DOT HS-802 347

FINAL DESIGN AND IMPLEMENTATION PLAN FOR EVALUATING THE EFFECTIVENESS OF FVMSS 301: FUEL SYSTEM INTEGRITY

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 802 347		

4. Title and Subtitle	5. Report Date
FINAL DESIGN AND IMPLEMENTATION PLAN FOR EVALUATING THE EFFECTIVENESS OF FMVSS 301: FUEL SYSTEM INTEGRITY	May 1977
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No. CEM Report 4207-566
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 10/76 - 3/77 Tasks #4 & #5 Report 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report covers the final design and implementation plan for evaluating the effectiveness of FMVSS 301 (Fuel System Integrity). The plan for the evaluation study considers measurability criteria, alternative statistical techniques, data availability/collectability, resource requirements, work schedule, and other factors. The Standard requires operational integrity of the fuel system after various barrier crash conditions, and it sets explicit limits on the amount of fuel spillage under test conditions. The ultimate objective of the Standard is to reduce the deaths and injuries due to auto collision fires by limiting fuel spillage/leakage. Fires in motor vehicles due to collision are rare events. For example, only 5 percent of all auto fires are due to collisions; the probability of fire in a collision is about 0.001. About two percent of auto accident fatalities are due to fires. Because the event population is small, a number of methods are proposed for evaluating this Standard. Described herein are: (1) using newly collected data on fuel system rupture in towaway accidents in specified localities to search for significant shifts in the rupture/no rupture rate; (2) using historical data from fire departments on automobile fires, and cross-indexing these data with police accident files; and (3) using information from vital statistics on deaths due to fire in automobile crashes, and information from data files on fatal accidents.

17. Key Words	18. Distribution Statement
Federal Motor Vehicle Safety Standards FMVSS 301 Fuel System Integrity Standard Evaluation Statistical Methods	Document is available to the public through the National Technical Information Service, Springfield, VA 22161

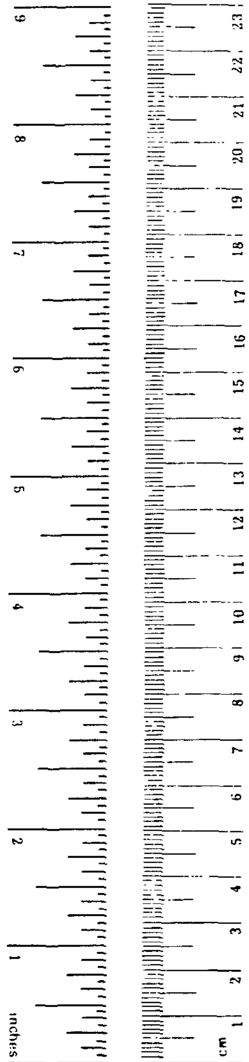
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	69	

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

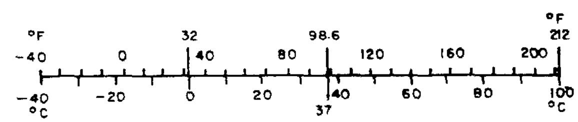


TABLE OF CONTENTS

ABBREVIATIONS USED

AIS	Abbreviated Injury Scale
AMC	American Motors Corporation
BLS	Bureau of Labor Statistics
CDS	Collision Deformation Classification
CPIR	Collision Performance and Injury Report
FARS	Fatal Accident Reporting System
FMVSS	Federal Motor Vehicle Safety Standard
GAO	General Accounting Office
GM	General Motors
GVWR	Gross Vehicle Weight Range
HC	Hydrocarbon
HSRC	Highway Safety Research Center
HSRI	Highway Safety Research Institute
MPV	Multipurpose Vehicles
NCSS	National Crash Severity Study
NHTSA	National Highway Traffic Safety Administration
PPM	Parts per Million
SPSS	Statistical Package for Social Sciences
UCLA	University of California at Los Angeles
VIN	Vehicle Identification Number
VSDSS	Vehicle Safety Design Surveillance System
VW	Volkswagen

1.0 INTRODUCTION

This report is the third 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 301 - Fuel System Integrity.

1.1 Background

Since its introduction in 1968, this Standard has been modified several times, increasing the difficulty of meeting the test criteria. For example, the static rollover test was first proposed in 1973 for the 1976 models; that test requirement was temporarily suspended, while new test criteria were considered. The 1976 models had to meet the frontal crash and static rollover requirements. The present 1977 models must meet front, side, and rear barrier crashes as well as static rollovers. Vehicles in the 6,000 to 10,000 pound GVWR* (typically multipurpose vehicles such as vans or pickups) must meet the passenger car requirements by the 1978 model year. Table 1-1 describes the applicability of the Standard by model year.

Purpose of FMVSS 301

- The specific purpose is to establish requirements for the integrity of motor vehicle fuel systems.

- The general purpose is to reduce deaths and injuries occurring from fires resulting from fuel spillage in motor vehicle accidents [1].

General Requirements of FMVSS 301

- In the barrier tests for fuel spillage, the vehicle must not lose more than:
  - One ounce by weight during the crash.
  - Five ounces during the next five minutes after the crash.
  - One ounce in any one minute period during the next twenty-five minutes.

- In the rollover test, fuel spillage is limited to five ounces in the first five minutes at any 90° increment or more, and is limited to no more than one ounce during any subsequent one minute period while the vehicle is at rest.

---

*Gross Vehicle Weight Range.

TABLE 1-1

APPLICABILITY OF THE STANDARD BY MODEL YEAR

Model Year	Fuel System Integrity Requirements Set by FMVSS 301*
Pre-1968	• No requirements
1968	• Frontal barrier crash (30 mph) and limited leakage from fuel tank, filler pipes, and fuel tank connections during impact (one ounce) and after impact (one ounce per minute). Effective January 1, 1968.
1971	• In response to air pollution control legislation, auto manufacturers installed evaporative emission-control systems increasing fuel system elements.
1976	• Passenger cars must meet front barrier impact and static rollover test.
1977	• Side and rear barrier impact tests are added to passenger car requirements. • Other vehicles up to 6,000 pounds GVWR must meet 1976 passenger car conditions plus the rear impact test. • 6,000 to 10,000 pound GVWR vehicles must meet only the front barrier test.
1978	• All vehicles up to 10,000 pounds GVWR must meet the 1977 passenger car requirements.

*The 1976 modifications were announced in 1973 and manufacturers had considerable lead time to introduce improvements in pre-1976 models in anticipation of the effective date of the Standard.

- Currently, passenger cars (1977 model) must undergo 30 mph front barrier and rear moving barrier crashes, a 20 mph lateral moving barrier crash and a static rollover.

- The 1977 model year multipurpose vehicles of less than 6,000 lb GVWR must undergo only the perpendicular front barrier crash, the rear moving barrier crash, and the static rollover. The 1978 models must meet the current passenger car criteria.

- The 1977 multipurpose vehicles of between 6,000 and 10,000 lb GVWR must meet the perpendicular front barrier crash criteria. The 1978 models must meet the current passenger car criteria.

- School buses, which are 10,000 lb GVWR or greater, have to meet a special moving contoured-barrier crash test starting July 15, 1976. The evaluation of the effectiveness of this Standard with regard to these school buses is not within the scope of this project.

The static rollover test occurs after an impact test. The vehicle is rotated about its longitudinal axis in 90° increments. Each incremental rotation should take between one and three minutes and the vehicle should remain in each position for five minutes.

Measures of Effectiveness

There seems to be no direct, quantitative scalar measure which relates accident conditions to the effectiveness of this Standard. Using the Abbreviated Injury Scale (AIS), police or accident investigators would have to classify burns separately from other injuries. For instance, AIS-1 includes all first degree burns or some second degree. It also applies to minor aches and sprains. An occupant may suffer slight (AIS-1) burns and more severe (AIS-2) bodily injuries. However, normally only one injury (the most serious) classification is designated for each victim in a crash. This would decrease the effectiveness of using existing AIS data with regard to burns. The Collision Deformation Classification (CDC) depends on many investigator judgments in making measurements. To measure the effectiveness of the Standard using CDC, many additional items of information would be needed (fuel system spillage or rupture and location of tank, spout, and lines). A combination of these factors would seem more promising than using the CDC alone. Use of vehicle deformation or any other such impact measure (vehicle speed, direction and location) adds the factor of "indirect" collisions--that is, the initial impact causes some other part of the vehicle to impact and damage the fuel system.

The best quantitative measures may exist only on an aggregate basis, such as: fire-caused deaths in auto collisions as a percent of all fatal accidents, or the rate of fuel system ruptures in the towaway accident population. Neither measure is likely to directly reflect the effect of the Standard. Deaths due to fire in auto accidents may increase (or decrease) because of better (or worse) escape conditions, materials giving off toxic fumes, etc.* Ruptured fuel systems in towaway accidents may represent a biased sample of accidents and the number of fires may increase or decrease, depending on the ignition sources. Also, there is the further possibility that the fire (and subsequent injury or death) may not be due to the occupant's vehicle but to some other vehicle. For example, cars striking exposed fuel tanks on trucks may result in fire and injury in the striking vehicle.

*The plastic materials being used to lighten new cars increase the available combustible material and burn at an intense heat, thus increasing the hazard to occupants, once a fire is initiated.

Means of Complying with the Standard

A variety of approaches, most of which can be implemented in concert, have been suggested for compliance. The means of compliance are briefly listed below and are discussed in References 2, 3, and 4.

- Fuel Tank Location. For a front-engine vehicle the most protective location would be the area between the rear wheels above the rear axle and below the rear window. The regions close to the rear fender or either side of the car are more vulnerable to rear end or side impacts. (Mercedes and the VW Dasher have protected or interior fuel tanks, as do many U.S. station wagons.)

- Fuel Tank Material and Shape. Horizontally aligned rectangular flat tank configurations with smoothed contours and corners offer the least hazardous design. The strength of tank walls should take into account fuel capacity and size of car. Alternatives to rigid metal construction include plastic fuel tanks and expandable tanks with corrugated folds which permit altering the geometric shape of the tank [2].

- Fuel Tank Anchorage. The straps and anchor points for the tank must be sufficiently strong to withstand extreme distortion and inertial forces associated with impact.

- Filler System. In general, the protrusion of the filler neck from the tank should be as short as possible, consistent with the location of the tank. The major change that manufacturers made to initially satisfy the Standard was to upgrade the filler tank cap. Self-sealing breakaway type fittings have been suggested for the filler system and the other outlets from the fuel tank. The vapor vents have float valves to prevent fuel leakage but these could be defeated in rollover accidents.

- Vent Line and Fuel Line. As mentioned above, it has been suggested that all fittings to the fuel tank be of a self-sealing breakaway type. In addition, the location, length, flexibility and strength of the vent and fuel lines all affect the possibility of rupture and fuel leakage.

