clamps may result in an open circuit, these are relatively infrequent and minor problems. In an EV, however, they are serious. Dirty or loose connections on any of the 40 battery posts can significantly degrade performance, cause improper charging, and sometimes generate enough heat (because of the high resistance) to melt the battery posts. Currently, most connectors used in EVs are similar to those used for gasoline-vehicle starting batteries. They were not designed to carry high currents with a minimum voltage drop for long periods. Tightening and cleaning connections has been a regular and time-consuming maintenance item on EVs in the demonstration project. The EV task force efforts in this regard are directed toward testing new connectors and developing other alternatives. One recently manufactured type of connector is spring loaded to maintain a tight connection and has a plastic cap to keep the connection clean.

An EV that is as owner foolproof as, and competitive with, a gasoline vehicle will depend on an overall systems approach rather than modification of off-the-shelf components. Such an EV will probably be produced by the same companies that now produce gasoline vehicles. The efforts of the EV task force are important to the near-term improvement of EVs and very possibly may contribute to the ultimate system design. The incentives for task force members to contribute are great since all members foresee an important role for EVs in their own vehicle fleets.

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Analysis of the Effectiveness of Bumper Standard FMVSS 215

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The primary objective of this paper is to evaluate the effectiveness of crash-protecting automobile bumpers as required by Federal Motor Vehicle Safety Standard 215—Exterior Protection, Passenger Cars. This study focused on three distinct versions of the standard: (a) the initial 1973 regulations that required compliance with a barrier test, (b) regulations after 1974 that required both a pendulum and an upgraded barrier test, and (c) regulations after 1978 that limited total vehicular damage as a result of the pendulum and barrier tests. Following the recommendations of several previous studies, insurance claims were used as the data base. A comprehensive data base provided by the State Farm Insurance Company was categorized by vehicle model years that represent four time periods—1972, 1973, 1974-1978, and 1979—and into vehicle-size classes, impact points, vehicle age, and repaired and replaced damaged bumper categories. By using reported claims and average cost of these claims as measures of effectiveness, it was shown that the model years with more protective bumper systems experienced significantly lower proportions of bumper-related claims relative to all property-damage claims. However, in general, these model years also had higher average repair costs. The reduced percentages of bumper-related claims were primarily attributable to decreased claims that involve bumpers being replaced rather than claims that involve bumper repair only.

In 1971, the National Highway Traffic Safety Administration (NHTSA) issued Federal Motor Vehicle Safety Standard (FMVSS) 215--Exterior Protection, Passenger Cars. The general purpose of this standard was to prevent low-speed accidents from impairing safe operation of the vehicle and to reduce the frequency of override and underride impacts in higher-speed collisions (i.e., collisions of two vehicles where the initial contacts slide over or below the bumper). It was also hoped that, as a consequence of FMVSS 215, the cost of repairs to vehicles involved in low-speed collisions would be reduced. Hence, an economic advantage to the consumer would be realized.

Bumper-performance tests used to determine that safety-related items (lights, fuel system, cooling system, etc.) are not rendered inoperable include pendulum and barrier-impact tests of the bumper system. The barrier tests consist of front and rear impacts against a flat rigid barrier at specified speeds. The pendulum-impact test consists of striking the bumper at specified heights and angles with a pendulum hammer. This test is designed to promote consistent bumper heights so as to reduce the likelihood of underride or override of bumpers in car-to-car collisions.

The performance testing for compliance with the safety-related requirements of FMVSS 215 has gone through various stages of development [see Table 1 (1)]. The initial standard model year (1973) was subject to barrier-impact testing only (5-mph front and 2.5-mph rear impacts). Beginning with the following model year (1974), the rear-barrier test was upgraded to 5 mph and the pendulum-impact test (longitudinal and corner impacts) was introduced. The pendulum-impact test was amended starting with the 1976 model year, which decreased the number of longitudinal pendulum impacts.

Title I of the Motor Vehicle Information and Cost Savings Act (P.L. 92-513, 1972) instructed NHTSA to develop property-damage bumper standards that would provide the maximum feasible reduction of costs to the public and to the consumer. The Part 581 standard issued under the authority of this Act required that, effective with the 1979 model year, front and rear bumpers must be capable of protecting vehicles from damage in barrier and pendulum longitudinal crash tests at 5 mph and pendulum corner impacts at 3 mph. In addition, damage criteria were upgraded to permit damage only to the bumper itself and the brackets, fasteners, etc., that attach the bumpers to the chassis framework and not to any other vehicle components or surfaces. For 1980 and future models, the standard also limited bumper face-bar damage.

