESS AND COSTS OF FEDERAL MOTOR VEHICLE SAFETY STANDARDS, CODE 34728

Summary of Survey Scope

During the period of August 1974 through November 1975, representatives of the General Accounting Office at the request of the Chairman of the Committee on Commerce, United States Senate, attempted to identify the probable factors responsible for changes in the annual accident trends to determine what impact safety standards have had in the aggregate, on reducing accidents, deaths, and injuries. Additionally, GAO was asked to provide evaluations of (1) cost of automobile safety during the same period, (2) overall benefit-cost, and (3) comparison of GAO results with other evaluations if available.

SUMMARY OF GAO FINDING

The General Accounting Office determined that a creditable nationwide estimate of the effectiveness of motor vehicle safety standards cannot be made due to the present limitations of accident data. (page 1) 1/

To conform with the limitations of the data available, GAO conducted three analyses in an attempt to (1) show the probable effectiveness of motor vehicle safety standards as a function of trends by model year, (2) develop total cost to the consumer for the motor vehicle safety program from 1966 through 1974 based on information provided by the manufacturers, and (3) compare the similarities and differences of various effectiveness studies undertaken by researchers on four specific standards. (pages 2, 3) 1/

The basic conclusions shown in the draft report, based on a model-year comparison (to pre-1966 models) of death rates and serious injuries suffered by drivers, are as follows:

- Drivers in 1966 cars were 7% safer
- Drivers in 1967-68 cars were 19-23% safer
- Drivers in 1969 cars were 25-29% safer
- Drivers in 1970-73 cars were not safer than 69 cars (page ii) 1/

GAO discussion of benefits and costs concludes that no change in benefits accrued for 1970-73 cars compared with 1966-69 cars, but with a $33 cost per 1970-73 car for safety equipment.

GAO could not estimate the additional benefits from a reduction in serious injuries. (page iii) 1/

GAO found intervening factors makes it virtually impossible to isolate any influence of crash avoidance standards. (page 10) 1/

GAO found that its estimates could not be compared with other evaluations reviewed. (page 51) 1/

1/GAO note: Page references refer to our draft report and may not correspond to this final report.

SUMMARY OF DOT POSITION

NHTSA welcomes the research contribution of the General Accounting Office in this controversial and basically unknown area of scientific evaluation. In its Report to the Committee on Commerce, United States Senate, "Need To Improve Benefit-Cost Analysis In Setting Motor Vehicle Safety Standards" (B164497(3)) dated July 22,1974, GAO clearly identified the deficiencies in currently available accident data as a base for scientific evaluation. GAO specifically concluded that "the Committee may wish to discuss with the Safety Administration the need to evaluate the data, data bases, and assumptions used in estimating accident costs. This evaluation should consider estimates made by and data available to other organizations to determine that all identified cost elements are considered, data bases are reasonable and assumptions and discounting rates are realistic."

The National Highway Traffic Safety Administration agrees in principle with the GAO findings regarding the present limitations of accident data, which precludes a creditable nationwide estimate of the effectiveness of motor vehicle safety standards. For this reason, NHTSA believes that the definitive conclusion by GAO that 1970 to 1973 models showed little if any further improvement over prior year models needs to be more fully supported by the materials presented in the draft report, so as not to be misleading or lending to misinterpretation.

Specifially, the NHTSA believes the GAO should reevaluate the data, data bases, and assumptions used in arriving at their conclusions to assure that all cost elements, data base limitations, assumptions, discount rates, etc., are clearly shown so as to afford an authoritative critique and revalidation of the findings by the research community.

POSITION STATEMENT

With respect to the specific analyses presented in the report and the conclusion that:

> "1966 cars were 7 percent safer;
> 1967 and 1968 models were from 19 to 23 percent safer;
> 1969 models were from 25 to 29 percent safer; and
> 1970-1973 models showed little if any further improvement;"

The questions that follow are based on a review of the evaluation analysis presented by GAO and the need for clarification on assumptions, possible oversights, and seeming contradictions which appear to have led to the conclusions.

TITLE OF REPORT

The GAO draft report is based on an analysis of passenger car accident data with respect to the Federal Motor Vehicle Standard promulgated to improve the crashworthiness of passenger cars. It does not address accident avoidance standards. Since "Crash Avoidance" standards are specifically excluded from the evaluation, the report should be retitled to clearly indicate that only "Crashworthiness" standards are being considered.

--The report title has been changed.

DIGEST

page ii (ii) 1/:

"The results are offered only as rough approximations."

Q. Do "results" refer to the estimates of safety improvement cited previously on the page?

--No. "Results" refers to the estimate of lives saved. The estimate is, however, based upon the previously cited estimates of safety improvement.

page ii (i and ii) 1/:

"Benefits derived in terms of occupant's lives saved by safer cars." (underscoring supplied)

"GAO compared death and injury rates for model years of cars"

"GAO estimates that in relation to the rates of death and serious injuries suffered by drivers..." (underscoring supplied)

Q. If benefits were derived in terms of occupant's lives saved, why are estimates presented in relation to deaths and serious injuries suffered by drivers?

--GAO studied deaths and serious injuries suffered by drivers and presented the results as improvement rates by model years. The data showed approximately the same trend for other occupants. Thus, to estimate benefits in terms of occupants' lives saved, we computed occupant improvement rates based upon driver improvement rates. The method used is discussed in chapter 4. (See pp. 31 and 32.)