- Carburetor/Fuel Pump/Fuel Filter Locations. The location of these components in the front end relative to other systems will influence successful compliance with front or lateral moving side barrier tests.

Primary and Secondary Effects of Compliance

"Even a cursory review of contemporary designs shows that fuel systems have not been considered as a single, integrated, rupture-resistant system, but as a set of components adapted to a particular vehicle after its basic design has been completed" [5]. The major effects of the Standard have been the repositioning of the fuel tanks and filler spouts and the upgrading of the fuel filler cap.

The repositioning of the tank might have some secondary effect on the performance of motor vehicles, because it changes the weight distribution. However, this would be hardly perceptible and probably beneficial. Repositioning the fuel tank to more interior parts of the car would increase the hazards to the occupants in the case of a fire (though the probability of fire and leakage may be reduced). Thus, most design change recommendations include fuel tank repositioning and introduction of a fire wall for protection of rear seat passengers.

Another secondary effect, at least partially ascribable to the Standard, is the increased complexity of the carburetor.* The system has become more enclosed and more difficult to service, partly to prevent leakage from the carburetor during the rollover test.

For Multipurpose Vehicles (MPVs), there has been rapid design development to meet the Standard. With the greater weight,longer fuel lines, and lack of energy absorbing bumper systems of MPVs it is more difficult to control fuel leakage in frontal crash tests. To meet the Standard, MPVs may require structural changes which passenger cars do not need.

Real World Performance of the Standard

It is clear that FMVSS 301 does not apply to a number of crash situations. These include:

- Those at speeds higher than specified in the Standard.
- Impacts with any object which is not perfectly flat (poles, abutments, car bumpers, etc.).
- Real world rollover crashes, especially where the filler spout projects out from the vehicle body.
- Collisions causing intrusion into the area of the fuel tank, filler spout or evaporative canister.
- Running off the roadway over barriers or rocky, uneven terrain.

In general, fire and/or fuel spillage are relatively rare events in motor vehicle collisions [5, 6, 7]. The various studies summarized in Reference 5 point out an important fact in evaluating the real world performance of this Standard: fire occurs in approximately one in a thousand motor vehicle accidents, and only one in twenty of all vehicle fires is due to a collision. Given these figures, there are about 17,000 accident-related vehicle fires per year

*The majority of the changes to the carburetor have resulted in engine performance improvement.

in the entire country; and of the vehicle fire records which fire departments might keep, only 5 percent of their reports would apply to vehicle fires due to collision. The measurement of the more frequent occurrence of fuel spillage is harder to detect because of evaporation and absorption of the lost fuel. The frequency of fuel system damage in real world accidents is perhaps the best physical measure of an indirect effect of the Standard.

Because there is an obvious relationship between fires, fuel sources and ignition sources, the real world performance of the Standard will depend on limiting potential interactions between the fuel and ignition sources. Therefore, the impacts of the introduction of the fuel vapor recovery system and catalytic converter, as well as a consumer trend toward purchase of vans, motor homes and other potentially hazardous larger vehicles, makes the evaluation of the performance of the Standard even more difficult.

1.2 Summary of Evaluation, Cost Sampling, and Work Plans

The plan to evaluate the effectiveness of FMVSS 301 will be concerned with three analyses. These are:

- Analysis of Fuel System Rupture in Towaway Accidents
- Analysis of the Frequency of Fire and Fuel Spillage
- Analysis of Deaths Due to Fire in Automobile Accidents.

The latter two analyses make use of historical data, but these data must be specially collected and automated. These two analyses also require the availability of mass accident data. The first analysis requires a new data collection.

1.2.1 Fuel System Rupture in Towaway Accidents

The analysis of fuel system rupture in towaway accidents is designed to evaluate the effects of the Standard both on crashes which approximate the test conditions of the Standard and on crashes which clearly are not within these test conditions. The towaway accident data will be collected by a team of trained investigators or technicians. Fuel system rupture and vehicle data will be obtained from a detailed inspection of the accident-involved automobile while accident-related information will be extracted from police reports. Sample regions will be selected such that (1) at least some of the regions coincide with NCSS data collection areas and (2) the police and police-designated towtruck operators are willing to cooperate with the study teams. In the analysis of the data it will be important to control for speed, area of impact, position of fuel tank and filler cap and presence of corrosion of the fuel system. In the selection process for including towtruck accidents in the study, crashes involving older pre-Standard cars will be overrepresented to allow analysis comparisons to be made.

1.2.2 Frequency of Vehicle Fires and Fuel Spillage

The analysis of the frequency of vehicle fires and fuel spillage requires historical data which would be obtained from fire department records, supplemented when needed with data from police accident records. Also, data on all accidents would be obtained from mass accident data. The selection of sample regions where vehicle fire data would be acquired depends on (1) securing the cooperation of the fire department and police department; (2) including, to the extent possible, NCSS data on vehicle fires and fuel spillage, and (3) the availability of mass accident data. Procedures must be established for cross-referencing fire and police data. The analysis will be directed toward determining if a difference exists in the frequency of accidents involving fire and fuel spillage relative to all accidents for pre-Standard and post-Standard cars. The major factors included in the analysis are: (1) model year (pre-Standard *vs.* post-Standard); (2) calendar year; (3) impact location (in relation to fuel system components); (4) vehicle age;and (5) state. Vehicle age will be treated as both a linear and a categorical variable. The significance of results will be established with a standard χ^2 test.

1.2.3 Fire-Related Fatal Accidents

The analysis of fire-related fatal automobile accidents will require data obtained from a variety of sources. These sources include (1) state files of hardcopy or microfilmed fatal accident reports; (2) vital health statistics of medical examiners; and (3) NHTSA's Fatal Accident Reporting System (FARS) for post-1974 data. It is estimated that useful data as to whether or not a fire was involved can be obtained for over 88,000 fatalities from the following data sources: (1) North Carolina; (2) Texas; (3) New York State; and (4) FARS. Mass accident data will be needed to obtain accident and vehicle information for both fire-related and non-fire-related fatal accidents. The analysis is directed toward determining whether there has been a significant decrease in fire-related car accidents relative to all accidents between pre- and post-Standard vehicles. Contingency table analysis will be used if the effect due to vehicle age can be included in two or three discrete categories. Alternatively vehicle age will be treated as a continuous linear variable and a likelihood ratio test performed. Interpretation of the effects of FMVSS 301 is complicated by the simultaneous introduction of 19 other Standards which may have different impacts on fatal and non-fatal accidents.

1.2.4 Cost Sampling Plan

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 in gather data in two replications for six market classes during the model years 1968 (pre-Standard), 1969 (post-Standard), and 1976 (major upgrading of Standard).

1.2.5 Work Plan

The work plan for the evaluation study and cost analysis is carried out in four tasks. The work on all four tasks could be conducted simultaneously, since the tasks are basically independent of each other. The total personnel resources required for all four tasks are 11 person-years, ten of which are consumed in the first three tasks. The data collection efforts (whether of new or historical data) account for over half of this effort. A total of $10,000 is required for computer processing and over $30,000 is estimated to be needed for expenses attendant to data acquisition, data collection and personnel training.

Task 1 is concerned with the collection and analysis of new data on fuel system rupture in towaway accidents. The 18-month effort will require resources of 4.5 person-years, $2000 for computer processing, and $13,000 for expenses associated with data collection and personnel training.

Task 2 deals with the acquisition of data on vehicle fires and fuel spillage,mainly from fire departments. Mass accident data are also required for information on all accidents. The 12-month study is estimated to require resources of 2.5 person-years, $3,000 for data processing and $10,000 for expenses associated with collecting fire data and acquiring mass accident data.

---

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

Task 3 is directed toward collecting and analyzing data on fire-related fatalities. The fire-related fatalities are determined from state accident records, vital health statistics and FARS. Mass accident data are also required. Resources of 3.0 person-years, $4000 for computer processing and $10,000 for data acquisition expenses are required for this 12-month study.

Task 4 is concerned with the determination of direct costs to implement FMVSS 301. Resources of 1.0 person-year and $1000 for computer processing are needed for the seven-month effort.

1.3 References for Section 1.0

1. NHTSA, *Part 571-Motor Vehicle Safety Standards: Standard No. 301 - Fuel System Integrity*, Federal Register, Vol. 40, No. 200, October 15, 1975, p. 48353.

2. Severy, D., D. Blaisdell, and J. Kerkhoff, *Automobile Collision Fires*, Proceedings of the Eighteenth STAPP Car Crash Conference. Society of Automobive Engineers, Inc., 1974.

3. Robertson, S.H., *A New Look at Fuel System Design Criteria*, Proceedings of the Tenth STAPP Car Crash Conference. Society of Automotive Engineers, Inc., 1966.

4. Severy, D.M., H.M. Brink, and J. D. Baire, *Postcrash STudies Show Need for Rear-Seat Fire Wall and Rupture-Proof Fuel Tank*, SAE Journal, July 1969.

5. Cooley, P., *Fire in Motor Vehicle Accidents*, HIT LAB Reports. Highway Safety Research Institute, Volume 5, Number 1, September 1974.

6. Siegel, A., and A. Nahum, *Vehicle Postcollision Considerations*, 1970 International Automobile Safety Conference Compendium. Society of Automotive Engineers, Inc., 1970.

7. Johnson, N., *An Assessment of Automotive Fuel System Fire Hazards*, DOT-HS-800-624, Dynamic Science, Phoenix, 1971.

2.0 APPROACHES TO THE EVALUATION OF FMVSS 301

The purpose of FMVSS 301 is to reduce deaths and injuries occurring from fires resulting from fuel spillage in motor vehicle accidents. The Standard attempts to achieve this goal through establishing limits to fuel spillage in vehicle test situations.

The main problems with evaluating this Standard are:

(1) The infrequency of fire-related deaths in fatal accidents.

(2) Fires due to fuel spillage in accidents account for only a small percentage of vehicle fires, so that even mass data bases with motor vehicle fire data would be unuseable.

(3) Due to pollution control requirements, considerable changes have been made to the fuel system, possibly increasing the fire hazard.

Other problems in evaluating the Standard are:

(4) Without special training and equipment, it is difficult to detect fuel spillage/fuel system rupture, in an on-site investigation.

(5) In the case of fires, and fire-related deaths, there is the question of the cause of death. And in multi-car accidents there is the question of which vehicle caused the fire.

(6) Given the relatively low numbers of incidents of interest,the analyses will probably be limited to answering simple questions about whether there is any discernable effect of the Standard. Detailed analyses of makes and models or crash configuration may not be statistically meaningful, unless large effects actually exist.

To obtain information on fire and/or fuel spillage, at least the following approaches are potential candidates:

(1) Analyze the frequency of fuel system rupture in towaway accidents for various model years.