In general, the objective of this study addresses the basic question, Has the imposition of a bumper standard resulted in reduced damage and overall cost to the motorist? The analysis attempts to answer this question by determining whether or not insurance claims and their estimated repair costs have been changed by the imposition of FMVSS 215. The major portion of the analysis is aimed at determin-

Table 1. Basic requirements of FMVSS 215 by model year.

Model Year	Test Requirement		
	Barrier	Pendulum	Impact
1973	5-mph front	None	
	2.5-mph rear	None	
1974[a]	5-mph front	5-mph front	6
	5-mph rear	5-mph rear	6
		3-mph corner at 20-in front	1
		3-mph corner at 20-in rear	1
1975	5-mph front	5-mph front	6[b]
	5-mph rear	5-mph rear	6[b]
		3-mph corner at 20-in front	1
		3-mph corner at 20-in rear	1
1976	5-mph front	5-mph front	2
	5-mph rear	5-mph rear	2
		3-mph corner front at 20 and 16 in[c]	2
		3-mph corner rear at 20 and 16 in[c]	2
1977, 1978	5-mph front	5-mph front	2
	5-mph rear	5-mph rear	2
		3-mph corner front at 20 and 16 in	2
		3-mph corner rear at 20 and 16 in	2

[a]Pendulum test requirements did not apply to cars with wheelbases of 115 in or less that have either convertible tops or no roof supports between the A-pillar and the roof-support structure or no rear designated seating positions.
[b]Reduced to 2 impacts for cars manufactured after May 12, 1975.
[c]Corner impacts at 16 in did not apply to cars with wheelbases greater than 120 in.

ing whether statistically significant variations in claim frequency percentages and average repair costs have occurred for vehicle model years of the poststandard periods. Comparisons are made after the data are stratified into appropriate categories. Additional analyses also include an estimate of the relative contribution of repaired versus replaced bumper claims to the total of all bumper claims.

METHODOLOGY

A basic measure of bumper effectiveness should be the changes in vehicle damage incurred in low-speed collisions. However, direct real-world observation cannot be made of low-speed, low-damage crashes. An added problem exists because there is no single data source that contains information on all crashes (i.e., reported and unreported crashes). It has been recommended that insurance claims be used as a measure for reported vehicle involvement and damage (2,3). These claims should include collision coverage involvement as well as property-damage coverage involvement claims.

Collision coverage provides insurance for damage to a policyholder's automobile. Under collision coverage, a deductible is applied, which means that the policyholder pays for some of the damage. (Typical deductible amounts are $100 and $150.) Liability coverage provides insurance for damage to other property, including other automobiles, caused by the policyholder. These coverages do not have deductibles.

Claims under these two coverages, both of which involve damage to the automobile, produce different patterns of damage due to the nature of the coverages. As an illustration, consider a typical two-car low-speed crash in which one car is struck in the rear by the other. The damage to the car struck in the rear will typically be paid for by the property-damage liability coverage of the striking car. The striking car's damage, if it exceeds the deductible, will be paid for by the collision coverage. Because of these sorts of differences, collision coverage claims more often involve front-end damage than property-damage liability claims, which more often involve rear-end damage.

The principal data source for this study is the computerized data base maintained by the State Farm Insurance Company, which includes files on both collision and property-damage (liability) coverage claims. The following sections describe the nature of the State Farm data base, the stratification applied to the data base, and the measures of effectiveness tested. Note that other stratifications (and analyses) are not presented here but are detailed elsewhere (4,5). These include coverage involvement (collision and liability), object struck (fixed object and other vehicles), and bumper design.

Data Base

The data base maintained by State Farm Insurance contains a sample of claim information obtained from their claim service centers. The data used in this study consist of tabulations of these data, subject to various factors. The factors and subsequent comparisons of the data were therefore restricted by the data-base content. The number of claim records for the individual model years was at least 10 000 claims. No totaled-vehicle claims were included in this study.

Stratification of Data Base (Independent Variables)

Stratification of State Farm's claim data base was dictated, in large part, by its own format and content. These stratifications constitute independent study variables in the study. Listed below are the study variables and their respective categories.

Model-Year Comparison

The model-year categories that generally describe changes and refinements of the bumper standard are grouped in the following manner:

1. Pre-1973 model year--These vehicles are not required to meet any performance standards;
2. 1973 model year--These vehicles were subject to the initial version of FMVSS 215;
3. 1974-1978 model years--For these years, most vehicles had to meet both barrier- and pendulum-test requirements (note that various versions of the performance requirements applied for certain model years); and
4. 1979 model year--Limited-damage criterion applicable for barrier and pendulum tests.

Age of Car

Both one-year-old and three-year-old vehicles were analyzed. These ages were selected since appropriate data were available for both the prestandard and poststandard vehicle models.