Q. Did GAO "compare" death and injury rates by model year for "occupants," "drivers," or both?

--Death and injury rates related to drivers only and the wording was clarified.

1/Page numbers refer to the draft report. Numbers in parentheses refer to pages in this report.

page iii (ii) 1/:

Paragraph 1. "GAO could not estimate benefits from a definite reduction in serious injuries; and serious injuries are substantially greater in numbers than fatalities. In North Carolina, however, GAO found the standards were as effective in reducing serious injuries as saving lives." (underscoring supplied)

Q. "If GAO found the standards as effective in reducing serious injuries as saving lives," why couldn't the same estimating techniques be used for the benefits of reduction in injuries as was [sic] applied in estimating for lives saved?

--The technique for estimating lives saved is based upon the rather certain number of deaths reported each year in the Nation.

On the other hand, the numbers and degrees of injuries reported each year varies widely depending upon data source. Thus it is difficult to determine a national base upon which to make a reasonable estimate of injuries reduced or avoided. (See p. 29.)

page iii (iii) 1/:

"GAO also reviewed various research studies and benefit estimates for specific occupant protection standards. Although these studies generally analyzed accidents in great depth, they use small samples, usually must assume the effect of a single standard because of the interaction of other standards, and their conclusions are speculative."

Q. What relation do these other studies hold to the GAO effort? Are the "small" sample sizes more or less statistically valid than the two State samples used by GAO as representative of the 50 States and other participating jurisdictions?

--Studies of individual safety standards by others are not directly related to GAO's effort. They do, however, add a dimension to our study of the aggregate benefits of safety standards.

1/See footnote, p. 91.

The small sample sizes in chapter 5 are probably not as statistically valid as the larger number of accidents we analyzed in chapter 3. Nevertheless, we must reemphasize that our estimate of benefits is based on the "assumption" that North Carolina accident data is representative of the Nation. This is one of the primary reasons that we offered our results only as approximations (see pp. ii and 31.)

Q. Has the GAO made assumptions on the effect of "single standards" during the period 1970-1973?

--GAO did not make assumptions as to the effects of single standards during any period.

Q. Are the estimates of benefits, 1970-1973 to be considered other than speculation?

--Our estimate of little, if any, benefits for model years 1971-73 is not speculative. It is based upon our analyses of North Carolina and New York accident data in which most of the analyses showed no major improvement after 1970. (See p. 76)

INTRODUCTION (ch. 1)

page 2 (1) 1/:

"This approach does not deal with the frequency of accident occurrence."

Q. What are the potential ramifications of this fact on the results obtained?

--There should be little, if any, effect on our results. We are dealing with percent of drivers killed or seriously injured within the total universe of drivers involved in accidents for each model year. In any event, we have minimized any effects resulting from frequency of accident occurrence by controlling for such factors as speed, type of highway, etc.

1/See footnote, p. 91.

page 2 (2) 1/:

"...results are not necessarily representative of the Nation."

Q. What confidence limits are placed on the data by the researchers?

--Extensive statistical testing was done on both the North Carolina and New York data to assure that our results were statistically valid. Table III in appendix II (pp. 81 and 82) details results of the statistical testing performed on North Carolina data for the overall results. All changes between model years were significant at a probability level of less than or equal to 0.05 except for those so noted. That is, the probability that changes between model years are due to chance is less than or equal to 5 percent. Statistical tests were also performed on the New York data, and the probability levels are shown in appendix II, p. 76. Also for New York, several equation stability checks were made, and these stability checks are detailed in appendix II, pp. 73 and 75. In summary, the results are statistically valid for the States studied; however, these States may or may not be representative of the Nation.

page 2 (2) 1/:

"Second, an underlying assumption is that changes in the injury severity are primarily attributed to motor vehicle safety standards..."

Q. What adjustment is made for the impact of the Emergency Medical Services standard?

--No adjustment was made for any of the 18 highway safety standards, one of which is emergency medical services. These standards were excluded from our study because they are primarily directed

---

1/See footnote, p. 91.

to accident avoidance and their effects cannot be measured. (See p. 7.) If they had an effect, they would tend to somewhat lessen benefits derived from the crash survivability standards.

page 4 (3) 1/:

"We analyzed available accident data from North Carolina for 1966 and 1968 through 1974 and from New York for 1971 through 1973."

Q. Why was 1967 data excluded and what if any impact would this have on the outcome?

--Data for calendar year 1967 was not included because it was not available in machine-readable form. The text has been revised. In our statistical testing the variable "calendar year" did not have a significant effect on the seriousness of injury; hence, we are confident that lack of 1967 calendar year data did not affect model-year results.

page 4 (3) 1/:

"Analysis of North Carolina...was performed...by the Highway Safety Research Center...We analyzed the accident data from New York."

Q. To what extent were different analytical techniques employed by the different researchers?

--The different analytical techniques used are discussed on p. 16.

Q. What techniques were used to aggregate the results?

--Rather than using "aggregated" results, we have decided to use North Carolina analysis IV in our final report because it also uses 1965, which we consider to be the most appropriate base. (See p. 76.) As a result of this change, our estimate of 26,170 lives saved increased to 28,230.

1/See footnote, p. 91.

Q. What, if any, biases might have been introduced by these factors?

--None, since final results have not been aggregated. See our comments on page 103 concerning the effects of using different regression techniques.