(2) Analyze the frequency of fire and/or fuel spillage in motor vehicle accidents by using historical accident data from fire and police departments, or through new data collection.

(3) Analyze the frequency of fire-related deaths in motor vehicle accidents using various state Fatal Accident files and possibly Vital Statistics records.

Determining the frequency of fuel spillage in motor vehicle accidents will be difficult because of the fast evaporation rate of gasoline and other difficulties in detection. Also, until the 1977 model year, other vehicles (multipurpose vehicles, vans, trucks, buses) up to 10,000 lb GVWR did not have to meet FMVSS 301. Therefore, these vehicles cannot be included in the basic analysis. However, these vehicles represent a significant portion of the vehicle population (20% of passenger car sales in 1970, 29% in 1975) and any information gathered on them would be of value.

The first approach encounters the basic problem of measuring fuel system rupture. Obviously, immediate investigation of accidents would afford greater reliability in detecting fuel spillage. However, even rapid response times may be too slow, compared to the volatility of gasoline, and other difficulties of on-site investigations. Therefore, it is necessary that special training and equipment be given to the investigators in order to determine the occurrence of fuel spillage/fuel system rupture. The type of accident would have to be restricted to towaways in order to assure that the vehicle is available for thorough examination.

The second approach reduces the stringency of the fuel system integrity question by focusing on visible evidence which is immediately observable and probably requires fire department attention. The informaiton on fire/fuel spillage could be obtained from a variety of sources: (1) historical fire department records; (2) new data collection by police; and a limited number of cases from (3) the National Crash Severity Study (NCSS). The problem with this approach depends on the source of data. In the case of using historical records from fire departments, the data must be retrieved from hardcopy files and put in a consistent form for analysis. The areas selected for data collection should be representative, have cooperative fire departments with the proper data collection system and accident data. Stratifying the fire/fuel spillage accidents by crash configuration will require access to local accident records. Also the states in which the data collection takes place should have computerized mass accident data files with county or town variables, such as New York, Texas, or North Carolina, so that the basis of comparison is geographically consistent. The use of new data collected by police as part of a normal accident investigation would take time to set up and administer and would yield less data on older vehicles, which is where the initial effect of the Standard will exist. Using the NCSS data, we can only expect some few hundred instances of fire/fuel spillage accident-involved vehicles of more recent model years. These data, since they will be easily available, should be looked on as a source of corroborating evidence.

The third approach, the study of motor vehicle fatalities due to fire, has the basic problem of sample size and data accumulation. Fire involvement is not normally included on computerized mass accident files, and even where it is, there remains the question as to whether the fire was a direct cause fo death or just an incidental event. Fatal accidents involving fire seem to represent only about two percent of all fatal accidents. In those cases where fire was involved, additional information might be obtained from such sources as a coroner's report or death certificate, which are likely to be part of the fatal accident file. The actual accumulation of such data depends on the way states gather and maintain information on fatalities. Preliminary investigations indicate that four states* segregate fatal accident hardcopy files to make them readily accessible. We believe it is safe to infer that at least the majority of states also maintain easily accessed fatal accident files.

In summary, the first approach is the most systematic and precise but it suffers from having relatively few early models in the accident population. When historical data are used, the second approach overcomes the first problem but encounters potential problems of data inconsistencies. If police collect new data, there is the time delay and underrepresentation of earlier models. However, potentially more data could be made available. The last approach most directly addresses the objectives of the Standard. However, the infrequency of fatalities due to fires in motor vehicle accidents limits data availability.

Some Special Words of Caution

The evaluation of the effects of FMVSS 301 faces two potential problems:

(1) The use of current information from specially investigated accidents implies that all cars preceding the Standard are "old." Therefore, deterioration of the fuel system--rust, corrosion, fatigue, deterioration of rubber or plastic components, etc.--may increase the risk of fuel spillage.

(2) In older accident data, which involve pre-Standard cars when still "young " and presumably not (or less) affected by fuel system deterioration, it is not clear that fuel spillages and fires are reported completely or consistently.

The degree to which these problems will arise is an empirical question which cannot be answered with the currently available information. It is quite likely, however, that they will have some effect. Therefore, it is not feasible to design a straightforward evaluation plan which will result in the conclusion that FMVSS 301 has a specific effect of reducing fuel spillage by X percent,or

*Connecticut, North Carolina, and Texas have physically separate files. New York saves low file numbers for fatal accidents.

that an effect, if any, is less than Y percent. One may possibly obtain such a result, but it is quite likely that the only possible conclusion will be that there are other effects, possibly masking all or part of the effect of FMVSS 301. In such a case, only *ad hoc* analyses, designed to eliminate such effects as far as possible, promise some hope of isolating the effect of the Standard.

Therefore, all approaches proposed above and described in the remainder of this report are to a large extent speculative. None will lead with certainty to a conclusive result. As a purely subjective judgment, it is expected that the analysis of new data to be collected will be the most promising approach, provided that there is no significant fuel system deterioration with age. The analysis of fire department records appears to be the second most promising example. Analysis of fatal accidents appears least promising by itself. Using any two, or all three of these approaches, however, may give convincing overall results because of the independent nature of the basic data, even though each analysis by itself may be actually or potentially subject to uncontrolled influences.

3.0 EVALUATION PLAN

3.1 Analysis of Fuel System Rupture in Towaway Accidents

3.1.1 Data Requirements

The fuel system rupture analyses will depend on towaway accident data collected by a team of qualified, trained investigator/technicians. Data will be gathered for a defined occurrence of fuel system rupture relative to each of the following components:

- Gasoline cap
- Filler pipe connector
- Gasoline tank
- Fuel line and connectors
- Fuel pump
- Carburetor
- Vapor control carbon canister

A complete analysis of fuel system rupture will require additional information relative to both the vehicle and the accident. The information required for each vehicle is:

- Vehicle model year
- Vehicle make/model
- Detailed information on fuel system components and configuration
- Area of impact
- Severity of impact, e.g., the Traffic Accident Data (TAD) scale might be used
- Pre-existing damage or corrosion/fatigue of fuel system
- Occurrence of vehicle rollover.

The information required for each accident is:

- Type of collision (front-side, etc.)
- Type of accident (single or multi-vehicle)
- Estimate of speed (if available)
- Road type.

The accident-related data would have to be obtained from the police report. The vehicle-related data and the detailed data on fuel system rupture would be obtained by the trained investigator who could gather the data by inspection and/or testing.

A question arises as to how representative the selected towtruck accidents are compared with all accidents in the area. The only timely way to answer this question would be to manually collect all accident data. This might increase the data collected by an order of magnitude. The alternative of waiting for mass accident data, if available, might delay the study for 1-2 years.

3.1.2 Data Acquisition

The acquisition of fuel system rupture data in towaway accidents must address the following considerations:

- Selection of sample regions.
- Securing cooperation of police and police-designated towtruck operators.
- Preparation of data forms and training of investigator/technician.
- Requirements of sample size and length of study.

Data will be collected with the cooperation of both the police and police-designated towtruck operators. The ability to secure such cooperation will influence the selection of sample sites. It may be advantageous to locate the sample regions in National Crash Severity Study (NCSS) data collection areas.

In addition to site selections and securing the cooperation of police and towtruck operators, two other tasks must be accomplished in preparation for data acquisition. The first task is the preparation of forms which can be used for entering the data required. Two forms may be appropriate: the first would be used by the investigator/technician to enter the information obtained from his inspection and/or testing of the vehicle involved in the towaway accidents; the second form would be used when extracting additional accident-related information from the police report.

A second critical task which must be accomplished prior to initiating the field data collection is the training of the field inspector or technician. This training includes assembling all required data on data forms from vehicle inspection and review of police accident records. Perhaps the most exacting and critical facet of this training pertains to the inspection and testing of fuel system components immediately following an accident.

The recommended procedure for inspecting and testing fuel system components is discussed below:

1. Check for obvious fuel spillage or fuel dye residue, particularly in the area of the fuel tank and engine. In the region of the engine, it is important to discern fuel leakage from the following fluids: radiator fluid, brake fluid, power steering fluid, pump fluid and window washer fluid. For this purpose, a hydrocarbon (HC) "sniffing" device calibrated to detect at least 200 parts per million (PPM) HC is recommended. Evaporated fuel on the roadway may be evident in the form of dissolved asphalt; however, caution should be taken to determine that the evidence is related to the vehicle in question.

2. Check to determine that the fuel tank filler cap is in place and note any reading on the HC "sniffer" placed near and around the fuel tank cap area. On pre-1970 model year vehicles, the gas

fill cap may be of the vented type and can usually be identified by a small vent hole in the cap. If this is the case, the presence of the vented cap should be recorded with the NC "sniffer" reading.

3. Check to determine if there is an obvious separation of the fuel tank filler pipe leading from the filler cap to the fuel tank. This may be difficult to establish on some car models, because the filler pipe is often enclosed within the vehicle body and fender panels. Every effort should be made to determine if the filler pipe is damaged to the extent that a fuel leak has occurred. The HC "sniffer" should be used to check under the fender wells and within the trunk and side panel region.

4. Check for obvious fuel tank punctures. Suspect areas include regions where shock absorbers, spring shackles, differential or drive shaft may have struck the tank. The HC "sniffer" should be used as an aid to locate tank rupture areas.

5. The air cleaner must be removed from the engine carburetor to allow inspection for fuel leakage conditions in and around the carburetor. Fuel line connections to the carburetor and fuel filter should be checked for looseness or clamp failures. Evidence of carburetor flooding should be noted and may be detected by clean washed areas down the side of the carburetor near and on the outside surfaces of the carburetor float bowl. The HC "sniffer" should be used with discretion during this check as HC vapors may emanate from the air inlet venturi region and are not to be considered abnormal. Covering the carburetor inlet area with one hand and orally blowing away any existing HC vapors should assist in obtaining meaningful HC readings and allowing possible fuel line leaks to be detected. Any broken or cracked carburetor housings or flanges should be noted.

6. The evaporative emission control canister should be checked for fracture and proper vent tube connections. Completely enclosed canisters may be readily checked for leakage, using the HC "sniffer." Some vehicle models have a canister with a filter element on the lower surface. These canisters may emit HC vapors in the region of this filter element and such leakage should be considered normal.

7. Check the fuel pump region with the HC "sniffer" and note any loose fuel line connections or flange leakage where the pump mounts to the engine or between housings of the pump.

Consideration was given to a pressure check of the fuel tank. However, due to the wide variety of venting systems employed on various vehicle models and the various vent and fuel line capping requirements necessary, it is not likely that all fuel tank lines and openings will be found. If all lines and openings are not properly capped, leak down pressure indication will be a highly unreliable indication of a leaking fuel system. For this reason and the probable dangers of inspection personnel overpressuring the large area fuel tanks,a pressure test of the fuel system is not recommended.

