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Comprehensive evaluation of the benefits, costs and benefits to consumers of the bumper standard as modified in 1982 compared to the previous standard.

16. Abstract

An evaluation of the Bumper Standard was conducted to determine actual benefits and costs and cost effectiveness of changes made (in 49 C.F.R. Part 581) in 1982. These changes, effective with the 1983 model year, reduced required damage resistance for passenger car bumpers from 5 mph longitudinal front and rear barrier and pendulum impacts and 3 mph corner pendulum impacts to 2.5 and 1.5 respectively. The requirement that there be no damage to the bumper itself beyond a 3/8 inch "dent" and 3/4 inch "set" (or displacement) from original position was changed to allow damage to the bumper itself while still requiring no damage to safety-related parts and exterior surfaces not involving the bumper. The evaluation was conducted under requirements of Executive Orders 12291 and 12498.

The evaluation compares collision damage experience and bumper system costs of 1983/84 models (post-standard modification) to a two year baseline of 1981/82 models (pre-modification). Manufacturers were selective in implementing the new minimum requirements, with only 35 percent of the cars sold in the U.S. in 1983 being equipped with bumpers that were changed in a way which reduced collision damage resistance when compared to the predecessor 1981/82 models. By the 1984 model year, slightly over 50 percent of models sold were equipped with bumpers changed in comparison to 1981/82 models.

The principal conclusions are:

(1) The costs to consumers have not changed as a result of the modification of the bumper standard from 5 to 2.5 mph.

(2) The net effect, over a car's 10 year life, is a small increase in repair cost, which is offset by a reduction in the cost of the bumpers.

(3) The change in the bumper standard has not affected the protection of safety-related parts.

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SUMMARY

On April 9, 1971, the National Highway Traffic Safety Administration (NHTSA) issued its first regulation on passenger car bumpers. Federal Motor Vehicle Safety Standard (FMVSS) 215, "Exterior Protection," was initially effective on September 1, 1972, and imposed requirements which prohibited damage to specified safety-related components such as headlamps and fuel systems in a series of perpendicular barrier impacts, at 5 mph for front and 2.5 mph for rear bumper systems.

Under subsequent legislation and regulations, performance requirements were changed several times. For the 1979 model year, the standard required that there be no damage to safety-related parts and exterior surfaces not involving the bumper system--a requirement known as Phase I--at impact test speeds of 5 mph. The most stringent requirements were in effect for 1980 to 1982 models, and required 5 MPH longitudinal front and rear barrier and pendulum impacts, as well as no damage to the bumper itself beyond a 3/8 inch "dent" and 3/4 inch "set" or displacement from original position. These latter requirements which limited damage to the bumper are referred to as "Phase II." The last change in the bumper standard took place on May 14, 1982 when the requirements were modified, reducing the test impact speeds from 5 mph to 2.5 mph for longitudinal impacts and from 3 mph to 1.5 mph for corner pendulum impacts. The Phase II damage requirement was dropped and replaced with the previous Phase I requirement.

Drawing on the best available data and public comments, NHTSA completed a Final Regulatory Impact Analysis (FRIA) in support of the final rule amending the bumper standard to the 2.5 mph, Phase I requirement. The new requirement became effective on July 6, 1982, affecting 1983 and subsequent model year cars.

Executive Order 12291, dated February 17, 1981, requires Federal agencies to perform evaluations of their existing regulations, including those rules which result in an annual effect on the economy of $100 million or more. The objectives of an evaluation are to determine the actual benefits and costs of equipment, systems and devices installed in production vehicles in connection with a regulation -- and to assess cost effectiveness. Evaluation of standards is also consistent with, and part of, the Regulatory Program initiated under Executive Order 12498, dated January 4, 1985.

This evaluation compares the collision damage experience and bumper system costs of 1983 and 1984 models to a two year baseline consisting of 1981 and 1982 models which correspond to the period before the standard was modified. An important aspect of this comparison is the fact that manufacturers were selective in implementing the new minimum requirements of the regulation. In 1983, for example, only 35 percent of the cars sold in the United States were equipped with bumpers that, upon close scrutiny and analysis, were <u>changed</u> in a way which reduced collision damage resistance -- in comparison to their 1981 and 1982 model predecessors.

In 1984, additional models were found to incorporate strength reducing changes, and other models, whose front bumpers had been reduced in 1983, now also were given reduced strength rear bumpers. By the 1984 model year slightly over 50 percent of the models sold were equipped with changed bumpers when compared to 1981 and 1982 models. Most of the changes were made to both the front and rear bumpers of a model.

It is important to define the term "changed," since the technique used for evaluating the effect of the bumper standard modification relies entirely on the difference between "changed" and "unchanged" bumper systems and comparing each of these populations to their 1981 and 1982 predecessors. Changed bumper designs are those make/model bumpers which in 1983 and/or 1984 were reduced in strength when compared to their 1981/1982 predecessors. Reduced strength was determined on the basis of a detailed examination of bumper designs and parts; it was not measured directly (i.e., by impact test). Unchanged bumper designs are the make/model bumpers which in 1983 and/or 1984 were essentially identical to their 1981/1982 predecessors. The cars with unchanged bumpers serve as the control group in the experimental design for the evaluation.

When referring to changes, alterations to general styling, aerodynamic flow shape and other "cosmetic" changes are excluded from the analyses and only the energy management components -- the major portion of a bumper system -- are considered. Consequently, the changes found in 1983 and 1984 bumpers were categorized into four mutually exclusive groups:

- o Facebar thinning or downgauging
- o Structural reductions or eliminations involving mounting brackets, reinforcements, end caps, etc.
- o Energy absorber replacement with rigid brackets
- o A combination of structural and energy absorber changes

The fifth category is composed of those bumpers which were left unchanged from their 1981 and 1982 predecessors that had to meet the 5 mph, Phase II standard. Overall, the population of cars with changed bumpers averaged a curb weight of 2,690 lbs. in contrast to 2,920 lbs. for cars with unchanged bumpers. There appears to have been a tendency to change bumpers on the smaller models -- subcompacts and compacts -- more often than on intermediates and standard sized passenger cars.

As has been the practice for evaluations of regulations, the analyses of weight, cost and component identification were supported by "teardown" methodology, a complete disassembly and analysis performed under contract, on an average of 60 make/models for each of the four (1981 through 1984) model years in the study. Each year this number represented at least 85 percent of domestic production and 55 percent of import sales, or approximately 80 percent of the combined fleets. These data form the primary basis for the cost side in the benefit-cost analysis.

Estimation of benefits is based on differences in both damage frequency and repair cost between changed and unchanged systems, in 1983 and 1984, relative to their respective 1981 and 1982 predecessors, in low-speed collisions.

To focus on low-speed, bumper-related collisions two data sets are needed. One is obtained from a national survey of incidents not reported to insurance companies. The other is derived from a sample of insurance claim files screened to exclude incidents involving injuries and cases where the vehicle had to be towed from the scene. These sources and procedures are essentially the same as those used in the bumper evaluation published in April 1981.

The primary conclusion of the evaluation is that after two years in which certain design changes were made to a growing population of bumpers -- in response to a modified bumper regulation -- the road experience in terms of low-speed bumper-related collisions for the cars with changed bumpers has remained the same as the experience with cars equipped with bumpers manufactured to the previous 5 mph standard.

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

Principal Findings

Bumper System Weights and Costs

- Combined front and rear bumper systems that were changed -- that is reduced in strength -- after the standard was modified, weighed less than their 1981 and 1982 model predecessors. The 1983 model bumpers weighed 72 lbs. compared to 85 lbs. for the 1981/82 models. In 1984, the average bumper that was changed, weighed 74 lbs.---a slight gain over 1983 models.

- Costs of bumpers decreased from $138 (1984 dollars) for the 1981/82 models to $114 for 1983 models. By 1984, bumper costs went back up to $125 because more energy-absorbing materials were added to certain bumper designs, and in some cases, aluminum was substituted for steel in facebars.

- In 1984 more than 50 percent of the new passenger car fleet was equipped with bumpers that incorporated a design change which reduced the strength of the bumper.

- The dominant design change was a reduction in the number of structural bumper parts such as reinforcements to facebars, brackets and end caps. In 1984, one quarter of the cars produced had bumpers with this change. They were 13 lbs. lighter and cost $21 less than their 1981/82 model predecessors.

- Another design change was the thinning of the main bumper strength member--the facebar. This was done on 14 percent of the 1984 passenger car fleet and resulted in a 6 lb. weight drop and a $7 cost reduction relative to 1981/1982 models.

- A combination of changes was made on 10 percent of the 1984 production fleet, including the replacement of hydraulic or similarly actuated plunger-type bumper energy absorbers with rigid brackets. Selected structural parts were also eliminated. The substitution of rigid brackets for hydraulic energy absorbers would normally result in a cost reduction and little or no change in weight, but due to the use of more costly high impact absorbing plastics instead of standard plastics for the fascia, prospective cost savings were offset to yield only a net reduction of $3. Weights of this group of bumper designs dropped by 7 lbs. due solely to the elimination of structural parts.

- In 2 percent of the 1984 production fleet, the only design change affecting energy management was the substitution of rigid brackets for hydraulic energy absorbers. This group also included the use of aluminum in place of steel for facebars or reinforcements. The added cost of this change in material offset most of the drop in costs for replacing the energy absorbers with brackets yielding a net reduction of $6. A substantial weight reduction of 18 lbs., relative to 1981/82 predecessor models, was due entirely to the material substitution.

Collision Damage Frequency

- The 1984 and combined 1983 and 1984 changed bumper models did not encounter a significantly different rate of damage frequency, compared to unchanged bumper models, in low-speed unreported collisions.

- Based on collisions for which an insurance claim was filed, there was an increase of 6 percentage points (from 59 to 65 percent) in the proportion of bumper-related damage claims for 1983/1984 changed bumper-equipped models. Most of the increase was attributable to claims for rear end damage. Beyond a fairly low impact speed, a bumper offers little or no protection. In frontal collisions, the bumper is less of a factor in preventing damage since these generally involve higher impact speeds than rear collisions. Therefore, increased damage is more likely when rear bumpers are built to a reduced standard.

Damage Repair Cost

- In unreported low-speed collisions, the average cost to repair damage is $450. There was no significant difference in damage repair cost between changed and unchanged 1983/1984 bumper models, relative to their 1981/1982 predecessors, when front and rear bumper systems are combined.

- Bumper-related damage that is severe enough for an insurance claim costs, on the average, $1,000 to repair. This average value is based upon reported incidents involving both changed and unchanged bumper systems for the whole range of 1981 through 1984 models. Repair costs of 1983/1984 changed models showed a statistically significant reduction of $62 when compared to their 1981/1982 predecessors.

Damage to Safety and Other Parts

- In unreported low-speed collisions, there is no statistically significant difference in the damage frequency of safety-related and other bumper protected parts in models equipped with changed bumpers compared to models with unchanged bumpers.

- The insurance data revealed that parts such as lamps, radiators, trunks and fuel tanks showed no significant change in damage frequency in cars protected by changed bumper systems. Only hood latches incurred a higher rate of damage in cars protected by changed bumper systems. Past studies have shown that hood latches rarely malfunction and when hoods fly open, they seldom cause collisions.

Override and Underride

- The bumper standard modification did not change bumper height requirements. The difference in bumper contact frequency of 1983/1984 changed bumper systems (86 percent) and their 1981/1982 predecessors (83 percent) is not statistically significant.

Benefits and Costs

- Collision damage repair costs dropped for both changed and unchanged 1983/84 models, relative to their 1981/82 predecessors. The unchanged model repair costs dropped more, but the $36 difference between these and the changed systems is not statistically significant. The Final Regulatory Impact Analysis (FRIA) prepared in 1982 projected a $76 increase (in 1984 dollars) in lifetime collision damage repair cost for bumpers designed to meet the 2.5 mph standard.

- The lifetime cost of the combined front and rear bumpers of changed systems relative to unchanged systems dropped by $44. The FRIA in 1982 projected a bumper system cost reduction of $91 (in 1984 dollars) for bumpers designed to meet the 2.5 mph standard.

- The net benefit of changed versus unchanged systems is $8 ($44 decrease in bumper cost minus the $36 increase in lifetime collision damage repair), over the life of a car, but this change is not statistically significant. There still were no significant differences in net benefits between changed and unchanged bumper systems even when benefits and costs were disaggregated by facebar, structural, energy absorber and a combination of structural and energy absorber changes. The 1982 FRIA projected a $15 net benefit.

Time and Inconvenience

- The driver survey of low-speed, unreported collisions yielded estimates of the average time spent in connection with incidents involving damage, as follows:

At the scene:	35 minutes
Filling out forms:	78 minutes
Getting repair estimates:	4 hours
Getting car repaired:	1.5 days
Time without use of car:	2 days

There was no difference in the amount of time expended per incident between cars with changed bumpers compared to cars with unchanged bumpers. However, on a lifetime basis, given the respective collision damage rates of changed and unchanged cars, there is a net increase in cost of $4 for cars equipped with changed (reduced strength) bumpers.

Conclusions

- The costs to consumers have not changed as a result of the modification of the bumper standard from 5 to 2.5 mph.
- The net effect, over a car's 10 year life, is a small increase in repair cost, which is offset by a reduction in the cost of the bumpers.
- The change in the bumper standard has not affected the protection of safety-related parts.

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 Evaluation of Federal Motor Vehicle Safety Standards

The National Traffic and Motor Vehicle Safety Act of 1966 [14] 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. The first bumper standard issued under the 1966 Act was Federal Motor Vehicle Safety Standard (FMVSS) 215 - Exterior Protection [4] 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. Under subsequent legislation and regulation, performance requirements were changed several times since the first standard was promulgated. The purpose of this evaluation is to determine the change in benefits and costs of the latest regulatory changes which took effect on July 6, 1982, [7] and which are applicable to passenger cars manufactured for 1983 and subsequent model years.

Executive Order 12291, dated February 17, 1981, requires Federal agencies to perform evaluations of their existing regulations, including those rules which result in an annual effect on the economy of $100 million or more [5]. Evaluation of standards is also consistent with, and part of, the Regulatory Program [8] initiated under Executive Order 12498, dated January 4, 1985.

1.2 The Bumper Standard

After passage of the National Traffic and Motor Vehicle Safety Act of 1966, 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. As shown in Table 1-1, the standard was changed for model year 1974 by requiring compliance with impact tests of 5 mph front and rear. This standard remained in place through model year 1978.

In October 1972, Congress enacted the Motor Vehicle Information and Cost Savings Act (MVICS Act) [13] 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 (49 C.F.R. Part 581) applicable to passenger cars beginning with model year 1979 and referred to as the Part 581, Phase I standard. At the same time, a "no damage" requirement (Part 581, Phase II) was placed on bumper systems for model year 1980 and subsequent years (see Table 1-1). The description of Part 581 bumper standards is included in Appendix A.

TABLE 1-1

Summary of Bumper Standards

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 facebar and its fasteners.
As above	1980-1982	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.
As above	1983 and thereafter	2.5 mph front and rear impacts with barrier and pendulum; 1.5 mph corner impact with pendulum. No damage to safety-related parts and exterior surfaces, except bumper facebar and fasteners.

1.3 The Evaluation of the Bumper Standard - April 1981

The National Highway Traffic Safety Administration began to evaluate its existing regulations in 1975--in accordance with both Department of Transportation policies and the subsequent Executive Order 12044, dated March 1978. A bumper standard evaluation was begun in 1979 and completed, with a report published in April 1981 [10]. The evaluation determined the net benefits (the change in costs) to the consumer attributable to each successive standard (applicable through model year 1980) in relation to unregulated bumper systems in model year 1972 and prior years.

The evaluation findings were that bumper systems complying with the standard requirements for model years 1979 and 1980 (most, if not all, bumpers were built to the 1980 "no damage" standard in 1979) tended to show net consumer losses--based on a 10-year car life--when compared to unregulated bumper systems. When taken separately, front bumpers were cost effective, although yielding very small net benefits, but this was negated by a consistent net loss for rear bumper systems through each successive standard requirement.

Much of the history, design practice and techniques used by manufacturers to meet the bumper standards are covered in the April 1981 evaluation report and will not be repeated here. In brief, after the standard was first promulgated, bumpers became heavier and extended away from the car body. Redesign during the mid to late seventies, as part of the downsizing programs, reduced bumper weights and manufacturers often replaced exposed facebars with elastomeric covered steel or aluminum extrusions to meet the 1980, Phase II requirements.

While the costs of 1979/1980 systems were lower than those in 1974 through 1978, they were between $150 to $200 higher than unregulated bumpers (1972 and earlier model years).

A review of all NHTSA regulations in 1981 took cognizance of the 1981 bumper evaluation findings in light of the criterion in the MVICS Act which stipulated that bumper standards yield the maximum feasible reduction of costs to the public.

1.4 Modification of the Bumper Standard - 1982

In 1981, the agency began rulemaking proceedings which included a Notice of Proposed Rulemaking [6], accompanied by a Preliminary Regulatory Impact Analysis [16], which outlined a series of bumper system impact test alternatives, and scheduled public hearings. Based on testimony, docket submissions and extensive agency analysis, a Final Regulatory Impact Analysis (FRIA, May 1982) [9] was prepared in support of the final rule amending the bumper standard by reducing the test impact speeds from 5 mph to 2.5 mph for longitudinal front and rear barrier and pendulum impacts. Phase I damage resistance criteria were substituted for Phase II criteria. The final rule [7] was issued on May 14, 1982, and became effective on July 6, 1982, thereby affecting 1983 and subsequent model year passenger cars.

The discussion in the final rule summary included a statement that "(I)nnovation, variety and a range of implemented choices in the marketplace will permit the agency to monitor cost and benefit trends and collect data about different performance levels of bumpers in the future." This evaluation addresses these trends through a series of analyses designed to establish the change in net benefits between bumper systems manufactured in response to the 2.5 mph standard and those manufactured under the previous 5 mph standard.

How does this objective contribute to the quest for the maximum feasible reduction in costs to the public? A "maximum feasible reduction" suggests that there is an optimum impact speed at which, theoretically, such a cost reduction would occur. This impact speed will differ from model to model, and for the aggregate model year fleet would depend on how many cars of a particular make are sold. Moreover, manufacturers have the choice of bumper design, limited only by a minimum performance standard. As will be shown in subsequent chapters, lowering impact test requirements from 5 mph to 2 1/2 mph did not, at least through model year 1984, result in bumper system changes for all of the passenger car fleet.

It should be clear at the outset that modification of the bumper standard only allows an iteration toward the Congressionally mandated goal of a "maximum feasible reduction in costs to the public" on the basis of on-the-road collision experience with bumpers, some changed, others unchanged as a result of a modified standard. The first determination must, therefore, be the discovery of which post-standard modification models (the evaluation is based on 1983 and 1984 models) were changed--considering factors such as weight reduction, down-gauging (reducing the thickness of main structural parts such as facebars), parts elimination or substitution.

The analysis of net benefit changes between bumpers built under the modified (2 1/2 mph) standard and their counterparts built under the 5 mph standard can yield three outcomes. A positive (net benefit) result would tend toward the goal of "maximum feasible cost reduction." A negative result (net loss) would mean the opposite. The third possibility is where no significant change is found or where the change is so small that more on-the-road data are needed to establish the significance of the result.

The analytic procedures and methods closely parallel those used in the first bumper evaluation (April 1981). The evaluation design differs since the first evaluation determined the effect of successive standards, each with more stringent minimum requirements than the one before, although manufacturers were free to design bumper systems to any impact test level above the minimum. During that period, it was evident that bumper systems were strengthened in most cases. The evaluation design, therefore, compared respective model year fleets without disaggregation by design within that fleet. The evaluation of the effect of the modified (2 1/2 mph) standard separates the effects of bumpers that have been changed (reduced) from those that were not changed--and thus likely to have continued to meet the previous 5 mph, Phase II requirements.

The following chapters deal with the evaluation design, bumper weights and costs, the incidence, frequency and damage repair costs of bumper-related collisions, the sources and use of data sets, the analysis, and results in terms of any change in effectiveness, net benefits and costs that emerged from the bumper standard modification that took effect on July 6, 1982.

CHAPTER 2

BUMPER DESIGN, WEIGHTS AND COSTS

During the past decade the design of bumpers has undergone significant change brought about by the need to conserve energy and reduce the risk of low speed collision damage, while at the same time making bumper systems as cost effective as possible. Bumper weights have declined since 1978 as the effect of downsizing began to take hold. The "weighted average" curb weight of the 1984 model fleet was 2780 lbs. in contrast to 3768 lbs. for the 1973 model fleet. To reduce bumper weight, materials such as aluminum, elastomerics and hard plastics are being used. Table 2-1 illustrates, in the aggregate, the relative bumper and curb weights. With the modification of the bumper standard for 1983 and subsequent model years, bumper designs were changed in several model lines in 1983 and additional models in 1984, but a sizable portion of both domestic and imported fleets retained their pre-standard modification (1981/82 model) designs.

TABLE 2-1

AUTOMOBILE BUMPER AND CURB WEIGHTS

Model Year	Standard	Bumper Weights (lbs.)	Curb Weight (lbs.)	Ratio of Bumper to Curb Weight
1972	Unregulated	79	3599	.022
1973	5/2.5	126	3768	.033
1974	5/5	150	3672	.041
1979	5/5, Phase I	118	3180	.037
1980	5/5, Phase II	114	2867	.040
1981	5/5, Phase II	89	2863	.031
1982	5/5, Phase II	85	2694	.032
1983	2.5/2.5, Phase I	82	2778	.030
1984	2.5/2.5, Phase I	80	2780	.029

2.1 Bumper Design Changes

In the 1983 model year, 35 percent of the fleet had bumpers which were changed in apparent response to the modified bumper standard. In 1984, this figure rose to 51 percent. The term "changed" in this context means that the energy management components of the bumper system were reduced by either eliminating parts, substituting components, and/or reducing the size and weight of strength members.

2.1.1 Sample Selection

To identify changes, and to establish weights and costs of bumper systems, a sample of 1981 through 1984 model bumpers were analyzed in detail using the "teardown" method [11], [12]. The 1981 model year passenger car sample consists of 51 nameplates, 39 of which are identical to the 1982 models and 12 which are different. Of the total, 39 are domestic and 12 are imports. For 1982, 56 sets of front and rear bumpers were analyzed (44 domestic and 12 imports). The 1983 model sample totals 58 nameplates (46 domestic, 12 imports), and the 1984 sample includes 62 nameplates of which 50 are domestic and 12 are imports. Each model year sample represents at least 85 percent of the domestic production and 55 percent of the import sales.