Impact Points

A bumper-related claim was defined as a claim in which damage occurred to the face bar and the direction of impact was one of four different categories: front, front corner, rear, or rear corner. Additional data were tabulated for other categories: side impacts, other impact points (includes front and rear impacts for which the face bar did not require repairs), and all claims regardless of impact point.

Vehicle-Size Class

Size class designations are those as defined by the Highway Loss Data Institute (HLDI). The four levels of stratification are as follows:

Vehicle Size	Wheelbase (WB) Length (in)
Subcompact	WB ≤ 101
Compact	101 < WB ≤ 111
Intermediate	111 < WB ≤ 120
Full sized	WB > 120

Bumper Damage

Two levels of bumper damage were tabulated: bumper repaired and bumper replaced. Bumper damage was defined as damage to the face bar of the bumper. If a vehicle had any part of the bumper assembly replaced or parts both repaired and replaced, then the claim was categorized as a replaced claim. Since vehicle speed is not directly obtainable from the data base, bumper damage was an attempt to define a surrogate measure of relative impact speed of crashes that resulted in claims. Claims that showed that the bumper had only been repaired indicate a relatively lower-impact speed than claims where the bumper was replaced. Although bumper damage itself is not a criterion of FMVSS 215, the effectiveness of the standard will be judged, in part, by any change in bumper-repair costs. Hence, the damage resistance of the bumper system itself becomes an important factor.

Measures of Effectiveness

Although the primary purpose of FMVSS 215 is to prevent low-speed collisions from impairing the safe operation of vehicle systems, standardized and strengthened bumpers should effect crash damage in general. Thus, vehicles that meet the bumper requirements should experience proportionally fewer incidents that require insurance claims. In addition, the total cost of repairs as a result of all crashes (including unreported) should be reduced.

Hence, the measures of effectiveness are (a) proportion of bumper-related reported claims and (b) costs of these reported claims. The analysis of reported claims will determine if the proportions of claims by vehicles in the different comparison periods have changed significantly for various stratifications. The costs of reported damage claims will determine if average repair costs for vehicles of the different comparison periods have changed due (in part) to the effect of FMVSS 215.

CLAIM ANALYSIS

By using claims as a measure of effectiveness, this analysis aims to determine whether or not the bumper standards have significantly altered the proportion of bumper-related claims. Hypothesis tests on the difference between claim proportions are applied to indicate the effectiveness of the standards.

Analysis of Bumper-Related Claim Trends

The percentage of total insurance claims that are bumper related for the individual model years during their first year of exposure is presented in Figure 1. For ease of presentation, the vehicle-size class stratification has been collapsed to form the economy (subcompact and compact) and standard (intermediate and full-sized) categories. Important observations from this trend graph include the following:

1. The prestandard (1972) model-year's proportion of bumper-related claims is greater than any poststandard (1973 or later) model year.
2. The initial standard (1973) model-year's proportion of bumper-related claims is greater than any subsequent model year. The initial version of the standard required only a barrier-impact test (5-mph front and 2.5-mph rear-impact speeds). For the following model years, the performance criteria were upgraded to include a pendulum test and a 5-mph impact speed for the rear bumper during the barrier test (see Table 1).
3. Economy and standard vehicles maintain the same trend characteristics between individual model years. The proportion of bumper-related claims for standard vehicles has been less than that of economy vehicles for each model year except 1979.

In general, the bumper-related claim trend of one-year-old vehicles can be described as decreasing with each model year from the prestandard (1972) model year until the poststandard (1975) model year. The following years (1976-1978) experienced increases with each model year and then declined for the 1979 model year.

These trends clearly indicate that the imposition of the bumper standard has influenced the claim experience of these model years. However, these trends are also influenced by other factors, such as the distribution of claims by coverage type (i.e., collision or liability), the influx of imported vehicles and an overall shift to a fleet of smaller vehicles, changes in vehicle design (particularly the use of elastomeric materials and one-piece multifunctional fabrication of bumpers and their related vehicle features), and other changes in the

