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DOT HS-802 344

FINAL DESIGN AND IMPLEMENTATION PLAN FOR EVALUATING THE EFFECTIVENESS OF FMVSS 215: EXTERIOR PROTECTION

Contract No. DOT-HS-6-01518

May 1977

Final Report

PREPARED FOR:

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
WASHINGTON, D.C. 20590

Prepared for the Department of Transportation, National Highway Traffic Safety Administration, under Contract No.: DOT-HS-6-01518. This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-802 344		

4. Title and Subtitle	5. Report Date
FINAL DESIGN AND IMPLEMENTATION PLAN FOR EVALUATING THE EFFECTIVENESS OF FMVSS 215: EXTERIOR PROTECTION	May 1977
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No. CEM Report 4207-565
9. Performing Organization Name and Address The Center for the Environment and Man, Inc. 275 Windsor Street Hartford, Connecticut 06120	10. Work Unit No.
	11. Contract or Grant No. DOT-HS-6-01518
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration 400 Seventh Street, S.W. Washington, D.C. 20590	13. Type of Report and Period Covered Tasks #4 & #5 Report 10/76 - 3/77
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report covers the final design and implementation plan for evaluating the effectiveness of FMVSS 215 (Exterior Protection). The plan for the evaluation study considers measurability criteria, alternative statistical techniques, data availability/collectability, resource requirements, work schedule, and other factors. The Standard applies to front and rear bumpers, and is designed for effectiveness at low speeds (up to 5 mph). One major problem is that low speed accidents are much less likely to be reported. Therefore, the effects of the Standard are not expected to be directly discernable in mass accident data. The plan described herein will concentrate on the following sources of data: (1) Insurance records of the frequency of crash parts demand in repair bills. (2) Survey of new and older car owners using a mailed questionnaire. (3) Inferential use of mass accident data for confirmation. No single data source is expected to provide the principal basis for the evaluation. Up to 60,000 mailed questionnaires are likely to be needed in this car owner's survey to perform the evaluation at all the desired levels of stratification and within the acceptable confidence limits.

17. Key Words	18. Distribution Statement
Federal Motor Vehicle Safety Standards FMVSS 215, Bumper Evaluation Bumper Bumper Standard Statistical Methods	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

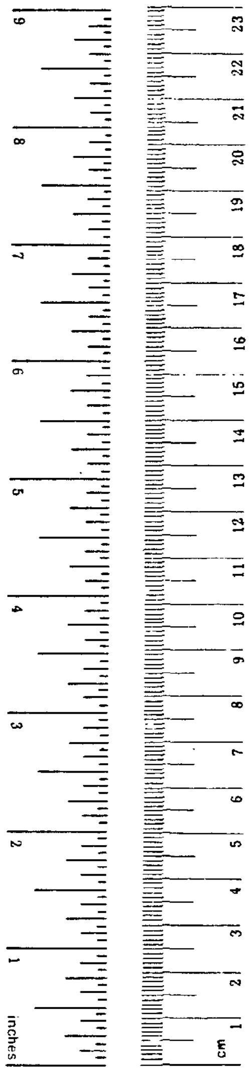
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassfied	71	

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

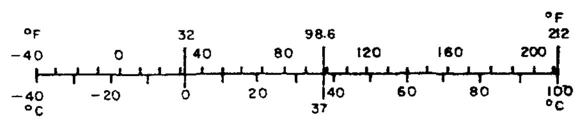
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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

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



Approximate Conversions from Metric Measures

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



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ABBREVIATIONS USED

AMC	American Motors Corporation
FMVSS	Federal Motor Vehicle Safety Standard
GAO	General Accounting Office
GM	General Motors Corporation
HLDI	Highway Loss Data Institute
HSRC	Highway Safety Research Center of the University of North Carolina
IIHS	Insurance Institute for Highway Safety
NCSS	National Crash Severity Study
NHTSA	National Highway Traffic Safety Administration
OMB	Office of Management and Budget
SPSS	Statistical Package for Social Sciences
TAD	Traffic Accident Data
VW	Volkswagen

1.0 INTRODUCTION

This report is the second in a series of four reports which contain the final design and implementation plan for evaluating the effectiveness of each of four selected Federal Motor Vehicle Safety Standards (FMVSS). The four selected FMVSS which have been examined are:

- FMVSS 214 - Side Door Strength
- FMVSS 215 - Exterior Protection
- FMVSS 301 - Fuel System Integrity
- FMVSS 208 - Occupant Crash Protection.

This report contains the final design and implementation plan for evaluating the effectiveness of FMVSS 215 - Exterior Protection.

1.1 Background

This Standard has changed considerably since it first became effective on September 1, 1972. The increasingly stringent crash test requirements created considerable difficulty and there were numerous modifications and exemptions, especially for specialty cars (sports, vintage, etc.). In March 1976 a new Bumper Standard (Part 581 of Title 49) was issued under the authority of Title I of the Motor Vehicle Information and Cost Savings Act. Manufacturers presently can comply under either FMVSS 215 or Part 581; however, beginning September 1, 1978, Part 581 is mandatory, with its broader damageability standards. Table 1-1 below shows the major changes to FMVSS 215 as they apply to vehicle model years.

TABLE 1-1
APPLICABILITY OF THE STANDARD BY MODEL YEAR*

Model Year	Exterior Protection Standard Requirements
pre-1973	• No requirements.
1973	• 5 mph front; 2.5 mph rear barrier crash.
1974	• Horizontal pendulum test added over 115" wheelbase. • Rear barrier crash increased to 5 mph.
1975	• Number of horizontal pendulum impacts reduced to 2 front and rear. • Horizontal pendulum test for all cars.
1976	• Corner impact test for cars less than 120" wheelbase.
1977	• Corner impact test for all cars more than 120" wheelbase.
1979	• FMVSS 215 superseded by Part 581 - Bumper Standard, which increases damageability standards.

*Some changes in the Standard may have gone into effect after the start of a model year so that in that year some models may not have satisfied the Standard.

Purpose of FMVSS 215

- The specific purpose is to establish requirements for impact resistance and the configuration of front and rear bumpers.

- The general purpose is to prevent low-speed accidents from impairing safe operation of the vehicle and to reduce the frequency of override and underride in higher speed collisions.

  [The new Bumper Standard (Part 581) deals with reducing all physical damage to the front and rear of the vehicle.]

General Requirements of FMVSS 215

The current Standard requires both pendulum and barrier crash tests. Earlier versions (see Table 1-1) exempted certain vehicles or had lower criteria. Generally, the test conditions are:

- Two pendulum tests
  - The longitudinal impact test consists of impacting the front and rear bumper surface two times each at 5 mph with an impacting mass equal to the weight of the vehicle.
  - The corner impact test consists of impacting the front and rear corner twice each at 3 mph at an angle of 60 degrees from the longitudinal centerline of the vehicle.

- Barrier test
  - Two fixed barrier collisions with the vehicle traveling at 5 mph, once forward, once in reverse.

Generally, the protective criteria are that safety equipment not be impaired; hood, trunk and doors operate normally; there are no leaks from fuel, cooling, exhaust or energy-absorbing systems; vehicle mechanical systems remain normal; and that the test device impact only on its impact ridge.

Measures of Effectiveness

The primary purpose of the bumper Standard FMVSS 271/215 is to prevent low speed collisions from impairing the safe operation of vehicle systems and to reduce the frequency of override or underride in higher speed collisions. As a consequence, the cost of repairs to vehicles as a result of low speed collisions is expected to be reduced and economic advantages to the consumer would be realized directly through less cost and convenience of necessary repairs, and indirectly through reduced cost of insurance. Reduced damage in highway accidents could reduce traffic tie-ups and, hence, result in fewer secondary accidents.

Performance measures used to insure that safety related items are not rendered inoperable include pendulum and barrier impact testing of the bumper system. The safety-related requirements are:

- Reflectors not be cracked, and lamps (excepting license plate lights) not be damaged beyond adjustability.
- Hood, trunk and doors operate in a normal manner.
- Fuel and cooling systems develop no leaks or constrictions and caps and seals remain unaffected.
- Exhaust systems develop no leaks or constrictions.
- The propulsion, suspension, steering and braking operate in a normal manner.
- The impact device should not strike the vehicle <u>except</u> along a specified impact ridge.
- The energy-absorbing impact device should not suffer any loss of gas or liquid.

<u>Means of Complying with the Standard</u>

FMVSS 215 for front and rear bumpers has undergone considerable revision since it first became effective on September 1, 1972. The elimination or reduction of damage resulting from low-speed impacts requires the application of the basic principle of energy absorption. A variety of approaches and methodologies has been suggested and/or utilized including various torsional systems, mechanical systems, or energy-absorbing materials. The energy-absorbing materials used are springs, pneumatic shock absorbers, plastic foams, etc.

A listing of the major means for compliance that have been used or suggested include the following [1, 2, 3, 4].

- Full-width steel reinforcement behind a bumper attached to rubber block which is energy-absorbing. *(Chrysler)*
- Steel beams on both sides of vehicle support steel bumper and are connected to energy-absorbing devices consisting of prestressed rubber (slabs which stretch or shear upon impact). *(Ford)*
- U-shaped steel bumper which contains energy-absorbing cellular plastic blocks in the interior of the bumper. *(Saab)*
- Reinforced steel bumpers with external rubber guards attached to energy-absorbing hydraulic/pneumatic cylinders on either side of the car. *(General Motors)*
- Soft-faced front end of elastomeric material such as urethane which is energy-absorbent. *(General Motors)*
- Steel cable bumper decelerator which rides freely over car frame extensions and alters the direction of energy absorption from longitudinal to transverse.

Systems designed to meet the Standard can be classified as either (a) returnable: spring, spring and shock absorber (hydraulic), state-of-the-art bumper material (metallurgy) with or without any combination of the above, elastomeric bumper materials with or without the above, or (b) non-returnable: shock absorber types which are either rechargeable or reset by hand, or deformable energy absorbers which must be replaced after collision to bring them to their original manufactured state. The most frequently used compliance method in recent model years has been the returnable energy-absorbing hydraulic/pneumatic cylinder.

Primary and Secondary Effects of Compliance

The primary effect of the Standard is to reduce or eliminate vehicle damage and prevent impairment to the safe operation of the vehicle for the following low speed (5 mph or less) crash situations.

- Front end, rear end and front and rear angular collisions with fixed objects at least the height of the bumper.

- Head-on collisions between vehicles with equal bumper heights on a surface allowing them to be level with respect to each other (except for very large differences in mass of two vehicles).

- Collisions where bumper mismatch does not result when the rear colliding vehicle is pitched due to braking, crown of road, and/or inclining or declining grade.

- Angular collisions between vehicles (front-to-front, rear-to-rear and front-to-rear) that are level with respect to each other, within a maximum angle.

A number of potentially significant secondary effects can be noted. The new bumper designs have more complicated interfaces with other systems such as the radiator, grille and lights. In higher speed crash situations not covered by the Standard, the cost of damage sustained to the bumper and interface components may be higher. Because of the greater protrusion of some new bumpers which meet the Standard, the complying vehicle may cause greater damage in higher speed collisions.

Real-World Performance of the Standard

Comparison of the desired effects of Standard FMVSS 215 indicate the following areas to be considered in actual vehicle operating conditions.

- The desired bumper match may not occur under the conditions of uneven roadways; particularly on crowned roads at intersections, and also when there is considerable vehicle pitch due to weight transfer caused by acceleration and braking. Also, a dangerous load mismatch may occur when a bumper end strikes another bumper surface at an angle causing high unit load force and local deformation.

- The strengthened bumper may cause more severe penetration into the side and door structure of other vehicles at both low and high speed side impacts.

- Five mile per hour impact damage may result in extensive vehicle structural damage depending on bumper configuration and attachment methods employed, even though safety-related items are undamaged. This most probably might occur on unibody type vehicles having reduced strength capability at the bumper bracket attachment locations, as in smaller cars with relatively light frames.

- With the wrap-around projecting bumpers, "hooking" a front and rear bumper becomes a hazard.

1.2 Summary of Evaluation, Cost Sampling, and Work Plans

The plan to evaluate the effectiveness of FMVSS 215 will be concerned with up to five sources of data.

- State Farm Accident Data
- Car Owner Survey Data
- Mass Accident Data
- Towaway Survey Data
- HLDI Data

The Car Owner Survey and the Towaway Survey represent new data collections, while the other three samples are existing sources of accident data.

The data from the State Farm Mutual Automobile Insurance Company in Bloomington, Illinois, is a useful source of information with regard to damaged parts and their costs in collision claims resulting from accidents. This data is available from model year 1972 to the current model year (1977), and additional information on earlier model years back through 1968 will be added as available. Data will be stratified according to impact site, replacement part, market class, model year and accident year. Detailed contingency table analysis of front and rear parts replaced in pre- and post-Standard cars will be performed.

The last four data bases involve either the difficulties and expenses of data collection (Car Owner Survey and Towaway Survey) or serious problems in data analysis (Mass Accident Data and HLDI Data). The Car Owner Survey is designed to collect data regarding low speed, no-damage accidents that will not be found in police accident data. A mailing of about 60,000 survey questionnaires will be required to obtain 3000 cases, a sufficient sample to stratify by four market classes and five groupings of model years. The Mass Accident Data from states such as Texas, New York, and North Carolina will be analyzed to determine if there has been a shift in the distribution of vehicle damage away from bumper areas in cars with post-Standard bumpers. The contingency table analysis is complicated by lack of detailed information and an absence of standardization in reporting procedure. The Towaway Survey will be carried out with the cooperation of police-designated tow-truck operators. Information on front/rear involvement for about 2000 cars will be collected to determine if cars with post-Standard bumpers have a smaller percentage of front/rear involvement in towaway accidents.

A cost sampling plan has been developed to estimate costs as a function of the following cost categories: (1) direct manufacturing, (2) indirect manufacturing,

(3) capital investment (including testing), (4) manufacturers' markup,* (5) dealers' markup,* and (6) taxes.* "Out-of-pocket" costs are only loosely related to the items listed above and lifetime operating and maintenance costs are explicitly excluded. A frequency sampling plan has been proposed which considers vehicle manufacturer and market class. In consideration of data gathering costs, it is desirable to limit the number of models sampled. This necessitates making assumptions about the variance of cost data and the representativeness of the stratifications used. An experimental design has been formulated to gather data in two replications for six market classes during the model years 1972-1977.

The work plan for the evaluation study and cost analysis is carried out in six tasks. The work on all six tasks could be conducted simultaneously, since the tasks are basically independent of each other. However, in recognition that this might not be the most effective approach, four alternative plans (various combinations of tasks) for initial evaluation work are proposed. The six tasks and required resources are very briefly summarized below.