TRENDS IN TRAFFIC ACCIDENTS AND FATALITIES AND IN AUTOMOBILE SAFETY IMPROVEMENTS (ch. 2)

page 5 (-) 1/:

"This reduction has been attributed primarily to the establishment of the 55 m.p.h."

Q. What percentage of the reduction is being attributed, and what are the sources of the data?

--The quoted sentence merely summarizes the detailed information shown later. We have clarified this sentence and moved it to the detailed section. (See p. 7.)

page 5a. (4) 1/:

Chart - Fatalities/100 MVM

Q. The trend line for the period 1970 to 1974 appears to be decreasing at other than a constant rate. How is this interpreted in relation to the estimate (page ii) of little if any further improvements for the period 1970-73?

--For several reasons, the trend should not be interpreted in relation to the estimate. The trend line is by calendar year and our estimates are by model year. Each is derived from different sets of data. The trend line is the result of many interrelated factors (driver, highway, automobile), some of which are discussed beginning on p. 5. Our estimate relates only to the automobile and those safety features designed to protect occupants in an accident.

page 6 (5) 1/:

1/See footnote, p. 91.

Q. Why are the years 1961, 66 and 73 considered to be key:

--The trend line on p. 4 shows that the fatality rate decreased until 1961 and began to increase until 1966 when the rate once again began to decline. The last year shown is 1973.

page 6 (-) 1/:

"In as much as this report is concerned with the safety standards for passenger cars only...."

Q. If the "key" figures include passenger cars, trucks, buses and motorcycles and the safety standards cover the same universe, why are fatalities and serious injuries averted in other than passenger cars not considered?

--There are many reasons why we chose only to consider passenger cars in our analyses. Some of them follow.

Passenger cars represent the largest single group of motor vehicles and thus affect the most people in terms of fatalities and injures. According to the NSC, passenger cars were involved in 70 percent of fatal accidents and 82 percent of all accidents in 1974.

Crash survivability safety standards in effect through model year 1973 apply universally to passenger cars but not to the other types of motor vehicles.

Q. If the effects of the standards on the frequency and severity of accidents in other vehicles is not a part of the GAO report, what adjustments were made in arriving at the estimated benefits, and how were the adjustments made?

--No adjustments were necessary because estimated benefits are based solely on accident data of passenger cars, as explained in chapter 3.

1/See footnote, p. 91.

page 7 (5) 1/:

"Some causes of reduced accident and fatality rates."

Q. What percentage of the reduction is attributed by the researchers to these "causal factors" and how were these conclusions reached? Note: No qualification is made as is found on page nine (9) for Highway Improvement and Highway Safety standards.

--We know of no way to attribute a percent reduction in fatality rates to these "causal factors," nor was there any intent on our part to do so. The entire theme of chapter 2, as explained in the second paragraph on p. 4, was to summarize "The trend in accidents from 1961 to 1974, some of the public efforts and other factors which reduced accidents and their human cost, and developments in automobile safety***."

page 9 (7) 1/:

"The safety features of motor vehicles are of two main types: those designed to enable drivers to avoid accidents; and those to protect the occupants in the event of accidents. The former type include improved braking, steering, lights, driver visibility and the like. At present there is no reliable measure by which reductions in accidents can be related to developments in crash avoidance designs."

Q. To what extent did the researchers attempt to isolate the effect of crash avoidance standards on the "causes" of reduced accident and fatality rates (1966-present)? (p. 7.)

--None was necessary since our analyses were based on accidents that had occurred. See our answer to the previous question and our sentence on p. 7 which states, "The interaction of efforts under the Highway Safety Act and the construction of safer highways during the same time frame make it virtually impossible to isolate any influence of crash avoidance standards on the downward trend of the accident mileage rate since 1966."

1/See footnote, p. 91.

Q. What effect if any do these factors have on the results attributed by the researchers to the "crash survivability" standards?

--These factors would have little, if any, measurable effect on our results. Crash avoidance standards are intended to eliminate accidents or reduce their severity. If they did have an effect it would be to somewhat lessen the benefits derived from crash survivability standards. This is the reason we compensated for the effects of factors such as speed, alcohol use, and weight of car in our regression analyses reported in chapter 3 (see p. 15).

Q. Could the conspicuous absence of qualification on "causes" (page 7) be misconstrued as a research bias in favor of explanations supporting the GAO effectiveness estimates?

--No. See our answers to preceding questions.

page 10 (7) 1/:

"Because the effect of crash avoidance standards cannot be measured, our study is limited to the effectiveness of occupant protection standards in reducing injuries and deaths when accidents occur."

Q. Since the GAO " estimates" of effectiveness are given as a function of a forecasted "lives saved", why wouldn't a parallel forecast of accidents avoided based on the reduction of the accident mileage rate since 1966 be at least equally valid?

--For several reasons, the suggested parallel forecast of accidents avoided would not be as valid as our estimate of "lives saved." Accident data generally is subject to a wide margin of error (see p. 7) whereas our estimates are based on accurately reported fatalities and the regression analyses discussed in chapter 3. It would be virtually impossible to separately identify the number of accidents avoided as a result of automobile safety improvements from those accidents

---

1/See footnote, p. 91.

avoided due to other causes. (See p. 7.) Also, estimated accidents avoided would be based upon calendar year results which would not relate to automobile model years.

page 10 (-) 1/:

"...the 55 mile per hour speed limit accounted for about one-fourth to 50 percent of the reduced fatalities." (underscoring supplied).

