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NHTSA TECHNICAL REPORT

DOT HS-805 866

EVALUATION OF THE BUMPER STANDARD

APRIL 1981

Prepared by:

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Plans & Programs
Office of Program Evaluation

NHTSA Technical Report
DOT-HS-805-866

ERRATA

Page	Change
3-2	Add to the first paragraph of Section 1.2.2 the word "damage".
3-34	After the text and before footnote 18, add the following:

3.1.6 Sample Size and Survey Assumptions

The first question to be answered in determining sample size is what will the data be used for. Basically, the survey data will be used to detect any difference in

3-42	Delete list of manufacturers and list of bumper type which are duplicated on page 3-43
6-26	Change "G" to "g" for the 1979 price of gas (third item)
" "	Change 1980 to 1988 on next to last line of page.

Technical Report Documentation Page

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16. Abstract The objectives of the bumper standards are to reduce damage and provide cost savings to consumers, and to protect safety-related parts. The evaluation, presented in this report, includes: (1) determining the effectiveness of the bumper standard by comparing the amounts of crash damage to passenger cars that were not required to comply with the standard (1972 and earlier model years) with the damage sustained by vehicles that had to comply; (2) measuring changes in actual costs of bumper systems to meet the standards; and (3) assessing the cost effectiveness of post-standard bumper systems in terms of net benefits or losses. The evaluation is based on statistical analyses of both 65,000 property damage insurance claims and data from a national survey of 10,223 households having 14,902 cars. The costs of meeting the bumper standards are based on teardown studies of 94 bumper systems representing 1972 (pre-standard) through 1980 makes and model passenger cars. It was found that:

- o Front bumpers have tended to be cost effective since bumper standards were first met in 1973 model cars.
- o Rear bumper systems are not and have never been cost effective since the promulgation of the standards.

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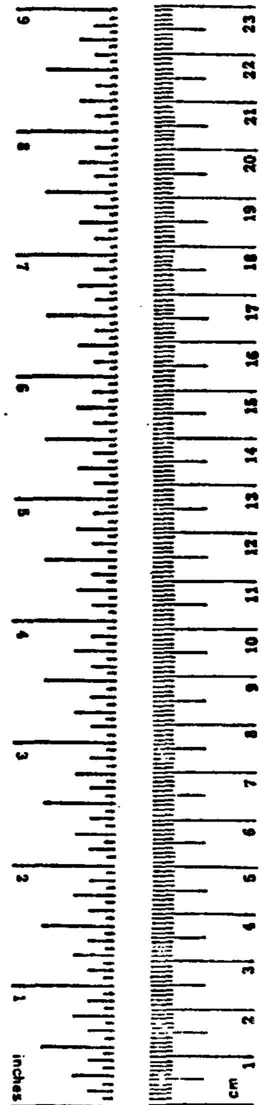
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

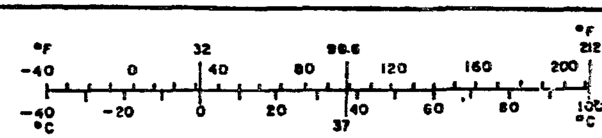
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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

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



Approximate Conversions from Metric Measures

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



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EXECUTIVE SUMMARY

The objectives of the bumper standards are to reduce damage and provide cost savings to consumers, and to protect safety-related parts. Title I of the Motor Vehicle Information and Cost Savings Act of 1972, and section 103 of the National Traffic and Motor Vehicle Safety Act of 1966 are the bases for the objectives.

The evaluation of the bumper standards was carried out under the policy of Executive Order 12291 (Federal Regulation), dated February 17, 1981, which superseded Executive Order 12044, and under Department of Transportation Regulatory Policies and Procedures (February 26, 1979).

The bumper standard added more weight and cost to passenger cars than any motor vehicle safety standard in existence. The evaluation of the effectiveness of the bumper standard compares the amount of crash damage to vehicles that were not required to comply with the standard (those manufactured prior to the 1973 model year), with the damage sustained by vehicles that had to comply. The first standard , FMVSS No. 215, required the protection of safety parts (damage protection) at impact speeds of 5 miles-per-hour (mph) for the front bumper, and 2 1/2 mph for the rear bumper. The standard was made more stringent for the 1974, and later, model years, and again upgraded for both the 1979 and 1980 model years as the part 581 Bumper Standard.

In making comparisons there are two measures of effectiveness:

- Frequency of Damage -- Given a population of low-speed collisions and assuming a similar distribution with respect to impact speed for both pre- and post-standard cars, the change in damage frequency (the number of cars damaged) will reflect the degree of effectiveness of exterior protection provided on post-standard cars.

- Extent of Damage -- The effectiveness of exterior protection systems on the extent of damage in a low-speed collision, is based on the change in damage repair costs between pre- and post-standard cars, again, assuming a similar pre- and post-collision speed distribution.

Both the frequency and the extent of damage can be affected by the degree of over or underride of the colliding bumper systems. Beginning with model year 1974, pendulum impact tests were required at bumper heights of 16 to 20 inches above a surface to align bumper heights on post-standard cars so that both over and underride are minimized in low-speed collisions.

Changes in the cost of collision damage must be compared to the cost of providing increased exterior protection. Bumper systems designed to meet the standard in earlier years tended to be comprised mostly of steel, adding weight and its concomitant increased fuel use, as well as resulting in price increases, to post-standard cars. Fleet downsizing and the need to improve fuel economy, hence reduce weight, led to the use of lighter materials and simpler attaching devices. Therefore, key results in this report are presented in terms of net benefits, difference between gross benefits and incremental costs to meet standards.

Low-speed accidents often cause slight or no damage and thus go unreported leaving a vast gap in available data. To approach this problem, the potential applicable accident population had to be defined. Low-speed collisions may be reported, but only for insurance claim purposes. The findings in this study are based on statistical analyses of 65,000 property damage insurance claims and data from a national survey of 10,223 households having 14,902 cars. The costs of meeting the bumper standard are based on teardown studies of 94 bumper systems representing 1972 (pre-standard) through 1980 makes and models.

PRINCIPAL FINDINGS

Low Speed Collisions

Bumper standards were established to prevent car damage in low-speed collisions. Estimates based on the national survey, show:

- Approximately one in five cars on the road (22 percent) is involved in a low-speed collision each year.

- Of the 22 percent, 14 percent do not report the collision either to the police or an insurance company, another 7 percent of those involved file insurance claims and may report the accident to the police, and the remaining 1 percent report the collision to the police, but do not file insurance claims.

- Half of the cars involved in unreported low-speed collisions incur damage. Thus, 7 percent of all cars on the road sustain damage in unreported low-speed collisions.

BUMPER EFFECTIVENESS

The standard's effectiveness in reducing damage in low-speed collisions is measured by comparing the following pre- and post-standard values:

- Damage frequency - the proportion of cars damaged in unreported collisions.

- Damage frequency - the proportion of cars where property damage insurance claims are filed.

- Repair Cost - the cost to repair damage sustained in unreported collisions.

- Repair Cost - the cost to repair damage as determined from cases where insurance claims are filed.

- Over or underride in multi-vehicle collisions

Summary of Effectiveness Findings

Damage Frequency:

- There was a reduction of between 20 to 30 percent in the number of times post-standard cars suffered damage in low-speed collisions, when compared to cars with pre-standard bumpers. This reduction is statistically significant.

- Front bumper systems were instrumental in reducing the frequency of damage, although their effectiveness did not improve as standards became more stringent from 1973 through 1980. The reduction in damage frequency is between 28 and 37 percent.

- Rear bumper systems were only effective in reducing the frequency of damage in the 1974-78 models. There are conflicting results for the 1979-80 models, possibly due to sample size. In cases where collisions were unreported - the expected "lowest" speed contacts - the 1979-80 rear bumpers were not effective when compared to pre-standard rear bumpers. From cases based on insurance claims, which tend to reflect the higher damage range of low-speed collisions, they were effective.

- The 2 1/2 mile per hour rear bumper (1973) did not reduce the frequency of damage when compared to pre-standard bumpers.

- The degree of bumper effectiveness was not affected by type of bumper material nor by make of car.

Damage Repair Cost - Unreported Collisions

Unreported collisions represent bumper accidents with the lowest impact speeds--reflected in their smaller damage repair costs, compared to insurance claimed collisions. Analysis of unreported accidents showed the bumper standard having a significant effect in reducing repair costs for cars damaged in unreported collisions.

- Cars with bumper systems meeting post-standard requirements are $20 less expensive to repair than vehicles with pre 1973 systems when struck in the front end. This is a statistically significant reduction, $188 vs. $166. The average post-standard front bumper repair cost varied little from the latter value, even though the standard changed several times over the 1973-1980 period.

- The cost to repair damage in the rear of a car dropped an average of $7 as a result of 1973 through 1978 bumper standards, but increased by over $40 (relative to pre-standard) for cars meeting the 1979-80 requirements.

Damage Repair Cost - Collisions for Which Insurance Claims Were Filed

Insurance claims were analyzed for front and rear damage (bumper related). This damage tends to result from the higher end of the low-speed collision range as is evident from repair costs, which are almost four times greater per damaged car than for a car in an unreported collision. While the bumper standard significantly reduced the number of bumper related damage claims, the effect on damage repair cost per claim is higher for post-standard cars.

- The damage repair cost per post-standard car (1974-1979) with a front bumper related damage claim significantly increased compared to 1972 pre-standard cars, by about $145 per claim (a 20 percent increase). The number of such claims decreased, however, by about 30 percent so that the total dollar amount per insured car of such claims decreased by 15 percent. The bumper standard had the effect of reducing the extent of damage in many collisions which then went unreported. The net effect is that insurance claims are filed only for the more severely damaged cars -- hence a higher repair cost per claim for post-standard cars.

- The post standard cars struck in the rear incurred damage repair costs of about $600 per bumper related damage claim. This represents some $60 (10 percent) more than the repair cost for a pre-standard car. There were, however, 20 percent fewer insurance claims for post-standard cars, which had the net effect of reducing the total amount of such claims by 10 percent.

Effectiveness of Bumper Height Requirements

- As a result of bumper height requirements there was a 12 percent increase in the number of times bumpers made contact (matched) in multi-vehicle collisions, compared to pre-standard cases.

- Damage frequency and damage repair costs decreased as a result of more "matched" collisions.

Bumper Costs

There are two kinds of costs which were determined:

- The complete cost of a bumper system for various make/model cars and,
- The incremental cost--the difference between pre- and post-standard cars, reflecting the actual cost to meet a particular bumper standard.

The incremental costs include the sum of:

- The incremental cost due to bumper weight changes.
- The discounted lifetime fuel costs due to bumper weight changes.
- The total secondary weight costs.
- The discounted lifetime fuel cost due to secondary weight.

Summary of Bumper Cost Findings

- The 1979-80 bumper standards increased the cost of bumpers (front and rear) by $150 to $200. This is the increase relative to pre-standard bumper systems, and is based on secondary weight ratios of between 0.35 and 0.75 (which added $25 to $75 to the cost of bumpers.)

- For the same parameters as above, the increased cost for front (1979-80) bumpers is $80 to $110; rear, $65 to $90.

- The consumer costs, exclusive of added fuel consumed, and secondary weight, of 1979-1980 bumpers--front and rear--were $89 higher than for pre-standard cars.

- The heavier weight of 1979-1980 bumpers over pre-standard bumpers results in the increased consumption of 43 gallons of fuel over the life of a car, at a discounted cost penalty of $36.
  (NOTE: All of the above values are discounted to 1979 dollars.)

- Bumper redesign for downsizing, including material substitution, improved technology, etc., reduced both the weight and cost of 1979-80 systems when compared to 1974-78 bumpers, even though the standard's requirements were more stringent in 1979-80.

5.0 NET BENEFITS

When the actual costs associated with the bumper standard are subtracted from the gross benefits due to the standard, the result is a net benefit or loss. This is simply a measure, in dollars, of whether, or to what degree, a standard has paid for itself--i.e., is cost effective.

The findings reflect values discounted to 1979 dollars. Gross benefits are based on the difference in damage repair cost between pre- and post-standard cars involved in low-speed collisions.

The following Table lists a complete set of net benefits for various secondary weight ratios and for each version--1973 through 1979--of the bumper standard. Although the actual cost of all standards through the 1980 model year was obtained, gross benefits could not be calculated for that model year since insurance claim data--a necessary part of the gross benefit calculation--was not available at the conclusion of the evaluation work.

5.1 Summary of Findings Related to Net Benefits

Net benefit (or loss) values are shown for secondary weight ratios 0.35, 0.50, 0.75 and 1.00 in addition to values when no secondary weight is considered. The results are further divided by two values of cost per pound of secondary weight. One at $0.60 per pound reflects the cost of adding material only,

DISCOUNTED NET BENEFITS
(DISCOUNTED TO 1979 DOLLARS)
- At Indicated 1979 Secondary Weight Costs/lb. -

Secondary Weight Factor	1973 Bumper System		1974-78 Bumper System		1979 Bumper System	
	$0.60/lb	$1.60/lb.	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.
Front and Rear						
0.00	13	13	45	45	27	27
0.35	-15	-32	4	-21	6	-7
0.50	-28	-52	-14	-50	-3	-22
0.75	-48	-84	-43	-97	-20	-47
1.00	-68	-116	-73	-144	-32	-71
Front						
0.00	57	57	59	59	61	61
0.35	36	24	38	26	49	42
0.50	27	10	29	12	44	33
0.75	13	-14	15	-12	36	20
1.00	-2	-37	0	-35	28	6
Rear						
0.00	-43	-43	-13	-13	-33	-33
0.35	-51	-55	-34	-47	-42	-48
0.50	-54	-60	-43	-62	-46	-55
0.75	-59	-69	-58	-86	-53	-65
1.00	-65	-78	-73	-110	-59	-76

NOTE 1. Values may not add due to rounding.

NOTE 2. Values are point estimates.

the other at $1.60 per pound represents the cost per pound of total car weight. Both are consumer costs in 1979 dollars.

Views on the existence and/or amount of secondary weight - the added weight for strengthening affected vehicle systems and parts due to an added weight to bumper systems - differ. This evaluation does not attempt to resolve the issue, therefore net benefits (and losses) were calculated for a number of secondary weight ratios.

In the following summary, net benefit (and loss) values will be discussed, in most cases based on a secondary weight ratio and cost per pound of 0.50 and $0.60, respectively.

- Front bumper systems have tended to be cost effective since bumper standards were first met in 1973 model cars. The 1979 front bumper system shows a definitive net benefit of $44 (basis is 0.5 secondary weight ratio and $0.60 per pound of secondary weight.)

- Rear bumper systems are not, and have never been, cost effective since the promulgation of the standards. They have consistently incurred net losses, of between $43 to $54 (1973). The net loss for the 1979 bumper systems is $46 (same basis as above). The rear bumper systems show net losses even when no secondary weights are considered.

- The combined front and rear results for post standard bumper systems present a varied picture. Only the 1974-78 bumper systems show a definitive net benefit, and that is limited to when no secondary weight is included. The 1979 models tend toward a net benefit under similar circumstances.

- At a secondary weight ratio of 0.5 (and $0.60/lb.) the results begin to shift and when secondary weight ratios of 0.75 or higher are used, the combined front and rear post standard bumper systems tend toward, or show, a net loss.

- The relatively positive results (net benefits) for front bumper systems may stem from a number of conditions. One of these is the finding that the damage frequency to the front ends of cars is between 25 and 50 percent higher than to the rear ends. The damage reduction (and benefit) potential is consequently higher for the front. This is borne out by the reduction in damage frequencies for post-standard cars (compared to pre-standard cars) which favored the front end over the rear by a factor of between 2 and 3 to one. Damage repair cost reductions for post-standard cars, compared to pre-standard, show similar trends.

- There is no evidence that downsizing--that is, both the decrease in weight or the substitution of materials--had an effect on net benefits of bumper systems. The improvement in front bumper net benefits, 1979 over 1974-78, is as high as 50 percent (0.5 secondary weight ratio) at the same time that the weight of front bumper systems was reduced by 16 percent (75 lbs. to 63 lbs.).

° The weight reduction, 1974-78 to 1979-80, for rear bumper systems is 20 pounds, or 27 percent (75 lbs. to 55 lbs.) and net losses increased by 7 percent. While no direct cause-effect relationship can readily be established, the relatively large weight reduction can be a contributing factor, particularly in light of damage frequency and repair cost findings for the rear bumper systems on 1979-80 cars.

Additional Factors Affecting Net Benefits

° A previous assessment by the agency included estimates of consumer and insurance (fewer claim settlements) savings resulting from bumper standards.1/ A total of $61 in additional net benefits (1979 dollars) was estimated for the front and rear bumper system. It was not possible to collect data to analyze and construct these secondary effects in this evaluation. The results are neither verified nor disputed.

° Bumper damage is not always repaired, which may reduce the value of a car when it is sold. The effect of such cases was calculated, assuming that none of the damage in unreported collisions was repaired. The result could reduce net benefits by an amount of $12 (1979 front and rear bumpers combined).

1/ National Highway Traffic Safety Administration, Final Assessment of the Bumper Standard, DOT HS-804-718 (June 1, 1979).

6.0 CONCLUSIONS

- Front bumper systems have been effective in reducing property damage. They generally show net benefits, particularly for the 1979 model cars. The lack of damage reduction potential to parts and components in the rear of a car lead to consistent net losses for rear bumper systems installed to meet standard requirements. When results for the front and rear systems are combined they tend toward a net benefit only when little or no secondary weight is included; at secondary weight ratios of 0.50 and above the results shift toward or show net losses.

- The chance for rear bumper systems to achieve net benefits is very limited. Rear bumper systems for 1979-80 models weigh some 20 pounds less than their 1974-78 predecessors, and 8 pounds less than their front counterparts.

- Downsizing through weight reduction and material substitution appeared to have no effect on either the damage reducing capability or cost effectiveness of front bumpers. It may have had a slight aggravating effect on rear end protection.

- While a series of secondary effects such as time and insurance cost savings, the value of unrepaired damage, additional interest cost on car loans due to added bumper costs, etc., can affect net benefits (or losses), reliable data are difficult to obtain. Estimates of such effects, when available, should be considered, as an adjunct to the primary results.

- The mix of the car fleet can be a significant factor affecting both damage frequency and net benefits. How bumper systems fare when small cars predominate would require assumptions beyond the scope of this evaluation.

CHAPTER I

LOW-SPEED COLLISIONS AND THE BUMPER STANDARD

1.0 AGENCY MISSION AND AUTHORITY

1.1 Introduction

The primary mission of the National Highway Traffic Safety Administration (NHTSA) is to reduce traffic accidents and their consequences in terms of persons injured or killed and to reduce property damage. The National Traffic and Motor Vehicle Safety Act of 1966 provides the authority for issuing safety standards and specifies that these standards be practicable, meet the needs of motor vehicle safety and provide objective criteria. NHTSA issues vehicle safety regulations (Federal Motor Vehicle Safety Standards, FMVSS) which require that new motor vehicles or motor vehicle equipment sold in the U.S. meet specified performance levels.

The first bumper standard issued under the 1966 Act was FMVSS 215--Exterior Protection, which called for passenger cars, beginning with model year 1973, to withstand 5 mph front and 2 1/2 mph rear impacts against a barrier without damage to certain safety related components. Impact and test requirements were upgraded for subsequent model years, as will be discussed in more detail later.

In October 1972, Congress enacted the Motor Vehicle Information and Cost Savings Act (MVICS Act) which included, under Title I, the authority to issue bumper standards which would yield the maximum feasible reduction of costs to the public, taking into account:

- o The cost of implementing the standard and the benefits attainable as a result of implementation;
- o The effect on the cost of insurance and legal fees;
- o Savings in terms of consumer time and inconvenience; and
- o Health and safety considerations.

The initial requirements under the MVICS Act were integrated with FMVSS 215 and promulgated in March 1976 as a new bumper standard applicable to passenger cars beginning with model year 1979. It allowed damage to bumpers and limited damage to other front and rear surfaces in low-speed crashes, as well as to numerous safety-related components.

1.2 Need to Evaluate Existing Regulations

The Secretary of Transportation issued the Department's Regulatory Polices and Procedures (February 26, 1979) which included a requirement that the Department prepare, for publication in the Federal Register, a semi-annual list of existing regulations it has selected for review. An order issued by the Department (DOT 2100.5 updated 5-22-80), "Policies and Procedures for Simplification, Analysis, and Review of Regulations," gives guidelines for identifying and ranking regulations to be reviewed. Some factors to be considered include: the nature and extent of complaints about a regulation, the length of time since a regulation was last reviewed, the importance and continued relevance of the problem the regulation was originally intended to solve, the burdens imposed on those directly or indirectly affected by the regulation, and the degree to which technology, economic conditions or other factors have changed in the area affected by the regulation.

Executive Order 12291 issued on February 17, 1981 requires agencies to initiate reviews of currently existing regulations and perform Regulatory Impact Analyses of currently existing major rules. The purpose of such reviews is to ascertain whether the benefits of the rule exceed the costs to society. This bumper evaluation, which includes new information not used in previous reviews, meets this latter requirement. The bumper standard was initially chosen for review nearly 4 years ago because it added more weight, and cost, than any other regulation issued by the Agency at that time. In addition, it has long been the center of public controversy over its costs and benefits.

2.0 HISTORY OF THE STANDARD

2.1 Historical Highlights

The automobile bumper was originally designed in the early 1900's to protect the front and rear of the vehicle in low-speed accidents. Bumpers were generally unsophisticated but effective--a beam held by spring-like supports.

These bumper systems did not absorb energy (unless parts were permanently bent or broken under collision forces); rather, they stored energy for release in a rebound motion when struck. Bumpers were in an extended position from the car body and were made of high-strength materials so that low speed collision forces were spread over a sufficient period of time and space to prevent severe damage to the car. When bumper heights of two cars matched, they also aided parking maneuvers.

After World War II, automobiles became more stylish and the bumper's protective nature tended to be sacrificed to designs that more attractively matched vehicle shapes. Bumpers were moved closer to body sheet metal and other vulnerable parts and were often made of lighter weight materials. These changes resulted in increased damage to bumpers and other front and rear parts when cars were involved in low-speed collisions. The results were higher repair and insurance costs to the motoring public.1/

After passage of the National Traffic and Motor Vehicle Safety Act in 1966 and the subsequent establishment of the Agency, work began toward the development of a safety regulation for exterior protection--the bumper standard designated FMVSS 215. The final rule, issued on April 9, 1971, required that passenger cars, beginning with model year 1973, be in compliance with the standard.

1/ Stanford Research Institute, Evaluation Methodology for Federal Motor Vehicle Safety Standards, Report No. DOT-HS-802-341 (May 1977), p. 2-10. 1-5

2.2 Development of the Bumper Standard

The current (1980) bumper standard is best described in terms of four successive stages, which constitute the object of this evaluation. While Tables I-1 and I-2 list the purposes, requirements and compliance test criteria, the following is a brief description of each of the four bumper standard stages for identification and reference throughout the report:

Standard	Model Year(s) Applicable	Barrier/Pendulum Speed and Parts Affected
FMVSS 215	1973	5 mph front and 2 1/2 mph rear impact with barrier. Safety related parts only.
FMVSS 215	1974-1978	5 mph front and rear impacts with barrier and pendulum; 3 mph corner impact with pendulum. Safety related parts only. Pendulum test established bumper height between 16 and 20 inches.
Part 581 incorporating FMVSS 215	1979	As above, plus no damage to exterior surfaces, except bumper face bar and its fasteners.
As above	1980	As above, except face bar can have no permanent deviation in contour or position greater than 3/4 inch, and no permanent localized surface deviation greater than 3/8 inch.

TABLE I-1

STANDARD 215--EXTERIOR PROTECTION

ITEM	DESCRIPTION	
Effective Date	September 1, 1972	September 1, 1973*
Model Year	1973	1974-1978
Purpose of Standard	o Specific purpose: Establish requirements for impact resistance and height of bumpers. o General purpose: - Prevent low-speed accidents from impairing safe operation. - Reduce the frequency of override or underride in higher speed collisions.	
General Requirements of Standards	Vehicle can impact fixed barrier at 5 mph forward or 2.5 mph in reverse and suffer limited damage to: Lamps and reflectors; hood, trunk and doors; fuel, cooling and exhaust systems.	*Vehicle can be impacted by a pendulum-like test device (5 mph front and rear and 3 mph corner) between 16 and 20 inches from ground followed by front and rear fixed-barrier impacts at 5 mph, and suffer limited damage, to: Same items as earlier test; and propulsion, suspension, steering, and braking systems.
Alternative Compliance Methods	The basic principle used in meeting this Standard is energy absorption. Various torsional systems, mechanical systems, and energy absorbing materials have been used: springs, pneumatic shock absorbers, plastic foams, etc. (See Section 2.3).	
Scope of Coverage	Standard 215 has been in effect for all passenger cars since September 1, 1972. Certain special configuration vehicles with less than 115 inch wheelbase were exempted from the September 1, 1973, pendulum impact requirements until August 31, 1974.	

TABLE I-2

BUMPER STANDARD (PART 581)1/

ITEM	DESCRIPTION	
Effective Date	September 1, 1978	September 1, 1979*
Model Year	1979	1980
Purpose of Standard	o Specific purpose: Establish requirements for impact resistance of vehicles in low-speed front and rear accidents. o General purpose: Reduce the physical damage to the front and rear ends of motor vehicles.	
	The vehicle must undergo the front and rear barrier impact test at 5 mph and the pendulum 5 mph impact test to both front and rear bumpers and to the corners. All the damage criteria listed in in Table I-1 must be met and:	
	Exterior surfaces shall not be damaged or have permanent deviations except for damage to the bumper face bar and components and fasteners that attach the bar to the chassis frame	*Exterior surfaces shall not be damaged or have permanent deviations except for face bars which can have no permanent deviation greater than 3/4" from its original contour and position relative to the vehicle frame vehicle frame, and no permanent surface deviation greater than 3/8" from the original contour on areas of contact with test devices.

1/ Issued under authority of Title I of the Motor Vehicle Information and Cost Savings Act of 1972, and Sections 103 and 119 of the Safety Act.

Bumper standards applicable to passenger cars beginning with the 1979 models limit damage to vehicle bumpers and other front and rear surfaces in low-speed crashes. The new standard (Part 581) was issued under the concurrent authority of Title I of the Motor Vehicle Information and Cost Savings Act and Sections 103 and 119 of the National Traffic and Motor Vehicle Safety Act. In addition to specifying limitations on damage to non-safety related components and vehicle surfaces, Part 581 incorporates the safety components specified in Standard 215.

2.3 Complying with the Bumper Standard

The components that typically make up a bumper system include the following:

- Face bar and protective strip
- Face bar reinforcement
- Bumper guards
- License plate bracket
- Filler and valance panels
- Energy absorbers
- Air deflectors (front bumper)
- Heat shield (rear bumper)
- Miscellaneous brackets, braces, etc.[2]

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[2] John Z. DeLorean Corporation, Cost Evaluation for Four Federal Motor Vehicle Standards: Volume I, DOT-HS-803-871 (October 1978), p. 39.

Of the components listed, the basic ones that affect the bumper system's protective capability are the face bar, the face bar reinforcement, and the energy absorbers. Figure I-1 is a simplified sketch of a bumper system with these basic components identified. Pre-standard bumper systems, except for some brackets and fastening devices, generally consisted of just the face bar.

The automotive industry responded to the first bumper standard by installing bumper systems of varying designs. For example:

- General Motors used reinforced steel bumpers with external rubber guards attached to a pair of energy absorbing hydraulic/pneumatic cylinders.

- General Motors on a few models installed elastomeric material which absorbed impact energy.

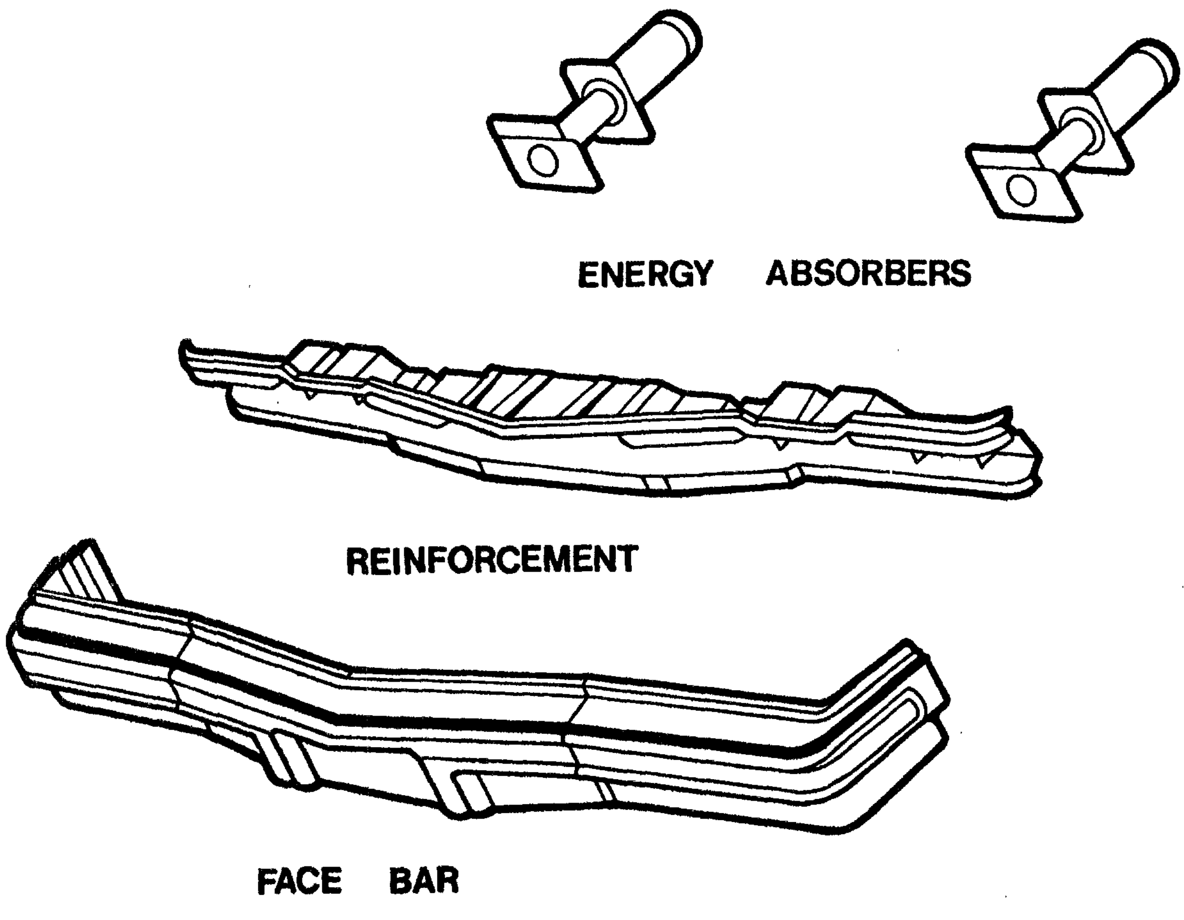
- Ford used reinforced steel bumpers connected to energy absorbing blocks of rubber which acted in shear upon impact.

- Chrysler used a full width steel reinforcement attached directly to the vehicle's frame. The bumper had large energy absorbing rubber blocks [which looked like bumper guards] attached to it.3/

3/ Ibid., pp. 38-39.

FIGURE I-1

BASIC BUMPER SYSTEM COMPONENTS



Generally General Motors' full size models in 1972, the year before the bumper standard took effect, were equipped with bumper systems that met the bumper standard requirement.4/

2.3.1 Energy Absorbers

After the pendulum test was required as part of the bumper standard, the rubber shear and Chrysler's large rubber blocks were less useful as energy absorbers in bumper systems.

The piston type energy absorber and use of elastomeric materials were typically installed on 1979 models.5/

2.3.2 Face Bars and Reinforcements

The heaviest components of bumper systems are the face bar and face bar reinforcement. Most face bars and reinforcements were made of steel for the 1973 model cars. This had a significant effect on the total bumper weight. For example, the weight of the front bumper system for a 1973 Nova was almost twice that of a 1972 Nova.

4/ KLD Associates, Inc., Analysis of Insurance Claims to Determine Bumper Effect on Crash Damage, DOT-HS-842-843 (March 1980), p. 13.

5/ John Z. DeLorean Corporation, Cost Evaluation for Four Federal Motor Vehicle Standards: Task VI, 1979 Selected Bumper Systems, Report No. DOT-HS-803-873 (December 1978); and A Cost/Weight Study on 1977-1980 Production Bumper Systems (New York: The International Nickel Co. [1980]). These reports contained parts lists for 19 different 1979 model cars. These lists were reviewed to arrive at this conclusion.

The pendulum test resulted in rear bumper systems weighing as much or more than the front systems.[6] Most of the weight increase came from the added material to the face bar and the addition of extra components, the biggest of which was the face bar reinforcement.