Both the domestic and import samples were constructed by starting with the highest sales volume nameplate and adding subsequent models in descending order to reach the 85 and 55 percent sales volumes. In assembling each model year sample several factors were considered to assure--to the degree possible--that the same nameplates appear for each model years' list. In addition, the sample was designed to represent each major manufacturer, market class (vehicle size), design and major bumper material content. Information obtained by the agency from major manufacturers describing bumper design changes made to 1983 and 1984 models was also used for sample selection.

The final lists of models studied together with their sales volume and market shares are shown in Appendix B.

2.1.2 Model Year Comparisons

Most models in each of the 4 model year samples retained their nameplates over the 4 model years so that 1983 or 1984 models could be compared with their 1981 and/or 1982 predecessors to determine changes in weight and cost. For example, the Ford Mustang was manufactured in 1981, 1982, 1983, and 1984 and for each model year, ranked sufficiently high in sales volume to be included in the respective model year samples. Some make/model nameplates changed only slightly, such as the 1982 Mercury Grand Marquis which was replaced with a new model in the same market class. Others, such as the Datsun 210 served as an equivalent predecessor to its replacement, the Nissan Sentra.

In 1983 and in 1984, several new nameplates, without equivalent predecessors, were introduced by manufacturers, such as the Ford Tempo and Topaz models in 1984, at about the time Ford discontinued the Fairmont. A few models were not included in the 1983 or 1984 samples because their market shares shrank considerably, e.g., the Pontiac Phoenix and Bonneville.

The nameplates that are included in the 1981 through 1984 comparisons are shown in Appendix C.

2.1.3 Bumper Design Classification

The front and rear of a passenger car design includes both integrated and component bumper systems. Many front bumpers are covered with a one-piece plastic fascia material that includes the grille, bumper facebar or reinforcement cover, and the valence panel. Turn signals and/or side-marker lamps can also be integrated with the bumper system. In the teardown analysis, bumper system parts were classified into two groups: energy management and cosmetic (and the total of both). Where possible, however, parts of bumper systems not related to energy management were excluded from the study. For example, the Ford Mustang fascia has a clear line between the grille and the front bumper reinforcement cover. The grille was cut off the fascia at that line before the fascia was weighed and its consumer cost was estimated. In other instances, parts could not be separated because they were clearly integral to the assembled bumper system even though they served no energy-management function. Optional parts that are not necessary in order to comply with the standard--based on manufacturer information--were included with the "cosmetic" group. Thus bumper guards were classified as energy management if they were part of the basic vehicle bumper system, but were classified as cosmetic if they were optional equipment added on later to meet market demand.

The data sets for each system are, as shown in the contractor reports, identified as "Total", "Energy Management" and "Cosmetic." It is the energy management portion which will be the focal point of the analysis.

2.1.4 Design Change Classification and Analysis

Changes in energy management bumper parts were classified into 5 groups (a no-change group plus 4 levels of change). To determine if and what changes were made to 1983 and 1984 model bumper systems, each of the systems were compared to their 1982 model counterparts or "predecessors." Each change fits only into one group for a given make/model comparison. A given make/model may, for instance, have no change, or a different type change in either the front or rear bumper system (this was found in 10 percent of the 83 to 82 and 84 to 82 comparisons). Combinations of change groups can likewise be compared.

The definition of each design change classification is based on judgments of its effect on energy management. For example, changes in facebar thickness and changes from hydraulic energy absorbers to stamped brackets are likely to decrease the energy absorption capability of bumper systems. The classifications are ranked from the least to the most effect on energy management.

No change - All energy management parts of 1983 and 1984 model bumper systems when compared to their corresponding 1982 model bumper system parts are essentially unchanged. Bumper systems with minor changes in fascia design were included in this "no change" group if the first criterion was met.

Facebar change - Bumper system parts designated as "facebars" for exposed bumper systems, or "reinforcement" for bumper systems covered with pliable plastic or rubber fascia material were compared to parent 1982 parts to determine changes in the gauge or the amount of material when the overall bumper dimensions (length, height, offset) remained unchanged. If other changes were minor such as removal of shims or attaching parts (bolts, nuts, washers) along with facebar changes, the bumper systems were included in this classification. Not included as a facebar change is the substitution or replacement of one material for another, such as changes from steel to aluminum or high strength steel to galvanized steel.

Without a detailed design analysis, it would not be possible to determine if the material change resulted in a change in energy management capability.

Structural Changes - When several 1983 and 1984 model bumper systems were compared with their corresponding 1981 and/or 1982 model bumper systems, and the facebar and energy absorbers were unchanged, but other parts such as mounting brackets, end caps, nerf strips, reinforcements (behind the primary facebar or reinforcement) were reduced in size or eliminated entirely. These design differences were classified as structural changes.

Energy Absorber Changes - For several 1983 and 1984 model bumper systems, the only energy management design change made, compared to their corresponding 1982 model bumper systems was to replace the hydraulic energy absorber with a stamped rigid assembly or bracket or with a rubber block. Since this type of change would result in potentially less energy absorption capability as well as more crash energy being transmitted directly to the bumper system itself, this classification was considered a greater reduction in energy management than either facebar or structural change.

Energy Absorber + Structural Change - In addition to changing the energy absorber to a rigid bracket, some 1983 and 1984 model bumper systems when compared to their 1982 model systems included structural changes as previously defined. This classification is assumed to result in bumper systems with less energy management capability than any of the aforementioned categories.

Bumper design change classifications by make/model for 1983 compared to 1982/1981 and for 1984 compared to 1982/1981 are shown in Appendix D.

As already mentioned, the aggregate of bumper models in each of the 5 groups, for both the 1983 and 1984 model year, were compared to their predecessors in model years 1981 and or 1982. When a new nameplate was introduced, such as the Tempo/Topaz in 1984, where no 1981 or 1982 predecessor was available, the new bumper systems were first analyzed to determine what components it contained and to what degree these differed from typical 1982 installations. For example, the Ford Tempo has a bumper system similar to other unchanged 5 mph bumpers, that is, it has energy absorbers and equivalent facebar structures. Therefore, the Tempo bumpers were included in the "unchanged" 1984 group which also included the Datsun 200SX, Mazda GLC, Ford Escort, Oldsmobile Cutlass Supreme, Buick Skylark, etc. The sales weighted average weight and cost of this group became the "dummy" weight and cost values of an equivalent 1982 model Tempo and Topaz (e.g., 248,202 Ford Tempos were sold in 1984 and this volume was applied to both the 1982 and 1984 weights and costs for the Tempo).

2.2 Market Effect

Because passenger cars of equal size, except for luxury and specialty cars, have similar sales prices, their size categories are called market classes. Passenger car size is expressed several ways: curb weight, wheel base (length), and interior passenger and luggage compartment volumes. The energy crises of the 1970's resulted in a shift toward smaller vehicle dimensions for all market classes. In addition, passenger car sale trends changed and more smaller cars were purchased than larger cars. However, during the 1980's and especially during 1983 and 1984, the public reverted to buying somewhat larger cars again.

Bumper system designs, material, weight and cost are generally similar in a market class. If the distribution of cars in each market class does not change appreciably from year to year, each model year's sales weighted average bumper weight and cost can be compared from year to year to determine differences. In other words, if consumer buying preferences do not change from year to year, the sales weighted average bumper system weights and costs will not only reflect the respective model year fleet data but can be directly compared to determine true differences. The bumper data comparisons shown in the contractor final report [11] are based on averages weighted using the respective model year sales volumes and the differences reflect both changes in design and sales distribution due to market shifts. Therefore, those figures were not used as provided in the contractor report to avoid biasing data, as explained below.

If, for example, there is an upward shift toward larger cars from one year to the next, the average bumper weights and costs for the most recent year will reflect this. To remove any potential market effect, sales volumes among models from one model year to the next should be held constant. The 1984 model year was selected as the basic year and its sales volume distribution was applied to the other model years to establish comparative weight and cost differences between model years.

The analysis and tables that follow address straight differences in bumper system weight and cost for the respective years. The costs are consumer costs expressed in 1984 dollars. Consumer cost is developed from manufacturing costs by mark-ups to account for burden and dealer profit. Manufacturing cost is estimated from an assumed full vehicle production process. Hence consumer costs are not to be confused with replacement part costs that one would pay a dealer to obtain parts. Details of the costing methodology are contained in the contractor's final report.

In a subsequent chapter, where the net changes in benefits are computed, the bumper weights and costs will be converted to lifetime net discounted costs, including secondary weight considerations and fuel costs.

2.3 Bumper System Weights and Costs

In this section, bumper weights, costs and model year differences are presented in a series of tables. Given the large number of disaggregations possible (nearly 500), it is best to begin with the model years that will be used not only for determining weight and cost changes, but will also align with collision frequency, damage incidence and repair cost data that will be part of net benefit calculations later on. The model year sets to be compared are as follows;

1983 *vs* 1981 + 1982

1984 *vs* 1981 + 1982

1983 + 1984 *vs* 1981 + 1982

Each set will be subdivided into Front plus Rear, Front only and Rear only bumper systems. The total, and energy management only portion will be shown for each of the three sets. As explained earlier, weight and cost values are also grouped by "change category", of which there are six namely: Unchanged bumper systems, Facebar, Structural, Energy Absorber, Structural plus Energy Absorber and All Design Changes (the aggregate of the last four).

Table 2-2 shows bumper weights by model year (1981 through 1984). These are U.S production/import sales weighted values based on the 1984 model year market distribution. Bumper costs are shown in Table 2-3.

These two tables constitute the basic weight and cost data set, but one aspect has to be explained to clarify what the values represent. As the notes on each table state, the columns for both 1981 and 1982 models list the weights and costs for both 1983 and 1984 successor models, respectively. This is because in each post-standard modification model year (1983 and 1984) the make/models that were changed are different. In 1983, changes were made to Chrysler, Honda and several GM models. In 1984, changes were extended to more nameplates, and in both years there were cases where only the front or rear of a model was changed or the rear bumper was changed in 1983 followed by the front bumper in 1984, and vice versa.

2.4 Bumper Weight and Cost Differences Between Model Years

Each of the three pre/post-standard modification comparisons are presented in Tables 2-4 through 2-6. Weight and cost differences are shown only for the energy management portion of bumper systems.

TABLE 2-2
BUMPER WEIGHTS BY MODEL YEAR
Production/Sales Weighted Averages
(Weight in lbs.)

	1981						1982						1983			1984		
	Front + Rear		Front		Rear		Front + Rear		Front		Rear		Front + Rear	Front	Rear	Front + Rear	Front	Rear
Predecessor Year 1/	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984						
Unchanged Bumpers 2/																		
Total 3/	97	95	48	48	48	47	95	93	47	46	48	47	95	47	48	93	45	47
Energy Mgt.	90	89	45	44	45	45	88	87	43	42	45	45	88	43	45	87	42	45
Changed Bumpers 2/																		
Facebar																		
Total	92	89	46	40	46	49	82	83	43	38	39	45	77	41	36	81	38	43
Energy Mgt.	86	83	41	36	45	47	76	77	38	34	38	42	70	36	34	74	34	40
Structural																		
Total	114	107	57	55	56	52	104	102	49	51	55	51	94	45	50	91	46	45
Energy Mgt.	108	101	53	51	54	50	98	95	45	47	53	49	89	41	47	85	42	43
Energy Absorber																		
Total	104	96	56	49	49	47	104	97	56	49	49	48	77	46	31	78	47	31
Energy Mgt.	100	91	52	45	48	46	100	91	52	45	48	46	74	44	30	73	44	30
Struct.+ Energy Abs.4/																		
Total	62	62	30	30	32	31	60	60	30	30	31	30	51	25	26	52	25	27
Energy Mgt.	57	58	28	28	29	29	54	55	27	28	27	27	45	22	22	49	24	25
All Changes Combined																		
Total	94	93	47	46	47	47	87	89	43	44	44	46	78	39	39	80	40	41
Energy Mgt.	89	87	44	43	45	45	81	83	39	40	42	43	72	35	36	74	36	38

1/ The 1983 and 1984 model years have different models in each design category, thus both 1981 and 1982 models are grouped in the same manner.
2/ See Section 2.1.4 for design definitions.
3/ See Section 2.1.3 for definitions of total and energy management.
4/ Design change included both structural and energy absorber changes.

TABLE 2-3
BUMPER COSTS BY MODEL YEAR
Production/Sales Weighted Averages
(1984 Dollars)

	1981						1982						1983			1984		
	Front + Rear		Front		Rear		Front + Rear		Front		Rear		Front+ Rear	Front	Rear	Front+ Rear	Front	Rear
Predecessor Year 1/	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984						
Unchanged Bumpers 2/																		
Total 3/	168	169	87	89	81	80	170	167	88	87	82	80	169	87	82	168	88	80
Energy Mgt.	150	154	77	80	73	74	150	152	77	78	73	74	150	77	73	153	79	74
Changed Bumpers																		
Facebar																		
Total	138	152	67	75	71	77	135	154	70	77	65	77	130	71	59	151	77	74
Energy Mgt.	126	132	58	61	68	71	122	131	61	63	61	68	107	54	53	125	60	65
Structural																		
Total	179	170	93	89	86	81	172	166	86	85	86	81	156	78	78	149	78	71
Energy Mgt.	161	151	83	78	78	73	154	147	76	74	78	73	134	66	68	128	66	62
Energy Absorber																		
Total	162	159	84	81	78	78	162	160	84	82	78	78	145	79	66	147	82	65
Energy Mgt.	149	141	75	70	74	71	149	141	75	70	74	71	136	73	63	136	75	61
Struct.+ Energy Abs.4/																		
Total	133	134	66	66	67	68	124	125	62	62	62	63	102	50	52	124	59	65
Energy Mgt.	122	123	61	61	61	62	109	111	55	56	54	55	87	43	44	112	54	58
All Changes Combined																		
Total	156	158	79	81	77	77	149	155	76	79	73	76	133	68	65	145	74	71
Energy Mgt.	141	140	70	70	71	70	134	136	67	68	67	68	114	57	57	125	63	62

1/ The 1983 and 1984 model years have different models in each design category, thus both 1981 and 1982,models are grouped in the same manner.
2/ See Section 2.1.4 for design definition for design definitions.
3/ See Section 2.1.3 for definitions of total and energy management.
4/ Design change included both structural and energy absorber changes.

TABLE 2-4
BUMPER WEIGHT AND COST DIFFERENCES 1/
1983 vs. 1981 and 1982

(Weight in lbs., 1984 Dollars)

	Front + Rear	Front	Rear
Unchanged Bumpers 2/			
Weight	-1	-1	0
Cost	0	0	0
Production/sales (000) 3/	6730		
% of fleet	65		
Changed Bumpers			
Facebars			
Weight	-11	-4	-7
Cost	-17	-6	-11
Production/sales (000)	828		
% of fleet	8		
Structural			
Weight	-14	-8	-6
Cost	-24	-14	-10
Production/sales (000)	1553		
% of fleet	15		
Energy Absorber			
Weight	-27	-9	-18
Cost	-14	-2	-12
Production/sales (000)	311		
% of fleet	3		
Structural and Energy Absorber			
Weight	-11	-5	-6
Cost	-30	-16	-14
Production/sales (000)	932		
% of fleet	9		
All Changes Combined			
Weight	-13	-6	-7
Cost	-23	-11	-12
Production/sales (000)	3624		
% of fleet	35		

1/ Differences are between the energy management portion of bumper systems as defined in Section 2.1.3.
2/ See Section 2.1.4 for design definitions.
3/ Base Year is 1984.

TABLE 2-5
BUMPER WEIGHT AND COST DIFFERENCES 1/
1984 vs. 1981 and 1982

(Weight in lbs., 1984 Dollars)

	Front + Rear	Front	Rear
Unchanged Bumpers 2/			
Weight	-1	-1	0
Cost	2	1	1
Production/sales (000)	5073		
% of fleet	49		
Changed Bumpers 2/			
Facebars			
Weight	-6	-2	-4
Cost	-7	-2	-5
Production/sales (000)	1449		
% of fleet	14		
Structural			
Weight	-13	-7	-6
Cost	-21	-10	-11
Production/sales (000)	2588		
% of fleet	25		
Energy Absorber			
Weight	-18	-2	-16
Cost	-6	5	-11
Production/sales (000)	207		
% of fleet	2		
Structural and Energy Absorber			
Weight	-7	-4	-3
Cost	-3	-4	1
Production/sales (000)	1035		
% of fleet	10		
All Changes Combined			
Weight	-11	-5	-6
Cost	-13	-6	-7
Production/sales (000)	5280		
% of fleet	51		

1/ Differences are between the energy management portion of bumper systems as defined in Section 2.1.3.
2/ See Section 2.1.4 for design definitions.

TABLE 2-6
BUMPER WEIGHT AND COST DIFFERENCES 1/
1983 + 1984 vs. 1981 and 1982

(Weight in lbs., 1984 Dollars)

	Front + Rear	Front	Rear
Unchanged Bumpers 2/			
Weight	-1	-1	0
Cost	0	0	0
Production/sales (000)	5798		
% of fleet	56		
Changed Bumpers 2/			
Facebars			
Weight	-8	-3	-5
Cost	-10	-3	-7
Production/sales (000)	1139		
% of fleet	11		
Structural			
Weight	-14	-7	-7
Cost	-22	-11	-11
Production/sales (000)	2071		
% of fleet	20		
Energy Absorber			
Weight	-23	-6	-17
Cost	-10	1	-11
Production/sales (000)	311		
% of fleet	3		
Structural and Energy Absorber			
Weight	-9	-5	-4
Cost	-16	-9	-7
Production/sales (000)	1035		
% of fleet	10		
All Changes Combined			
Weight	-12	-6	-6
Cost	-17	-8	-9
Production/sales (000)	4555		
% of fleet	44		

1/ Differences are between the energy management portion of bumper systems as defined in Section 2.1.3.
2/ See Section 2.1.4 for design definitions.

The weight and cost of bumper systems that had not changed in the 1983 and 1984 model years, those that presumably retained at least a 5 mph impact capability, show very little difference--a pound or less and two dollars or less--when compared to their predecessor 1981 and 1982 models. This largely confirms judgments about whether or not a particular bumper system underwent a strength reduction change after the 2.5 mph bumper standard went into effect.

The unchanged systems, representing 65 percent of the 1983 models and 49 percent of the 1984 models, are used as the control group, against which the effect of changed bumpers will be measured.

2.4.1 Bumper Facebar Changes

Thinning or using less material in the main load-bearing bumper components--the facebar or reinforcement behind the fascia--was probably done in response to the change from the Phase II no-damage bumper requirement to Phase I (Phase II which applied to 1980 through 1982 models required that test damage be held to a 3/8 inch diameter dent on the bumper and a 3/4 inch set back from the original outer bumper contour). In the samples, seven 1983 models and twelve 1984 models incorporated "thinned" facebars, representing 8 and 14 percent, respectively of the fleet. The weight reduction ranged from 6 to 11 pounds per system and the cost dropped by between 7 and 17 dollars.

The facebar change was found principally on General Motors cars such as the 1984 Buick Regal and Electra, the Olds Omega, the Chevrolet Celebrity and Chevette.

2.4.2 Structural Changes

Structural changes are defined as a size reduction or elimination of bumper system parts such as support brackets, and caps, nerf strips and reinforcements behind the primary energy management facebar or fascia covered structure. It is a specific change category which does not include facebar changes, described previously (in Section 2.1.4), nor energy absorber changes covered in the next category.

About 15 percent of the 1983 model bumpers had structural changes when compared to predecessor 1981 and 1982 models. This increased to 25 percent in 1984. The changes amounted to a weight reduction of 14 pounds and a drop in costs between $20 and $24.

Structural changes to bumper systems were made by several manufacturers for a number of their carlines, and included GM, Ford, Toyota, Nissan, Volvo and BMW.

2.4.3 Energy Absorber Changes

The removal of energy absorbers is perhaps the leading basis for reclassifying bumpers from Phase II to Phase I and the most likely design change expected after the modified bumper standard went into effect. So far, at least, no industry-wide absorber eliminations have taken place. This category and the next account for 13 percent of the fleet through 1984. Some imported and domestic models had adopted elastomeric absorption materials even before the standard changed (and met 5/5 Phase II compliance test requirements).

The change from plunger type energy absorbers to rigid brackets, without any other change, was only found in certain Chrysler products, based on the samples that were torn down. At between 2 and 3 percent of the new fleet, this category is very small, particularly when sampled for collision data.

2.4.4 Structural and Energy Absorber Changes

About 10 percent of the 1983 and 1984 sales volume included cars with bumpers having both structural and energy absorber changes. All vehicles in this category are either subcompacts or compacts manufactured by Honda and Chrysler. The design changes, especially for some of the 1983 sample, reflect the greatest potential change in the bumper energy management capability.

After a decline in 1983 models, costs for the 1984 models increased substantially in the representative sample, largely due to Honda's bumper change on their 1984 Accord and Civic models. The bumper weight increased by 5 lbs. on the Civic and 8 lbs. on the Accord (sales of 147,000 and 131,000, respectively). The Accord bumper system cost $48 in 1983 and $91 in 1984. The Civic system jumped from $39 in 1983 to $76 in 1984. Most of the cost increase went into energy management rather than the cosmetic portion of the bumper systems. The Civic fascia, apparently a new plastic material, doubled in cost and the rubber block that serves as an energy absorber cost $3 in 1983 and $10 in 1984.

Overall, the sample fleet incorporating a combination structural and energy absorber change for 1984, represented slightly over 1 million cars, and showed a 50 lb. increase in curb weight over its predecessor sample for 1983. For example, Chrysler Reliant/Aries models which included a combination structural and energy absorber change went from a 2323 lb. curb weight in 1983 to 2372 in 1984. The Honda Accord's curb weight increased by 98 lbs. in the same period.

2.4.5 Summary of Design Change Effects

The sum of all design change categories (facebar, structural, energy absorber, structural plus energy absorber) are shown below, using 1983 and 1984 vs the 1981/82 baseline years. To highlight the aggregate effect of the changed bumper systems, they are compared to the unchanged systems.

Weight and Cost Differences
1983 vs. 1981/82

	Unchanged Bumper Systems		Bumper Systems with Design Changes	
	Wt. (lbs.)	Cost ($)	Wt. (lbs.)	Cost ($)
Total System				
Energy Mgmt.	-1	0	-13	-23

The net differences between systems that were changed and those that were not is 12 lbs. and $23 for the energy management portion of the bumper system.

Weight and Cost Differences
1984 vs. 1981/82

	Unchanged Bumper Systems		Bumper Systems with Design Changes	
	Wt. (lbs.)	Cost ($)	Wt. (lbs)	Cost ($)
Total System				
Energy Mgmt.	-1	-1	-10	-13

By 1984, some weight had been put back on bumper systems (about 3 lbs.) and the weighted average cost had risen $8 relative to the 1983 model bumpers. One factor was the "Honda effect" discussed earlier, where the manufacturer incorporated costlier parts in their 1984 system in contrast to the 1983 bumpers which had been reduced in weight and cost after the change in the bumper standard.