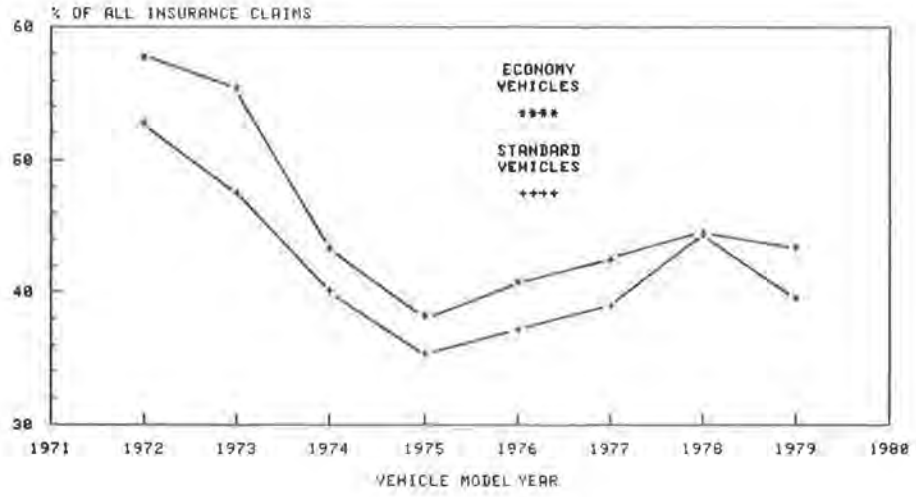

Figure 1. Claim distribution—bumper-related claims.

driving environment in general.

The following analysis compares in detail the claim trends subjected to vehicle-size class and impact-point stratification. The 1974-1978 model years are grouped for this detailed analysis as they were all subject to some version of the barrierand pendulum-impact tests (see Table 1) with the same performance criteria.

Analysis of Claim Distributions

Table 2 presents the percentage of claims that are bumper related and the principal point of impact of these claims for the vehicles that comply with the different versions of FMVSS 215. The claim percentages are tabulated for the front-center, front-corner, rear-center, rear-corner, and side (not bumper-related) impacts. The total bumper category is the sum of the four front- and rear-impact points and constitutes the total proportion of claims that are bumper related. The hypothesis test for differences in proportions (percentages) relative to the prestandard (1972) model year has been applied, and statistically significant differences are indicated in the table.

(A possible bias is introduced because the sum of the percentages of the size class impact-point distribution must equal 100 percent. A bumper design change may result in an expected reduction in the percentage of front of rear damage claims and therefore increase the percentage of side involvement. No adjustment is applied at this time because it would tend to enhance any claim frequency reduction that may exist in the data.)

One-Year-Old Vehicles

Comparisons of claim distributions for the different model-year groupings for one-year-old vehicles are presented in Table 2. This table compares the 1973, 1974-1978, and 1979 model years with the prestandard (1972) model year. Comparing the claim percentages for the prestandard (1972) model year with the poststandard (1973) model year during their first year of exposure showed that the proportion of front-impact claims was significantly reduced for the poststandard vehicles for all market classes. The 1973 version of the standard introduced barrier-impact performance criteria for the front and rear bumper. However, the criterion for the front bumper was 5 mph while for the rear bumper it was at 2.5 mph. The 1973 model-year results for the other impact points (front corner, rear, and rear corner) were not consistent for all market classes, as explained below.

1. Subcompacts and compacts experienced an increase in both rear and rear-corner impact claims, where most of these increases are statistically significant. There were significant reductions for the front-corner impact point.
2. Intermediate vehicles indicated reductions for front-corner and rear impacts and an increase for rear-corner impacts, none of which were significant, although the total bumper-related claim percentage has been significantly reduced for the 1973 model year.
3. Full-sized vehicles exhibited a significant reduction for the rear-impact point claims and a significant increase for rear-corner claims for the 1973 model year. However, the total percentage of bumper-related claims has been significantly reduced for the 1973 model year.

Thus, for all bumper-related claims, the total claim percentages were reduced to a greater extent as vehicle size increased for the 1973 model year.

The upgraded versions if the standard that applied to the 1974-1978 model years introduced the pendulum-impact test and increased the performance requirement of the barrier test of the rear bumper to 5 mph. Table 2 also compares prestandard (1972) to poststandard (1974-1978) model years and showed significantly lower claim percentages in all front, front-corner, and rear-center claims for all size classes. In addition, all size classes showed significantly lower percentages for the total of all bumper-damage claims. In comparing the model years that represent two versions of the standard--the 1973 with the upgraded 1974-1978 version--vehicles of the later model years (1974-1978) indicated significant reductions in claim percentages primarily for the front-corner, rear-corner, and rear-center impact points. The front impact point experienced both increased and decreased percentages, although only the decrease for intermediate vehicles was significant. (Note, although not shown in Table 2, significance tests at the 5 percent level were conducted comparing the sets of poststandard model-year data.) Since the 1974-1978 version of the standard introduced the pendulum test and an improved rear bumper, these results are consistent

Table 2. Claim distribution for one-year-old vehicles by model year.