By the late 1970's it became obvious to the auto industry that material substitution could significantly reduce the weight of bumper systems. Various combinations came into use. The 1978 Ford-Fairmont was equipped with an aluminum face bar with steel reinforcement; the 1979 Chevrolet-Malibu had a steel face bar but aluminum reinforcement.[7]

Of course another weight saver was the downsizing of the automobile in the late 1970's. This allowed for much smaller face bar reinforcements for two reasons. The dimensions of the car were reduced so that face bars were not as long. The car weighed much less so that the bumper systems did not have to absorb as much energy because the pendulum test specifies that the weight of the pendulum shall equal that of the car being tested.

6/ John Z. DeLorean Corporation, Volume I, pp. A-5, A-7, and A-9. This report shows that the Nova rear bumper system weighed 31 pounds in 1972, 47 pounds in 1973, and 81 pounds in 1974 whereas the front bumper system for a Nova weighed 61 pounds.

7/ A Cost/Weight Study on 1977-1980 Production Bumper Systems (New York: The International Nickel Company, 1980), pp. 22 and 24.

Downsizing and use of light weight materials resulted in many 1979 bumper systems weighing less than 1974 systems and in some instances less than the comparable 1972 model.8/

3.0 EVALUATION OBJECTIVES

3.1 Introduction

The objective of the bumper standard, unlike most safety standards, is to reduce damage. To be sure, the standard specifie, that safety-related parts must be protected, but under Title I of the Motor Vehicle Information and Cost Savings Act, the primary emphasis is on cost savings to the consumer. The bumper standard also differs from other safety standards in that it applies to low speed accidents, given the maximum test speed of 5 mph. Low-speed accidents often cause slight or no damage and thus go unreported leaving a vast gap in available data. To approach this problem, the potential applicable accident population must be defined before proceeding with specific evaluation objectives.

3.2 Low-Speed Collisions

The primary problem in setting bumper standards and in the evaluation of effectiveness is the definition and identification of low-speed

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8/ DeLorean Corporation, Volume I, p. 5 and Task VI, p. A-6. These reports show that the bumper system for a Caprice in 1972 weighed 194 pounds. In 1974 the weight increased to 216 pounds, but in 1979 it decreased to 150 pounds.

collisions. There is little information at the State, local or national level on the number of auto accidents that occur at various speeds, especially the lower speeds. Computer models have been developed for simulating impact speeds of higher-speed accidents using data on tire skid marks on the road, before and after locations of the vehicles in the crash, and the dimensions of the physical damage to these vehicles. The computer model is accurate for estimating speeds of the more severe accidents. Even so, the estimates are not very precise. From the computer modeling one can only determine what is not a low-speed collision, namely, one that includes injured occupants, long tire skid marks, or a large displacement of vehicles on impact unless one of the vehicles is much larger than the other (e.g., tractor-trailer impact with a subcompact car).

From a purely energy management design perspective, bumpers are intended to be effective in preventing superficial vehicle damage. When the collision speed exceeds a certain threshold, bumpers are not physically capable of absorbing all the impact energy and the vehicle frame or other main body structure or system often is damaged. When this happens the auto usually cannot be driven from the scene of the accident. Therefore, low-speed collisions generally would not include vehicles that must be towed away after the accident.

Low-speed collisions often result in no damage or just a few dents or scratches and seldom is anyone injured. This means that the police or insurance companies may not be notified and that the occurrence of the collision is not recorded. Police reports are only required when damage exceeds a certain dollar amount or when persons are injured. When the damage is below a driver's deductible for collision insurance (typically $100), an insurance claim is not filed. When no damage occurs as the result of a low-speed collision, there is no report of the accident under most circumstances.

3.3 Bumper Standard Effectiveness

An evaluation of the effectiveness of the bumper standard basically compares the amount of crash damage to vehicles that were not required to comply with the standard with the damage sustained by vehicles that had to comply with some version of the standard. Such an analysis should also make comparisons between vehicles meeting different versions of the standard to determine if one version has been more effective in reducing damage than another. In making these comparisons there are two quantities which measure the effectiveness of the bumper standard--<u>frequency</u> of damage and <u>extent</u> of damage.

While subsequent chapters will cover the approach, measurement and analysis in more detail, the main evaluation questions are described in the following sections.

3.3.1 Damage Frequency

Given a population of low speed collisions and assuming a similar distribution with respect to impact speed for both pre- and post-standard cars, the change in damage frequency will reflect the degree of effectiveness of exterior protection provided on post-standard cars.

Damage can range from measuring any deformation or breakage to an assessment of the cumulative damage caused to each part in a single collision, or simply counting up the number of parts that are damaged. In evaluating damage frequency the incidence of any damage and the incidence by part--to the degree possible--will constitute one basis for determining effectiveness.

3.3.2 Extent of Damage

The effectiveness of exterior protection systems on the extent of damage in a low-speed collision is based on the change of collision damage repair costs between pre- and post-standard cars, assuming a similar pre- and post-collision speed distribution. A series of subset analyses may be possible to examine bumper effectiveness in reducing the extent of damage to key safety parts.

3.3.3 Effect of Over and Underride

Both the frequency and the extent of damage can be affected by the degree of over or underride of the colliding bumper systems. Compliance tests, beginning with model year 1974 required pendulum impacts within specified bumper height limits (16 to 20 inches above a surface), the obvious purpose being to align bumper heights on post-standard cars so that both over and underride are minimized in low-speed collisions.

3.4 Bumper Standard Costs

Changes in the cost of collision damage must be compared to the cost of providing increased exterior protection. Bumper systems designed to meet the standard in earlier years tended to be mostly of steel. Fleet downsizing led to the use of lighter materials and simpler attaching devices. Any weight added to produce bumpers which comply with the standards will result in a fuel penalty thus increasing fuel costs over the life of the car. The key question here is how does the lifetime incremental cost of the bumper system compare with incremental lifetime benefits.

4.0 ORGANIZATION OF REPORT

Chapter II, which follows, contains the findings and conclusions based on an analysis of data collected for this evaluation. Chapter III presents methods of collecting data with which to measure the reduction in the frequency and extent of crash damage in low-speed collisions. Bumper standard effectiveness in analyzed in Chapter IV and the costs of the bumper standard are presented in Chapter V. The cost-effectiveness of the bumper standard is evaluated in Chapter VI.

CHAPTER II

FINDINGS AND CONCLUSIONS

1.0 DATA SOURCES

The findings are based on statistical analyses of:

- 65,000 property damage insurance claims
- A national survey of 10,223 households, with 14,902 cars.
- Tear down studies of 94 bumper systems covering 1972 through 1980 makes and models. Actual bumper costs are estimated from such tear downs.

The year 1979 was selected as the base year for the analysis of benefits and costs of the bumper standard since it was the latest year for which actual economic data were available. Most of the unreported collisions from the national survey occurred during that year, therefore, all dollar values shown in this study are expressed in 1979 dollars.

2.0 LOW-SPEED COLLISIONS

Bumper standards were established to prevent car damage in low-speed collisions. Estimates based on the national survey, show:

- Approximately one in five cars on the road (22 percent) is involved in a low-speed collision each year.

- Of the 22 percent, 14 percent do not report the collision to the police or an insurance company, another 7 percent of those involved file insurance claims, and the remaining 1 percent report the collision to the police, but do not file insurance claims.

- Half of the cars involved in unreported low-speed collisions incur damage. Thus, 7 percent of all cars on the road are damaged each year in unreported low-speed collisions.

3.0 BUMPER EFFECTIVENESS

The standard's effectiveness in reducing damage in low-speed collisions is measured by comparing the following pre- and post-standard values:

- Damage frequency - the proportion of cars damaged in unreported collisions.

- Damage frequency - the proportion of cars where property damage insurance claims are filed.

- Repair Cost - the cost to repair damage sustained in unreported collisions.

- Repair Cost - the cost to repair damage as determined from cases where insurance claims are filed.

- Over or underride in multi-vehicle collisions.

Tables II-1 through II-5 show the results together with their statistical significance.[1/] Not included in this section, but covered in Chapter IV, are several supplemental effectiveness measures relating to damaged parts.

Summary of Effectiveness Findings

Damage Frequency:

- There was a reduction of between 20 to 30 percent in the number of times post-standard cars suffered damage in low-speed collisions, when compared to cars with pre-standard bumpers. This reduction is statistically significant.

- Front bumper systems were instrumental in reducing the frequency of damage, although their effectiveness did not improve as standards became more stringent from 1973 through 1980. The reduction in damage frequency is between 28 and 37 percent.

- Rear bumper systems were only effective in reducing the frequency of damage in the 1974-78 models. There are conflicting results for the 1979-80 models, possibly due to sample size. In cases where collisions were unreported - the expected "lowest" speed contacts - the 1979-80 rear bumpers were not effective when compared to pre-standard rear bumpers. From cases based on insurance claims, which tend to reflect the higher damage range of low-speed collisions, they were effective.

1/ All statistical tests are at 95 percent confidence or $\alpha = 0.05$

- The 2 1/2 mile per hour rear bumper (1973) did not reduce the frequency of damage when compared to pre-standard bumpers.

- The degree of bumper effectiveness was not affected by type of bumper material nor by make of car.

Damage Repair Cost - Unreported Collisions

Unreported collisions represent bumper accidents with the lowest impact speeds--reflected in their smaller damage repair costs, compared to insurance claimed collisions. Analysis of unreported accidents showed the bumper standard having a significant effect in reducing repair costs for cars damaged in unreported collisions.

- Cars with bumper systems meeting post-standard requirements are $20 less expensive to repair than vehicles with pre 1973 systems when struck in the front end. This is a statistically significant reduction, $188 vs. $166. The average post-standard front bumper repair cost varied little from the latter value, even though the standard changed several times over the 1973-1980 period.

- The cost to repair damage in the rear of a car dropped an average of $7 as a result of 1973 through 1978 bumper standards, but increased by over $40 (relative to pre-standard) on cars meeting the 1978-80 requirement.

Damage Repair Cost - Collisions for Which Insurance Claims Were Filed

Insurance claims were analyzed for front and rear damage (bumper related). This damage tends to result from the higher end of the low-speed collision range as is evident from repair costs, which are almost four times greater per damaged car than for a car in an unreported collision. While the bumper standard significantly reduced the number of bumper related damage claims, the effect on damage repair cost per claim is higher for post-standard cars.

° The damage repair cost per post-standard car (1974-1979) with a front bumper related damage claim significantly increased compared to 1972 pre-standard cars, by about $145 per claim (a 20 percent increase). The number of such claims decreased, however, by about 30 percent so that the total dollar amount per insured car of such claims decreased by 15 percent. The bumper standard had the effect of reducing the extent of damage in many collisions which then went unreported. The net effect is that insurance claims are filed only for the more severely damaged cars -- hence a higher repair cost per claim for post-standard cars.

° The post standard cars struck in the rear incurred damage repair costs of about $600 per bumper related damage claim. This represents some $60 (10 percent) more than the repair cost for a pre-standard car. There were, however, 20 percent fewer insurance claims for post-standard cars, which had the net effect of reducing the total amount of such claims by 10 percent.

TABLE II-1

CAR DAMAGE FREQUENCY IN UNREPORTED COLLISIONS

Model Year Group	FREQUENCY OF CAR DAMAGE/COLLISION (PERCENT)1/	SIGNIFICANTLY LESS THAN PRE-STANDARD
FRONT AND REAR-END COLLISIONS COMBINED		
Pre-Standard (1972 and Earlier)	53	---
Post-Standard:		
1973	40	Yes
1974-78	37	Yes
1979-80	42	Yes
FRONT-END COLLISIONS ONLY		
Pre-Standard (1972 and Earlier)	60	---
Post-Standard:		
1973	37	Yes
1974-78	42	Yes
1979-80	38	Yes
REAR-END COLLISIONS ONLY		
Pre-Standard (1972 And Earlier)	48	---
Post-Standard:		
1973	43	No
1974-78	31	Yes
1979-80	46*	No

1/ Damage frequency of each post-standard group is compared with preceding post-standard group's frequency. Significance is shown as follows:

* -significantly greater than preceding group's frequency
**-significantly less than preceding group's frequency
No symbol-frequencies are not significantly different

TABLE II-2

PROPORTION OF BUMPER INVOLVED CLAIMS

IN ALL PROPERTY DAMAGE CLAIMS1/

Model Year Group2/	PROPORTION OF BUMPER INVOLVED CLAIMS (Percent)3/	SIGNIFICANTLY LESS THAN PRE-STANDARD
FRONT AND REAR END COLLISIONS COMBINED		
Pre-Standarad (1972)	56	---
Post-Standard:		
1973	53	Yes
1974-78	42**	Yes
1979	42	Yes
FRONT END COLLISIONS		
Pre-Standard (1972)	35	---
Post-Standard:		
1973	28	Yes
1974-78	25**	Yes
1979	24**	Yes
REAR END COLLISIONS		
Pre-Standard (1972)	22	---
Post-Standard:		
1973	25	No, higher
1974-78	16**	Yes
1979	18*	Yes

1/ Collision and property damage liability claims.
2/ Insurance claim data was unavailable for the 1980 model year.
3/ Each post-standard group was compared with the preceding post-standard group to determine significance as follows:

*-Significantly greater than proportion of preceding group
**-Significantly less than proportion of preceding group
No symbol-proportions are not significantly different

TABLE II-3

REPAIR COST OF DAMAGE IN UNREPORTED COLLISIONS

MODEL YEAR GROUP	REPAIR COST PER DAMAGE-CAUSING COLLISION (1979 DOLLARS)1/	SIGNIFICANTLY LESS THAN PRE-STANDARD
FRONT OR REAR-END COLLISIONS COMBINED		
Pre-Standard (1972 and earlier)	159	---
Post-Standard:		
1973	139	Yes
1974-78	143	Yes
1979-80	168*	No, greater
FRONT-END COLLISIONS		
Pre-Standard (1972 and earlier)	188	---
Post-Standard:		
1973	168	Yes
1974-78	163	Yes
1979-80	166	Yes
REAR-END COLLISIONS		
Pre-Standard (1972 and earlier)	127	---
Post-Standard:		
1973	121	No
1974-78	119	Yes
1979-80	171*	No, greater

1/ Each post-standard group was compared with the preceding post-standard group to determine significane as follows:

*-significantly greater than repair cost of preceding group
**-significantly less than repair cost of preceding group
No symbol-repair costs are not significantly different

TABLE II-4

DAMAGE REPAIR COST IN INSURANCE-CLAIMED COLLISIONS

MODEL YEAR GROUP 1/	REPAIR COST PER BUMPER CLAIM 2/ (1979 DOLLARS)	SIGNIFICANTLY LESS THAN PRE-STANDARD?
FRONT OR REAR END COLLISIONS COMBINED		
Pre-Standard (1972)	669	
Post-Standard:		
1973	682	No, higher
1974-78	772*	No, higher
1979	778*	No, higher
FRONT END COLLISIONS		
Pre-Standard (1972)	745	
Post-Standard:		
1973	783	No, higher
1974-78	890*	No, higher
1979	891	No, higher
REAR END COLLISIONS		
Pre-Standard (1972)	544	
Post-Standard:		
1973	565	No, higher
1974-78	591*	No, higher
1979	618*	No, higher

1/ Insurance claim data was unavailable for the 1980 model year.

2/ Each post-standard group was compared with the preceding post-standard group to determine significance as follows:

* - significantly greater than repair cost of preceding group

** - significantly less than repair cost of preceding group

no symbol - repair costs are not significantly different

TABLE II-5

BUMPER CONTACT IN UNREPORTED, MULTI-VEHICLE COLLISIONS1/

Model Year Group2/	Collisions where Bumpers Made Contact2/ (Percent)	Significantly Greater Than Pre-Standard?
FRONT OR REAR END OF SURVEYED CAR		
Pre-Standard (1972 and earlier)	74	
Post-Standard:		
1974-78	85	Yes
1979-80	79	Yes
FRONT-END OF SURVEYED CAR		
Pre-Standard (1972 and earlier)	72	
Post-Standard:		
1974-78	82	Yes
1979-80	78	No
REAR-END OF SURVEYED CAR		
Pre-Standard (1972 and earlier)	76	
Post-Standard:		
1974-78	87	Yes
1979-80	80**	No

1/ Based on driver/owner survey.

2/ The 1973 model year was not shown because there were no applicable bumper height requirements.

3/ Each post-standard group was compared with the preceding post-standard group to determine significance as follows:

* - significantly greater than percentage of preceding post-standard group

** - significantly less than percentage of preceding post-standard group

no symbol - percentages are not significantly different.

Effectiveness of Bumper Height Requirements

- As a result of bumper height requirements there was a 12 percent increase in the number of times bumpers made contact (matched) in multi-vehicle collisions, compared to pre-standard cases.

- Damage frequency and damage repair costs decreased as a result of more "matched" collisions (see Chapter IV for details).

4.0 BUMPER COSTS

There are two kinds of costs which were determined:

- The complete cost of a bumper system for various make/model cars and,

- The incremental cost--the difference between pre- and post-standard cars, reflecting the actual cost to meet a particular bumper standard.

Table II-6 shows the incremental costs. These include the sum of:

- The incremental cost due to bumper weight changes.
- The discounted lifetime fuel costs due to bumper weight changes.
- The total secondary weight costs.
- The discounted lifetime fuel cost due to secondary weight.

4.1 Summary of Bumper Cost Findings

- The 1979-80 bumper standards increased the cost of bumpers (front and rear) by $150 to $200. This is the increase relative to pre-standard bumper systems, and is based on secondary weight ratios of between 0.35 and 0.75 (which adds $25 to $75, respectively, to bumper costs).

- For the same parameters as above, the increased cost for front (1979-80) bumpers is $80 to $110; rear, $65 to $90.

- The consumer costs, exclusive of added fuel consumed and secondary weight, of 1979-1980 bumpers--front and rear--were $89 higher than for pre-standard cars.

- The heavier weight of 1979-1980 bumpers over pre-standard bumpers results in the increased consumption of 43 gallons of fuel over the life of a car, at a discounted cost penalty of $36.
  (All values are discounted to 1979 dollars)

- Bumper redesign for downsizing, including material substitution, improved technology, etc., reduced both the weight and cost of 1979-80 systems when compared to 1974-78 bumpers, even though the standard's requirements were more stringent in 1979-80.

TABLE II-6

TOTAL DISCOUNTED INCREMENTAL (LIFETIME) BUMPER COSTS 1/
(DISCOUNTED TO 1979 DOLLARS)
- At Indicated 1979 Secondary Weight Costs/lb. -

Secondary Weight Factor	1973 Bumper System		1974-78 Bumper System		1979 Bumper System		1980 BUMPER SYSTEM	
	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.
Front and Rear								
0.00	94	94	153	153	125	125	127	127
0.35	122	139	194	219	146	158	148	160
0.50	135	159	212	248	155	172	157	174
0.75	155	191	241	295	172	199	174	201
1.00	175	223	270	342	184	223	186	225
Front								
0.00	71	71	69	69	69	69	70	70
0.35	92	104	90	102	81	88	82	89
0.50	101	118	99	116	86	97	87	99
0.75	115	142	113	140	94	110	95	111
1.00	130	165	128	163	102	124	103	125
Rear								
0.00	23	23	84	84	56	56	57	57
0.35	31	35	105	118	65	71	66	72
0.50	34	40	114	133	69	78	70	79
0.75	39	49	129	157	76	88	77	89
1.00	45	58	144	181	82	99	83	100

1/ The summation of: (1) the incremental cost due to bumper weight changes; (2) the discounted lifetime fuel costs due to the weight changes; (3) the total secondary weight costs, and (4) the discounted lifetime fuel cost due to secondary weight.

5.0 NET BENEFITS

When the actual costs associated with the bumper standard are subtracted from the gross benefits due to the standard, the result is a net benefit or loss. This is simply a measure, in dollars, of whether, or to what degree, a standard has paid for itself--i.e., is cost effective.

The findings reflect values discounted to 1979 dollars. Gross benefits are based on the difference in damage repair cost between pre- and post-standard cars involved in low-speed collisions. Details of both the methods used and calculations are found in Chapter VI.

Table II-7 lists a complete set of net benefits for various secondary weight ratios and for each version--1973 through 1979--of the bumper standard. Although the actual cost of all standards through the 1980 model year is shown in Table II-6 in the previous section, gross benefits could not be calculated for that model year since insurance claim data--a necessary part of the gross benefit calculation--was not available at the conclusion of the evaluation work.

5.1 Summary of Findings Related to Net Benefits

Net benefit (or loss) values are shown for secondary weight ratios 0.35, 0.50, 0.75 and 1.00 in addition to values when no secondary weight is considered. The results are further divided by two values of cost per pound of secondary weight. One at $0.60 per pound reflects the cost of adding material only,

TABLE II-7

DISCOUNTED NET BENEFITS
(DISCOUNTED TO 1979 DOLLARS)
- At Indicated 1979 Secondary Weight Costs/lb. -

Secondary Weight Factor	1973 Bumper System		1974-78 Bumper System		1979 Bumper System	
	$0.60/lb	$1.60/lb.	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.
Front and Rear						
0.00	13	13	45	45	27	27
0.35	-15	-32	4	-21	6	-7
0.50	-28	-52	-14	-50	-3	-22
0.75	-48	-84	-43	-97	-20	-47
1.00	-68	-116	-73	-144	-32	-71
Front						
0.00	57	57	59	59	61	61
0.35	36	24	38	26	49	42
0.50	27	10	29	12	44	33
0.75	13	-14	15	-12	36	20
1.00	-2	-37	0	-35	28	6
Rear						
0.00	-43	-43	-13	-13	-33	-33
0.35	-51	-55	-34	-47	-42	-48
0.50	-54	-60	-43	-62	-46	-55
0.75	-59	-69	-58	-86	-53	-65
1.00	-65	-78	-73	-110	-59	-76

NOTE 1. Values may not add due to rounding.

NOTE 2. Values are point estimates, see Chapter IV for confidence intervals the other at $1.60 per pound represents the cost per pound of total car weight. Both are consumer costs in 1979 dollars.

Views on the existence and/or amount of secondary weight - the added weight per strengthening affected vehicle systems and parts due to an added weight to bumper systems - differ. This evaluation does not attempt to resolve the issue, therefore net benefits (and losses) were calculated for a number of secondary weight ratios.

In the following summary net benefit (and loss) values will be discussed, in most cases based on a secondary weight ratio and cost per pound of 0.50 and $0.60, respectively. The interpretation of results shown in Table II-7 must be tempered since these are "midpoint" values within larger confidence intervals. Tables showing these intervals (or bounds) and a brief explanation of interpretive procedures can be found in Chapter VI.

- Front bumper systems have tended to be cost effective since bumper standards were first met in 1973 model cars. The 1979 front bumper system shows a definitive net benefit of $44 (basis is 0.5 secondary weight ratio and $0.60 per pound of secondary weight.)

- Rear bumper systems are not, and have never been, cost effective since the promulgation of the standards. They have consistently incurred net losses, of between $43 to $54 (1973). The net loss for the 1979 bumper systems is $46 (same basis as above). The rear bumper systems show net losses even when no secondary weights are considered.

- The combined front and rear results for post standard bumper systems present a varied picture. Only the 1974-78 bumper systems show a definitive net benefit, and that is limited to when no secondary weight is included. The 1979 models tend toward a net benefit under similar circumstances.

- At a secondary weight ratio of 0.5 (and $0.60/lb.) the results begin to shift and when secondary weight ratios of 0.75 or higher are used, the combined front and rear post standard bumper systems tend toward, or show a net loss.

- The relatively positive results (net benefits) for front bumper systems may stem from a number of conditions. One of these is the finding that the damage frequency to the front ends of cars is between 25 and 50 percent higher than to the rear ends. The damage reduction (and benefit) potential is consequently higher for the front. This is borne out by the reduction in damage frequencies for post-standard cars (compared to pre-standard cars) which favored the front end over the rear by a factor of between 2 and 3 to one. Damage repair cost reductions for post-standard cars, compared to pre-standard, show similar trends.

- There is no evidence that downsizing-that is both the decrease in weight or the substitution of materials had an effect on net benefits of bumper systems. The improvement in front bumper net benefits, 1979 over 1974-78, is as high as 50 percent (0.5 secondary weight ratio) at the same time that the weight of front bumper systems was reduced by 16 percent (75 lbs. to 63 lbs.).

- The weight reduction, 1974-78 to 1979-80, for rear bumper systems is 20 pounds, or 27 percent (75 lbs. to 55 lbs.) and net losses increased by 7 percent. While no direct cause-effect relationship can readily be established, the relatively large weight reduction can be a contributing factor, particularly in light of damage frequency and repair cost findings for the rear bumper systems on 1979-80 cars.

5.2 Additional Factors Affecting Net Benefits

- A previous assessment by the agency included estimates of consumer and insurance (fewer claim settlements) savings resulting from bumper standards.1/ A total of $51 in additional net benefits (1979 dollars) was estimated for the front and rear bumper system. It was not possible to collect data to analyze and construct these secondary effects in this evaluation. The results are neither verified nor disputed.

- Bumper damage is not always repaired which may reduce the value of a car when it is sold. The effect of such cases was calculated, assuming that none of the damage in unreported collisions was repaired. The result could affect net benefits by an amount of $12 (1979 front and rear bumpers combined) in net benefits.

1/ National Highway Traffic Safety Administration, Final Assessment Bumper Standard, DOT HS-804-718 (June 1, 1979).

6.0 CONCLUSIONS

- Front bumper systems have been effective in reducing property damage. They generally show net benefits, particularly for the 1979 model cars. The lack of damage reduction potential to parts and components in the rear of a car lead to consistent net losses for rear bumper systems installed to meet standard requirements. When results for the front and rear systems are combined they tend toward a net benefit only when little or no secondary weight is included; at secondary weight ratios of 0.50 and above the results shift toward or show net losses.

- The chance for rear bumper systems to achieve net benefits is very limited. Rear bumper systems for 1979-80 models weigh some 20 pounds less than their 1974-78 predecessors, and 8 pounds less than their front counterparts.

- Downsizing through weight reduction and material substitution appeared to have no effect on either the damage reducing capability or cost effectiveness of front bumpers. It may have had a slight aggravating effect on rear end protection.

- While a series of secondary effects such as time and insurance cost savings, the value of unrepaired damage, additional interest cost on car loans due to added bumper costs, etc., can affect net benefits (or losses), reliable data are difficult to obtain. Estimates, of such effects, when available should be considered, as an adjunct to the primary results.

- The mix of the car fleet can be a significant factor affecting both damage frequency and net benefits. How bumper systems fare when small cars predominate would require assumptions beyond the scope of this evaluation.

CHAPTER III

COLLECTING CRASH DAMAGE DATA

1.0 ESTABLISHING DATA REQUIREMENTS

1.1 Introduction

This chapter deals with the subject of collecting data on changes in damage resistance and any resulting changes in repair costs. The next chapter presents the findings of the analysis of this data. Changes in costs due to weight, material, or other changes necessitated by the standard are covered in Chapter V. Finally, Chapter VI compares the overall benefits derived from damage reduction with the total costs of providing increased exterior protection and includes an analysis of the standard's cost-effectiveness.

1.2 Measures of Effectiveness

An evaluation of the effectiveness of the bumper standard basically compares the amount of crash damage to vehicles that were not required to comply with the standard with the damage sustained by vehicles that had to comply with some version of the standard. Such an analysis should also make comparisons between vehicles meeting different versions of the standard to determine if one version has been more effective in reducing damage than another. In making these comparisons there are two quantities which measure the effectiveness of the bumper standard--frequency of damage and extent of damage.

1.2.1 Frequency of Damage

The question of the probability or frequency of damage is a very important one because this standard's principal goal is to reduce property damage in low-speed collisions. It is a two part question:

How many low-speed bumper-related accidents was a particular model year vehicle involved in, and did any damage occur given that a bumper-involved accident took place. The ratio of the number of low-speed bumper accidents in which damage occurred, to the total number of low-speed bumper accidents, is the probability or frequency of damage. Given a population of low-speed collisions and assuming a similar distribution with respect to impact speed for both pre- and post-standard cars, the changes in damage frequency will reflect the degree of effectiveness of exterior protection provided on post-standard vehicles.

1.2.2 Extent of Damage

The second measure of effectiveness is the extent of damage in low-speed collisions. There are several ways to measure this: The number of damaged parts, the number of damaged parts by degree of damage, and the cost to repair the

The "number of damaged parts" measurement is a simple count of how many bumper and safety-related parts were damaged. Such a count is deficient in that it does not reflect the severity of damage to the parts or the relative value of the parts. For example, two vehicles may have the same number of parts damaged; however, one vehicle may have a scratched or chipped headlamp while the other may have a trunk lid so deeply creased that it will not open. Clearly the second vehicle's damage is much worse and will be more costly to repair.

This deficiency can be corrected somewhat by including a qualitative determination of how severely a part is damaged. For example, damage might be classified as being either major or minor or requiring either repair or replacement. Such a measure, while an improvement over a simple count, is difficult to use in making comparisons between benefits and costs of the standard since it can only indicate shifts in the severity of damage to individual parts and gives no single estimate of the overall change in the extent of damage.

Using an estimate of the cost to repair damage eliminates many of the problems of the other two measures. It is a single value reflecting the severity of collisions involving damage to the bumper system and safety-related parts. Comparisons can then be made between pre- and post-standard vehicles, and vehicles meeting various versions of the standard, i.e., comparisons between the benefits of the standard (the change in the cost to repair damage) and the change in the cost of the bumper system.

1.2.3 Bumper Override and Underride

A second purpose of the bumper standard is to reduce the incidence of bumper override and underride. Compliance tests, beginning with model year 1974, required pendulum impacts within specified bumper height limits, the objective being to standardize bumper heights on post-standard cars and thereby reduce the incidence of bumper mismatch. The measure of whether or not the standard has been effective in achieving this goal is the change in frequency of mismatch between cars that did not have to pass the pendulum impact test (pre-1974 models) and those that did (1974 and later models).

Given an incidence of bumper mismatch, the measures of effectiveness are identical to those for low-speed accidents--frequency of damage and extent of damage.

1.3 Low-Speed Collisions

The main focus of the bumper standard is on low-speed collisions. But what are low-speed collisions and how can they be identified? Only estimates of speed can be obtained from drivers since most are not looking at their speedometers when collisions occur, and, even if they are, car speedometers are often not accurate.1/ Therefore, it is important to put limits on what is considered a low-speed collision. Two such bounds were put on the data collected--accidents causing injuries were not included, and only vehicles that could be driven away from the accident (non-towaways) were used.

1/ The accuracy range of most speedometers is within ± 4 mph (49FR6404, January 28, 1980). Such a range is considerable in light of the 5 mph or less compliance testing speeds for the bumper standard.

There is little information at the local, State, or national level on the number of accidents that occur at various speeds, especially the lower speeds. Low-speed collisions often result in little or no damage and seldom is anyone injured. This means that the police or insurance companies may not be notified and that the occurrence of the collision is not recorded.[2]

In accident analysis the amount of damage is often used as a surrogate measure of collision speed. Clearly such an approach is not feasible for the bumper standard since extent of damage is a measure of effectiveness and is expected to differ between different model year vehicles traveling at the same speed. However, from the purely energy management design perspective, bumpers are intended to be effective in preventing superficial vehicle damage. When the collision speed exceeds a certain threshold, bumpers are not physically capable of absorbing all the impact energy and the vehicle frame or other main body structure or system is damaged. When this happens the auto usually cannot be driven from the scene of the accident. Therefore, low-speed collisions would not include vehicles that must be towed away after the accident.

2/ Police reports are only required when damage exceeds a certain dollar amount or when persons are injured. When the damage is below a driver's deductible for collision insurance (typically $100), an insurance claim may not be filed. When no damage occurs as the result of a low-speed collision, there is generally no need to report the accident at all.

1.4 Required Data

The first requirement of a data source is that it contain enough information to identify an accident as being in the low-speed range. In other words, it must be ascertained whether any injuries occurred in an accident and if the vehicle(s) involved could be driven from the scene of the accident. For an accident to be included in the evaluation of the bumper standard it must cause no injuries and the vehicle(s) involved must be driveable after the accident.

A second requirement is that a data source must include the model years of the vehicles involved in these low-speed collisions. With model year data, vehicles can be grouped as pre- or post-standard or by the version of the standard under which they are covered (if any) so that comparative analyses can be made between the groupings.

What other data elements can and need to be collected is highly dependent upon the source used. However, the measures of effectiveness indicate, in general, the types of data required. Basically the following data are needed:

- The number (frequency) of low-speed bumper collisions included in the data source.
- The probability of <u>any</u> damage, given that an accident of interest occurs.
- The amount (extent) of damage to the bumper system and safety-related parts protected by the bumper. Data needed to measure this include:
  - the number of parts damaged,

- the severity of damage to each part,
- dated repair estimates or bills (the date is needed to account for inflation),
- an insurance claim, or
- a cost estimate of damage, obtained from information on the number of parts damaged and the severity of damage.

o In a two-vehicle collision, did the bumpers meet or did one bumper override the other?