Task 1 is concerned with the acquisition and analysis of aggregated insurance claim data available from the State Farm Mutual Insurance Company. The six-month effort will require resources of 0.5 person-year and $1000 for computer processing. Task 2 deals with the collection of data through a mail survey which will permit an analysis of the effects of post-Standard bumpers in reducing or eliminating damage at low speeds. Resources of 1.6 person years, $65,000 for survey mailing and followup and $3000 for computer processing are needed in this 12-month study. Task 3 is directed toward processing and analyzing mass accident data. The 6-month study requires resources of 0.5 person year, and $3,000 for computer processing. Task 4 is concerned with the collection and analysis of towaway accident data. Resources of 0.5 person year and $30,000 for the cooperation of the towtruck operators (data collection) and $500 for computer work are required for the 16-month study. Task 5 deals with the analysis of HLDI data which contain the total amount of collision claims and detailed information on car models. The 6-month study requires resources of 0.5 person year and $1000 for computer processing. Task 6 is directed toward the determination of direct costs to implement FMVSS 215. Resources of 1.0 person year and $1000 for computer processing are needed for this seven-month effort.

*CEM considers that reliable information on these items for specific models is not available.

1.3 References for Section 1

1. Larousse, Rene, *Energy Absorption by Structural Deformation*, SAE Report No. 73007, January 8-12, 1973.

2. Hai, Wu, *A Study of Automotive Energy Absorbing Bumpers*, SAE Report No. 730024, January 8-12, 1973.

3. Compton, R. H., C. Westphal, Jr., and R. Crone, *Bumper Systems Soft Face vs. Model 1973 Steel System*, Motor Vehicle Programs (NHTSA), November 1974.

4. Appleby, Michael R., *Occupant Safety and Damageability Considerations Related to 1974 Automotive Bumpers*, SAE Report No. 740989, October 21-25, 1974.

2.0 APPROACHES TO THE EVALUATION OF FMVSS 215

The purpose of FMVSS 215 is to prevent damage to safety related parts of cars in low speed crashes. In addition, it is expected that damage to other parts will also be reduced.

The main problems with evaluating this Standard are:

(1) It is very specific in terms of the vehicle parts and systems to be protected, and

(2) It applies to low speed crashes, of which many are not reportable, and many of the reported ones are not investigated by the police or any other non-involved party.

To obtain information on damage to the vehicle parts covered by the Standard, at least the following approaches are potential candidates:

(1) Identify and investigate in detail low damage crashes.

(2) Analyze automobile insurance claims.

(3) Analyze sales of repair parts for the protected vehicle parts and systems.

(4) Analyze the frequency of towaway due to damage to the protected parts and systems.

(5) Analyze the frequency of front (or rear) impacts relative to all impacts in old accident data, because damage reduction may bring certain collisions below the reporting threshold.

The first approach encounters the second difficulty mentioned above: that low damage crashes are not reported. The question is: "How does one identify low speed crashes?" The leading possibility for identification suitable for statistical analysis is a survey of car owners. Even if the car owners respond to the survey, it is unlikely that more than rudimentary information on the crash be obtained. To obtain details on vehicle damage, a follow-up vehicle inspection would be required. It appears highly doubtful that a sufficient number of owners would agree to such inspection, if only because of the inconvenience involved. Furthermore, the expense of inspection would be very high. Another problem is that a specific car owner might not be aware of no-damage collisions in which other drivers in their household has been involved with the car.

The second approach--analysis of automobile insurance claims--is subject to the following problems:

(1) Automobile insurance policy holders are a biased sample, by company policy, and by owner choice. Also, automobile insurance claims for low damage crashes are a self-selected sample.

(2) The claims data automated by insurance companies are very limited. To retrieve detailed data from the hard copy files is inherently difficult and likely to be prohibitively expensive.

(3) Two distinctly different kinds of insurance deal with vehicle damage: collision insurance and property damage liability. The first is limited to damage to the insured vehicle (and also to damage to other vehicles driven by the insured), the second covers all property damage of third parties, including non-vehicle damage. In addition, the relation between claimant and insurance company in a liability case is adversary; therefore, information availability may be limited.

There appear to exist only two insurance data bases which are usable: Highway Loss Data Institute (HLDI) collision claim data, and detailed collision damage data sampled by State Farm Mutual Insurance Company.

HLDI data contain the total amount of a collision claim, detailed car model information, the applicable deductible, use of the car by a young driver, and rating area. Total claim figures are of extremely limited value: they reflect the influence of collision types, of repair parts cost, and of repair labor cost, in addition to the influence of the physical damage. It appears impossible to draw any specific conclusions on damage reduction due to FMVSS 215 from these data.

State Farm Mutual Insurance Company has analyzed samples of collisions claim repair bills beginning in 1973. Usually, these samples cover the current model year, but occasionally samples of <u>all</u> insured vehicles are made. For each case the damaged parts are identified. Comparing the frequencies of damage to certain parts between model years should allow a realistic estimate of changes in vehicle damage patterns.

The third approach would analyze sales of repair parts, including parts which are protected by the Standard. Certain parts, e.g., lenses to taillights, are model and model-year specific. Analyzing the time trends of sales of such parts in relation to parts not protected by the Standard could indicate an effect of the Standard. The main problems are: there are only few parts which are model/model year specific, and the manufacturer's sales records would have to be obtained. A statistical problem would be to account for fluctuating inventories held by distributors and dealers. Therefore, this approach appears to hold little promise.

The fourth approach uses the fact that some of the parts protected are necessary for the operation of the vehicle, such as fuel system, cooling system, propulsion system, steering and braking. If damage to them becomes less frequent, the need for towing crash-damaged cars should be reduced. Aside from the fact that towing is only indirectly related to the requirement of the Standard, this approach appears possible and promising.

The fifth approach would use existing mass accident data, beginning with 1972, and analyze the relative frequencies of front and rear impact accidents relative to all others. A reduction in damage might bring certain crashes below the reporting threshold and thereby reduce their relative frequency. Mass accident data from Virginia and New York suggest that a change in reporting requirements does indeed result in a change in actual reporting practice. Therefore, it is plausible that a reduction in damage will result in a reduction in reported accidents. An important advantage of this approach would be that it would analyze cars not satisfying the Standard when they were still new, and damage is more likely to be reported.

In summary, the most promising approaches for evaluating FMVSS 215 appear to be the following, listed in order of decreasing potential:

- Analysis of State Farm data, because they are available and provide a considerable level of detail, although they do not reflect all aspects of the objectives of the Standard.
- A mail survey of car owners to determine the frequency of no-damage (or, very minor damage) collisions, which generally to unreported.
- An analysis of current towaway accidents, which will address the question of vehicle functioning after a front or rear impact. A potential problem is that today all vehicles not meeting the standard are relatively old, and may be structurally weaker and/or driven by a different class of drivers, relative to the newer cars which meet the Standard.
- An analysis of existing mass accident data might possibly show an effect.

With the exception of the first, the above approaches are speculative, whether considered singly or in combination.

Two other possible approaches are rejected as having little promise. The analysis of sales of repair parts may encounter difficulty in data acquisition, and is unlikely to provide much information, even if data could be acquired. The HLDI data for damage costs are so highly aggregated that there appears little chance of success using that base to determine the effectiveness of FMVSS 215.

3.0 EVALUATION PLAN

3.1 State Farm Accident Data

Insurance data for crash-damaged automobiles are a unique source of information. The State Farm* data are a useful source of information with regard to the damaged parts and their costs in collision claims. State Farm started collecting such damage repair estimates regularly for the current models in January 1973, as part of their "Current Model Year Study." At that time similar information was also collected on selected 1972 vehicles. Some of these data were presented in *Patterns of Automobile Crash Damage* by Sorenson, Gardner and Cassassa [1]. They also take occasional samples of all claims during a certain period covering all model years.

In the 1973 Current Model Study, State Farm obtained information on 13,108 vehicles. The items of interest are:

- Point of impact:
  - Square front
  - Front corner
  - Right side
  - Other
  - Left side
  - Square rear
  - Rear corner
  - All
- Market class:
  - Subcompact
  - Compact
  - Intermediate
  - Full size
  - All
- Component replacement/repair:
  - Bumper cushion, front
  - Bumper cushion, rear
  - Bumper guards, front
  - Bumper guards, rear
  - Bumper mounting brackets,front
  - Bumper mounting brackets, rear
  - Energy absorber, front bumper
  - Face bar, front
  - Face bar, rear
  - Face bar, reinforcement, front
  - Face bar, reinforcement, rear
  - Fender, front
  - Fender, extension
  - Filler panel,front bumper (center)
  - Filler panel,front bumper (end)
  - Grille, complete
  - Grille, header panel
  - Grille, partial
  - Headlight
  - Hood
  - Radiator
  - Tail lamp,lens,or assembly†
  - Other parts not protected by the bumper‡

*State Farm Mutual Automobile Insurance Company, Bloomington, Illinois.

†Not all of these items would be included individually but would be grouped in many analyses. Those items which are most related to the exterior protection function of post-Standard bumpers are selected.

‡Replacement of these parts would be grouped together and would be used as a basis of comparison for the changes in bumper-related replacement frequency.

The basic form of the data for the contingency table analysis would be the number of cars with a designated set of characteristics--for example, 1973 cars with repaired bumpers, or a more detailed characteristic such as 1973 subcompact with front fender damage in square frontal impacts.

There are various drawbacks to use of the State Farm data. First, the data are based on collision claims, and normally collision and liability claims have a different mix of accident types with the former having more frontal and single vehicle accidents. Second, if the data are available only in aggregate form, then certain factors cannot be tested, such as the efficiency of different types of energy absorber.

3.1.2 Data Acquisition and Preparation

As was mentioned earlier, the data would have to be obtained from State Farm Mutual Automobile Insurance Compnay, other than those which have been published [1]. The raw data are understood to be proprietary information. However, some of the aggregated data for certain years have appeared in print. CEM has been informed that aggregated data for other years could be made available [2].

The preparation of the data for the contingency table analysis would amount to key punching and verifying. The absolute amount of data is not large--a total of 43 car parts, 7 impact points and 4 market classes for 1,204 items per model year. It would be desirable to analyze data for at least 1972 through the current model year (1977), as well as any additional information on earlier model years back through the 1968 model year. These data would be put on magnetic tape or disk for computer-aided analysis.

3.1.3 Data Analysis

The kind of data to be obtained is categorical. As examples, a bumper is or is not replaced; the point of impact is one of six places. Because the data are in categorical form, contingency table analysis is deemed most appropriate.

In contingency analysis, a table of observed data is established for all categories. For example:

Eye Color	Hair Color			Row Total	Row Variable
	Blond	Brown	Other		
Blue	30	50	20	100	R_1
Other	10	60	30	100	R_2
Column Total	40	110	50	N = 200	
Column Variable	C_1	C_2	C_3		

One then determines how many occurrences are expected in each cell according to his hypothesis, e.g., if it is wished to test whether or not hair color and eye color are related, one realizes that if they are not related, then one-half of the blonds in the sample should be blue-eyed since one-half of all the individuals in the sample are blue-eyed. A table of expected values is:

Eye Color	Hair Color		
	Blond	Brown	Other
Blue	20	55	25
Other	20	55	25

The Chi-squared statistic is, then,

$$\chi^2 = \sum_{\substack{\text{all} \\ \text{cells}}} \frac{(\text{Expected} - \text{Observed})^2}{\text{Expected}}$$

The hypothesis that gives the expected value is untenable if χ^2 is too large, i.e., if the difference between expected and observed frequencies is too large. What is too large is determined by looking up values in a χ^2 table with the appropriate number of degrees of freedom. The number of degrees of freedom is a technical problem, but the usual value is (r-1) (c-1) where r = number of rows and c = number of columns. For the eye-color/hair color example, the degrees of freedom equal 1 x 2 = 2.

The proposed analysis of State Farm data is similar to the above example, but more complex. Below is a simplified example of how contingency table analysis would be used. Suppose it is wished to do a contingency table analysis of the replacement of front bumpers in 1972 and 1973. The expected values are derived by the number of side impacts.* This number should not change from a change in bumper effectiveness. The total number of crashes is not used because if the bumper is effective, many low speed crashes will not be reported. From the collected data, a table like that below can be constructed:

*If the number of cars having parts replaced due to side impacts were an explicit category in the contingency table, the expected value would be simply derived from the row and column frequencies. The benefit of this is that strictly speaking, the χ^2 test is not appropriate when the expected values are normalized functions.

Year	Actual Bumper Replacements by Impact Location			
	Front	Front angle	Rear	Rear angle
1972	25	50	8	7
1973	5	10	1	2
Total	30	60	9	9

The number of side collisions in 1972 = 1,000 is defined as S_1.

The number of side collisions in 1973 = 1,000 is defined as S_2.

If there is no difference, then one-half $(=S_1/(S_1+S_2))$ of the 30 front replacements will be on 1972 cars and one-half $(=S_2/(S_1+S_2))$ will be on 1973 cars. Thus, the expected values are:

Year	Expected Bumper Replacements by Impact Location			
	Front	Front angle	Rear	Rear angle
1972	15	30	4.5	4.5
1973	15	30	4.5	4.5

and $$\chi_3^2 = \frac{(25-15)^2}{15} + \frac{(50-30)^2}{30} + \frac{(8-4.5)^2}{4.5} + \frac{(7-4.5)^2}{4.5} + \frac{(5-15)^2}{15}$$

$$+ \frac{(10-30)^2}{30} + \frac{(1-4.5)^2}{4.5} + \frac{(2-4.5)^2}{4.5} = 13.3 + 26.7 + 2.72$$

$$+ 1.38 = +2.72 + 1.38 = 48.21$$

The value of the χ^2 distribution with 3 degrees of freedom and an α of 0.01 is 11.3. Therefore, reject the hypothesis that a change in bumpers has no impact on bumper replacement. i.e., 1973 cars have fewer front bumpers replaced.*

*Note that a usual χ^2 analysis would show no difference between years.

Year	Bumper Replacements by Impact Site				
	Front	Front angle	Rear	Rear angle	Row Total
1972	25 *24.9*†	50 *49.8*	8 *7.5*	7 *7.5*	90
1973	5 *5.1*	10 *10.2*	1 *7.5*	2 *7.5*	18
Column Totals	30	60	9	9	108

$\chi^2 = .14$

†Expected Value

The application of the contingency table method should follow the structure outlined by Figure 3-1. The step-by-step approach which should be followed for this analysis is described below.*

Starting with the State Farm repair and replacement data described in Section 2.1.1, the various analysis steps would be:

Step 1: Tabulate the data according to potentially important variables:

- Impact Site: square front, front corner, right side, left side, square rear, rear corner, other, all.
- Replacement Part: Assorted bumper parts (bumper cushions, bumper guards, etc.), other front and rear parts (lights, fenders, etc.), non-bumper related parts (doors, etc.)
- Market Class: Subcompact, compact, intermediate, full size and all classes.
- Model Year: individual years 1968 through the latest available data.
- By accident year.

These tabulations would be done on a detailed and aggregated basis, and in absolute and percentage terms. Some graphic presentation should help in revealing obvious trends and relations.