		Distribution of Claims by Impact Point (percentage of all claims)						
		Bumper Related (bumper repaired or replaced)						
Vehicle-Size Class	Model Year	Front	Front Corner	Rear	Rear Corner	Total	Side	All Claims[a]
Subcompact	1972	16	21	14	9	60	28	100
	1973	12[b]	19[b]	15	13[b]	59	28	100
	1974-1978	11[b]	17[b]	8[b]	8	45[b]	36[b]	100
	1979	12[b]	14[b]	8[b]	7	41[b]	35[b]	100
Compact	1972	13	21	13	8	56	32	100
	1973	9[b]	19[b]	15[b]	10[b]	55	34	100
	1974-1978	10[b]	16[b]	7[b]	9	42[b]	39[b]	100
	1979	11[b]	12[b]	7[b]	7	37[b]	37[b]	100
Intermediate	1972	13	20	11	9	53	36	100
	1973	10[b]	18	11	10	49[b]	38	100
	1974-1978	8[b]	14[b]	8[b]	9[b]	39[b]	42[b]	100
	1979	11	11[b]	10	11	42[b]	39	100
Full sized	1972	12	19	13	9	53	35	100
	1973	7[b]	17	10[b]	13[b]	46[b]	39[b]	100
	1974-1978	7[b]	14[b]	7[b]	10	38[b]	44[b]	100
	1979	8	16	9	12	45[b]	40	100

[a]All claims include all bumper-related claims, side-impact claims, and other impact-type claims.
[b]Null hypothesis of equal proportion relative to the prestandard (1972) model-year data rejected at 5 percent significance level.

with the intent of the standard. In addition, all vehicle classes experienced significant reductions for the total percentage of bumper-related claims from the 1973 to 1974-1978 model-year data.

Beginning with the 1979 model year, the performance criteria of the barrierand pendulum-impact tests were amended to limit damage of all vehicle surfaces, including the bumper itself. The previous versions of the standard only afforded protection to vehicle safety features. The claim data for the 1979 model year are included in Table 2 and indicated significantly lower claim percentages for the total of all bumper claims for all size classes relative to prestandard vehicles. In reviewing the bumper-related trend (Figure 1), the 1979 model year is significant in that it reverses a pattern of increases in the percentage of bumper-related claims between the 1975 and 1978 model years. A detailed comparison for the 1979 model year with the 1978 model year is presented in Table 3. This comparison indicates significant decreases in the proportion of claims that are bumper related for subcompact and compact vehicles between the two model years. These decreases are concentrated in the front-corner and rear-corner impact points. Comparisons of the intermediate and full-sized vehicle classes indicate no significant pattern of differences between the two model-year's claim experiences.

Three-Year-Old Vehicles

The detailed results for three-year-old vehicles can be found elsewhere (1). In general, the data exhibit similar trends as the one-year-old vehicle damage-claims comparisons: front-impact claim percentages were reduced in the 1973 version and rear-impact claim percentages were reduced in the upgraded 1974 version. However, fewer reductions were statistically significant. Yet, some statistically significant reductions remained evident relative to the prestandard model year (1969). These reductions included percentages of most front-impact claims of the 1973 model year, rear-impact claims of the 1974 model year (except subcompact), and the total claim proportion for all size classes for both the 1973 and 1974 model years. In comparing the claim percentages of the 1973 model year with that of 1974, few differences were statistically significant except for rear-impact claims for subcompact and compact vehicles and the total claim proportion of subcompact vehicles.

The results of the three-year-old vehicles may be influenced by the fact that the 1974 model year was the only available data to represent the upgraded versions of the standard. However, it appears that even after three years of exposure, the imposition of a bumper standard has influenced claim experience.

Repaired and Replaced Bumper Claims

In this analysis, the relative contribution of repaired and replaced bumper claims to the combined bumper-claim distributions were examined for the different model years. It might be hypothesized that these stratifications represent surrogate measures of the impact speeds. Claims that involve bumpers repaired are considered lower-speed impacts relative to claims that involved bumper replacement.

Table 4 indicates the percentage of claims that involve bumpers repaired versus bumpers replaced for all vehicle-size classes. It is clear that the overwhelming percentage of bumper claims for all size classes resulted from replaced rather than repaired bumper claims.

In comparing prestandard (1972) with poststandard (1973) model years for one-year-old vehicles, the percentage of repaired bumper claims generally increased while the percentage of replaced bumpers decreased significantly. The latter of these trends becomes more pronounced when comparing the latter poststandard (1974-1978 and 1979) vehicle claims with the prestandard (1972) data. Between the poststandard vehicles, replaced claim percentages significantly decreased.

For three-year-old vehicles (4), replaced bumper claims decrease for the improved bumpers on vehicles in almost all cases. Repaired bumper claims show an increase for some market classes between the prestandard (1969) and poststandard (1973) model years. In general, there is a shift from replaced bumper claims to repaired bumpers. This shift, however, cannot account for the total change in the two damage categories, since there is a larger reduction in replaced bumpers than there is an increase in repaired bumpers. Some of the shift may, therefore, be accounted for by an increase in accidents that sustain no damage or, at least, do not require that the bumper be repaired or replaced. The shift appears to be more pronounced in the poststandard model-year comparisons. Thus, the major effect of the reduced frequencies is due to a decrease in replaced bumper claims.