Data sources should be sought which provide information about the circumstances of a collision and the vehicles(s) involved. Such information can be used to explore biases and to make comparisons within the data. Information of interest includes:

o vehicle data--make, model, size, use and miles travelled annually;

o accident configuration--estimated impact speed, angle of collision, and object struck;

o accident setting--traffic conditions, location, and environmental factors.

2.0 DATA SOURCES

2.1 Introduction

In earlier methodology development work,[3] no data sources were found that could accurately estimate the total benefits of the bumper standard over the life of a car. The main evaluation problem has been a lack of data describing real-world low-speed collisions. Often these accidents involve little or no damage and are never reported to the police or an insurer.

Consideration of the courses of action a vehicle owner might take after a collision indicates possible sources of data on low-speed crash damage. If no or slight damage occurs, the accident may never be reported to the police or an insurance company. Only the occupants of the vehicles involved are likely to know the details of the collision. If damage does occur, there are several possibilities--the police may be notified, an insurance claim may be filed, both may occur, or neither may occur. Regardless of whether or not the accident is reported, the owner has the options of having the car repaired, repairing it himself, or leaving the damage unrepaired.

3/ Two methodology studies for FMVSS 215 were prepared for the National Highway Traffic Safety Administration:
- o Stanford Research Institute, Evaluation Methodology for Federal Motor Vehicle Safety Standards, Report No. DOT-HS-802-341 (May 1977).
- o Center for the Environment and Man, Final Design and Implementation Plan for Evaluating the Effectiveness of FMVSS 215: Exterior Protection, Report No. DOT-HS-802-344 (May 1977).

The following potential sources of real-life data were identified during the early work on methodology development for this and other motor vehicle safety standards:[4]

- Police accident reports
- State accident records
- National accident records
- Repair shop, garage and body shop records
- Auto parts sales and inventory records
- Towaway business records
- Inspection of automobiles in parking lots
- Insurance claim files
- Surveys of automobile owners or drivers

Each source's potential for providing the data needed to evaluate the bumper standard will be discussed below.

2.1.1 Police Accident Reports

Police accident records include those accidents that are either investigated by police departments or reported by drivers in accidents. Police officers usually investigate injury accidents and those which involve extensive property damage. Similarly, drivers involved in property damage accidents are usually required to submit a report to the police when the estimated damage exceeds a certain amount. The reporting threshold varies from State to State and is raised

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[4] Ibid.

periodically to reflect inflation. This means that a low-speed collision with only minor property damage is not likely to be investigated by a police officer or reported by a driver.

Even if a report is filed, its focus is typically on the cause of the accident rather than the damage that occurred. The main use of police reports is to determine if any traffic violation was committed and to document evidence for damage suits. In the case of low damage, non-personal injury collisions, even the latter use is rare since generally the driver at fault has adequate insurance to cover repair costs.

Due to their minor nature and limited usefulness to police departments, records of low damage, non-injury accidents are rarely abstracted or compiled for analytic purposes and are usually only held for a short time at local precincts.

While a study of local police accident records might indicate whether there has been a shift in the distribution of crash damage away from bumper areas, the numerous difficulties with these records make them an unusable source of data. In summary, these problems include:

- Low damage accidents are generally not recorded.
- Due to differing reporting thresholds, the damage severity level of recorded accidents varies among the States.
- Police records lack data on damage.
- Searching these records would be extremely time-consuming and expensive since

- there are many police jurisdictions, each holding a low volume of data, and
- the records are seldom abstracted or compiled.

o Records of minor damage, non-injury accidents are generally kept for only a short time.

2.1.2 State Accident Records

State accident records are compiled from State and local police accident records. As with the local police records, these files were considered for use in a study of whether there has been a shift in the distribution of crash damage away from bumper areas. The main advantages of State files over local police accident records are that the former contain a much larger volume of data and have in many cases been automated, making them much more accessible and useful. In addition, the files often contain pre-standard vehicles which were involved in accidents while they were still "young."

However, many of the problems mentioned in Section 2.1.1 on police accident records are also problems here. Since State files are compiled from local police files, many of the accidents the bumper standard is concerned with, i.e., low speed collisions causing little or no damage, are again not available. A second major problem is that these summary records lack detailed information on key variables such as vehicle damage.

Information obtained on vehicle damage varies from State to State. Most States limit their questions on damage to the location of damage and the dollar amount to repair the damage (estimated by the driver involved or the police officer investigating the accident). Some States ask for a written description of the damage. Some request that damage be classified on a severity scale. For example, a respondent might be asked whether damage was "none," "minor," "moderate," "major," or total." However, terms such as "minor" and "major" are not defined for the respondent.

Two States, North Carolina and Texas, now use the Traffic Accident Data (TAD) vehicle damage scale.[5/] (Texas has used the TAD scale since 1971 and North Carolina since 1973.) This scale defines damage severity through the use of pictures of damaged vehicles. However, even this rating scale is not sensitive enough to detect changes in the kind and amount of damage generally found in low-speed collisions.

2.1.3 National Accident Records

The National Highway Traffic Safety Administration (NHTSA) presently maintains, or has compiled in the past, several files of data on accidents occurring throughout the Nation. These files include only police-reported accidents. For the most part, these national records contain data on accidents involving fatalities, injuries, and towed vehicles. The problem with using such files to

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5/ National Safety Council, Vehicle Damage Severity for Traffic Accident Investigators (2nd ed.)

evaluate the bumper standard is that the type of accident the standard is concerned with, i.e., low-speed collisions, seldom causes fatalities, injuries, or enough damage to necessitate towing.

NHTSA files include the Fatal Accident Reporting System (FARS), the Multidisciplinary Data Accident Investigation (MDAI), the National Crash Severity Study (NCSS), and the National Accident Sampling System (NASS). FARS is a case file of all accidents involving at least one fatality. The MDAI file contains primarily special or catastrophic accidents. This is an older file, no longer being updated. NCSS, now supplanted by NASS, is a limited sample of towaway accidents. NASS is a potential source of data but has not yet been completely inplemented. Eventually NASS will include some low-speed non-towaway accidents; however, at present, plans are to undersample these accidents. In order to use data from NASS for evaluating the bumper standard, special in-depth studies of front and rear end low-speed collisions would have to be implemented into the system.

2.1.4 Repair Shop Records

Repair shop, garage, and body shop records were considered as a possible source of collision damage and repair cost data. However, the problems with obtaining useful data from this source were overwhelming. First, going through repair records to separate bumper-related accident repairs from other accident and non-accident repairs would be very time-consuming. The amount of order and detail would vary from shop to shop. Second, the number of shops that would have to be contacted to obtain an adequate sample size would be enormous.

Finding data on pre-standard vehicles would be particularly difficult since repair records would generally only be available for recent years. A third problem is that the records would not contain information on the circumstances of the accident (speed, object struck, etc.). Finally, the more severe accidents would be overrepresented in these records since damage due to minor accidents often goes unrepaired even if an insurance claim is filed.

2.1.5 Auto Parts Sales and Inventory Records

Automobile parts are sold in dealerships, automotive supply stores, department stores, and service stations. Certain parts, e.g., lenses to taillights, are model and model year specific. Analyzing the time trend of sales of such parts in relation to parts not protected by the bumper standard could indicate an effect of the standard.

This approach has little promise of success for the following reasons:

- o Inventory policies often have more to do with when parts are reordered than sales.
- o Few parts are model/model year specific, and parts departments would not generally have records identifying the vehicle for which a part was purchased.

- o Parts are sold for uses other than accident damage repair. For example, some parts such as headlamps may need to be replaced as a result of normal usage.
- o No information on the circumstances of accidents can be obtained from this source.

2.1.6 Towaway Service Records

An analysis of current towaway accidents was proposed[6] to determine if vehicles with post-standard bumpers had to be towed less often than pre-standard cars. This approach uses the fact that some of the parts protected by the standard (e.g., the fuel, cooling, and propulsion systems) are necessary for the operation of the vehicle. This data source was rejected since one of this study's criteria for an accident to be classified as low-speed is that the car involved can be driven from the scene of the accident (see Section 1.3 of Chapter III).

2.1.7 Inspection of Automobiles in Parking Lots

Parking lot surveys of cars can provide information on unrepaired damage. This is one possible method for finding out about damage in low-speed accidents, many of which may never have been reported to the police or insurers.

6/ Center for the Environment and Man, p. 2-2.

However, without considerable follow-up with vehicle owners, there would be no way to know what caused the damage. If the damage was accident-related, did it occur in one or several accidents and were these accidents reported? Such a survey underrepresents the frequency of accident involvement since vehicles in accidents causing no damage or for which damage has been repaired are not included.7/

Since this method would require a follow-up contact with vehicle owners, it was rejected in favor of a random survey of vehicle owners and drivers, discussed in Section 2.1.9.

2.1.8 Insurance Claims Files

Collision and liability are the two major forms of property damage insurance coverage. Collision insurance provides protection for the insured driver who is at fault by covering the damage to the insured driver's car. Liability insurance protects the driver at fault by paying for damage to the other car. (Liability claims are also made for personal injury, but such accidents are not included in the definition of low-speed collisions for this evaluation.)

The other forms of automobile insurance include comprehensive, medical payments, uninsured motorist, and no-fault. Comprehensive insurance covers fire, theft,

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7/ These parking lot surveys were reviewed for potential use in selecting the survey methodology:

- S.J. Sterback and E. J. Rohn, Ford Motors Co., "1975 Model Extended Time in Service and Initial 1976 Model Bumper Effect on Ford Car Accident Damage," May 19, 1977.
- General Motors," Passenger Vehicle Impact Damage Survey," January 17, 1973.

and accidents where no one in particular is at fault. Medical payments are like a liability insurance for injuries. It pays for the injuries to the insured driver and his or her passengers. Uninsured motorist coverage is for situations where the other driver is at fault but has no liability insurance. Recently, several States have enacted laws requiring no-fault insurance. This form of insurance combines collision, liability, medical payments, and uninsured motorists into one type of insurance. The insurance company of each insured driver pays for all property damage to the driver's car and injuries to occupants of that car.

Potentially the bumper standard could have several effects on automobile insurance since insurance claims are essentially a surrogate measure of property damage. If the standard reduces the freqency of damage in low-speed bumper-involved collisions, there should be fewer property damage claims involving bumpers of post-standard cars than there are for pre-standard cars. The average amount of these claims should also be lower for post-standard vehicles (once adjusted for inflation) if the standard is effective. These two effects could produce a third one, namely, lower insurance premiums for post-standard vehicle owners.

Simple statistical analysis techniques are available to handle comparisons of claim frequency and average claim cost. However, a method for measuring changes in insurance premiums caused by the implementation of the bumper standard could not be found. Even though discounts were given by some insurance companies, there is no way of knowing if the discounted amount was actually realized by the insurance companies, if other forms of insurance cost more, or if drivers of older cars actually paid more to compensate for the new car discounts. In addition, the effect of inflation distorts any study of the effect of the standard on premiums.

There are millions of insurance claims processed by automobile insurance companies each year and the cost of manually screening insurance claim files is time-consuming and expensive. Fortunately, two computerized insurance files are presently available--State Farm and the Highway Loss Data Institute (HLDI) files.

State Farm Insurance Company maintains a detailed data file of a sample of claims made at its drive-in claim centers throughout the country. The file contains data for claims on both pre-standard (1969-1972) and post-standard (1973-present) vehicles. Both collision and liability claim data are included. Coded, raw data are available in addition to summary data.

The computerized HLDI files contain data from many major insurance companies including State Farm. No liability or pre-1972 claim data are available on these files. The level of data stratification possible with the State Farm base is not obtainable from this source.

There are several difficulties with using these two files:

- No adequate description of the crash environment can be retrieved from the insurance data base. Therefore, damage itself becomes, in effect, a surrogate measure of the accident impact speed. This is a problem since frequency and extent of damage are measures of effectiveness of the standard. Thus, there is a danger that the effectiveness of the standard will be underestimated. If the post-standard bumper is effective, then damage sustained by a pre-standard car in a low-speed collision should be comparable to that sustained by a post-standard car in a higher speed collision.

- Any sample of insurance claims will not be representative of the entire accident population. Unreported accidents are obviously not included, and low-cost claims are less frequent because of the deductible amount.

- Two distinctly different kinds of insurance policies--collision and property damage liability--deal with vehicle damage. The first is limited to damage to the insured vehicle (and also to damage to other vehicles driven by the insured); the second covers all property damage of third parties. Collision claims tend to be higher than property damage liability claims since collision insurance often has a deductible amount which the policy holder must pay. Another reason for higher collision claims is that they tend to be for the more severe single car accidents, whereas liability cases include a preponderance of rear end accidents. These and other differences between liability and collision insurance need to be reconciled in order to combine the two types.

- Accidents outside the scope of this evaluation (i.e., side collisions, rollovers, towaways, injury-causing accidents) are included in the files.

- Stratification of data within the files dictate what analyses can be performed. HLDI data, for instance, is not stratified by impact point. Thus, this confounding variable could not be analyzed using the HLDI file.

- Although representative claim data exist in the HLDI files beginning in mid-1972, adequate claim data are not available for the years before 1972. Thus, analysis of pre-standard collision claims would be severely limited if the HLDI file was used exclusively.

- The State Farm file contains data for only one insurance company and therefore may not be representative of the insurance industry.

Most of these problems appear to be solvable if both of the computerized insurance data sources are used and data is collected on accidents for which no insurance claim is made. The State Farm file contains the detailed data needed to evaluate bumper effectiveness, historical data predating the bumper standard, and both collision and liability claim data. The HLDI data can be used for comparisons at an aggregate level with State Farm summaries to determine the extent to which the State Farm data represents the insurance industry.

2.1.9 Surveys of Automobile Drivers

This approach involves soliciting information directly from the public using established sampling techniques. Since the principal driver is the person most likely to know of minor collisions, he or she is potentially the best source of data on low-speed, unreported accidents. Drivers can be questioned about any low-speed collisions their cars were involved in, and the damage, if any, sustained. In addition, data can be obtained on the car itself, the use of the car, and the circumstances of any collisions.

There are two potential problems with public surveys. One is the willingness of individuals to participate and the other is the accuracy of the information they provide. Both difficulties can be lessened through appropriate selection of a survey method or combination of methods. Basically, three survey methods are available--in-person, telephone, and mail (self-administered). Each method has advantages and disadvantages.

The mail or self-administered approach is the least expensive method of the three. Either randomly selected households or households owning a randomly selected registered vehicle can be mailed a questionnaire. (However, current vehicle registration data is difficult to obtain.) Use of the mail is a slow process usually yielding a low return rate even with considerable follow-up. This approach relies on the ability of participants to accurately complete a questionnaire without an interviewer's assistance. The advantage of the method is that participants have records and other household members available for consultation in answering the questionnaire.

Surveying drivers in person has the appeal of being able to observe the automobile while questioning the driver. This method does not have to rely on a participant's ability to estimate extent of damage as the mail and telephone surveys do since the interviewer would presumably be trained to make these estimates. However, people may be reluctant to spend time being questioned unless they are forewarned about the interview. Depending on where the interview is held (e.g., parking lot, service station, state inspection center), the participant may or may not have access to household records or family members to help fill in data gaps. Assuring that a sample is random and representative is also a problem in doing in-person interviews at certain locations. Finally, face-to-face surveys are expensive.

The telephone method has the advantage of immediate feedback from drivers. Participants at home generally have access to records and others in the household to help recall the details of an accident. People often feel less threatened answering questions over the phone than in person and thus are generally more willing to participate and more candid in their answers. As in the mail survey,telephone surveys have to rely on the participant for estimates of damage, a determination that the participant may not have the technical background to make.

A telephone survey assumes that a random selection of households with phones will also result in a random and representative selection of automobiles. The problem with this assumption is that a household may not have a phone but may have a car and that these "phoneless" households may also have older model year vehicles.

The National Housing Survey done in 1975 showed that overall, more than 80 percent of all U.S. households had at least one car. The percent of households with cars ranged from a little less than 50 percent for low income families to 100 percent for upper income families.[8/] In contrast, almost 90 percent of all households had a telephone in 1978. Breaking this down by income, 70 percent of low income families and almost 100 percent of higher income families had phones.[9/] This means that for all households there is a greater likelihood that there will be a telephone than there will be an automobile (70 percent of the low income families had a phone, but only 50 percent had cars). Therefore one can assume that few households having a car, but no phone, will be missed by the telephone survey.

8/ U.S. Departments of Commerce and Housing and Urban Development, Annual Housing Survey: 1975, Part C: Financial Characteristics of the Housing Investory, Current Housing Reports, Series H-150-75C (Washington, D.C.: Government Printing Office, 1975), p.3.

9/ Owen T. Thornberry and James P. Massey, "Correcting for Undercoverage Bias in Random Digit Dialed National Health Surveys," American Statistical Association Proceedings of the Section on Survey Research Methods, 1978, pp. 224-229.

For both the in-person and telephone methods, having someone administering the survey can be helpful in obtaining more accurate data. A trained survey-taker can ask questions that will help a participant remember dates and events. Such questions would not normally be asked on a mail-out survey.

Combinations of survey techniques can also improve survey response and accuracy. For example, follow-up to any of the survey methods might include a phone call, a post card, or a visit.

2.2 Selection of Data Sources

Two different data sources were selected for use in the evaluation of the bumper standard. The two chosen were: insurance claim files and the survey of vehicle drivers. In Section 2.1 the advantages and disadvantages of these two data bases were discussed in detail along with those of other potential sources of low-speed collision data.

Specifically, the computerized State Farm Insurance Company file was selected as the primary source of insurance data. The State Farm file contains the detailed data needed to evaluate bumper effectiveness, historical data predating the bumper standard, and both collision and liability claim data. Statistical analysis techniques are available to handle comparisons of claim frequency and average claim cost, the two measures of effectiveness.

An additional source of insurance claim data--the Highway Loss Data Institute (HLDI) file--was also used as a check on whether the State Farm data was representative of the insurance industry as a whole. The HLDI file contains data from many major insurance companies including State Farm. Its availability enabled comparisons to be made at an aggregate level with State Farm summaries.

The primary deficiency of the insurance claims analysis is the bias introduced by unreported damage loss. To determine the magnitude of this bias, a second source of data was needed. Of the sources of data on low-speed unreported collisions described in Section 2.1, the survey of automobile drivers was the most direct and fruitful method of obtaining this information. Since the principal driver is the person most likely to know of minor collisions, he or she is potentially the best source of data on low-speed unreported incidents.

A combination of survey techniques was chosen. The principal data collection effort was the household telephone survey. This method held the most promise of obtaining a good response rate in a timely fashion. One advantage of a household telephone survey is that respondents are at home where records and other family members are generally available to help fill in any data gaps.

Another consideration in doing a driver survey was that drivers might not have the technical background or experience to accurately access the extent of damage. To overcome this problem a portion of the surveys were taken in-person to spot-check the accuracy of participants' responses.

3.0 DATA SOURCES USED IN STUDY

3.1 Driver Survey

One component of the data collection process was a survey of car owners and drivers. The purpose of this survey was to obtain data on unreported, low-speed collisions. The survey, conducted under contract,[10/] included three phases: design phase, pilot survey, and national survey. Each phase is briefly described in the following paragraphs.

During the design phase a work plan, survey instruments, procedures, and manuals to be used and tested during the pilot survey were developed. Work began on these documents in October 1978. In March 1979, the Office of Management and Budget[11/] approved the survey design, clearing the way to begin the pilot survey.

10/ Information for Section 3.1 was taken from a report prepared for the National Highway Traffic Safety Administration for use in this evaluation: Westat, Inc., Driver Survey on Unreported and Low-Damage Accidents Involving Bumpers: Final Report, Report No. DOT-HS-805-838 (May 1980).

11/ All Federal surveys of the public involving more than nine individuals must be reviewed by the Office of Management and Budget to assure that the summary is necessary and minimizes the burden placed on the public in responding to the survey.

The pilot survey was run for six months (mid-March through early September 1979) in Montgomery County, Maryland. Approximately 1,100 county households were contacted through a random digit telephone dialing system. One or two months after the initial interview, about 800 of these households were contacted again. Of these follow-up contacts, 20 percent were in person and 80 percent were by phone.12/

The purposes of the pilot survey were to detect possible problems with survey instruments and procedures and to obtain estimates on the number of households that would need to be contacted to obtain a nationally representative sample. Drawing upon experience and estimates gained from the pilot survey, the national survey was conducted.

Between September 1979 and June 1980, 10,326 households throughout the nation were contacted. Approximately half of these households were recontacted about two months after the first interview. Of the follow-up contacts, 90 percent were by phone and 10 percent were in person.

The following subsections describe the design of the national survey.

12/ For a more detailed description of the procedures used and results obtained in the pilot consult: Westat, Inc., Drivers Survey on Unreported and Low-Damage Accidents Involving Bumpers: Final Report - Pilot Study, (September 1979).

3.1.1 Survey Overview

The nationwide driver survey was conducted under a design which would yield a statistically valid sample of unreported, low-speed collisions. Basically, there were three problems in obtaining such a sample. First, since the low-speed incidents of interest were relatively minor, they might be difficult to remember. Second, due to the low incident rate of these accidents, considerable screening of respondents would be necessary to obtain information on incidents of interest. Third, respondents might not be able to report accurately about vehicle damage due to diminished recall or because they did not have the technical background to describe the extent of damage accurately. Each of these problems had to be dealt with in the survey design.

The survey plan that was developed overcame the problems identified above in the following manner. The plan allowed for estimating response bias due to memory recall. Information was collected on incidents occurring during a six month retrospective period at the time of original contact and again at the end of a bounded prospective follow-up period. The follow-up data collection provided statistics for measuring the recall bias during the six month retrospective period.

To contact the number of households needed to obtain the desired number of incidents and still stay within a reasonable cost, a random digit dialing telephone survey methodology was employed. However, some households were visited in person and the cars used by household members inspected. The in-person interviews and car inspections were used to verify the accuracy of the information collected during the initial contact and the follow-up interview.

3.1.2 Survey Design

In order to locate households, a random digit dialing procedure was used.[13] While this technique excludes households without phones from the sample, the sampling bias introduced was not expected to be important. Households without telephones are more likely to have lower incomes, and are, therefore, more likely to have older vehicles. However, this difference does not introduce a bias in measuring bumper effectiveness since bumper system performance should be independent of household characteristics.

After ascertaining that a household had at least one car and one licensed driver, a screening questionnaire was used to obtain basic information about the household vehicles (e.g., make, model, year, mileage in last six months). Next, data was collected from each principal driver (i.e., the person who drove the car most of the time) on whether a low-speed collision to the front or rear of a car had occurred during the preceding six months. If such a collision had taken place, households were asked whether the incident had been reported to the police or an insurance company and if the car could be driven after the accident.

13/ This time and cost-saving method of obtaining a random national sample reduces the number of calls needed to reach a working residential phone number, whether or not it is listed in the phone book. This method is fully described in the Westat final report (footnote 7).

If the low-speed collision was not reported to the police or an insurance company and the car was driveable after the accident, an interview was conducted with the person knowing the most about the incident. In the main interview, data was collected on the characteristics of the incident (i.e., object contacted, location of contact, speed, place), the amount of damage to property and/or people, and the exposure of the car (i.e., type of driving).14/

Upon completion of the screener or main questionnaire, the respondent was asked to participate during the two month follow-up period. Immediately following the initial contact, respondents were sent a log in which they could record data on incidents if they occurred during the follow-up period. In addition, about one month after the initial contact, participating households were sent a postcard reminder. For the follow-up period interviews, about 90 percent of the respondents were recontacted by telephone and the remainder were visited in person at which time vehicle inspections were conducted. The in-person vehicle inspection provided visual verification of information collected during the initial telephone interview, i.e., the presence or absence of damage to the car under study. Questions asked during the follow-up paralleled those asked during the initial interview.

14/ Copies of the questionnaires used are available in the Westat final report, pp. D-41 through D-81 (footnote 7).

3.1.3 Representativeness of Sample

The 6,996 households that were eligible in the main survey (i.e., those having at least one licensed driver and one vehicle) and willing to participate in the national survey had over 12,000 passenger cars. Table III-1 shows the breakdown of these vehicles by the model year groupings which coincide with the different versions of the bumper standard. (An additional 3,277 households with 2,854 1979 and 1980 model year cars were subsequently contacted in the summer of 1980)

TABLE III-1

NUMBER OF SURVEYED VEHICLES BY MODEL YEAR

MODEL YEAR GROUPING	NUMBER OF CARS
Pre-1973	4,156
1973	1,041
1974-78	5,624
1979-80	1,227
TOTAL	12,048

Because the initial phone interviews took several months to accomplish, the actual time span of the survey was about ten months, May 1979 to February 1980. Over this time span, older cars were scrapped and new 1979 and 1980 models were purchased. In addition, cars of all ages were bought and sold. Therefore, the model year mix was continually changing over the survey period. Table III-1 includes any cars owned by the surveyed households during an eight-month period--the six months prior to and the two months following the initial phone interview. These vehicles were not necessarily held the entire eight months.

As a check on whether a representative sample of the Nation's automobiles had been obtained, the survey's model year mix data was compared with U.S. vehicle registration data. From the 1980 Market Data Book Issue of Automotive News, U.S. automobile registration data as of July 1, 1979 and new car sales data through December 1979 were obtained.[15/] To arrive at the model year mix for 1979, the registration data was adjusted with the 1979 new car sales data. Table III-2 compares the survey data with the adjusted national automobile registration data.

TABLE III-2

MODEL YEAR DISTRIBUTION OF PASSENGER CARS

MODEL YEAR GROUPING	PERCENT SURVEYED	PERCENT REGISTERED
Pre-1973	34.8	38.3
1973	8.6	9.2
1974-78	46.9	42.7
1979-80	9.7	9.8

15/ Automotive News: 1980 Market Data Book Issue, April 30, 1980, p.12 (new car sales data) and p. 22 (registration data)

The survey and national distributions are very similar with differences appearing as expected. The survey distribution has fewer older cars and more late model cars than the national distribution does. This was expected since the survey is based on a more current time period. The percentages of 1979 cars are quite close because both sets of data were based on essentially the same time period. From the comparison of the two distributions, the model year distribution of cars surveyed adequately represents the national distribution.

Another test of the representativeness of the survey was done using 1977 national driver license data[16/] and 1977 national housing data on the average number of cars per household.[17/] The comparisons are shown in Table III-3. The survey found fewer drivers and more cars per household than the national data shows. Considering the age of the national data, the comparisons indicate that the survey data describes the Nation's population of licensed drivers and cars fairly well.

TABLE III-3

AVERAGE NUMBER OF CARS AND LICENSED DRIVERS PER HOUSEHOLD

	SURVEY DATA	NATIONAL ESTIMATES
Drivers	1.76	1.82
Cars	1.41	1.34

16/ 1977 driver license totals compiled by the Federal Highway Administration

17/ U.S. Departments of Commerce and Housing and Urban Development, Annual Housing Survey: 1977, Part A: General Housing Characteristics, Current Housing Reports, Series H-150-77 (Washington, D.C.: Government Printing Office, 1977), p.8.

3.1.3 Eligible Incidents

The 12,000 cars surveyed were involved in 1483 low-speed front or rear collisions during the six month recall period before the survey and the two month follow-up period. Table III-4 shows the distribution of these collisions by reason for ineligibility and by model year groups.

TABLE III-4
DISTRIBUTION OF LOW-SPEED INCIDENTS BY MODEL YEAR AND REASON FOR INELIGIBILITY

MODEL YEAR GROUP	INSURANCE CLAIMED (%)	POLICE REPORTED, NO INSURANCE CLAIM (%)	VEHICLE UNDRIVABLE, UNREPORTED(%)	UNREPORTED ELIGIBLE (%)
Pre-1973	30	10	1	59
1973	32	4	1	62
1974-78	32	7	0	60
1979-80	29	4	0	66
TOTAL	31	7	1	61

As shown in Table III-4, approximately 61 percent of the screened low-speed collisions involving the front or rear of a vehicle were eligible for the survey, i.e., 61 percent were not reported to the police or an insurance company, and the cars involved could be driven after the accident. Claims were made to an insurance company for about 31 percent of the low-speed collisions. Thus, about 92 percent of the screened incidents were eligible for inclusion in either the survey or in the analysis of insurance claims (Section 3.2).

3.1.5 Incident Rates

The rate of incidents reported in the national study was found to be much lower than the rate experienced in Montgomery County, Maryland, during the pilot test. During the recall period, the unreported incident rate was an average of 0.012 collisions per car per month. The follow-up survey came up with an unreported incident rate of 0.010 collisions per car per month.

Each of the two phases of data collection, retrospective vs. follow-up, has its strong and weak points as far as its usefulness in making estimates of incidence rates. The follow-up data will not have the memory bias of the retrospective data, but it will have a relatively higher variance because of the shorter collection period (2 months). The retrospective data, while biased by drivers' inability to remember low-speed collisions, will have a small variance because of a longer collection period (6 months). Using a procedure which adjusts the data for bias by combining the recall and follow-up estimates (see Appendix A for a description of this procedure), the monthly rate for unreported, low-speed collisions was estimated to be 0.0114 incidents/car-month. Thus, approximately 13.7 percent of all cars-on-the-road are involved in a low-speed unreported accident each year.18/

18/ The parking lot surveys (footnote 7/) estimated 3.63 to 4.18 lifetime accidents per car. The driver survey showed that 22 percent of cars on the road were involved in low speed front or rear bumper accidents each year. Over a ten year car life this would be 2.2 collisions per car. The parking lot surveys included more than front and rear collisions whereas the driver survey was a partial slice in time and did not include seasonal and year-to-year variations. No precise measure of lifetime accidents - reported and unreported currently exists, but the driver survey incident rate can be considered a conservative estimate.

the frequency of damage to cars in unreported, low-speed collisions in a comparison of pre-standard (pre-1973) cars with all post-standard cars (1973 and later). Granted the data will need to be stratified further (e.g., pre-1973 cars vs. 1974-78 cars) to compare versions of the standard; however, these subgroups are too small to base the design on at the level of precision desired.

To calculate what percent change in damage frequency could be detected, assumptions had to be made about the frequency of unreported low-speed collisions, household characteristics, participation rates, and the probability of obtaining a working residential number. Pilot study results were used to estimate these parameters.

The following estimates were obtained from the pilot study:

- Frequency of unreported low-speed accident involvement = 2.4-3.6 percent/car-month
- Average number of cars/household = 1.55
- Households having both a car and a licensed driver = 88.6 percent
- Households willing to participate = 79 percent
- Percent of dialed phone numbers that are working residential numbers = 63 percent

3.1.6 Sample Size and Survey Assumptions

The first question to be answered in determining sample size is what will the data be used for. Basically, the survey data will be used to detect any difference in A budgetary restraint set the upper limit on the number of households to be contacted at 11,000. Working from this number, the number of unreported low-speed involvements that could be investigated was found using the lower estimate of the frequency of unreported low-speed accidents (2.4 percent/car-month):

Telephone Attempts = 17,460

Residences Contacted (63 percent) = 11,000

Residences Participating (79 percent) = 8,690

Residences with Car and Driver (88.6 percent) = 7,700

Number of Vehicles (1.55 per residence) = 11,935

Unreported, Low-Speed Involvements (2.4 percent per month for 8 months) = 2,290

The difference in damage frequency (between pre-and post-standard cars) that could be detected with this sample of unreported low-speed involvements was calculated using the procedure for detecting a difference between proportions (α = 0.05 and β = 0.10).19/ The calculation showed that at least a seven percent difference could be detected.

In the national survey, 16,483 telephone attempts were actually made with 10,326 residences contacted. There were 6,996 eligible households (i.e., households having both a car and a driver) among the 8,759 residences that were willing to participate. An additional 3,277 eligible households with 2,854 1979 and 1980 model year cars were subsequently contacts in the summer of 1980.

19/ A description of this procedure and the calculations of the percent change that could be detected are available in Appendix B.

3.2 Description of Insurance Claim Analysis

Insurance claim files were the second source of data used in the analysis of the effectiveness of the bumper standard.[20/] Basically, two measures were used to determine from the insurance data if the standard is effective. The two measures, frequency of bumper-related insurance claims and average bumper claim amount, were computed and compared for the various versions of the standard to determine if their values differed significantly.

3.2.1 Measures of Effectiveness

Potentially the bumper standard could have several effects on automobile insurance. If the bumper standard reduces the frequency of damage in low-speed collisions, there should be fewer collision and property damage bumper-involved claims, and the average amount of claims should be lower for vehicles covered by the standard. These two effects should produce a third one, namely, lower insurance premiums for post-standard car owners. In fact, several insurance companies, beginning in 1973, gave their new car owners a reduced premium in the form of a discount on the cost of collision coverage.