Fuel supply lines are almost always routed through frame and channel members away from exposure to road debris and the likelihood of scraping roadside objects. Because the tubes are well protected and, in most cases, out of sight to examiners, the examination of these fuel tubes in all areas from the fuel tank to the engine is not reasonable and is not considered necessary in all but the most severe impact and body intrusions. The use of the HC "sniffer" should suffice to locate a general region of fuel tube failure and any such indication should be noted as a probable fuel tube rupture, even if the actual failure cannot be isolated and observed. Accident investigation experience has shown that in moderate to severe impacts, fuel lines almost always bend, without failing and leaking.

If the towtruck survey is conducted in 1978, only about 12 percent of all accidents would involve pre-Standard cars.(See Appendix A.)
This clearly dictates that a much higher percentage of accidents with older cars must be sampled in the towtruck survey. However, care must be taken to insure that the process of biased selection of older cars is objectively tied to vehicle age alone and does not in any way relate to the occurrence or non-occurrence of vehicle fuel system rupture (i.e., report of fuel spillage).

An estimate of overall sample size requirements can be obtained with the aid of Table 3-1. The table gives the confidence levels, one can assume for given sample sizes, probability of event occurrences (P_1 and P_2), and percent differences between P_1 and P_2. Past studies indicate that the percentage of accidents involving fuel system rupture is about 5 percent [1]. Thus, the estimate for the probability of rupture in a crash for post-Standard cars is 5% (P_2 = 0.05) and Table 3-1 (b) is the applicable table. If we assume that the probability of rupture in a pre-Standard car (P_1) is 50% greater than P_2, one could detect this effect in a simple 2 x 2 contingency table analysis (Pre- and Post-Standard cars *vs.* Rupture and No-Rupture) with a confidence level of 0.94, if the total sample size were 5000 cases. If P_1 is only 20% greater than P_2, even with a sample size of 20,000 cases, the 20% effect would be detected only with a confidence level of 0.85. Thus, it is abundantly clear that the sample size requirements become alarmingly large if one expects to detect small changes in a relatively rare event (fuel system fupture). Note also that the above

TABLE 3-1

CONFIDENCE LEVELS FOR DETECTING DIFFERENCE IN PRE- AND POST-STANDARD CARS FOR GIVEN SAMPLE SIZES

(a) Probability P_2 of Event for Post-Standard Cars: $P_2 = 0.10$

Percent P_1 Exceeds P_2	Total Cases						
	100	500	1,000	2,000	5,000	10,000	20,000
10	0.05	0.05	0.05	0.07	0.15	0.29	0.55
20	0.05	0.07	0.12	0.22	0.53	0.84	0.99
50	0.07	0.30	0.57	0.88	1.00	1.00	1.00

(b) $P_2 = 0.05$

Percent P_1 Exceeds P_2	Total Cases						
	100	500	1,000	2,000	5,000	10,000	20,000
10	0.05	0.05	0.06	0.06	0.10	0.17	0.32
20	0.05	0.06	0.08	0.14	0.30	0.55	0.85
50	0.06	0.17	0.33	0.59	0.94	1.00	1.00

(c) $P_2 = 0.02$

Percent P_1 Exceeds P_2	Total Cases						
	100	500	1,000	2,000	5,000	10,000	20,000
10	0.05	0.05	0.05	0.06	0.08	0.10	0.15
20	0.05	0.05	0.06	0.08	0.15	0.26	0.47
50	0.05	0.10	0.16	0.28	0.60	0.88	0.99

(d) $P_2 = 0.01$

Percent P_1 Exceeds P_2	Total Cases						
	100	500	1,000	2,000	5,000	10,000	20,000
10	0.05	0.05	0.05	0.05	0.06	0.06	0.07
20	0.05	0.05	0.05	0.06	0.06	0.10	0.16
50	0.05	0.06	0.08	0.10	0.20	0.35	0.61

P = Probability of Event for Pre-Standard Cars.
It is assumed that the number of pre-Standard and Post-Standard cars is equal.

estimate of sample size assumes approximately equal numbers of pre- and post-Standard cars in the sample population.

The above-mentioned 2 x 2 contingency table analysis will be carried out with those cars that do not exhibit serious effects of aging. Serious aging is defined as a pre-existing condition of the fuel system that would greatly increase the likelihood of rupture. These conditions are: (1) pre-existing damage; (2) corrosion; (3) metal fatigue and crystallization; and (4) hardening of plastic or rubber.* A separate trend analysis will be performed with this portion of the sample.

3.1.3 Data Preparation

The preparation of the fuel system rupture and related data for computer analysis requires a normal sequence of quality control measures to assure validity and adequacy of data. The form information on fuel system rupture, the vehicle and the accident must first be collected and initially screened for completeness and consistency. The data must then be edited and encoded for key punching. The punched card data should be verified prior to loading onto magnetic tape. The basic data on magnetic tape must first be error-checked for invalid codes and gross inconsistencies. After making any data corrections or deletions that are required, additional information might be reconstructed as needed. For example, from car make/model and model year, estimates of car weight can be inferred. The final step in the data preparation is to print out all or selected portions of the data sample and prepare 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 rate-trend and possibly contingency analysis, as described in the next section.

---

*For cars about 5 to 10 or more years old, in automobile accidents where there is some evidence of fuel spillage, the following "ball park" probabilities are estimated for fuel system components, based on extensive personal experience in automobile accident investigation [4]:

- ∿75% - Broken or missing gasket on gas cap.
- ∿50% - Cracked or broken (synthetic) rubber tubing or leaking fuel pump diaphragm.
- ∿25% - Cracked or broken plastic tubing or inline gas filter.
- ∿ 5% - Corroded and/or fatigued metal components: tubing, tank, filler neck, etc.

3.1.4 Data Analysis

The basic analysis scheme for evaluating FMVSS 301 with fuel system rupture data is given in three steps in Figure 3-1. The basic question toward which the analysis is addressed is given for each step.

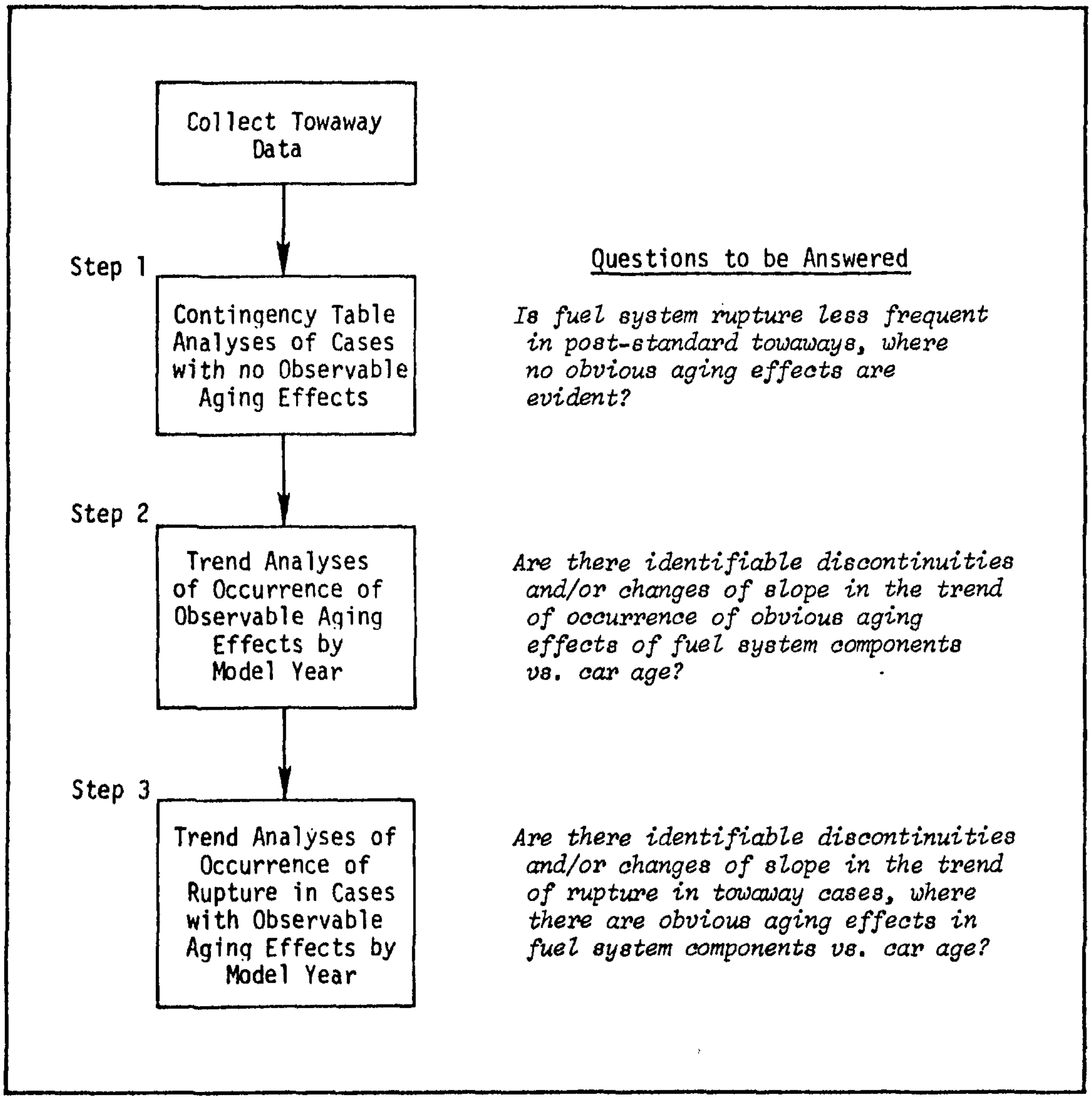


Figure 3-1. Proposed analysis scheme for evaluating FMVSS 301 with fuel system rupture towaway data.

The first step involves a 2 x 2 contingency table analysis with all cases in which obvious aging effects were not observed in the fuel system of the vehicle. The aging effects include pre-existing damage, corrosion, fatigue, crystallization of metal, extensive hardening of rubber or plastic, etc. The 2 x 2 contingency table analysis is outlined in Figure 3-2. A standard χ^2 test would be employed to determine if there is a significant difference in the occurrence of fuel system rupture in pre-Standard *vs.* post-Standard cars.

Model Year Class	Fuel System Integrity		Total
	Rupture	No-Rupture	
Pre-Standard Cars			
Post-Standard Cars			
Total			

Figure 3-2. Contingency Table Analysis for cars without obvious aging effects.