COST ANALYSIS

The cost analysis examined the average claim costs of the model years that represent the different versions of the standard. All costs were adjusted to the base economic year (1972) by using a discount rate of 10 percent/year (4). The statistical test applied was the t-test of significance between means. The experimental hypothesis is that there is no difference between the average repair costs being compared. However, an increase in average repair cost for reported crashes (as measured by this study) may in fact be expected. If a bumper stan-

Table 3. Claim comparison of one-year-old vehicles for 1978 and 1979 model years.

Vehicle-Size Class	Model Year	Distribution of Claims by Impact Point (percentage of all claims)						
		Bumper Related (bumper repaired or replaced)						
		Front	Front Corner	Rear	Rear Corner	Total	Side	All Claims[a]
Subcompact	1978	11	19	9	8	47	33	100
	1979	12	14[b]	8	7	41[b]	36	100
Compact	1978	10	15	8	9	42	37	100
	1979	11	12	7	7[b]	37[b]	37	100
Intermediate	1978	9	16	9	10	45	39	100
	1979	11	11[b]	10	11	43	39	100
Full sized	1978	9	16	9	10	43	45	100
	1979	8	16	9	11	45	40	100

[a]All claims include all bumper-related claims, side impact claims, and other impact-type claims.
[b]Null hypothesis of equal proportion rejected at 5 percent significance level.

Table 4. Comparison of repaired and replaced bumper claims for one-year-old vehicles.

Vehicle-Size Class	Model Year	Claim Proportion (percentage of all claims)			Avg Repair Cost (1972 $)		
		Repaired	Replaced	Total Bumper Related	Repaired	Replaced	Total Bumper Related
Subcompact	1972	3.5	56.8	60.3	172	331	322
	1973	6.0[a]	52.5[a]	58.5	230[b]	341	331
	1974-1978	5.7[a]	39.0[a]	44.6[a]	218	423[b]	398[b]
	1979	6.8[a]	34.4[a]	41.2[a]	188	410	379
Compact	1972	5.3	50.5	55.8	196	383	365
	1973	6.0	47.4[a]	53.4	230	345[b]	333[b]
	1974-1978	5.6	36.6[a]	42.2[a]	227	425[b]	400[b]
	1979	4.8	32.4[a]	37.2[a]	220	507[b]	470[b]
Intermediate	1972	5.6	47.3	52.8	150	371	348
	1973	6.2	42.6[a]	48.9[a]	219[b]	395	372
	1974-1978	4.0[a]	35.0[a]	39.0[a]	224[b]	412[b]	394[b]
	1979	4.5	38.0[a]	42.5[a]	183	395	373
Full sized	1972	4.8	48.1	52.9	163	376	357
	1973	5.3	40.9[a]	46.2[a]	193	400[b]	376
	1974-1978	4.2[a]	34.0[a]	38.1[a]	218	414[b]	393[b]
	1979	6.2[a]	39.1[a]	45.3[a]	230	424	402

[a]Null hypothesis of equal proportion relative to the prestandard (1972) model-year data rejected at 5 percent significance level.
[b]Null hypothesis of equal average costs to the prestandard (1972) model-year data rejected at 5 percent significance level.

dard is effective in reducing the percentage of insurance-reported incidents, those reported that remain may involve, on average, repairs to more severe crash damage.

Claim Cost Trends

Figure 2 presents the average total repair cost of all bumper-related claims for each individual model year during their first year of experience. Vehicles have been grouped as before into the economy or standard categories. Unlike the claim trends, the cost trends between the individual model years were not similar between economy and standard vehicles. The overall trend of higher costs for the later model years (after an inflationary adjustment) holds true for both vehicle categories. However, if the imposition of the bumper standard has influenced claim frequency by eliminating low-speed crash-damage claims from the distribution, then this result is to be expected. The previous analysis has indicated that a significant percentage of low-speed crashes were missing from the claim distribution. These missing claims probably were the result of insufficient damage for a claim or no vehicular damage being produced from a crash. Hence, the elimination of these low-speed, low-cost claims would tend to shift the distribution of claim costs and the average of the total repair costs higher.