Step 2: Based on results of the first step and on exogenous information from engineering or other effectiveness studies, the information would be grouped into consistent categories in order to compare those items of interest. The 1968-1972 models would form one grouping; 1973 models are a transition year; 1974 and 1975 models represent another group; and possibly the effect of corner impact requirements could be estimated from 1976 and later models. Similarly, the stratification of cars by parts replaced could be grouped by all bumpers (or front and rear separately), and all other bumper protected parts. In the case of trying to determine the effectiveness of the corner impact tests, certain of these parts might form a consistent group.

Step 3: Construct contingency tables according to those differences to be tested: number of cars with bumpers replaced *vs.* cars with non-protected parts replaced in pre- *vs.* post-Standard cars, or any categorization more detailed. For instance, consider yearly changes in front bumper replacement in cars which are in square front collisions, or headlight replacement in front corner impacts.

Step 4: Contingency table analysis computer packages are available [e.g., Statistical Package for Social Sciences, (SPSS)], or a new program can be written with little effort. The key element in performing the analysis is the calculation of the expected number of elements in any cell. If cars with non-protected part replacement are explicitly part of the contingency table, the expected value of any cell is the product of the row and column frequencies. The χ^2 test of significance

*The general procedure described here can also be applied to the contingency table analysis outlined in the following subsections.

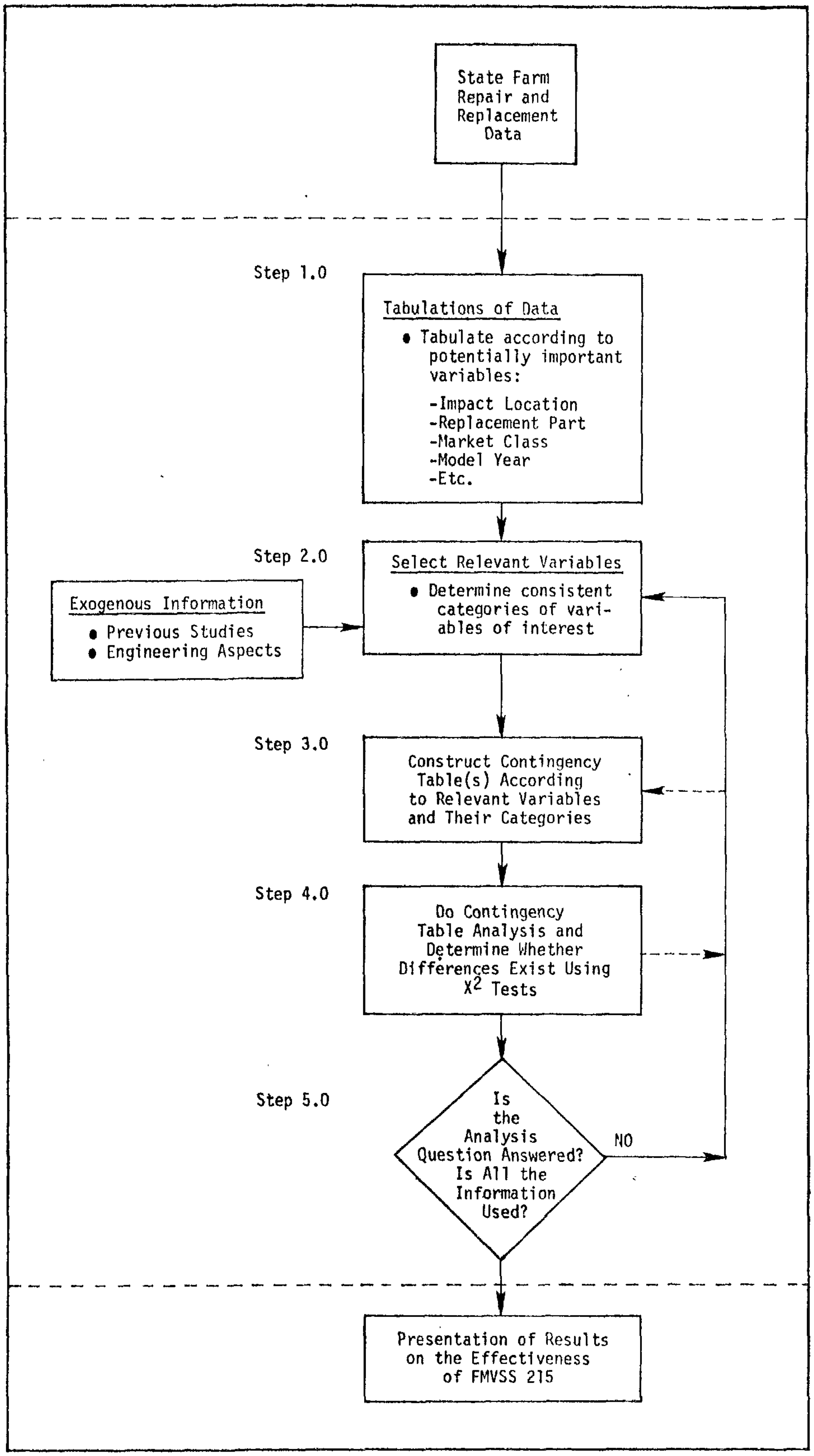

Figure 3-1. Proposed Statistical Analysis Scheme for Evaluating FMVSS 215 (Exterior Protection).

is normally part of the statistical routines and simple measures the degree to which the observed and expected frequencies differ, i.e., the expected number of bumpers replaced *vs.* the actual number replaced.

Step 5: At this point, given the significance (or insignificance) of the above results, one may develop additional comparisons which might require a different grouping (or disaggregating) of the data. Another possibility is to make different types of comparison, given the same categorization of the data (e.g., comparison of effectiveness of bumpers by market class). The basic analysis question is whether the cars equipped with post-Standard bumpers have less damage. The question can be subdivided with regard to car classes, specific model years, specific kinds of damage, or specific types of collisions. The analyses could continue until comparisons no longer yield significance (fail the χ^2 test) at which point the statistical information content of the data is exhausted.

The final results of the analysis should then be presented in such a form as to show the degree of effectiveness of the post-Standard bumpers. Probably the best method of presentation is graphic representation of contingency table analysis--that is comparison of the expected *vs.* observed frequencies for each set of parameters analyzed.

3.2 Car Owner Survey

The survey of vehicle owners is designed to collect data which will permit a study of cars with and without bumpers that meet the requirements of FMVSS 215. Specifically, the analysis of data will be directed toward determining the frequency of collisions and the level of damage (including no-damage) at low speeds. The successful collection and analysis of the survey data will require prior recognition of a number of potentail pitfalls. Care must be taken to insure that the vehicle owner population sampled does not contain socio-economic biases. If improperly done, the wording of the questions in the survey may inadvertently guide the answers of respondents in a way that gives an invalid or biased sample. These and other considerations dictate that the services of a professional polling organization be utilized in the survey. The questionnaire used in the survey must obtain the approval of the Office of Management and Budget, under OMB Circular No. A-40.

3.2.1 Data Requirements

The survey of car owners should be designed to determine information on vehicle accidents which occurred during the prior six months. The information required for each accident is:

- Vehicle year
- Vehicle make/model
- Type of collision
- Amount of damage, including none
- Damage repaired or not
- Towing of car required or not.

The first two above items will be known and will be part of the basis for selecting the owner in the survey, as will be discussed in Section 3.2.2. The questionnaire must be clearly worded so that the respondent will realize that he or she is to include very minor collisions, such as "bumps" which resulted in little or no damage.

The style of the questionnaire and the strategy of posing the questions in such a way as to obtain an unbiased response will be significantly dependent on the professional advice of a psychologist/market researcher and/or professional polling company involved in the study. The final form of the survey questionnaire must be approved by the Office of Management and Budget.

3.2.2 Data Acquisition

The data acquisition, which is assumed to be undertaken by a company with survey data collection experience and competence, must address the following considerations:

- Means of survey data collection - mail and/or phone
- Representative sampling
- Sequence of sampling - pilot study
- Response rates and sample size requirements.

Survey data of the type required in this study could, at least in principle, be collected by either phone or mail. However, in our judgment, the amount of information required and the time for reflection on the part of the respondent that is needed to assure a valid answer, would dictate a mail survey. This, of course, does not rule out the possibility of selective phone followup to increase the rate of response. It would appear, however, that the survey data must be transmitted in written form *via* the mail to assure adequate quality. The question of a token monetary incentive must be considered in the light of past experience with such measures. (Examples are given in Appendix C.)

The question of representative sampling or to whom the questionnaires should be targeted must be carefully planned prior to the initiation of the survey. At least two aspects are involved. First, a decision must be made as to whether all or some market classes (or make/models) will be sampled. For example, it could be determined that only subcompact and full size cars will be included in the survey. Or the decision could be reached that it is desirable to sample all five principle market classes (subcompact through luxury cars). Obviously, this decision will have implications on requirements for sample size as discussed below. In conjunction with this decision, care must be exercised that the vehicle owners sampled are representative of the socio-economic span in the driver population. The targeting of survey questionnaires can be most expeditiously accomplished using R.L. Polk data, which relates vehicle registration to socio-economic characteristics of owners, at least by census tract.

It is recommended that the sampling design allow for a pilot study in which a sufficient number of questionnaires is sent to determine a probably response rate.* The mail and/or phone followup to the initial mailing that is anticipated for the full study should also be undertaken in the pilot study.

*A pilot survey resulting in about 400-500 responses will probably be adequate.

The response rates given in Appendix C are encouraging and indicate that responses in excess of 50% can be achieved if there are adequate followups and incentives. In any event, the pilot study will permit a much firmer estimate to be made of the expected rate of return and also will allow an evaluation to be made of the adequacy of the questionnaire form in obtaining the required collision data.

An estimate of the sample size which is required can be made with the aid of Table 3-1 which gives the relationships among estimated reduction in the frequency of damage (Δ, in percent), frequency of damage or towaway accidents found in the total sample (in percent) and the total sample size required ($N = 2n$), for a standard error of half the difference in damage or towaway accident reduction ($\sigma = 0.5 \frac{\Delta}{100}$). The use of Table 3-1 requires the assumption that there are equal sample sizes (n) of both pre-Standard cars and post-Standard cars. That is, the number of cars with pre-Standard bumpers is approximately equal to the number of cars with post-Standard bumpers. This can be achieved by selection of owners surveyed.

In the examples of required sample size given below, it is assumed that the analysis will be restricted to one market class and a comparison of two types of vehicles: pre-Standard bumpers (model years 1972 and earlier) and cars with post-Standard bumpers (model years 1973 and later). The discussion of sample size requirements for more than one market class and more than two groupings of model years will be given at the end of this section.

The three parameters with which we are concerned in detecting changes are:

- Ratio of no-damage front or rear accidents to all front or rear accidents.
- Ratio of no-damage front or rear accidents to side accidents.
- Ratio of front or rear impacts accidents to all accidents.

The sample requirements for these measures are given in Table 3-1 for (1) various levels of reduction due to FMVSS 215 and (2) appropriate estimates of the frequency with which no-damage front or rear accidents and towaway accidents would occur in the survey sample. For example, if there is a 50% reduction in front or rear damage accidents for post-Standard vehicles and such front or rear non-towaway accidents would represent 30% of the cars in the pre-Standard vehicle sample and 15 % in the post-Standard sample, then the total sample needed to detect that shift with 95% confidence is approximately 300 accident cases.

Nearly the same sample would be needed if one is trying to detect shifts in damage away from the front and rear; the front and rear damage accidents may represent a higher proportion of all accidents; however, the percentage drop would probably be less. For example, for 70% frequency and a 20% shift, approximately 330 cases would be needed. It is uncertain whether this survey can answer any questions about the effect of the Standard on towaway accidents. If the effectiveness were very high (50%), but the frequency of towaway accidents in front or rear collisions small (10%), then over 1000 total accidents would be needed.

TABLE 3-1

APPROXIMATE TOTAL SAMPLE SIZE NEEDED TO DETECT REDUCTIONS IN FREQUENCIES OF EVENTS

Total Sample Size[†] (N = 2n)							
Frequency of the Event in Subsample n	Percent Reduction in Frequency						
	5	10	15	20	30	50	70
0.05	235,000	60,000	26,000	14,600	6,500	2,350	1,200
0.10	110,000	27,600	12,300	7,000	3,000	1,100	560
0.25	37,000	9,200	4,100	2,300	1,000	370	190
0.50	12,300	3,100	1,360	760	340	120	30
0.70	5,200	1,300	600	330	140	50	*
0.90	680	170	75.	40	20	*	*

[†]Total sample size is based on the assumption of equal variance for both frequency distributions, new and old. The variance of the estimates of the frequencies decreases as the frequency approaches 0.0 or 1.0. Therefore, the sample sizes in those areas may be somewhat larger than necessary.

It should be remembered that the numbers cited above represent the number of cases required for an analysis of a single market class where all pre- and post-Standard cars are grouped into two samples. Furthermore, these cases represent the number of "good" accident responses, not the number of questionnaires sent out. The number of cases required must be increased according to the factors given in Table 3-2 for additional classes of market shares and more detailed groupings of model years.

It is apparent that unless very large effects can be detected, the extent of stratification by market share and model year must be limited. It is also

TABLE 3-2

FACTOR BY WHICH CASES IN TABLE 3-1 MUST BE INCREASED TO ACCOMMODATE ADDITIONAL CLASSES

Number of Classes of Market Shares	Number of Classes of Model Years			
	2	3	4	5
1	1	1.5	2	2.5
2	2	3	4	5
3	3	4.5	6	7.5
4	4	6	8	10

apparent that the car owner survey is not likely to be a suitable means for evaluating reductions in towaway accidents, unless very large effects (20% reduction or greater) can be determined.

The number of questionnaires that will be required to obtain a single car owner survey accident is difficult to estimate. The pilot study will help to make this estimation. The important factors to consider are:

- Response rate. A response rate of between 40% and 70% seems possible based on the information given in Appendix C. However, the response rate for questions relating to accidents might be lower than the response rate for questions relating to cars in general.

- Accident frequency. It is difficult to estimate the number of low level accidents per car occurring over a 6-month period. This is especially true since we are attempting to include minor incidents which result in little or no damage and are usually not reported as accidents. If the number of these incidents is sufficiently large (as hearsay experience indicates to be the case), we might expect an accident from between 1 in 4 and 1 in 8 cars. A higher rate of accident response could possibly be obtained if the recall period covered by the survey were increased from 6 months to a year. However, since the accidents of principal concern in the survey are minor in nature, the reliability of information provided is likely to deteriorate when the recall period is extended significantly.

In summary, it is estimated that with a survey recall period of six months, between 10 and 20 survey questionnaires will be required to obtain an accident case for the sample, based on about half the questionnaires being returned, and about 20% or less of those returned reporting an accident case. Thus, if the required sample size is 3,000 (frequency of event = 30%, reduction = 50%, 4 market classes and 5 time periods) cases, it is estimated that between 30,000 and 60,000 questionnaires would be required.