Q. Does this statement contradict the statement on page 5, i.e., attributed primarily (underscoring supplied) to the 55 mph speed limit?

--No, but to avoid apparent confusion, the statement on page 5 has been clarified and incorporated in the detailed section on page 7.

page 11 (7) 1/:

Fatal Accident Relationship 1961-74 "Accident data generally is subject to a wide margin of error, and nationwide projections from even a large sample are likely to have a wide margin of error." (underscoring supplied).

Q. Is the 26,000 lives saved as shown in the Digest (ii) based on this table?

--No. Our estimate of lives saved is based upon the data and procedures set forth in chapter 4.

Q. If so, what confidence is placed on the figure, given the "wide margin of error," and what is the impact of this on the effectiveness estimates for the 1970-73 period?

--See our answer to the previous question.

page 16 (11) 1/:

Crash survivability standards and amendments issued after 1967.

Q. As FMVSS 212 for windshield mountings is the only standard within the scope of this study to come effective during the period January 1970-January 1973, what "further

---

1/See footnote, p. 91.

improvement" in "Crash Survivability" might have been expected?

--This question is not accurately stated. On page 16 of our draft report we identify three additonal standards or amendments which became effective during the period in question--FMVSS 208, 214, and 302. (See p. 11.) Our study disclosed little, if any, improvement in crash survivability in the 1971 to 1973 model-year cars.

EFFECTIVENESS OF THE CRASH SURVIVABILITY STANDARDS (ch. 3)

page 18 (12) 1/:

"Our analysis of accidents was limited to the fate of the drivers...."

Q. Page 16 describes the FMVSS 202 as requiring head restraints for the outboard front seating position. How can an analysis limited to drivers only purport in any way to measure the effectiveness of a standard designed to protect both outboard front seating position occupants?

--Several points should be remembered about the analyses. Our analyses were limited to the fate of drivers in accidents because the number of uninjured occupants involved in an accident is often not reported or is misstated. (See p. 12.) Also, we do not purport to measure the effectiveness of individual standards, but deal with all crash survivability standards in each model year. Finally, we explain in chapter 4 our method of extending the data on drivers only to the other occupants. (See pp. 31 and 32.)

page 19 (13) 1/:

Analysis of Raw Data.

Q. Were the same techniques applied to the North Carolina and New York data bases?

1/See footnote, p. 91.

--The same technique--simple cross-tabulation--was used to analyze raw data in each of the data bases.

Q. What were the specific changes in North Carolina reporting, and how might this impact the results obtained?

--The most important changes in North Carolina reporting after 1972 were (1) adding a vehicle damage index, (2) adding information on use of restraint systems, and (3) a change in definition of injury levels. The first two changes have no effects. The third change has an absolute effect on the proportion of serious injuries in the file, but no effect on the relative proportion by model year on which our results are based.

page 21 (-) 1/:

"Fluctuations in the data for recent model years i.e., 1971 to 1973, we believe are due more to abnormalities in the data than to changes in safety."

Q. What is the basis for this "belief?"

--The primary basis is the small number of accidents in later model years. We have clarified our statement in the report. (See p. 14.)

Q. Assuming the changes were "in safety," what impact would result on the estimates?

--None. Our estimates are based on 1973-74 raw data which did not fluctuate or the adjusted data where the regression procedures and grouping of model years were correct for nonsafety factors in the data.

page 22 (15) 1/:

"We adjusted to the raw data to compensate for factors which may possibly distort the model-year results."

1/See footnote, p. 91.

"Unless the proportions of such accidents and other severity factors are equalized for all model years the relative safety of each model year of cars cannot be demonstrated" (underscoring supplied)

"The variables considered for use in the regression analyses depended on what variables were available in the States' accident files..." "Some of them were eventually eliminated by statistical tests and further analysis."

Q. Which elements shown on the table (page 23 (16) 1/) were finally retained?

--All variables except calendar year, road defects, and number of violations were used, but not in every analysis. Variables used in each of the eleven analyses are shown on pages 79 and 80.

page 23 (16) 1/:

"The analyses of North Carolina data were performed under contract by the Highway Safety Research Center of the University of North Carolina using categorical regression procedures. The GAO staff performed the analyses of the New York accident data using multiple step-wise regression procedures. (See appendix II for discussion of these specific procedures.)"

Q. Given the absolute criticality stated on page 22 for analyzing the factors why were different techniques used on the different data bases?

--The categorical regression technique was applied in North Carolina because its use was recommended by the contractor and agreed to by our consultants. We used the standard regression technique on New York data because it could best be applied by our staff. Both techniques produce valid results, and while using both techniques in both States would have added confidence to the results, it was not necessary. Additional time and cost precluded us from applying the different techniques to opposite data bases. Furthermore, we believe the use of different techniques did not greatly affect our results.

1/See footnote, p. 91.

Q. What are the specific effects of each technique, with specific emphasis on differences considered in the merging of the separate results?

--As previously explained, the results have not been merged in the final report. (See p. 95.) While different statistical techniques were used to analyze the North Carolina and New York data bases, we believe that the techniques do not bias the results. GAO consultants expressed no concern over the use of two different statistical techniques. Additionally, in an empirical study (Lehnen, Robert G., and Koch, Gary G. "A Comparison of Conventional and Categorical Regression Techniques in Politicial Analysis," The American Political Science Association, 1973) both regression techniques were applied to the same set of data and results were nearly identical.

page 23 (16) 1/:

"One special factor we investigated was vehicle age. The issue is whether old model cars are less safe because of their lack of safety features or just because of their age. The vehicle age might affect how well safety features operate, the frequency and accuracy of accident reporting and the type of accidents in which the cars are involved. A special analysis of the age effect was made with North Carolina data and no significant effects due to aging were noted."