Given that 1981/82 bumpers weighed 85 lbs. the change in the standard, from 5 to 2 1/2 mph, by 1984 has resulted in a weight drop of approximately 12 percent (10 lbs.) for those bumper systems that were, in fact, changed from their 1981/82 predecessors.

The actual cost effect--a $13 basic drop by 1984--will be covered in more detail in a subsequent chapter which will take into account fuel consumption and secondary weight reductions.

CHAPTER 3

ON-THE-ROAD COLLISION EXPERIENCE

The main purpose of bumpers, in compliance with the standard, is to minimize damage in low speed collisions. The actual speed can, at best, only be estimated since drivers are not likely to be looking at their speedometer at the instant of collision. Moreover, speedometers are not very accurate - particularly at low speeds. This accuracy range is generally within $\pm$ 4 mph, which obviously negates any precision in the collision cases of interest. In a low speed collision there is often little or no damage, and few if any injuries. The amount of damage and degree of injury is used as a surrogate measure of collision speed in accident reconstruction, but clearly this approach is applicable only to more severe collisions in contrast to those for which a bumper is designed to be effective in preventing, by its energy management capability, relatively light (and repairable) 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 car usually cannot be driven from the scene of the accident.

In identifying a low speed, or light, collision - involving the bumper - incidents with injuries and/or vehicles that had to be towed from the scene should be screened out.

Another factor in a low speed collision is that it may not be reported, either to the police, or for insurance claim purposes, and thus no record exists. Police reports are only required when damage exceeds a certain dollar amount (and the amounts vary from State to State) or when persons are injured. When damage is below a driver's deductible for collision insurance (typically $100), an insurance claim may not be filed. Unreported cases are, however, an important data need, and the method used to obtain such data will be described later in this chapter.

3.1 Measures of Bumper Effectiveness

The evaluation of bumper effectiveness measures the changes in damage sustained by cars meeting the 2.5 mph as compared with those meeting the 5 mph bumper standard. There are two quantities which measure effectiveness, one is the damage frequency and the other the extent of damage.

3.1.1 Damage Frequency

The probability or frequency of damage in a low speed collision is defined as the ratio of the number of low speed bumper-involved accidents in which damage occurred, to the total number of low-speed collisions. 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 to which effectiveness of exterior protection has changed on cars built to the modified (2.5 mph) standard.

3.1.2 Extent of Damage

There are several ways to measure the change in the extent of damage in low-speed collisions: The numbers of damaged parts, the number of damaged parts by degree of damage, and the cost to repair the damage. The "number of damaged parts" measurement is a simple count of how many bumper and safety-related parts were damaged. This does not, however, reflect the considerable variation in damage severity which is possible for any given part. A qualitative assessment of severity can be made by classifying damage as major or minor and whether the damage can be repaired or the part has to be replaced. This is an improvement over a simple parts count, but still falls short because it is difficult to use in making comparisons between benefits and costs of a standard since it can only indicate shifts in damage severity for individual parts.

Measuring the cost to repair damage eliminates many of the problems of the damaged part counts. It is a single value reflecting collision severity, and allows comparisons (changes) in effectiveness between pre- and post-standard modification bumper systems to be made.

3.1.3 Bumper Override and Underride

Another measure of effectiveness is bumper mismatch frequency--determining whether regulating bumper height leads to damage reduction. Uniform heights should allow bumpers to meet head-on, avoiding potential damage caused by over or underride. Both mismatch and match frequencies of 1981 through 1984 models together with their respective damage, will be compared to provide a measure of uniform height effectiveness.

3.2 Data Requirements and Sources

The evaluation design calls for data on four model years: 1981 through 1984. Specific data requirements are:

- The number of low speed, bumper-involved collisions
- The number of collisions when damage has occurred, and the extent of the damage in terms of,
  - the number of parts damaged,
  - the severity of damage to each part,
  - repair cost estimates (and/or replacement cost).
- In a two-vehicle collision, whether bumpers made direct (head on) contact, or if one bumper overrode the other.

The report on the evaluation of the bumper standard published in April 1981 [10] covered, in some detail, a series of potential data sources including police accident reports, repair shop records, etc.

After a review and discussion of the data, the report came to the conclusion that the most promising methods/sources were a national sample of drivers, obtained by survey, whose bumper-involved low-speed collisions went otherwise unreported. The source for insurance-reported collisions screened to eliminate injury and/or towaway incidents, likewise remains insurance claim files.

The survey was conducted under contract [17] over a period of six months beginning in January 1985. While this method is designed to primarily obtain data on unreported collisions, insurance reported cases were also counted (in contrast to the survey in 1979) in order to measure the possible shift in damage severity that could occur as a result of the bumper standard modification.

Insurance claim cases were obtained from the State Farm Insurance Company computerized files and from a repair cost estimating service. Both sources compiled data sets for the insurance data analysis conducted under contract [1], [2], [3].

Throughout this report where data are collected using sampling techniques, results are compared with their 95 percent confidence intervals to determine if the result is statistically significant (α = 0.05). If the result is within the range of the interval (+ or -), it is judged not to be statistically significant. If the result lies outside the interval, the result is either significantly higher (an increase) or lower (a decrease). All terms used in reference to a result's significance are defined in terms of statistical significance as stated here.

3.3 The Driver Survey

The driver survey was conducted under a design that would yield a sample of U.S. households who owned or had exclusive use of 1981 through 1984 model year passenger cars. The key measures to be obtained from the survey include:

- The frequency of low-speed collisions;
- The proportion of such collisions resulting in damage;
- The proportion of damaged cars in which an insurance claim was filed or a police report prepared.
- The extent of damage; and
- The amount of owner/driver time and inconvenience resulting from a damaged car.

This survey, in comparison to the one performed in 1979, included questions relating to insurance claims (although the protocol was an abbreviated version for these cases) and questions about delay and inconvenience - the time spent at the collision scene, in filling out accident reports and insurance claims, in getting repair estimates, in having the car repaired, as well as the time the respondent was without use of the car, and which substitute transport modes were used during that time.

3.3.1 Survey Design

A total of 84,578 households were screened by telephone using random digit dialing procedures. Eligible vehicles (1981 through 1984 models) were located in 20,915 households which yielded 2,823 qualifying (no injury, car driveable) bumper incidents. The data base consisted of the separate surveys - an initial and a follow-up survey - each using a four-month retrospective reporting period.

Two potential problems in designing a survey are memory decay and telescoping. Memory decay is a significant problem on surveys in which respondents must retrospectively report over a large period of time, particularly when trying to recall relatively minor incidents. This problem can be alleviated by appropriate questioning. The techniques employed in the survey used an unaided question followed by a series of aided questions to optimize incident recall. The other potential problem, telescoping, consists of a reported event being displaced in time. By using only a four month retrospective reporting period the effect of telescoping was judged to be self cancelling [17].

Following the practice of the 1979 survey which showed no significant difference in damage reported by the respondent and damage observed by inspection of the car on site, in-person visits were conducted. These were limited to 3 percent of the total incidents involving damage. The inspections largely substantiated the accuracy of damage reported in the survey.

The survey methodology is described in detail in the reference indicated above, to which the survey instrument is appended.

3.3.2 Collision Damage Frequency - Results of the Driver Survey

It will be recalled that the primary purpose of the driver survey was to obtain data on unreported, low-speed bumper-related collisions. The results will, in a subsequent chapter, be combined with insurance claim data to determine net changes in benefits associated with the bumper standard's modification. In Tables 3-1 through 3-3, damage incidence of 1983 and 1984 cars are compared to their respective 1981 and 1982 predecessors, both for cars with changed as well as unchanged bumper systems.

Table 3-1 shows the effect of low-speed collisions on changed (i.e., reduced strength) 1983 bumper systems. Overall there is a drop in the frequency with which these bumpers are damaged. However, when broken down between front and rear incidents, there is no statistically significant difference between changed 1983 bumpers and their 1981/82 predecessor systems--relative to differences for systems that were not changed, i.e., when bumper strength remained at prior levels.

The 1984 bumper model experience is shown in Table 3-2 with results opposite to those for 1983 bumpers. In essence, 1984 bumpers had a higher damage frequency than their 1981/82 predecessors. This difference was, however, not statistically significant.

TABLE 3-1

DAMAGE FREQUENCY-SURVEY OF LOW SPEED COLLISIONS

Net Differences Between Changed and Unchanged Systems

1983 vs. 1981/82 Models

	UNCHANGED BUMPERS			CHANGED BUMPERS					
	A. 1983	B. 1981/82	C. DIFFERENCES (A-B)	D. 1983	E. 1981/82	F. DIFFERENCES (D-E)	NET DIFFERENCE (F-C)	CONFIDENCE INTERVAL - OR +	SIGNIFICANT INCR. OR DECR. OF CHANGED BUMPER INCIDENTS
FRONT + REAR									
TOTAL UNREPORTED INCIDENTS	219	489		159	283				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	70	144		40	91				
PERCENT	32	29	3	25	32	-7	-10	9	Signif. lower
FRONT									
TOTAL UNREPORTED INCIDENTS	118	231		70	134				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	47	88		24	52				
PERCENT	40	38	2	34	39	-5	-7	15	No Signif. difference
REAR									
TOTAL UNREPORTED INCIDENTS	101	258		89	149				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	23	56		16	39				
PERCENT	23	22	1	18	26	-8	-9	12	No Signif. difference

NOTE: SIGNIFICANT > 0 WHERE Ho: $p1=p2$ vs. H1: $p1>p2$, Alpha=0.05

TABLE 3-2

DAMAGE FREQUENCY-SURVEY OF LOW SPEED COLLISIONS

Net Differences Between Changed and Unchanged Systems

1984 vs. 1981/82 Models

	UNCHANGED BUMPERS			CHANGED BUMPERS					
	A. 1984	B. 1981/82	C. DIFFERENCES (A-B)	D. 1984	E. 1981/82	F. DIFFERENCES (D-E)	NET DIFFERENCE (F-C)	CONFIDENCE INTERVAL - OR +	SIGNIFICANT INCR. OR DECR. OF CHANGED BUMPER INCIDENTS
FRONT + REAR									
TOTAL UNREPORTED INCIDENTS	230	358		260	370				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	58	107		73	107				
PERCENT	25	30	-5	28	29	-1	4	9	No signif. difference
FRONT									
TOTAL UNREPORTED INCIDENTS	106	169		126	175				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	28	54		38	61				
PERCENT	26	32	-6	30	35	-5	1	13	No signif. difference
REAR									
TOTAL UNREPORTED INCIDENTS	124	189		134	195				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	29	53		36	46				
PERCENT	23	28	-5	27	24	3	8	12	No signif. difference

NOTE: SIGNIFICANT >0 WHERE Ho: $p1=p2$ vs. H1: $p1>p2$, Alpha=0.05

Combining the two model years before and after the bumper standard modification yields a larger sample size, and the comparison is shown in Table 3-3. The net difference in collision damage frequency, when comparing changed 1983/84 bumper systems to their 1981/82 predecessors, is essentially nil. This may appear to be counterintuitive since one might expect a larger incidence of damage to bumpers and other parts when protected by systems with lesser strength. The fact that these data are based only on unreported incidents likely screens out the more severe damage cases which are reported.

3.3.3 Damage Repair Cost - Unreported Low Speed Collisions

Damage repair costs for 520 cases of unreported low-speed collision damage were estimated (under a separate contract). The cases covered the 1981 through 1984 model years. While these data will be combined with much larger insurance claim case files for the overall net benefit analysis, it is of interest to see both the repair cost level and trends for bumper systems that were changed as a result of the bumper standard modifications.

Table 3-4 shows the net repair cost differences - and their statistical significance - between changed and unchanged front and rear bumper systems. The comparison first establishes differences between respective changed and unchanged 1983 + 1984 vs 1981 + 1982 predecessor models. Then the net differences between changed and unchanged are shown

TABLE 3-3
DAMAGE FREQUENCY-SURVEY OF LOW SPEED COLLISIONS
Net Differences Between Changed and Unchanged Systems
1983+1984 vs. 1981/82 Models

	UNCHANGED BUMPERS			CHANGED BUMPERS					
	A. 1983/84	B. 1981/82	C. DIFFERENCES (A-B)	D. 1983/84	E. 1981/82	F. DIFFERENCES (D-E)	NET DIFFERENCE (F-C)	CONFIDENCE INTERVAL - OR +	SIGNIFICANT INCR. OR DECR. OF CHANGED BUMPER INCIDENTS
FRONT + REAR									
TOTAL UNREPORTED INCIDENTS	449	424		419	327				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	126	128		113	100				
PERCENT	28	30	-2	27	31	-4	-2	6	No signif. difference
FRONT									
TOTAL UNREPORTED INCIDENTS	224	200		196	155				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	75	72		62	57				
PERCENT	33	36	-3	32	37	-5	-2	12	No signif. difference
REAR									
TOTAL UNREPORTED INCIDENTS	225	224		223	172				
PERCENT	100	100		100	100				
NO. OF UNREPORTED INCIDENTS RESULTING IN DAMAGE	51	56		51	43				
PERCENT	23	25	-2	23	25	-2	0	12	No signif. difference

NOTE: SIGNIFICANT >0 WHERE Ho: $p1=p2$ vs. H1: $p1>p2$, Alpha=0.05

TABLE 3-4

DAMAGE REPAIR COSTS FOR UNREPORTED LOW SPEED COLLISIONS

Net Differences Between Changed and Unchanged Bumper Systems

1983 + 1984 vs. 1981/82 Models

(1984 Dollars)

	UNCHANGED BUMPERS ($)			CHANGED BUMPERS ($)					
	A. 1983/84	B. 1981/82	C. DIFFERENCES (A-B)	D. 1983/84	E. 1981/82	F. DIFFERENCES (D-E)	NET DIFFERENCE (F-C)	CONFIDENCE INTERVAL - OR +	SIGNIFICANT INCR. OR DECR. OF CHANGED BUMPER INCIDENTS
FRONT + REAR									
No. of Unreported Damage Incidents	126	128		113	100				
Average Repair cost per Incident	$396	$452	-$56	$375	$487	-$112	-$56	114	No signif. difference
Confidence Bounds: Lower and upper	$349 443	$400 505		$335 415	$407 568				
FRONT									
No. of Unreported Damage Incidents	75	72		62	57				
Average Repair cost per Incident	$389	$450	-$61	$400	$433	-$33	+$28	137	No signif. difference
Confidence Bounds: Lower and upper	$329 448	$389 512		$339 462	$347 518				
REAR									
No. of Unreported Damage Incidents	51	56		51	43				
Average Repair cost per Incident	$406	$455	-$49	$340	$589	-$249	-$200	199	Signif. lower
Confidence Bounds: Lower and upper	$331 482	$363 548		$301 379	$428 750				

NOTE: SIGNIFICANT >0 WHERE Ho: p1=p2 vs. H1: p1>p2, Alpha=0.05

followed by an indication of whether changed 1983 and 1984 bumper system collision repair costs were significantly higher or lower or whether there was no significant difference relative to unchanged bumpers.

Both the front and combined front and rear results show no significant differences between pre/post changed bumper systems. The average repair cost of unreported rear end collisions with damage is significantly lower for cars with changed bumper designs as compared to their predecessors and to cars with unchanged designs. This can be accounted for by the fact that more bumper-involved rear end collisions for the changed bumper group were reported to insurance companies (as will be shown later). This would occur if changed bumper designs resulted in a greater amount of damage which would cause people to place an insurance claim. The net effect of an increase in insurance claims is to leave a group of lower cost unreported cases in which damage occurred.

The survey data, in summary, indicates that little, if anything, has changed for cars with modified bumper designs in 1983 and 1984 when these are compared to their 1981 and 1982 predecessors. The frequency with which damage occurs has essentially remained the same for incidents that are not reported and for which no insurance claim is filed--although it is possible that there are more cases of extensive damage which would not show up in the survey. The cost to repair damage has not changed either, with the exception of repair cost to the rear bumper and rear body area. That has declined significantly and analyses of insurance claims and parts damaged in the following sections may explain the reasons for lower repair costs for rear end damage.

3.3.4 Damage to Parts in Unreported Low Speed Collisions

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 safety-related parts remain undamaged or at least continue to be operable after impact testing. Damage limitations also apply to certain front and rear exterior sheet metal parts. The following list contains the parts that were included for damage screening in the survey of unreported collisions.

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

3.3.4.1 Number of Parts Damaged

Table 3-5 is a distribution of unreported collisions by the number of damaged parts. These data are from the driver survey (another similar data set will be shown later, based on insurance claim cases).

The statistical analysis included in the table shows mixed results for damage to safety-related and other bumper protected parts in models equipped with changed (i.e., reduced strength) bumpers.

TABLE 3-5
DISTRIBUTION OF UNREPORTED LOW-SPEED
COLLISIONS BY NUMBER OF DAMAGED PARTS

Number of Damaged Parts per Collision	1984 Number	1984 Percent	1983 Number	1983 Percent	1981/1982 1984 Predecessors Number	1981/1982 1984 Predecessors Percent	1981/1982 1983 predecessors Number	1981/1982 1983 predecessors Percent
Unchanged Bumper Models								
None	172	74.8	149	68.1	251	70.1	345	70.6
One	30	13.0	40	18.3	52	14.5	69	14.1
Two	12	5.2	15	6.8	24	6.7	27	5.5
Three or More	16	7.0	15	6.8	31	8.7	48	9.8
Changed Bumper Models								
None	187	71.9	119	74.8	263	71.1	193	68.0
One	42	16.2	23	14.5	68	18.4	44	15.4
Two	12	4.6	5	3.1	17	4.6	21	7.4
Three or More	19	7.3	12	7.5	22	5.9	26	9.2

Statistical Analysis of Differences
Between Changed and Unchanged Bumpers

NUMBER OF DAMAGED PARTS	1984 VS 81/82 NET DIFFERENCE	CONFIDENCE INTERVAL	SIGNIFICANT INCR. OR DECR. OF CHANGED DESIGNS	1983 VS 81/82 NET DIFFERENCE	CONFIDENCE INTERVAL	SIGNIFICANT INCR. OR DECR. OF CHANGED DESIGNS
NONE	-3.9%	+ or - 4.3%	No Signif. Diff.	9.3%	+ or -4.77%	Signif. Incr.
ONE	-0.7%	+ or -3.46%	No Signif. Diff.	-5.1%	+ or -3.83%	Signif. Decr.
TWO	1.5%	+ or -2.14%	No Signif. Diff.	-4.6%	+ or -2.36%	Signif. Decr.
THREE OR MORE	3.1%	+ or -2.49%	Signif. Incr.	1.3%	+ or -2.85%	No Signif. Diff.

The significance tests reveal shifts from 1983 to 1984 relative to 1981/82 models in each group--no damage, one, two and three or more parts damaged--that appear to signal reversals. For example, in 1983 there was a significant reduction in collisions where a one or two parts were damaged. In 1984 models, these groups were not significantly different when compared to the 1981/82 pre-standard modification base. In the case of three or more damaged parts, 1984 models experienced a significant increase.

To determine the total effect of changed bumpers on damage to safety-related and other parts, the 1983 and 1984 data were combined and the damage percentages summed after weighting each category by the number of damaged parts. Using this approach, the net difference between changed and unchanged bumpers in terms of damaged parts, is 1.2% and the 95% confidence interval is ± 3.5%. This means there is no statistically significant difference in the aggregate in the number of damaged parts for changed versus unchanged bumpers.

3.3.4.2 <u>Severity of Damage to Parts</u>

In addition to the number of parts, the damage severity for changed and unchanged bumper systems is of interest. For this purpose a classification of severity and descriptive terms for such a classification were provided to respondents in the survey. The survey in 1979 used these levels of damage severity - major, moderate, minor and none. This proved to be excessive since most major damages required part replacement and minor damage was repaired. The current survey used major, minor and none, with relevant examples of what each category could involve.

Tables 3-6 and 3-7 show damage severity for each of nine front and nine rear parts, respectively. Each table is broken down into changed and unchanged bumper design groups. Analyses are provided at the bottom of each table on whether or not there is a significant difference in the percentage of parts suffering major or minor damage in 1983 or 1984, in contrast to 1981/82.

For changed bumper designs there were significantly fewer front parts with either major or minor damage--both in 1983 and 1984. Only right front fenders showed an increase--in minor damage--in 1983, and in 1984 there were more cases of minor damage to front lamps.

In the case of rear end damage, Tables 3-7, the first year (1983) that changed bumper designs were on the road, they incurred a lesser amount of damage overall, but in 1984 there was a significant increase in the extent of damage to parts, particularly the rear bumper itself, and to the fenders.