Therefore, analyses of changes in three measures might be useful: (1) the number of bumper-involved collision and property damage liability claims; (2) the average bumper-involved claim cost; and (3) insurance premiums. These changes can be

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20/ Information for Section 3.2 was taken from a report prepared for the National Highway Traffic Safety Administration for use in this evaluation: KLD Associates, Inc., Analysis of Insurance Claims to Determine Bumper Effect on Crash Damage, Report No. DOT-HS-805-842 and 843 (March 1980).

measured by comparing vehicles made before any bumper standard was in effect with those produced after the standard was required. Also, changes should be measured between model year cars which correspond to the different versions of the bumper standard.

Methods of measuring differences in claim frequency and average claim costs were available, but no method for measuring insurance premimum changes, related to the implementation of the bumper standard, could be found. Even though discounts were given by some insurance companies, there is no way of knowing if the discounted amount was actually realized by the insurance companies, if other forms of insurance cost more, or if drivers of older cars actually paid more to compensate for the new car discounts. In addition, the effect of inflation distorts any study of the effect of the standard on premiums.

3.2.2 Types of Insurance Coverage

The types of insurance and their applicability were previously described in section 2.1.8. This includes collision, liability, medical payments and no fault provisions. To simplify the data collection process while obtaining the largest number of cases possible, the two major types of automobile insurance covering crash damage, collision and liability, were selected for study. Other forms of insurance could be eliminated because they involve relatively few or no claims for vehicle crash damage, the focus of the standard.

3.2.3 Sources of Insurance Data

Because there are millions of insurance claims processed by auto insurance companies each year and the cost of manually screening insurance claim files is time-consuming and expensive, only automated insurance data sources were considered. Two such sources of insurance data, the Highway Loss Data Institute (HLDI) files and the State Farm Insurance Company files, were found to be useful.

State Farm Insurance Company maintains a detailed data file of a sample of claims made at its drive-in claim centers throughout the country. The file contains data for claims on both pre-standard (1969-1972) and post-standard (1973-present) vehicles. Both collision and liability claim data are included. Coded raw data is available in addition to summary data.

The computerized HLDI files contain data from many major insurance companies including State Farm. No liability or pre-1972 claim data are available on these files. The level of data stratification possible with the State Farm base is not obtainable from this source.

The State Farm file was selected because it contained the detailed data needed to evaluate bumper effectiveness, historical data predating the bumper standard, and both collision and liability claim data. The HLDI data was compared at an aggregate level with State Farm summaries to determine the extent to which the State Farm data represents the insurance industry.

3.2.4 Description of State Farm Files

All pre-standard data (pre-1973 model year vehicles) were taken from a State Farm tape containing 1969 to 1972 model year vehicles, for which claims were made in the first quarter of 1972. This all-model-year tape contained about 33,000 claims. All 1972 vehicles that already met the bumper standard (mostly, General Motors full size cars) were eliminated.

Post-standard data (1973 and later model vehicles) were found on two groups of tapes. One group included only current model year vehicles and accidents (i.e., the 1974 calendar year tape contained 1974 model cars involved in collisions in 1974) and covered calendar years 1973 to 1978. The number of claims per model year tape ranged from 9,000 to 20,000. The second group of tapes having post-standard data contained all claims made in a particular calendar year for all vehicle model years. Tapes in this format were available beginning with the 1976 calendar year.

The data on State Farm tapes is restricted to the following reported claims:

- Only passenger cars
- Only damaged vehicles that were repairable (no "totaled" vehicles). Generally, damaged vehicles were driven to and inspected by local State Farm agents.
- Only collision and property damage accidents.

3.2.5 Stratification of the Data Base

Stratifications of the data (and thus the analyses that could be performed) were dictated by the State Farm Data tape format and contents. The following stratifications were used at some point in the analyses:

- Model Year
  - Pre-1973 Model Years (vehicles not required to meet any bumper standards)
  - 1973 Model Year (vehicles subject to the first version of FMVSS No. 215)
  - 1974 Model Year (a transition year which was analyzed both separately and in combination with 1975-78 model years)
  - 1975-78 Model Years (most vehicles had to meet all the bumper standard requirements)
- Age of Car
  - One-year-old vehicles (the main focus of the analysis)
  - Three-year-old vehicles
- Impact Points
  - Front
  - Front Corner
  - Rear
  - Rear Corner

- Market Class (defined by Wheelbase, WB)
  - Subcompact (WB ≤ 101 inches)
  - Compact (101" < WB < 111")
  - Intermediate (111" < WB ≤ 120")
  - Full-Size (WB > 120")
- Bumper Damage
  - Repaired
  - Replaced
- Object Struck
  - Fixed
  - Moving
- Type of coverage
  - Collision, deductible less than $100
  - Collision, deductible greater than or equal to $100
  - Liability
- Manufacturer
  - General Motors
  - Ford
  - Chrysler
  - All others
- Bumper Type
  - Steel
  - Aluminum
  - Soft-face (hybrid)

- Manufacturer
  - General Motors
  - Ford
  - Chrysler
  - All others
- Bumper Type
  - Steel
  - Aluminum
  - Soft-face (hybrid)
- Parts Damaged
  - Front head lamp
  - Tail lamp
  - Hood
  - Trunk
  - Front quarter panel
  - Rear quarter panel

4.0 USE OF THE DATA

The driver survey and insurance claim data will be used in the following chapter to determine how effective the bumper standard has been in reducing the frequency and extent of crash damage in low-speed collisions and the frequency of bumper mismatch. Subsequently, in Chapter VI, the gross lifetime benefits attributable to the standard will be compared with the standard's incremental lifetime costs to determine if the standard is "cost-effective," i.e., did the standard "pay for itself?"

CHAPTER IV

BUMPER STANDARD EFFECTIVENESS

1.0 INTRODUCTION

This chapter presents the results of the drivers survey on unreported, low-speed collisions and the analysis of insurance claims. Three measures of bumper effectiveness are analyzed:

- o Damage frequency
- o Extent of damage
- o Bumper mismatch frequency

Damage frequency is the percent of cars, on the road, damaged in low-speed collisions. A car was classified as "damaged" if one or more exterior parts in the front or rear was damaged. As discussed in Chapter III, the change in damage frequency between pre-and post-standard cars reflects the degree of effectiveness of exterior protection provided by bumpers on post-standard vehicles. (In this report, cars manufactured prior to the bumper standard are designated "pre-standard" and those made after the various standard requirements were effective, beginning with model year 1973, are referred to as "post-standard.")

Damage frequencies were computed using driver survey data on unreported, low-speed collisions. Damage frequencies for all post-standard cars were first compared with pre-standard cars. Then the damage frequencies for cars covered by various versions of the standard were compared with each other to evaluate differences in the effectiveness of the various versions of the bumper standard. The damage frequency analysis was further refined by separately comparing respective front and rear damage frequencies of pre-standard vehicles with post-standard frequencies.

The extent of damage for pre- and post-standard cars is another basis for evaluating bumper effectiveness. The damage amount, or extent, was measured using both driver survey data and insurance claim data. For each data source several measures were obtained, as follows:

Driver Survey

- o Number of parts damaged per car
- o Number of parts damaged by severity of damage
- o Repair costs of damage in unreported, low-speed collisions

Insurance Claims

- o The annual number of property damage insurance claims per insured vehicle
- o The annual number of bumper-involved property damage insurance claims per insured vehicle
- o Repair costs for front and rear damage
- o Repairs costs of damage to specific parts covered by the bumper standard

Since accident risk is directly associated with automobile use, the more miles a car is driven, the greater the chance of an accident. Insurance claims for cars of similar age were used in this analysis to minimize differences in vehicle use (exposure). This assumes that every car model in its first year is driven the same number of miles. However, a one-year-old 1972 model car may well have a different mileage history compared to a one-year-old 1979 model, due to changes in car usage since 1972. Mileage may also vary with vehicle size.

Insurance claim data were analyzed (number of claims) to determine the effect, if any, of vehicle use in different calendar years, and for different vehicle sizes. The annual miles driven by the average car (of all ages) for calendar years 1972 through 1977 were obtained by vehicle size. The mileage history each year of one-year-old cars was assumed to follow the same trend as the average car. Using 1972 as the base year and compact cars as the base vehicle size, an index of vehicle miles per year (Table IV-18) and vehicle size (Table IV-19) was constructed. The indices were applied to the number of insurance claims for each model car and the change in claims of pre- and post-standard cars were calculated (Table IV-20). (The method for calculating the indices and adjusting the number of claims is explained in Tables IV-18, 19 and 20.) The adjusted results were also statistically tested and compared with the unadjusted results to see if the outcomes on bumper standard effectiveness were different.

As vehicles age, their mileage history changes--both in the number of miles and the type of use. The bumper systems may also deteriorate with age, thereby affecting their ability to reduce damage in low-speed collisions. To account for vehicle age as a factor in bumper system effectiveness, insurance claims of one and three-year-old cars were compared.

The objective of the third measure of effectiveness, bumper mismatch frequency, is to determine whether regulating bumper height leads to damage reduction. Uniformity in bumper height should allow bumpers to meet on impact thereby enhancing the bumper's protective capability. Both bumper mismatch and match frequencies of pre- and post-standard cars were compared, together with their respective damage profiles.

2.0 DAMAGE FREQUENCY IN UNREPORTED, LOW-SPEED COLLISIONS

2.1 Damage Frequency by Vehicle Model Year Group

Damage in unreported, low-speed collisions occurs when any auto part is broken, torn, bent or otherwise impaired. Damage frequency refers to the proportion of these collisions in which one or more parts are damaged. Since the bumper standard's objective is to prevent or reduce damage in low-speed collisions, post-standard cars should sustain a lower damage frequency than pre-standard cars. If each succeeding version of the bumper standard improves exterior protection, damage frequency should decrease from one model year group to the next.

Table IV-1 shows damage frequencies of unreported, low-speed collisions by model year group. The confidence bounds indicate the range within which the true damage frequency lies (at the 95 percent confidence level). The last column shows the significance test conclusions of each post-standard model year group compared with the pre-standard group (one sided, $\alpha = 0.05$).

The damage frequency of pre-standard cars (pre-1973) is 53 percent, while the combined frequencies of subsequent model groups, which met a bumper standard, is 39 percent. The statistical test of significance (H_0: $p_1 = p_2$ vs. H_1: $p_1 > p_2$) indicated that the damage frequency of all post-standard cars was significantly less than that of pre-standard cars.

The damage frequency of each post-standard model group (1973, 1974-78, 1979-80) was also significantly less than the pre-standard frequency. However, when the damage frequency of each successive post-standard model group was compared with its successor's frequency, no significant difference was found.

The damage frequency analysis indicates that the various versions of the bumper standard are effective in reducing the frequency of damage (front and rear combined) to exterior parts covered by the respective standard, but that there was no significant difference in effectiveness as bumper standards became more stringent over the years since the 1973 model year requirement.

TABLE IV-1

DAMAGE FREQUENCY IN UNREPORTED, LOW-SPEED COLLISIONS

(Front and Rear Collisions Combined)

MODEL YEAR GROUP	TOTAL NO. OF CARS IN COLLISIONS	CARS DAMAGED (PERCENT)	STD. ERROR	CONFIDENCE BOUNDS 1/		Significance different from 0? POST-STD. COMPARED TO:	
				LOWER	UPPER	Pre-Std. Group 2/	Preceding Post-Std. Group
Pre-Standard (Pre-1973)	283	53	3	48	59	-	-
Post-Standard							
1973	87	40	5	30	50	yes	-
1974-78	448	37	2	33	41	yes	no
1979-80	217	42	3	36	48	yes	no
Total Post-Standard Cars	752						
Weighted Average Percentage		39	2	35	43	yes	-

1/ 95 percent confidence level

2/ Significant > 0 where: $H_0: p_1 = p_2$ vs. $H_1: p_1 > p_2, \alpha = 0.05$

2.2 Damage Frequency by End of Car Struck

2.2.1 Front End Damage Frequency

Table IV-2 shows damage frequencies of cars in front end collisions. The front end damage frequency for pre-standard cars is 60 percent. For all post-standard cars the front end damage frequency is 41 percent, which is a statistically significant decrease. This continues to hold true for each version of the standard when compared to the frequency for pre-standard cars. However, the front end damage frequencies of post-standard cars were not significantly different from each other.

The damage frequency of cars in front end collisions shows that, in general, the bumper standard effectively reduced damage to front end exterior parts specified for protection by the standard, but that there is no significant difference between the various versions of the bumper standard in damage reduction ability in low-speed front end collisions.

2.2.2 Rear End Damage Frequency

Table IV-3 shows a damage frequency for pre-standard cars in rear end low-speed collisions of 48 percent. The combined damage frequency for all post-standard model groups is 37 percent, which is significantly less than that of pre-standard cars.

When comparing the damage frequency of each post-standard model group with the pre-standard frequency, only the 1974-1978 model group was significantly

TABLE IV-2

DAMAGE FREQUENCY IN UNREPORTED, LOW-SPEED COLLISIONS

(Front End Collisions)

MODEL YEAR GROUP	TOTAL NO. OF CARS IN COLLISIONS	CARS DAMAGED (PERCENT)	STD. ERROR	CONFIDENCE BOUNDS 1/ LOWER	UPPER	Significance different from 0? POST-STD. COMPARED TO: Pre-Std. Group 2/	Preceding Post-Std. Group
Pre-Standard (Pre-1973)	136	60	4	51	68	-	-
Post-Standard							
1973	38	37	7.5	22	52	yes	-
1974-78	207	42	3.5	36	49	yes	no
1979-80	94	38	5	28	48	yes	no
Total Post-Standard Cars	339						
Weighted Average Percentage		41	2.5	36	46	yes	-

1/ 95 percent confidence level

2/ Significant > 0 where: $H_0: p_1 = p_2$ vs. $H_1: p_1 > p_2, \alpha = 0.05$

TABLE IV-3

DAMAGE FREQUENCY IN UNREPORTED, LOW-SPEED COLLISIONS

(Rear End Collisions)

MODEL YEAR GROUP	TOTAL NO. OF CARS IN COLLISIONS	CARS DAMAGED (PERCENT)	STD. ERROR	CONFIDENCE BOUNDS 1/		Significanct difference from 0? POST-STD. COMPARED TO:	
				LOWER	UPPER	Pre-Std. Group 2/	Preceding Post-Std. Group 3/
Pre-Standard (Pre-1973)	147	48	4	40	56	-	-
Post-Standard							
1973	49	43	7	29	57	no	-
1974-78	241	31	3	25	37	yes	no
1979-80	123	46	4.5	37	55	no	yes
Total Post-Standard Cars	413						
Weighted Average Percentage		37	2.5	32	42	yes	-

1/ 95 percent confidence level

2/ Significant > 0 where: H_0: $p_1 = p_2$ vs. H_1: $p_1 > p_2, \alpha = 0.05$

3/ Significant < 0 where: H_0: $p_1 = p_2$ vs. H_1: $p_1 < p_2, \alpha = 0.05$

lower. Further analysis indicates that an increase in sample size alone would not change the lack of significance found for the 1973 and 1979-80 model groups.

The reduction in damage frequency in rear end collisions for 1974-1978 post-standard cars is not significantly less than the 1973 post-standard group. The 1979-80 model group however, has a significantly higher damage frequency than the 1974-1978 model cars. In other words, the 1973 and 1974-1978 model groups have damage frequencies that are not statistically different, but the 1979-1980 model group does have a significantly higher damage frequency in unreported, rear end collisions.1/

There were fewer than a hundred 1979 and 1980 model cars involved in unreported, low-speed collisions during the driver survey field data collection period (October 1979-January 1980). This was too small a sample for analysis; therefore, additional field work, which more than doubled the sample size, was done in the summer of 1980. Since the procedure for collecting data was the same, damage frequency results of the two time periods were combined. The assumption was that the occurrence of the damage to exterior parts in low-speed collisions was a function of the design of the bumper systems and not the circumstances that resulted in the collision. If factors such as the requirements for reporting low-speed collisions to the police or filing an insurance claim changed sufficiently between the two time periods, the damage frequency data could be affected. In the absence of any

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1/ The higher damage frequency for 1979-80 model cars may result from their weight reduction due to downsizing, thus making them more vulnerable to earlier, heavier models which are the largest portion of cars on-the-road (about 80 percent or more were 1978 and earlier models, during the time of the survey).

information suggesting that such reporting factors had changed, this was rejected as a cause for the higher rear end damage frequency of 1979-1980 model cars.

2.2.3 Comparing Front End to Rear End Damage Frequency

In this section, the decrease in damage frequencies in front end collisions will be compared with rear end collision frequency reductions. As shown in Tables IV-2 and IV-3, the damage frequencies of pre-standard cars in front end and rear end collisions were 60 and 48 percent, respectively. Forty-one percent of post-standard cars were damaged in front end collisions while 37 percent were damaged in rear end incidents.

In general the frequency of damage in unreported, low-speed, front end collisions was greater than for rear end collisions. Front end damage was more often claimed under collision coverage (the car owner's own insurance policy). Rear end collisions are usually the "other person's fault" and are claimed under that person's liability insurance. Collision insurance often has a deductible amount which the policy holder pays. For example, an accident may result in a repair bill of $500. If the policy holder has $100 deductible collision insurance, the insurance company pays $400 and the policy holder $100. Liability insurance has no such deductible, thereby generating lower damage claims.

Because of the deductible nature of collision insurance, drivers in low-speed collisions whose cars have a lesser amount of damage may not file collision claims. In contrast, drivers whose cars are in collisions where the other person was at fault, have an incentive to file a liability claim with the other person's insurance company, regardless of the amount of damage. Since collision claims are mostly for front end damage, and liability claims are more frequently filed for rear end damage, there are more unreported damage-related front end collisions than rear end collisions. Because of this inherent difference in the reporting of front and rear end collisions, the relative improvement of these frequencies should be compared to determine differences in the effectiveness of the bumper standard.

Front end damage frequency dropped 19 percent, from 60 to 41 percent, for pre- and post-standard cars, respectively. The relative reduction in damage frequency was 32 percent (19/60). For rear end damage frequencies there was an 11 percentage point drop between pre- and post-standard cars. The relative reduction was 23 percent (11/48). These relative percentages indicate that the bumper standard may have led to a higher reduction in damage frequency from front end collisions.

2.3 Analysis of Confounding Variables

Several factors that could influence damage frequency were considered to assure that the changes in damage frequency were associated with the bumper standard and not other factors. A method known as "log-linear analysis" was used for this purpose.[2]

2/ See Appendix C for an explanation of the log-linear analysis method.

The effect of the following factors was determined:

- Car accelerating or braking
- Car struck or striking vehicle
- Traffic density (light or heavy)
- Contact point (on, above, below bumper)
- Accident location (on road, in parking lot)
- Relative motion (both cars moving, other car moving, driver's car moving)
- Relative position (front-to-rear, rear-to-rear, rear-to-front, front-to-rear)
- Vehicle size (subcompact, compact, intermediate full size)
- Object struck (vehicle, stationary object)
- Roadway type (interstate, residential)
- Estimated impact speed--only one vehicle moving (over 5 mph, under 5 mph)

TABLE IV-4

KEY FACTORS INFLUENCING
DAMAGE FREQUENCY1/

Control Variable	Effect on Damage Frequency: Control Variable Significant?	Effect on Damage Frequency: Model Year Significant?
Front/rear	possibly2/	yes3/
Accelerating/braking	yes	possibly2/
Striking/struck	yes	yes
Traffic density	no4/	yes
Contact point (on/above/below)	yes	yes
Location of accident	yes	yes
Relative motion	yes	yes
Relative position	no	yes
Vehicle size	possibly2/	yes
Object contacted	no	yes
Roadway type	no	yes
Estimated speed	yes	possibly2/

1/ Burke, John S. et al., Westat, Inc., Drivers Survey on Unreported and Low-Damage Accidents Involving Bumpers: Final Report, Report No. DOT-HS-805-838 (May 1980), pp. 5-9.
2/ $0.01 < \alpha < 0.10$
3/ $\alpha \leq 0.01$
4/ $\alpha > 0.01$

Table IV-4 summarizes the results of this analysis. Model year group, the factor representing the various versions of the standard, had a significant influence ($\alpha < 0.05$) on damage frequency independent of every control variable. Independence from the control variables is important in this study for several reasons. The most important reason deals with the question of speed since the standards being evaluated require protection in low speed accidents. One of the most difficult aspects of the evaluation is to insure that attention is focused on this class of incident. To do this, several variables related to the speed at impact were analyzed. These included the driver's estimate of speed, as well as accident characteristics at the scene. If the conclusions regarding bumper effectiveness are true when these "speed surrogates" are controlled for, the conclusions are justifiable. If all of the speed-related factors are determined to be independent of the relation between "percent damaged" and model year class, then a clear conclusion can be reached about bumper effectiveness. In this manner, the confounding effect of the independent variables can be removed. This means that the model year of the car involved in a low-speed collision--which represents the presence of a pre- or post-standard bumper system on the car--is the primary determining factor in predicting whether the car will be damaged.

2.4 Damage Frequency Evaluation Summary

The evaluation of damage frequency from the survey of unreported, low-speed collisions shows there were <u>statistically significant reductions</u> in:

- The damage frequency of 1973 model cars compared with pre-standard cars (front and rear end collision combined)
- The damage frequency of 1973 model years compared with pre-standard cars in front end collisions
- The damage frequency of 1974-1978 model cars compared with pre-standard cars (front and rear end collisions combined)
- The damage frequency of 1974-1978 model cars compared with pre-standard cars both in front and rear end collisions
- The damage frequency of 1979-1980 model cars compared with pre-standard cars in front and rear end collisions combined

- The damage frequency of 1979-1980 model cars compared with pre-standard cars in front end collisions

The following damage frequencies were not found to be reduced significantly:

- The damage frequency of 1973 model cars compared with pre-standard cars in rear end collisions
- The damage frequency of 1979-1980 model cars compared with pre-standard cars in rear end collisions
- The damage frequency of 1974-1978 model cars compared with 1973 model cars for front, rear, or combined collisions
- The damage frequency of 1979-1980 model vehicles compared with 1974-1978 model cars for front end and combined (both front and rear end) collisions

In rear end collisions, the damage frequency of 1979-80 models was found to be significantly higher than that of 1974-78 cars. The analyses of the extent of damage covered in the next section will provide more information about the effectiveness of the 1979 and 1980 version of the bumper standard in rear end collisions.

3.0 EXTENT OF DAMAGE IN LOW-SPEED COLLISIONS

3.1 Introduction

This section presents several measures describing how much damage was sustained by cars in low-speed collisions. Findings are based on both the survey of unreported, low-speed collisions and the analysis of insurance-claimed collisions. Changes in the amount of damage were determined from comparisons of damage to pre-standard cars with the damage to cars meeting various standard requirements.

The following descriptors of the extent of damage will be examined:

- Number of parts damaged in unreported, low-speed collisions
- Number of damaged parts in collisions for which an insurance claim was filed
- Bumper repair vs. replacement from insurance claim data
- Degree of damage, by individual part, in unreported, low-speed collisions
- Repair cost of cars damaged in unreported, low-speed collisions
- Repair cost of cars for which an insurance claim was filed
- Number of property damage insurance claims per insured vehicle
- Bumper vs. non-bumper collision and liability claims
- Number of bumper-involved insurance claims per insured vehicle

3.2 The Number of Parts Damaged in Unreported, Low-Speed Collisions

3.2.1 Parts Studied

One method for determining the magnitude of damage in unreported, low-speed collisions is to count the number of damaged parts. The bumper standard specifies that certain parts are to remain undamaged or at least in an operating state after impact testing. Other front and rear exterior sheet metal parts are included under the broader 1979-1980 specifications. Following is the list of parts screened for damage in unreported, low-speed collisions:

- Front bumper
- Grille
- Front reflectors
- Front right fender
- Front left fender
- Hood
- Hood latch
- Radiator
- Rear bumper
- Rear lamps
- Rear reflectors
- Right rear fender
- Left rear fender
- Truck lid
- Truck latch
- Tail pipe
- Fuel tank or filler neck

3.2.2 Distribution of the Number of Damaged Parts in Unreported Low-Speed Collisions

From the survey of unreported, low-speed collisions, the number of parts damaged in each collision was determined. To enhance the analysis, categories of number of parts damaged per collision were established as follows: 0, 1, 2, and 3 or more. The number of unreported collisions with these categories was obtained by model year group and is shown along with the percent distribution in Table IV-5.

TABLE IV-5

DISTRIBUTION OF UNREPORTED, LOW-SPEED COLLISIONS BY NUMBER OF DAMAGED PARTS

Number of Damaged Parts/ Collision	Distribution of Collisions by Model Year Groups: Pre-standard		1973		1974-1978		1979-1980		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
None	130	47	52	61	281	65	120	57	583	58
One	70	25	18	21	98	23	63	30	249	25
Two	28	10	4	5	26	6	13	6	70	7
Three or More	49	18	12	14	27	7	14	7	102	10
										100

Chi-Square = 43.5
Degrees of Freedom = 9
Probability = 0.0001

A chi-square test of the data in Table IV-5 (shown at the bottom of the table) indicates that the distribution of collisions by the number of damaged parts differs significantly from one model year group to another. Since the model year groups were selected to correspond with the various bumper standard versions, the chi-square results suggest that the bumper standard significantly affected the number of damaged parts per collision.

The comparison of damage to the same parts (Section 3.2.1) on pre-standard versus post-standard cars showed that fewer parts are damaged on post-standard cars than on pre-standard cars when involved in unreported, low-speed collisions. The number of parts damaged on 1974-78 model cars was less than on the 1973 models. Parts damaged on the 1979-80 models, however, nearly equaled the number damaged on 1973 models. This suggests that the 1979-80 version of the standard provided less protection (for parts) than the 1974-78 version and about the same protection as the original standard.

3.3 Damaged Parts in Collisions for Which an Insurance Claim Was Filed

Property damage insurance claims were screened to identify those claims where any of the following parts were damaged: hood, front lights, front quarter panel, rear lights, rear quarter panel, and trunk. These stratifications of the data were dictated by the format of the State Farm file. Hence, the list of parts is shorter and less specific than the one used in the driver survey.

Insurance claims of one-year-old cars were analyzed. This assured that cars were driven about the same number of miles and had the same accident risk. The insurance claims were stratified by the model year of the involved car in relation to the bumper standard's effective dates as follows: 1972 models represented the pre-standard cars; 1973 models stood for the original bumper standard; and 1975 models represented the 1974-78 version of the standard. (This analysis did not include the 1979-80 version of the standard.)

Table IV-6 shows the percentage of insurance claims for the damaged parts listed above. In this analysis an insurance claim can be counted more than once if more than one of the specified parts is damaged in the collision.

A two-sided Z-test was used to test the significance of the difference in the percent of claims between pre-standard (1972) and post-standard (1973 and 1975) automobiles. The percentage of claims decreased significantly from pre- to post-standard cars for all the parts under study except rear quarter

TABLE IV-6

PERCENT OF INSURANCE CLAIMS
WHICH INCLUDED PARTS LISTED

Model Year	Hood	Head Lights	Front Quarter Panels	Rear Quarter Panels	Tail Lights	Trunk
1972	22	26	33	16	13	19
1973	17*	13*	28*	19**	8*	13*
1975	14*	9*	24*	15	6*	6*

*Significance > 0 where $H_0: p_1 = p_2$ vs. $H_1: p_1/p_2$ and $\alpha/2 = 0.025$, meaning that the percent of claims is significantly less than that of the 1972 vehicles.
** Significance < 0 where $H_0: p_1 = p_2$ vs. $H_1: p_1/p_2$ and $\alpha/2 = 0.025$, meaning that the percent of claims is significantly higher than that of the 1972 vehicles.

panels. In other words, damage to hoods, trunks, front quarter panels, and lights was not claimed as often for post-standard cars. The reduction is statistically significant. In contrast, rear quarter panels were claimed significantly more often for 1973 cars than for 1972 models. Claim percentages for rear quarter panels did not differ significantly between pre-standard (1972) and 1975 models.

In a separate analysis, the percentage of claims for damage to rear quarter panels was compared for one-year-old 1972 (pre-standard), 1975 (post-standard), and 1977 (post-standard) automobiles. The analysis showed that a significantly lower percentage of claims involving rear quarter panels were made for 1977 vehicles (12%) than for 1972 (16%) or 1975 (15%) vehicles.3/

3/ KLD Associates, Inc., Analysis of Insurance Claim to Determine Bumper Effect on Crash Damage, Report No. DOT-HS-805-842 and 843 (March 1980), p. 131.

The percentages of insurance claims involving hoods, trunks, lights, rear quarter panels, and front quarter panels were compared for two post-standard model years--1973 and 1975 one-year-olds. The test of significance indicated a significant decrease in the percentage of claims for all of these parts between 1973 and 1975.

In general, the parts studied were better protected with each successive version of the standard. The only exception was the rear quarter panels whose claim percentage increased significantly for the 1973 standard and then declined from the 1973 level for the later versions.

3.4 Comparison of Repaired vs. Replaced Bumpers in Insurance Claims

Another analytic approach was used to determine the extent of bumper damage using insurance claims. As a first step in this analysis, claims for damage to the bumper face bar were sorted from other claims. Next bumper damage claims were separated into those where the face bar was replaced and those where it was repaired. Claims were then stratified into model year categories corresponding to the effective dates of the bumper standard and were analyzed to determine if there was a shift from replaced to repaired bumper face bars.

The assumption of this analysis is that whether a bumper face bar had to be repaired or replaced indicates how severe the damage was, i.e., repaired bumper face bars sustained less damage than those that had to be replaced. A shift in the frequency of face bar replacement to face bar repair would indicate a reduction in bumper damage.

Table IV-7 displays the percentage of insurance claims for one-year-old cars which had a bumper face bar either repaired or replaced. Insurance claims were stratified by the following model years: 1972 models, representing pre-standard cars; 1973 models, the original bumper standard; 1974-1978 models, the second version of the standard; and 1979 models, the 1979 version of the standard. The percentage of bumper repair claims increased significantly for post-standard cars while the percentage of bumpers that had to be replaced on post-standard cars was significantly less than that of pre-standard cars.

TABLE IV-7

INSURANCE CLAIMS FOR REPAIRED VS. REPLACED BUMPERS (ONE-YEAR-OLD CARS)

MODEL YEAR	PERCENT OF INSURANCE CLAIMS	
	BUMPER REPAIRED	BUMPER REPLACED
1972	4.6	51.7
1973	5.9**	47.0*
1974-78	5.0**	36.6*
1979	5.8**	35.8*

*Significance > 0 where $H_0:p_1=p_2$ vs. $H_1:p_1=p_2$ and $\alpha/2=0.025$, meaning that the percent of claims is significantly less than that of pre-standard cars.

**Significance < 0 where $H_0:p_1=p_2$ vs. $H_1:p_1=p_2$ and $\alpha/2=0.025$, meaning that the percent of claims is significantly more that that of pre-standard cars.

This analysis of bumper damage shows that there has been a shift from having bumpers replaced to having them repaired. It is an indication of the bumper standard's effect in reducing damage to face bars in collisions, based on data from insurance claims. The analysis also shows that 1974-78 and 1979 model cars sustained significantly less bumper damage than 1973 cars, indicating that the more stringent bumper standards, following the initial 1973 version, further reduced damage to bumper face bars.

Although there was a shift from replacing to repairing bumpers, the increase in the number of repaired bumper face bars did not completely offset the decrease in replacements. A possible explanation of this discrepancy is that there has been an increase in bumper-involved accidents where either no damage was sustained or no claim filed.

A separate analysis of insurance claim cost for both repaired and replaced bumpers was performed.4/ Claims requiring bumper repair, cost about the same amount for pre- and post-standard cars. However, when a bumper had to be replaced, the cost was higher for post-standard cars, reflecting the higher manufacturing cost of post-standard bumpers (discussed in Chapter V).

4/ Ibid. p. 63.

3.5 Degree of Damage to Parts--Unreported, Low-Speed Collisions

The focus of this section is on how much damage occurred to individual exterior auto parts in unreported, low-speed collisions. The analysis is based on data obtained during the driver survey. Questions about the degree of damage to exterior auto parts were asked of drivers whose cars were damaged. The definitions used to described damage and the results obtained are discussed in the following sections.

3.5.1 Defining Damage Severity

For each part listed in Section 3.2.1, the degree of damage was assessed by driver survey repondents. (As will be seen later, this data provided a basis for estimating repair cost since drivers seldom had repair records for unreported, low-speed collisions.) To make sure that respondents used the same definitions of the classifications of severity, "minor," "moderate," and "major," each of these terms was defined by a description of the damage. For example, to determine the degree of hood damage, the driver was asked if the damage fitted one of these descriptions: (A) only surface paint was scraped off with a scratch 6 inches or less or that there was a dent less than the size of a quarter, or (B) the hood was torn or had deep creases or could not be opened or closed. The first description, A, was classified as "minor" damage and the second, B, "major" damage. Damage that fell between the two was classified as "moderate." Similar descriptions were developed for the other auto parts surveyed.5/

3.5.2 Degree of Damage to Front and Rear End Parts

The severity of damage to front and rear parts is shown in Tables IV-8 and IV-9, respectively. To facilitate comparisons between the various versions of the standard, the severity data is stratified by model year groups representing the period each version was effective. The "moderate" and "major" classifications used in the survey were combined into one category for these tables to simplify comparisons.