Q. To the extent that vehicle age might affect the frequency and accuracy of accident reporting and the type of accidents in which the cars are involved, thus needing to be factored out, so too, the age of the driver in relation to the age of the vehicle would also appear equally critical--what equalization or special analysis was made on this factor?

--Driver age was a variable used in analyses III, IV, V, and IX. (See pp. 72 and 79.) Since vehicle age was previously shown to be not significant, we did not examine the interaction of both vehicle and driver age as they affect injury severity.

1/See footnote, p. 91.

page 26 (17) 1/

"To compare the results of the analyses, a safety index was developed using the rate of survivability in prestandard models as the base. The base year selected could greatly influence the results. It is difficult to know which one to use because of the evolutionary way in which safety features were implemented since the early 1960s as discussed in chapter 2. In some of our analyses we considered prestandard cars to be those of model year 1965 and earlier, while in others we included 1966 models among those considered "prestandard."

Q. Given the criticality of the base year, why was the base year changed?

--In most of our analyses we considered prestandard cars to be the average of model years 1966 and earlier. As our work progressed and we learned more of the history of safety standards development, we decided that 1966 should be excluded. This was based primarily on the fact that American manufacturers incorporated most of the GSA standards in all 1966 models produced (see p. 9). For this reason, we used 1965 and earlier as the prestandard model for analysis IV. This has been clarified in the text.

Q. Does selection of a given base year, plus or minus, favor or bias the relative percent change in safety estimates for the later years?

--Selection of a given base year would determine the percent change in safety but numbers obtained for the later years (1971-73) would still show little or no improvement over the prior years (1969-70). However by using the average of model years during the base year and earlier, the chance of obtaining a large bias one way or the other is minimized. We used 1965 as our prestandard model because we considered 1965 to be the most appropriate base period.

1/See footnote, p. 91.

page 28, 29 and 30 (19, 22, and 23) 1/:

Charts-Model Year and Speed, Drinking

Q. How do the reductions shown for these "key" factors in model years 1970 to 1973 correspond with the statement on page ii, i.e., 1970 to 1973 models showed little or no improvement?

--The reductions in each category of speeding and drinking are based only on analysis I which showed improvement in the later model years. On the other hand, our statement on p. ii is based on all eleven analyses. The text of our report has been clarified. (See p. 19.)

ESTIMATED COSTS AND BENEFITS OF THE CRASH SURVIVABILITY SAFETY STANDARDS (ch. 4)

page 33 (24) 1/:

"Measured by our estimates of lives saved alone, cumulative effect of safety improvements introduced through the 1969 model-year car appear to be cost beneficial. Additional benefits from a reduction in injuries, although not measurable, would add confidence to this conclusion."

"The analyses described in the prior chapter show that by the 1969 model year of cars, the rate of death or serious injury for drivers in accidents was reduced by about 25 percent to 30 percent compared to the average for all model-year cars of 1965 and prior. We estimate that about 26,000 lives may have been saved from 1966 through 1974 because of these safety features. At all but the lowest valuation of the cost of a death to society, our estimates of these benefits exceed the cost of the safety standards."

"The cumulative unit costs of additional crash survivability standards (excluding bumper standard) required in model-year cars of 1970 through 1973 was about $33 or a total of about $950 million for these additional features on all cars sold through 1974. Most of the analyses of accidents in North Carolina and New York showed no significant additional change in the rate of driver deaths and injuries for these model years of cars, compared to the

---

1/See footnote, p. 91.

1966-69 years. We conclude therefore, that these model years offer the same protection as their immediate predecessors, but yielded no significant additional protection from death or serious injury for the additional $33 of safety requirements."

Q. What data provides the basis for this conclusion without qualification given the apparent contradiction on page 12 which emphasizes the "wide margin of error" leading to the projected 26,000 lives saved?

--As previously explained, our estimate of lives saved was not based on the data on p. 12 (8) 1/ but on the North Carolina data and procedures set forth in chapter 4.

page 35 (26) 1/:

Estimated Average Cost Per Car

page 36 (25) 1/:

"The estimates represented the incremental cost in a model year of introducing a new standard or modifying an existing standard to comply with an amended standard."

Q. In that no change in cost per car for FMVSS is shown in consecutive model years on 7 of 9 lines in the table, is it to be concluded that the effects of inflation materials cost etc., have been exactly offset by productivity gains or other factors?

--To arrive at such a conclusion is not correct. We chose not to consider the kinds of factors mentioned because we could not possibly anticipate all that should be considered or determine how to measure their effects--e.g., choice of a discount rate. More importantly, our consideration of such factors would have implied a degree of preciseness to our methods and estimates which we do not wish to convey.

It was for this reason that we chose not to adjust the three estimates of society's cost of a fatality and an injury when computing total benefits.