The analysis of fuel system rupture should also be concerned with the following questions:

- If the test conditions are approximately met in the crash, is there no fuel spillage?
- What effect, if any, has the Standard had on crashes where the impact is either concentrated (e.g., corner) or at high speeds and thus not within the test conditions of the Standard?

Figure 3-3 illustrates the type of data which would be analyzed. The comparison of fuel system rupture and no-rupture by pre- and post-Standard cars should be undertaken with the following stratifications: (1) crash type (front-rear, front-side, etc.); (2) single or multi-vehicle; (3) area of impact; (4) severity of impact. It is recognized that for some of the above suggested stratifications, inadequate sample sizes may preclude obtaining results that are statistically significant.

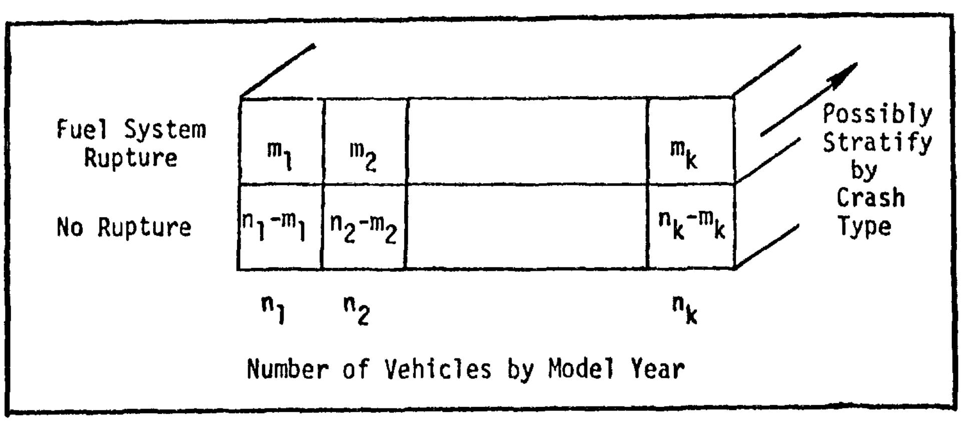


Figure 3-3. Categorization of data.

The second and third steps in the analysis procedure involve trend analysis. The second step consists of a relatively simple analysis of the frequency of occurrence of observable aging effects by model year. Obviously, the entire sample of cars with and without aging effects is to be utilized. The analysis is designed to identify discontinuities and/or changes in the trend of the occurrence of obvious aging effects of fuel system components by car age (i.e., model year). The detection of such an effect,if relatable to the Standard, could indicate that improvements in the materials used to comply with the Standard has reduced the aging effects of corrosion, fatigue, etc.

The third step in the analysis is a trend analysis of the occurrence of fuel system rupture in cases with significant observable aging effects. The trend analysis is designed to identify discontinuities and/or changes of slope in the trend of rupture (by model year) in accidents where there are obvious aging effects in the fuel system components. The trend analysis in this third step is described in some detail below.

In comparing fuel system rupture and no-rupture by model year, a number of stratifications might be attempted. The data sample could be stratified according to (1) crash type (front-rear, front-side, etc.); (2) single or multi-vehicle; (3) area of impact; and (4) severity of impact. Obviously the appropriateness and degree of stratification is limited by sample size.

For a given condition (stratification) the frequency of ruptures ($\hat{P}_i = \frac{m_i}{n_i}$) for all available model years would be plotted as shown in Figure 3-4.

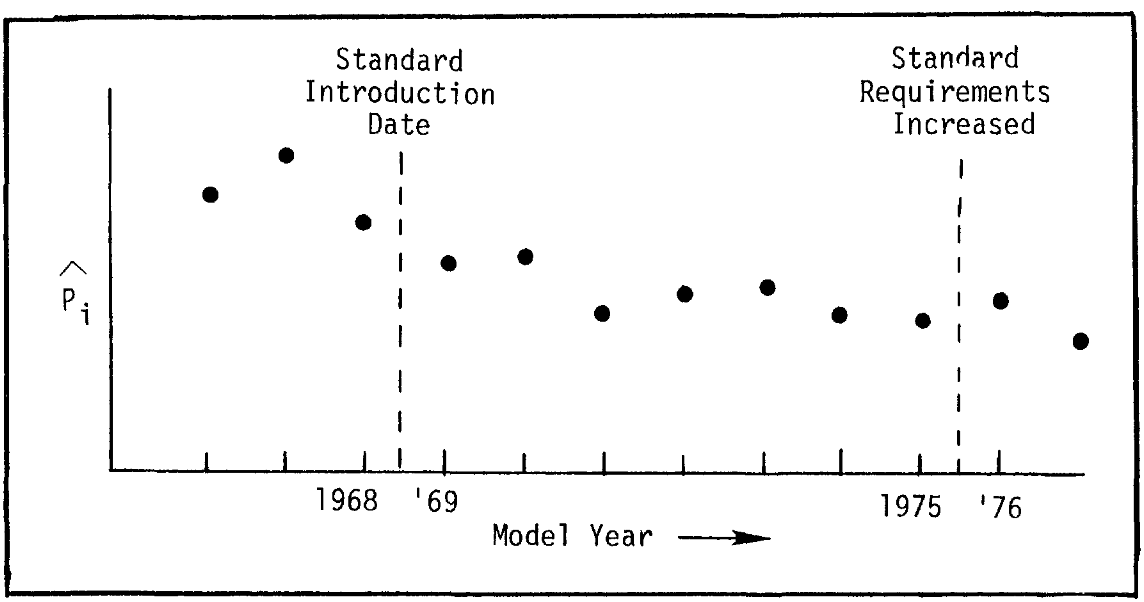


Figure 3-4. Possible trend of fuel system rupture.

The analysis would concentrate on the trend of the average rate of fuel system rupture ($\hat{P}_1$) over all the model years. The cases should be initially stratified by crash type because of the possibility of shifts in crash types with age of vehicle due to ownership, use, or other factors. Of course, such stratification reduces the number of observations in any one cell, which may require later reaggregation of the data. There are several possible patterns which might define the effectiveness of the Standard: (1) there could be a consistent steady drop in frequency of rupture (although this might have been expected from normal manufacturing improvements); or (2) there could be distinct downward shifts in rupture rate following the introduction of the Standard, and again following the upgrading of the Standard.

The evaluation of the trend is as follows. A linear analysis would fit the equation $P_i = a_i + b_i t$ to the observed P_i. If there is a consistent linear trend, the test would be whether the slope (b) was significantly different from zero (H_o:b=0). To test if there are significant break points (but no trend) before and after the important dates, the test would be whether the intercept (a_i) for one portion is significantly different from the intercept in another ($H_o: a_i = a_k$). The size of the sample needed for each cell is approximately 55 if $P_i \sim 10\%$ [2].

Of course, there is the possibility that other factors might confound this linear trend analysis, such as changes due to evaporative emissions control systems. In that event, the data would be grouped into consistent periods, e.g., pre-Standard, post-Standard, pre-evaporative system, etc. A contingency analysis would be performed, comparing the relative frequencies of events in different categories.

3.2 Analysis of the Frequency of Fire and Fuel Spillage

3.2.1 Data Requirements

The analysis of the frequency of fire and fuel spillage can be undertaken both with existing historical data and new data collected for this purpose. The historical data on vehicle fires and fuel spillage due to collisions would be obtained mainly from fire department records, supplemented when needed with data from police accident records. Accident data on all accidents in the region could most efficiently and economically be obtained from mass accident data, where the region is identified by a county/city/town.

The accident data required include the following:

- Vehicle make/model
- Vehicle model year
- Occurrence of fire
- Location of fire
- Occurrence of fuel spillage
- Collision type (front-rear, etc.)
- Single or multi-vehicle crash

In addition to the above, it would be desirable to obtain information on damage severity.

The new data collection referred to above would depend on cooperation of the police departmants. It would basically consist of a special short form containing the above variables which would be filled out by the police in addition to their normal accident reports, or perhaps made part of their forms.

3.2.2 Data Acquisition

3.2.2.1 Existing Data

The acquisition of fire and fuel spillage accident data requires the following considerations:

- Selection of sample regions.
- Securing the cooperation of fire departments and police departments.
- Developing procedures for cross-referencing data between fire departments and police departments and training personnel for data acquisition.
- Requirements of sample size and length of sample period.

The collection of data requires the cooperation of both the fire department and probably also the police department. It is possible that in some states all necessary information can be obtained from the fire department records. A personal visit to the Fire Marshall's Office of the City of Hartford (Connecticut) revealed that all necessary data can be obtained readily from the fire department records for most fire or fuel spillage accidents. (This will be discussed in more detail below.) It is probable, at least in medium or large communities (Hartford's population is about 150,000), that similar records are kept in many other states. Obviously, the adequacy of fire department records and the cooperation in obtaining access to them will influence the selection of data collection locations.

At least two other factors are also very important in selection. Data on vehicle fires and fuel spillage are being collected in the NCSS. While the volume of NCSS data by itself is insufficient for an analysis of vehicle fires, it would be cost-effective to include these data in such an analysis. Therefore, regions included in the NCSS should be prime candidates for selection for the fire and fuel spillage data collection effort. In addition to this consideration, the availability of mass accident data is an important requirement. The analysis of the frequencies of vehicle fires and fuel spillage in accidents requires a knowledge of all accidents occurring during the same time periods and locations. The information would be very costly to determine from manual inspection of police records and, hence, the need for automated mass accident data is indicated (in the states which have localities included in the vehicle fire/fuel spillage analysis). Mass accident data normally specify the county, city or town in which the accident occurred and the small subset of accidents of interest would be selected from the full volume of statewide accident data. Thus, localities in states such as New York, Texas and North Carolina would be of prime interest.

The procedures for obtaining vehicle fire and fuel spillage accident data may vary from state to state. The following discussion of information available in Hartford is based on a personal visit to the Fire Marshall's Office [3]. It is obviously illustrative of a given situation, but there is no reason to believe that the standard forms and procedures used in Hartford are very different from many other medium-sized or large cities.

In Hartford from 1971 to 1976, the number of responses of the fire department to alarms ranged from 7700 to 13,800 annually. Each of these responses is entered on a single line of a log book with the reason for the alarm indicated. This log book can be scanned to determine which responses must be looked at in greater detail. During the 1971 to 1976 time period, the number of vehicle-related responses ranged between 750 and 800 annually. The information which can typically be derived from the detailed accident form is the following: (1) incident number; (2) time and location; (3) vehicle year make, model, serial number; (4) vehicle occupants and injuries and fatalities; (5) occurrence of fire and/or fuel spillage; (6) location of fire and material ignited; (7) involvement in accident and single or multi-vehicle; and (8) type of collision (rear end, etc.). It is of considerable interest to note that, in Connecticut, state law requires a report to be filed by the Local Fire Marshall to the State Fire Marshall within 10 days after each fire. Thus, reports contain the above information in summary form, together with a dollar estimate of damage. Thus, in Connecticut, all fire-related vehicle accident information from various cities and towns can be obtained at a single location (State Fire Marshall's Office). Note: this is not true of fuel spillage accidents.