3.2.3 Data Preparation

The preparation of the car owner survey data for computer analysis will require a normal sequence of quality control measures to assure validity and adequacy of the data. These steps include:

- Initial manual screening of the survey forms to determine if they provide accident data and to ascertain if the data given appear to be complete enough for inclusion in the study.
- Coding, keypunching and error checking data.
- Loading punched card data onto magnetic tape and error checking for invalid codes and gross inconsistencies.
- Finally, correcting data, printing out all data on tape, and, perhaps, preparing the data in specified formats for statistical analysis.

At the conclusion of the data preparation phase, the survey data are in final form ready for contingency table analyses, as described in the next section.

3.2.4 Data Analysis

The contingency table analysis of frequency distribution is designed to provide an answer to the following question.

- Are post-Standard bumper cars involved in a greater percentage of no-damage or low damage accidents relative to all the accidents in which they are involved, than pre-Standard bumper cars?

This question will be considered relative to two measures of potential post-Standard bumper effects: (1) no-damage accidents, and (2) frequency of frontal (or rear) impact relative to side impact in towaway accidents. The basic analysis will consist of evaluating the distributions in a 2 x 2 contingency table, consisting of model year categories (1972 and earlier; 1973 and later) and accident type (front/rear impacts and other impacts).

In principle, the contingency table analysis can be extended to five market class types and four groupings of model years. The market class types are (1) subcompact, (2) compact, (3) intermediate, (4) full size, and (5) luxury. The groupings of model years are: (1) 1968-1972, (2) 1973, (3) 1974-1975, and (5) 1976-1977. The grouping of model years reflects major changes in the requirements of FMVSS 215 as summarized in Table 1-1. In practice, the extent to which sample stratification can be performed will depend on sample size and characteristics (i.e., how many market classes were included) and, of course, the magnitude of the effect of post-Standard bumpers in reducing no- and low-damage accidents and towaway accidents.

3.3 Mass Accident Data

The use of mass accident data poses both certain difficulties and potential advantages. Mass accident data are characterized by a lack of detailed information on key variables and an absence of standardization of reporting procedure among those states that do have automated data bases. This brings into question the adequacy of the data to answer the analytical questions raised in Section 3.3.3. On the other hand, the data do contain large numbers of vehicles with old pre-Standard bumper systems which were involved in accidents while they were still "young." Beginning with the 1973 models, all cars contain bumper systems which must comply with increasingly stringent crash test requirements under FMVSS 215.

3.3.1 Data Requirements

Automated mass accident data from states which contain a large volume of accident data are required. Appropriate states would include Texas, New York, North Carolina and others. The North Carolina data cover about 120,000 accidents per year, involving approximately 220,000 vehicles. Between 1969 and 1972, point of impact is identified but damage severity is not. Starting in 1973, the TAD vehicle damage rating is given.* The Texas accident data include about 500,000 accidents per year, involving about 800,000 vehicles. From 1971 and later, vehicle make and model can be identified in sufficient detail and vehicle damage is given, using the TAD scale.

The variables that are required from the mass accident data files are:

- Vehicle make
- Vehicle model
- Vehicle model year
- Vehicle damage area
- Driver age
- Driver sex.

Two additional variables that are not required but would permit greater flexibility of analysis are:

- Vehicle damage level
- Accident year.

3.3.2 Data Acquisition and Preparation

Mass accident data files can be acquired from the relevant administrative agencies of individual states. Although the format of accident data varies widely among the states, those data bases which are automated are generally available on magnetic tape computer files. In addition to acquiring copies of

*TAD = Traffic Accident Data, a vehicle damage scale.

accident tapes, all file coding manuals which are relevant for each year's data should be obtained. In the case of North Carolina, edited versions of the state's accident tapes have been created and are maintained by the Highway Safety Research Center of the University of North Carolina.*

Once data tapes and coding manuals have been obtained, the data must be edited so that the proposed analyses can be performed efficiently. This involves the writing of data preprocessing programs which will standardize the different codes used by different states and, if needed, will reconstruct necessary variables from other related variables which are available.

The editing procedure will take place in the following steps:

- Decode the variables on the file.
- Extract and construct variables needed for the analysis.
- Re-encode variables into standardized formats.
- Extract relevant accident types.
- Merge condensed information onto one (if possible) data tape for analysis.

At this point the data will be ready for the analyses outlined in the next section.

3.3.3 Data Analysis

The mass accident data will be analyzed to answer the following basic question:

- Has there been a shift in the distribution of vehicle damage away from bumper areas?

Answering the above question requires an analysis of the frequency of damage occurrence by area of vehicle. This can most appropriately be undertaken through contingency table analysis. The primary breakdown of area of damage would be front, side and rear. Where data permit, subcategorization of the damage area could be used. The analysis will attempt to determine if the frequency of reported accidents involving bumper systems has changed on new models since 1973 as compared with old models prior to 1973. This would be done to test for the underrepresentation of accidents involving bumpers which meet the requirements of FMVSS 215. If underrepresentation is the case, then it would support the hypothesis that the new bumpers are effective in reducing the damage to vehicles equipped with them.

The comparative analysis of area damage frequency for pre- and post-Standard cars will require several data stratifications and controlling for extraneous effects. The shift (if any) in area damage frequency in the contingency table

*The HSRC tapes are proprietary and negotiations may be needed to obtain access to them.

analysis may be more susceptible to detection if stratification according to damage severity is performed. It is possible that frequency shifts will be detected only in collisions with lesser damage. Additionally, it may be necessary to control for effects due to driver age and/or sex. For example, more younger persons drive older cars and due to more aggressive driving characteristics tend to be more frequently involved in front-end collisions. If this is the case, older (and predominantly pre-Standard) cars could have a higher frequency of bumper-involved accidents than newer (and predominantly post-Standard) cars, but this effect should not be ascribed to the new bumper systems.

The contingency table analysis should also be carried out for data stratified according to market class (subcompact, compact, intermediate, full size, heavy). The effects and effectiveness of the new bumper system may differ between a subcompact and a full-size car. Additionally, there has been a shift in the relative market share of the above five vehicle classes in recent years, and this should be considered in the analysis.

The analysis should initially be carried out separately by accident year. There are several exogeneous factors which might be changing over time. For example, a state may change the minimum dollar amount of damage required for an accident to be reportable. It has been observed in the past that when such reporting limits change, the number of accidents actually reported changes significantly. Exposure is another factor that changes over time. As the economic cycles change the amount of driving changes correspondingly. If certain types of driving are affected more than others by the economy, the relative occurrence of different accident configurations may change. This would affect a comparison of frequency of accidents by damage area which combined all the accident years together. Depending on the results of the initial analysis, similar accident years may be combined to increase sample size, especially where accidents involving pre-Standard vehicles are infrequent, as is the case with the latest accident data.

3.4 Towaway Survey

The survey of towaway accidents and subsequent analysis which is described in this section is envisioned as a modest effort designed to provide information on towaway accidents which is relevant to evaluation of the effectiveness of FMVSS 215. While the effort is speculative in nature, because of uncertainty as to possible results, it should be realized that only limited resources are required and useful information could be obtained.

3.4.1 Data Requirements

The following basic information on each towaway accident involving front and rear collisions is required:

- Vehicle model year
- Vehicle make/model
- Reason for towing (to insure that an accident is involved)
- Front/rear bumper involvement
- Location of accident.

In addition, a count is required of the total number of towaway accidents by model year, handled by the towtruck operators.

3.4.2 Data Acquisition and Preparation

Data will be collected with the cooperation of police-designated towtruck operators. The data will be collected over a period of a year at a sufficient number of locations to accumulate about 2000 bumper cases during that time period. The site could include NCSS data collection areas and also would preferably be located in states such as New York and Texas which have automated mass accident data bases. The towtruck operator would, for a modest fee, include the information specified in 3.4.1 in his routine log for towtruck operations. This information would periodically be sent to or collected by the individuals responsible for the survey data collection and analysis.

A second data acquisition task would be to obtain (if available) mass accident data for a time period as close to that of the towaway survey as possible. The data can be acquired following procedures described in Section 3.3.2. Only accident data for the regions serviced by towtruck operators participating in the survey are desired,i.e., a given county or city. It may be necessary to acquire mass accident data for the entire state and, as part of the data preparation, select accident data for those counties/cities which are part of the towaway survey.

The data preparation required for the towaway survey data is distinctly limited in scope. However, even with a limited amount of information being tabulated and the very simple analysis to be performed, computer automation of the data base is recommended. One reason is accuracy of machines, vs. hand calculations. Another reason is to allow on-going initial computations which give an increasingly better understanding of the efficacy of the data collection effort, and the information to be obtained from the analysis after all data are collected.

If the towaway survey is conducted in 1977-1978, the number of pre- and post-Standard bumper cars will be approximately equal. We can then estimate the number of cases of front/rear towaway accidents that would be required using Figure 3-2. Figure 3-2 shows the relationship among the differences in reduction of rear/front towaway accidents (Δ, in percent), frequency of rear/front towaway accidents found in the total sample (in percent) and the total sample size required (N=2n), for a standard error of half the difference in rear/front towaway accident reduction ($\sigma = 0.5 \frac{\Delta}{100}$).

The results are given in Table 3-3 for the following situations: (1) assume a 5%, 10%, or 20% reduction in the number of front/rear impact towaway accidents relative to all towaway accidents and (2) assume that front/rear impact towaway accidents constitute 20% or 50% of all towaway accidents.

For example, assume a 10% reduction in rear/front towaway accidents due to compliance with the Standard and only 20% of towaway accidents are rear/front impacts (a very low percentage). According to Figure 3-2, a total sample size of about 7000 would be required, but only 20% of these (1400 cases) would require the tabulated data listed in Section 3.4.1. If 50% of the towaway accidents are rear/front impacts, about 1800 cases would be needed, with 50% of these (900 cases) containing the tabulated data. Thus, it is estimated that 2000 cases of tabulated front/rear towaway accident data will be sufficient unless only very small (e.g., 5%) reductions in rear/front towaway accidents must be detected. In this eventuality, the required sample size may have to be doubled.

3.4.3 Data Analyses

A very simple contingency table analysis is planned to answer the following question:

- Do vehicles with post-Standard bumpers have a smaller percentage of frontal or rear involvement in towaway accidents?

If post-Standard bumpers reduce front/rear impact damage in low-speed collisions and also help to maintain the operable integrity of safety related items in lighting, fuel, exhaust, etc. systems, it is possible that there will be a reduction in towaway accidents involving front/rear impacts in

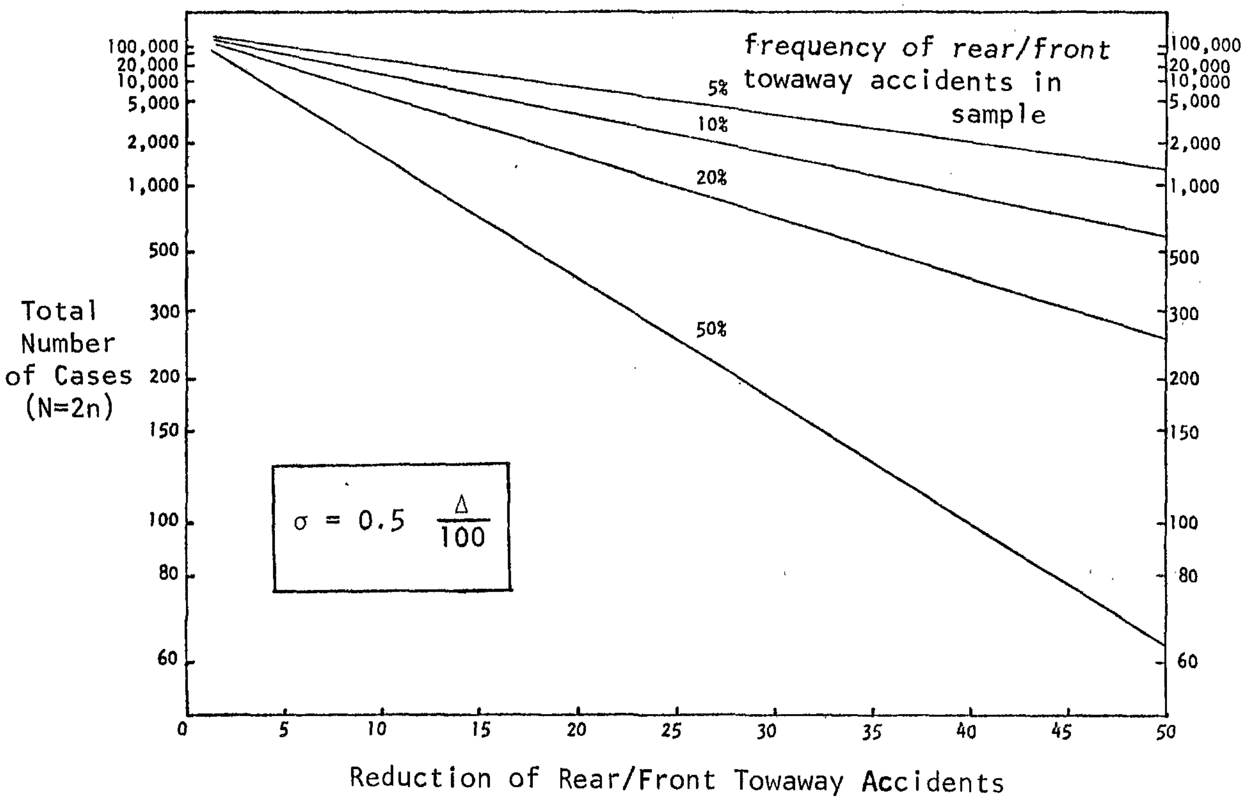

Figure 3-2. Total number of cases (N) needed to estimate a difference (Δ) in rear/front impact towaway accidents between two samples of equal size, with a standard error of half the difference.

TABLE 3-3

ESTIMATES OF REQUIRED TOWAWAY SURVEY SAMPLE SIZE

Reduction of Rear/Front Towaway Accidents (%)	Percent of Rear/Front Towaway Accidents in All Towaway Accidents	Sample Size of Rear/Front Towaway Accidents Required
5	20 50	4000 3500
10	20 50	1400 900
20	20 50	380 225

post-Standard cars as compared with pre-Standard cars. This in turn implies that the number of low-speed accidents which are included in police accident records and, for that matter, in insurance company claims will be reduced due to the effects of the Standard.

A simple 2 x 2 contingency table analysis illustrated in Figure 3-3 can be used to examine this effect. The significance of shifts in the distribution frequency can be evaluated with a chi-square test.

The above result can also be evaluated in the light of a similar analysis with mass accident data from the same regions in which the towaway survey was conducted. The mass accident data analysis will indicate if any shift in the frequency of the occurrence of all reported front/rear impact accidents relative to all reported accidents in the survey areas has taken place.

Model Year	Towaway Accident Impact		Total
	Front/Rear	Other	
≤ 1972			
≥ 1973			
Total			

Figure 3-3. Illustration of 2 x 2 contingency table analysis designed to estimate the reduction in front/rear towaway accidents due to the effect of post-Standard bumpers (model year 1973 and later).