1/See footnote, p. 91.

page 39 (29) 1/:

A North Carolina Automobile

"Our first approach was to estimate the benefits and costs that occur over the useful life of different model year cars in North Carolina. The benefits of fatalities and injuries prevented are the product of (1) the number of fatalities and injuries prevented per accident, (2) the number of accidents a car is expected to be involved in over its life and (3) the societal cost of a fatality or injury."

page 40 (29) 1/:

"The number of fatalities and injuries prevented were calculated from the North Carolina raw data 1973-74 on page 21. This was done by subtracting the number of fatalities or injuries for the model year after 1965 from the average number of fatalities or injuries that occurred in 1965 and prior cars. The pre-standard rates used (weighted averages based on number of cases) were .45 percent for fatalities and 19.5 percent for injuries."

page 40 (29) 1/:

"We assumed that a car will be in one reportable accident based on discussions with auto safety experts. The number of accidents experienced by the average car is critical to the analysis, because the benefits vary in direct proportion to it. This number will vary widely among States depending on the driving environment and the States' criteria and method of reporting accidents. Also, as the chances of being in an accident are reduced through highway safety standards or other means the benefits of crash survivability standards are also reduced." (underscoring supplied).

Q. The assumption that a North Carolina car will be in one reportable accident over its life is in serious conflict with national data provided on page 5 indicating one in four motor vehicles is involved in an accident each year. The national data, supported in the 1974 Edition of Accident Facts, would suggest 2.5 reportable accidents rather than 1 assumed. What impact if any does the national data imply on the cost-benefit estimates shown in the report?

1/See footnote, p. 91.

--The national data would imply that benefits in our report are understated. Such an implication is not valid because national data is subject to a wide margin of error (see p. 7). The estimated number of accidents, for example, is based on summary data from fewer than 20 States. We have already pointed out (p. 29) that the number of accidents will vary widely among States depending on driving environment and their criteria and methods of reporting accidents. It is interesting to note that a later edition (1975) of <u>Accident Facts</u> suggests only 1.96 reportable passenger car accidents in 1974.

On the other hand, our use of one reportable accident in North Carolina is based on actual accident reports of that State and on our discussion with auto safety experts. This has been clarified in the report. (See p. 29.)

Q. What impact does the wide variation of North Carolina data to the national data on this critical factor have on the credibility of using North Carolina data on the other estimates, particularly the effectiveness of the 1970-73 period?

--See response to previous question. As shown on pp. 12 and 13 the North Carolina and New York accident experiences do not vary widely from the U.S. experience. In addition, the 11 regression analyses deal with relative rather than absolute numbers and therefore the leveling off of the 1971-73 models would not be changed.

<u>page 41 (30)</u> <u>1</u>/:

"These computations are based only on driver fatalities and injuries prevented per accident. Total fatalities and injuries prevented for all occupants may produce higher benefit-cost ratios. It is also important to note the importance of injuries to the benefit-cost ratios. Reduced injuries account for about 36 percent of the benefits when RECAT values are used, 52 percent when Safety Administration values are used, and 64 percent when NSC values are used."

<u>1</u>/See footnote, p. 91.

Q. Given that only driver fatalities and injuries were used, what is the total potential gross margin of error in the cost-benefit figures if all occupant fatalities and injuries were used, computed on the RECAT, NHTSA and NSC values?

> --We do not know the answer to this question. If we made the same assumption here that we did for our nationwide estimates (p. 31) the benefits would increase by 27 percent.

page 41-42 (30-32) 1/:

NATIONWIDE ESTIMATES

"Because of the problems in estimating injury reduction on a nationwide basis, as discussed earlier, this section deals only with benefits of fatality reduction. In the previous analysis we considered only safety benefits to the driver, but in this section we have included benefits to other occupants."

"For applying a measure of safety improvements nationwide, the North Carolina results are probably more appropriate than the New York results. Considerably more analysis of various conditions affecting severity of accidents was possible, and all model years of cars were identified in the North Carolina accidents back to those of 1960 and prior. The New York accident reports lacked a few significant elements of information, such as the identification of model years earlier than 1965 cars. We have proceeded with North Carolina rates of improvement, therefore, as having a somewhat higher confidence factor and being more conservative."

"On the basis of the North Carolina analyses described in the prior chapter we have used the following percent reductions for drivers killed or seriously injured in accidents by model-year groups, with 1965 and prior as the base."

Percent Reduction in Drivers Killed or Seriously Injured

(model-year groups)

1965 & Prior	1966	1967-68	1969-70	1971-73
0	7	19	25	25

1/See footnote, p. 91.

Q. To what extent would the suspected critical difference in the North Carolina data over national data be carried forward to this analysis, as the researcher's report having more confidence in North Carolina data?

--As previously explained, our use of relative percents and reported fatalities precludes any "suspected critical difference" from being carried forward to our analysis.

Q. To what extent does the choice of 1965 as the base favor the relative percentage change over periods show?

--We chose 1965 as the most appropriate base period because of the many safety features incorporated in the 1966 model-year cars. This choice was dictated by our desire to do the best possible analysis and not to predetermine the results. In our opinion the use of 1965 as the base period neither "favors" nor "prejudices" the results.

page 42 (31 and 32) 1/:

"In as much as the basic analyses pertain to drivers only, the question arises as to whether or not the improvements in drivers' safety are equally applicable to other occupants. Of all passenger car occupants killed in accidents, about 65 percent have been drivers and 35 percent other occupants. The fatalities and serious injuries combined for other occupants in the data base show approximately the same trend as the drivers' fate by model year. Accordingly, we believe that a reasonable assumption for benefit analysis is to consider that improvements in passenger safety are only one-half that attained for drivers."