A look at the degree of damage by model year group indicates that auto parts of post-standard cars generally sustained less damage than those on pre-standard automobiles. This trend continues with each succeeding version of the standard.

5/ Burke, John S. et al., Westat, Inc., Drivers Survey on Unreported and Low-Damage Accidents Involving Bumper: Final Report, Report No. DOT-HS-805-838 (Nov. 1980), pp. D-71-D-75.

TABLE IV-8

DAMAGE SEVERITY TO FRONT EXTERIOR PARTS

Part Damage, by Model Yea Group, in Each Severity Class
(in Percent of Model Year Cars)1/

Part	Pre-1973			1973			1974-1978			1979-1980		
	None	Minor	Major	None	Minor	Major	None	Minor	Major	None	Minor	Major
Front Bumper	58	20	22	70	22	8	71	20	9	92	8	0
Grille	79	9	12	92	8	0	92	2	6	97	3	0
Front Lamps	80	5	15	81	3	16	86	3	11	94	0	6
Front Reflectors	89	3	8	94	0	6	97	0	3	100	0	0
Front Right Fender 2/	87	4	9	92	0	8	94	2	4	100	0	0
Front Left Fender 2/	83	8	9	89	6	5	92	3	5	100	0	0
Hood 2/	84	7	9	92	3	5	96	1	3	100	0	0
Hood Latch	90	3	7	100	0	0	97	2	1	100	0	0
Radiator	93	5	2	100	0	0	99	1	0	100	0	0

1/ Car population includes those cars for which at least one part was damaged in a low-speed, unreported collision. Definitions of "minor" and "major" damage vary by part and can be found in the Westat, Inc. report (see footnote 5 of text) on pages D-74 and D-75.

2/ The severity category "moderate" used in the Westat report for these reports was combined with "major" damage to simplify this table.

TABLE IV-9

DAMAGE SEVERITY TO REAR EXTERIOR PARTS

Part Damage, by Model Year Group, in Each Severity Class
(in Percent of Model Year Cars)1/

Part	Pre-1973			1973			1974-1978			1979-1980		
	None	Minor	Major	None	Minor	Major	None	Minor	Major	None	Minor	Major
Rear Bumper	63	25	12	63	24	13	80	14	6	82	13	5
Rear Lamps	89	4	7	94	0	6	95	0	5	93	3	4
Rear Reflectors	94	2	4	98	0	2	97	2	1	100	0	0
Rear Right Fender 2/	98	1	9	94	2	4	95	2	3	95	2	3
Rear Left Fender 2/	93	1	6	96	0	4	97	2	1	96	2	2
Trunk Lid 2/	91	4	5	88	7	5	97	1	2	100	0	0
Trunk Latch	95	3	2	96	2	2	100	0	0	100	0	0
Tail Pipe	96	3	1	98	0	2	99	1	0	100	0	0
Fuel Tank or Filler Neck	98	2	0	100	0	0	100	0	0	100	0	0

1/ Same as for Table IV-8.
2/ Same as for Table IV-8.

While a test of statistical significance was not performed,[6] the decreasing trend in severity of damage to individual parts does suggest that the standard improved the protection capability of bumpers in low-speed collisions. The continuation of this trend for each succeeding model year group indicates further improvement with each version of the standard.

3.6 Cost to Repair Damage

3.6.1 Average Repair Cost for Damage in Unreported, Low-Speed Collisions

The damage descriptions from the driver survey (used to establish degree of damage) were the basis for estimating repair costs for unreported, low-speed collisions. Repair estimates had to be reconstructed from damage descriptions since only 14 percent of the drivers surveyed, and whose cars were damaged, possessed repair bills or estimates.

For parts sustaining minor damage, a cost estimate was based on the cost to repair the parts. Where damage was major, the cost to replace the part was used. For parts with moderate damage (this classification was only used for parts, such as fenders, made of sheet metal), repair and replacement costs

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6/ No such test was done due to the lack or absence of data in some of the cells of the tables and questions regarding the usefulness and validity of the resulting statistics.

were averaged. Part costs were obtained from 1979 replacement parts manuals. A national average of 1979 labor rates was estimated based on regional rates and techniques used by insurance adjusters.7/

Table IV-10 shows the average repair cost estimates for damage in unreported, low-speed collisions in 1979 dollars. For all post-standard cars combined, the average estimated, per car, repair cost of $151 was significantly less than the average repair cost for pre-standard cars ($159). Compared to pre-1973 models, repair costs for 1973 and 1974-78 model cars were significantly lower. The newer 1979-80 model cars were significantly more costly to repair ($168), however.

Only about ten percent of the cars on-the-road at the time of the survey were either 1979 or 1980 models. These more recent models were lighter, on average, than 1978 and earlier models due to downsizing. Thus, in a multi-car collision, a 1979 or 1980 model was more likely to be involved with a heavier earlier model car than with another 1979 or 1980 model. This involvement of 1979 and 1980's with heavier cars may explain their higher repair cost in unreported collisions.

7/ The labor rate used was $22 in 1979 dollars.

TABLE IV-10

REPAIR ESTIMATES FOR DAMAGE IN UNREPORTED, LOW-SPEED COLLISIONS

(1979 Dollars)

MODEL YEAR GROUP	TOTAL NO. OF CARS DAMAGED	AVERAGE REPAIR COST/CAR ($)	STD. ERROR	CONFIDENCE BOUNDS 1/ LOWER	CONFIDENCE BOUNDS 1/ UPPER	Significance difference from 0? POST-STD. COMPARED TO: Pre-Std. Group 2/	Significance difference from 0? POST-STD. COMPARED TO: Preceding Post-Std. Group
Pre-Standard (Pre-1973)	147	159 188 Front 127 Rear	12	136	182	-	-
Post-Standard: 1973	35	139 168 Front 121 Rear	13	113	165	Yes	-
1974-1978	161	143 163 Front 119 Rear	9	124	161	Yes	No
1979-1980	92	168 166 Front 171 Rear	14	141	195 3/	Yes 3/	Yes
Total Post-Standard Cars	288						
Weighted Average Cost		151	11	129	173	Yes	-

1/ 95 percent confidence level

2/ Significant > 0 where: H_0: $u_1 = u_2$ vs. H_1: $u_1 > u_2$, $\alpha = 0.05$, meaning the latter group is significantly less.

3/ Significant < 0 where: H_0: $u_1 = u_2$ vs. H_1: $u_1 > u_2$, $\alpha = 0.05$, meaning the latter group is significantly more.

3.6.2 Average Repair Cost of Damage Based on Insurance Claims

The average repair costs of bumper damage based on insurance cases[8/] are shown in Table IV-11. Repair costs for both front and rear end damage are shown as well as the average cost by model year group. Tests of statistical significance apply only to the average cost figures.

For all model year groups (pre- and post-standard), the repair costs for damage in front-end collisions are consistently higher than those in rear end collisions. This is partially due to the fact that front end collisions are more often covered by collision insurance and rear end collisions by liability insurance. Collision insurance usually has a deductible amount that the auto owner pays. This means that collision insurance claims are only filed when the cost to repair is greater than the deductible. Liability claims, on the other hand, can be made for any repair cost, no matter how small.

The average repair cost of all post-standard groups combined was significantly higher than that of pre-standard cars. In addition, each successive post-standard group had an average repair cost that was significantly higher than the cost for the pre-standard group or the preceeding post-standard group.

8/ KLD Associates, Inc., Analysis of Insurance Claims to Determine Bumper Effect on Crash Damage, Report No. DOT-HS-805-842-843 (March 1980).

TABLE IV-11

AVERAGE REPAIR COST FOR DAMAGE REPORTED IN BUMPER-INVOLVED INSURANCE CLAIMS

(1979 Dollars)

MODEL YEAR GROUP	TOTAL NO. OF CLAIMS	AVERAGE REPAIR COST/CAR $	STD. ERROR	CONFIDENCE BOUNDS 1/ LOWER	CONFIDENCE BOUNDS 1/ UPPER	Significance difference from 0? POST-STD. COMPARED TO: Pre-Std. Group 2/	Significance difference from 0? POST-STD. COMPARED TO: Preceding Post-Std. Group 2/
Pre-Standard 1972	4657	669 745 Front 544 Rear	9	651	687	-	-
Post-Standard: 1973	7893	682 783 Front 565 Rear	6	670	694	Yes	-
1974-1978	13989	772 890 Front 591 Rear	6	760	784	Yes	Yes
1979	3306	778 891 Front 618 Rear	21	736	820	Yes	Yes
Total Post-Standard Cars	25188						
Weighted Average Repair Cost/Claim		745 857 Front 593 Rear	9.5	726	764	Yes	-

1/ 95 percent confidence level

2/ Significant <0 where: H_0: $u_1 = u_2$ vs. H_1: $u_1 < u_2$, $\alpha = 0.05$, meaning the repair cost has increased significantly.

These higher post-standard costs may have been caused by more expensive replacement parts, particularly for bumper systems. Another possible reason for the higher post-standard cost is that insurance claims filed for post-standard cars may actually have involved collisions occurring at higher speeds, thus causing more damage, than claims for pre-standard cars. (If the post-standard bumper is effective, then damage sustained by a pre-standard car in a low-speed collision should be comparable to that sustained by a post-standard car in a higher speed collision.) This may be the explanation if the protective quality of post-standard bumpers is more a "step-function" than a linear one, meaning post-standard bumpers provide good protection up to a given impact speed, but above that speed, they provide little or no protection.

The ratio of average repair costs for insurance claims to that of unreported accidents is about 6 to 1. The insurance claim average repair cost was between $669 and $778 while the unreported collision average repair cost ranged from $139 to $168. This should be expected, since the repair costs of unreported collisions were only slightly higher than the typical $100 deductible amount for collision insurance. It also means that total benefits of the bumper standard will be most heavily influenced by the insurance claim data.

3.6.3 Analysis of the Effect of Vehicle Make on Insurance-Claimed Repair Costs

From the insurance files, claims were extracted for the major domestic manufacturers (General Motors, Ford, Chrysler). An average insurance claimed repair cost was determined for each of these three manufacturers and for the rest of the auto manufacturers combined. As in previous insurance claim analyses, 1972 model cars represented pre-standard cars, 1973 models the original bumper standard, 1975 model cars the 1974-1978 version of the bumper standard, and 1979 cars the latest version of the standard. In addition, repair costs for 1977 model cars were analyzed to see how their bumper system designs compared with the 1975 bumper systems since both 1975 and 1977 model years came under the same bumper requirements. Due to small sample sizes, no attempt was made to analyze different bumper types produced by the various manufacturers.

Table IV-12 shows the average repair cost for bumper claims by make of car in 1979 dollars. When compared to pre-standard models by manufacturer, no significant differences were found--even though there appeared to be an increasing trend in repair costs. This lack of significance may have been caused by the smaller sample sizes which resulted from stratifying the data. In addition the total sample of insurance claims for this analysis was smaller than that in the previous section because not all insurance claim records had the make identified.

TABLE IV-12

AVERAGE REPAIR COST FOR BUMPER

CLAIMS BY MAKE OF CAR

(1979 Dollars)

Model Year	General Motors	Ford	Chrysler	All Other Makes
Pre-Standard				
1972	$686	$665	$663	$669
Post-Standard:				
1973	669	706	606	682
1975	750	770	711	766
1977	721	737	791	729
1979	751	778	783	777

Note:

1. For each manufacturer, there was no significant difference between pre- and post-standard groups. H_0 $u_1 = u_2$ vs. H_1: $u_1 < u_2$, $\alpha = 0.05$

2. There was no significant difference between manufacturers for vehicles within the same model year group. H_0: $u_1 = u_2$ vs. H_1 u_2, $\alpha/2 = 0.025$.

Additional tests were performed across each model year to determine if repair costs by make were significantly different from each other (e.g., 1972 repair costs of GM cars were compared with 1972 costs of Ford cars). No significant differences were found. This lack of statistically significant differences does not provide absolute proof that all makes had bumper systems equally capable of protecting passenger cars. However, the tests do indicate that no manufacturer had a design that weas significantly more effective than another. Thus, it appears that the auto indistry, in general, developed bumper systems of nearly equal property damage capability.

3.6.4 Analysis of the Effect of Bumper Materials on Insurance-Claimed Repair Costs

Bumpers were classified by their material type (i.e., steel, aluminum, and hybrid--a combination of materials such as steel and rubber). Only subcompact and compact cars were analyzed because bumper systems of larger cars generally continued to be made of steel, meaning there were inadequate sample sizes in the "aluminum" and "hybrid" material categories. Bumpers on 1973 and 1974 model year cars were not analyzed because they were usually made of steel as were pre-standard bumpers. Pre-standard vehicles, constructed of steel exclusively, were represented by one-year-old 1972 models. The post-standard comparison years were 1975, 1977, and 1979.

Table IV-13 shows comparisons by bumper type. No unusual distribution of the cost data as a function of body type is discernible, perhaps because the sample size was small due to stratification of the data and the fact that bumper material type could not be determined for all insurance claims.

Repair costs increased in general for post-standard models in comparison to pre-standard vehicles for all bumper types. (The only exceptions were the 1977 steel and 1975 hybrid compact bumpers.) This increase may in part be due to higher labor costs, the sophistication of the different bumper designs, or the incorporation of additional parts into the bumper assembly. Another possible

TABLE IV-13

AVERAGE INSURANCE-CLAIMED REPAIR
COST BY BUMPER MATERIAL

(1979 Dollars)

Material	Model Year	Repair Cost by Vehicle Size Subcompact	Compact
Combined (Average of All Materials Below)	1972	628	711
	1975	787*	733
	1977	696	684
	1979	741	916*
Steel	1972	628	711
	1975	766*	737
	1977	735	647
	1979	745	936*
Aluminum	1972	See Steel	See Steel
	1975	795	735
	1977	752	762
	1979	680	830
Hybrid	1972	See Steel	See Steel
	1975	826*	682
	1977	741	776
	1979	832*	840*

*Repair cost is significantly greater than for 1972 (pre-standard) bumpers (all steel). Significance < 0 where: H_0: $u_1 = u_2$ vs. H_1: $u_1 = u_2$, $\alpha/2 = 0.025$.

explanation could be that newer designs have reduced the number of less severe low-cost accidents, causing mean costs to shift to a higher value.[9] Overall, the 1977 models had the lowest post-standard repair cost; bumpers on 1979 models were more costly to repair than those on any other model year vehicle studied.

3.7 Analysis of the Number of Insurance Claims per Insured Vehicle

3.7.1 Scope of Analysis

Property damage insurance claims per insured vehicle should be less frequent if the bumper standard is effectively reducing property damage in low-speed collisions. In particular, there should be fewer insurance claims involving damaged bumpers. In this section the first analysis will be of the number of property damage claims per insured vehicle by model year. Next, bumper involvements will be separated from other property damage claims and the ratios of property damage claims involving the bumper to claims for non-bumper property damage will be compared for the two types of property damage insurance claims--collision and property damage liability. In order to determine how the standard is affecting vehicles of different sizes in various accident configurations, the two types of vehicle damage insurance will be combined and the frequency of bumper-involved claims will be stratified by impact point (front, front corner, rear, rear corner), vehicle size, and model year. The last two analyses look at the effects of vehicle use and vehicle age on the percent of insurance claims involving the bumper.

9/ KLD Associates, p. 107.

The support study[10] for this analysis relied on data supplied by State Farm Insurance Company on insurance claims filed at the Company's drive-in claim centers. The insurance data analyzed consisted of property damage insurance claims involving the bumper--the number and damage repair cost for these claims. In addition, data on the number of property damage insurance claims per insured vehicle was obtained from State Farm. This number, representing all passenger cars insured by the company, was an annual figure for all car makes, sizes and model years combined and included both collision and property damage liability claims.

3.7.2 Comparison of Property Damage Claims

The annual number of insurance claims per insured vehicle, in the same calendar year as its model year, are compiled in Table IV-14. This figure declined each year from 1972 through 1979. All post-standard groups combined, as well as each group individually, showed a significantly smaller number of insurance claims per insured vehicle per year. When each post-standard group was compared with the preceding post-standard group, the decrease in the number of insurance claims was also significant.

10/ KLD Associates, Inc., Analysis of Insurance Claims to Determine Bumper Effect on Crash Damage, Report No. DOT-HS-805-842+843 (March 1980).

TABLE IV-14

NUMBER OF PROPERTY DAMAGE INSURANCE CLAIMS PER INSURED VEHICLE PER YEAR 1/

(1979 Dollars)

MODEL YEAR GROUP	NO. OF INSURED VEHICLES	2/ NO. OF CLAIMS/ INSURED VEHICLE-YEAR	STD. ERROR	CONFIDENCE BOUNDS 3/ LOWER	UPPER	Significance difference from 0? POST-STD. COMPARED TO: Pre-Std. Group 4/	Preceding Post-Std. Group
Pre-Standard 1972	46,000	0.179	0.0015	0.176	0.182	-	-
Post-Standard: 1973	88,000	0.169	0.0013	0.166	0.172	Yes	-
1974-78	214,000	0.157	0.0008	0.155	0.159	Yes	Yes
1979-80	54,000	0.147	0.0015	0.144	0.150	Yes	Yes
Total Post-Standard Cars	356,000						
Weighted Average No. of Claims		0.158	0.0006	0.157	0.159	Yes	-

1/ Collision and property damage liability claims.

2/ Since data on total number of insured vehicles in sample files, these figures are estimated from Table IV-II. This column provides estimates of the number of 1972 model years cars insured in 1973, 1973 models insured in 1973, and so forth.

3/ 95 percent confidence level.

4/ Significance > 0 where H_0: $p_1 - P_2 = o$ vs H_1: $p_1 - p_2 > 0$, $\alpha = 0.05$.

3.7.3 Comparison of Bumper vs. Non-Bumper Collision and Liability Claims

Two distinctly different kinds of insurance--collision insurance and property damage liability--deal with vehicle damage. Both types include claims for accidents outside the scope of this evaluation (i.e., side collisions, rollovers, towaways, injury-causing accidents, and non-bumper-involved front and rear collisions). Both collision and property damage liability files were screened for bumper involvements. Collision bumper claims were further stratified by deductible amounts--less than $100 and more than $100.

With the screened files of bumper cases, comparisons were made between the various model year groups representing the versions of the standard. This was done to see if the bumper standard had affected the proportion of bumper to non-bumper claims for collision or property damage liability claims. These model year comparisons are listed in Table IV-15, which shows the percentage of each model year's property damage claims by claim type. For example, of the property damage claims for 1972 models, 31 percent were collision claims with a $100 or less deductible amount, 34 percent were collision claims with deductibles over $100, and 32 percent were liability claims. These three claim types add up to 97 percent of total property damage claims. The remaining 3 percent of property damage claims were covered by comprehensive insurance. The collision claims with deductibles less than $100 comprised about the same proportion of property damage claims for all three model year groups. Collision claims with deductibles over $100 increased while liability claims decreased as a portion of total property damage claims from pre- to post-standard groups.

TABLE IV-15

BUMPER VS. NON-BUMPER-INVOLVED PROPERTY DAMAGE CLAIMS

(One-Year-Old Cars)

Claim Type	Model Year	Percentage of Model Year Property Damage Claims: Not Involving the Bumper	Involving the Bumper	Total	Ratio of Bumper To Non-Bumper Claims
Collision, With Deductible Less Than $100	1972	13	18	31	1.38
	1973	15	15	30	1.0
	1974-78	23	10	33	0.43
Collision, With Deductible More Than $100	1972	13	21	34	1.62
	1973	15	22	37	1.47
	1974-78	18	20	38	1.11
Liability	1972	16	16	32	1.0
	1973	14	13	27	0.93
	1974-78	15	10	25	0.67

A distinct pattern of bumper involvement was evident in each type of claim. Collision claims, with a deductible under $100, tended toward a decreasing percentage of bumper involvements (and thus contained increasing percentages of non-bumper-involved claims). The frequency of collision claims with a deductible over $100 showed a negligible change in bumper involvements, but non-bumper-involved claims rose. Liability claims, involving the bumper, decreased while non-bumper-involved claims remained almost constant. The net effect of these trends was a shift from a preponderance of pre-standard property damage claims which involved the bumper (55 percent of 1972 claims) to less than half for 1974-1978 (40 percent of the claims). This shift is evident for the three claim types based on the ratio of bumper to non-bumper claims.

Most of the decrease in property damage claims is attributable to the decrease in bumper-involved liability claims, because there was no corresponding increase in non-bumper-involved claims. This explains the decrease in frequency of property damage claims seen in Table IV-14 and discussed in section 3.7.2.

Among bumper-involved claims, claim frequency has generally decreased between pre-standard and post-standard groups for all claim types. The lower deductible collision claims decreased the most, followed closely by liability claims. Since a low-speed collision would tend to cause less damage than a higher speed collision, a shift in insurance claims caused by a reduction in bumper-involved claims would have more of an effect on claims of lower amounts. The analysis shows that, in fact, the less costly collision claims--collision claims with a deductible less than 100 dollars and the liability claims--did decrease more than the costlier collision claims, whose deductibles were over $100.

3.7.4 Comparison of the Number of Insurance Claims Involving the Bumper by Vehicle Size and End of Car Struck

In this section claim frequencies for bumper involvement are examined in detail. The number of insurance claims involving the bumper were separated by vehicle size, and four impact points: direct front end collisions, angle collisions to the corners of the front end, direct rear end collisions, and angle collisions to rear corners. For comparison, the number of property damage claims for collisions into the sides of automobiles are also shown. Pre-standard cars are represented by 1972 models, 1973 models represent post-standard cars meeting the original bumper standard, 1978 model year cars represent the 1974-78 version of the bumper standard, and 1979 model year cars represent the 1979 version of the standard.

Table IV-16 shows the number of insurance claims involving the bumper. Front, front corner, and rear claim frequencies generally declined for post-standard cars, for all vehicle sizes. Rear corner bumper claim frequencies showed an increase for 1973 models over 1972 models. The 1974-1978 models, while showing fewer rear corner bumper claims than 1973 models, had more than the pre-standard (1972) models. The 1979 model subcompact and compact size cars had fewer rear corner claims than the preceding post- and pre-standard models.

TABLE IV-16

BUMPER-INVOLVED CLAIMS AS A PERCENTAGE OF

TOTAL PROPERTY DAMAGE CLAIMS -- BY MODEL YEAR AND VEHICLE SIZE

(One-Year-Old Vehicles)

BUMPER INVOLVEMENT	MODEL YEAR	SUBCOMPACT	COMPACT	INTERMEDIATE	FULL
Front	1972	15.8	13.2	12.7	12.4
	73	11.6	9.3	9.8	6.8
	78	11.1	10.0	8.0	7.4
	79	11.7	10.7	10.7	8.4
Front Corner	1972	21.3	21.4	20.2	19.0
	73	18.9	18.6	18.3	17.1
	78	17.3	15.7	14.4	14.1
	79	14.4	12.4	11.1	16.2
Rear	1972	14.0	13.0	11.2	12.9
	73	15.4	15.2	10.8	9.7
	78	8.2	7.4	7.5	7.1
	79	8.0	7.2	9.6	8.9
Rear Corner	1972	9.2	8.1	8.7	8.5
	73	12.6	10.4	10.0	12.6
	78	8.0	9.0	9.0	9.6
	79	7.1	6.9	11.1	11.7
All Bumper (Direct)	1972	60.3	55.8	52.8	52.9
	73	58.5	53.4	48.8	46.2
	78	44.6	42.2	39.0	38.1
	79	41.2	37.2	42.5	45.3
All Bumper (Corner)	1972	39.7	44.2	47.2	47.1
	73	41.5	46.6	51.2	53.8
	78	55.4	57.8	61.0	61.9
	79	58.8	62.8	57.5	54.7

The results of Table IV-16 support the conclusion of the previous section that the bumper standard reduced the number of insurance claims. However, from the detailed analysis the standard did not reduce the number of claims, involving the bumper, for angle collisions to rear corners.

3.7.5 Analysis of the Effect of Vehicle Use on the Number of Insurance Claims Involving the Bumper

Both insurance claim costs and the number of claims were analyzed for one-year-old cars to normalize the claims for the exposure to risk of having a bumper-involved accident. This was also done to minimize vehicle age as a factor, since it may influence insurance coverage as well as the filing of a claim.

Exposure to the risk of having an automobile accident is usually based on the number of miles the car is driven each year. Another refinement of the exposure measurement is to determine the type of use made of the car (e.g., urban, rural). Studies have shown that vehicle age and size are factors having an effect on how much cars are used (and the type of use).11/ The method of using insurance records for one-year-old cars to eliminate vehicle age, and normalizing for exposure, is based on the findings from the reference above that show cars of similar age are driven about the same amount.

11/ KLD Associates, Inc., Analysis of Insurance Claims to Determine Bumper Effect on Crash Damage, Report No. DOT-HS-805-842 and 843 (March 1980).

In this section vehicle mileage data by vehicle size will be used to adjust the data on the number of insurance claims involving bumpers. The adjusted data will be analyzed using the same procedure as for the unadjusted data to determine any effect vehicle use may have on previous conclusions.

Vehicle miles of travel (VMT)12/ are the total miles driven by vehicles in the U.S. VMT has generally been increasing each year; however, when divided by the number of autos registered in the U.S.13/, the average miles driven per automobile dropped from 1973 to 1974, but has been increasing slightly through 1977 (see Table IV-17). This change in vehicle use could effect the number of insurance claims per insured vehicle and so will be used later to adjust the insurance data.

TABLE IV-17

VEHICLE MILES TRAVELLED, AUTO REGISTRATION, AND ANNUAL MILES DRIVEN PER CAR

Calendar Year	Vehicle Miles (100 Million)	U.S. Auto Registration (Millions)	Annual Miles/Car
1972	986.4	96.9	10,180
1973	1016.9	101.2	10,048
1974	990.7	104.7	9,462
1975	1028.1	106.7	9,635
1976	1075.8	110.4	9,749
1977	1118.6	113.7	9,838

12/ Calculated and published annually by the Federal Highway Administration.
13/ Ibid.

Two studies of miles driven, by vehicle size, have been cited which show that smaller cars are driven less than large cars.14/ Indices were developed to adjust for differences in miles driven by vehicle sizes and are shown in Table IV-18. Similar indices were developed for the average mileage data from Table IV-17 with 1972 as the base year. The two sets of indices (average miles driven per car each calendar year, and mileage by vehicle size) were multiplied and are shown in Table IV-19.

The number of insurance claims involving the bumper were adjusted for vehicle use by multiplying them by the appropriate indices. The adjusted number of insurance claims were statistically tested as was done with the raw data; the number of claims of pre- and post-standard cars were compared to determine if there was a significant difference.

As can be seen from Table IV-20, which shows the original and adjusted data on the number of insurance claims involving the bumper, the findings of the adjusted data are the same as for the orginal data. This means that the use of insurance claims of one-year-old cars was an adequate surrogate for equalizing the insurance data for vehicle use.

3.7.6 The Effect of Vehicle Age on the Percentage of Insurance Claims Involving The Bumper

To analyze the effect of vehicle age on bumper effectiveness (effects of bumper deterioration), the percentages of insurance claims involving the bumper for one-year-old and three-year-old cars were compared. Table IV-21 shows the comparisons. One-year-old pre-standard cars were represented by 1972 models and three-year-old pre-standard cars by 1969 models.

14/ KLD Associates, p. 72.

TABLE IV-18

RELATIVE RATIO OF VMT BY CAR SIZE

	Car Size (Compact Mileage is Base)			
	Subcompact	Compact	Intermediate	Full
Ratio	1.10 1/	1.00	1.09	1.19

1/ The relative ratio of vehicle miles travelled by car size comes from studies of North Carolina and New York state data. Compact cars in North Carolina average 12,099 miles in 1974 whereas subcompacts were driven 13,301 miles. Using compacts as a base, the relative ratio for subcompacts is 13301/12099 = 1.10. For New York state subcompacts the ratio was 1.09. These results were averaged ([1.10 + 1.09]/2 = 1.095).

TABLE IV-19

RELATIVE RATIOS FOR VMT BY CALENDAR YEAR AND CAR SIZE

	Car Size (1972 Compact Mileage is Base)			
Model Year Group	Subcompact	Compact	Intermediate	Full
1972	1.10	1.00	1.09	1.19
1973	1.08 1/	0.99	1.07	1.17
1974-78	1.04	0.95	1.03	1.13

1/ By dividing the national VMT for passenger cars by the number of registered passenger cars in the same year, an average mileage estimate per car was determined. For the average passenger car in 1972 the mileage was 10,180 (986.4×10^8 VMT/96.9×10^6 registered cars). For cars in 1973 the average was 10,048 miles per car per year. The ratios, based on 1972, for 1973 is 0.987 (10,048/10,180). The relative ratio by vehicle size (1.095 for subcompacts) were multiplying by the calendar VMT ratios (0.987 for 1973) to get the relative ratios for VMT by calendar year and car size (for 1973 subcompacts 1.095 x 0.987 = 1.08).

TABLE IV-20

BUMPER-INVOLVED INSURANCE CLAIM PERCENTAGES
ADJUSTED FOR VEHICLE USE

Model Year Group	Subcompact		Compact		Intermediate		Full	
	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted
1972	60.3	66.3	55.8	55.8	52.8	57.6	52.9	63.0
1973	58.5*	63.2*	53.4*	52.9*	48.9*	52.3*	46.2*	54.1*
1974-78	44.6*	46.4*	42.2*	43.5*	39.0*	40.2*	38.1*	43.1*

Notes:

1. The original bumper involved insurance claim percentages were multiplied by the relative ratios from Table IV-19 (for 1972 subcompacts 60.3 x 1.10 = 66.3). The original percentage represents claims per insured vehicle per year. The adjusted percentage represents claims per insured vehicle per annual miles driven.

2. Vehicle use is based on Table IV-19.

3. An asterisk (*) indicates that the percentage is significantly smaller than the corresponding 1972 percentage. Significance > 0 where H_0: $p_1 = p_2$ vs. H_1: p_1 p_2, $\alpha/2 = 0.025$.

TABLE IV-21

COMPARISON OF PERCENTAGES OF PROPERTY DAMAGE RELATED INSURANCE CLAIMS INVOLVING THE BUMPER FOR ONE VS THREE-YEAR-OLD CARS

Model Year	Percent of Claims Involving Bumpers	
	One-Year-Old Cars	Three-Year-Old Cars
Pre-standard	56.3	57.5
1973	53.0	47.1*
1974-78	41.6	43.1

---

* Percent is significantly less than that of corresponding one-year-old models. Significance 0 where H_0: p. = p_2 vs. H_1: p=p_2, $\alpha/2$ = 0.025.

Table IV-21 shows that one and three-year-old cars had similar bumper-involved claim pecentages except for 1973 where the three-year-old cars yielded significantly fewer claims than one-year-old cars. However, this is most likely caused by the small sample of insurance claims for three-year-old cars 1973 model cars. With the larger sample of 1974-1987 models, claim percentages for the one and three-year-old cars were similar. Trends by model year for the one and three-year-old cars are also similar.

Vehicle age can represent vehicle use in miles driven, type of use (commuting vs. pleasure), as well as deterioration. This analysis has shown little difference in the percentage of insurance claims involving the bumper because of vehicle age. It shows that bumper systems have funtioned about as well in three-year-olds as in one-year-old cars and do not appear to deteriorate.

3.8 Extent of Damage--Evaluation Summary

Several measures of the extent of damage were developed based on: (1) a survey of unreported, low-speed collisions and, (2) an analysis of insurance claims. There were significant reductions in:

- o The number of parts damaged on post-standard cars compared to pre-standard cars (from survey)
- o Damage to hoods, trunks, front and rear lights and front quarterpanels on post-standard cars compared to pre-standard cars (based on insurance claim data)
- o The number of damaged rear quarterpanels on 1977 model cars compared to 1973 model cars, and pre-standard cars (based on insurance claim data)
- o The number of damaged bumper face bars which were replaced on post-standard cars compared to pre-standard cars (from insurance claim data)
- o The repair cost of damage for 1973 and 1974-1978 model cars compared to pre-standard cars (from survey)
- o The repair cost of damage for 1979 model cars compared to 1974-1978 model cars (based on insurance claims)
- o The number of property damage claims for all post-standard cars and for each post-standard group of cars compared to pre-standard cars (from insurance claims)

- The number of property damage insurance claims for each post-standard group of cars compared to its preceding post-standard group (1974-78 compared to 1973 and 1979 compared to 1974-78)

The following measures of the extent of damage to cars in low-speed collisions showed statistically significant increases in:

- The number of insurance claims for damaged rear quarterpanels on 1973 model post-standard cars compared to pre-standard cars

- The number of damaged bumper face-bars which were repaired for post-standard cars compared to pre-standard cars (from insurance claims)

- The cost to repair damage for 1979 and 1980 model cars compared to other post-standard cars and pre-standard cars (from survey)

- The damage repair costs for all post-standard cars compared to pre-standard cars, and for 1974-1978 model cars compared to 1973 model cars (from insurance claims)

The following measures of the extent of damage generally declined, but were not statistically significant (or did not lend themselves to statistical testing):

- Front and rear exterior parts of post-standard cars compared to pre-standard cars (from survey)

- o Property damage claims, of post-standard cars, which included damaged bumper face bars in comparison to such claims for pre-standard cars.