The main point of the above discussion is that the Hartford/Connecticut illustration indicates that the use of fire department records to determine fire and fuel spillage is a tractable task. In some states and localities, it is likely that access to police accident files will be required to obtain all the required data for some or perhaps all of the fire and fuel spillage accidents. The cross-referencing of data between the fire and police departments should be very feasible, given accurate information on time and location and other data characterizing the accident. The training of personnel for data extraction and cross-referencing when required is not likely to be a major task.

Table 3-1, given earlier in Section 3.1, permits an estimation to be made of required sample size. First, it is estimated from past studies, that the frequency of fuel spillage in accidents is about 5 percent [1]. Thus, the probability of fuel spillage in post-Standard cars P_2 is 0.05 [Table 3-1 (b) applies). If we assume that fuel spillage occurs 20 percent more often in pre-Standard cars then this effect could be determined at a confidence level of 0.85 if the total sample size (all accidents) is 20,000 cases (divided equally between pre- and post-Standard cars). Approximately 1000 of these cases (or about 5%) would involve fuel spillage and require the detailed information obtained from the fire department and police department records. Obviously the above number of cases will increase if (1) the confidence level desired is to be higher; or (2) if the percentage differences in fuel system spillage incidence between pre- and post-Standard cars is smaller than 20%.

3.2.2.2 New Data

The collection of new data on vehicle fires and fuel spillage as part of routine recording of accident data by the police will obviously require the total cooperation of the individual police departments in the selected localities. It would seem that the localities for new data collection should include at least some of the localities in which historical vehicle fire data are being determined. Special short data forms must be prepared for police use. Procedures must be established to have these forms mailed on a regular basis to a central data collection office.

3.2.3 Data Preparation

The forms containing the extracted historical accident data on fire- and fuel-spillage-related accidents and the ongoing police data must both undergo a normal sequence of quality control measures in the process of automating the data. This process includes (1) screening the forms for completeness and consistency; (2) editing the information and encoding it for keypunching; (3) placing the data on punched cards,verifying the punched card data and loading it onto magnetic tape; (4) error-checking the data on tape for invalid codes and inconsistencies; (5) correcting and deleting data as needed and constructing other variables, if required;and (6) printing out all or selected portions of the data and preparing it in special formats for statistical analysis.

The major effort in the preparation of the mass accident data consists of selecting a small subset of the entire data base for (a) variables required; (b) localities included in the study; and (c) time periods of interest. The small subset of mass accident data must then undergo data preparation as outlined in Steps (4) through (6) above.

3.2.4 Data Analysis

The analysis of vehicle accidents in which fire or fuel spillage occurred is directed toward answering the following question:

- Is there a difference in the frequency of accidents involving fire and fuel spillage relative to all accidents for pre-Standard and post-Standard cars?

In answering this question, the importance of vehicle age must be considered. Pre-existing (to the accident) damage or serious corrosion is more likely to be present in older cars and this increases the possibility of fuel system failure and resulting fuel leakage or fire. It is also important to note that fire or fuel spillage accidents are likely to be over-reported in older vehicles as there is a distinct tendency to omit reporting a variety of minor accidents in older vehicles.

The steps in the analysis are outlined in Figure 3-5. The first step in the analysis is to tabulate the data according to potentially important variables. These include:

- Pre-and Post-Standard Vehicles. The most basic breakdown is into two categories--model years 1968 and earlier and model years 1969 and later. However, as discussed in Section 1.1, the addition of emission control systems in 1971 and more stringent requirements in 1976 and 1977 model years suggest possible further breakdowns.

- Calendar Year. Individual years or years grouped by twos or threes could be considered.

- Impact Location. Locations include front, right side, left side and rear,and need to be considered in relation to the location of the filler pipe.

- Vehicle Age. Vehicles could be grouped into three age groups (e.g., 3 years or younger, 4-7 years old, 8 years or older) or vehicle age could be treated as a continuous variable.

- State Grouping. Because of differences in reporting procedures and record-keeping, it may be desirable to group data according to state.

The tabulations would be done on a detailed and aggregated basis, and in absolute and percentage terms. From the initial tabulations one can investigate potentially troublesome questions such as the possible need to treat "unusual" vehicles such as the VW and most station wagons separately from the main analysis.

The results of individual tabulations of data will be assessed to determine which potential groupings or categories of variables seem most appropriate for further analysis. This is particularly important with regard to (1) categorizing vehicles relative to the Standard's initial implementation and/or subsequent modifications; (2) grouping of calendar years; and (3) treatment of vehicle age either as a linear variable or grouped into appropriate age groups.

Contingency tables will be constructed according to the differences to be tested. The fundamental measures of the Standard's effectiveness are differences in the ratios of fire-related accidents to all accidents and fuel spillage accidents to all accidents for pre- *vs.* post-Standard cars. The analysis will permit the examination of variations of this effect with calendar year, vehicle age and type of impact. Also possible differences as a function of location (state) may be identified.

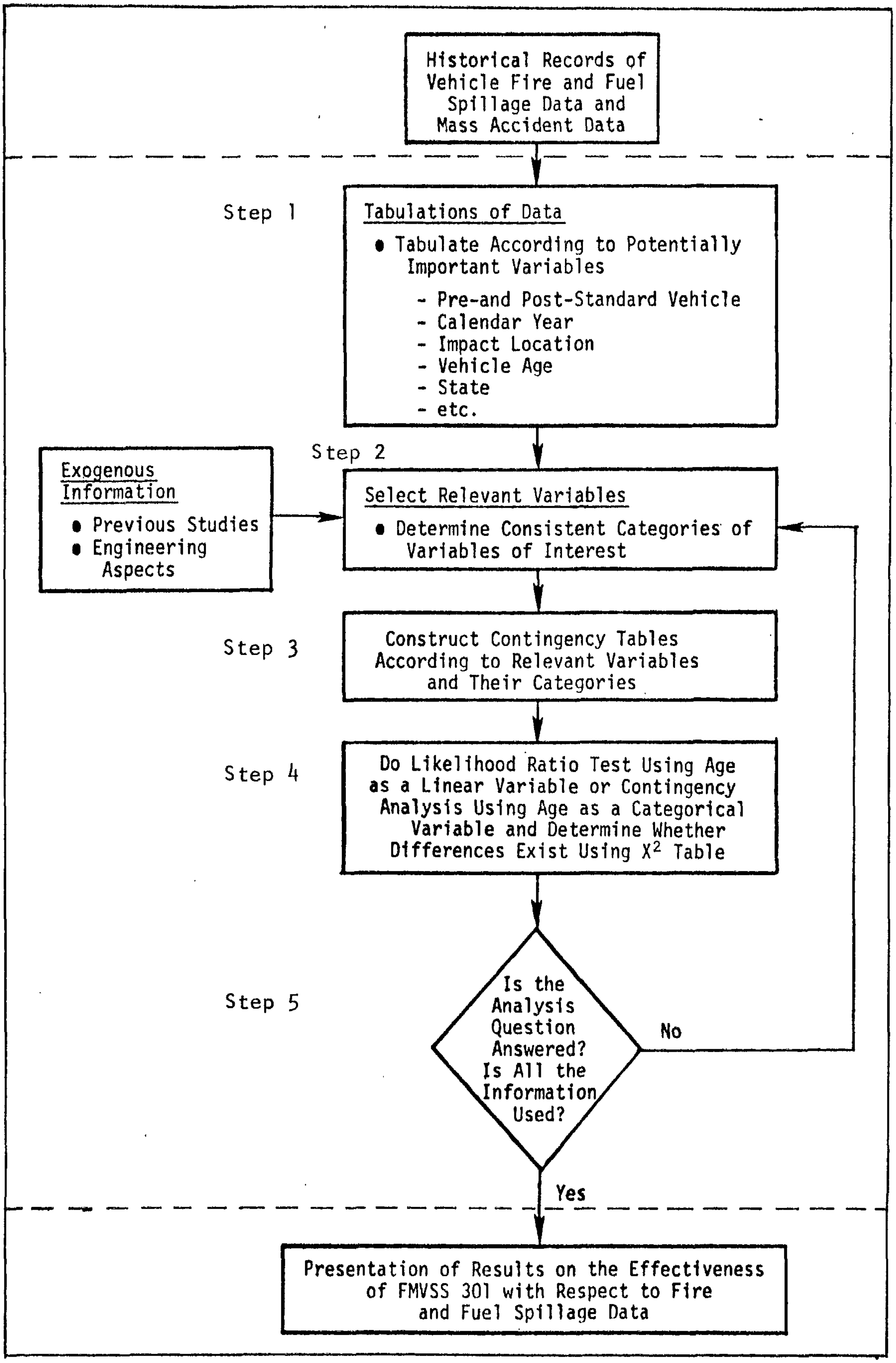


Figure 3-5. Proposed statistical analysis scheme for evaluating FMVSS 301 with vehicle fire and fuel spillage data.

A Likelihood Ratio Test will be used in those analyses where vehicle age is treated as a linear rather than a categorical variable. Contingency table analyses and the χ^2 test of significance are available in a number of standard statistical analysis packages (e.g., Statistical Package for Social Sciences [SPSS]).

The statistical analyses can effectively and inexpensively be carried out in a series of iterative steps. The comparison of accident fire and fuel spillage frequencies should be made with a variety of data aggregations and disaggregations until further analyses no longer yield results that are statistically significant.

3.3 Analysis of Fire-Related Fatal Automobile Accidents

The specifications of FMVSS 301 limit the amount and rate of fuel leakage allowable in a motor vehicle which has been subjected to specific dynamic and static tests. However, the real-world performance of FMVSS 301 is measured by the degree to which it reduces the occurrence of fires in motor vehicle accidents. The purpose of this analysis is to determine whether such a reduction can be detected between pre- and post-Standard 301 vehicles.

The main reason that the recommended analysis is restricted to fatal accidents is that reliable data on fires in motor vehicle accidents is scarce. We know of no automated state mass accident data base which codes the occurrence of fire except New York,which incorporated this variable beginning in 1976. State hardcopy files on fatal accidents tend to have more reliable information and are retained longer than non-fatal accident files. Another reason for using fatal accidents is that the definition of a fatality is more uniform among states than the definition of an accident. It might be possible, therefore, to aggregate data from different states for the analysis. In addition, since the risk of death in a fire-related accident is greater than in the average accident, using fatal accident files should result in a higher proportion of fires than would be found using all accidents.