"Thus, a composite occupant percentage would be derived from the formula--driver improvement percentage X 65 percent plus 50 percent of driver improvement X 35 percent."

Q. How was the assumption of a one-half benefit and subsequent formula derived from the 65% drivers 35% other occupants killed?

1/See footnote, p. 91.

--Assumption of a one-half benefit for other occupants was a judgmental estimate based upon the data we were analyzing. The 65-percent driver and 35-percent occupant formula was taken from a Safety Administration Staff Report.

Q. To what extent could a logical or mathematical error at this point affect the subsequent analyses?

--We have reexamined our logic and mathematics and have found no errors. Had our logic dictated we give equal benefits to both drivers and occupants our estimate of lives saved would have increased by 6,390 (28,230 to 34,620) and the most favorable benefit-cost ratio would have increased by .4/1 (1.9/1 to 2.3/1).

page 45 (33) 1/:

"The relative safety indices calculated by this procedure carry the assumption that all model years of cars are exposed to accidents in proportion to the number on the road, regardless of the age of cars. The procedure tends, therefore, to understate the effect of the safety improvements in reducing fatalities over the time period, and again introduces a more conservative element in the estimate of benefits."

"One method of estimating lives saved by the use of these indices would be to apply them to the annual fatalities calculated at the average rate of fatalities per 100 accidents for the high-rate years 1961-66. These calculations are shown in the table on page 12. This method, however, has several problems affecting the reliability of the results. One is that it makes no allowance for the relative severity of accidents from year to year. An obvious illustration of that factor is in 1974, when the reduced speed limit considerably lowered the severity of impacts for all model cars involved in accidents. Another problem of the method is that it is highly dependent on estimates of how many cars were involved in accidents each year, which are subject to more error than are estimates of passenger car fatalities."

page 46 (33 and 34) 1/:

1/See footnote, p. 91.

"In our opinion, a better approximation of how many passenger car fatalities might have occurred from 1966 to 1974, if safety improvements had not been introduced, can be derived by starting with the National Safety Council's estimates of passenger car occupant fatalities. Dividing the annual fatalities by the annual safety indices from the table above provides an estimate of possible deaths without the safety improvements. The differnce between how many might have been killed and the estimates of actual fatalities represents an approximation of lives saved by the introduction of safety improvements from the 1966 to 1969 models."

Q. Is there a logical inconsistency in applying the "safety indices" which were developed from the North Carolina data (p. 45) to National Safety Council data on the basis that the procedure used to develop the indices was unreliable?

--We do not believe the procedure used to develop the safety indices was unreliable or that the indices were illogically applied to national data on numbers of fatalities because the safety indices are essentially independent of accident frequency. (See p. 93.) It would, however, be illogical to apply the safety indices to national data on numbers of accidents since we believe such data is unreliable. (See p. 33.)

Q. Is it mere coincidence that the unreliable estimate (p. 12) of 26,130 corresponds almost exactly with the preferred estimate of 26,126 (p. 46) based on the safety indices and the NSC data?

--Yes, it was mere coincidence. The estimate on page 12 (now p. 8) corresponds in the final report to our revised estimate of 28,230 lives saved.

page 48 (35) 1/:

BENEFIT-COST COMPARISONS

"On the basis of the three estimates of the cost of a traffic fatality to society, the estimated lives saved through 1974 by safety improvements introduced in the 1966-69 models would be valued as follows:

1/See footnote, p. 91.

Estimated lives saved	26,170
Value at:	
$ 52,000	$1,360.8 million
140,000	$3,663.8 million
$200,700	$5,252.3 million

The estimated amortized costs of the 1966-69 standards in all 1966 and later models over the same period are about $2,959 million (see page 38). Thus, the estimated benefit-cost ratios are:

at $ 52,000: $\frac{\$1,360.8}{\$2,959.1}$ = .5/1

at $140,000: $\frac{\$3,663.8}{\$2,959.1}$ = 1.2/1

at $200,700: $\frac{\$5,252.3}{\$2,595.1}$ = 1.8/1

"Inasmuch as the benefit-cost ratio is more than 1/1 of the medium estimate of life value, as well as for the Safety Administration's higher value, the costs of safety standards introduced in those years (1966-69) appear to be beneficial. Additional benefits from a definite reduction in serious injuries, although not measurable on a national basis, adds confidence to that conclusion."

Q. Is this analysis dependent upon the validity of the safety indices i.e., 26,170 lives saved?

--Yes, although our revised estimate is 28,230 lives saved. (See p. 34.)

page 49 (-) 1/:

"With respect to the cost of complying with standards introduced in the 1970-73 models, no benefits are attributed to reduced deaths or serious injuries."

Q. What in the chapter or elsewhere in the study purports to support this lone sentence?

--Most of our 11 analyses showed no major improvements in the 1971-73 model-year cars. (See p. 19.) Thus there were

---

1/See footnote, p. 91.

little, if any, benefits, in terms of reduced deaths and serious injuries, which could be attributed to the standards introduced in those models. The cost of the standards exceeded $800 million without corresponding benefits.

page 49 (-) 1/:

Cost-benefits in 1974 accident conditions.

Q. How does the speculative review of 1974 conditions without data, based upon a series of unreconstructable events add to the analysis of actual cost-benefits?

--We agree that this segment of the report does not add to the benefit-cost analyses and it has been deleted.