- o Collision and liability claims for post-standard cars which involved the bumper compared to pre-standard cars.

- o Collision coverage claims, with deductible less than 100 dollars, and liabililty coverage, compared to collision coverage with deductibles over 100 dollars.

- o Insurance claims for all post-standard cars in front, front corner and rear collisions, compared to pre-standard cars; and for each post-standard group of cars compared to its preceding group.

The analysis of extent of damage for different types of insurance coverage showed a general increase--though not statistically significant as follows:

- o Collision coverage claims with all deductibles, but not involving the bumper, showed an increase for post-standard cars, compared to pre-standard cars (liability claims contained about the same number of non-bumper claims).

- o Insurance claims, involving the bumper, for rear-corner collisions of 1973 model cars compared to pre-standard cars. 1974-1978 model cars had fewer such claims for rear-corner collisions than 1973 model cars but, more than pre-standard cars. Intermediate and full size 1979 model cars had more insurance claims for rear-corner collisions, but subcompact and compact size cars had fewer such claims, compared to pre-standard cars.

The measures of extent of damage when tested to determine the effects of other factors on findings showed no significant differences as follows:

- o Major domestic manufacturers made bumper systems that are about equally effective in reducing property damage.

- o Bumper systems made of different materials have similar damage repair costs, although repair costs for aluminum bumpers seem to be lower.

- o Variations in vehicle use, vehicle size and vehicle age do not appear to affect previously determined findings on the extent of damage in insurance claims.

4.0 BUMPER MISMATCH IN UNREPORTED, LOW-SPEED COLLISIONS

4.1 Definition and Data Source

When two cars collide front-to-front, front-to-rear, or rear-to-rear, their bumpers' damage protection capabilities depend on whether the bumpers meet on contact. This matching of bumpers is enhanced when the bumpers are the same, or nearly the same height. Achieving uniform bumper heights is one of the bumper standard's objectives and the pendulum test establishes the bumper height range. The pendulum test specifies that a vehicle's front, rear and corresponding bumper corners be struck by a pendulum at heights between 16 and 20 inches.

Bumper mismatch in unreported, low-speed collisions was recorded during the driver survey. When cars were in multi-car collisions, drivers were asked if the bumpers of the cars made contact. That is, did the bumpers meet, or was one bumper higher (or lower) than the other? In the analysis, collision impact configurations were classified as "on the bumper" if the bumpers met and as "mismatch" if the respondent's car was struck above or below the bumper.

4.2 Comparison of Bumper Mismatch

Table IV-22 shows the number and percentage of multi-car, unreported low-speed collisions, by bumper contact configuration and model year group. The data is stratified into accidents involving the front and the rear of a respondent's car.

TABLE IV-22

COLLISIONS BY BUMPER CONTACT CONFIGURATION AND MODEL YEAR GROUP 1/

Model Year	Number of Collisions	Collisions Percent: On Bumper	Collisions Percent: Not on Bumper (Mismatch)	Significance different from 0? Post-Std. Compared to: Pre-Standard Group 2/	Significance different from 0? Post-Std. Compared to: Preceding Post-Standard Group
Front End:					
Pre-Standard	120	72	28	-	-
1973	36	88	12	Yes	-
1974-78	188	82	18	Yes	No
1979-80	87	78	22	No	No
Rear End:					
Pre-Standard	135	76	24		
1973	45	80	20	No	-
1974-78	213	87	13	Yes	No
1979-80	111	80	20	No	Yes 3/

1/ Using unreported, low-speed collision data (from survey) on the interviewed person's car.

2/ The percentage of bumpers not meeting (mismatching) decreased significantly. H_0: $p_1 = p_2$ vs. H_1: $p_1 > p_2$, $\alpha = 0.05$.

3/ The percentage of bumpers mismatching increased significantly. H_0: $p_1 = p_2$ vs. H_1: $p_1 < p_2$, $\alpha = 0.05$.

In multi-car collisions, cars with bumpers meeting the standards were more often hit on the bumper (no mismatch) than those with pre-standard bumper systems. In front end collisions, 1973 and 1974-78 model car's bumper mismatched on significantly fewer occasions than pre-standard cars. Although mismatch of bumpers involving 1979-80 model cars was less than for pre-standard cars, the sample was too small to be statistically confident of the reduction. In rear end collisions, only the 1974-78 model car mismatches were of a sufficient number to show a significant reduction in relation to pre-standard cars.

The bumper standard appears to have reduced the incidence of bumper mismatch in unreported, low-speed collisions.

4.3 Comparison of Bumper Contact Configuration and Damage Frequency

The effect of bumper contact configuration, that is "on bumper" or "mismatch", on damage frequency in multi-car collisions is shown on Table IV-23.

In collisions where the bumpers contacted, post-standard cars were damaged significantly less frequently than pre-standard cars. In bumper "mismatch" collisions, the percentage of cars damaged, in both pre- and post-standard groups remained about the same.

4.4 The Effect of Bumper Height Requirements on Damage Repair Costs

The damage frequency, when bumpers matched in low-speed collisions, is lower than when they did not match, as is shown in the previous section. Also, when cars with bumpers meeting the standard requirements collided, and their bumpers made contact, the damage frequency was lower than when pre-standard cars were in a similar situation.

In this section the damage repair cost when bumpers matched, in unreported, low-speed collisions,is compared to the damage repair costs when bumpers mismatched. This measure is intended as an indication of benefits of the bumper height requirement. Data for the measure is obtained from the driver survey which showed that for the 1979-80 model year, 157 cars made contact with the bumper in a low-speed collision. Of these, 50 cars suffered damage which cost an average of $182 per car to repair, yielding an average repair cost of $58 per car for the sample population of 157 cars making a bumper contact in a low-speed collision (both damaged and undamaged).

A similar process is applied to the cars that "mismatched" in low speed collisions, which for 1979-80 model years came to $102 per car, or $44 more per car than the average damage repair cost for cars that made bumper contact. A complete set of results for pre- and post-standard cars is shown in Table IV-24, where the last column lists the measure of difference between (average, per car, repair costs for all cars) "mismatch" and "on bumper" collisions.

TABLE IV-23

DAMAGE FREQUENCY IN MULTI-VEHICLE UNREPORTED, LOW-SPEED COLLISIONS BY BUMPER CONTACT CONFIGURATION AND MODEL YEAR GROUP

Model Year Group	On Bumper		Not on Bumper (Mismatch)	
	Number of Cars	Cars Damaged (Percent)	Number of Cars	Cars Damaged (Percent)
Pre-Standard	190	45	65	62
Post-Standard:				
1973	68	31*	13	62
1974-78	359	26*	42	74
1979-80	157	29*	41	71
All Post Standard	584	27*	96	71

* Significance > 0 where H_0: $p_1 = p_2$ vs. H_1: $p_1 > p_2$, $\alpha = 0.05$, meaning the percentage is significantly less than the corresponding pre-standard percent.

TABLE IV-24
EFFECT OF BUMPER HEIGHT REQUIREMENTS ON REPAIR COSTS

	"ON BUMPER" COLLISIONS				"MISMATCH" COLLISIONS				
	No. of Cars[1]/	No. of Cars[2]/ Damaged	Repair[3]/ Cost/Car	Ave. Repair Cost/Car for All Cars	No. of Cars[1]/	No. of Cars[2]/	Repair[3]/ Cost/Car Damage	Avg. Repair[4]/ Cost/Car for All Cars	Difference between Avg. Repair Cost/Car "Mismatch" less "On Bumper"
Pre-Std.	190	85	$153	$71	65	40	$161	$ 99	$28
1973	68	21	140	43	13	8	136	84	41
1974-78	359	90	157	39	42	31	102	75	36
1979-80	157	50	182	58	41	29	144	102	44

1/ From Table IV-23

2/ Based on Driver Survey

3/ Calculated from damage repair estimates, based on damage extent reported in Driver Survey.

4/ (No. of Cars Damaged) x (Repair Cost per damaged car) ÷ (Total No. of Cars in respective types of collisions).

Bumper height requirements, a factor in providing for "on bumper" contact in low-speed collisions can be credited with lowering the repair cost when such costs are spread over the number of cars so involved-which includes both damaged and undamaged cars. The reduction is over 40 percent for post-standard cars and less than 30 percent for pre-standard cars. There is not, however, a great deal of difference in damage repair cost for the particular cars that sustain damage, be it in "on bumper" or "mismatch" collisions, although the number of cars damaged in the latter situation is considerably higher (by almost 3 to 1) than the former.

4.5 Bumper Mismatch Evaluation Summary

The evaluation of the bumper standard for uniform bumper heights was based on data gathered during the driver survey. The major findings on bumper mismatch in multi-vehicle collisions are as follows:

- Cars in compliance with the standard were contacted significantly more often on the bumper (bumper match) than pre-standard cars. This was the case for both front and rear end collisions.

- In rear end collisions, 1979-80 model cars were involved in significantly more incidences where bumpers mismatched than 1974-78 models.

- When bumper heights matched on contact, the frequency of damage was significantly less for all post-standard car groups (together and individually) than the pre-standard group.

- When post-standard bumpers mismatched, the damage frequency was about the same as that of pre-standard bumpers.

- When bumpers matched on contact, repair costs were 28 to 49 percent less than when they mismatched for both pre- and post-standard cars. The average repair cost of post-standard cars was lower than for pre-standard cars, when bumpers matched. This was also true for mismatching collisions except for 1979-80 model cars.

CHAPTER V

ACTUAL COST OF THE BUMPER STANDARDS

1.0 INTRODUCTION

While bumper systems, designed to meet Federal regulations, may reduce repair bills, their weight and cost must also be considered. A cost-effective standard will achieve sufficient consumer savings to offset any increases in the automobile purchase price or fuel costs. This chapter looks at the added cost and weight resulting from the bumper standard.

Bumper systems meeting the standard generally weighed more, had more complex designs, and required more costly materials to manufacture. Any weight added to the automobile requires more fuel. With today's fuel prices, a small increase in fuel consumption can have a significant effect on operating expenses over the life of an automobile. Post-standard bumper system designs included new parts; energy absorbers and face bar reinforcements were the major ones. Current bumper systems are commonly made of high-strength metals and elastomerics. These new parts and materials have added to the cost of manufacturing bumper systems.

The bumper standard required changes to be made to existing vehicle hardware, i.e., the bumper system. Thus, only the incremental consumer bumper system cost (the difference in cost to the buyer between pre- and post-standard bumper systems) rather than the total bumper system cost is attributable to the standard. Incremental consumer bumper system costs, reflected in the purchase price of a vehicle, were obtained for each version of the standard through tear-down studies. Tear-downs were performed on 1972 model cars, representing pre-standard bumper systems; 1973 models, for the original standard; 1974 models, covered by the 1974-78 version; and 1979 and 1980 cars, representing the two versions of the standard in effect for those model years.[1]

To determine the total incremental cost of the bumper standard, the additional fuel cost attributable to heavier post-standard bumper systems must be added to the incremental consumer bumper system cost. During the tear-down studies, bumper system weights were obtained. The weight differential between pre- and post-standard bumper systems was calculated and multiplied by the lifetime fuel penalty (number of gallons of gas used over the lifetime of a car per additional pound times the cost per gallon) to determine the added lifetime fuel cost.

1/ C.B. Eckel. et al. De Lorean Motor Company Implementation Cost to the Consumer of Part 581 - Bumper Standard, Phase II; Weight and Cost Studies of Three "X" Body Bumper Systems; and Consumer Replacement Cost for Complete Bumper Systems Studied, Report No. DOT-HS-805-779 (October 1980).

M.R. Harvey, Clifford Eckel, David Cowan, John Z. De Lorean Corp., Cost Evaluation for Four Federal Motor Vehicle Safety Standards, Task VI Additional Bumpers, FMVSS 215 - Exterior Protection, Report No. DOT-HS-803-873 (May 1979).

Robert F. McLean, Clifford Eckel, and David Cowan, John Z. De Lorean Corp., Cost Evaluation for Four Federal Motor Vehicle Safety Standards, Volume I, Report No. DOT-HS-803-871 (October 1978).

This chapter includes:

- o The method for determining the actual cost of a bumper system.
- o Incremental consumer costs for each version of the bumper standard in relation to pre-standard bumpers.
- o The added lifetime fuel cost due to added bumper weight.
- o The total incremental cost for each version of the bumper standard.

2.0 METHOD FOR DETERMINING THE ACTUAL COST OF BUMPER SYSTEMS

2.1 Consumer Cost Elements

For the purposes of this section, consumer cost is defined as the manufacturer's suggested retail price of a new car. While the suggested retail price is not generally the actual selling price, it does reflect the typical manufacturer and dealer costs that are passed on to the consumer. Factors which cause the actual sales price to differ from the suggested retail price (e.g., factory rebates, financing, trade-ins, consumer demand, dealer discounts, shipping distances, taxes) have no direct connection with the bumper system and can only be estimated for a whole vehicle rather than a system.

The conamer cost of a bumper system is not as readly available, and the actual costs of such systems must be estimated. Starting with torn down components, a precedure to cost out the elements of consumer cost is used.

Figure V-1 shows the elements of consumer cost. Each element is defined below:

- Variable Cost -- expenses that vary with the production quantity. Consists of direct labor, direct material (material in finished product plus scrap), and variable burden (all other expenses due to production process that vary directly with production volume and contribute to cost of sales, such as perishable tools or fuel) to produce each component.

- Fixed Cost -- expenses related to the operation of a manufacturing plant that do not vary, regardless of the volume. Major contributors to this category are indirect labor (e.g., plant supervision), indirect materials (e.g., plant maintenance supplies), and fixed burden (e.g., insurance costs).

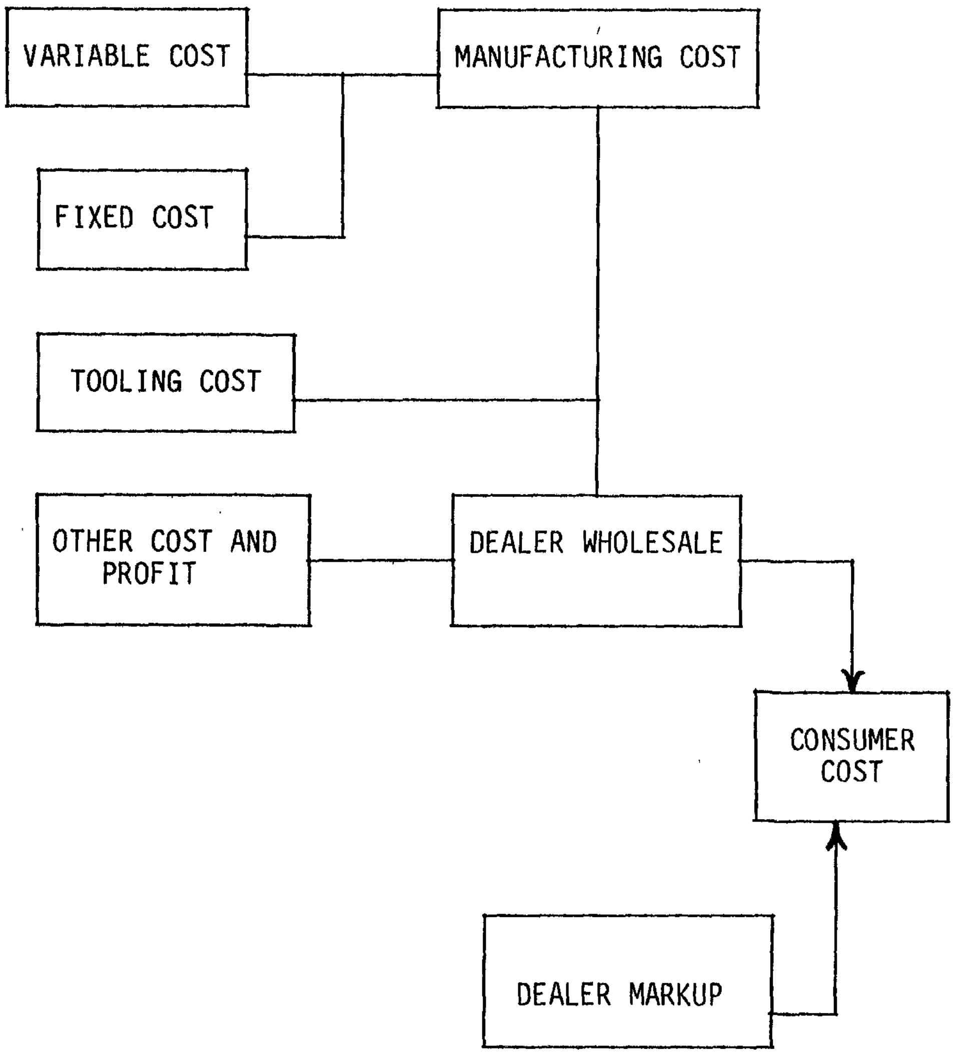
- Manufacturing Cost -- all fixed and variable costs (except tooling) incurred during the production of each component.

- Tooling Cost -- expense of special tools and dies to manufacture a bumper system component. The total expense is apportioned by dividing it by the lifetime production volume of the component (the number of years the component, as designed, was used multiplied by the average annual volume of the component).

- Other Cost and Profit -- includes engineering, warranty, selling, and administrative costs and corporate burden, taxes, depreciation,

FIGURE V-1

CONSUMER COST ELEMENTS



maintenance, profit, and other expenses (excludes factory burden, taxes, depreciation, and maintenance).

- Dealer Wholesale -- manufacturing cost, tooling cost, and "other" cost and profit.

- Dealer Markup -- the amount, usually expressed as a percent of dealer wholesale, covering all costs incurred in the operation of a dealership (e.g., salaries, taxes, depreciation, advertising, maintenance) and profit.

- Consumer Cost -- the sum of dealer wholesale and dealer markup.

2.2 Bumper Systems Studied -- Selection Criteria

There were over 400 model and body style combinations produced in 1979 by domestic and foreign manufacturers.[2/] To represent this large market mix, a sample of bumper systems was selected to provide a high volume representation of the industry rather than any specific manufacturer. The models selected are representative of the high volume vehicles in each vehicle size and body style class. Both domestic and imported models are included.

Model year 1972 cars were chosen to represent the pre standard-models (1972 models for which manufacturers had anticipated the standard and installed a bumper system intended to comply were not included). The first model year

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2/ Automotive News: 1980 Market Data Book Issue, April 30, 1980, pp. 52, 53, and 82.

in which cars had to comply with a particular version of the standard was selected to represent it (i.e., 1974 cars represented the 1974-78 version, and 1980 vehicles represented the 1980 and later version). In addition, a subsample of 1975-78 models was used to study design trends affecting cost and weight since the standard that went into effect for the 1974 model year covered the next four model years as well. Only rear bumpers of 1973 and 1974 vehicles were compared since manufacturers in general anticipated the 1974 front bumper requirements in 1973.

Table V-1 shows the 1972 through 1980 models for which actual bumper costs were estimated.

2.3 Method for Estimating Lifetime Fuel Cost

Additional weight, as a result of the bumper standard, means that more fuel is required to operate a post-standard car. Lifetime fuel expenses are calculated using three elements: the bumper system weight increase, the lifetime gallons of fuel consumed per pound of weight, and the unit price of fuel.

A lifetime weight penalty of 0.9 to 1.1 gallons of fuel consumed per pound of vehicle weight is used in this evaluation.3/

3/ "Economic Impact Assessment-Amendment to Federal Motor Vehicle Safety standard No. 208". National Highway Traffic Safety Administration, Public Docket No. 73-19, Washington, 1977; U.S. Department of Transportation. "Nonpassenger Automobile Average Fuel Economy Standards Model Year 1980-81". Public Hearings before National Highway Traffic Safety Administration, January, 1978, Dr. Potter, V.P. General Motors, Statement.

TABLE V-1
MODELS SELECTED FOR COST EVALUATION

Manufacturer	Model Years: 1972, 1973, 1974 1/	1975-78	1979	1980
Domestic:				
American Motors	Gremlin	Pacer (1975)	-	Concord
Chrysler	Fury, Valiant	Cordoba (1975) Volare (1976)	LeBaron, Volare	LeBaron, Volare
Ford	Galaxie, Pinto, Gran Torino, Maverick	Granada (1975)	Fairmont, LTD, LTD II, Pinto	Fairmont, LTD, Mustang, Pinto
General Motors	Camaro, Vega, Nova, Caprice, Malibu, Firebird	Caprice (1977) Malibu (1978) Seville (1975)	Camaro, Nova, Caprice, Firebird, Grand Am, Malibu	Cadillac, Camaro, Caprice, Chevette Citation, Cutlass, Electra, Malibu, Phoenix, Regal, Salon, Skybird, Sunbird
Foreign:				
Toyota	Corona, Celica	-	Corona	Corona
Volkswagen	Beetle	Rabbit (1975)	-	Rabbit
Volvo	Volvo 2/	-	Volvo	

1/ The same models were selected for each model year.

2/ 1971 and 1973 model years only.

Until 1973, gas prices had been nearly stable for over 20 years.[4] Since then, prices have continuously risen, and the average price of unleaded gasoline in 1979 was $0.95 per gallon.[5] The Federal Highway Administration, in its study of the cost of owning and operating an automobile in 1979, used $1.00 per gallon, the average price of gasoline in the Baltimore, Maryland study area during 1979.[6] Since the bumper systems that were evaluated, as well as the period during which the survey and insurance studies were conducted, covered 1979 and previous years, the Federal Highway's 1979 value of $1.00 per gallon was used as the baseline value for fuel cost.

2.4 Secondary Weight Consideration

Some automotive system designs vary with total vehicle weight (i.e., suspension, brakes, frame). When systems such as bumpers increase or decrease car weight, the size and weight of these dependent systems also changes. This size/weight change is called the "Secondary Weight Effect."[7]

4/ Federal Highway Administration, Cost of Owning and Operating Automobile and Vans, 1979 (Washington, D.C.: U.S. Government Printing Office, 1980), p.6.

5/ National Highway Traffic Safety Administration, "Final Regulatory Analysis of the Model Year 1982 Light Truck Fuel Economy Standards," March 1980, pp. II-4.

6/ Federal Highway Administration, p. 6.

7/ N.E. South, "The Fuel Shortage and Some Potential Effects on Body Engineering," Vol. 1, No. 1, October 1973, p. 31.

Auto industry docket comments on the Agency assessment [8] of the bumper standard stated that secondary weight was a design factor. The Agency summarized these comments and stated that it doubts secondary weight is actually applied to auto designs.[9] However, the assessment did include secondary weight as a cost factor using 0.35 pounds of secondary weight per one pound of bumper weight. For actual cost analysis in this report, secondary weight is considered in the calculation of net benefits in Chapter VI.

3.0 INCREMENTAL CONSUMER COSTS OF THE BUMPER STANDARD

3.1 Derivation of Representative Weights and Costs

Incremental costs (and weights) are defined as the difference between the complete costs (and weights) of pre- and post-standard bumper systems. To arrive at both representative weights and costs, based on tear-down estimates of the selected bumper systems, a "weighted" average weight and cost is calculated for each vehicle size class in each of the model year cars torn down. The basis is the model year proportion of the total production volume in the size class sample. For example, the sample of 1973 full size cars included:[10]

8/ National Highway Traffic Safety Administration, Final Assessment of the Bumper Standard, DOT-HS-804-71 (June 1, 1979).

9/ National Highway Traffic Safety Administration Administrator to Congressman James H. Scheuer, Chairman, House Subcommittee on Consumer Protection and Finance, March 18, 1980, p.8 of Enclosure 1, "Excerpt on Secondary Weight from December 1979 Review of Comments on the Bumper Standard Assessment."

10/ Taken from the third reference of footnote 1/ of this chapter.

Ford Galaxie	Approximately 860,000 produced
GM Caprice	Approximately 940,000 produced
Chrysler Fury	Approximately 280,000 produced
Total	2,100,000 produced

The representative weight (or cost) for the full size, 1973 models is obtained by "weighting" each of the above models as follows:

$$(\text{Galaxie wt.})\,\frac{86}{210} + (\text{Caprice wt.})\,\frac{94}{210} + (\text{Fury wt.})\,\frac{28}{210}$$

The baseline weights and costs, i.e., for the 1972, pre-standard bumper systems, are shown in Table V-2. The table includes data for front, rear and total bumper systems. Costs are in 1979 dollars. Weights and costs for post-standard bumper systems are presented in Tables V-3 and V-4, respectively.

A further aggregation has to be performed before incremental costs (and weights) are obtained. The costs and weights of each size class (subcompacts, compacts, etc.) in each model year are "weighted" to yield a single average weight (or cost) for front, rear and total bumper systems. To do this the size class mix for 1979 is used as follows:11/

11/ Based on 1979 new car registration data in Wards Automotive Year Book, 1980 (Detroit: Ward's Communications, Inc., 1980), p. 154. All imports were classified as subcompacts; luxury cars were classified as full size; and passenger vans were excluded since they are not required to comply with the standard.

Subcompact	38.9 percent
Compact	18.3 percent
Intermediate	22.1 percent
Full Size	20.7 percent
	100.0 percent

Applying this distribution, for example, to the respective weights of rear bumper systems, in 1972 models, for the four size classes (Table V-2), the "weighted" average weight is:

Subcompact, rear bumper	20 lbs. (0.389) =	7.78 lbs.
Compact, rear bumper	29 lbs. (0.183) =	5.31 lbs.
Intermediate, rear bumper	44 lbs. (0.221) =	9.72 lbs.
Full Size, rear bumper	73 lbs. (0.207) =	15.11 lbs.
"Weighted" Average Weight (rounded)	=	38.00 lbs.

The "weighted" average values--shown in each of the tables on weight and cost (Tables V-2, 3 and 4) represent completed costs of a model's bumper sytems, for the model years needed. To establish what weight and cost in associated with a bumper standard the incremental values are obtained.

3.2 Incremental Consumer Cost

The effect of bumper standards on bumper costs--the incremental costs--are derived for each size class in each model year for which a version of the standard applied (1973, 1974-78, 1979, 1980). The cost increments are shown in Table V-5. The values are the differences between respective post- and pre-standard amounts as shown in Tables V-4 and V-2, respectively.

TABLE V-2

BASELINE WEIGHT AND COST DATA
1972 BUMPER SYSTEMS 1/
(1979 Dollars)

VEHICLE SIZE	WEIGHT PER CAR (LBS.)			COST PER CAR		
	Front	Rear	Total	Front	Rear	Total
Subcompact	19	20	39	$29	$31	$60
Compact	40	29	69	$52	$38	$90
Intermediate	46	44	90	$62	$56	$118
Full Size	75	73	148	$74	$77	$151
Weighted Average 2/	41	38	79	$50	$47	$97

1/ Robert F. Mc Lean, Clifford Eckel, and David Cowan, John Z. De Lorean Corp., Cost Evaluation for Four Federal Motor Vehicle Safety Standards, Volume I, Report No. DOT-HS-803-871 (October 1978).

2/ Based on 1979 new car registration volumes.

TABLE V-3

POST-STANDARD BUMPER SYSTEMS WEIGHTS 1/
(Lbs.)

VEHICLE SIZE	1973 MODELS Front	Rear	Total
Subcompact	36	21	57
Compact	69	38	107
Intermediate	120	67	187
Full Size	106	99	205
Weighted Average	75	51	126

VEHICLE SIZE	1974 MODELS Front	Rear	Total
Subcompact	36	42	78
Compact	69	76	145
Intermediate	120	101	221
Full Size	106	109	215
Weighted Average	75	75	150

VEHICLE SIZE	1979 MODELS Front	Rear	Total
Subcompact	43	41	84
Compact	88	52	140
Intermediate	67	61	128
Full Size	72	75	147
Weighted Average	63	55	118

VEHICLE SIZE	1980 MODELS Front	Rear	Total
Subcompact	43	42	85
Compact	88	53	141
Intermediate	66	62	128
Full Size	73	75	148
Weighted Average	63	55	118

1/ See the first footnote of this chapter for data source reference.

TABLE V-4

COST OF POST-STANDARD BUMPER SYSTEMS 1/
(1979 Dollars and Vehicle Mix)

VEHICLE SIZE	Front	Rear	Total
		1973 MODELS	
Subcompact	52	36	88
Compact	70	42	112
Intermediate	120	70	190
Full Size	112	92	204
Weighted Average	83	56	139

VEHICLE SIZE	Front	Rear	Total
		1974 MODELS	
Subcompact	52	56	108
Compact	70	94	164
Intermediate	120	126	246
Full Size	112	128	240
Weighted Average	83	93	176

		1979 MODELS	
Subcompact	82	82	164
Compact	109	75	184
Intermediate	96	82	178
Full Size	125	115	240
Weighted Average	99	87	186

VEHICLE SIZE	Front	Rear	Total
		1980 MODELS	
Subcompact	83	83	166
Compact	109	75	184
Intermediate	97	84	178
Full Size	126	115	241
Weighted Average	100	88	188

1/ Sources of the cost information are listed under the first footnote in this chapter.

TABLE V-5
INCREMENTAL CONSUMER COSTS OF EACH BUMPER STANDARD VERSION[1/]
(1979 Dollars and Vehicle Mix)

	1973 MODELS			1974 MODELS			1979 MODELS			1980 MODELS		
VEHICLE SIZE	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Subcompact	32	5	28	23	25	48	53	51	104	54	52	106
Compact	18	4	22	18	56	74	57	37	94	57	37	94
Intermediate	58	14	72	58	70	128	34	26	60	35	28	63
Full-Size	38	15	53	38	51	89	51	38	89	52	38	90
Weighted Average	33	9	42	33	46	79	49	40	89	50	41	91

1/ Incremental cost is the difference between post and pre-standard (1972)--bumper system costs.

The costs of post-standard bumper systems were higher than pre-standard bumper systems costs. The bumper systems of 1979 and 1980 intermediate and full size vehicles had lower or equal costs compared to 1974 models. These lower costs may reflect improved designs, technology, use of new materials, or downsizing. Pre-standard bumpers were generally made of steel whereas post-standard bumpers were made of various materials (aluminum and elastomerics as well as steel). The costs of post-standard bumpers represent an average of these material types.

Comparing costs of 1973 and 1974 models shows the effect of the more stringent 1974 rear bumper requirements. The incremental cost of rear bumpers in 1973 was $9; for 1974 cars it was $46. The front bumpers of 1973 and 1974 models remained virtually the same, so both 1973 and 1974 incremental costs of front bumpers are the same.

The 1979 model incremental costs are lower than the 1974 model costs even though the requirements of the standard for 1979 call for more damage protection than the 1974-1978 version of the standard. This lower incremental cost probably reflects the previously mentioned improvements in design and technology plus use of stronger, lighter weight materials and the 1979 downsizing of many domestic manufactured vehicles.

The incr mental costs of 1979 and 1980 models (relative to pre-standard) are almost the same. This suggests that manufacturers, when redesigning for the 1979 models, anticipated the 1980 standard. The review of part numbers for 1979 and 1980 model bumper systems disclosed that most parts were the same.

To confirm that the lower cost change for 1979 model bumper systems relative to 1974 model bumper systems is the result of technological improvements, a trend study of 1977-1978 model bumper systems was performed. These models had to comply with the same basic bumper requirements as the 1974 models. Therefore, differences in bumper system costs should be the result of design or technology improvements.

Table V-6 shows the average cost of post-standard bumper systems including the trend study results. The 1975-78 models selected were comparable to those cost-estimated for 1974 and 1979 models (see Table V-1). Because of the small sample size of 1975-78 cars studied, only the composite average bumper system costs were compared. The trend study indicates that the 1974 bumper system cost estimates were higher than the costs of the comparable 1975-78 models. This suggests that the previous conclusion was correct and that improved design and technology and the use of new materials probably helped to lower bumper system costs.

TABLE V-6

AVERAGE COST TREND OF POST-STANDARD BUMPER SYSTEMS
(1979 Dollars and Vehicle Mix)

Average Cost/Car (Front and Rear Combined)	1973	1974	1975-1978	1979	1980
	$139	$176	$161	$186	$188

4.0 ADDED LIFETIME FUEL COST

4.1 Incremental Bumper System Weight

Table V-7 shows weight increases of the bumper systems (without secondary weight) for each version of the standard compared with the weights of 1972 pre-standard model cars. The incremental weights are shown by vehicle size for both front and rear bumper systems. The method for arriving at these increments is the same as for incremental costs in the previous section (all respective values in Table V-3 are subtracted from those in Table V-2).