Given the sample size, it is difficult to show conclusions for each post-standard model year. It appears that in the aggregate there is

TABLE 3-6

DAMAGE SEVERITY TO FRONT EXTERIOR PARTS

Part Damage by Model Year for Unchanged and Changed Bumper Systems

(Percent Damaged in each Severity Group 1/)

Part	1984			1983			1981/1982 2/ 1984 Predecessors			1981/1982 2/ 1983 Predecessors		
	None 1/	Minor	Major	None	Minor	Major	None	Minor	Major	None	Minor	Major
Unchanged Bumper Models												
Front Bumper	83.96	7.55	8.49	79.66	16.10	4.24	83.43	10.06	6.51	79.65	14.29	6.06
Grille	92.45	3.77	3.77	89.83	5.93	4.24	92.90	4.73	2.37	91.34	5.63	3.03
Front Lamps	93.40	2.83	3.77	85.59	7.63	6.78	92.90	3.55	3.55	89.61	5.19	5.19
Front Reflectors	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Front Right Fender	94.34	1.89	3.77	88.98	8.47	2.54	94.08	3.55	2.37	91.34	5.63	3.03
Front Left Fender	94.34	1.89	3.77	88.98	8.47	2.54	94.08	3.55	2.37	91.77	5.19	3.03
Hood	98.11	0.94	0.94	94.07	3.39	2.54	95.86	2.37	1.77	95.24	2.60	2.16
Hood Latch	98.11	0.94	0.94	97.46	1.69	0.85	98.22	1.78	.00	97.84	1.30	0.87
Radiator	100.00	0.00	0.00	99.15	0.85	.00	100.00	0.00	0.00	99.57	0.43	.00
Changed Bumper Models												
Front Bumper	76.19	17.46	6.35	75.71	18.57	5.71	68.00	23.43	8.57	67.16	23.88	8.96
Grille	95.24	4.76	.00	94.29	4.29	1.43	87.43	5.71	6.86	85.82	5.22	8.96
Front Lamps	86.51	7.14	6.35	84.29	8.57	7.14	85.14	6.86	8.00	86.57	5.97	7.46
Front Reflectors	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Front Right Fender	92.86	5.56	1.59	81.43	14.29	4.29	82.86	10.86	6.29	83.58	9.70	6.72
Front Left Fender	92.86	5.56	1.59	82.86	12.86	4.29	82.86	10.86	6.29	83.58	9.70	6.72
Hood	99.21	0.79	.00	97.14	2.86	.00	94.29	4.00	1.71	94.78	3.73	1.49
Hood Latch	99.21	0.79	.00	98.57	1.43	.00	95.43	2.29	2.29	96.27	2.99	0.75
Radiator	100.00	0.00	0.00	100.00	0.00	0.00	98.29	1.71	.00	97.01	2.99	.00

Statistical Analysis of Differences

Between Changed and Unchanged Bumpers

	1984 Confidence Intervals			1984 Net Differences			1983 Confidence Intervals			1983 Net Differences		
	None	Minor	Major	None	Minor	Major	None	Minor	Major	None	Minor	Major
Front Bumper	5.00	1.92	1.02	7.66	-3.46	-4.20	3.98	3.60	2.22	8.54	-7.13	-1.42
Grille	3.55	0.64	0.53	8.26	0.01	-8.26	4.12	0.76	0.72	9.98	-1.24	-8.73
Front Lamps	3.96	0.72	0.75	0.87	1.01	-1.87	4.94	1.10	1.02	1.74	0.17	-1.90
Front Reflectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Front Right Fender	3.63	0.80	0.52	9.74	-3.64	-6.11	4.98	1.61	0.67	0.21	1.74	-1.94
Front Left Fender	3.63	0.80	0.52	9.74	-3.64	-6.11	4.92	1.51	0.67	2.07	-0.12	-1.94
Hood	2.25	0.30	0.17	2.67	-1.78	-0.89	3.04	0.48	0.25	3.54	-1.67	-1.87
Hood Latch	1.97	0.20	0.16	3.89	-0.66	-3.23	2.25	0.29	0.10	2.68	-1.95	-0.73
Radiator	0.80	0.11	0.00	1.71	-1.71	0.00	2.25	0.29	0.10	2.68	-1.95	-0.73

1/ See Section 3.3.4.2 for definition of damage severity categories.

2/ The 1983 and 1984 model year have different models with and without bumper design changes, thus 1981 and 1982 are grouped in the same manner.

TABLE 3-7
DAMAGE SEVERITY TO REAR EXTERIOR PARTS
Part Damage by Model Year for Unchanged and Changed Bumper Systems
(Percent Damaged in each Severity Group 1/)

Part	1984			1983			1981/1982 2/ 1984 Predecessors			1981/1982 2/ 1983 Predecessors		
	None 1/	Minor	Major	None	Minor	Major	None	Minor	Major	None	Minor	Major
Unchanged Bumper Models												
Rear Bumper	86.29	9.68	4.03	84.16	9.90	5.94	88.89	8.47	2.65	88.37	8.91	2.71
Rear Lamps	90.32	4.84	4.84	92.08	5.94	1.98	92.59	3.17	4.23	94.57	2.71	2.71
Rear Reflectors	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Rear Right Fender	95.97	4.03	0.00	98.02	0.99	0.99	95.77	2.65	1.59	96.12	2.71	1.16
Rear Left Fender	95.97	4.03	0.00	98.02	0.99	0.99	95.77	2.65	1.59	96.12	2.71	1.16
Trunk Lid	98.39	1.61	.00	98.02	1.98	.00	98.41	1.06	0.53	98.84	0.78	0.39
Trunk Latch	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Tail Pipe	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Fuel Tank/Filler Neck	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Changed Bumper Models												
Rear Bumper	85.07	10.45	4.48	86.52	7.87	5.62	90.77	7.69	1.54	87.92	7.38	4.70
Rear Lamps	91.04	5.22	3.73	96.63	2.25	1.12	93.85	4.10	2.05	90.60	6.04	3.36
Rear Reflectors	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Rear Right Fender	93.28	5.97	0.75	97.75	2.25	0.00	96.92	1.54	1.54	95.30	2.68	2.01
Rear Left Fender	93.28	5.97	0.75	97.75	2.25	0.00	96.92	1.54	1.54	95.30	2.68	2.01
Trunk Lid	98.51	1.49	.00	100.00	0.00	0.00	99.49	0.00	0.51	99.33	0.00	0.67
Trunk Latch	99.25	0.75	.00	100.00	0.00	0.00	99.49	0.51	0.00	99.33	0.67	0.00
Tail Pipe	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
Fuel Tank/Filler Neck	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00

Statistical Analysis of Differences
Between Changed and Unchanged Bumpers

	1984 Confidence Intervals			1984 Net Differences			1983 Confidence Intervals			1983 Net Differences		
	None	Minor	Major	None	Minor	Major	None	Minor	Major	None	Minor	Major
Rear Bumper	4.10	1.17	0.46	-3.10	1.54	1.55	4.67	1.20	0.75	2.81	-0.50	-2.31
Rear Lamps	3.49	0.59	0.51	-0.53	-0.54	1.07	3.42	0.66	0.32	8.52	-7.02	-1.50
Rear Reflectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rear Right Fender	2.71	0.54	0.14	-3.84	3.04	0.80	2.40	0.31	0.17	0.56	1.29	-1.84
Rear Left Fender	2.71	0.54	0.14	-3.84	3.04	0.80	2.40	0.31	0.17	0.56	1.29	-1.84
Trunk Lid	1.52	0.17	0.04	-0.95	0.94	0.02	1.37	0.17	0.05	1.49	-1.21	-0.28
Trunk Latch	0.74	0.06	0.00	-0.23	0.23	0.00	0.55	0.05	0.00	0.67	-0.67	0.00
Tail Pipe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Tank/Filler Neck	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1/ See Section 3.3.4.2 for definition of damage severity categories.
2/ The 1983 and 1984 model year have different models with and without bumper design changes, thus 1981 and 1982 are grouped in the same manner.

no significant difference between changed and unchanged bumper designs in terms of damage severity to safety-related and other bumper protected front and rear parts.

3.4 Insurance Claim Data

Collision and liability are the two major forms of property damage insurance coverage. Collision insurance provides protection for damage to the insured driver's car. Liability insurance protects the driver at fault by paying for damages 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 in this evaluation).

The objective in analyzing insurance claim data is to establish the change in both damage frequency and claim amount which can be attributed to the modification of the bumper standard. These measures again require that claim cases: (1) be screened to exclude injury and towaway incidents; and (2) be limited to front and rear bumper-related collisions. A detailed discussion of sources is included in the April 1981 evaluation of the bumper standard [10]. The same sources and approaches are used in this evaluation. Specifically, the computerized State Farm Insurance Company file was selected as the primary source of insurance data. It contains the detailed data needed to evaluate bumper effectiveness, for the years 1981 through 1984, and includes both collision and liability claim data. To check the representativeness of the single main data source, it was compared to the distribution of claim frequency and damage repair cost obtained from an estimating service which obtains case files from a number of insurance companies. An additional source, the Highway Loss Data Institute (HLDI) provides information on collision claims (not liability claims) for many major insurance companies, including State Farm, and this source was used to determine the average loss payments per insured vehicle year.

3.4.1 Description of State Farm 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. File tapes are assembled for each model year containing both collision and liability claims data. In 1983, the first model year to which the modified bumper standard was applicable, State Farm began to use a computerized estimating service - ADP Collision Estimating Services Inc. (Audatex System) - for processing damage claims at many of their drive-in service centers. Other centers continued to use "manual" procedures that had been in place prior to 1983.

Comparing the results of automated with manual estimates (for example 1983 vs 1982) yielded consistent differences in both the amount of damage repair cost - and the proportion of bumper-related claims to all claims. Further research into the data tapes by the insurance data analysis contractor (KLD Associates, Inc.) revealed that computer estimates (by the estimating service) contained claims with severe damage. They also found claims in the manual estimates which included towing charges reflecting a collision severity which was to be excluded, as previously noted. The computer estimates included cases where State Farm representatives performed a field inspection of damage since the vehicle was not driveable. Such cases were, as before, not to be included in the analysis. Removing towables by an appropriate filtering method yielded data sets which were usable for comparative analysis.

In preparing data sets for analysis, every effort was made to assure year to year compatibility. The various data set adjustments, including testing by the contractor and the recommendations for use, are documented in the contractor final reports [1], [2], [3]. In each case the largest possible case file was utilized and, for the years in which both manual and automated procedures were used to estimate repair costs or to identify bumper related cases, both sets were combined.

Three basic comparisons are made for changed and unchanged bumper systems between pre- and post- bumper standard modifications. The relative net change in effectiveness (pre/post) is derived by the difference in damage frequency and damage repair cost between changed and unchanged bumper systems, as was done for the data sets used in the analysis of unreported collisions in the previous sections. As has already been stated, the pre/post comparisons always involve matched data for changed and unchanged bumper systems. For example the 1983 changed bumper systems are compared to their 1981/82 nameplate predecessors.

3.5 Analysis of Effectiveness Based on Insurance Claims Data

The reduction of the bumper standard from 5 to 2.5 mph could have several effects. It could increase the rate at which bumpers are damaged in a low-speed collision. The cost to repair the damaged bumper system will vary depending on the extent of damage and whether it is repaired, or if several parts have to be replaced. Both measures - the proportion of bumper damage claimed to all claims, and the average damage repair cost - are presented and discussed in the following sections.

3.5.1 The Proportion of Bumper Related Insurance Claims

The insurance claims data base consists of a sample of property damage insurance claims, which include those that involved the bumper (both front and rear). The objective, in this section, is to determine the difference between the claim made for collisions involving cars with changed bumpers compared to claim rates for unchanged designs. Table 3-8 shows that net difference - and its statistical significance - between changed and unchanged bumper insurance claim rates.

In every case there has been a significant increase in the proportion of claims for rear end bumper-related collisions, which, when combined with claims for front end damage, also show a significant increase for 1983 and 1984 models.

TABLE 3-8
PROPORTION OF INSURANCE CLAIMS FOR BUMPER RELATED DAMAGE
Net difference Between Changed and Unchanged Bumper Systems

	UNCHANGED BUMPER CLAIMS			CHANGED BUMPER CLAIMS 1/					
	A. 1983	B. 1981/82	C. (1983-81/82)	D. 1983	E. 1981/82	F. (1983-81/82)	Net Diff. Net (F-C)	Confidence Interval 2/	Significant Incr. or Decr. of Changed Bumper Systems 3/
			1983 Vs. 1981/82						
FRONT+REAR	0.59	0.60	-0.01	0.62	0.59	0.03	0.04	0.01	Signif. Increase
FRONT	0.37	0.37	0.00	0.38	0.39	-0.01	-0.01	0.01	No Signif. Change
REAR	0.22	0.23	-0.01	0.24	0.20	0.04	0.05	0.01	Signif. Increase
			1984 Vs. 1981/82						
	1984	1981/82	(1984-81/82)	1984	1981/82	(1984-81/82)			
FRONT+REAR	0.63	0.62	0.01	0.66	0.59	0.07	0.06	0.01	Signif. Increase
FRONT	0.37	0.38	-0.01	0.39	0.38	0.01	0.02	0.01	Signif. Increase
REAR	0.26	0.24	0.02	0.27	0.21	0.06	0.04	0.01	Signif. Increase
			1983+1984 Vs. 1981/82						
	1983/84	1981/82	(1983/84-81/82)	1983/84	1981/82	(1983/84-81/82)			
FRONT+REAR	0.61	0.61	0.00	0.65	0.59	0.06	0.06	0.01	Signif. Increase
FRONT	0.37	0.37	0.00	0.39	0.38	0.01	0.01	0.01	No Signif. Change
REAR	0.24	0.24	0.00	0.26	0.21	0.05	0.05	0.01	Signif. Increase

1/ See Section 2.1.4 for explanation of changed bumpers.
2/ 95 Percent Confidence Level
3/ Significant > 0 where Ho: p1=p2 vs. H1: p1>p2, alpha=0.05

Beyond a fairly low impact speed, the bumper offers little or no protection. In frontal collisions, the bumper is less of a factor in preventing damage since these generally involve higher impact speeds than rear collisions. Therefore, damage is more likely when rear bumpers are built to a reduced standard.

3.5.2 The Average Repair Cost of Bumper Damage Based on Insurance Claims

The average repair costs for bumper-involved claims for the 3 sets of comparisons are arrayed in Table 3-9 in the same format as the claim frequencies. It shows the average repair costs and the net differences between changed and unchanged post-standard bumper systems relative to their pre-standard predecessors.

The cost to repair collision damage, based on insurance claims, averages $1000, compared to $450 when collision damage is not reported and claimed under insurance coverage. Repair cost dropped by $62 for 1983/84 models compared to their 1981/82 counterparts, largely the result of less expensive bumper systems.

Those models which were equipped with changed (reduced strength) bumpers encountered a significant decrease in damage repair cost for 1983 and 1984 models as well as for the aggregate of both years.

TABLE 3-9
AVERAGE DAMAGE REPAIR COST FOR BUMPER RELATED DAMAGE INSURANCE CLAIMS
Net difference between Changed and Unchanged Bumper Systems
(1984 Dollars)

	UNCHANGED BUMPER CLAIMS A. 1983	B. 1981/82	C. (1983-81/82)	CHANGED BUMPER CLAIMS 1/ D. 1983	E. 1981/82	F. (1983-81/82)	Net Diff. Net (F-C)	Confidence Interval 2/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
			1983 Vs. 1981/82						
FRONT+REAR	$996	$1094	-$98	$920	$1043	-$123	-$25	11	Signif. Decrease
FRONT	$1081	$1159	-$78	$972	$1102	-$130	-$52	18	Signif. Decrease
REAR	$854	$990	-$136	$825	$927	-$102	+$34	22	Signif. Increase
			1984 Vs. 1981/82						
	1984	1981/82	(1984-81/82)	1984	1981/82	(1984-81/82)			
FRONT+REAR	$1010	$1119	-$109	$865	$1044	-$179	-$70	11	Signif. Decrease
FRONT	$1140	$1212	-$72	$1007	$1100	-$93	-$21	17	Signif. Decrease
REAR	$824	$972	-$148	$727	$943	-$216	-$68	20	Signif. Decrease
			1983+1984 Vs. 1981/82						
	1983/84	1981/82	(1983/84-81/82)	1983/84	1981/82	(1983/84-81/82)			
FRONT+REAR	$1003	$1105	-$102	$880	$1044	-$164	-$62	9	Signif. Decrease
FRONT	$1112	$1181	-$69	$996	$1101	-$105	-$36	15	Signif. Decrease
REAR	$838	$982	-$144	$754	$936	-$182	-$38	18	Signif. Decrease

1/ See Section 2.1.4 for explanation of changed bumpers.
2/ 95 Percent Confidence Level
3/ Significant $\geq$ 0 where Ho: p1=p2 vs. H1: p1>p2, alpha=0.05

The insurance repair estimates for frontal and rear damage claims declined significantly, a $36 net differential for frontal and $38 for rear claims, based on the relative differences between changed and unchanged bumpers. Claims for frontal damage of 1983 models was slightly lower than for 1984 models but both showed statistically significant decreases in average repair cost for changed bumper designs. Rear end claims showed a somewhat different change -- 1983 models with changed bumpers had a higher average repair cost whereas 1984 models showed a significant decrease. In the aggregate, rear claims had significantly lower changes in repair costs in about the same magnitude as frontal claims.

Much of the reduction in average repair cost can be attributed to lower costs of changed bumper systems. The repair cost reductions are larger than the estimated reductions in consumer cost of bumpers. This can occur because automotive replacement part costs are generally about 4 times higher than the original consumer cost.

3.6 The Effect of the Type of Bumper System Changes Made in Response to the Bumper Standard Modification

As will be recalled, the changes made to 1983 and 1984 bumper systems were analyzed and placed into four categories: Facebar, Structural, Energy Absorber, and the combination of Structural and Energy Absorber. Each category had different effects on the weights and costs of bumpers and this section explores these effects on damage frequency and its average repair cost. Since each of the categories is a subaggregate of all changes combined, the data sets are smaller, and in order to have enough of a sample size to show statistical significance, only one comparison is made - 1983 and 1984 vs 1981 and 1982 cases. Tables 3-10 and 3-11 show the damage frequency and average repair costs for each category, respectively.

3.6.1 Damage Frequency by Change Category

The proportion of bumper-related damage claims for cars with bumper systems that were not altered (after the standard was modified to 2.5 mph) did not change in relation to the experience of their 1981/82 predecessors. This was already shown in Table 3-8; the values (proportions) are listed in Table 3-10 merely for comparing the proportion levels to the change categories.

Statistically significant increases in the proportion of damage claims were found in cases where thickness (gauge) of the bumper's facebar was reduced, and also where structural parts (reinforcements, brackets, etc.) were either eliminated or reduced in size. These two change categories represent 17 and 24 percent of the cars produced in 1983 and 1984, respectively. In both of these categories, damage to the rear of the struck cars contributed to the significantly higher damage rate. It was the 1983 and 1984 GM compacts and subcompacts such as the Citation, Skyhawk, Chevette, and Century models that had downgauged facebars, and Chrysler Reliant, Omni and the 400 as well as the Honda Civic and Accord

TABLE 3-10
PROPORTION OF INSURANCE CLAIMS FOR BUMPER RELATED DAMAGE
By Design Change Categories 1/
Net Difference Between Changed and Unchanged Bumper Systems

1983+1984 vs. 1981 +1982

CHANGE CATEGORY 1/	UNCHANGED BUMPER SYSTEMS A. 1983+1984	B. 1981+1982	C. (A-B)	CHANGED BUMPER SYSTEMS D. 1983+1984	E. 1981+1982	F. (D-E)	Net Diff. (F-C)	Conf. 2/ Interval - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
Facebar									
Front + Rear	0.61	0.61	0.00	0.66	0.59	0.06	0.06	0.01	Signif. Increase
Front	0.37	0.37	0.00	0.40	0.40	0.00	0.00	0.01	No Signif. Change
Rear	0.24	0.24	0.00	0.26	0.19	0.07	0.07	0.01	Signif. Increase
Structural									
Front + Rear	0.61	0.61	0.00	0.67	0.61	0.06	0.06	0.01	Signif. Increase
Front	0.37	0.37	0.00	0.41	0.38	0.03	0.03	0.01	Signif. Increase
Rear	0.24	0.24	0.00	0.26	0.23	0.03	0.03	0.01	Signif. Increase
Energy Absorber									
Front + Rear	0.61	0.61	0.00	0.64	0.65	-0.01	-0.01	0.01	No Signif. Change
Front	0.37	0.37	0.00	0.32	0.34	-0.02	-0.02	0.02	No Signif. Change
Rear	0.24	0.24	0.00	0.32	0.31	0.01	0.01	0.02	No Signif. Change
Structural & Energy Absorber									
Front + Rear	0.61	0.61	0.00	0.64	0.55	0.09	0.09	0.01	Signif. Increase
Front	0.37	0.37	0.00	0.39	0.37	0.02	0.02	0.01	Signif. Increase
Rear	0.24	0.24	0.00	0.25	0.18	0.07	0.07	0.01	Signif. Increase

1/ See Section 2.1.4 for design change category definitions.

2/ 95 Percent Conficence Level

3/ Significant > 0 where Ho: p1=p2 vs. H1: p1 > p2, Alpha=0.05

TABLE 3-11
AVERAGE DAMAGE REPAIR COST FOR BUMPER RELATED INSURANCE CLAIMS
By Design Change Categories 1/
Net Difference Between Changed and Unchanged Bumper Systems

1983+1984 vs. 1981 +1982

(1984 Dollars)

CHANGE CATEGORY 1/	UNCHANGED BUMPER SYSTEMS A. 1983+1984	B. 1981+1982	C. (A-B)	CHANGED BUMPER SYSTEMS D. 1983+1984	E. 1981+1982	F. (D-E)	Net Diff. (F-C)	Conf. 2/ Interval - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
Facebar									
Front + Rear	$1003	$1105	-$102	$827	$962	-$135	-$33	11	Signif. Decrease
Front	$1112	$1181	-$69	$982	$1048	-$66	+$3	15	No Signif. Change
Rear	$838	$982	-$144	$710	$895	-$185	-$41	19	Signif. Decrease
Structural									
Front + Rear	$1003	$1105	-$102	$962	$1060	-$98	+$4	11	No Signif. Change
Front	$1112	$1181	-$69	$1096	$1172	-$76	-$7	18	No Signif. Change
Rear	$838	$982	-$144	$820	$937	-$117	+$27	16	Signif. Increase
Energy Absorber									
Front + Rear	$1003	$1105	-$102	$973	$1083	-$110	-$8	72	No Signif. Change
Front	$1112	$1181	-$69	$1102	$1225	-$123	-$54	110	No Signif. Change
Rear	$838	$982	-$144	$835	$921	-$86	+$58	70	No Signif. Change
Structural & Energy Absorber									
Front + Rear	$1003	$1105	-$102	$848	$1049	-$201	-$99	22	Signif. Decrease
Front	$1112	$1181	-$69	$881	$995	-$114	-$45	19	Signif. Decrease
Rear	$838	$982	-$144	$793	$1104	-$311	-$167	51	Signif. Decrease

1/ See Section 2.1.4 for deelgn change category definitions.

2/ 95 Percent Conficence Level

3/ Significant > 0 where Ho: p1=p2 vs. H1: p1>p2, Alpha=0.05

that reduced or eliminated structural parts, together with substituting brackets for hydraulic energy absorbers in 1983. The complete list of make/models by change category for 1983 and 1984 is in Appendix D.

Where only the energy-absorbers were removed, and replaced by bracketry--and this group represents only 2 percent of the production fleet in 1983 and 1984--no significant change in the proportion of bumper-related collision damage could be detected. Of the bumper systems analyzed, approximately 60 make/models for each of the 4 model years, only Chrysler models, specifically the LeBaron, 600, E Class and New Yorker were in this category. It is possible that sample size may be a factor since there were only 500 bumper claims cases in this sample set in contrast to between 6000 and 12,000 for the other design change categories. It would, in any event, take a sizeable sample to detect even a small claim rate change.

There was a significant increase in damage claim rates for cars whose bumpers underwent certain structural changes, such as reducing or eliminating reinforcements to the facebar, eliminating brackets, pads, etc. These changes, in 1983, were made to intermediate and larger GM models such as the Bonneville, Cadillac, LeSabre, Electra and Camaro, and were extended to the Cavalier, and Chevrolet group in 1984. Nissan's Sentra, the Toyota Tercel, as well as the Volvo models, were also in this category. The increase in damage rate appears to be borne equally by front and rear collision cases. The production/sales volume of cars whose bumpers incorporated this change was 15 percent in 1983 and 25 percent in 1984.