One-Year-Old Vehicles

Table 5 shows the comparison of the average cost of repairs for one-year-old vehicles relative to the prestandard (1972) model year (all costs adjusted for 10 percent inflation rate in 1972 dollars). In comparing prestandard (1972) with poststandard (1973) model years, the costs for the poststandard (1973) vehicle claims were, in general, higher for all size classes (except compact). Claims for front impacts consistently showed significant increases in repair cost for the models after the initial implementation of the standard while changes in costs for other impact points varied from size class to size class.

Poststandard (1974-1978) model-year repair costs showed significantly higher average repair costs for most front-impact points relative to prestandard costs. Moreover, the average cost of total bumper-related claims was significantly higher for all market classes. Assessment of the incremental cost increases between the two versions of the standard was also statistically compared and indicated that subcompact and compact vehicles exhibited significant increases in total bumper-related claim costs. The poststandard (1979) model year average repair claim costs are significantly higher than the prestandard (1972) model year for the front-impact claims of subcompacts and compacts and the total bumper-related claims of compacts. In a comparison with the previous (1978) model year's experience (shown in Table 6), the only size class with consistently higher average claim costs was compact vehicles (all costs adjusted for 10 percent inflation rate in 1972 dollars). Intermediate and full-sized vehicles experienced lower average claim costs for most impact points relative to the 1978 model year. However, neither of these trends proved statistically significant.

Three-Year-Old Vehicles

Poststandard (1973) average repair costs compared with prestandard (1969) costs showed decreased repair costs (4). The decrease was significant only for the rear-corner impact and total of all bumper claims for full-sized vehicles. For poststandard (1974) vehicles, average costs were generally higher than the prestandard data, particularly for the subcompact or compact classes. However, there was a general trend (significant for compact total bumper claims) of increased costs for the total of all bumper claims from the 1973 to 1974 model year.

Thus, an initial decrease in average cost with the introduction of the standard (1973 model year) has been offset somewhat with the upgrading of the standard (1974 model year). The resultant effect of the two stages of the standard was a general increase (not statistically significant) in the average repair costs.

Repaired and Replaced Bumper Claims

Table 4 presented the average claim costs for repaired and replaced bumpers for one-year-old vehicles. The average costs are all in terms of a 1972 economic year, adjusted by using a 10 percent/year inflation rate.

The comparisons show that for one-year-old vehicles both replacement and repair costs were higher

for the poststandard model years. Between poststandard vehicles, repaired bumper costs have remained about the same and replacement costs have increased.

For three-year-old vehicles (4), some repair costs have increased and all replacement costs have decreased from the prestandard to the initial poststandard (1973) model year. Between poststandard model years, repair costs have remained about the same but replacement costs have increased. Thus, the pattern of cost variation between poststandard model years is mainly attributed to increased costs of bumper-replacement claims.

FINDINGS AND CONCLUSIONS

The primary findings and conclusions obtained in this study are as follows:

1. Statistically significant reductions in the proportion of bumper-related front-impact claims were indicated for the initial poststandard vehicles (1973) that were subjected to barrier-test require-

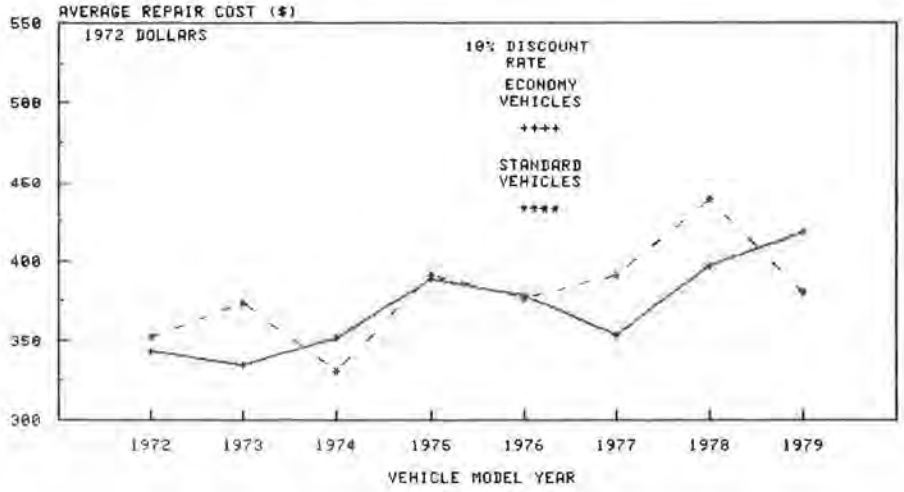

Figure 2. Average repair cost–bumper-related claims.

Table 5. Average repair cost comparison for one-year-old vehicles by model year.