The costs of post-standard bumper systems were higher than pre-standard bumper system costs. The bumper systems of 1979 and 1980 intermediate and full size vehicles had lower or equal costs compared to 1974 models. These lower costs may reflect improved designs, technology, use of new materials, or downsizing. Pre-standard bumpers were generally made of steel whereas post-standard bumpers were made of various materials (aluminum and elastomerics as well as steel). The costs of post-standard bumpers represent an average of these material types.

TABLE V-7
INCREMENTAL BUMPER SYSTEM WEIGHT[1] PER CAR
(1979 Vehicle Mix)

	1973 MODELS			1974 MODELS			1979 MODELS			1980 MODELS		
VEHICLE SIZE	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Subcompact	17	1	18	17	22	39	24	21	45	24	22	46
Compact	29	9	38	29	47	76	48	23	71	48	24	72
Intermediate	74	23	97	74	57	131	21	17	38	20	18	38
Full-Size	31	26	57	31	36	67	-3	2	-1	-2	2	0
Weighted Average	35	13	48	35	37	72	22	17	39	22	17	39

1/ All incremental weights were found by subtracting the weight of 1972 of pre-standard systems from the post-standard bumper weights. All weights are to the nearest pound.

4.2 Added Lifetime Fuel Cost

Using $1 per gallon (average price of gas in 1979), multiplying by 1.1 gallons per pound of bumper weight (estimated over the life of a car) times the incremental bumper system weights shown in Table V-7, the lifetime fuel costs, due to increased weight for the bumper standard, are calculated.12/ These fuel costs are shown in Table V-8. Added fuel costs for post-standard cars ranged from $42 for 1979 models, to $79 for 1974 models. In Chapter VI projected fuel costs for the remaining lives of various models are used, and then discounted to 1979, to reflect both the inflationary effect and present value of the added lifetime fuel costs.

5.0 TOTAL INCREMENTAL BUMPER COST

Adding the values from Table V-5 (Incremental Consumer Costs) and Table V-8 (Lifetime Fuel Costs) yields the total incremental cost of the bumper system for each version of the bumper standard. The results, broken down by vehicle size for both front and rear bumper systems, are shown in Table V-9 for each model year group.

In general, bumper system costs increased for post-standard vehicles. The 1973 models showed the smallest increase ($94) while 1974 bumper systems increased the most (by $158) in comparison to 1972 (pre-standard) cars. (Only the front bumper systems of 1979 and 1980 subcompacts declined in costs.)

12/ See brief discussion and sources in Section 2.3 of this chapter.

TABLE V-8

LIFETIME FUEL COST PER CAR1/
(in constant 1979 Dollars)

	1973 MODELS			1974 MODELS			1979 MODELS			1980 MODELS		
VEHICLE SIZE	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Subcompact	$19	1	20	19	24	43	26	23	49	26	24	50
Compact	32	10	42	32	52	84	53	25	78	53	26	79
Intermediate	81	25	106	81	63	144	23	19	42	22	20	42
Full Size	34	29	63	34	40	74	-3	2	-1	-2	2	0
Weighted Average	38	14	52	38	41	79	24	18	42	24	19	43

1/ Based on weights in Table V-7 and using $1 per gallon (the price of gas in 1979) and 1.1 gallons per pound of bumper weight (estimated over the life of a car).

TABLE V-9

TOTAL INCREMENTAL COST OF BUMPER STANDARD DUE TO INCREASED WEIGHT AND LIFETIME FUEL USE
(In Constant 1979 Dollars)

	1973 MODELS			1974 MODELS			1979 MODELS			1980 MODELS		
VEHICLE SIZE	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Subcompact	42	6	48	42	49	91	79	74	153	80	76	156
Compact	50	14	64	50	108	158	110	62	172	110	63	173
Intermediate	139	39	178	139	133	272	57	45	102	57	48	105
Full Size	72	44	116	72	91	163	48	40	88	50	40	90
Weighted Average	71	23	94	71	87	158	73	58	131	74	60	134

Intermediates had the greatest average increase for the 1973 and 1974 versions of the standard, and compact models' bumper systems increased the most for the 1979 and 1980 standards. For 1973 models, the cost of front bumper systems increased more than rear systems while for 1974 and later models the reverse was true.

The next chapter addresses the benefits of bumper systems, and together with the cost of such systems, net benefits are derived, taking into account a range of secondary weights.

CHAPTER VI

BUMPER STANDARD--BENEFITS AND COSTS

1.0 INTRODUCTION

1.1 Comparing Benefits and Costs

In this chapter the lifetime benefits of each version of the bumper standard are computed and compared with the respective lifetime incremental costs. The lifetime benefits of the standard are the difference in repair costs between pre- and post-standard cars for the total number of low-speed collisions that occur in an average car's life. The repair cost data for pre- and post-standard cars were obtained in both the driver survey of unreported, low-speed collisions and the insurance claim study and were presented in Chapter IV.

Lifetime incremental costs, calculated in Chapter V, include the incremental cost to the consumer plus the added lifetime fuel cost that can be attributed to the bumper standard. The incremental consumer cost was estimated from tear-downs of pre- and post-standard bumper systems.

Since both benefits and costs of the standard are expressed in dollars, they can be compared directly to determine if the standard was sufficiently effective to "pay for itself."

1.2 Selection of an Effectiveness Measure

The objective of this report is to determine if the bumper standard achieved sufficient benefits to offset the added costs associated with the standard. For the standard to do this, its lifetime benefit--the difference between pre- and post-standard cars' damage repair costs in low-speed collisions over a car's life--must be larger than the lifetime cost of the standard--incremental consumer cost plus added fuel cost. There are several ways to compare benefits and costs:

- Benefit to cost ratio
- Number of years to recoup costs
- Net benefit (benefit minus cost)

Each of these methods will be briefly discussed below.

If the standard is cost-effective, the benefit-cost ratio (B-C ratio) should equal or exceed unity. It is a "quick" ratio to measure the effectiveness of the standard. Such ratios are useful in comparing alternative programs or solutions to a problem, but by themselves do not reflect the magnitude of benefits or costs. B-C ratios are valuable when there is a large difference among alternatives (e.g., B-C ratios of 2/1, 10/1, etc.). The difference in the effectiveness of the versions of the bumper standard may not be sufficiently large to result in B-C ratios that would be useful for analysis.

Computing the number of years to recoup costs of the standard is a comparison of the annual benefits with the total costs of the standard. The technique can be applied when the costs are a one time investment, and there is an expected time period in which the costs should be offset by benefits. The costs of the bumper standard are both "one time" (consumer costs) and variable (fuel cost). There is no prescribed time period in which a standard is to achieve a predetermined level of effectiveness. Therefore, using the "number of years to recoup costs" technique is not appropriate for evaluating the bumper standard.

The net benefit of the standard is the difference between the lifetime benefits and the lifetime costs. After all the costs associated with the standard are deducted from its gross benefits, the remainder, or net benefit of the standard, is a measure of effectiveness. The implied intention here is that the bumper standard should provide sufficient property damage protection to offset its added costs.

The net benefits measure was selected as the appropriate effectiveness criterion for comparing benefits and costs of the bumper standard.

1.3 Contents of the Chapter

This Chapter is divided into the following topics:

- o Description of Factors Involved in the Calculation of Lifetime Benefits and Costs
- o Calculation of Lifetime Benefits
- o Calculation of Lifetime Costs
- o Net Benefits of the Bumper Standard
- o Additional factors Affecting Net Benefits

2.0 DESCRIPTION OF FACTORS INVOLVED IN THE CALCULATION OF LIFETIME BENEFITS AND COSTS

2.1 Selection of Inflation Rate

The bumper standard has been in effect for over seven years, during a time when the value of the dollar has changed considerably. The purchase price of an automobile has nearly doubled during this period. The cost of both labor and materials for repairs has increased by a similar magnitude. In order to evaluate the standard, dollars from different time periods had to be compared. To do this, an inflation rate that is representative of the overall time period was estimated. This rate is a measure of the change in the value of money over that time period.

To select an appropriate inflation rate, a comparison of four of the Bureau of Labor Statistic's indices, relevant to automobile repair costs, was conducted. These included the Auto Repair Index, the New Car Price Index, the New Tire Price Index, and the Consumer Price Index.1/ During most of the years in question, a ten percent inflation rate best fitted the rate of change in the indices and was used to adjust the benefits and costs of the bumper standard for inflation.

2.2 Establishment of a Base Year for Analysis

A base year is needed for economic analysis so that dollar values of benefits and costs from different time periods can be compared. In theory, any year--even one outside the study period--can be selected. This assumes that possible errors are small when using inflation or discount rates not representative of the actual change in money values during the time period; that is, the rate is too high or too low or the change in the rate over time is geometric rather than linear.

The year 1979 was selected as the base for the analysis of benefits and costs since it was the latest year for which actual economic data were

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1/ KLD Associates, Analysis of Insurance Claims to Determine Bumper Effect on Crash Damage, DOT-HS-805-842 and 843, March 1980, pp. 23-25.

available. Most of the unreported, low-speed collisions which were studied occurred during 1979 and the repair costs for damaged cars in those collisions were estimated using 1979 labor rates and part costs. Insurance data were analyzed for 1972 through 1979 calendar years and included claims for 1969 through 1979 model cars. Consumer costs for 1972 through 1980 bumpers were analyzed from tear-downs. Calendar year 1980 had not ended when this analysis was begun and complete actual 1980 economic information was not available.

2.3 Controlling for a Changing Vehicle Size Mix

During the time period the bumper standard has been in effect (1973-1980), the mix of new vehicle sizes sold each year changed from one in which full size cars predominated to a mix containing more economical, fuel efficient, subcompact cars. The values of the following three variables used in the calculation of net benefits differed significantly by vehicle size class: (1) the proportion of bumper-involved insurance claims, (2) the repair cost for damage in bumper-involved insurance-claimed accidents, and (3) the incremental consumer cost of the standard. For these variables the vehicle size mix was held constant from one model year to the next. This approach helped to ensure that differences in net benefits of the various versions of the standard were due to the different requirements of the standards rather than the effect of a changing vehicle mix.

To correspond with the base year selected for the analysis, the vehicle mix of 1979 model cars sold in 1979 was used as the constant vehicle mix for weighting and calculating, broken down by vehicle size class, the three affected variables. Section 6.0 looks at the effect on net benefits of using vehicle mixes which correspond to the model years of the different versions of the standard rather than using the 1979 mix.

2.4 Low-Speed Collisions Reported to the Police

Certain low-speed collisions which result in property damage may have to be reported to the police. Generally, if an injury occurs, the collision must be reported. When the collision only involves property damage, it is usually reported to the police if the estimated repair cost exceeds a predetermined amount. For some of these collisions, although a police report is completed, an insurance claim may not be filed, especially if the estimated repair cost is about the same as the deductible amount in the driver's insurance policy.

The driver survey showed that about seven percent of low-speed collisions involving the bumper were reported to the police only--no insurance claim was filed. The other 93 percent were either unreported or an insurance claim was filed. To obtain a representative sample of police reported collision reports would have required another, costly survey. The variety of police reporting requirements--particularly those for low-speed collisions--would have made obtaining a representative sample difficult. Also, the cost of damage in a police-reported collision is probably quite close to that of an unreported collision. Benefits from reduced repair costs in police-reported collisions would be very small when compared to the benefits from unreported collisions or collisions in which an insurance claim was filed. Excluding benefits based on police reported collisions would have the effect of slightly understating the estimates of benefits of the bumper standard.

Because of these factors, police-reported collisions were not included in this study.

2.5 Effect of Secondary Weight

Chapter V included a discussion of secondary weight--weight of dependent automotive systems, such as suspension and brake systems, which change with total vehicle weight changes. Because the bumper standard increased the weight of the bumpers, consideration of the effects of secondary weight are necessary.

Previous studies have included estimates of the secondary weight factor. An assessment of the bumper standard published in 1979 assumed an adjustment of 0.35 pounds of secondary weight per pound of primary bumper weight change.[2/] In response to automotive industry comments to the docket regarding the assessment's secondary weight factor, an analysis of primary and secondary weights was performed, and the factor was revised to 0.5.[3/] The auto industry submitted several estimates of secondary weight: General Motor's estimated factor was between 0.75 and 1.0[4/] and Ford's was 1.1 to 1.6[5/] The Ford estimates of secondary weights were not specifically keyed to bumper systems alone and may not solely reflect changes in bumper system weight.[6/] The secondary weight factors used in subsequent sections range from 0.35 to 1.0.

As in the previous calculations of incremental cost, described in Chapter V, two costs are associated with secondary weight--consumer cost and additional lifetime fuel cost. The consumer cost was estimated for two different assumptions. One is based on the average consumer cost per pound of car ($1.60/pound in 1979 dollars). The other is the additional "material only" cost of steel and aluminum incorporated into the car in

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2/ National Highway Traffic Safety Administration, "Final Assessment of the Bumper Standard," June 1, 1979, p. 48.

3/ The Transportation Systems Center analyzed industry data and performed an independent analysis. The results are summarized in an attachment to a letter dated March 18, 1980, from the Administrator of NHTSA to the Chairman of the House Subcommittee on Consumer Protection and Finance, p. 16.

4/ Ibid, p. 20.

5/ Ibid.

6/ Ibid, p. 16.

production (using a 9 to 1 steel to aluminum ratio, at $0.22 and $1.11 per pound, respectively). This works out to a consumer cost of $0.60 per added pound of bumper weight in 1979 dollars.7/ The added lifetime fuel cost for secondary weight is the product of the lifetime fuel requirements (1.1 gallons/pound), the cost of fuel, the change in weight due to the standard, and the secondary weight factor (the number of pounds added to dependent systems per additional pound of bumper weight).

3.0 LIFETIME BENEFITS

3.1 Definition of Lifetime Benefits

Benefits come from property damage protection in low-speed collisions afforded by bumper systems which meet the standard. Measurement of property damage protection is a comparison of the difference in repair cost (incremental repair cost) of damage to pre- and post-standard cars in low-speed collisions. The incremental repair cost summed over the number of low-speed collisions that can occur in a car's life is defined as the lifetime benefit of the standard.

7/ The calculation for this consumer cost is:

[$0.22 x 0.9 + $1.11 x 0.1] = $0.31 (the variable cost in 1978 dollars)
Consumer cost = Variable cost x 1.767 = $0.31 x 1.767 = $0.55 (1978 dollars)
Consumer cost (1979 dollars) = $0.55 x 1.1 = $0.60

The number of low-speed collisions that can occur in a car's life is assumed to be the same for both pre- and post-standard cars.[8/] Because post-standard bumper systems are expected to reduce damage in some collisions to zero, the number of low-speed collisions in which the car is damaged should be different for pre- and post-standard cars and must be taken into account when computing lifetime benefits.

The survey and insurance claim analysis are the data sources that were used for computing lifetime benefits. In the following sections benefits will first be calculated in constant 1979 dollars and then discounted to reflect the stream of future benefits for the various make/model bumper systems.

3.2 Gross Lifetime Benefits in Constant 1979 Dollars

The benefit as derived here is the incremental change in dollars of repair costs between pre- and post-standard cars. The total repair cost is the sum of repair costs obtained from unreported and "insurance

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8/ Drivers were asked as part of the national survey on unreported collisions how many miles their cars had been driven during the same time period for which unreported collisions occurred. Incident rates per 1,000 vehicle miles were computed and showed older cars had a greater collision rate per mile than newer cars. The newer cars, however, were used more and had higher mileage for the same time period. The net effect was that the unreported collision rate based on time alone was about the same for old and new cars. The small sample sizes of each model year group plus lesser confidence in data based on drivers ability to recall vehicle mileage, led to the assumption that an average incident rate per year should be used for all age vehicles.

claimed" collisions. To determine the lifetime benefit, it is assumed that annual benefits are average values which are then expanded to reflect a 10 year life for a car.9/,10/

3.2.1. Calculation of Gross Lifetime Benefits in Constant 1979 Dollars

The following expression is used to calculate the value of incremental gross benefits (B):

$$B = L\ [U \left\{ (D_1C_1)-(D_2C_2) \right\} + (N_1I_1K_1) - (N_2I_2K_2)\ ]$$

where:

B = The incremental gross benefits of post-standard bumper systems in dollars.

L = Average car life = 10 years.

U = The low speed collision incident rate of all cars on the road each year. A value of 13.7 percent was found from the driver survey (see Chapter III, Sec. 3.1.5).

9/ Transportation Systems Center study of R.L. Polk registration data contained in the following publication: Environmental Protection Agency, Passenger Car Fuel Economy: EPA and Road, (Washington, D.C.: U.S. Government Printing Office, September 1980), pp. 264-271.

10/ Federal Highway Administration, Cost of Owning and Operating Automobiles and Vans, 1979 (Washington, D.C.: U.S. Government Printing Office, 1980), p. 4.

D = The damage frequency of cars per unreported collision, that is, the percentage of cars damaged in unreported collisions. Ref. Tables IV-1, 2 and 3 for combined front and rear collisions, front collisions, and rear collisions, respectively.
(D_1 = pre-standard; D_2 = post-standard)

C = The cost ($) to repair damage, per car, in unreported collisions. Ref. Table IV-10.
(C_1 = pre-standard; C_2 = post-standard)

N = Number of property damage insurance claims, per insured car, per year. Ref. Table IV-14
(N_1 = pre-standard; N_2 = post-standard)

I = Proportion of property damage insurance claims involving the bumper, to all property damage insurance claims (ratio). Ref. Table VI-1
(I_1 = pre-standard; I_2 = post-standard)

K = The cost ($) to repair damage in insurance claims involving the bumper. Ref. Table IV-11.
(K_1 = pre-standard; K_2 = post-standard)

This equation yields values of incremental gross benefits for the combination of front and rear bumper systems. Before continuing with an example, two tables are presented which give the ratios (I) of property damage insurance claims involving the bumper, to all property damage insurance claims (Table VI-1); and the ratios of cars in unreported collisions struck in either the front or rear (Table VI-2). The latter values are used when calculating the incremental benefits for either the front or rear bumper systems.

TABLE VI-1

PROPORTION OF PROPERTY DAMAGE INSURANCE CLAIMS, INVOLVING THE BUMPER, TO ALL PROPERTY DAMAGE INSURANCE CLAIMS

MODEL YEAR	COMBINED FRONT AND REAR	FRONT ONLY	REAR ONLY
Pre-Std. (1972)	0.57	0.35	0.22
1973	0.53	0.28	0.25
1974-78	0.41	0.25	0.16
1979	0.42	0.24	0.18

TABLE VI-2

PROPORTION OF CARS STRUCK IN FRONT OR REAR IN UNREPORTED, LOW SPEED COLLISIONS

MODEL YEAR	FRONT ONLY	REAR ONLY
Pre-Std (All pre-1973)	0.48	0.52
1973	0.44	0.56
1974-78	0.46	0.54
1979-80	0.43	0.57

3.2.2. Sample Calculation of Incremental Benefits for the 1979 Model Year Front Bumper System

The equation for calculating the incremental benefit of either the front or rear bumper system differs only slightly from the one used for combined bumper systems.

$$B(Front)=L\left[U\left\{(D_1C_1P_1) - (D_2C_2P_2)\right\} + (N_1I_1K_1)-(N_2I_2K_2)\right]$$

All definitions are the same as listed in Section 3.2.1 except that substitions for D, C, I and K must reflect the appropriate value for front bumpers, and where:

P = The proportion of cars in unreported collisions that were struck in the front or rear (ratio).
Ref. Table VI-2
(P_1 = pre-standard; P_2 = post-standard)

Using the values for 1979 Model Year front bumper systems found in the references listed in each definition, and using L = 10 years (average life of a car) and U = 0.137 (13.7 percent of all cars on the road are involved in an unreported low-speed collision per year):

$$B(front) = 10[0.137\ ((0.60 \times 188 \times 0.48) - (0.38 \times 166 \times 0.43)) + (0.179 \times 0.35 \times 745) - (0.147 \times 0.24 \times 891)]$$

B(front) = <u>$ 189</u>

The incremental gross lifetime benefits for all bumper standard versions, front and rear systems combined and separately, are shown in Table VI-3.

TABLE VI-3

GROSS LIFETIME BENEFITS
OF BUMPER SYSTEMS IN CONSTANT 1979 DOLLARS

MODEL YEAR AND SYSTEM	INCREMENTAL GROSS BENEFIT $	CONFIDENCE INTERVAL 1/ $
1973 Front and Rear	111	72 to 150
Front	133	98 to 168
Rear	-21	-45 to 3
1974-78 Front and Rear	229	197 to 261
Front	148	113 to 183
Rear	82	63 to 101
1979 Front and Rear	221	176 to 266
Front	189	147 to 231
Rear	33	6 to 60

1/ Due to sampling error, the range of gross benefits at a 95 percent confidence level is shown.

3.3 Discounting Gross Lifetime Benefits

Discounting is the process by which a future stream of benefits are valued in present dollars. The purpose of the calculation is to bring expected benefits that accrue over varying future lives back to a common base period so that preferred program actions can be taken when choosing among alternatives. While this definition does not completely apply here, discounting future benefits of the various bumper systems is appropriate since all post-standard cars, as well as a number of pre-standard models are, and will be, on the road to complete their individual life spans.

A car life is assumed to be 10 years during which it travels 100,000 miles (see Section 3.2 for reference). It is also assumed that the benefits will accrue on a mileage basis over a car's life. The frequency of low-speed collisions is somewhat dependent on the amount of miles a car is driven. This suggests the benefits will also be mileage dependent. A measure of the rate that benefits accrue per mile of driving is estimated using the gross lifetime benefits from Table VI-3 divided by the lifetime vehicle miles (100,000 miles). The vehicle miles traveled each year are shown in Table VI-4.

TABLE VI-4

VEHICLE MILES TRAVELED
DURING A CAR'S LIFE

YEAR		ANNUAL MILES TRAVELED 1/	CUMULATIVE MILES TRAVELED
1		18,110	18,110
2		15,110	33,220
3		13,260	46,480
4		11,830	58,310
5		10,580	68,890
6		9,240	78,130
7		7,820	85,950
8		6,200	92,150
9		4,600	96,750
10		3,250	100,000
	TOTAL	100,000	

1/ National Highway Traffic Safety Administration, Department of Transportation, Final Assessment of the Bumper Standard, DOT HS-804-718, (June 1, 1979), p. 23.

3.3.1 Discounting Method for Lifetime Benefits

Future benefits are discounted to this evaluation's base calendar year of 1979 (end of year). A 1979 model year car, for example, is considered to be new with ten years to go for discounting purposes.

Likewise, a 1973 model will have accumulated six "historical" years through calendar year 1979 and have four "future" years over which benefits are still to be obtained.

To calculate discounted future benefits, a discount rate of 10 percent is used.11/ Discount factors to be applied in the calculation are given in Table VI-5.

TABLE VI-5

DISCOUNT FACTORS FOR A 10 PERCENT RATE

YEAR	FACTOR
1	0.909
2	0.826
3	0.751
4	0.683
5	0.621
6	0.564
7	0.513
8	0.467
9	0.424
10	0.386

11/ Office of Management and Budget, "Discount Rates to Be Used in Evaluating Time Distributed Costs and Benefits," Circular A-94, Revised (March 27, 1972), Attachment A.

The expression for discounted gross benefits is as follows:

$$B\ (\text{discounted}) = \frac{B}{M}\left[\sum_{y=1}^{y=H} A\ (y) \quad + \quad \sum_{y=H}^{y=10} A\ (y)\cdot S\ (y-H)\right]$$

where:

B The gross incremental benefits of post-standard bumper systems in dollars (constant 1979 dollars), from Table VI-3.

M = Lifetime vehicle miles traveled--100,000 miles, Ref. Table VI-4.

A = Annual miles traveled over a car's ten year life. Ref. Table VI-4.

y = Year of car life, 1 through 10.

H = Number of "historical" years--the number of years a car model has been on the road through the base year for discounting.

S = Discount factor at a 10 percent rate. Ref. Table VI-5.

3.3.2. Sample Calculation of Discounted Gross Benefits for the Model Year 1979 Front Bumper System

The 1979 model year cars have no "historical" years (H = 0) through the base calendar year 1979 (end of year). The stream of benefits due in the "future" ten years have to be discounted to the base year. Therefore, the equation shown in the previous section is now expressed with the appropriate summation limits.

$$B\ (\text{discounted}) = \frac{B}{M}\left[\sum_{y=1}^{y=0} A\ (y) \quad + \quad \sum_{y=1}^{y=10} A\ (y)\cdot S\ (y)\right]$$

Substituting, and summing up, B (discounted) is:

$$\frac{\$\ 189}{100{,}000}\left\{0 \quad + \quad \begin{array}{r} 18{,}110 \times 0.909 \\ +15{,}110 \times 0.826 \\ +13{,}260 \times 0.751 \\ +11{,}830 \times 0.683 \\ +10{,}580 \times 0.621 \\ +\ 9{,}240 \times 0.564 \\ +\ 7{,}820 \times 0.513 \\ +\ 6{,}200 \times 0.467 \\ +\ 4{,}600 \times 0.424 \\ +\ 3{,}250 \times 0.386 \end{array}\right\} = \$\ 130$$

The complete discounted incremental gross benefits for all post-standard bumper systems are shown in Table VI-6.

TABLE VI-6

GROSS LIFETIME BENEFITS OF POST STANDARD BUMPER SYSTEMS--DISCOUNTED TO 1979 DOLLARS

MODEL YEAR AND SYSTEM	DISCOUNTED INCREMENTAL GROSS BENEFITS $	CONFIDENCE INTERVAL 1/ $
1973 Front and Rear	107	69 to 145
Front	128	95 to 161
Rear	-20	-43 to 3
1974-78 Front and Rear	198	170 to 226
Front	128	98 to 161
Rear	71	55 to 3
1979 Front and Rear	152	121 to 183
Front	130	101 to 159
Rear	23	4 to 42

1/ Due to sampling error, the range of gross benefits, at a 95 percent confidence level, is shown.

4.0 LIFETIME COSTS

4.1 Introduction

In Chapter V, the lifetime costs of the bumper standard were presented and included both the incremental consumer cost to make bumpers comply with the standard, and the lifetime fuel cost for the extra weight of post-standard bumpers. The former cost (incremental consumer cost) is a one-time expense paid by consumers when purchasing a new car. In this sense, it is a sunk cost and as such has no future implications. The incremental consumer costs of the bumper standard (taken from Table V-4) are repeated in Table VI-7 for 1973, 1974 and 1979 models (since insurance data was not available for 1980 model year cars, their gross benefits were not calculated and so their costs are not included in this section).

TABLE VI-7

INCREMENTAL CONSUMER COST OF EACH
BUMPER STANDARD VERSION
(1979 Dollars and Vehicle Mix)

	1973 MODELS			1974 MODELS			1979 MODELS		
VEHICLE SIZE	FRONT	REAR	TOTAL	FRONT	REAR	TOTAL	FRONT	REAR	TOTAL
Subcompact	23	5	28	23	25	48	53	51	104
Compact	18	4	22	18	56	74	57	37	94
Intermediate	58	14	72	58	70	128	34	26	60
Full	38	15	53	38	51	89	51	38	89
Weighted Average	33	9	42	33	46	79	49	40	89

Fuel costs, for added bumper weight, accumulate over the car's life and should be discounted in the same manner as were future gross benefits. Fuel costs in Chapter V were calculated using a factor of 1.1 gallons of fuel required over the life of a car for each additional pound of bumper weight. The bumper weights (taken from Table V-7) are repeated in Table VI-8 (1980 bumper weights are excluded).

4.2 Lifetime Discounted Fuel Costs

In Chapter V the fuel costs were calculated in constant 1979 dollars for which only the 1979 price of fuel was required ($1/gallon was the estimate) and the total lifetime rate (1.1 gallons per pound) was used without regard to how the fuel costs were distributed over the car's life. To discount the future fuel costs, a basis for distributing these costs must be assumed. The approach used here is that fuel costs will accrue on a mileage basis over a car's life--the same assumption that was made for discounting future gross lifetime benefits. Again a car's life is assumed at 10 years with a total mileage of 100,000 miles, which is distributed annually as shown in Table VI-4. To compute the fuel cost each year, for discounting purposes, an estimate of the cost per mile is required. This is done as follows: (1.1 gallons/pound x incremental bumper weight) divided by 100,000 to yield the fuel cost per mile for the added bumper weight. The lifetime fuel costs in constant dollars (from Chapter V) are shown in Table VI-9.

TABLE VI-8

INCREMENTAL BUMPER SYSTEM WEIGHT

VEHICLE SIZE	1973 FRONT	1973 REAR	1973 TOTAL	1974 FRONT	1974 REAR	1974 TOTAL	1979 FRONT	1979 REAR	1979 TOTAL
Subcompact	17	1	18	17	22	39	24	21	45
Compact	29	9	38	29	47	76	48	23	71
Intermediate	74	23	97	74	57	131	21	17	38
Full	31	26	57	31	36	67	-3	2	-1
Weighted Average	35	13	48	35	37	72	22	17	39

TABLE VI-9

LIFETIME FUEL COST
IN CONSTANT 1979 DOLLARS
(FUEL PRICE = $1.00/GALLON)

VEHICLE SIZE	1973 FRONT	1973 REAR	1973 TOTAL	1974 FRONT	1974 REAR	1974 TOTAL	1979 FRONT	1979 REAR	1979 TOTAL
Subcompact	19	1	20	19	24	43	26	23	50
Compact	32	10	42	32	52	84	53	25	78
Intermediate	81	25	107	81	63	144	23	19	42
Full	34	29	63	34	40	74	-3	2	-1
Weighted Average	39	14	53	39	41	79	24	19	43

4.2.1. Discounting Method for Lifetime Fuel Cost

Future lifetime fuel costs are discounted to this evaluation's base calendar year (end of 1979). A 1979 model year car is considered new with a full ten year life remaining for discounting purposes; whereas, a 1973 model has accumulated six "historical" years (H = 6 in the following equation) through calendar year 1979 and has four remaining years over which fuel costs must be discounted. A 10 percent discount rate is used. The factors in Table VI-5 will also apply here.

Since fuel prices have been rising at a rate greater than inflation, their actual and projected prices in 1979 dollars for each year starting with the base year 1979 must be used for discounting. Table VI-10 shows the fuel price projections. For historical fuel costs (prior to the 1979 base year), the 1979 fuel price ($1.00/gallon) applies since all dollars are expressed in 1979 dollars.

The equation for discounted lifetime fuel costs is as follows:

$$F(\text{discounted}) = \frac{F}{M}\left[g \sum_{y=1}^{y=H} A\,(y) + \sum_{y-H+1}^{y=10} A\,(y)\cdot(y-H)\cdot G\,(y-H) \right]$$

where:

F = Lifetime fuel cost for added bumper weight in constant 1979 dollars from Table VI-9.

M = Lifetime vehicle miles traveled - 100,000 miles. Ref. Table VI-4.

g ~~G~~ 1979 price of gas = $1.00/gallon, constant price for "historical" miles traveled. Ref. Table VI-10.

A = Annual miles traveled over a car's ten year life Ref. Table VI-4.

y = Year of car life, 1 through 10.

H = Number of "historical" years--the number of years a car model has been on the road through the base year for discounting.

S = Discount factor at a 10 percent rate Ref. Table VI-5.

G = Price of gas each year projected through 198~~0~~8 in 1979 dollars Ref. Table VI-9.

TABLE VI-10

ESTIMATED AVERAGE PRICE
OF UNLEADED GASOLINE[1/]

CALENDAR YEAR	PRICE ($/GALLON IN 1979 DOLLARS)[2/]
1979	1.00[3/]
1980	1.18
1981	1.20
1982	1.25
1983	1.27
1984	1.33
1985	1.38
1986	1.39
1987	1.40
1988	1.41

1/ National Highway Traffic Safety Administration, Department of Transportation, Final Regulatory Analysis for Model Year 1983-85 Light Trucks, (November 1980), Table II-3, p. II-8.

2/ Original table was in 1980 dollars starting with the 1980 fuel price and was deflated by 10% to get prices in 1979 dollars.

3/ See Chapter V for reference.

4.2.2 Sample Calculations of Discounted Lifetime Fuel Cost

Model Year 1979 Front Bumper System

The 1979 model year cars have no " historical " years (H=0) through the base calendar year 1979 (end of year). The stream of fuel costs in the ten year future have to be discounted to the base year. Therefore, the previous equation for the 1979 model year cars becomes:

$$F(\text{discounted}) = \frac{F}{M}\left[g \sum_{y=1}^{y=0} A(y) + \sum_{y=1}^{y=10} A(y) \cdot S(y) \cdot G(y) \right]$$

Substituting, and summing up, F(discounted) is:

$$\frac{\$\,24}{100{,}000}\left[\;0 \;+\; \begin{array}{l} +18110 \times 0.909 \times 1.00 \\ +15110 \times 0.826 \times 1.18 \\ +13260 \times 0.751 \times 1.20 \\ +11830 \times 0.673 \times 1.25 \\ +10580 \times 0.621 \times 1.27 \\ +\ 9240 \times 0.564 \times 1.33 \\ +\ 7820 \times 0.513 \times 1.38 \\ +\ 6200 \times 0.467 \times 1.39 \\ +\ 4600 \times 0.424 \times 1.40 \\ +\ 3250 \times 0.386 \times 1.41 \end{array}\right] = \$20$$

All the discounted lifetime fuel costs for post-standard bumper systems are shown in Table VI-11.