3.6.2 Average Repair Cost by Change Category

Bumpers which were subjected to the more extensive design changes appear to cost significantly less to repair after a collision. As Table 3-11 shows, the combination of a structural revision and the elimination of hydraulic energy absorbers produces a significant decrease in damage repair costs--an aggregate of $99 per front or rear incident. As mentioned in the last section, this category contains primarily Chrysler Reliant/Aries, Omni/Horizon, and Honda Accord/Civic models in the make/model sample used in this evaluation.

The category which includes intermediate and large GM models, Nissan's Sentra, the Toyota Tercel, and Volvo models showed that as a result of structural changes (e.g., bumper reinforcement or bracket part reductions) there was no significant change in repair costs overall, but that there was a significant increase in repair cost attributable to rear end collisions.

Each change category either showed a significant decrease or no change in damage repair costs relative to 1981/82 predecessor incidents, except for incidents involving rear bumpers whose changes were in the structural category. The effect of just eliminating energy absorbers, while only applicable to about 2 percent of the cars produced and/or sold in 1983 and 1984, shows no significant change in repair cost, although as already mentioned, the sample size is relatively small (about a 10 percent sample would be needed to judge significance).

The overall trend for 1983 and 1984 model collisions shows a tendency for damage to occur more frequently, although at a lower repair cost, than the 1981/82 predecessors of the models whose bumpers were changed.

3.7 Damaged Parts in Collisions for Which an Insurance Claim was Filed

Property damage claims were screened to identify those insurance claims where any of the following parts were damaged: headlamps, parking lamps, taillamps, hood, radiator, trunk and fuel tank. This list is shorter, and less specific, than the one used in the driver survey. The limitation is due to the fact that while repair cost estimates are based on all damaged parts, retrieval of this computerized information depends on widely differing manufacturer part numbers.

Lamps represent one third of all parts cited in insurance claims and, as Table 3-12 shows, this percentage holds for both the changed and unchanged bumper systems in model years 1983 and 1984. There is also no significant difference in the incident rate for lamp damage between the changed 1983/84 bumper systems and their 1981/82 predecessors.

The other safety-related parts--hood, radiator, trunk and fuel tank, excluding hood latches, showed no significant change in damage frequency between 1983/84 modified designs and their 1981/82 predecessors, and the hood mechanisms are only a small portion of damaged part claims in any case.

3.8 Bumper Mismatch in Unreported, Low Speed Collisions

As expected, since the bumper standard modification in 1982 did not change the bumper height requirements (16 to 20 inches above road level) there was no significant difference in incidence of over- or underride. Table 3-13 shows the bumper contact frequency, which, while it indicates a small net increase in cases where bumpers met--and conversely would result in a lesser frequency of bumper over- or underride, is not statistically significant between the 1983/84 changed bumper systems and their 1981/82 predecessors.

TABLE 3-12
FREQUENCY OF DAMAGED PARTS IN BUMPER RELATED INSURANCE CLAIMS
FRONT AND REAR COMBINED
Net Difference Between Changed and Unchanged Bumper Systems 1/
(Percent Present in Claims)

1983+1984 vs. 1981 +1982

	UNCHANGED BUMPER SYSTEMS			CHANGED BUMPER SYSTEMS					
PART	A. 1983+1984	B. 1981+1982	C. (A-B)	D. 1983+1984	E. 1981+1982	F. (D-E)	Net Diff. (F-C)	Conf. 2/ Interval - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
Headlamps	10	15	-5	13	15	-2	+3	1	Signif. Increase
Tailamps	11	8	+3	11	8	+3	0	1	No Signif. Change
Parking Lamps	16	10	+6	13	10	+3	-3	1	Signif. Decrease
Total Lamps	37	33	+4	37	33	+4	0	1	No Signif. Change
Hood	19	16	+3	21	16	+5	+2	1	Signif. Increase
Radiator	4	4	0	3	4	-1	-1	1	No Signif. Change
Trunk	5	5	0	5	5	0	0	1	No Signif. Change
Fuel Tank	1	1	0	1	1	0	0	1	No Signif. Change

1/ See Section 2.1.4 for explanation of changed bumper systems.

2/ 95 Percent Confidence Level

3/ Significant >0 where Ho: p1=p2 vs. H1: p1>p2, Alpha=0.05

TABLE 3-13
FREQUENCY OF BUMPER CONTACT IN TWO CAR UNREPORTED COLLISION
Net Difference Between Changed and Unchanged Bumper Systems 1/
(Percent of Collisions where Bumpers Met)

1983+1984 vs. 1981 +1982

	UNCHANGED BUMPER SYSTEMS			CHANGED BUMPER SYSTEMS					
End of Respondant's car	A. 1983+1984	B. 1981+1982	C. (A-B)	D. 1983+1984	E. 1981+1982	F. (D-E)	Net Diff. (F-C)	Conf. 2/ Interval - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
Front	83	82	+1	85	82	+3	+2	4	No Signif. Change
Rear	88	84	+4	88	84	+4	0	3	No Signif. Change

1/ See Section 2.1.4 for explanation of changed bumper systems.

2/ 95 Percent Confidence Level

3/ Significant > 0 where Ho: p1=p2 vs. H1: p1 > p2, Alpha=0.05

CHAPTER 4

BENEFITS AND COSTS

The basic measure used to determine the effects of the modification of the bumper standard from 5 mph (Phase II) to 2.5 mph (Phase I) is the change in net benefits (in dollars). Net benefits are the difference between the change in lifetime benefits and the change in lifetime costs of bumper systems for the respective pre- and post-standard systems. The change in lifetime benefits is based on differences in damage repair costs for the total number of low-speed collisions that occur in an average car's life. The change in lifetime costs includes the difference in bumper system costs to the consumer plus the fuel costs attributable to the bumper weight change. Since both benefits and costs involve consumer dollar outlays, the change in net benefits can also be thought of as a change in costs to consumers.

This approach is identical to one used in the bumper standard evaluation published in 1981 [10] except that in the present case the relative differences between bumper systems that remained unchanged (the control group) and those that changed in 1983 and 1984 (relative to their 1981 and 1982 predecessors) must be taken into account.

This chapter addresses the calculation of relative net benefits using the following steps (a detailed model with definitions is included in Appendix E.):

- o Description of factors involved in the calculation of lifetime benefits and costs.
- o Calculation of lifetime benefits.
- o Calculation of lifetime costs.
- o Relative net benefits as a result of the bumper standard modification.

4.1 Description of Factors Involved in the Calculation of Lifetime Benefits and Costs

Several factors, which are either part of the net benefit calculations or which constitute the basis for assumptions, are described in the following paragraphs.

4.1.1 Selection of Inflation Rate

In cases where bumper cost or damage repair cost data were reported or estimated at their current year prices, inflation factors were applied to convert these to 1984 dollars. Bumper costs were adjusted using the Bureau of Labor Statistics Consumer Price Index (CPI) for new car prices. Damage repair cost estimates for both unreported incidents as well as insurance claims were adjusted using the CPI for auto maintainance and repair.

4.1.2 Establishment of a Base Year for Analysis

In order to compare dollar values of benefits and costs from different time periods, a base year is established to which the other years' dollar values are adjusted. The year 1984 was selected since it was the latest full year for which actual economic data were available at the time this evaluation was reaching completion. While the survey of unreported low-speed collisions was conducted in the first half of 1985, all repair cost estimates for cars with collision damage were in 1984 dollars. Insurance claim damage repair estimates which were obtained for 1981 through 1984, following each respective calendar year, were adjusted as necessary. Analyses of bumper cost to the consumer, which were conducted for each of the four model years in this evaluation, were adjusted as well.

4.1.3 Controlling for a Changing Vehicle Size Mix

During the time period under consideration, the vehicle size mix changed relatively little. Major downsizing programs resulted in the introduction of many new nameplates in 1981 - the Chrysler K cars, Ford Escorts, and GM J and A series. Average curb weights for the 1981 through 1984 model fleet were 2863, 2694, 2778, and 2780 pounds, respectively.

In order to ensure that differences in net benefits and costs reflect the effect of the bumper standard modification, the vehicle mix of 1984 model cars sold in 1984 was used as the constant vehicle mix for weighting and calculating: (1) the proportion of bumper-involved insurance claims, (2) the repair cost for damage in bumper-involved insurance-claimed crashes, and (3) the incremental consumer cost of the standard modification.

4.1.4 Low-Speed Collisions Reported to the Police

A low-speed collision - one that results in property damage - may have to be reported to the police. This depends on dollar value thresholds which vary from State to State. Generally, if an injury occurs, the collision must be reported. For some of the property damage collisions, although a police report is completed, no insurance claim is filed since the estimated repair cost is about the same as the deductible amount in the driver's insurance policy.

The driver survey showed that about 6 percent of the low-speed collisions involving the bumper were reported to the police only - no insurance claim was filed. Given that collisions reported only to the police represent a relatively small portion and that the cost of damage repair is probably quite close to that of an unreported collision, they are grouped with the latter. Damage descriptions for police reported collisions were combined with the unreported collisions to compute average repair cost estimates.

4.1.5 Effect of Secondary Weight

According to auto manufacturers, certain design characteristics affect the weight of dependent systems such as the suspension, brakes, frame, etc. A bumper weight change would tend to have a secondary effect on the design of load and/or power related systems. When a bumper's weight is measured, a proportional increase is also assigned to these other systems - and is referred to as the "secondary weight." A decrease in bumper weight relative to preceding models would likewise involve a weight reduction to dependent systems. Both the 1981 bumper evaluation [10] and the 1982 Final Regulatory Impact Analysis (FRIA) [9] include discussions of the subject and use various secondary weight factors in the analytic process.

Secondary weight factors ranging from 0.35 to 1.0 pounds of secondary weight per pound of primary weight change were used in the 1981 evaluation. The FRIA was based on factors of 0.7 and 1.0, and these values are used here in addition to the base net benefit calculation which excludes the effect of secondary weight (i.e., secondary weight factor = 0).

There are two costs associated with secondary weight - consumer cost of the weight increment and the effect on lifetime fuel cost. Since secondary weight is assigned to a variety of dependent systems an average cost per pound is derived.

The FRIA used a cost of $0.60 per lb. (in 1981 dollars) which reflected the cost of added material plus the variable manufacturing cost. These costs were in turn derived from teardown studies and auto manufacturers comments to the bumper docket in 1981 and 1982. Using the ratio of 1984 to 1981 Consumer Price Indices for new car prices, a value of $0.66 is obtained for 1984.

The lifetime fuel cost for the secondary weight increment is the product of the lifetime fuel requirements (1.25 gallons per pound as calculated in Appendix E), the cost of fuel (see Appendix E), the change in weight due to the standard's modification, and the secondary weight factor.

4.1.6 Collision Incident Rates

The low speed collision incidence rate of all cars on the road each year is a measure of the frequency with which cars are involved in collisions where no insurance claims are filed - although damage may have been sustained. The driver survey yielded 1829 such collisions over an eight month period from a population of 22,393 cars of model years 1981 through 1984 in the survey. This comes to a 12.2 per cent annualized involvement rate.

The range based on a 95 percent confidence level is from 11.9 to 12.6 percent -- and the incidence rate for each model year (1981, 82, 83 and 84) fell within this range. The average annual value found from the survey is slightly lower than the 13.7 percent found in the survey performed as part of the bumper evaluation completed in 1981. At that time the surveyed population covered 15 model years and included about half as many cars in total. Factors peculiar to the two different time periods (1979-80 versus 1985) such as weather, road conditions, vehicle mix, traffic laws (right-turn-on-red) and their enforcement and economic conditions might account for the differences.

4.1.7 Discounting Applicability and Methods

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 car lives back to a common base in order to obtain a comparative present value of net benefits. The discounting process is applicable to the "benefit" side of the equation since it measures the difference in lifetime dollar values of damage repair cost per car, per collision. It also applies to fuel costs over a car's life - fuel costs being part of the "cost" side of the equation. The cost of the bumpers and cost differences between pre- and post-standard modification models are not subject to the discounting procedure since their costs are in "present" terms (adjusted to 1984 dollars) and essentially disposed of when purchasing a car.

For the purpose of discounting, a car's life is assumed to be 10 years during which it travels 95,345 miles (mileage is based on in-house studies of vehicle mileage and survival data used for fuel economy). It is also assumed that benefits will accrue on a mileage basis over a car's life. Since the frequency of low-speed collisions is dependent, to a certain degree, on the amount of miles a car is driven, the benefits will also depend on mileage. To determine the rate that benefits accrue per mile of driving, gross benefits are divided by lifetime vehicle miles.

Estimates of annual travel by car age, weighted by survival probability each year and summed over 20 years, is 106,952 based on current available data. This means that the sum for the last 10 years is 11,607 miles, and that during the first 10 years 90 percent of the total miles are accumulated. To discount future benefits properly, the miles driven each year are discounted back to the current time using the discount factor for each year. Then the total discounted miles are divided by the actual miles to establish the gross discount factor. Table 4-1, using a 10 percent discount rate, shows how a gross factor of .7393 is derived.

Future benefits are discounted to the year of purchase, except they are stated in 1984 dollars. A 1984 model year car, for example, is considered to be new with ten years to go for discounting purposes. A sample procedure for a discount calculation is included in Appendix F. A discount rate of 10 percent is used throughout [15] (see Table 4-1).

TABLE 4-1
VEHICLE MILES DISCOUNTED OVER 10 YEAR LIFE 1/

A. VEHICLE AGE (YEARS)	B. AVERAGE ANNUAL VEHICLE MILES TRAVELED	C. SURVIVAL PROBABILITY	D. (B*C)	E. PRESENT WORTH FACTOR(10%)	F. (D*E)
1	14535	1.000	14535	1.0000	14535
2	13924	0.993	13827	0.9091	12570
3	12846	0.982	12615	0.8264	10425
4	11378	0.964	10968	0.7513	8241
5	10749	0.935	10050	0.6830	6864
6	10119	0.892	9026	0.6209	5604
7	9490	0.831	7886	0.5645	4452
8	8860	0.753	6672	0.5132	3424
9	8231	0.662	5449	0.4665	2542
10	7601	0.568	4317	0.4241	1831
TOTAL			95345		70487

DISCOUNT FACTOR= 70487/95345= .7393

1/ See Section 4.1.7 for discussion of average car life.

4.2 The Effect of the Bumper Standard Modification in Terms of Benefits and Costs

This section presents and discusses the results obtained by a comparative analysis of the changes in benefits and costs for bumper systems manufactured before and after the modified standard. As we have seen, there is a mix of both changed and unchanged systems, relative to their pre-modification predecessors, in the respective 1983 and 1984 model fleets. And as explained at the beginning of this chapter, it is the relative net benefit between changed and unchanged bumper systems that reflects the actual effect of the standard modification.

Before addressing this "bottom line" result, it is useful to separate benefits from costs since the former is based on what happened to changed bumpers in terms of damage incidence and the cost of damage repair. Changes to bumper systems resulted almost exclusively in a weight and cost reduction, as was shown in Chapter II, but it is important to analyze the cost change separately with the attendant secondary weight and fuel cost effects.

4.2.1 Incremental Gross Discounted Lifetime Benefits

The term "Incremental Gross Discounted Lifetime Benefits" means the difference in damage repair costs between pre- and post-standard bumper designs adjusted to present values via the discounting process. In simpler terms, it is the monetary value of damage repair that is either saved or has to be spent over the 10-year operating life of a car whose bumpers are made to meet the 2.5 mph rather than the 5 mph standard. It does not factor in the reduction in car purchase price, which at least in theory would come from a less costly bumper system.

The incremental benefits (gross lifetime, discounted) are shown in Table 4-2. They are listed for bumper systems that were changed as well as those that remained essentially the same when compared to their respective 1981/82 predecessors.

Compared to the typical lifetime discounted benefits -- averaging $600 and based on both insurance claimed and unreported repair costs -- the net difference between changed and unchanged bumper systems is small. The $7 decrease in benefits shown for 1983 changed systems is not statistically significant, although by 1984, there is a significant $66 decrease in lifetime benefits for the models whose bumpers were reduced in strength -- when compared to bumpers which were not changed.

When data for both post-standard model years are combined, the outcome is a decrease of $36 in incremental lifetime benefits -- which is, however, not statistically significant.

The incidence and repair cost of damage to the rear of a car, while averaging half that of frontal damage -- $200 vs $400 -- is a main contributor to a decrease in benefits over a car's lifetime if the car is equipped with changed bumpers.

TABLE 4-2
INCREMENTAL GROSS LIFETIME DISCOUNTED BENEFITS
Net difference Between Changed and Unchanged Bumper Systems 1/
(1984 Dollars)

	UNCHANGED BUMPER SYSTEMS A.	B.	C.	CHANGED BUMPER SYSTEMS 1/ D.	E.	F.	Net Diff. Net (F-C)	Confidence Interval 2/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
			1983 Vs. 1981/82						
	1983	1981/82	(1983-81/82)	1983	1981/82	(1983-81/82)			
FRONT+REAR	$625	$730	-$105	$586	$684	-$98	+$7	56	No Signif. Change
FRONT	$420	$469	-$49	$390	$458	-$68	-$19	41	No Signif. Change
REAR	$205	$261	-$56	$196	$226	-$30	+$26	29	No Signif. Change
			1984 Vs. 1981/82						
	1984	1981/82	(1984-81/82)	1984	1981/82	(1984-81/82)			
FRONT+REAR	$697	$769	-$72	$674	$680	-$6	+$66	50	Signif. decrease
FRONT	$450	$498	-$48	$433	$449	-$16	+$32	33	No Signif. Change
REAR	$247	$271	-$24	$241	$231	$+10	+$34	28	Signif. decrease
			1983+1984 Vs. 1981/82						
	1983/84	1981/82	(1983/84-81/82)	1983/84	1981/82	(1983/84-81/82)			
FRONT+REAR	$662	$750	-$88	$630	$682	-$52	+$36	54	No Signif. Change
FRONT	$436	$484	-$48	$411	$454	-$43	+$5	33	No Signif. Change
REAR	$226	$266	-$40	$219	$228	-$9	+$31	24	Signif. decrease

1/ See Section for explanation of changed bumper systems.
2/ 95 Percent Confidence Level
3/ Significant > 0 where Ho: p1=p2 vs. H1: p1>p2, alpha=0.05

There appears to be a downward trend -- although not significant so far for front bumper systems -- for lifetime benefits (i.e., losses), due to more frequent damage in bumper-related collisions on cars with changed bumper systems.

The Final Regulatory Impact Analysis [9] prepared in 1982, projected a $76 (in 1984 dollars) loss in gross lifetime benefits per car as a result of the change from a 5 to 2.5 mph bumper standard. This value was, however, based on the assumption that all of a year's new production/sales would be equipped with bumpers designed to meet the lowered 2.5 mph standard. So far this has probably not occurred, since only half the bumpers were changed and the changed bumpers were not necessarily designed for speeds as low as 2.5 mph.

4.2.2 Incremental Lifetime Costs

Weight and cost differences between the pre- and post-modification bumpers were presented and discussed in Chapter II. The incremental lifetime costs shown in Table 4-3 reflect the basic cost difference between changed and unchanged bumper systems, adjusted for each secondary weight (three different values are shown) and decreasing costs of fuel over the car's 10 year life, discounted to 1984.

The effect of secondary weight is considerable. It nearly doubles the lifetime cost of a bumper system when one pound of secondary weight is added for each pound of primary weight.

TABLE 4-3
INCREMENTAL COSTS, INCLUDING LIFETIME DISCOUNTED FUEL COSTS 1/
Net difference Between Changed and Unchanged Bumper Systems 2/
(1984 Dollars)

		UNCHANGED BUMPER SYSTEMS			CHANGED BUMPER SYSTEMS 2/			
		A.	B.	C.	D.	E.	F.	
				1983 Vs. 1981/82				
	SECONDARY WEIGHT FACTOR 3/	1983	1981/82	(1983-81/82)	1983	1981/82	(1983-81/82)	Net Diff. Net (F-C)
FRONT+REAR	0.0	$242	$243	-$1	$189	$228	-$39	-$38
	0.7	$347	$349	-$2	$275	$330	-$55	-$53
	1.0	$392	$395	-$3	$312	$374	-$62	-$59
FRONT	0.0	$122	$123	-$1	$95	$113	-$18	-$17
	0.7	$173	$175	-$2	$138	$162	-$24	-$22
	1.0	$195	$198	-$3	$156	$184	-$28	-$25
REAR	0.0	$120	$120	$0	$94	$115	-$11	-$11
	0.7	$174	$174	$0	$137	$168	-$31	-$31
	1.0	$197	$197	$0	$156	$190	-$34	-$34
				1984 Vs. 1981/82				
		1984	1981/82	(1984-81/82)	1984	1981/82	(1984-81/82)	
FRONT+REAR	0.0	$244	$245	-$1	$202	$228	-$26	-$25
	0.7	$348	$350	-$2	$290	$330	-$40	-$38
	1.0	$392	$395	-$3	$328	$373	-$45	-$42
FRONT	0.0	$123	$124	-$1	$100	$113	-$13	-$12
	0.7	$173	$175	-$2	$143	$162	-$19	-$17
	1.0	$194	$197	-$3	$162	$183	-$21	-$18
REAR	0.0	$121	$121	$0	$102	$115	-$13	-$13
	0.7	$175	$175	$0	$147	$168	-$21	-$21
	1.0	$198	$198	$0	$166	$190	-$24	-$24
				1983+1984 Vs. 1981/82				
		1983/84	1981/82	(1983/84-81/82)	1983/84	1981/82	(1983/84-81/82)	
FRONT+REAR	0.0	$242	$243	-$1	$197	$228	-$31	-$30
	0.7	$347	$349	-$2	$284	$330	-$46	-$44
	1.0	$392	$395	-$3	$322	$373	-$51	-$48
FRONT	0.0	$122	$123	-$1	$98	$113	-$15	-$14
	0.7	$173	$175	-$2	$141	$162	-$21	-$19
	1.0	$195	$198	-$3	$160	$183	-$23	-$20
REAR	0.0	$120	$120	$0	$99	$115	-$16	-$16
	0.7	$174	$174	$0	$143	$168	-$25	-$25
	1.0	$197	$197	$0	$162	$190	-$28	-$28

1/ See Appendix E for equation defining "C"--Gross Cost.
2/ See Section 2.1.4 for explanation of bumper systems changes.
3/ See Section 4.1.5 for definition of secondary factor.