Vehicle-Size Class	Model Year	Bumper Related (bumper repaired or replaced) Front	Front Corner	Rear	Rear Corner	Avg	Side
Subcompact	1972	375	349	248	277	322	232
	1973	445[a]	344	300[a]	242	331	228
	1974-1978	525[a]	413[a]	293[a]	295	398[a]	227
	1979	519[a]	359	287	292	379	250
Compact	1972	405	425	272	292	365	240
	1973	485	341[a]	268	276	333[a]	254
	1974-1978	541[a]	414	293	306	400[a]	235
	1979	625[a]	457	325	409	470[a]	248
Intermediate	1972	409	376	293	286	348	247
	1973	469	402	285	316	372	245
	1974-1978	516[a]	411[a]	296	338[a]	394[a]	221[a]
	1979	468	382	330	314	373	235
Full-sized	1972	416	376	317	286	357	233
	1973	521[a]	386	346	308	376	255
	1974-1978	529[a]	425[a]	333	288	393[a]	226
	1979	514	448	307	331	402	294

[a]Null hypothesis of equal proportion relative to the prestandard (1972) model-year data rejected at 5 percent significance level.

Table 6. Average repair cost comparison of one-year-old vehicles for 1978 and 1979 model years.

Vehicle-Size Class	Model Year	Average Repair Cost by Impact Point[a] ($) Bumper Related (bumper repaired or replaced) Front	Front Corner	Rear	Rear Corner	Avg	Side
Subcompact	1978	525	409	285	275	389	228
	1979	519	359	287	292	379	250
Compact	1978	563	423	279	306	405	235
	1979	625	457	325	409	470	248
Intermediate	1978	592	414	372	345	428	241
	1979	468	382	330	314	373	235
Full Sized	1978	663	489	393	290	461	250
	1979	514	448	307	331	402	294

[a]Null hypothesis of equal proportion relative to the prestandard (1972) model-year data rejected at 5 percent significance level.

ments as compared with prestandard vehicles (1972 or earlier).

2. Consistent with the intent of the 1974 (and later) version of the standard, which introduced the pendulum test (front, rear, and corner impacts) and upgraded the rear-barrier test speed to that of the front, the 1974-1978 vehicle model years showed significant reductions in the proportion of bumper-damage claims, primarily for corner and rear impacts, when compared with the poststandard (1973) model year. In addition, the proportion of front and rear-center bumper-damage claims and the total proportion of bumper-damage claims for all vehicle-size classes of the poststandard (1974-1978) model years were significantly lower when compared with the prestandard (1972) model year.

3. The 1979 model year, which introduced the limited-damage criterion as a result of FMVSS 215 impact-test requirements, experienced statistically significant reductions for the total proportion of bumper-damage claims for the subcompact and compact vehicle classes when compared with the previous years' damage claims. When compared with the prestandard (1972) model year, all vehicle classes experienced significantly lower damage claim percentages.

4. Claims for poststandard model years showed higher average repair costs when compared with the prestandard (1972) model year. The increases were statistically significant for most front-impact claims and for the total of all bumper-damage claims of all vehicle-size classes of the 1974-1978 model year comparison. Comparison of claim costs between poststandard model years resulted in few significant differences.

5. Reduced claim trends of the model-year comparisons and increased average claim costs were generally attributable to claims that involve replacement of the bumper rather than those that involve only bumper repairs.

In reviewing these conclusions, several points must be noted. First, if the standard has, in fact, been effective in reducing low-speed, low-cost crash damage, the cost distribution would be influenced. As a result of protective bumpers, the low-cost crash-damage claims would disappear from the low end of the cost distribution of reported damage and the average claim dollar amount would tend to increase. Thus, the claim and cost trends noted are not necessarily independent. In addition, the mixture of claim types (collision with deductible of $100 or greater, collision with deductible less than $100, and property-damage liability) experienced by State Farm policyholders has changed in more recent years to include a larger percentage of collision claims with higher deductible amounts. This pattern would also produce higher average claim costs due to the more expensive nature of collision claims as well as the higher deductible amounts. A final important point is that the bumper standard only specified performance criteria, not design criteria. Manufacturers still determine the specific bumper design. Thus, this study truly only evaluates the performance of those designs chosen by the manufacturers.

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Present Status of Inertia-Collection System

LARS Th COLLIN

The inertia-collection (INCOLL) concept for engine emission checking is based on transients that use inertia forces as braking torque. Thus, the emission-control systems developed for cars during the late 1970s have necessitated a further development of the INCOLL system. It is shown that the method has a high potential of predicting federal test procedure results. Results from official tests of the INCOLL system in the United States are presented together with some indications of results from similar tests in Europe, as well as the prospects for the further development of the method.

The purpose of this paper is to describe the present status of the inertia-collection (INCOLL) method and to present results achieved by the U.S. Environmental Protection Agency (EPA) in Ann Arbor, Michigan, in 1980, as well as other activities during the past few years.