3.5 HLDI Data

The Highway Loss Data Institute (HLDI) is a non-profit organization that gathers, processes, and provides the public with insurance data. It has published a series of reports on collision claims, *Automobile Insurance Losses, Collision Coverages, Variations by Make and Series* [5]. However, this information has many serious drawbacks and it is doubtful whether it has useful information for evaluating the effects of FMVSS 215. First, loss payments for collision claims have several elements mixed inseparably--inflation of crash parts prices, labor costs, and used car prices. The loss payments are affected by insurance deductibles and the car's scrap value. Also, all accident types are mixed together, and collision claims differ in accident types from liability claims. Secondly, as all accidents are included, the new bumper's effect of cost saving in lower speed accidents may be offset by higher replacement costs in other accidents. In fact, HLDI has published a special analysis of 1972 and 1973 collision claims in a effort to estimate the effect of FMVSS 215 [6]. It also acknowledges the limitations of the data base. In its analysis, HLDI has had to make considerable adjustments to the data due to age of driver and size of deductible. However, the dollar amounts do not reflect the effects of price changes. The analysis shows some reduction between 1972 and 1973 model year in the average loss payment on an insured vehicle basis. (See Table 3-4 below.) Despite these results, it is not certain whether this reduction was due to the Standard or to some other factor or combination of factors: changes in the mix of accidents, in the severity of accidents, in the cost of repair parts, in the replacement value of cars, etc.

TABLE 3-4

AVERAGE LOSS PAYMENT PER INSURED VEHICLE YEAR BY MARKET CLASS AND DEDUCTIBLE AMOUNT - COLLISION COVERAGES

Market Class	Average Loss Payment Per Insured Vehicle Year					
	$50 Deductible			$100 Deductible		
	1972	1973	Change	1972	1973	Change
Sub Compact	$60	$63	+$3	$55	$53	- $2
Compact	$60	$51	- $9	$51	$45	- $6
Intermediate	$58	$53	- $5	$51	$48	- $3
Full Size	$48	$45	- $3	$39	$40	+$1

Source: HLDI [6].

3.5.1 Data Requirements, Acquisition, and Preparation

In order to improve upon the HLDI analysis mentioned above, both the HLDI data and auxiliary data are needed. The auxiliary data include information on price increases for labor, crash parts, and used cars--the fair market value representing the upper limit on the distribution of the claim payments. The HLDI data contain the following information for make, series and body type:

- Insured vehicle years
- Claim frequency per 100 insured vehicle years
- Average loss payment per claim
- Average loss payment per insured vehicle year.

This information is given by deductible amount ($50 and $100) and operator age group (under 25, or not) and by model year and accident year. In order to conduct the anticipated analysis, this data would have to be available on a case-by-case basis in order to generate distribution of claim payments. It is these distributions, adjusted by insured vehicle years and a price deflator, which will be analyzed statistically.

For the analysis, the HLDI data would be used to generate these distributions of claim payments weighted at least by the number of insured vehicle years. It would be desirable to deflate the dollar amounts by an appropriate index, such as the State Farm crash parts index, consumer price index for new cars, etc.

HLDI data have a special characteristic which must be recognized before undertaking a statistical analysis: The data are truncated. That is, the cost of a claim to the insurance company does not include the deductible amount at the lower end, where $50, $100, and $200 are typical damage deductions. The upper end of the damage scale is limited by the used car value of the vehicle according to its make, model year, and age. In addition to the above characteristic, damage claims data are skewed to the lower end of the range, which suggests the possibility of a log normal representation. In analyzing HLDI data, the objective is to identify a shift in the distribution of damage claims costs. Fortuitously, a set of procedures exists for comparing truncated log normal distributions to identify shifts in the characteristics of the distributions. These procedures are discussed next.

3.5.2 Data Analysis

The two statistical analysis approaches discussed below focus on determining whether there is a significant difference between distributions--pre-*vs.* post-Standard cars, or perhaps more detailed comparisons such as stratified by market class, etc. The two methods differ in that the first develops statistical estimates of the character of the truncated distributions and compares these estimates. The second compares the distributions within intervals. This latter method is the more powerful, given large sample sizes. It is appropriate to note here that success in delineating the effectiveness of FMVSS 215 by either of these methods is speculative.

Comparison of Truncated Log Normal Distributions

Outline of Approach 1: Suppose each of two sets of samples is taken from a truncated log normal distribution. The assumption of a functional form for the distribution enables estimation (maximum likelihood or method of moments) of the parameters of each distribution. However, the development of a test statistic for the comparison of samples must be ad hoc because of the absence of a large sample distribution theory for these estimators. This approach is preferred for estimation of parameters.

Outline of Approach 2: Suppose the samples are censored--that is, for the i^{th} population ($i = 1, 2$), a total of N_i observations (accidents) is taken, but only M_i are uncensored (i.e., M_i actual repair costs are observed and the remainder are censored by the current value of the car). This corresponds to developing tests based on the first M_1 order statistics from the first sample and the first M_2 order statistics from the second sample. Nonparametric procedures using Generalized Wilcoxon test statistics are available to compare the population under this arrangement, and these test statistics are known to be asymptotically normal. Since no functional form is specified, estimation must be confined to percentiles (i.e., medians, quartiles, etc.). This approach is intended to test the hypothesis of no difference between repair cost distributions for pre-Standard and post-Standard cars.

In the discussion below, these two approaches are amplified.

Approach 1: A random variable, X, is log normal on $(0, \infty)$, when log X has a normal distribution with mean, μ, and variance, σ^2. Then, based on a sample of size n, estimates for μ and σ^2 are:

$$\hat{\mu} = \frac{\Sigma \log X_i}{n}, \quad \hat{\sigma}^2 = \frac{\Sigma (\log X_i - \hat{\mu})^2}{n}$$

Without truncation, $\hat{\mu}$ is normally distributed and $\hat{\sigma}^2$ is (up to a constant) chi-square distributed and thus hypothesis testing between two samples proceeds exactly as in the case of any two-sample normal theory testing.

Consider truncation is imposed on the log normal above a certain value, say, A. (We may also wish to truncate below to allow for collision deductible, but here we illustrate only with truncation above A.). The corresponding normal is truncated at log A and has an adjusted mean equal to:

$$\mu = \frac{\sigma \, \phi\left(\frac{\log A - \mu}{\sigma}\right)}{1 - \rho}$$

and adjusted variance equal to:

$$\sigma^2 \left[1 - \frac{\left(\frac{\log A - \mu}{\sigma}\right) \phi\left(\frac{\log A - \mu}{\sigma}\right)}{1 - \rho} - \left(\frac{\phi\left(\frac{\log A - \mu}{\sigma}\right)}{1 - \rho} \right)^2 \right]$$

where ρ is the proportion of the distribution censored (ρ is presumable easily estimated) and ϕ is the standardized normal density function, i.e.,

$$\phi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$$

Estimation of μ and σ^2 is done by obtaining iterative solutions to maximum likelihood or method of moments equations. Such estimates are not available in closed form. Discussion is provided in Johnson and Kotz, *Continuous Univariate Distributions* [7]. A paper by A.C. Cohen [8] obtained closed form estimates using the first three sample moments above the truncation point. Since these estimates become functions of the sample moments, they can be developed to be asymptotically normal using the method of Cramér in *Mathematical Methods of Statistics* [9], but the use of the third moment would appear to significantly increase the variability of these estimates.

As far as testing in concerned, only an approximate procedure is suggested. Taking the iterated maximum likelihood estimators for each sample, if M_1 and M_2 are large enough, then approximately:

$$\frac{\hat{\mu}_1 - \hat{\mu}_2}{\sqrt{\frac{\hat{\sigma}_1^2}{M_1} + \frac{\hat{\sigma}_2^2}{M_2}}} \cong \text{Unit Normally Distributed}$$

The above approximation is very rough. The true level of the test may be far from the nominal level and the power of the test is completely uncontrolled.

Approach 2: Approach 2 is immediately concerned with testing; although within any sample, percentiles (including the median or quartiles) may be estimated using empirical proportions of the total of N_i observations up to M_i/N_i.

The test statistic suggested is a Generalized Mann Whitney U-Statistic first formulated by Basu [10]. It is intended to detect location shift between distributions. If there is concern that the original distribution (approximately log normal) may not be parameterized by location parameters, one may take a log transformation of the variables to make them approximately normal so that location parameters (μ's) now become appropriate. The most appealing aspect of Basu's test is its nonparametric nature which suspends concern with the exact form of the underlying distributions. The test level may be set quite accurately and the power of the test is most certainly much greater than that of the only available competitor, the previous ad hoc test, especially since reasonably large sample sizes are expected to be available.

To define the test statistic, let $M_1 + M_2 = r$ and arrange the samples as one overall sample of size r in increasing order. Let

$$\delta_i = \begin{cases} 1 \text{ if } i^{th} \text{ ordered observation is from first sample.} \\ 0 \text{ if } i^{th} \text{ ordered observation is from second sample.} \end{cases}$$

Let

$$T_r^{(N)} = \sum_{i=1}^{r} \frac{(i - r - 1)}{N} \delta_i + \frac{M_1(r + 1)^2}{2N^2} \qquad N = N_1 + N_2$$

Basu shows that this test statistic is consistent and asymptotically normal and provides the normalizing constants. The technique involves observing that $T_r^{(N)}$ is linearly related to a linear rank statistic with well known asymptotic properties. Although the previous discussion suggests that this may be a rather complicated procedure, in fact, it has been computer programmed and performed quite straightforwardly.

3.6 References for Section 3.0

1. Sorenson, W.W., R.E. Gardner, and J. Casassa. "Patterns of Automobile Crash Damage," *Automotive Engineering Congress*, Detroit, Michigan, February 25-March 1, 1974. SAE 740065

2. Personal communication with Dr. Wayne W. Sorenson of State Farm Mutual indicates that the basic claims data are proprietary, but aggregate data could be made available.

3. Casassa, J., W.W. Sorenson, and R. E. Gardner. "Bumpers: Effective, But How Cost Beneficial?" *Automotive Engineering Meeting*, Toronto, Canada, October 21-25, 1974. SAE 740986

4. Anonymous, *Crash Damage to Automobiles, An Insurance Research Study*, Allstate Insurance Co., Kemper Insurance Cos., Liberty Mutual Insurance Cos., and State Farm Mutual Insurance Co. in cooperation with American Mutual Insurance Alliance, October 1972.

5. Highway Loss Data Institute, *Automobile Insurance Losses Collision Coverages, Variations by Make and Series, 1973 Models*, 1974.

6. Highway Loss Data Institute, *Automobile Insurance Losses Collision Coverages, A Comparison of Results for 1972 and 1973 Models*, May 1974.

7. Johnson, N.L., and S.I. Kotz, *Continuous Univariate Distributions*. Boston: Houghton Mifflin Vol 1 p. 81-87. 1970.

8. Cohen, A.C., "Estimating the mean and variance of singly truncated normal frequency distributions from the first sample moments," *Annals of Institute of Statistical Mathematics*, Tokyo, Vol. 3 p. 37-44. 1950.

9. Cramer, Harold, *Mathematical Methods of Statistics*. Princeton, Princeton University Press, pp 363-370, 1946.

10. Basu, D., "On the large sample properties of a generalized Wilcoxon Mann Whitney Statistic, *Annals of Mathematical Statistics*, Vol. #3, p. 905.

4.0 COST DATA AND SAMPLING PLAN

4.1 Background *

FMVSS 215 has undergone considerable revision since it first became effective on September 1, 1972. The government has broadened the Standard in subsequent years in different ways, for different car classes. Also the industry has adopted several modes of complying with the Standard depending on manufacturer, model size, and year. See Table 4-1 for an overview of the changes which have taken place.

TABLE 4-1

APPLICABILITY OF THE STANDARD BY MODEL YEAR*

Model Year	Exterior Protection Standard Requirements
pre-1973	• No requirements.
1973	• 5 mph front; 2.5 mph rear barrier crash.
1974	• Horizontal pendulum test added over 115" wheelbase. • Rear barrier crash increased to 5 mph.
1975	• Number of horizontal pendulum impacts reduced to 2 front and rear. • Horizontal pendulum test for all cars.
1976	• Corner impact test for cars less than 120" wheelbase.
1977	• Corner impact test for all cars more than 120" wheelbase.
1979	• FMVSS 215 superseded by Part 581 - Bumper Standard, which increases damageability standards.

*Some changes in the Standard may have gone into effect after the start of a model year so that in that year some models may not have satisfied the Standard.

The basic systems [1, 2] of which we know are:

- Full width steel reinforcement behind a bumper attached to rubber block which is energy absorbing. (Chrysler)
- Steel beams on both sides of vehicle support steel bumper and are connected to energy absorbing devices consisting of pre-stressed rubber (slabs which stretch or shear upon impact). (Ford)
- Reinforced steel bumpers with external rubber guards attached to energy absorbing hydraulic/pneumatic cylinders on either side of car. (General Motors)
- Soft-faced front end of elastomeric material such as urethane which is energy absorbent. This system satisfies both FMVSS 215 and Part 587. (Many newer models)

*The material in this Background is repeated from Section 1.1 for the convenience of the reader.

There are also other systems, such as Saab's energy absorbing cell structure [3]; however, the analyses of costs for implementing the Standard should be primarily concerned with those systems on the most popular models.

In determining the costs of meeting the Standard, NHTSA has stated that to measure the consumer's out-of-pocket expenses, the cost categories should be:

- Direct manufacturing
- Indirect manufacturing
- Capital investment (including testing)
- Manufacturers' markup
- Dealers' markup
- Taxes [4].

However, the latter three cost categories cannot be estimated reliably for specific car models or market classes. Also we have found that the cost of complying with the FMVSSs, as estimated by the General Accounting Office, and the retail price increases of cars is loosely related [5]. (See Appendix B for a detailed discussion of problems with the above cost categories.)

4.2 Relevant Cost Items

The points of interest for the steel bumper systems include:

- Front Bumper System:

  License Plate Bracket
  Bumper Guards with Protective Strips
  Face Bar
  Face Bar Impact Strip
  Face Bar Reinforcement
  Energy Absorbers
  Bumper Spring Assembly
  Filler Panel
  Frame Mounting Brackets
  Bumper Valance
  Air Deflector
  Brackets, Braces, Insulators, Sight Shields, Spacers

- Rear Bumper System:

  License Bracket
  Bumper Guards with Pads
  Face Bar Protective Strip
  Face Bar
  Face Bar Reinforcement
  Energy Absorbers
  Frame Mounting Brackets
  Filler or Valance Panel
  Heat Shield
  Brackets, spacers, etc.

In the case of the soft-face bumper system the components front and rear are:

- Fascia skin
- Elastomeric energy absorbers
- Steel backing beam.

Costs are to be considered a function of:

- Material amount
- Material cost
- Labor required for component assembly
- Wage rate
- Overhead rate (indirect labor and material)
- Labor required for component installation.

Capital investments including testing should be amortized over the useful life of the equipment and estimated level of production. Manufacturer and dealer markups, and taxes are percentage amounts applied to the base cost.