When bumpers were changed and their weight and cost reduced (in 1983/84) the drop in cost relative to unchanged bumper systems ranged from $17 to $34 without secondary weight considerations. A larger lifetime cost reduction of between $28 and $55 is attributable to a secondary weight factor of 1.0

As was discussed in Chapter II, the first year's changes (1983) to bumper systems reflected cases where relatively extensive design -- and weight-- changes were made to selected nameplates, some of which reverted to more damage resistant bumpers in 1984. This is reflected in the overall results when in 1983 the net difference in lifetime bumper costs (changed relative to unchanged bumpers) was a $53 reduction (0.7 secondary weight factor) for both the front and rear systems. In 1984 the equivalent reduction was $38.

Again, referring back to the 1982 Final Regulatory Impact Analysis, the projected bumper system cost reduction, inflated to 1984 dollars was $91, an amount almost twice the $44 (at 0.7 secondary weight factor) for the combined 1983/84 vs 1981/82 comparison. Another consideration here is the effect of a change in the way fuel costs are now calculated. Using the 1.0 gallons/pound from the FRIA instead of 1.25 gallons/pound used in this evaluation would alter the $44 amount to $39.

4.2.3 Net Benefits

Net benefits are the algebraic differences between incremental gross lifetime benefits and lifetime costs which were presented separately in the previous two sections. The net benefits, as already discussed, are relative values since on-the-road experience by both the changed and unchanged bumper systems in the post-standard model years (1983 and 1984) is compared relative to respective predecessor experience in 1981 and 1982. Net benefits for each of the three pre- and post-comparisons are shown in Table 4-4. The table gives net benefit outcomes for all the major variables that constitute the evaluation.

Since the previous two tables list incremental gross lifetime discounted benefits and costs separately, Table 4-4 shows only the values of the net difference (Benefits less Costs) which are here designated as relative net benefits. The relative benefit is the amount in dollars over the 10 year life of a car that is either gained (benefit) or lost (loss or disbenefit) as a result of the changes made to bumpers -- in those models where, in fact, system changes were made -- to meet (or exceed) the modified (2.5 mph) bumper standard.

Looking first at the combined front and rear results, it appears that in 1983 the changed bumpers, those with a reduced strength relative to their 1981/82 predecessors, yielded net benefits ranging from $31 to $52 depending on the secondary weight factor. The 1984 changed models did not

TABLE 4-4
RELATIVE NET BENEFITS 1/
Net Differences (Benefits less costs)
Between Unchanged and Changed Bumper Systems 2/
(1984 Dollars)

		1983 Vs. 1981/82			1984 Vs. 1981/82			1983+1984 Vs. 1981/82		
	SECONDARY WEIGHT FACTOR 3/	Relative Net Benefit1/	Confidence Interval 4/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 5/	Relative Net Benefit 1/	Confidence Interval 4/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 5/	Relative Net Benefit 1/	Confidence Interval 4/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 5/
FRONT+REAR	0.0	+$31	56	No Signif. Change	-$41	50	No Signif. Change	-$6	54	No Signif. Change
	0.7	+$46	56	No Signif. Change	-$28	50	No Signif. Change	+$8	54	No Signif. Change
	1.0	+$52	56	No Signif. Change	-$24	50	No Signif. Change	+$12	54	No Signif. Change
FRONT	0.0	+$36	41	No Signif. Change	-$20	33	No Signif. Change	+$9	33	No Signif. Change
	0.7	+$41	41	No Signif. Change	-$15	33	No Signif. Change	+$14	33	No Signif. Change
	1.0	+$44	41	Signif. Increase	-$14	33	No Signif. Change	+$15	33	No Signif. Change
REAR	0.0	-$15	29	No Signif. Change	-$21	28	No Signif. Change	-$15	24	No Signif. Change
	0.7	+$5	29	No Signif. Change	-$13	28	No Signif. Change	-$6	24	No Signif. Change
	1.0	+$8	29	No Signif. Change	-$10	28	No Signif. Change	-$3	24	No Signif. Change

1/ See Appendix E for algorithm defining net benefit.

2/ See Section 2.1.4 for explanation of bumper system changes.

3/ See Section 4.1.5 for Definition of Secondar weight factor.

4/ 95 Percent Confidence Level

5/ Significant >0 where $H0: p1 = p2$ vs. $H1: p1 > p2$, $Alpha = 0.05$

fare so well in comparison to their predecessors (and as normalized for differences that affected unchanged bumpers). They show a net loss of between $-24 and $-41 over the car's 10 year life. Given that the 1984 "changed bumper" fleet accounted for 51 percent of the new cars sold, up from 35 percent for the 1983 fleet, and that the variance in insurance repair estimates was large, the effect for 1984 is that there is a net loss, but it is not statistically significant.

The relative "weight" of the 1984 statistics carries over into the combined analysis -- 1983/84 vs 1981/82. Although this is the maximum available data set, it still shows that there is no statistically significant difference in net benefits (or losses) over a 10 year car life. This is due to changed bumper systems and their low speed collision experience (more accidents, less damage per accident), when compared to cars still equipped (in 1983/84) with systems identical to their 1981/82 predecessors.

The $8 relative net benefits is comparable to a value of $15 (in 1984 dollars) projected in the 1982 FRIA ($28 in 1981 dollars and methodology).

Separating the analysis into front and rear damage and bumper cost effects shows that, for the 1983 changed models, the net benefit is derived from the cost effectiveness of front bumper systems which yield a $36 to $44 lifetime net benefit, in contrast to the rear bumpers which are only a third as cost effective. Both front and rear 1984 changed bumper systems show a net loss, but this is too small to be significant. When the data for the respective two years before and after the standard's modification are analyzed, front changed bumpers show benefits and rear bumpers incur losses -- but neither result is statistically significant.

The primary conclusion of the evaluation is that after two years in which certain design changes were made to a growing population of bumpers -- in response to a modified bumper regulation -- the road experience in terms of low-speed bumper-related collisions for the cars with changed bumpers has remained the same as the experience with cars equipped with bumpers manufactured to the previous 5 mph standard.

4.3 Effects on Net Benefits by Type of Bumper Design Change

To establish the effects - incremental gross discounted lifetime benefits, lifetime costs and relative net benefits - for each type of bumper design change, the same procedures described in the previous section (4.2) are used. Since sample sizes shrink in this subaggregate analysis, only the comparison between the two post- and two pre-bumper standard modification years is made.

4.3.1 Incremental Gross Lifetime Discounted Benefits by Bumper Design Change Category

Table 4-5 lists the four change categories into which make/models were placed after an analysis of changes to their bumper

TABLE 4-5

INCREMENTAL LIFETIME DISCOUNTED BENEFITS

By Design Change Categories 1/

Net Difference Between Changed and Unchanged Bumper Systems

(1984 Dollars)

1983+1984 vs. 1981+1982

	UNCHANGED BUMPER SYSTEMS			CHANGED BUMPER SYSTEMS					
CHANGE CATEGORY 1/	A. 1983+1984	B. 1981+1982	C. (A-B)	D. 1983+1984	E. 1981+1982	F. (D-E)	Net Diff. (F-C)	Conf. Interval2/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 3/
Facebar									
Front + Rear	$662	$750	-$88	$647	$665	-$18	+$70	54	Signif. Decrease
Front	$436	$484	-$48	$426	$455	-$29	+$19	43	No Signif. Change
Rear	$226	$266	-$40	$221	$210	+$11	+$51	31	Signif. Decrease
Structural									
Front + Rear	$662	$750	-$88	$726	$737	-$11	+$77	52	Signif. Decrease
Front	$436	$484	-$48	$479	$482	-$3	+$45	41	No Signif. Change
Rear	$226	$266	-$40	$247	$255	-$8	+$32	30	Signif. Decrease
Energy Absorber									
Front + Rear	$662	$750	-$88	$675	$773	-$98	-$10	149	No Signif. Change
Front	$436	$484	-$48	$381	$456	-$75	-$27	135	No Signif. Change
Rear	$226	$266	-$40	$294	$317	-$23	+$17	79	No Signif. Change
Structural & Energy Absorber									
Front + Rear	$662	$750	-$88	$597	$644	-$47	+$41	64	No Signif. Change
Front	$436	$484	-$48	$373	$408	-$35	+$13	39	No Signif. Change
Rear	$226	$266	-$40	$224	$236	-$12	+$28	44	No Signif. Change

1/ See Section 2.1.4 for design change category definitions.

2/ 95 Percent Confidence Level

3/ Significant > 0 where Ho: $p1=p2$ vs. H1: $p1>p2$, Alpha=0.05

systems to determine the type of change, relative to 1981/82 model predecessors. Although not statistically significant in most cases, every category contributed to a decrease in lifetime benefits (changed relative to unchanged bumper systems) except for front bumpers whose energy absorbers were replaced by rigid brackets. This category only represents a small, two to three percent, part of the new car sales population in each post standard year.

As can be seen in Table 4-5, reductions in facebar thickness (downgauging) are significant contributors to lifetime losses, apparently driven by repair costs for rear end damage. Structural changes, particularly the elimination of reinforcement bars and reductions in the size of brackets also lead to lifetime losses. Reducing the gauge of a facebar could reflect the reversion to a Phase I bumper system, where damage to the bumper itself is allowed, in contrast to Phase II where a dent is to be no larger than 3/8 inch. With many designs incorporating an elastomeric facia which covers metal facebars, this kind of damage also becomes less visible.

Minor structural changes accompanying the replacement of energy absorbers -- found in 10 percent of the new fleet (1983 and 1984) -- and the relatively small number of designs where only energy absorbers were replaced with rigid brackets, appear to lead to somewhat lower lifetime loss values. However, as has already been pointed out, these results are not statistically significant.

4.3.2 Incremental Lifetime Costs by Bumper Design Change Category

The lifetime cost of bumper systems, including the fuel penalty and secondary weight effect for each of the four change categories, is shown in Table 4-6. The analysis is limited, as in the previous section, to a combination of 1983/84 vs 1981/82 model years. Only values for a secondary weight factor of 0.7 are shown.

Lifetime bumper cost reductions range from $28 to $55 for the combined front and rear bumper systems. The latter value appears to be attributable to rear bumpers whose only change in strength reduction is the substitution of energy absorbers with rigid mounting brackets. This is, however, only a very small population of the new fleet for 1983 and 1984 (approximately 2 percent) and the main contribution to weight reduction is a downsized bumper system, or in some cases a substitution of aluminum for steel.

Overall the lifetime cost of a typical bumper system is in the $400 range for unchanged bumpers and between $250 to $400 for changed designs, depending on the kind of change.

4.3.3 Net Benefits by Design Change Category

Table 4-7 summarizes the relative net benefits (and losses) contributed by each of the four design change categories. In each case the result is not statistically significant.

TABLE 4-6
INCREMENTAL COSTS, INCLUDING DISCOUNTED FUEL COSTS 1/
By Design Change Categories 2/
Net Difference Between Changed and Unchanged Bumper Systems
(Secondary Weight Factor 0.7, 1984 Dollars) 3/

1983+1984 vs. 1981+1982

CHANGE CATEGORY 2/	UNCHANGED BUMPER SYSTEMS A. 1983+1984	B. 1981+1982	C. (A-B)	CHANGED BUMPER SYSTEMS D. 1983+1984	E. 1981+1982	F. (D-E)	Net Diff. (F-C)
FRONT + REAR							
Facebar	$347	$349	-$2	$279	$309	-$30	-$28
Structural	$347	$349	-$2	$323	$377	-$54	-$52
Energy Absorber	$347	$349	-$2	$302	$359	-$57	-$55
Structural + Energy Absorber	$347	$349	-$2	$207	$241	-$34	-$32
FRONT							
Facebar	$173	$175	-$2	$135	$145	-$10	-$8
Structural	$173	$175	-$2	$159	$187	-$28	-$26
Energy Absorber	$173	$175	-$2	$173	$181	-$8	-$6
Structural + Energy Absorber	$173	$175	-$2	$102	$120	-$18	-$16
REAR							
Facebar	$174	$174	$0	$144	$164	-$20	-$20
Structural	$174	$174	$0	$164	$190	-$26	-$26
Energy Absorber	$174	$174	$0	$129	$178	-$49	-$49
Structural + Energy Absorber	$174	$174	$0	$105	$121	-$16	-$16

1/ See Appendix E for equation defining "C" -Gross Cost.

2/ See Section 2.1.4 for explanation of bumper system changes.

3/ See Section 4.1.5 for definition of secondary weight factor.

TABLE 4-7
RELATIVE NET BENEFITS 1/
Net Differences (Benefits less Costs)
Between Changed and Unchanged Bumper Systems
By Design Change Categories 2/
(1984 Dollars and 0.7 Secondary Weight Factor) 3/

1983+1984 Vs. 1981/82

DESIGN CHANGE CATEGORY 2/	Relative Net Benefit	Confidence Interval 4/ - or +	Significant Incr. or Decr. of Changed Bumper Systems 5/
FRONT + REAR			
Facebar	-$42	54	No Signif. Change
Structural	-$25	52	No Signif. Change
Energy Absorber	+$65	149	No Signif. Change
Structural + Energy Absorber	-$9	64	No Signif. Change
FRONT			
Facebar	-$11	43	No Signif. Change
Structural	-$19	41	No Signif. Change
Energy Absorber	+$33	135	No Signif. Change
Structural + Energy Absorber	+$3	39	No Signif. Change
REAR			
Facebar	-$31	31	No Signif. Change
Structural	-$6	30	No Signif. Change
Energy Absorber	+$32	79	No Signif. Change
Structural + Energy Absorber	-$12	44	No Signif. Change

1/ See Appendix E for Algorithm defining net benefit.

2/ See Section 2.1.4 for for explanation of design changes.

3/ See Section 4.1.5 for definition of secondary weight factor.

4/ 95 percent Confidence Level.

5/ Significant > 0 where H0: p1=p2 vs. H1: p1>p2, Alpha=0.05.

The relatively larger net benefit values for the energy absorber change category reflect a wide variation due to the small sample size in a population that is only a 2 percent of new vehicle sales in 1983 and 1984. The other net benefit or loss amounts -- over a 10 year lifetime -- are quite small so that in summary the overall results, which show no difference between changed and unchanged bumper systems relative to their respective 1981/82 predecessors, are not explained or further clarified by disaggregation into design categories.

4.4 Effects of Additional Factors

The Motor Vehicle Information and Cost Saving Act [13] calls for, in addition to the benefits and costs attributable to the bumper standard, an accounting of the effects of insurance and legal fees and costs, effects on consumer time and inconvenience and a consideration of health and safety, including emission standards.

The driver survey, described and analyzed in Chapter III, included questions on the time spent at the collision scene, in filling out forms/police reports, in getting repair estimates, in getting the car repaired, the time without the use of the car, and transportation alternatives used when the car was unavailable as a result of a low-speed collision.

The question of safety is essentially limited to the changes in damage to certain vehicle parts such as lamps, latches, etc. The analysis in Chapter III presented the results based on both the driver survey and insurance claim data. Other aspects of the safety issue were discussed at length in the FRIA of 1982 and no new data has emerged to change the conclusions therein that there would be no adverse effect on safety-related parts.

4.4.1 Time and Inconvenience

Persons whose cars were involved in low speed collisions in which damage occurred were asked, as part of the driver survey, questions on delay and inconvenience. Almost no difference was found in the amount of time involved at the scene, filling out reports, getting repair estimates and being without a car-- when cars with changed bumpers were compared to cars with unchanged bumpers. In summary, these time values are:

Time Period	
At Scene	35 minutes
Filling out Forms	78 minutes
Getting Estimates	245 minutes
Total Time	358 minutes

Time getting car repaired	1-1/2 days
Time without use of car	2 days

About 15 percent of the persons with damaged cars in low speed collisions, who chose to get their cars repaired, had to obtain alternate means of transportation (other than from family members) while their car was being fixed. These persons used a variety of modes. No reliable out-of-pocket cost estimates are available.

The analysis in the 1982 Final Regulatory Impact Analysis assumed the amount of time per damaged car was about the same regardless of bumper design. The FRIA further assumed that the difference in delay time among the car owners had to be caused by the number of low speed collisions with damage that occurred during a cars' life. From both the driver survey and insurance claim analysis, the lifetime number of low-speed damaged-involved collisions is 1.07 for cars with unchanged bumpers and 1.14 for car with changed bumpers. The FRIA further assumed 1.5 people were in the car at the time of a collision so that the 35 minutes spent at the scene should be increased by 50 percent to 53 minutes. This means the total time per damage collision is 6.3 hours. The FRIA also used an average wage rate of $7.10/hour in 1981 and valued inconvenience at $10-$25 per case. Bringing both these values to 1984 dollars yields $8.33 per hour and $12-$29 per case for inconvenience. Applying these rates to the time per damage collision results in a $64-$81 cost per collision.

Combining the lifetime collision rates with the cost per collision and discounting over a 10 year car life results in a cost of $50-$64 for a car with unchanged bumpers and $54-$68 per car with changed bumpers. This is a net increase in delay and inconvenience of $4, for owners of cars with changed bumpers.

4.4.2 The Cost of Insurance and Legal Fees

No new information on the cost of insurance premiums and legal fees was obtained as part of this evaluation. From data collected and analyzed as part of the 1982 FRIA, 26 percent of insurance premiums are essentially fixed costs per claim. Also the costs associated with legal fees are incorporated in insurance premiums. Applying the 26 percent to the portion of lifetime discounted benefits from insurance claims in Table 4-2, results in a $10 lifetime decrease in benefits for 1983/84 models with changed front and rear bumpers when compared to models with unchanged bumpers. Table 4-2 shows a $36 decrease in lifetime benefits for 83/84 front and rear models which would increase to $46 if fixed costs are included. The confidence interval is ± $54, therefore the finding in Table 4-2, that there is no significant change in lifetime benefits, remains.

4.4.3 The Effect of Damage Not Repaired

The current driver survey found essentially the same unrepaired damage frequency as the 1980 survey--64 percent with unreported damage went unrepaired (the 1980 survey found 69 percent). There was no statistically significant difference between cars with different bumper designs.

No additional information was collected on the value placed on unrepaired damage by the public. When valued at 100 percent, unreported damage amounts to about 20 percent of the gross discounted lifetime benefits.

The 1982 FRIA valued unrepaired damage at 50 and 75 percent of repair estimates to adjust for some vehicle owners not repairing the damage. To completely evaluate the effectiveness of bumpers in reducing repair costs, the total (100 percent) estimate to repair all damage -- actually repaired or not -- would be included. This evaluation, as in the 1981 evaluation, values unreported damage at 100 percent of repair estimates. For comparison purposes with the 1982 FRIA, adjustments in relative net benefits for unrepaired damage valued at both 50 percent and at 75 percent have been calculated.

From the 1982 FRIA, the average consumer cost for damage when all damage was repaired was compared to the average consumer cost when unrepaired damage was valued at 50 percent and then at 75 percent. The FRIA assumed that only 50 or 75 percent of the damage would be repaired at lower speeds. For purposes of adjusting net benefits, ratios based on <u>averaging</u> the FRIA data were used. The data base consisted of a distribution of the number of lifetime accidents in each speed cell (e.g., 0-3 mph, 3-4 mph, etc.) and the average repair cost within that speed cell. With these data, weighted average lifetime repair costs were estimated for 100, 75, and 50 percent repair values. The average repair estimate for 50 percent and for 75 percent were each divided by the average repair estimate for the 100 percent level.

The ratios of average consumer cost for 50 and 75 percent, when compared to the average cost for 100 percent repaired damage, are 0.845 and 0.923 respectively. These ratios have been applied to the incremental gross lifetime discounted benefits in Tables 4-2 and 4-5. The net effect of valuing unrepaired damage at 50 percent and at 75 percent are shown in Table 4-8. This shows a net decrease of $6 in gross benefits when unrepaired damage is valued at 50% and a decrease of $3 when unrepaired damage is valued at 75% for changed bumpers. Table 4-9 shows the adjustment to net differences in gross benefits for unrepaired damage by design change category. At the 50% level value for unrepaired damage, the adjustment ranges from an increase of $1 to a decrease of $12. At the 75% level the adjustment ranges from + $1 to -$6.

TABLE 4-8

ADJUSTMENT TO NET DIFFERENCES IN GROSS BENEFITS
(from Table 4-2)

(1984 Dollars)

	UNREPAIRED DAMAGE VALUED AT	
	50%	75%
	1983 vs. 1981/82	
Front+Rear	-1	0
Front	+3	+1
Rear	-4	-1
	1984 vs. 1981/82	
Front+ Rear	-10	-4
Front	-5	-2
Rear	-5	-3
	1983 + 1984 vs. 1981/1982	
Front+Rear	-6	-3
Front	0	-1
Rear	-6	-2

TABLE 4-9

ADJUSTMENT TO NET DIFFERENCES IN GROSS BENEFITS
By Design Change Categories 1/
(from Table 4-5)

(1984 Dollars)

	UNREPAIRED DAMAGE VALUED AT	
	50%	75%
	1983 + 1984 vs. 1981/82	
CHANGE CATEGORY 1/		
Facebar		
Front + Rear	-11	-6
Front	-3	-2
Rear	-8	-4
Structural		
Front + Rear	-12	-6
Front	-7	-4
Rear	-5	-2
Energy Absorber		
Front + Rear	+1	+1
Front	+5	+2
Rear	-4	-1
Structural & Energy Absorber		
Front + Rear	-7	-3
Front	-2	-1
Rear	-5	-2

1/ See Section 2.1.4. for design change category definitions.

4.4.4 The Effect of High Speed Collisions.

The 1982 FRIA took into account the repair costs of cars with different bumpers which were involved in high speed collisions in which the car was not a complete wreck (totalled). The FRIA used 0.16 high speed collisions per car over its lifetime and considered only the difference in bumper replacement cost. Manufacturing variable cost is marked up twice to obtain consumer cost: a factor of 1.437 is applied to obtain wholesale cost, which includes overhead, and wholesale cost is marked up by 1.14 to obtain dealer cost to the consumer.

Applying these factors to the bumper costs in Table 2-3 and discounting over a 10 year car life results in an increase in gross benefits of $4.

4.4.5 Interest Savings

The 1982 FRIA also considered the effects of changes in consumer costs of cars for changes in bumper costs and secondary weight. A 10 percent interest rate was used in the FRIA which still seems appropriate, and the cost of secondary weight is 66 cents per pound. Assuming a secondary weight and using cost differences shown in Tables 2-4, 2-5 and 2-6 results in the adjustments to gross costs for interest savings shown in Table 4-10 which were +$2 for all changed bumpers.