TABLE VI-11

DISCOUNTED LIFETIME FUEL COST

(1979 Dollars)

VEHICLE SIZE	1973 FRONT	1973 REAR	1973 TOTAL	1974 FRONT	1974 REAR	1974 TOTAL	1979 FRONT	1979 REAR	1979 TOTAL
Subcompact	19	1	20	18	22	40	21	19	41
Compact	31	9	41	30	48	78	44	21	65
Intermediate	80	25	105	75	59	134	19	16	35
Full	33	29	62	32	37	69	-2	2	-1
Weighted Average	38	14	52	36	38	74	20	16	36

4.3 Discounted Incremental Lifetime Costs

Taking the incremental consumer costs (Table VI-7) and adding them to the discounted lifetime fuel costs (Table VI-11) yields the discounted incremental lifetime cost of the bumper standard with no secondary weight effect. These discounted incremental lifetime costs are shown in Table VI-12.

4.4 Secondary Weight Effect

In Section 2.5, secondary weight is defined and four factors (or ratios of secondary to primary weight) for estimating secondary weight are mentioned (0.35, 0.50, 0.75, 1.0). The consumer cost of secondary weight, which was also discussed in that section, can range from $0.60/pound (only the added cost of material plus manufacturing and sales overhead and profit) to $1.60/pound (the average consumer cost per pound of cars sold in 1979).

TABLE VI-12

DISCOUNTED INCREMENTAL LIFETIME COSTS
(NO SECONDARY WEIGHT)
1979 DOLLARS

VEHICLE SIZE	1973 FRONT	1973 REAR	1973 TOTAL	1974 FRONT	1974 REAR	1974 TOTAL	1979 FRONT	1979 REAR	1979 TOTAL
Subcompact	42	6	48	42	47	88	74	70	145
Compact	49	13	63	48	104	152	101	58	159
Intermediate	138	39	177	133	129	262	53	42	95
Full	71	44	115	70	88	158	49	40	88
Weighted Average	71	23	94	69	84	153	69	56	125

As in the case of the bumper standard (incremental consumer cost and lifetime fuel cost), the consumer cost of secondary weight is a sunk cost, but the fuel cost is distributed over time and has to be discounted.

4.4.1 Method for Calculating Consumer Cost and Discounted Fuel Costs for Secondary Weight

The consumer cost of secondary weight is calculated as follows:

$$J = E \cdot W \cdot P$$

Where:

J = consumer cost of secondary weight in 1979 dollars.

E = secondary weight factor (0.35, 0.5, 0.75 or 1.0).

W = incremental bumper system weight. Ref. Table VI-8.

P = Cost/# of secondary weight, $0.60 or $1.60.

To calculate discounted lifetime fuel costs for secondary weight, the discounted lifetime fuel costs for the incremental bumper system weight need only be multiplied by the secondary weight factor, as follows:

$$T \text{ (discounted)} = E \cdot F \text{ (discounted)}$$

where:

T = lifetime fuel cost of secondary weight in 1979 dollars (as discounted)

E = secondary weight factor (0.35, 0.5, 0.75 and 1.0)

F (discounted) = discounted lifetime fuel cost for added bumper weight. Ref. Table VI-11.

4.4.2 A Sample Calculation of Secondary Weight Cost (Discounted)

The two equations just presented will be used in this example for obtaining the discounted costs, due to secondary weight, of the model year 1979 front bumper system.

The incremental weight of 1979 front bumpers is 22 pounds (Table VI-8) and their discounted lifetime fuel cost is $20 (Table VI-11). The consumer cost (J) is: $J = E(22)(P)$

	For P = $0.60	For P = $1.60
$J_{(0.35)}$ =	$5	$12
$J_{(0.50)}$ =	$7	18
$J_{(0.75)}$ =	10	26
$J_{(1.0)}$ =	13	35

The discounted lifetime fuel cost of the secondary weight for 1979 front bumpers is:

$$T(\text{discounted}) = E\,(20)$$

$$T(\text{discounted})_{0.35} = \$7$$

$$T(\text{discounted})_{0.5} = 10$$

$$T(\text{discounted})_{0.75} = 15$$

$$T(\text{discounted})_{1.0} = 20$$

The total cost of secondary weight, the sum of J + T (discounted), is:

Unit Price of Secondary Weight

Secondary Weight Factor	$.60/Pound	$1.60/Pound
0.35	$12	$19
0.50	17	28
0.75	25	41
1.0	33	55

Using the same approach outlined above, the costs of secondary weight are shown in Table VI-13.

4.5 Total, Discounted Incremental (Lifetime) Bumper Costs

This section summarizes the various elements of cost, calculated in the preceding sections, to obtain the incremental bumper costs that are subtracted from gross benefits to arrive at net benefits. The cost elements are as follows:

TABLE VI-13

DISCOUNTED LIFETIME COSTS OF SECONDARY WEIGHT
(DISCOUNTED TO 1979)
- AT INDICATED 1979 COSTS PER POUND -

SECONDARY WEIGHT FACTOR	1973 BUMPER SYSTEM $0.60/lb.	1973 BUMPER SYSTEM $1.60/lb.	1974-78 BUMPER SYSTEM $0.60/lb.	1974-78 BUMPER SYSTEM $1.60/lb.	1979 BUMPER SYSTEM $0.60/lb.	1979 BUMPER SYSTEM $1.60/lb.
Front+Rear						
0.35	28	45	41	66	21	34
0.50	41	65	59	95	30	49
0.75	61	97	88	142	47	74
1.00	82	129	117	189	59	98
Front						
0.35	21	33	21	33	12	19
0.50	30	47	30	47	17	28
0.75	44	71	44	71	25	41
1.00	59	94	57	92	33	55
Rear						
0.35	8	12	21	34	9	15
0.50	11	17	30	49	13	22
0.75	16	26	45	73	20	32
1.00	22	35	60	97	26	43

1. The incremental cost due to weight changes to meet bumper standard requirements, that is, post to pre-standard differentials.

2. The discounted lifetime fuel costs due to the weight increase above.

3. The total secondary weight costs.

4. The discounted lifetime fuel cost due to secondary weight.

The first two elements are added and can be found in Table VI-12. The last two are shown, as a sum, in Table VI-13. It now remains to add the values of these tables, which is done in Table VI-14. Note that the Total, Discounted, Incremental (Lifetime) Bumper Costs are given for both the lower and upper range of secondary weight cost/pound assumptions.

TABLE VI-14

TOTAL DISCOUNTED INCREMENTAL (LIFETIME) BUMPER COSTS 1/
(DISCOUNTED TO 1979 DOLLARS)
- AT INDICATED 1979 SECONDARY WEIGHT COSTS/LB. -

SECONDARY WEIGHT FACTOR	1973 BUMPER SYSTEM		1974-78 BUMPER SYSTEM		1979 BUMPER SYSTEM	
	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.	$0.60/lb.	$1.60/lb.
Front+Rear						
0.00	94	94	153	153	125	125
0.35	122	139	194	219	146	158
0.50	135	159	212	248	155	172
0.75	155	191	241	295	172	199
1.00	175	223	270	342	184	223
Front						
0.00	71	71	69	69	69	69
0.35	92	104	90	102	81	88
0.50	101	118	99	116	86	97
0.75	115	142	113	140	94	110
1.00	130	165	128	163	102	124
Rear						
0.00	23	23	84	84	56	56
0.35	31	35	105	118	65	71
0.50	34	40	114	133	69	78
0.75	39	49	129	157	76	88
1.00	45	58	144	181	82	99

1/ The summation of: (1) the incremental cost due to bumper weight changes; (2) the discounted lifetime fuel costs due to the weight changes; (3) the total secondary weight costs; and (4) the discounted lifetime fuel cost due to secondary weight.

5.0 NET BENEFITS

Net benefits of the bumper standard are the remaining discounted benefits (in 1979 dollars) after the standard's discounted incremental lifetime costs have been deducted from the discounted incremental gross benefits.

5.1 Method for Determining Discounted Net Benefits

Since both gross lifetime benefits and the lifetime costs have been discounted using similar procedures, calculating the discounted net benefits involves a simple subtraction as follows:

Net Benefit (discounted) = B (discounted) - Q (discounted)

where:

B (discounted) = discounted incremental gross lifetime benefits <u>Ref</u>. Table VI-6.

Q (discounted) = discounted incremental lifetime costs including secondary weight effects <u>Ref</u>. Table VI-14.

5.2 Sample Calculation of Discounted Net Benefits Including Secondary Weight Effect

The 1979 model year front bumper system is used to work out an example of the net benefit calculation. The discounted, incremental gross lifetime benefit (B) for this bumper system is \$130 (discounted, 1979) from Table VI-6 (Section 3.3.2). The discounted incremental lifetime cost (Q) from Table VI-14 varies depending on the secondary weight factor used and on the cost of secondary weight per pound. Using 0.5 for the former and \$1.60 for the latter, and substituting Q = \$99 (Table VI-14), the discounted net benefit is:

Net Benefit (discounted) = B (discounted) - Q (discounted)

Net Benefit (discounted) = \$130 - \$99 = \$31

The discounted net benefits for 1973, 1974-78 and 1979 model year bumper systems are shown in Tables VI-15, 16 and 17. A brief discussion of net benefits follows these tables.

TABLE VI-15

DISCOUNTED NET BENEFITS
1973 BUMPER SYSTEMS
(1979 DOLLARS)

Secondary Weight Cost Factor 1/

SECONDARY WEIGHT RATIO	$0.60 per Pound		$1.60 per Pound	
	Net Benefit ($)	Confidence Interval ($) 2/	Net Benefit ($)	Confidence Interval ($) 2/
Front and Rear				
0.00	13	-25 to 51	13	-25 to 61
0.35	-15	-53 to 23	-32	-70 to 15
0.50	-28	-66 to 10	-52	-90 to -4
0.75	-48	-86 to -10	-84	-122 to -37
1.00	-68	-106 to -30	-116	-154 to -69
Front				
0.00	57	24 to 90	57	24 to 90
0.35	36	3 to 69	24	-9 to 57
0.50	27	-6 to 60	10	-23 to 43
0.75	13	-20 to 46	-14	-47 to 19
1.00	2	-35 to 31	-37	-70 to -4
Rear				
0.00	-43	-66 to -20	-43	-66 to -20
0.35	-51	-74 to -28	-55	-78 to -32
0.50	-54	-77 to -31	-60	-83 to -37
0.75	-59	-82 to -36	-69	-92 to -46
1.00	-65	-88 to -42	-78	-101 to -55

NOTE: Values may be off by $1.00 due to rounding

1/ The $0.60/pound secondary weight cost factor is the 1979 consumer cost of secondary weight of material incorporated into a production car. It assumes a 9 to 1 steel to aluminum mix. The $1.60/pound factor represents the 1979 consumer cost per pound of car.

2/ The 95 percent confidence level.

TABLE VI-16

DISCOUNTED NET BENEFITS
1974-78 BUMPER SYSTEMS
(1979 DOLLARS)

Secondary Weight Cost Factor 1/

SECONDARY WEIGHT RATIO	$0.60 per Pound		$1.60 per Pound	
	Net Benefit ($)	Confidence Interval ($) 2/	Net Benefit ($)	Confidence Interval ($) 2/
Front and Rear				
0.00	45	17 to 73	45	17 to 73
0.35	4	-24 to 32	-21	-49 to 7
0.50	-14	-42 to 14	-50	-78 to -22
0.75	-43	-71 to -15	-97	-125 to -69
1.00	-73	-101 to -45	-144	-172 to -116
Front				
0.00	59	29 to 89	59	29 to 89
0.35	38	8 to 68	26	-4 to 56
0.50	29	-1 to 59	12	-18 to 42
0.75	15	-15 to 45	-12	-42 to 18
1.00	0	-30 to 30	-35	-65 to -5
Rear				
0.00	-13	-29 to 3	-13	-29 to 3
0.35	-34	-50 to -18	-47	-63 to -31
0.50	-43	-59 to -27	-62	-78 to -46
0.75	-58	-74 to -42	-86	-102 to -70
1.00	-73	-89 to -57	-110	-126 to -94

NOTE: Values may be off by $1.00 due to rounding

1/ The $0.60/pound secondary weight cost factor is the 1979 consumer cost of secondary weight of material incorporated into a production car. It assumes a 9 to 1 steel to aluminum mix. The $1.60/pound factor represents the 1979 consumer cost per pound of car.

2/ The 95 percent confidence level.

TABLE VI-17

DISCOUNTED NET BENEFITS
1979 BUMPER SYSTEMS
(1979 DOLLARS)

Secondary Weight Cost Factor 1/

SECONDARY WEIGHT RATIO	$0.60 per Pound		$1.60 per Pound	
	Net Benefit ($)	Confidence Interval ($) 2/	Net Benefit ($)	Confidence Interval ($) 2/
Front and Rear				
0.00	27	-4 to 58	27	-4 to 52
0.35	6	-25 to 37	-7	-38 to 24
0.50	-3	-34 to 28	-22	-53 to 9
0.75	-20	-51 to 11	-47	-78 to -16
1.00	-32	-63 to -1	-71	-102 to -40
Front				
0.00	61	32 to 90	61	32 to 90
0.35	49	20 to 78	42	13 to 71
0.50	44	15 to 73	33	4 to 62
0.75	36	7 to 65	20	-9 to 49
1.00	28	-1 to 57	6	-23 to 35
Rear				
0.00	-33	-52 to -14	-33	-52 to -14
0.35	-42	-61 to -23	-48	-67 to -29
0.50	-46	-65 to -27	-55	-74 to -36
0.75	-53	-72 to -34	-65	-84 to -46
1.00	-59	-78 to -40	-76	-95 to -57

NOTE: Values may be off by $1.00 due to rounding

1/ The $0.60/pound secondary weight cost factor is the 1979 consumer cost of secondary weight of material incorporated into a production car. It assumes a 9 to 1 steel to aluminum mix. The $1.60/pound factor represents the 1979 consumer cost per pound of car.

2/ The 95 percent confidence level.

5.3 A Brief Discussion of Discounted Benefits

At this point the calculations leading to the results of the bumper standard evaluation are almost complete; the next section covers additional factors that could affect net benefits. The major results are, however, compiled in the preceding three tables and to simplify the following overview, a partial set of data are assembled from the tables.

The net benefits (and losses) with confidence bounds, at a secondary weight ratio and cost factor of 0.5 and $0.60 per pound, respectively, are:

Standard	Front (bounds)	Rear (bounds)	Front & Rear (bounds)
1973	27 (-6 to 60)	-54 (-77 to-31)	-28 (-66 to 10)
1974-78	29 (-1 to 59)	-43 (-59 to-27)	-14 (-42 to 14)
1979	44 (15 to 73)	-46 (-65 to-27)	- 3 (-34 to 28)

The choice of secondary weight and cost per pound of such weight is for illustrative purposes.

Whenever the confidence interval (bounds) includes the zero value, that is when the range is from a negative to a positive value, the result is not definitive. When, however, the bounds are either all positive or negative, the result can be considered definitive - that is a net benefit or loss.

On this basis, the 1979 front bumper system is cost effective, i.e., shows a definitive net benefit. Rear bumper systems for all post-standard models show consistent net losses. The combined front and rear bumper systems for all model years (post standard) show results (as per preceding illustration) that are not definitive.

Going back for a moment to front bumpers, the bounds for 1973 and 1974-78 models cross the zero value, but are predominantly in the positive range. While a strict adherence to the criteria would require that the results be termed "not definitive", there is, in these two cases, a "tendency toward" a net benefit.

Up to a secondary weight ratio of 0.5 (and $0.60/lb.) front bumper systems on post standard cars tended to be cost effective - the 1979 bumper system definitely. All rear bumper systems for post standard cars show net losses even when no secondary weights are included.

The combined front and rear results for post standard bumper systems vary quite a bit. Only the 1974-78 models yield a definite net benefit and that is limited to the case where very little, or no secondary weight is included. The 1979 models "tend" toward a net benefit under similar circumstances. All other cases are either not definitive or show net losses.

The introduction of standards in model year 1973 required "beefed up" bumpers at a sizeable weight and cost penalty. They tended to do the job of exterior protection in the front (1973), but the combination of bumper cost and the limited repair costs avoided (benefits) made the 2 1/2 miles per hour rear bumpers incur a net loss.

"Heavy" systems continued into the next bumper era, the 5 and 5, which ran for five model years and by 1978, more than 60 percent of the cars on the road were so equipped.

The next phase was, and is, the size and weight reduction--or downsizing--in response to energy conservation demands. This required a serious review of component design, and beginning in 1977 and continuing in the years since, bumper designs have emerged in harmony with car weight reduction programs. The incremental cost dropped (1979 $<$ 1974 in relation to pre-standard), improving the tendency of front bumper net benefits in 1979 models, but not doing much for rear bumpers.

With redesign--lower weight, new materials, advanced technology--the 1979 model front bumpers did relatively well, given the collision probabilities with heavier cars in the fleet--although it already included certain lines of downsized 1977 and 1978 models.

The results are based on data from several sources. The "benefit" side derives from the survey and insurance claim files. When comparing damage frequencies of post standard cars with pre-standard cars, the results from the survey are corroborated with insurance claim data. This is definitely the case for front bumper system damage frequencies, and combined front and rear values. The damage frequencies in rear-end collisions are generally lower for post standard compared to pre-standard models, but for the 1979 models this is statistically significant only when based on insurance claim cases. The rear-end bumper related damage to 1979 models was significantly costlier to repair than the damage to pre-standard cars, and to the preceding 1974-78 models - both the survey of unreported low speed collisions (with repairs estimated) and insurance claim data, show such trends.

The relatively positive results (net benefits) for front bumper systems may stem from a number of conditions. One is the finding that the damage frequency to the front end is between 25 and 50 percent higher than to the rear of a car. The damage reduction (or benefit) potential is consequently higher for the front than for the rear. This is borne out by the values of damage frequency for post standard cars where the reductions (compared to pre-standard cars) favored the front end over the rear by between 2 and 3 to 1.

Another factor which may affect the 1979-80 model rear bumper systems is their weight relative to prè-standard and 1974-78 models, as well as to the 1979-80 front bumpers. The average weight of a rear pre-standard bumper (1972) was 38 pounds. This rose to 51 pounds in the 1973 models and 74 pounds for 1974 models. Downsizing dropped the weight to 55 pounds for 1979 models where it stayed through the 1980 model. While the front bumper was slightly heavier in 1972 ($41^{\#}$ front, $38^{\#}$ rear) and increased to 75 pounds in 1974 models (same weight as the rear bumper), its average weight was 63 pounds for both 1979 and 1980 models, or 8 pounds heavier than the rear. Exploring this by vehicle size, front and rear bumpers weighed about the same in 1979-80 models except in compact sizes where there is a difference of more than 30 pounds. Compacts made up a little over 18 percent of the vehicle mix (1979) used in this evaluation.

There is no evidence that downsizing - that is both the decrease in weight or the substitution of materials had an effect on net benefits of bumper systems. The improvement in front bumper net benefits, 1979 over 1974-78, is as high as 50 percent (0.5 secondary wt. ratio), at the same time front bumper weight was reduced by about 16 percent.

The weight reduction, 1974-78 to 1979, for rear bumper systems is 20 pounds, or 27 percent (75 lbs. to 55 lbs.) and net losses increased by 7 percent (0.50 secondary wt. ratio).

When no secondary weight is considered, the improvement to net benefits, 1979 over 1974-80, in front bumper systems is quite small--about 3 percent, but the net loss for rear bumper systems goes from -$13 to -$33.

The question of how lighter late model (1979-80) cars fare in a population of heavier cars, mainly pre 1979, given the results from this evaluation, can only be answered separately for front and rear bumper systems. As discussed previously, the front bumpers are both effective in reducing frontal damage, and generally tend to be cost effective. Rear bumper systems have not fared well all along. What this bodes for a car population made up of predominantly smaller, lighter cars with "downsized" bumper systems can only be projected, a task which is not part of the evaluation of an existing regulation.

6.0 EFFECTS ON DISCOUNTED NET BENEFITS OF ADDITIONAL FACTORS (AFFECTING DISCOUNTED GROSS BENEFITS)

There are a number of factors which can affect the gross benefits, and thus net benefits of the bumper standard.

- Damage which, in fact, is not repaired (the evaluation assumed all damage is repaired) reduces gross benefits.

- The reduction of inconvenience to car owners, when no damage is sustained in a collision, due to improved bumper systems.

- Potential reductions in administrative costs involved in processing insurance claims for damage.

It was not possible to collect the necessary field data to account for the effect of the latter two factors. There are questions as to the possibility of such data being obtainable with sufficient precision, without a considerable resource investment. Their possible effect was, however, estimated in a previous study, and is discussed in subsequent sections.

Since so many analysis "cuts" are possible (e.g., by version of the standard; front, rear, front and rear; secondary weight ratio, etc.) the effects of the above factors are worked out for the 1979 bumper system only, and a limited (high and low) set of secondary weight ratios.

6.1 Effect on Net Benefits of Excluding Cost to Repair Damage in Unreported Collisions

The calculation of incremental gross lifetime benefits (discussed in section 3.2 of this chapter) included the change in repair costs from both unreported collisions and those for which insurance claims were filed. This assumed that all damaged cars involved in unreported collisions were repaired. This assumption is changed here to one where <u>none</u> of the damaged cars in unreported collisions are repaired (the real number is, most likely, somewhere between these extremes).

Using only the "unreported" portion of the expression for calculating incremental gross benefits (Section 3.2.1), and discounting, as was done in Section 3.3, the revised discounted incremental gross lifetime benefits for 1979 bumper systems--and the change from the original discounted gross benefits (Table VI-6)--are as follows:

1979 BUMPER SYSTEMS	(1979 DOLLARS) Revised Discounted Incremental Gross Lifetime Benefit	Change from Original Discounted Gross Benefits
Front and Rear	$140	-12
Front	105	-25
Rear	35	+12

The change in discounted gross benefits added to the original discounted net benefits (Table-17) yields the following revised discounted net benefits (shown only for: 0 and 1.0 secondary weight factors and a 1.60 cost/pound of secondary weight):

1979 Bumper Systems	Discounted Net Benefits (No Damage Repair in Unreported Collisions) - Secondary Weight Ratios - 0.0	1.0
Front and Rear	$ 15	-$93
Front	36	- 19
Rear	-21	- 64

The effect of assuming unreported damage is not repaired is to reduce net benefits for front bumpers and to decrease net losses for rear systems. With no secondary weight, the front bumper still comes out with net benefits, but now in the more stringent case (1.0 secondary weight ratio) yields a net loss.

6.2 Effects of Including Less Tangible Benefits

The Motor Vehicle Information and Costs Savings Act calls for the agency to set bumper standards, taking into account:12/

"(A) Cost of implementing the standard and benefits attainable as the results of implementation of the standard.

12/ Motor Vehicle Information and Cost Savings Act, Section 102(b)(1), 15 USC 1912 (1972).

(B) The effect of implementation of the standard on the cost of insurance and prospective legal fees and costs.

(C) Savings in terms of consumer time and inconvenience.

(D) Consideration of health and safety including emission standards."

This evaluation concentrated on measuring the costs and benefits called for in (A) above. It was not possible to obtain data to take into account (B), (C), and (D). However, estimates of benefits were previously made by the agency 13/ for: (1) the cost of insurance and (2) savings in car owner time and inconvenience.

6.2.1 The Effects on Discounted Net Benefits of the Cost of Insurance

The bumper standard resulted in fewer bumper-involved insurance claims which, in turn, reduced claim settlements. The Agency previously assumed that fewer settlements would have these effects.14/

- The agent's commission would not be paid;
- The administrative cost to adjust claims was not incurred; and
- Insurance company profits are reduced.

13/ National Highway Traffic Safety Administration, Final Assessment of the Bumper Standard, DOT HS-804-718 (June 1, 1979).

14/ Ibid, p. 41.

The adjustment to discounted gross benefits for these net savings was estimated at $25 per car ($28 in 1979 dollars).15/

Adding this amount to the discounted net benefits for 1979 front and rear bumper systems results in the following effect:

1979 Front and Rear
Bumper Systems

- Insurance Savings Effect -

Secondary Weight Ratio	Original (Discounted) Net Benefit	Adjusted (Discounted) Net Benefit
0.0	$ 27	$ 55
1.0	- 71	- 43

6.2.2 The Effect on Discounted Net Benefits of the Savings in Consumer Time and Inconvenience

For low-speed collisions in which no damage occurs, drivers benefit by not having to remain at the accident scene exchanging information and notifying the police. Other savings result from avoiding the inconvenience of getting car repairs. To estimate the value of these savings, the agency previously made several assumptions about the

15/ Ibid, p. 40 and Appendix A-6 through A-14.

value of a persons' time, the amount of time required at the scene, the number of vehicle occupants inconvenienced and the time required to obtain repairs.

The value of the total time savings was estimated to be about $30 per car, ($33 in 1979 dollars).[16/] Adding this amount to the original discounted net benefit of 1979 front and rear bumper systems (combined) gives the following:

1979 Front + Rear Bumper Systems
- Time Saving Effect -

Secondary Weight Factor	Original (Disc.) Net Benefit	Adjusted (Disc.) Net Benefit
0.0	$ 27	$ 60
1.0	-71	-38

16/ Ibid, pp. 43 and A-19 through A-26.

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APPENDIX A

PROCEDURE FOR ADJUSTING INCIDENT RATES FOR BIAS

Each of the two phases of data collection, retrospective vs. follow-up, has its strong and weak points as far as its usefulness in making estimates of incidence rates. The follow-up data will not have the memory bias of the retrospective data, but it will have a relatively higher variance because of the shorter collection period (2 months). The retrospective data, while biased by drivers' inability to remember low-speed collisions, will have a small variance because of a longer collection period (6 months). The following rationale was used to arrive at a combined estimate of the probability of an unreported low-speed collision:

Let r represent an unbiased estimate of the incidence rate as determined from the follow-up interviews and r' a biased estimate based on retrospective data. Then a linear combination,

$$r'' = wr + (1-w)r' \qquad o<w<1$$

may be an estimate with less mean square error (MSE) than r alone, if the proper w is selected. Denoting B as the bias of r', then

$$MSE(r'') = Var[wr = (1-w)r'] + (1-w)^2B^2.$$

This is minimized for

$$w = \frac{K + (1-p\sqrt{t})/t}{K + (t+1-2p\sqrt{t})/t}$$

where $K= B^2/Var(r)$ and t is the ratio of the lengths of the recall period to the follow-up period. The average time under study for vehicles during the recall period was 5.47 months and for the follow-up period, 2.11 months. Their ratio leads to a value of 2.59 for t.

Estimates had to be made of the bias of the recall data, B; the correlation of the follow-up and recall data, p; and the variance of the unbiased estimate of the incident rate, Var(r). These estimates were made separately for collisions with some damage and those with no damage.

Bias estimates, calculated as the difference between the collision rate for the retrospective period and that for the follow-up period, were 0.001. Assuming that the occurrence of the type of low probability event under study can be adequately modeled as a Poisson process, Var(r) can be estimated by the incident rate, r.

The correlation p was estimated as the sample correlation between I_r and I_f defined as follows:

I_r = 1 for vehicles with at least one unreported low-speed collision in the recall period;
0 otherwise.

I_f = 1 for vehicles with at least one unreported low-speed collision in the follow-up period;
0 otherwise.

Based on the sample data, p was estimated to be 0.02408.

Table III-5 shows the unreported low-speed collision rates by whether or not the accidents caused damage and the two study periods. Using the rationale described above, a combined unreported collision rate of 0.0114 collisions per car per month was found. Thus, approximately 13.7 percent of all cars are involved in a low-speed unreported accident each year.

TABLE A-1

MONTHLY UNREPORTED INCIDENT RATE

TYPE OF INCIDENT	RECALL RATE	FOLLOW-UP RATE	B	VAR (r)	W	COMBINED RATE
With some damage reported	0.005	0.004	-0.001	0.004	0.2738	0.0047
With no damage reported	0.007	0.006	-0.001	0.006	0.2738	0.0067
All eligible	0.012	0.010	-0.002	0.010	0.2739	0.0114

APPENDIX B

DETECTABLE PERCENT CHANGE IN DAMAGE FREQUENCY

The percent change that could be detected, given the upper bound of 11,000 for the number of residences to be contacted and the assumptions enumerated in Section 3.1.6 of Chapter III, was calculated using the following expression:

$$Z(1-\alpha) + Z(1-\beta) = \frac{p_1 - p_2}{\sqrt{\frac{p_1(1-p_1)}{N1} + \frac{p_2(1-p_2)}{N2}}}$$

- p_1 is the proportion of pre-standard vehicles damaged in low-speed, unreported collisions.
- p_2 is the proportion of post-standard vehicles damaged in low-speed, unreported collisions.
- $Z(1-\alpha)$, located on a standard normal distribution table, is 1.645 at $\alpha = 0.05$.
- $Z(1-\beta)$ is 1.282 at $\beta = 0.10$.
- N_1 is the number of pre-standard vehicles, involved in unreported, low-speed accidents, that need to be surveyed.
- N_2 is the number of post-standard vehicles.

Since only about 30 percent of the cars on the road are pre-standard, the total sample size, n, had to be weighted in order to have an adequate sample of pre-standard cars:

$n = n_1 + n_2 = 2290$ (from Section 3.1.6 of Chapter III)

$n_1 = 0.3\ n \quad = 0.3(2290) = 687$

$n_2 = 0.7\ n \quad = 0.7(2290) = 1603$

Assuming $p_1 = 0.50$ (the "worst case," i.e., the value which will yield the highest detectable percent change), the only "unknown" in equation (1) is p_2:

$$1.645 + 1.282 = \frac{0.5 - p_2}{\sqrt{\frac{0.5\ (0.5)}{687} + \frac{p_2\ (1 - p_2)}{1603}}}$$

After several manipulations, the equation comes down to:

$$p_2 - p_2^2 = 0.2456$$

Next several values are plugged in for p_2 with the following results:

For an 8 percent change, $p_2 = 0.42$:

$$p_2 - p_2^2 = 0.2436 < 0.2456$$

For a 7 percent change, $p_2 = 0.43$:

$$p_2 - p_2^2 = 0.2451 < 0.2456$$

For a 6 percent change, $p_2 = 0.44$:

$$p_2 - p_2^2 = 0.2464 > 0.2456$$

Thus, at least a 7 percent change in damage frequency will be detectable.

APPENDIX C

LOG-LINEAR ANALYSIS

The frequency of car damage in unreported, low-speed collisions appears to be dependent on the model year groups which correspond to the various versions of the bumper standard. To increase confidence in this finding, several independent factors were examined in relation to damage frequency and model year group. If the finding regarding damage frequency is true when these other variables are controlled for, then a clearer conclusion can be reached about bumper effectiveness. The log-linear model was developed to handle this type of analysis.

To evaluate the relation between damage frequency and model year group, several independent variables were introduced into the log-linear model as control variables. For example traffic density was one control variable which was compared with damage frequency and model year group. Another control variable was vehicle size and so forth. The objective of the analysis was to determine if any of the control variables influence damage frequency, and if so, were they independent of, and more important than model year group?

The actual log-linear model is a contingency table of frequency counts. Continuing with the example of vehicle size, damage, and model year group, the frequency counts would be defined with these indices:

$i = 1$ damage

$ = 2$ no damage

j = 1 - pre-1973

= 2 - 1973

= 3 - 1974-78

= 4 - 1979-80

k = 1 - subcompact

= 2 - compact

= 3 - intermediate

= 4 - full size

The frequency count would be noted as N_{ijk}. For the model the log of the frequency is expressed as follows:

$$\log (N_{ijk}) = \; + a_i + b_j + c_k + \text{interaction terms}$$

where a_i = factor representing damage

b_j = factor for model year group

c_k = factor for vehicle size

The estimate of the magnitude of differences between model year classes is obtained from the value of b_j, for vehicle size, from c_k, etc. If the variables are independent, the interaction terms will be small. The standard deviations of the factors are converted to confidence intervals for the probability of damage for each factor.

The log-linear analysis led to the conclusion that each factor examined was independent of the relationship between model year group and percent of cars damaged, and that model year group was the most important factor in predicting damage frequency.

To perform the analytical computations, a statistical package, the Statistical Analysis System (SAS) was used. The program FUNCAT, based on the work of Grizzle, Starmer, and Koch[1/] was used to obtain the log-linear values.

[1/] Grizzle, J.E. et al "Analysis of Categorical Data by Linear Models", Biometrics, p. 25 (1969)