A complicating factor which greatly diminishes the power of this analysis to detect effects of FMVSS 301 was the concurrent introduction of ten 100 series and nine 200 series FMVSS's in the 1968 model year. If these other Standards caused a significant decrease in fatal accidents (which is likely),it will be difficult to detect a beneficial effect solely attributable to FMVSS 301 on the basis of the proportion of fire-related fatal accidents to all fatal accidents.

3.3.1. Data Requirements

The base population chosen for this anlaysis is "fatal accidents" as described above. There is a possibility of biased results using "fatal accidents" because occupancy is a factor. Given the occurrence of an accident, the probability that it is a fatal accident increases with the number of occupants present. If older vehicles (which tend to be driven by younger drivers) have a higher occupancy rate than newer vehicles in fatal accidents, then the effect of higher occupancy will be incorrectly attributed to the age of the vehicle. This possible bias could be eliminated by using accidents where the driver was killed as the base population instead of all fatal accidents. But since fire-related fatal accidents are rare events and this criterion would exclude fire-related fatal accidents where an occupant other than the driver was killed, useful data would be discarded. Therefore, "fatal accidents" has been retained as the base accident population.

The variables needed for the analysis are:

1. Pre-Standard/Post-Standard Vehicle
2. Fire/No Fire
3. Vehicle in which Fire Occurred
4. Point of Impact
5. Vehicle Make, Model, Model Year
6. Type of Collision (single, multi-vehicle, etc.)
7. Position of Fuel Tank Filler Pipe
8. Age of Vehicle
9. Accident Year.

The sources of data for these variables will vary. The position of the fuel tank and whether the fuel system is pre- or post-Standard 301 may be decided from vehicle make, model, and model year. In the case of 1968 model year vehicles, the Vehicle Identification Number (VIN) may be necessary to distinguish pre- or post-Standard, because FMVSS 301's effective date was January 1, 1968 whereas September 1, 1967 starts the 1968 model year. The age of the vehicle may be determined from the accident year and the model year of the vehicle.

Mass accident data will be needed to obtain accident and vehicle information for both fire-related and non-fire-related fatal accidents. This includes all variables except whether fire was involved and in which vehicle the fire occurred. These two pieces of information are not present on mass state accident files. Most states retain hardcopy or microfilmed accident reports of fatal accidents for a number of years. It is possible to determine if fire was involved from these files.* In some states it is possible to expedite the search for fire-related fatal accidents by using Vital Health Statistics of Medical Examiner's data bases. Searching these automated systems for deaths caused by fire in motor vehicle accidents can lead to the associated accident files.†

NHTSA's Fatal Accident Reporting System (FARS) maintains detailed information on all fatal accidents. It includes information on the occurrence of fire and has been implemented beginning with 1975 accidents. Since FARS contains data from all states, it is a better source than individual state data, from

---

*To provide background for this discussion, on February 22, 1977 CEM staff conducted a brief review of fatal automobile accident files at the nearby Connecticut Department of Motor Vehicles. Telephone calls were made to similar agencies in other states.

†If definitive information on the cause of death is not available from the state fatal accident files, death certificates of the individuals involved could be checked for any missing facts.

1975 on. FARS data alone are not sufficient because only 15 percent would be pre-Standard vehicles and all of those would be at least seven years old. Therefore, state data must be used for the earlier years.

3.3.2 Data Acquisition and Preparation

The primary source of data for this analysis will be state mass accident files. There are two necessary variables which are not available on all state data files or for all years of those states that have included them. These are point of impact and a reliable coding of vehicle model. However, North Carolina has all the required variables sufficiently well-defined. It is expected that North Carolina mass data could be used from the years 1966 through 1976. Based on the annual number of fatal accidents in North Carolina and an assumed distribution of vehicle ages in fatal accidents*, it is estimated that 12,700 fatal accidents involving only cars will be available, with 57 percent pre-Standard and 43 percent post-Standard vehicles involved. Hardcopy fatal accident files are available from 1971 on and previous years are on microfilm.† These files may be used to determine if fire was involved and in which vehicle the fire occurred.

The State Medical Examiner's office in North Carolina has an automated system which allows one to extract all fire-related deaths occurring in motor vehicle accidents. A project is currently underway to append Motor Vehicle Department accident numbers to the medical examiner's files retroactively back to 1974.†† This system could significantly reduce the effort required to ascertain the incidence of fire. All data would be acquired from the relevant state departments in Raleigh, North Carolina.

Texas also maintains a large mass accident data base which could be used in this analysis. Prior to 1971, "point of impact" was not coded; therefore, Texas mass data can only be used from the years 1971 to 1976. Based on the number of fatal accidents in Texas, it is estimated that 13,300 fatal accidents involving only cars will be available, with 32 percent pre-Standard and 68 percent post-Standard vehicles involved. Texas has hardcopy fatal accident reports for 1976 and retains previous years on microfilm. It is not known whether any state medical examiner or vital statistics systems exist to expedite the search for fire-related accidents. Data would be acquired from the Texas Department of Public Safety in Austin, Texas.

---

*See Appendix A.

†Conversation with C. Bunn, Director Traffic Records Section, N.C. Dept. of Motor Vehicles, Feb. 23, 1977.

††Conversation with P. Schinhan, Chief Medical Examiner's Office, State of N.C., Feb. 23, 1977.

New York maintains a large mass accident data base but it unfortunately lacks both "point of impact" information and adequate vehicle model data. As a result of a special project called Vehicle Safety Design Surveillance System (VSDSS), New York data are available with all the required information for the years 1971 to 1973. If these data are used, they should yield approximately 6500 fatal accidents involving only cars with 44 percent pre-Standard and 56 percent post-Standard vehicles. New York only retains hardcopy accident reports for three years; therefore, hardcopy files are no longer available for the 1971-1973 years. This presents a problem in determining those accidents involving fire. New York does not have a medical examiner's system (as available in North Carolina) and the Vital Health Statistics system does not allow the extraction of all fire-related deaths in motor vehicle accidents.* A possible means of acquiring fire-related accident data would be cross-indexing the state Fire Marshall's records with police accident records as described in the analysis in Section 3.2. New York mass accident files would be acquired from the Department of Motor Vehicles, Albany, New York.

NHTSA's FARS file will contain all fatal accidents beginning with the year 1975. It contains all necessary information for this analysis and also designates whether or not a fire was involved. It is expected that FARS will contain 61,400 fatal accidents involving only cars,with 15 percent pre-Standard and 85 percent post-Standard vehicles involved. These data can be acquired from NHTSA on magnetic tapes.

A summary of the four data sources described and the sample size expected from each is displayed in Table 3-5 below. The preparation of each data base will include 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 analysis outlined in the next section.

---

*Conversation with T. Smith, N. Y. Health Department, Albany, N.Y., Feb. 25,1977.

TABLE 3-5

EXPECTED SAMPLE SIZES FROM EACH DATA BASE

Source†	Total Fatal Accidents	Total Involved Vehicles	Pre-Standard		Post-Standard	
			Percent	Involved Vehicles	Percent	Involved Vehicles
N.C.	12,700	19,000	57	10,800	43	8,200
Texas	13,300	20,000	32	6,400	68	13,600
N.Y.	6,500	9,800	44	4,300	56	5,500
FARS	61,400	92,000	15	13,800	85	78,200
Total*	87,200	130,800	25	33,800	75	99,800

*To prevent double counting with FARS, 6700 fatal accidents from 1975 and 1976 N.C. and Texas are omitted.

†Accident years of the available data are:
North Carolina: 1966-1976
Texas: 1971-1976
New York: 1971-1973
FARS: 1975-1976

3.3.3 Data Analysis

The data extracted from the various sources described in the previous section can be analyzed to determine if there is a significant decrease in fire-related fatal automobile accidents relative to all fatal automobile accidents between pre- and post-Standard 301 vehicles. As mentioned previously, the concurrent introduction of nineteen other FMVSS's at the same time will make it difficult to ascribe any detected effects specifically to FMVSS 301. It would be possible for the incidence of fire to decrease relative to all accidents, yet increase relative to all fatal accidents if the number of fatal accidents decreases significantly due to the other Standards. Therefore, an effort of FMVSS 301 can probably be detailed only if its effect is greater than the influence of the other Standards.

Once the available data have been extracted and prepared for the analysis, it is suggested that data from each source be analyzed separately to ensure that no unaccounted for factors are biasing results. A general outline of the proposed analysis is given in Figure 3-6. The various analysis steps would be:

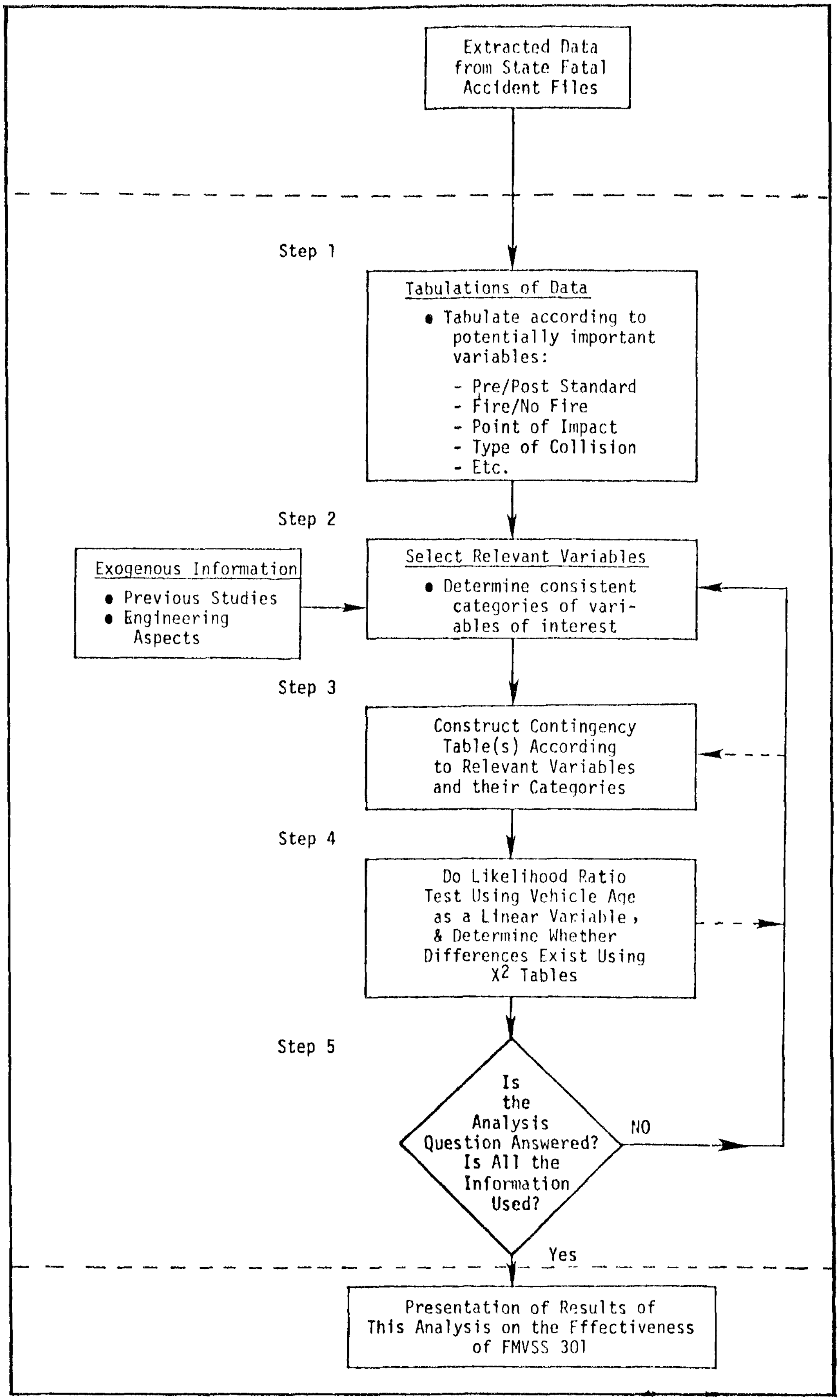


Figure 3-6 Proposed Statistical Analysis Scheme for analyzing fire-related fatal automobile accidents.