TABLE 4-10

ADJUSTMENT TO NET DIFFERENCE IN INCREMENTAL COSTS FOR INTEREST SAVINGS
By Design Change Categories 1/
(from Tables 2-4, 2-5, 2-6)

(1984 Dollars)

CHANGE CATEGORY 1/	1983 vs. 1981/82	1984 vs. 1981/82	1983 + 1984 vs. 1981/82
Unchanged Bumpers			
Front + Rear	0	0	0
Front	0	0	0
Rear	0	0	0
Changed Bumpers			
Facebar			
Front + Rear	-2	-1	-1
Front	-1	0	0
Rear	-1	-1	-1
Structural			
Front + Rear	-3	-3	-3
Front	-2	-1	-2
Rear	-1	-2	-1
Energy Absorber			
Front + Rear	-3	-2	-2
Front	-1	0	0
Rear	-2	-2	-2
Structural & Energy Absorber			
Front + Rear	-3	-1	-2
Front	-2	-1	-1
Rear	-1	0	-1
All Changed Categories Combined			
Front + Rear	-3	-2	-2
Front	-1	-1	-1
Rear	-2	-1	-1

1/ See Section 2.1.4. for design change category definitions.

4.4.6 Combined Effect of Additional Factors on Relative Net Benefits.

The dollar values of each factor discussed on Sections 4.4.1 through 4.4.5 have been applied to the relative net benefits from Tables 4-4 and 4-7. The relative net benefits adjusted for these factors are shown in Table 4-11. Only the 1983 + 1984 model years combined with 0.7 secondary weight factor are included in the table.

The statistical significance remained unchanged for combined bumper changes, and for the Front+Rear and Front bumpers of each design change category. For Rear bumpers with facebar changes, a statistically significant decrease in relative net benefits was found, instead of no significant difference for the unadjusted data. The relative net benefit of the rear bumpers for the other design change categories was still not statistically significant.

Taking into account all possible factors does not change the finding that there was no statistically significant difference between changed and unchanged bumpers, based on 14 of 15 comparisons in Table 4-11. The adjusted relative net benefit is either -$2 (unrepaired damage valued at 50%) or +$1 (with 75% of damage repaired). The 1982 FRIA value (in 1984 dollars) is $15. However, none of these values indicate any significant difference between changed and unchanged bumper designs.

TABLE 4-11
RELATIVE NET BENEFIT ADJUSTED FOR ADDITIONAL FACTORS
Net Differences (Benefits less Costs)
Between Changed and Unchanged Bumper Systems
All Changes Combined and By Design Change Categories 2/
(1984 Dollars and 0.7 Secondary Weight Factor) 3/

1983+1984 Vs. 1981/82

DESIGN CHANGE CATEGORY 2/	Relative Net Benefit	ADJUSTMENTS: Delay & Inconven.	Insurance Costs	Unrepaired Damage @50% / @75%	High Speed Collis-ions	Interest Savings	TOTAL ADJUSTMENT	Adjusted Relative Net Benefit	Conf. 4/ Interval - or +	Significant Incr. or Decr. of Changed Bumper Systems 5/
All Design Changes Combined										
FRONT + REAR	+8	-4	-10	-6/-3	+4	+2	-14/-11	-6/-3	54	No Signif. Change
FRONT	+14	-2	-6	0/-1	+3	+1	-4/-5	+10/+9	33	No Signif. Change
REAR	-6	-2	-4	-6/-2	+1	+1	-10/-6	-16/-12	24	No Signif. Change
FRONT + REAR										
Facebar	-42	-4	-10	-11/-6	+4	+1	-20/-15	-62/-57	54	Signif. Decrease
Structural	-25	-4	-10	-12/-6	+4	+3	-19/-13	-44/-38	52	No Signif. Change
Energy Absorber	+65	-4	-10	+1/+1	+4	+2	-7/-7	+58/+58	149	No Signif. Change
Structural + Energy Absorber	-9	-4	-10	-7/-3	+4	+2	-15/-11	-24/-20	64	No Signif. Change
FRONT										
Facebar	-11	-2	-6	-3/-2	+3	0	-8/-7	-19/-18	43	No Signif. Change
Structural	-19	-2	-6	-7/-4	+3	+2	-10/-7	-29/-26	41	No Signif. Change
Energy Absorber	+33	-2	-6	+5/+2	+3	0	0/-3	+33/+30	135	No Signif. Change
Structural + Energy Absorber	+3	-2	-6	-2/-1	+3	+1	-6/-5	-3/-2	39	No Signif. Change
REAR										
Facebar	-31	-2	-4	-8/-4	+1	+1	-12/-8	-43/-39	32	Signif. Decrease
Structural	-6	-2	-4	-5/-2	+1	+1	-9/-6	-15/-14	30	No Signif. Change
Energy Absorber	+32	-2	-4	-4/-1	+1	+2	-7/-4	+25/+36	79	No Signif. Change
Structural + Energy Absorber	-12	-2	-4	-5/-2	+1	+1	-9/-6	-21/-18	44	No Signif. Change

1/ See Appendix E for Algorithm defining net benefit.
2/ See Section 2.1.4 for for explanation of design changes.
3/ See Section 4.1.5 for definition of secondary weight factor.
4/ 95 percent Confidence Level
5/ Significant >0 where H0: p1=p2 vs. H1: p1>p2, Alpha=0.05.

PART 581—BUMPER STANDARD

AUTHORITY: Sec. 103, 119, Pub. L. 89-563, 80 Stat. 718 (15 U.S.C. 1392, 1407); sec. 102, Pub. L. 92-513, 86 Stat. 947 (15 U.S.C. 1912) delegation of authority at 49 CFR 1.50, unless otherwise noted.

SOURCE: 42 FR 24059, May 12, 1977, unless otherwise noted.

§ 581.1 Scope.

This standard establishes requirements for the impact resistance of vehicles in low speed front and rear collisions.

§ 581.2 Purpose.

The purpose of this standard is to reduce physical damage to the front and rear ends of a passenger motor vehicle from low speed collisions.

§ 581.3 Application.

This standard applies to passenger motor vehicles other than multipurpose passenger vehicles.

§ 581.4 Definitions.

All terms defined in the Motor Vehicle Information and Cost Savings Act, Pub. L. 92-513, 15 U.S.C. 1901-1991, are used as defined therein.

"Bumper face bar" means any component of the bumper system that contacts the impact ridge of the pendulum test device.

§ 581.5 Requirements.

(a) Each vehicle shall meet the damage criteria of §§ 581.5(c)(1) through 581.5(c)(9) when impacted by a pendulum-type test device in accordance with the procedures of § 581.7(b), under the conditions of § 581.6, at an impact speed of 1.5 m.p.h., and when impacted by a pendulum-type test device in accordance with the procedures of § 581.7(a) at 2.5 m.p.h., followed by an impact into a fixed collision barrier that is perpendicular to the line of travel of the vehicle, while traveling longitudinally forward, then longitudinally rearward, under the conditions of § 581.6, at 2.5 m.p.h.

(b) [Reserved]

(c) *Protective criteria.* (1) Each lamp or reflective device except license plate lamps shall be free of cracks and shall comply with applicable visibility requirements of S4.3.1.1 of Standard No. 108 (§ 571.108 of this part). The aim of each headlamp shall be adjustable to within the beam aim inspection limits specified in Table 2 of SAE Recommended Practice J599b, July 1970, measured with a mechanical aimer conforming to the requirements of SAE Standard J602a, July 1970.

(2) The vehicle's hood, trunk, and doors shall operate in the normal manner.

(3) The vehicle's fuel and cooling systems shall have no leaks or constricted fluid passages and all sealing devices and caps shall operate in the normal manner.

(4) The vehicle's exhaust system shall have no leaks or constrictions.

(5) The vehicle's propulsion, suspension, steering, and braking systems shall remain in adjustment and shall operate in the normal manner.

(6) A pressure vessel used to absorb impact energy in an exterior protection system by the accumulation of gas pressure or hydraulic pressure shall not suffer loss of gas or fluid accompanied by separation of fragments from the vessel.

(7) The vehicle shall not touch the test device, except on the impact ridge shown in Figures 1 and 2, with a force that exceeds 2000 pounds on the combined surfaces of Planes A and B of the test device.

(8) The exterior surfaces shall have no separations of surface materials, paint, polymeric coatings, or other covering materials from the surface to which they are bonded, and no permanent deviations from their original contours 30 minutes after completion of each pendulum and barrier impact, except where such damage occurs to the bumper face bar and the components and associated fasteners that directly attach the bumper face bar to the chassis frame.

(9) Except as provided in § 581.5(c)(8), there shall be no breakage or release of fasteners or joints.

[42 FR 24059, May 12, 1977, as amended at 42 FR 38909, Aug. 1, 1977; 43 FR 40231, Sept. 11, 1978; 47 FR 21837, May 20, 1982]

§ 581.6 Conditions.

The vehicle shall meet the requirements of § 581.5 under the following conditions.

(a) *General.* (1) The vehicle is at unloaded vehicle weight.

(2) The front wheels are in the straight ahead position.

(3) Tires are inflated to the vehicle manufacturer's recommended pressure for the specified loading condition.

(4) Brakes are disengaged and the transmission is in neutral.

(5) Trailer hitches, license plate brackets, and headlamp washers are removed from the vehicle. Running lights, fog lamps, and equipment mounted on the bumper face bar are removed from the vehicle if they are optional equipment.

(b) *Pendulum test conditions.* The following conditions apply to the pendulum test procedures of § 581.7 (a) and (b).

(1) The test device consists of a block with one side contoured as specified in Figure 1 and Figure 2 with the impact ridge made of AISI 4130 steel hardened to 34 Rockwell "C." The impact ridge and the surfaces in Planes A and B of the test device are finished with a surface roughness of 32 as specified by SAE Recommended Practice J449A, June 1963. From the point of release of the device until the onset of rebound, the pendulum suspension system holds Plane A vertical, with the arc described by any point on the impact line lying in a vertical plane (for § 581.7(a), longitudinal; for § 581.7(b), at an angle of 30° to a vertical longitudinal plane) and having a constant radius of not less than 11 feet.

(2) With Plane A vertical, the impact line shown in Figures 1 and 2 is horizontal at the same height as the test device's center of percussion.

(3) The effective impacting mass of the test device is equal to the mass of the tested vehicle.

(4) When impacted by the test device, the vehicle is at rest on a level rigid concrete surface.

(c) *Barrier test condition.* At the onset of a barrier impact, the vehicle's engine is operating at idling speed in accordance with the manufacturer's specifications. Vehicle systems that are not necessary to the movement of the vehicle are not operating during impact.

(Sec. 102, Pub. L. 92-513, 86 Stat. 947 (15 U.S.C. 1912); secs. 103, 119, Pub. L. 89-563, 80 Stat. 718 (15 U.S.C. 1392, 1407); delegation of authority at 49 CFR 1.50 and 501.7)

[42 FR 24059, May 12, 1977, as amended at 42 FR 38909, Aug. 1, 1977; 48 FR 43331, Sept. 23, 1983]

§ 581.7 Test procedures.

(a) *Longitudinal impact test procedures.* (1) Impact the vehicle's front surface and its rear surface two times each with the impact line at any height from 16 to 20 inches, inclusive, in accordance with the following procedure.

(2) For impacts at a height of 20 inches, place the test device shown in Figure 1 so that Plane A is vertical and the impact line is horizontal at the specified height.

(3) For impacts at a height between 20 inches and 16 inches, place the test device shown in Figure 2 so that Plane A is vertical and the impact line is horizontal at a height within the range.

(4) For each impact, position the test device so that the impact line is at least 2 inches apart in vertical direction from its position in any prior impact, unless the midpoint of the impact line with respect to the vehicle is to be more than 12 inches apart laterally from its position in any prior impact.

(5) For each impact, align the vehicle so that it touches, but does not move, the test device, with the vehicle's longitudinal centerline perpendicular to the plane that includes Plane A of the test device and with the test device inboard of the vehicle corner test positions specified in § 581.7(b).

(6) Move the test device away from the vehicle, then release it to impact the vehicle.

(7) Perform the impacts at intervals of not less than 30 minutes.

(b) *Corner impact test procedure.* (1) Impact a front corner and a rear corner of the vehicle one each with the impact line at a height of 20 inches and impact the other front corner and the other rear corner once each with the impact line at any height from 16 to 20 inches, inclusive, in accordance with the following procedure.

(2) For an impact at a height of 20 inches, place the test device shown in Figure 1 so that Plane A is vertical and the impact line is horizontal at the specified height.

(3) For an impact at a height between 16 inches and 20 inches, place the test device shown in Figure 2 so that Plane A is vertical and the impact line is horizontal at a height within the range.

(4) Align the vehicle so that a vehicle corner touches, but does not move, the lateral center of the test device with Plane A of the test device forming an angle of 60 degrees with a vertical longitudinal plane.

(5) Move the test device away from the vehicle, then release it to impact the vehicle.

(6) Perform the impact at intervals of not less than 30 minutes.

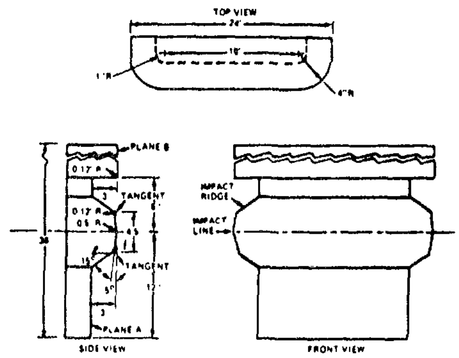

FIGURE 1

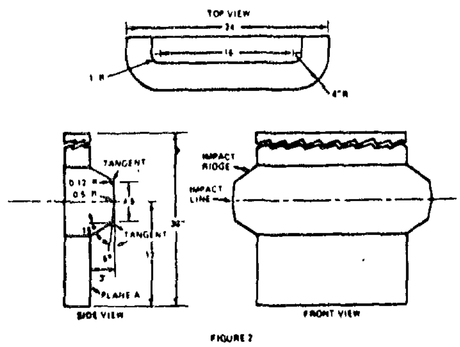

FIGURE 2

PART 581—BUMPER STANDARD

(Docket No. 74-11; Notice 12; Docket No. 73-19; Notice 9)

§ 581.1 Scope. This standard establishes requirements for the impact resistance of vehicles in low speed front and rear collisions.

§ 581.2 Purpose. The purpose of this standard is to reduce physical damage to the front and rear ends of a passenger motor vehicle from low speed collisions.

§ 581.3 Application. This standard applies to passenger motor vehicles other than multipurpose passenger vehicles.

§ 581.4 Definitions. All terms defined in the Motor Vehicle Information and Cost Savings Act, P.L. 92-513, 15 U.S.C. 1901-1991, are used as defined therein.

"Bumper face bar" means any component of the bumper system that contacts the impact ridge of the pendulum test device.

§ 581.5 Requirements.

(a) [Each vehicle shall meet the damage criteria of §§ 581.5(c) (1) through 581.5 (c) (9) when impacted by a pendulum-type test device in accordance with the procedures of § 581.7(b), under the conditions of § 581.6, at an impact speed of 1.5 m.p.h., and when impacted by a pendulum-type test device in accordance with the procedures of § 581.7(a) at 2.5 m.p.h., followed by an impact into a fixed collision barrier that is perpendicular to the line of travel of the vehicle, while traveling longitudinally forward, then longitudinally rearward, under the conditions of § 581.6, at 2.5 m.p.h." (47 F.R. 2182—May 20, 1982. Effective: July 4, 1982)]

(b) [Reserved.]

(c) Protective criteria.

(1) Each lamp or reflective device except license plate lamps shall be free of cracks and shall comply with applicable visibility requirements of S4.3.1.1 of Standard No. 108 (§ 571.108 of this part). The aim of each headlamp shall be adjustable to within the beam aim inspection limits specified in Table 2 of SAE Recommended Practice J599b, July 1970, measured with a mechanical aimer conforming to the requirements of SAE Standard J602a, July 1970.

(2) The vehicle's hood, trunk, and doors shall operate in the normal manner.

(3) The vehicle's fuel and cooling systems shall have no leaks or constricted fluid passages and all sealing devices and caps shall operate in the normal manner.

(4) The vehicles' exhaust system shall have no leaks or constrictions.

(5) The vehicle's propulsion, suspension, steering, and braking systems shall remain in adjustment and shall operate in the normal manner.

(6) A pressure vessel used to absorb impact energy in an exterior protection system by the accumulation of gas pressure or hydraulic pressure shall not suffer loss of gas or fluid accompanied by separation of fragments from the vessel.

(7) The vehicle shall not touch the test device, except on the impact ridge shown in Figures 1 and 2, with a force that exceeds 2000 pounds on the combined surfaces of Planes A and B of the test device.

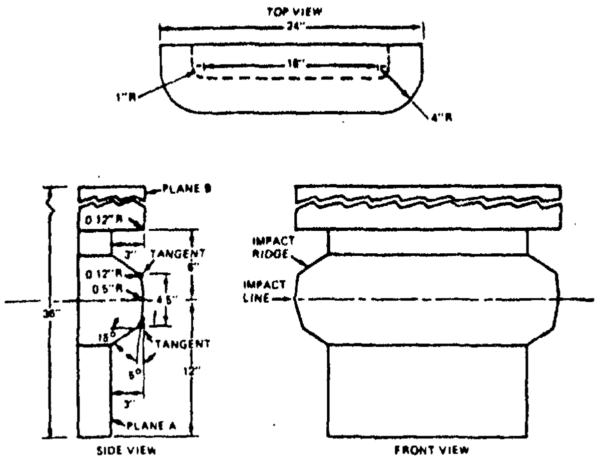

FIGURE 1

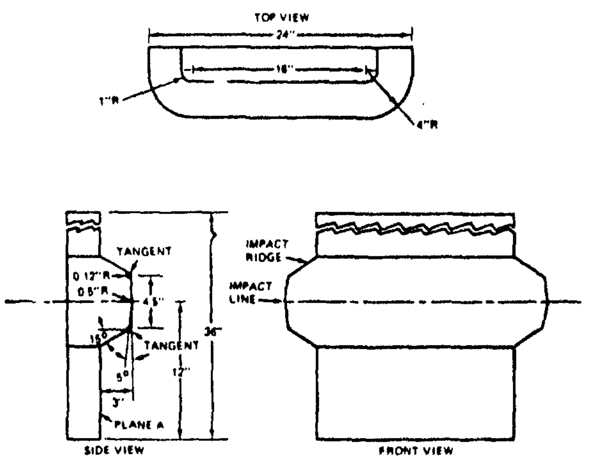

FIGURE 2

(8) The exterior surfaces shall have no separations of surface materials, paint, polymeric coatings, or other covering materials from the surface to which they are bonded, and no permanent deviations from their original contours 30 minutes after completion of each pendulum and barrier impact, except where such damage occurs to the bumper face bar and the components and associated fasteners that directly attach the bumper face bar to the chassis frame.

(9) Except as provided in § 581.5(c) (8), there shall be no breakage or release of fasteners or joints.

(10) Reserved.

(11) Reserved.

§ 581.6 Conditions. The vehicle shall meet the requirements of § 581.5 under the following conditions:

(a) General.

(1) The vehicle is at unloaded vehicle weight.

(2) The front wheels are in the straight ahead position.

(3) Tires are inflated to the vehicle manufacturer's recommended pressure for the specified loading condition.

(4) Brakes are disengaged and the transmission is in neutral.

(5) [Trailer hitches, license plate brackets, and headlamp washers are removed from the vehicle. Running lights, fog lamps, and equipment mounted on the bumper face bar are removed from the vehicle if they are optional equipment. (48 F.R. 43331—September 23, 1983. Effective: September 23, 1983)]

(b) *Pendulum test conditions.* The following conditions apply to the pendulum test procedures of § 581.7(a) and § 581.7(b):

(1) The test device consists of a block with one side contoured as specified in Figure 1 and Figure 2 with the impact ridge made of AIS1 4130 steel hardened to 34 Rockwell "C." The impact ridge and the surfaces in Planes A and B of the test device are finished with a surface roughness of 32 as specified by SAE Recommended Practice J449A, June 1963. From the point of release of the device until the onset of rebound, the pendulum suspension system holds Plane A vertical, with the arc described by any point on the impact line lying in a vertical plane

(for § 581.7(a), longitudinal; for § 581.7(b), at an angle of 30° to a vertical longitudinal plane) and having a constant radius of not less than 11 feet.

(2) With Plane A vertical, the impact line shown in Figures 1 and 2 is horizontal at the same height as the test device's center of percussion.

(3) The effective impacting mass of the test device is equal to the mass of the tested vehicle.

(4) When impacted by the test device, the vehicle is at rest on a level rigid concrete surface.

(c) Barrier Test Condition. At the onset of a barrier impact, the vehicle's engine is operating at idling speed in accordance with the manufacturer's specification. Vehicle systems that are not necessary to the movement of the vehicle are not operating during impact.

§ 581.7 Test Procedures.

(a) Longitudinal Impact Test Procedures.

(1) Impact the vehicle's front surface and its rear surface two times each with the impact line at any height from 16 to 20 inches, inclusive, in accordance with the following procedure.

(2) For impacts at aheight of 20 inches, place the test device shown in Figure 1 so that Plane A is vertical and the impact line is horizontal at the specified height.

(3) For impacts at a height between 20 inches and 16 inches, place the test device shown in Figure 2 so that Plane A is vertical and the impact line is horizontal at a height within the range.

(4) For each impact, position the test device so that the impact line is at least 2 inches apart in vertical direction from its position in any prior impact, unless the midpoint of the impact line with respect to the vehicle is to be more than 12 inches apart laterally from its position in any prior impact.

(5) For each impact, align the vehicle so that it touches, but does not move, the test device, with the vehicle's longitudinal centerline perpendicular to the plane that includes Plane A of the test device and with the test device inboard of the vehicle corner test positions specified in § 581.7(b).

(6) Move the test device away from the vehicle, then release it to impact the vehicle.

(7) Perform the impacts at intervals of not less than 30 minutes.

(b) Corner impact test procedure.

(1) Impact a front corner and a rear corner of the vehicle once each with the impact line at a height of 20 inches and impact the other front corner and the other rear corner once each with the impact line at any height from 16 to 20 inches, inclusive, in accordance with the following procedure.

(2) For an impact at a height of 20 inches, place the test device shown in Figure 1 so that Plane A is vertical and the impact line is horizontal at the specified height.

(3) For an impact at a height between 16 inches and 20 inches, place the test device shown in Figure 2 so that Plane A is vertical and the impact line is horizontal at a height within the range.

(4) Align the vehicle so that a vehicle corner touches, but does not move, the lateral center of the test device with Plane A of the test device forming an angle of 60 degrees with a vertical longitudinal plane.

(5) Move the test device away from the vehicle, then release it to impact the vehicle.

(6) Perform the impacts at intervals of not less than 30 minutes.