EFFECTIVENESS AND SAFETY BENEFITS OF INDIVIDUAL STANDARDS (ch. 5)

page 52 (37 and 38) 1/:

"The studies usually show a consensus opinion as to the effectiveness of a safety device and the range of agreement or disagreement. They do not, however, enable anyone to quantify safety benefits." "Estimated annual safety benefits can, however, be valued with the benefit measurement data of the National Safety Council, the RECAT Committee, and the Safety Administration and compared with the annual amortized cost of equipping all cars on the road in 1974 with the safety device. The following benefit-cost ratios are then obtained." (underscoring supplied)

Q. If the studies do "not enable anyone to quantify safety benefits," why have the researchers done so anyway?

--We have not quantitied safety benefits and have revised the body of our report to clarify the matter. (See p. 38.)

page 52 (38) 1/:

"They are estimates of annual safety benefits, based on the assumption that all cars on the road were equipped with the safety device, and are not comparable to the

1/See footnote, p. 91.

aggregate estimates of lives saved, which we discussed in the previous chapters of this report."

page 53 (-) 1/:

"In as much as the benefit-cost ratio is predominately less than 1/1 for head restraints and side door strength, it would seem they are marginally cost beneficial at best. This is not inconsistent with our findings in chapter 3 since these improvements came in model year 1969 or later. Conversely, the steering columns and seatbelts are apparently cost beneficial. Again, this is consistent with our findings in chapter 3 since these improvements had been installed in 1968 and earlier year models."

Q. If these study estimates are not comparable with those of previous chapters, why do the researchers cite them as supportive?

--We agree and have deleted the paragraph in question.

page 63 (-) 1/:

"Only O'Neill reports that their conclusions were statistically significant. Generally, the other study results were not statistically reliable because the difference between the frequency of injuries in vehicles equipped with head restraints was not significant in relation to the size of the sample investigated.

"These comments are generally applicable to the other safety devices discussed in this chapter and are not reported later."

Q. If as stated, only O'Neill reported statistical significance and "the other study results were not statistically reliable", what inference should be drawn as to the cited consistency between the GAO results and these not statistically reliable results?

--The text has been clarified to reflect the statistical uncertainty of results for these studies. (See p. 46.) We did not intend to imply that research findings were improper.

1/See footnote, p. 91.

page 82 (-) 1/:

"the probability of occurrence--"

Q. Probability of occurrence of what?

--Probability of occurrence as used in our report refers to the probability of the driver and right front passenger being killed in a frontal impact. The report has been clarified. (See p. 59.)

page 96 (72) 1/:

"The "R^2" was not computed for Analyses III through VIII due to acceptance of a hypothesis that the sum of squares due to error is small."

Q. What is the statistical meaning or relevance of this statement?

--We have clarified this technical statement in the report. (See p. 72.)

page 85 (65) 1/:

Appendix I

Q. If the report restricts itself to crash survivability standards, why are crash avoidance standards shown?

--The report directs itself to crash survivability standards, but accident avoidance standards are not ignored. They are discussed in chs. 2 and 4.

page 87 (68) 1/:

Appendix II

Q. Is the New York data not categorical?

--Some of the New York variables could have been treated as continuous variables (e.g., vehicle weight, population, driver age).

1/See footnote, p. 91.

Q. Why was it necessary to use two different techniques?

--It was not necessary to use two different techniques. Our reasons for doing so are stated on p. 103

page 88 (77 and 78) 1/:

Table 1

Q. Does the fact that the New York data corresponds to the North Carolina data in only 5 of the 18 variables used have any impact on the degree of reliability which can be placed on aggregated estimates?

--We do not aggregate our 11 regression analyses so there is no effect to consider. It is important to note that the New York data does closely approximate the North Carolina data for those variables of greatest importance.

pages 93 and 94 (79 and 80) 1/:

Table II - Significant Elements of Effectiveness Analyses.

Q. What cross-reference checks were made on the outcomes of the analysis in that I-VIII were conducted only on North Carolina data and used categorical regression (pages 95-97) while analysis IX-XI were conducted only on New York data using a different regression technique (pages 100-103)?

--We agree that additional cross-reference checks may add some confidence to our conclusions. However, in our opinion the overwhelming evidence developed on the program's effectiveness justify the conclusions.

1/See footnote, p. 91.

Copies of GAO reports are available to the general public at a cost of $1.00 a copy. There is no charge for reports furnished to Members of Congress and congressional committee staff members. Officials of Federal, State, and local governments may receive up to 10 copies free of charge. Members of the press; college libraries, faculty members, and students; non-profit organizations; and representatives of foreign governments may receive up to 2 copies free of charge. Requests for larger quantities should be accompanied by payment.

Requesters entitled to reports without charge should address their requests to:

U.S. General Accounting Office
Distribution Section, Room 4522
441 G Street, NW.
Washington, D.C. 20548

Requesters who are required to pay for reports should send their requests with checks or money orders to:

U.S. General Accounting Office
Distribution Section
P.O. Box 1020
Washington, D.C. 20013

Checks or money orders should be made payable to the U.S. General Accounting Office. Stamps or Superintendent of Documents coupons will not be accepted. Please do not send cash.

To expedite filling your order, use the report number in the lower left corner and the date in the lower right corner of the front cover.

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE,$300

POSTAGE AND FEES PAID
U. S. GENERAL ACCOUNTING OFFICE

U.S.MAIL

THIRD CLASS