4.3 Frequency Sampling Plan

The purpose of this activity is to acquire reliable estimates of the increased costs incurred by manufacturers in complying with FMVSS 301.

Automobile fuel system configurations vary considerably among manufacturers, makes, and model years. The major fuel system components affected by FMVSS 301 are listed in Table 4-1. The Standard specifies maximum allowable leakage in a crash without defining specifications for particular fuel system components. Therefore, each manufacturer may or may not have changed various vehicle components as a result of FMVSS 301. This would make it very expensive and inefficient to collect cost data on each fuel system component. In addition, GAO's estimate of the combined cost of compliance with FMVSS 301 and FMVSS 302 was an average of $5 per car for the 1974 model year [7]. Either very few cars were changed at all or the changes made were not very significant. These reasons support our recommendation that fuel system cost data be acquired from manufacturers stratified by market class, but in the aggregate for the model's complete fuel system. The recommended experimental design with a sample allocation of manufacturers to market classes is shown in Table 4-2 below.*

TABLE 4-2

SAMPLE EXPERIMENTAL DESIGN FOR COST DATA ACQUISITION

Market Class	Replication 1	Replication 2
Subcompact	VW	GM
Compact	Chrysler	Ford
Intermediate	AMC	GM
Full Size	Ford	Chrysler
Luxury	GM	Mercedes
Specialty	GM	Ford
Multipurpose	Chrysler	GM

The design has been limited to two replications because of data gathering cost considerations. Four domestic and two foreign manufacturers are represented and the assignments have been made such that a car model with significant sales volume exists in the assigned category (such as VW Rabbit in the Subcompact category and Chrysler Volare in the Compact category). The representation

*Fuel system costs and modifications for multipurpose vehicles may be significantly different from passenger cars.

choose within a particular manufacturer/market class cell, the following stratified sampling plan using "stratification before selection" may be used.

Each model a manufacturer produces within the market class would be assigned its percentage of sales volume. One of these models would then be chosen according to a weighting scheme based on the assigned percentage. To illustrate, assume it was desired to choose a Chrysler compact for "Replication 1" and the distribution of Chrysler compact sales are as shown in Table 4-3.

TABLE 4-3.

SAMPLE OF CHRYSLER COMPACT SALES DISTRIBUTION

	Plymouth Volare	Dodge Aspen
Sales Distribution	0.533	0.467
Probability Interval	$0.0<X \leq 0.533$	$0.533<X \leq 1.0$

A random number "X" from a uniform distribution would be generated on the interval [0, 1], and the probability interval in which the "X" fell would determine the model chosen. For the example shown in Table 4-3, the Plymouth Volare would be chosen if the random number generated was less than 0.533, the Dodge Aspen otherwise. The same selection procedures would be used for choosing GM and Ford models.

In summary, the process which should be followed is:

1. The manufacturer and market class would be selected using Table 4-2. For example, the first case will involve the VW/subcompact.

2. The models the manufacturer produces (if more than one) in that market class would be assigned their percentage of the manufacturer's production in that market class.

3. Using a random number generator (or table), one would choose the model to be cost sampled according to its sales percentage.

4. This process would be repeated for all the makes and market classes in Table 4-2.

5. The next, and major, step is to then collect information on the relevant cost items (Section 4.2) for each of the models for the years 1972 through 1977.

4.4 References for Section 4

1. Hai, Wu, *A Study of Automotive Energy Absorbing Bumpers*, SAE Report No. 73007, January 1973.

2. Compton, R.H., C. Westphal, Jr., and R. Crone, *Bumper Systems: Soft Face vs. Model 1974 Steel System*, Motor Vehicle Programs, NHTSA, November 1974.

3. Anonymous, "Automotive Requirements Meet Head On with Materials Capabilities," *Automotive Engineering*, 82, 2, pp 50-57, February 1974.

4. Personal communication from Warren G. LaHeist, NHTSA Contract Technical Monitor, 18 January 1977.

5. Joksch, H., J. Reidy, and G. Haas, *CEM Report 4194-574: Program Priority and Limitation Analysis*, December 1976, Contract No. DOT-HS-01225.

5.0 WORK PLAN

The work plan for the evaluation study of FMVSS 215 is divided into a total of six tasks. Ths sixth task is an analysis of costs to the consumer for implementation of FMVSS 215. The work to be conducted under each of the first five evaluation tasks is, to a very significant degree, self contained and independent of efforts undertaken in the other tasks. For this reason, the work in each task could be carried out concurrently and the basic work plan is formulated such that all tasks are initiated at the start of the study. We recognize that NHTSA may not choose to fund all tasks. After the work plan for each task is described, this section is concluded with a discussion of possible alternative combinations of tasks and the total resources that would be required for each alternative combination of tasks.

The logical sequence of subtasks within each task is given in Figure 5-1. The time sequencing of effort within each task and the estimated resources required (personnel, data processing and other significant expenses) are given in Figure 5-2.

5.1 Task 1 - State Farm Accident Data

Task 1 is concerned with the acquisition and analysis of aggregated insurance collision claim data available from the State Farm Mutual Automobile Insurance Company. The aggregated data covering model years from 1968 through 1977 must be key punched, verified and placed on magnetic tape for computer analysis. Rather extensive contingency table analysis will be accomplished using either existing standard programs (Statistical·Package for Social Science for example) or, if necessary, new programs written for this task. The analysis is designed to answer the basic question as to whether cars with post-Standard bumpers experience less damage than cars with pre-Standard bumpers. Computer processing costs are estimated to be no more than $1000 due to the relatively modest size of the data sample. It is estimated that the Task 1 effort will require resources of 0.5 person-year and can be completed in six months.

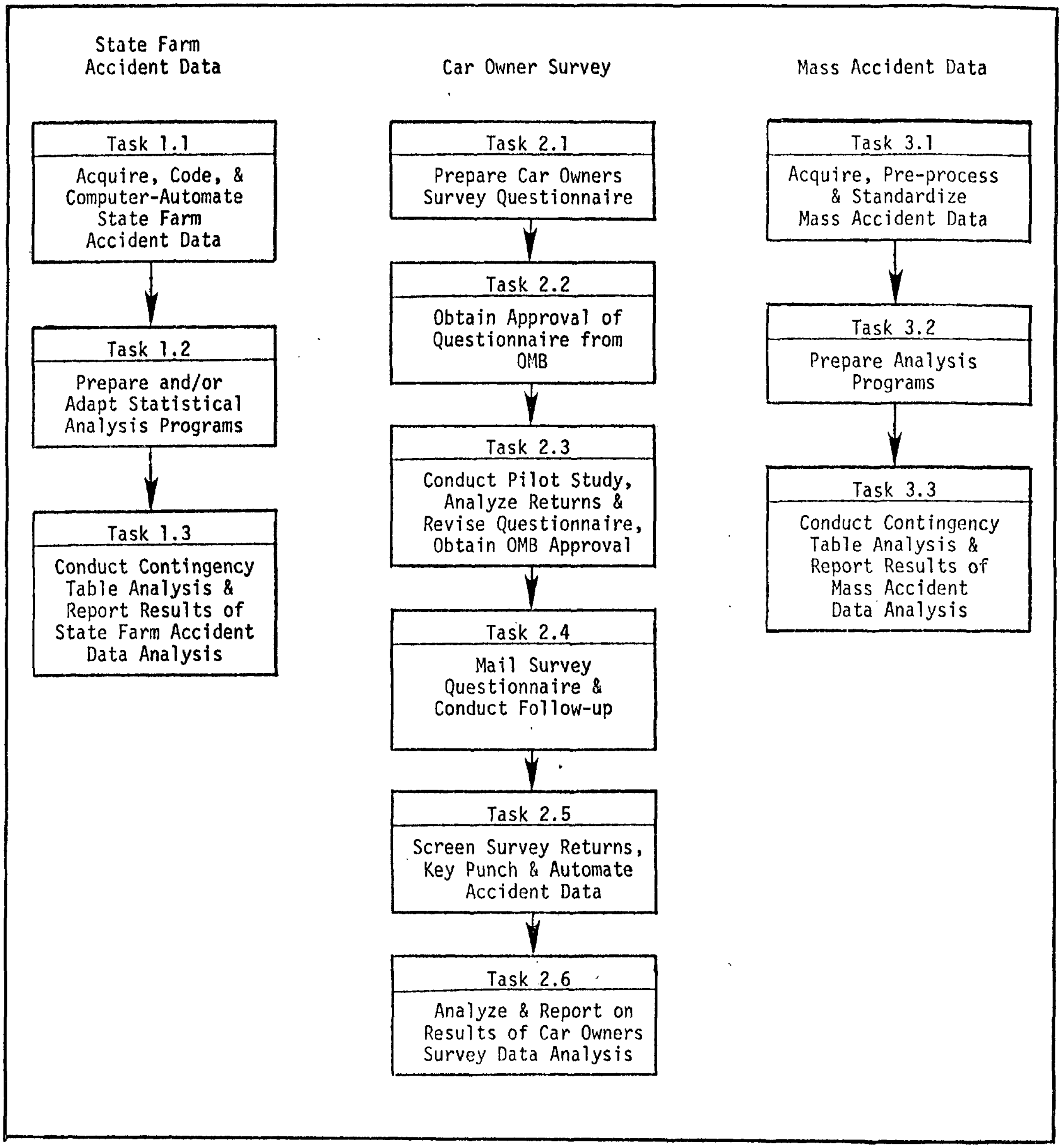

Figure 5-1. Flow chart for study to evaluate FMVSS 215.

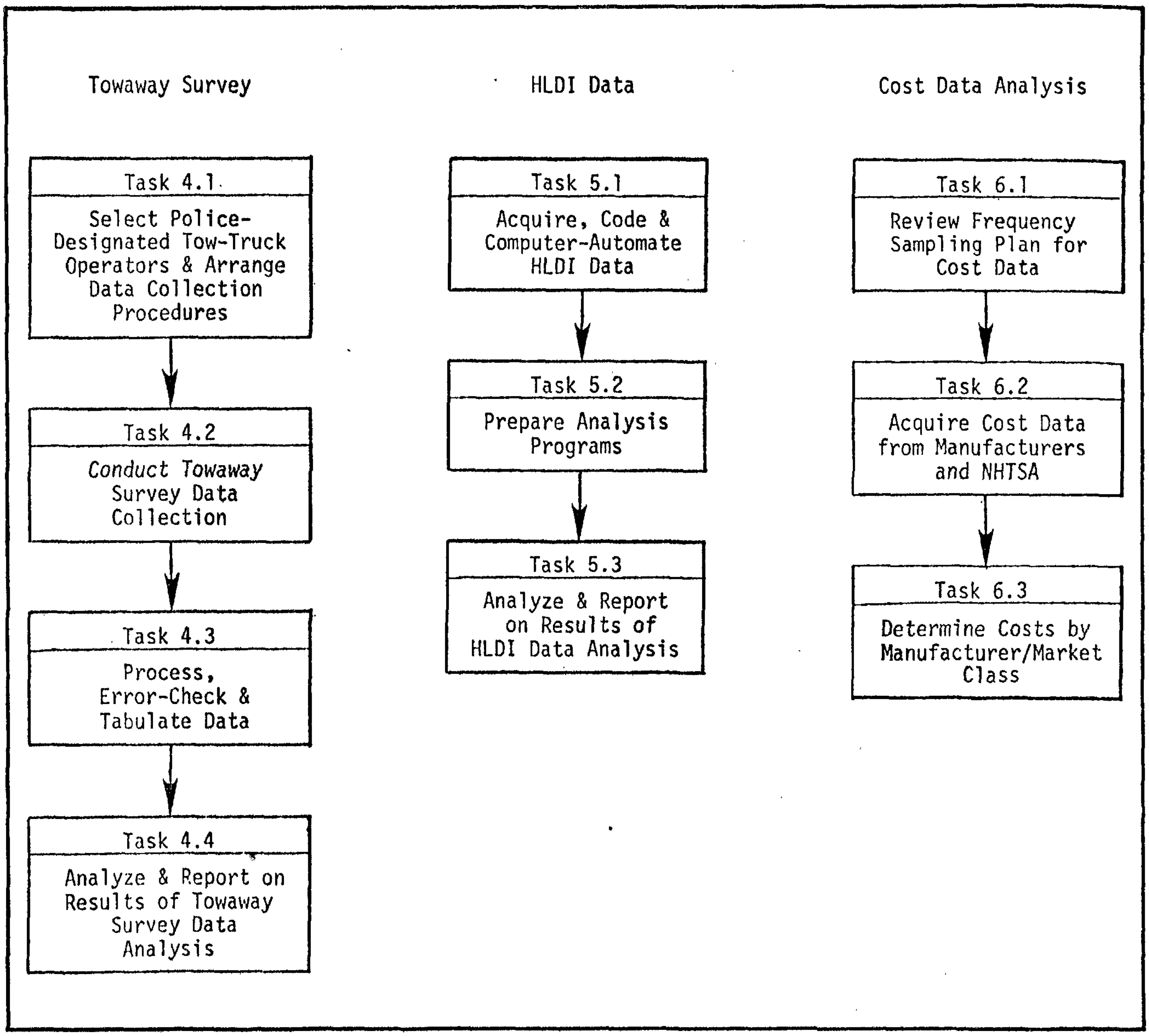

Figure 5-1 (continued).

Task	Description	Person-Years	Data Processing ($K)	Other Costs ($K)
	State Farm Accident Data			
1.1	Acquire & Prepare Data	0.25	$ 0.4	
1.2	Prepare Analysis Programs	0.1	$ 0.1	
1.3	Analyze & Report Results	0.15	$ 0.5	
		0.5	$ 1.0	
	Car Owner's Survey			
2.1	Prepare Survey Questionnaire	0.2		
2.2	Office of Management & Budget Approval			
2.3	Conduct Pilot Study, Analyze & Revise Questionnaire, OMB Approval	0.3		$ 5
2.4	Mail Survey & Follow-up	0.3		$ 60
2.5	Screen & Process Returns	0.5	$ 1.0	
2.6	Analyze & Report Results	0.3	$ 2.0	
		1.6	$ 3.0	$ 65
	Mass Accident Data			
3.1	Acquire & Preprocess Data	0.2	$ 1.5	
3.2	Prepare Analysis Programs	0.1	$ 0.3	
3.3	Analyze & Report Results	0.2	$ 1.2	
		0.5	$ 3.0	
	Towaway Survey			
4.1	Arrange Site Collection Centers	0.1		
4.2	Towaway Survey Data Collection	0.1		$ 30
4.3	Process & Tabulate Data	0.2	$ 0.5	
4.4	Analyze & Report Results	0.1		
		0.5	$ 0.5	$ 30
	HLDI Data			
5.1	Acquire & Preprocess Data	0.2	$ 0.3	
5.2	Prepare Analysis Programs	0.1	$ 0.2	
5.3	Analyze & Report Results	0.2	$ 0.5	
		0.5	$ 1.0	
	Cost Data Analysis			
6.1	Review Frequency Sampling Plan	0.1		
6.2	Acquire & Preprocess Data	0.3	$ 0.4	
6.3	Analyze Costs & Report Results	0.6	$ 0.6	
		1.0	$ 1.0	
	TOTAL RESOURCES REQUIRED	4.6	$ 9.5	$ 95

Figure 5-2. Schedule of tasks and required resources for evaluating FMVSS 215.