41 F.R. 9346
March 4, 1976

APPENDIX B

Models Studied, sales and Market Share

MAKE/MODELS	Model Year 1981	Market Share Percent	Model Year 1982	Market Share	Model Year 1983	Market Share	Model Year 1984	Market Share
TOYOTA CELICA	120025	1.33	103879	1.34	119140	1.37	90784	0.86
PONTIAC GRAND PRIX	108344	1.20	80650	1.04	87026	1.00	23953	0.23
VW RABBIT	179635	2.00	102664	1.33	83150	0.96	116585	1.11
BUICK REGAL	332005	3.69	225418	2.91	233016	2.68	224754	2.13
BUICK CENTURY	0	0.00	102965	1.33	134804	1.55	219858	2.09
FORD THUNDERBIRD/MERCURY COUGAR		0.00		0.00	164614	1.89	301722	2.86
FORD EXP		0.00	6692	0.09	26471	0.30	23016	0.22
OLDS CUTLASS SUPREME	454022	5.05	194337	2.51	314473	3.62	309124	2.93
MERCURY MARQUIS-GRAND MARQUIS	61638	0.68	77157	1.00	98341	1.13	90341	0.86
OLDS CUTLASS CIERA		0.00	101320	1.31	169939	1.95	280839	2.67
AMC/RENAULT ALLIANCE		0.00		0.00	124687	1.43	121015	1.15
DATSUN 280ZX-300ZX	62800	0.70	63791	0.82	68651	0.79	75968	0.72
FORD LTD-CROWN VICTORIA	78150	0.87	41943	0.54	124650	1.43	86084	0.82
FORD TEMPO/MERCURY TOPAZ		0.00		0.00		0.00	273392	2.60
FORD MUSTANG/MERCURY CAPRI	241498	2.68	166552	2.15	141620	1.63	162122	1.54
OLDS 88/98	268568	2.98	265178	3.42	332398	3.82	370701	3.52
FORD ESCORT/MERCURY LYNX	432705	4.81	418531	5.40	403862	4.64	397858	3.78
BUICK SKYLARK	200460	2.23	144560	1.87	107363	1.23	111211	1.06
AMC/RENAULT ENCORE		0.00		0.00		0.00	87609	0.83
DATSUN 200SX	77062	0.86	76024	0.98	37102	0.43	63914	0.61
MAZDA GLC	62195	0.69	62195	0.80	55418	0.64	51906	0.49
FORD GRANADA/MERC COUGAR-FORD LTD/MERC MARQUIS	174994	1.94	177273	2.29	200505	2.31	321560	3.05
PONTIAC BONNEVILLE	19819	0.22	80440	1.04	82002	0.94	29269	0.28
CADILLAC DEVILLE	150915	1.68	137600	1.78	173086	1.99	160599	1.52
TOYOTA TERCEL	121328	1.35	121328	1.57	151052	1.74	108889	1.03
CHEVROLET CAVALIER		0.00	195024	2.52	216297	2.49	462612	4.39
DATSUN 310-NISSAN PULSAR	77980	0.87	77950	1.01	56180	0.65	39131	0.37
BMW 320i-320i/318i-318i	31902	0.35	31902	0.41	34681	0.40	30134	0.29
VOLVO 240/260	21817	0.24	39288	0.51	40783	0.47	90592	0.86
PONTIAC J2000		0.00	118859	1.53	75509	0.87	169290	1.61
DATSUN 210-NISSAN SENTRA	159939	1.78	160077	2.07	212793	2.45	195355	1.85
TOYOTA COROLLA	241603	2.68	241630	3.12	144860	1.67	159323	1.51
CHEVROLET IMPALA/CAPRICE	184992	2.06	188178	2.43	226750	2.61	276492	2.62
BUICK ELECTRA/LE SABRE	158194	1.76	175052	2.26	216503	2.49	228901	2.17
CHEVROLET CAMARO	123138	1.37	178808	2.31	175004	2.01	261592	2.48
CHEVROLET CHEVETTE	453982	5.05	243463	3.14	183970	2.12	243904	2.32
CHEVROLET CITATION-CITATION II	300184	3.34	165647	2.14	116460	1.34	102205	0.97
PONTIAC FIREBIRD	70899	0.79	116364	1.50	93378	1.07	128304	1.22
CHEVROLET CELEBRITY		0.00	92314	1.19	155953	1.79	309288	2.94
CHEVROLET MONTE CARLO	157115	1.75	92391	1.19	98865	1.14	136778	1.30
OLDS FIRENZA		0.00	30108	0.39	43042	0.50	82475	0.78
BUICK SKYHAWK		0.00	47918	0.62	69946	0.80	145393	1.38
PONTIAC 1000	70194	0.78	44469	0.57	38286	0.44	55083	0.52
OLDS OMEGA	147918	1.64	77469	1.00	56210	0.65	52986	0.50
CHRYSLER E CLASS		0.00		0.00	36610	0.42	36494	0.35
CHRYSLER LE BARON "K"	36311	0.40		0.00	81478	0.94	111808	1.06
CHRYSLER NEW YORKER E		0.00		0.00	33494	0.39	69746	0.66
DODGE 600-600 4DR		0.00		0.00	30042	0.35	36864	0.35
PLY HORI/DGE OMNI 2DR-PLY TURISMO/TC3/DGE CHGR/024	151415	1.68	82003	1.06	82317	0.95	51799	0.49
PLYMOUTH HORI/DODGE OMNI 4DR	128116	1.42	85356	1.10	96704	1.11	290396	2.76
PLYMOUTH RELIANT/DODGE ARIES	410163	4.56	287596	3.71	286409	3.29	337947	3.21
HONDA CIVIC	154698	1.72	154698	2.00	139169	1.60	161123	1.53
HONDA ACCORD/LX	172557	1.92	172557	2.23	177219	2.04	139152	1.32
DODGE 400-400/600 COUPE		0.00	34340	0.44	31947	0.37	23443	0.22
PONTIAC PHOENIX	127869	1.42	49165	0.63		0.00	22847	0.22
FORD FAIRMONT/MERCURY ZEPHYR	277809	3.09	166831	2.15	99295	1.14	106036	1.01
CHEVROLET MALIBU	226727	2.52	116125	1.50	107761	1.24	107761	1.02

APPENDIX C

Nameplates included in 1981 thru 1984 Comparisons

1981/1982	1983	1984
TOYOTA CELICA	TOYOTA CELICA	TOYOTA CELICA
PONTIAC GRAND PRIX	PONTIAC GRAND PRIX	PONTIAC GRAND PRIX
VW RABBIT	VW RABBIT	VW RABBIT
BUICK REGAL	BUICK REGAL	BUICK REGAL
BUICK CENTURY(1982 ONLY)	BUICK CENTURY	BUICK CENTURY
	FORD T'BIRD/MERC. COUGAR	FORD T'BIRD/MERC. COUGAR
FORD EXP(1982 ONLY)	FORD EXP	FORD EXP
OLDS CUTLASS SUPREME	OLDS CUTLASS SUPREME	OLDS CUTLASS SUPREME
MERCURY MARQUIS	MERCURY GRAND MARQUIS	MERCURY GRAND MARQUIS
OLDS CIERA(1982 ONLY)	OLDS CUTLASS CIERA	OLDS CUTLASS CIERA
	AMC/RENAULT ALLIANCE	AMC/RENAULT ALLIANCE
DATSUN 280ZX	DATSUN 280ZX	NISSAN 300ZX
FORD LTD	FORD CROWN VICTORIA	FORD CROWN VICTORIA
		FORD TEMPO/MERCURY TOPAZ
FORD MUSTANG/MERC CAPRI	FORD MUSTANG/MERC CAPRI	FORD MUSTANG/MERC CAPRI
OLDS 88/98	OLDS 88/98	OLDS 88/98
FORD ESCORT/MERCURY LYNX	FORD ESCORT/MERCURY LYNX	FORD ESCORT/MERCURY LYNX
BUICK SKYLARK	BUICK SKYLARK	BUICK SKYLARK
		AMC/RENAULT ENCORE
DATSUN 200SX	DATSUN 200SX	DATSUN 200SX
MAZDA GLC	MAZDA GLC	MAZDA GLC
FORD GRANADA/MERC COUGAR	FORD LTD/MERC MARQUIS	FORD LTD/MERC MARQUIS
PONTIAC BONNEVILLE	PONTIAC BONNEVILLE	PONTIAC BONNEVILLE
CADILLAC DEVILLE	CADILLAC DEVILLE	CADILLAC DEVILLE
TOYOTA TERCEL	TOYOTA TERCEL	TOYOTA TERCEL
CHEV CAVALIER(1982 ONLY)	CHEVROLET CAVALIER	CHEVROLET CAVALIER
DATSUN 310	NISSAN PULSAR	NISSAN PULSAR
BMW 320i	BMW 320i/318i	BMW 318i
VOLVO 240/260	VOLVO 240/260	VOLVO 240/260
PONTIAC J2000(1982 ONLY)	PONTIAC J2000	PONTIAC J2000
DATSUN 210	NISSAN SENTRA	NISSAN SENTRA
TOYOTA COROLLA	TOYOTA COROLLA	TOYOTA COROLLA
CHEV IMPALA/CAPRICE	CHEV IMPALA/CAPRICE	CHEV IMPALA/CAPRICE
BUICK ELECTRA/LE SABRE	BUICK ELECTRA/LE SABRE	BUICK ELECTRA/LE SABRE
CHEVROLET CAMARO	CHEVROLET CAMARO	CHEVROLET CAMARO
CHEVROLET CHEVETTE	CHEVROLET CHEVETTE	CHEVROLET CHEVETTE
CHEV CITATION	CHEV CITATION	CHEV CITATION II
PONTIAC FIREBIRD	PONTIAC FIREBIRD	PONTIAC FIREBIRD
CHEV CELEBRITY(1982 ONLY)	CHEVROLET CELEBRITY	CHEVROLET CELEBRITY
CHEVROLET MONTE CARLO	CHEVROLET MONTE CARLO	CHEVROLET MONTE CARLO
OLDS FIRENZA(1982 ONLY)	OLDS FIRENZA	OLDS FIRENZA
BUICK SKYHAWK(1982 ONLY)	BUICK SKYHAWK	BUICK SKYHAWK
PONTIAC 1000	PONTIAC 1000	PONTIAC 1000
OLDS OMEGA	OLDS OMEGA	OLDS OMEGA
	CHRYSLER E CLASS	CHRYSLER E CLASS
CHRY LE BARON(1981 ONLY)	CHRYSLER LE BARON "K"	CHRYSLER LE BARON "K"
	CHRYSLER NEW YORKER E	CHRYSLER NEW YORKER E
	DODGE 600-600 4DR	DODGE 600-600 4DR
PLY HORI/DGE OMNI 2DR	PLY HORI/DGE OMNI 2DR	PLY HORI/DGE OMNI 2DR
PLY HORI/DGE OMNI 4DR	PLY HORI/DGE OMNI 4DR	PLY HORI/DGE OMNI 4DR
PLY RELIANT/DGE ARIES	PLY RELIANT/DGE ARIES	PLY RELIANT/DGE ARIES
HONDA CIVIC	HONDA CIVIC	HONDA CIVIC
HONDA ACCORD/LX	HONDA ACCORD/LX	HONDA ACCORD/LX
DGE 400/600CPE(1982 ONLY)	DGE 400/600CPE	DODGE 600 CPE
PONT PHOENIX(1982 ONLY)		
FORD FAIRMONT/MERC ZEPHYR	FORD FAIRMONT/MERC ZEPHYR	
CHEVROLET MALIBU	CHEVROLET MALIBU	

APPENDIX D

BUMPER DESIGN CHANGE CATEGORIES BY MAKE/MODEL FOR 1983, FOR 1984

FACEBAR

1983 CHANGED MODELS FRONT	1983 CHANGED MODELS REAR	1984 CHANGED MODELS FRONT	1984 CHANGED MODELS REAR
CITATION	CITATION	FIRENZA	FIRENZA
FIREBIRD	FIREBIRD	SKYHAWK	SKYHAWK
SKYHAWK	SKYHAWK	CHEVETTE	CHEVETTE
CHEVETTE	CHEVETTE	OMEGA	OMEGA
T1000	T1000	MONTE CARLO	MONTE CARLO
MALIBU,CHEVELLE	FIRENZA	FIREBIRD	FIREBIRD
	CENTURY	CELEBRITY	CELEBRITY
		T1000	T1000
		CITATION	CITATION
			CENTURY
			REGAL

STRUCTURAL

1983 FRONT	1983 REAR	1984 FRONT	1984 REAR
VOLVO(240 ETC.)	VOLVO(240 ETC.)	LESABRE	LESABRE
SENTRA(210/B210)	SENTRA(210/B210)	CHEVROLET	CHEVROLET
BONNEVILLE	BONNEVILLE	CAVALIER	CAVALIER
J2000	J2000	320I/318I	320I/318I
CAMARO	CAMARO	CADILLAC	CADILLAC
CADILLAC	CADILLAC	ELECTRA	ELECTRA
TERCEL	TERCEL	J2000	J2000
GRAN PRIX	LESABRE	VOLVO(240 ETC)	VOLVO(240 ETC)
	ELECTRA	BONNEVILLE	BONNEVILLE
		TERCEL	TERCEL
		COROLLA	COROLLA
		SENTRA(210/B210)	SENTRA(210/B210)
		CAMARO	CAMARO
		GRAN PRIX	
		CELICA	

ENERGY ABSORBER

1983 FRONT	1983 REAR	1984 FRONT	1984 REAR
400	LEBARON	E CLASS	E CLASS
LEBARON	600	LE BARON(K CAR)	LE BARON(K CAR)
600	E CLASS	NEW YORKER	NEW YORKER
E CLASS	OMNI/SHELBY/CHARGER	600	600
OMNI/SHELBY/CHGR	NEW YORKER		
NEW YORKER			

STRUCTURAL AND ENERGY

1983 FRONT	1983 REAR	1984 FRONT	1984 REAR
CIVIC	400	OMNI/SHELBY/CHGR	OMNI/SHELBY/CHARGER
RELIANT	CIVIC	HORIZON	HORIZON
OMNI	RELIANT	RELIANT	RELIANT
ARIES	OMNI	ARIES	ARIES
ACCORD	ARIES	CIVIC	CIVIC
HORIZON	ACCORD	ACCORD	ACCORD
	HORIZON	RABBIT	

APPENDIX E

MODEL FOR CALCULATING NET BENEFITS

Gross benefits are measured in lifetime repair costs resulting from low-speed bumper involved collisions that occur over a cars life. The two primary sources of information used to calculate gross benefits are a national driver survey and analysis of State Farm insurance claim data. The general equation for gross lifetime benefits discounted over a ten year car life using average annual mileage, vehicle survivability factors and a 10 percent discount rate is:

$$B = L[U(D_i C_i P_i) + (N_i I_i K_i)] \, [DF]$$

where:
- B= discounted gross lifetime benefits (Tables 4-2, 4-5)
- L= average car life = 10 years
- U= The low speed collision incident rate for cars in which no insurance claim is filed (driver's survey found this rate for 1981 thru 1984 model year cars to be 12.25 percent)
- D= The damage frequency of cars per unclaimed collision (Tables 3-1, 3-2, 3-3).
- i= subscript refers to data on a particular model year, bumper design category, and end of car involved in collision.
- C= The average cost to repair damage per car in unclaimed collisions (Table 3-4).

P= The proportion of cars in unreported collisions that were struck in the front or rear (ratio).

N= The rate of property damage insurance claims per insured vehicle year. This is the product of HLDI data collision claims per insured vehicle year, multiplied by the ratio of all property damage claims to collision claims from State Farm data. Nine to 10 percent of cars have a collision claim annually and another 3 percent have property damage liability claims. The overall average for 1981 through 1984 models in the first year was 12.3%.

I= The proportion of property damage insurance claims involving the bumper to all property damage insurance claims (ratio). (Tables 3-8, 3-10).

K= The average cost to repair damage in insurance claims involving the bumper. (Tables 3-9, 3-11).

DF= The discount factor for 10 year car life at 10 percent discount(Table 4-1) =.7393.

The Gross Costs, including lifetime fuel discounted costs and secondary weight considerations resulting in bumpers designed to meet a particular performance standard, are shown in the following equation:

$$C = BC_i + BW_i\ [(F)(DG)(1+S)] + (BW_i)(S)(BS)$$

Where:

C= Gross cost of bumper systems, secondary weight and fuel cost discounted over a car's ten year life, for operating a passenger car considering the weight of the bumper systems and secondary weight.

BC= Cost of the energy management portion of a bumper system

i= Subscript refers to data on particular Model year, bumper design category and end of car.

BW= Weight of energy management portion of a bumper system

F= Number of gallons used per pound of car to operate it over a ten year life (for this study F=1.25 gal/#)

To calculate the lifetime fuel use per pound of vehicle weight, the ratio of vehicle curb weight and fuel economies are considered as follows:

$$\text{Fuel Economy Car 2} = (\text{curb weight car/curb car 2})^{0.8} \times \text{fuel economy of car 1}$$

where

Curb weight car 1 = 2701# (curb weight of 1983/1984 changed Models plus reduction in bumper weight -12#)

Curb weight car 2 = 2689# (average curb weight of 1983/1984 models with changed bumpers)

Fuel Economy car 1 = 27.041 mpg (average EPA fuel economy 1983/1984 models with changed bumpers)

and

Fuel economy car 2 = 27.137 mpg

Reduce both fuel economy values by 15% to obtain actual on-road fuel economy.

Car 1 = 22.985 mpg

Car 2 = 23.067 mpg

Lifetime fuel use (10-year life - 95,345miles)

Car 1 = 95345/22.985 = 4148

Car 2 = 95345/23.067 = 4133

Difference in fuel use = 4148-4133 = 15 gallons

Difference in vehicle weight = 12 pounds

Ratio of gallons/pound - 15/12 = 1.25 gal/#

DG= discounted cost of fuel for a ten year car life based on 10 percent discount rate, current fuel price per gallon projection, and using the same mileage and vehicle survival values as for the repair cost discount factor (DF). For this study DG= .83513.

FUEL PRICE DISCOUNTED OVER 10 YEAR LIFE 1/

A. VEHICLE AGE (YEARS)	B. AVERAGE ANNUAL VEHICLE MILES TRAVELED	C. SURVIVAL PROBABILITY	D. (B*C)	E. PRESENT WORTH FACTOR(10%)	F. (D*E)	G. FUEL PRICE (1984 $)	H. (F*G)
1	14535	1.000	14535	1.0000	14535	$1.25	18169
2	13924	0.993	13827	0.9091	12570	$1.20	15084
3	12846	0.982	12615	0.8264	10425	$1.01	10529
4	11378	0.964	10968	0.7513	8241	$1.02	8405
5	10749	0.935	10050	0.6830	6864	$1.02	7001
6	10119	0.892	9026	0.6209	5604	$1.06	5940
7	9490	0.831	7886	0.5645	4452	$1.12	4986
8	8860	0.753	6672	0.5132	3424	$1.18	4040
9	8231	0.662	5449	0.4665	2542	$1.23	3127
10	7601	0.568	4317	0.4241	1831	$1.28	2344
TOTAL			95345		70487		79625

DISCOUNT FACTOR= 79625/95345= .83513

1/ See Section 4.1.7 for discussion of average car life.

S= secondary weight factor values of 0.00, 0.70 and 1.00 were used in this study. That is, for every pound of bumper weight an additional 0, .7, or 1 pound of material was added to weight-related vehicle parts (e.g. shock absorbers)

BS= Cost per pound of secondary weight. For this study, a cost of 66¢/lb of secondary weight was used. This represents material and overhead cost/pound in 1984 dollars.

The difference in gross benefits, gross costs and net benefits between cars with changed bumper designs and cars with unchanged bumper designs is based on the following general alogarithm.

$$T = [P_{(C83,\ 84)} - P_{(c82,\ 82)}] - P_{U83,\ 84)} - P_{(U81,\ 82)}]$$

where:

T = True difference in parameter

$P_{(c83,\ 84)}$ = Parameter for 1983 and 1984 models with changed bumper designs

$P_{c81,\ 82)}$ = Parameter for 1983 and 1984 models that are predecessors of of 1983 and 1984 models with changed bumpers

$P_{U83,\ 84)}$ = Parameter for 1983 and 1984 models with unchanged bumper design

$P_{U81,\ 82)}$ = Parameter for 1981 and 1982 models that are predecessors of 1983 and 1984 models with unchanged bumpers

The above alogarithm is two-fold. First, the difference between the 1983, 1984 model and its direct 1981, 1982 predecessor is determined; second, the difference between the 1983, 1984 unchanged models and their predecessors is deducted from the difference found for the changed models with their predecessors models. The second step uses the unchanged 83, 84 models as a control group and helps remove any influences that may have affected the 1983, 1984 model years differently from the 1981, 1982 models, regardless of bumper design such as weather, economic conditions etc.

To determine the net benefit of cars with changed bumpers compared to cars with unchanged bumpers, the true difference in gross benefits and gross costs are first determined using the general alogarithm and then these differences are subtracted from each other as follows:

$$\text{Net Benefit} = [\text{Delta } B_{(changed)} - \text{Delta } B_{(unchanged)}] - [\text{Delta } C_{(changed)} - \text{Delta } C_{(unchanged)}]$$

where:

$\text{Delta } B_{(changed)}$ = discounted gross benefit of 1983, 1984 cars with changed bumpers minus the discounted gross benefit of 1981, 1982 predecessor models of those 83,84 cars with changed bumpers.

$\text{Delta } B_{(unchanged)}$ = discounted gross benefits of 1983, 1984 cars with unchanged bumpers minus the discounted gross benefit of 1981, 1982 predecessor models of those 83,84 cars with unchanged bumpers.

$\text{Delta } C_{(changed)}$ = gross cost of changed 1983, 1984 bumper systems minus the gross cost of 1981, 1982 predecessor bumper systems.

$\text{Delta } D_{(unchanged)}$ = gross cost of unchanged 1983, 1984 bumper systems minus the gross cost of 1981, 1982 predecessor bumper systems.

APPENDIX F

DISCOUNT CALCULATION PROCEDURE

Future benefits are discounted to the base calendar year 1984 (end of year). A 1984 model year car, for example, is considered to be new with ten years to go for discounting purposes. Likewise, a 1981 model will have accumulated three "historical" years through calendar year 1984 and have seven "future" years over which benefits are still to be obtained.

To calculate discounted future benefits, a discount rate of 10 percent is used [15]. Discount factors to be applied in the calculation are given in Table F-1 below:

TABLE F-1

Discount Factors for a 10 Percent Rate

Year:	1	2	3	4	5	6	7	8	9	10
Factor:	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424

The expression for discounted gross benefits is as follows:

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

where:

B= The gross incremental benefit of post-standard (as modified in 1982) changed bumper system in 1984 dollars.

M= Lifetime vehicle miles travelled.

A= Annual miles travelled over a car's ten year life.

Y= Year of car life, 1 through 10.

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

S= Discount factor at a 10 percent rate, (Table F-1).

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