5.2 Task 2 - Car Owner Survey

Task 2 deals with the collection of data through a mail survey which will permit an analysis of the effects of post-Standard bumpers in reducing or eliminating damage at low speeds. It is the most costly of the six tasks included in the Work Plan because of the significant resources which must be committed to a mail survey required to collect the necessary data.

The major resource required in addition to task personnel is an allocation of $60,000 for the mail survey. This amount assumes a first mailing of 60,000 questionnaires and a followup mailing of over 30,000 questionnaires. The cost includes paper, printing, postage, a token monetary incentive ($0.25 with each questionnaire) and envelope addressing. The average cost of about $2 per returned questionnaire may be somewhat optimistic (i.e., low).

It is estimated that personnel resources of one-half person-year will be needed to screen and process survey questionnaire returns. It is assumed very roughly that about half the questionnaires are returned (30,000) and that about 3,000 of the returns contain useful accident information. The estimated personnel required for the initial screening and processing includes the key punching and verifying of the useful accident data and placing the data on magnetic tape.

It is estimated that 12 months will be required for the completion of the Task 2 study. This time includes an allowance of two months for approval of the initial survey questionnaire by the Office of Management and Budget (OMB). It also allows for a three-month period to conduct and evaluate a pilot study ($5000 for printing, mailing and followup) revise the initial questionnaire if necessary, and receive approval from the OMB for the revisions, if this is required.

The total resources required for Task 2 are estimated to be 1.6 person-years, $3000 for computer processing and $65,000 for printing, mailing and follow-up of the survey questionnaires. The effectiveness of followup mailings and token monetary incentives is discussed in Appendix C.

5.3 Task 3 - Mass Accident Data

Task 3 is directed toward processing and analyzing mass accident data. The objective of the analysis is to determine if there has been a shift in the distribution of vehicle damage away from bumper areas as a result of the implementation of FMVSS 215. Data files will be obtained from several states with large automated samples of accident records. Appropriate states include Texas, New York, North Carolina and others. The data should include calendar years prior to 1973 as well as more recent years.

A significant part of the data processing effort includes data reduction and format standardization among the data from several states. It is estimated that $3000 are needed for computer processing and analysis.

The acquisition of data, preprocessing, analysis and synthesis of results can be accomplished in a 6-month study period. Personnel requirements are estimated to be 0.5 person-year.

5.4 Task 4 - Towaway Survey

Task 4 is concerned with the collection and analysis of towaway accident data. The objective of the analysis is to determine if vehicles with post-Standard bumpers have a smaller percentage of frontal or rear involvement in towaway accidents. This task will require the longest time for completion of the six tasks. The 16-month study period is a consequence of allocating 12 months for towaway data collection, so that all seasons of one year are covered. About six police-designated towtruck operators will be hired to obtain the required data as part of their normal information tabulation procedures with tow calls. An estimated $30,000 has been assigned in the work plan for this purpose. It is anticipated that the entire Task 4 effort will require resources of 0.5 person-year, the above-mentioned $30,000 for the cooperation of the towtruck operators in obtaining the data, and $500 for computer processing.

5.5 Task 5 - HLDI Data

Task 5 deals with the analysis of Highway Loss Data Institute (HLDI) data which contain the total amount of collision claims and detailed information on car models. The objective of the analysis will be to determine if a shift in the distribution of collision claims has occurred as a consequence of bumpers complying with FMVSS 215. The analysis involves detailed consideration of variations in labor and materials with calendar year and model year as well as maintenance of constant dollar values. It is estimated that the acquisition, processing and analysis of the HLDI data can be accomplished in a 6-month study period. The resource requirements for Task 5 include 0.5 person-year and $1000 for computer processing.

5.6 Task 6 - Cost Data Analysis

Task 6 is directed toward the determination of direct costs to implement FMVSS 215. Cost categories are confined to direct manufacturing, indirect manufacturing, capital investment (including testing), manufacturer's markup, dealer's markup and taxes.* A frequency sampling plan specifies that cost data will be samples for selected manufacturers in six market classes for model years from 1972 through 1977. Two replications of the sampling procedure will be carried out. With an adequate sampling plan, the direct cost to the consumer of the Standard implementation can be obtained for most models through a statistical analysis of market shares. Task 6 will be completed seven months after the start of the study. It is estimated that 1.0 person-year will be required for Task 6 work, together with up to $1,000 for computer processing.

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*These are the cost categories specified by NHTSA. One should realize that manufacturers' and dealers' markups are not easily obtainable for specific models (if at all). The overall "markup" is the difference between the actual price set at the time of sale, largely according to market conditions, and the total manufacturing costs, which are to some extent determined years in advance, when the car is designed, and to some extent by the volume actually produced, which results from the market conditions.

Taxes play a different role: some are a factor which can enter the cost calculation (e.g., property taxes). Income taxes, however, are levied on profit, which is a residual and not predictable (if a manufacturer operates at a loss, no income taxes are due).

5.7 Alternative Implementation of Work Plan

All six tasks in the work plan are scheduled concurrently and all but Task 4 (Towaway Survey) can be completed within a year. It is at least open to discussion as to whether *all* six tasks should be undertaken simultaneously, even though they are essentially independent of each other. In the following discussion of alternatives, Task 6 is always undertaken; that is, the analysis of cost data will be performed in conjunction with any other set of tasks. The discussion, therefore, focuses on the first five tasks. It is CEM's considered opinion and recommendation that Task 1, (the analysis of State Farm accident data) be part of any initial evaluation of FMVSS 215 and this task is included in each alternative. The alternatives essentially are directed toward the group of tasks which are to be undertaken first. Obviously, the choice of alternatives does not preclude undertaking an omitted task at a later date, if the chosen alternative is insufficient for evaluation of the effectiveness of FMVSS 215.

Four work plan alternatives are summarized in Table 5-1. Alternative A includes only Task 1 in addition to the cost data analysis task. This minimum effort includes the evaluation task judged most likely to involve data which is presently available and believed to be adequate to determine a measure of the effectiveness of FMVSS 215. Following evaluation of the results obtained from Alternative A, other tasks could then be considered if Task 1 is not successful.

Alternative B avoids the two tasks requiring data collection efforts. Selection of this alternative would be made in recognition of the significant cost of Task 2 (Car Owners' Survey) and the speculative nature of Task 4 (Towaway Survey). The analysis of mass accident data (Task 3) and HLDI data (Task 5) pose significant problems, but the resources required are modest and all tasks can be completed within seven months, if the tasks are undertaken in parallel.

Alternative C includes Task 2 (Car Owners' Survey) in recognition of the fact that only from this task will direct information on the reduction of low speed, low (or no-) damage accidents be forthcoming. Task 4 is excluded because some towaway information might be forthcoming from the Task 2 survey. Task 5 is excluded because of the serious difficulties involved in detecting FMVSS 215 effects among other effects present in the HLDI data.

Alternative D includes all six tasks. At least two rationales could be put forward for taking this approach. The first might be that given the difficulties inherent in obtaining a comprehensive and unambiguous interpretation of FMVSS 215 effects, a complete investigation of all potential sources of information is justified. The second rationale is based on the judgment that Task 2 is essential. If this judgment is made, then one can argue that the much more modest resources required for the other tasks justify undertaking all other viable approaches, given at least a reasonable possibility of economically deriving some useful information on the effectiveness of FMVSS 215 from each of them.

TABLE 5-1

WORK PLAN ALTERNATIVES

Alternative	Tasks Included	Resources			Time to Complete Alternative (months)
		Person-Years	Data Processing ($K)	Other Costs ($K)	
A	1 - State Farm Accident Data 6 - Cost Data Analysis	0.5 1.0	1.0 1.0		7
	Total for A	1.5	2.0		
B	1 - State Farm Accident Data 2 - Mass Accident Data 5 - HLDI Data 6 - Cost Data Analysis	0.5 0.5 0.5 1.0	1.0 3.0 1.0 1.0		7
	Total for B	2.5	6.0		
C	1 - State Farm Accident Data 2 - Car Owner Survey 3 - Mass Accident Data 6 - Cost Data Analysis	0.5 1.6 0.5 1.0	1.0 3.0 3.0 1.0	65	12
	Total for C	3.6	8.0	65	
D	1 - State Farm Accident Data 2 - Car Owner Survey 3 - Mass Accident Data 4 - Towaway Survey 5 - HLDI Data 6 - Cost Data Analysis	0.5 1.6 0.5 0.5 0.5 1.0	1.0 3.0 3.0 0.5 1.0 1.0	65 30	16
	Total for D	4.6	9.5	95	

APPENDIX A

DISCUSSION OF STATISTICAL METHODS

A.1 INTRODUCTION

A number of statistical techniques can be considered as analytical tools to evaluate the effects of implementing FMVSS 214. Four of these techniques are discussed in this appendix.

- Regression Analysis
- Contingency Table Analysis
- Log Linear Analysis
- Index Method Analysis.

A.2 REGRESSION ANALYSIS

Statistics uses the term regression in two senses, one a broad sense and the other a restriction of the broad sense to a more "specific" one. Before we discuss these two (or more) concepts a word should be said about the term "regression" since it has various connotations that are not appropriate to most work. In the previous century, the British scientist, Galton, studied the "intelligence" of fathers and first born sons and found that if the father was more "intelligent" than average, the son usually was also, but he tended to be more average than the father. Galton referred to this phenomenon as "regression of mediocrity." The first part of the term has stuck as the name of the whole technique of which Galton's work is merely an early example. By the way, the above does not imply that the next generation is less intelligent than the previous, since, for example, for sons more "intelligent" than average, the fathers tend to be more average than the sons.

In the current broad-sense usage, regression is the study of the functional relationship between a dependent variable and one or more independent variables. The choice of terms does not imply a cause-and-effect relationship. In fact, taking the extreme case, the dependent variable could be the cause and the independent variable the effect, e.g., if one tried to regress the size of a bomb on the amount of damage caused.

It would be somewhat more precise to say that regression is the study of the mean or average structure of the dependent variable by means of the independent variates. One is usually not trying (in a primary sense) to find the variability of distribution of the dependent variable from the other variates. It is true that the research does look at the variability, but only in the second sense of wanting to see the stability or precision of the functional relationship of the average values of the dependent and independent variables.

Some examples of general regression would be:

(1) Finding the relationship between a student's college record (quantity point ratio) and his/her high school record, college boards and other records.

(2) The position of a stellar object as a function of time and previous positions.

(3) The probability of rain as a function of air pressure, previous weather, temperature, etc.

(4) The probability of a person's having blond hair as a function of whether or not he is Swedish, whether he is under 10 years, between 10 and 20,and over 20, etc.

This general restricted concept of regression considers dependent variables that have an interval scale, usually independent variables that are interval scaled,and a random error term. The random error term is assumed to be normally distributed. The independent variables are either values that can be adjusted by the researcher (e.g., the speed at which a test vehicle is driven) or normal random variables (e.g., the speeds of the cars in the population of cars considered is assumed to have a normal distribution). Both of these assumptions imply, in the linear case, that the dependent variable is normally distributed.

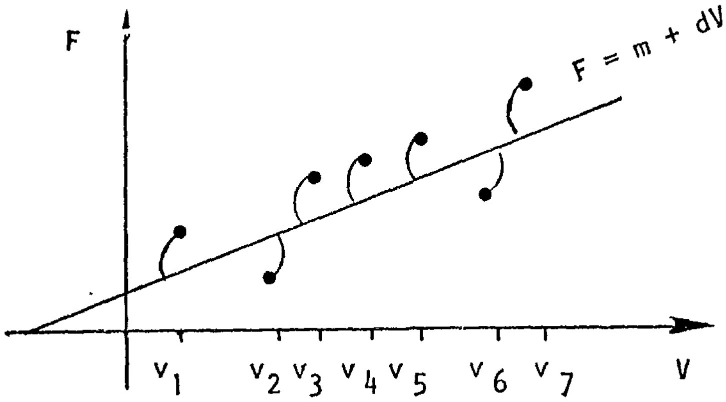
As an example, we might be interested in a model regressing fuel consumption per mile F, on velocity of the vehicle V, the weight W, and the horsepower H. As a first approximation, we would have:

$$F = \mu + \alpha V + \beta W + \delta H + \varepsilon,$$

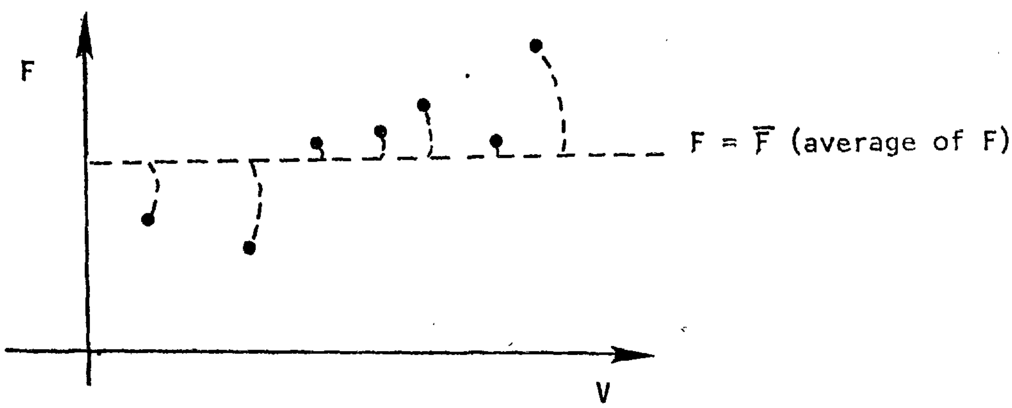
where ε is the random error term. Since each of the independent variables appears as a linear (first degree) term, we call this a linear equation. If we run the experiment under lab conditions and choose the speed, weight and horsepower values, these are considered fixed values and ε is usually assumed to have a normal distribution. On the other hand, if the data are sampled (collected) from a random selection of actual vehicles, then the values of the independent variables are not selected by the researcher and, in fact, have random distributions due to the random selection. However, the estimation of the usually unknown coefficients is, in both cases, carried out by least squares analysis. To accomplish this for all the data, we choose the values of m, a, b, c to minimize the summation

$$\Sigma\ (F_i - m - aV_i - bW_i - cH_i)^2.$$

The objective is to find the precise equation that is closest to the observed data. If we consider the equation, $F = \mu + dV$, then graphically we can obtain the following illustration.



If the dots represent the data points, the line F = m + dV is chosen so that the sum of the squared distances represented by ")" is as small as possible. In order to judge whether or not the line gives a good fit to that data, we compare the original variability of the data from a horizontal line,



with the sum of the squared distances from the sloping line. If the sloping line is a good fit there should be a substantial denumeration of the variability.

In practice there are various difficulties that can only be handled approximately at this stage of statistical development. In general, data are not normally distributed. In many cases the linear equation does not fit the data well enough and higher order terms are needed. However, if V is normally distributed, then V^2, V^3, etc. are not. Nonetheless, the procedure seems to work quite well even when the assumptions of normality are not satisfied. One of its great advantages is its widespread use in many applied fields. Furthermore, the procedures are quite standard and secondary analyses, such as comparing coefficients, can be done with little difficulty. On the other hand if the data, especially the dependent variable, are ordinal or nominal and if the range of the dependent variable is bounded, the results can be less than satisfactory. Also, if the dependent variable is not approximately normally distributed, the procedure is not as efficient as others that use any distributional knowledge. In addition, various statistical tests can be misleading if the distributional model does not reflect the true nature of the data in certain aspects.

A.3 CONTINGENCY TABLE ANALYSIS

A more recent development has been that of contingency table analysis based on log linear models. While the basic contingency table analysis goes back to Karl Pearson and his chi-square test, the log linear means structure is a more recent development.

In the Pearson chi-square v x c table, we usually have two factors or variables, for example, degree of injury and speed. These are made categorical e.g., injury is on the scale of slight or none, moderate or severe, while speed might be slow or fast. The body of the table contains the number of cases in each r and their respective probabilities (the latter) usually unknown in practice category.

INJURY	SPEED		
	Slow	Fast	
Slight or None	100 P_{11}	110 P_{12}	210 P_{1+}
Moderate or Severe	50 P_{21}	80 P_{22}	130 P_{2+}
	150 P_{+1}	190 P_{+2}	340

$P_{1+} = P_{11}+P_{12}$, $P_{+1} = P_{11}+P_{21}$, etc.
and $P_{11}+P_{12} + P_{21} + P_{22} = 1$.

The usual chi-square analysis would give*

$$\chi^2 = \frac{(100-92.65)^2}{92.65} + \frac{(110-117.35)^2}{117.35} + \frac{(80-72.65)^2}{72.65} + \frac{(50-57.35)^2}{57.35} = 2.44$$

with 1 degree of freedom. The value 2.44 is not significant at $\alpha = 0.10$.

This result indicates that there is no dependence between speed and injury (for these data) and so the apparent discrepancies are due to random fluctuation. However, an interpretation of the effects of speed and injury is not all that clear.

A.4 LOG LINEAR ANALYSIS

A log linear model can be formulated such that

$$\log P_{ij} = \mu + \Lambda_i + M_j + (\Lambda M)_{ij},$$

where

$$\Lambda_1 + \Lambda_2 = 0;\ M_1 + M_2 = 0;\ (\Lambda M)_{1j} + (\Lambda M)_{2j} = 0;\ (\Lambda M)_{i1} + (\Lambda M)_{i2} = 0;$$

and Λ is the effect of injury (deviation of frequency of injury from the average) and M is the speed effect and (ΛM) is the interaction, i.e., how much different speeds affect different levels of injury. This formula also gives the expected number E_{ij} in each cell ij as

$$\log E_{ij} = \log NP_{ij} = \log N + \log P_{ij}$$

$$= \log N + \mu + \Lambda_i + M_j + (\Lambda M)_{ij}$$

$$= \mu' + \Lambda_i + M_j + (\Lambda M)_{ij}$$

where N is the total number of cases.

The above χ^2 test tells us that $(\Lambda M)_{ij} = 0$ for all vehicle speeds, Λ_{ij}. Thus, we can say by appropriate analysis that the estimates of the E_{ij} are $\hat{E}_{11} = 92.65$, $\hat{E}_{12} = 117.35$, $\hat{E}_{21} = 57.35$, and $\hat{E}_{22} = 72.65$ and $\hat{\mu} = 4.41$, $\hat{\Lambda}_1 = -\hat{\Lambda}_2 = 0.237$, $\hat{M}_1 = -\hat{M}_2 = -0.121$. One can check these values of μ, the $\hat{M}$'s and the $\hat{\Lambda}$'s given the appropriate $\hat{E}_{ij}$'s. While this analysis can be done without the log linear model for this simple case, the model can easily be extended to more variables with the interpretation being similar to the usual analysis of variance. By extending the model we could include other factors such as weight of vehicle.

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*In general, $\chi^2 = \Sigma \frac{(\text{Observed}_{ij} - \text{Expected}_{ij})^2}{\text{Expected}_{ij}}$

An important property of the model is that it uses the discrete, multinomial character of the data, something the normal model fails to do. This fact should make the analysis more precise. However, one failing of such an analysis is that the dependent and independent variables are made discrete, which means that we cannot force the model to accept any ordering that we wish, e.g., we cannot force the effect of speed to be monotonic increasing.

Another choice of analysis is to allow the contingency table analysis to have a functional relationship that has continuous and discrete independent variables. One would still have the advantage of the underlying multinomial distribution but this would allow the type of interval variables that are found in the regression concept. Namely, consider models of the form $\log P = \mu + \Lambda_i + aC$ where Λ_i is discrete as before and the C is a continuous variable. Such an analysis should also consider interaction terms, e.g., what is the effect of impact angle with or without a head restraint.

This type of analysis, which we suggest, is non-standard. Anyone performing this analysis must be knowledgeable and highly trained. Suggestions for this analysis are included in Section 4 which presents the specific model recommended for evaluating FMVSS 214.

A.5 INDEX METHOD ANALYSIS

We recommend fitting the functional mean structure separately for cars with side beams and those without. The problem then is to compare the two situations. As a measure of effectiveness, if P_{SB} and P_{NSB} are the probabilities of a particular event (e.g., AIS $\geq$ 3) for a particular situation (e.g., speed = 20 mph, head restraint up, angle of impact = 90°) consider

$$\log_2 \frac{P_{NSB}}{P_{SB}} = I(SB, NSB), \text{ where I is an index.}$$

If the probabilities are the same, $P_{NSB} = P_{SB}$ then $I(SB,NSB) = \log_2 1 = 0$.
If side beams reduce the probability to half of the non-side beam level, i.e., $P_{SB} = 1/2\ P_{NSB}$, then

$$I(SB,NSB) = \log_2 \frac{P_{NSB}}{1/2 P_{NSB}} = \ell n_2 2 = 1.$$

If $P_{SB} = 1/4\ P_{NSB}$, then

$$I(SB,NSB) = \ell n_2 4 = 2.$$

Every doubling of the safety leads the index to increase by one. If the range of the improvement is smaller (e.g., $P_{SB} = 0.95\ P_{NSB}$), then using the logarithm to the base e is suggested, because

$$I(SB,NSB) = \log_e \frac{P_{NSB}}{0.95P_{NSB}} = -\log_e 0.95 = 0.5$$

which gives a 5% improvement. The interpretation of a percentage increase is only useful if the percentage increase or decrease is small ($\pm$10%).

We are recommending that the index be used as a function of the situation, not as an overall index. Use as an overall index would require an averaging of the individual values of the index. This averaging is difficult to perform in the sense that the weighting to be used in unclear. For example, if vehicles without side beams tend to travel at higher speeds than vehicles with side beams, how does one weight speed: higher or lower? The choice will affect the overall index. A statement such as "moderate and low speeds lead to some improvement while higher speeds give an index near zero" would be much more informative.

The index method is a possibility but it, too, is an averaging of the probabilities according to some reference population. The choice of the reference population is rather arbitrary.

A.6 APPLICATIONS

We now wish to consider the problems of statistical analysis of the difference between injuries and/or intrusion in side beam and non-side beam cars. Although various possibilities exist, the simplest is to consider a large test of homogeneity. Using the previous analysis, one could have decided which variables are important. If, for example, only speed is considered relevant, one would have for both side beams and non-side beams an r x c table with one factor being injury classification and the other being the various speeds. One could then compare the two r x c tables in a large homogeneity table.

Another possibility is to use a log linear model and fit the model where the side beam has an effect and where it does not. Using the asymptotic likelihood ratio test, one can then see if there is a significant difference. Since there is a subcollection of situations in which differences are expected to be more pronounced, one could just do a test for those also, since non-differences in other situations could mask the effect.

APPENDIX B

DISCUSSION OF PROPOSED STANDARD IMPLEMENTATION COST CATEGORIES

NHTSA has stated that to measure the consumer's out-of-pocket expenses the cost categories should be:

- Direct manufacturing
- Indirect manufacturing
- Capital investment (including testing)
- Manufacturers' markup
- Dealers' markup
- Taxes*

However, we feel that the consumer's initial costs are determined by a complex process, with different types of bargaining at the retail, wholesale, and manufacturing levels. It is well recognized, and also acknowledged by the auto manufacturers, that wholesale prices are set in response to market conditions, and that their relationship to manufacturing cost is loose. In a recent CEM study† this question was examined and no relation was found between annual increases in manufacturers' cost of satisfying FMVSS's as estimated by GAO, and the retail price increases.

Certain cost categories can be well estimated: direct and indirect manufacturing, and capital investment, including testing. These costs represent real resources used. The question of markups is conceptually very difficult, considering the manufacturers' pricing strategies (trying to cover a market spectrum) and the oligopolistic nature of the market. Using average gross profits for the manufacturing markup would be incorrect and misleading. To find the true markup would require a major study examining manufacturers' detailed cost data and pricing practices (internal and external).

The question of dealer markup is somewhat easier to consider conceptually; however, to determine it in practice is complicated by the trade-in of used cars. It appears highly likely that there is no fixed percentage markup on the dealer level, but a more complicated relationship which depends on the value of the new vehicle, the trade-in and other market conditions. Using an average gross profit, or the difference between wholesale and retail prices, would also be inaccurate and misleading.

With regard to the issue of taxes, this cost is not only borne in the form of a sales tax as the fraction of the components cost of the total car, but it is also accumulated at every stage of manufacturing in the form of property, payroll, sales (intermediate) and excise taxes. Income taxes are another cost;

*Personal communication from Warren G. HaHeist, Contract Technical Monitor, 18 January 1977.

†CEM Report 4194-574, *Program Priority and Limitation Analysis*, Dec. 1976, Contract DOT-HS-5-0.225.

however, they are not directly related to the resources used but to the profitability of the manufacturers.

Therefore, based on the above discussion, we consider it beyond the state-of-the-art to estimate the true out-of-pocket cost of new car buyers due to satisfying the FMVSS. Good estimates of the costs of real resources consumed can be made, but these costs apparently are not passed on immediately or directly to the consumer of that model. Other costs (markups and taxes) are conceptually and practically difficult to establish. The most reliable estimate of consumer cost would have to be aggregated over the entire market and a several year period in order to account for changes in market strategy and conditions.

Another point of concern with regard to the collection of data on cost items is the periods of comparison--one model year before the effective data *vs.* the model year that the Standard became effective or the next model year. The first point is that manufacturers have made changes to vehicles prior to the effective date of compliance, especially in the case of totally new models. Secondly, there is the learning curve effect in most manufacturing processes which will reduce the effective cost of manufacturing over time. With regard to this second effect, savings would be difficult to estimate, especially as these new components become more integrated into the basic structure of the vehicle. Therefore, using these time periods for comparison may tend to overestimate the cost of the Standard.

APPENDIX C. RATE OF RETURN FOR SURVEYS

C.1 AGENCIES CONDUCTING SURVEYS OF NEW CAR BUYERS

From 1962 to 1975, 12 surveys of new car buyers were conducted by the marketing departments of two large agencies interested in public opinion: *U.S. News and World Report* and *Newsweek*. In all but two of these mail surveys, the response rate was well above 50%, and in the two below that level, the rates were 47.7% and 46%, responses the research teams felt to be a "reliable tabulating base for the data." The table below summarizes the 12 surveys.

Range of Survey	Model Year	Month of Sample	Net Mailout	Return	
				Number	Percent
U. S. News and World Report					
All New Car Buyers	1962	January 1962	1,926	1,395	72.4 %
All New Car Buyers	1963	January 1963	3,879	2,522	65.0 %
All New Car Buyers	1964	November 1963	3,953	2,773	70.1 %
All New Car Buyers	1965	January 1965	3,906	2,626	67.2 %
All New Car Buyers	1966	November 1965	3,862	2,614	67.7 %
All New Car Buyers	1967	November 1966	3,882	2,410	62.1 %
All New Car Buyers	1968	January 1968	2,930	1,398	47.7 %
All New Car Buyers	1974	June 1974	3,897	2,358	60.5 %
Newsweek					
All New Car Buyers	1973	January 1974	3,041	1,571	51.7 %
New Imported Car Buyers	1973	May 1973	8,726	4,769	54.7 %
All New Car Buyers	1974	July 1974	2,893	1,332	46.0 %
New Imported & Small Domestic Car Buyers	1975	May 1975	15,868	8,322	52.4 %

C.2 MAILING METHODS USED

C.2.1 *U. S. News and World Report*

An original mailing and follow-up mailings were used in each of the studies conducted from 1962 through 1974. Only one mailing was made in the 1968 study, which the organization feels accounts for the lower rate of return that year. The initial mailing explained the survey, included the questionnaire plus a stamped, self-addressed reply envelope. About two weeks later, a reminder letter was sent and this second letter included another copy of the questionnaire ("in case you misplaced the original") and another stamped, addressed reply envelope. Two weeks after that--and four weeks after the original letter and questionnaire were sent-- a third letter, again with all the enclosures, was sent.

All letters were sent on letterheads of a research company. No reference was made anywhere to the sponsoring organization.

C.2.2*Newsweek*

This agency's policy was the same for the four surveys analyzed. In each case, an advance postcard was sent to a prospective respondee, explaining the survey, asking his help and announcing that a questionnaire would be sent "in the next few days." The questionnaire went out about four days after the post card and the package included a stamped, addressed envelope.

There were no follow-up letters sent by *Newsweek*, which may account for that organization's lower response rate, compared to the *U. S. News and World Report* return rate.

Again, all correspondence went out on a research company's letterhead, and there was no identification of the sponsoring organization.

C.3 INCENTIVES

It is a policy of both groups to offer token incentives--25¢ pieces, in each case. They are always offered informally, in the form of a P.S. to the letter sending the survey forms.

- *U. S. News and World Report*: "P.S. A token pocket-piece, in the form of a shiny new quarter, is attached as a small measure of our appreciation."
- *Newsweek*: "P.S. The enclosed coin is a token of our appreciation. You may wish to use it to brighten the day of some child."

It is interesting to note that *U.S. News and World Report* sent its "shiny new quarter" with every letter (initial and followup), which may have made the person who received letter number 3 and a third quarter finally fill out the survey form.

C.4 LENGTH OF QUESTIONNAIRE

The survey forms of both agencies are set up very similarly. They both average eight pages a survey and 31 multi-part, multiple choice questions, of which the last ten or so ask information for "statistical purposes only." In various surveys, these questions on age, sex, education, income, etc. have been directed to heads of households, or registered owners of the car, or to principal drivers of the car.