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

- Pre/Post Standard: Dichotomous variable designating whether vehicle conformed to FMVSS 301.
- Fire/No-Fire: Dichotomous variable designating whether or not this was a fire-related accident.
- Vehicle in which Fire Occurred: Dichotomous variable for each fire-involved vehicle designating whether or not the fire started in it.
- Point of Impact: Front, left-side, right-side, rear or clock direction of impact (where available).
- Vehicle Type: Regular passenger car, station wagon, pickup truck.
- Type of Collision: Single *vs.* multi-vehicle.
- Position of Fuel Tank Filler Pipe: Front-left, front-right, rear-left, rear right, rear center.
- Age of Vehicle: Current year, one year old, two years old,... ten years old, > ten years old.
- By Accident Year.

These tabulations would be done on a detailed and aggregate basis, and in absolute and percentage terms. Some graphic presentations 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 previous studies, the number and definition of data stratifications would be decided. This will depend to a great degree on the available sample sizes within each stratification. Since fire-related fatal accidents are approximately two percent of all fatal accidents, using Table 3-1 (c), a sample size of 10,000 cases would be required to detect a 50 percent effect of the Standard with an 88 percent level of confidence. The expected number of cases available from North Carolina is 19,000 (from Table 3-2); therefore, the separate analysis of North Carolina's data would be restricted to roughly two equal stratifications to detect a 50 percent effect with an 88 percent level of confidence. The number of stratifications possible will increase if data from different sources can be combined for the analysis.

Step 3: Construct contingency tables for each stratification as shown in Table 3-3 below.

TABLE 3-3

CONTINGENCY TABLE FOR ANALYSIS OF FIRE-RELATED FATAL ACCIDENTS

	Fire-Related Fatal Accidents	Non-Fire-Related Fatal Accidents
Pre-Standard Vehicles		
Post-Standard Vehicles		

Step 4: A contingency table analysis can be performed using the data from Step 3 if an effect due to vehicle age can justifiably be divided into two or three discrete categories. Otherwise, a likelihood ratio test should be performed using vehicle age as a continuous linear variable.

Step 5: At this point, given the significance (or lack of significance) of the above results, one may develop additional comparisons which might require a different grouping (or disaggregation) of the data. If the results of individual analysea correspond, the data may be pooled so that further stratifications could be investigated. Additional analyses may be undertaken at this point with the FARS data, since it contains a small percentage of pre-Standard vehicles (15%) all of which will be relatively old. This would consist of analyzing the effect of vehicle age with respect to pre- and post-Standard vehicles to determine if a functional representation of the age effect can be derived and also whether Standard 301's influence can be estimated.

3.4 References for Section 3

1. Cooley, P., *Fire in Motor Vehicle Accidents*, HIT LAB Reports. Highway Research Institute, Volume 5, Number 1, September 1974.

2. Brownlee, K.A., *Statistical Theory and Methodology in Science and Engineering*, John Wiley & Sons., Inc., New York, 1960.

3. Personal visit to Fire Marshall's Office, Fire Department of Hartford, Connecticut.

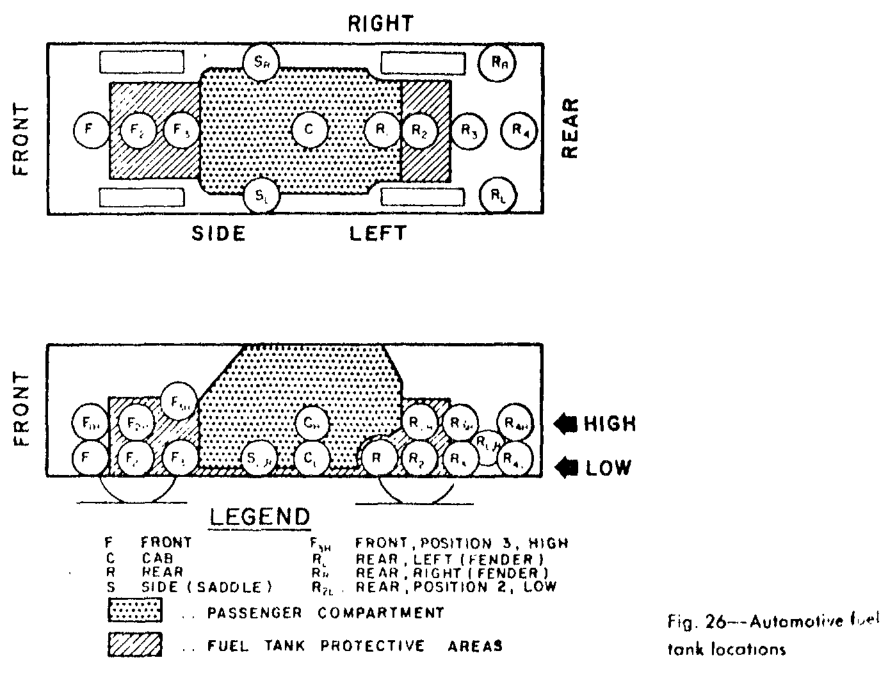
4. Personal communication from Mr. Robert Cromwell (P.E.), professional automobile investigator and CEM consultant for this study.

4.0 COST DATA AND SAMPLING PLAN

4.1 Background

FMVSS 301 has been modified several times since its introduction in the 1969 model year. The original version limited leakage from the fuel tank, filler pipes, and fuel tank connections in 30 mph frontal barrier crashes. Starting with the 1976 model year, a static rollover test was added and the fuel leakage limits were changed slightly. Side and rear barrier tests and off-perpendicular frontal barrier crashes were added for 1977 model year passenger cars. Also, starting with the 1977 model year, parts of FMVSS 301 were extended to other vehicles. Starting with the 1978 model year, all vehicles up to 10,000 lb GVWR will have to meet the 1977 passenger car requirements.

Since FMVSS 301 does not address specific components of the fuel system, manufacturers have a wide range of choices in complying with the Standard. The location of the fuel tank will affect the means (and the cost) of implementing the Standard's specifications. For example, a fuel tank located in the front of the vehicle would require a different construction to inhibit fuel leakage in a frontal 30 mph barrier crash than would an equivalent fuel tank positioned in the rear. An illustration of the variety of fuel tank locations is shown in Figure 4-1, taken from [3]. In addition to location, the type of



Source: Reference 3.

Figure 4-1. Fuel tank locations and protected areas.

construction of the tank can vary. Fuel tank integrity may be maintained by making the tank flexible so it can absorb energy before rupturing, or it can be made more rigid so that it resists deformation and transfers energy to adjacent structures. The costs of these two implementations may vary considerably.

Another factor which affected vehicle fuel systems since the 1971 model year was the installation of evaporative emissions-control systems as a result of Environmental Protection Agency requirements. Although these requirements were external to FMVSS 301, they did affect the construction of fuel system components and any resulting hardware must conform to the leakage restrictions of FMVSS 301.

Since the number of alternative means of complying with FMVSS 301 are large, it is recommended that cost data be collected from manufacturers for the entire fuel system rather than by individual components.

4.2 Relevant Cost Items

The vehicle components which are a part of the fuel system, and thereby affected by FMVSS 301, are listed in Table 4-1 below. Costs relating to changes in these items which were made as a result of FMVSS 301 should be included.

TABLE 4-1

VEHICLE COMPONENTS AFFECTED BY FMVSS 301

Fuel Tank
Fuel Tank Filler
Fuel Filler Cap
Fuel Tank Connection with Fuel and Vent Lines
Fuel Tank Straps and Anchor Points
Fuel Line
Fuel Line Connections
Vent Line
Vent Line Connections
Carburetor
Fuel Pump
Fuel Filter
Connections and Mountings

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 [8]

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 are loosely related [9]. (See Appendix C for a detailed discussion of problems associated with evaluating the latter three cost categories.)

4.3 Frequency Sampling Plan

The purpose of this activity is to acquire reliable estimates of the incremental costs incurred by manufacturers in complying with FMVSS 215.

Manufacturers will generally use the same bumper construction for all their car lines, although there may be changes from year to year. There do exist significant implementation differences among manufacturers (see Section 4.1). These differences will increase the variance of estimates for the cost of complying with FMVSS 215. Although the individual manufacturer will use the same bumper construction on virtually all models, the cost will vary with car size. We therefore propose that cost data be stratified by market class and manufacturer, as follows.

1. Manufacturer: GM, Ford, Chrysler, AMC, VW, Datsun
2. Market Class: Subcompact, Compact, Intermediate, Full Size, Luxury, Speciality

The recommended experimental design 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	GM
Intermediate	GM	AMC
Full Size	Ford	Chrysler
Luxury	GM	Ford
Specialty	Ford	Datsun

The design has been limited to two replications because of data gathering cost considerations; i.e., the large number of items to collect costs on and the number of years of interest. Since the Standard has been changed many times since 1973, all years from 1972 to the present would be of interest (see Table 4-1). Each of the six manufacturers is represented,and the assignments have been made such that a car model with significant volume exists in the assigned category (such as VW Rabbit in the subcompact category and Datsun 260Z in the specialty category). The representation of manufacturers in the sample design is based upon their respective sizes: GM (4 entries), Ford (3 entries), Chrysler (2 entries), AMC (1 entry), VW (1 entry), and Datsun (1 entry). To decide which car model to of manufacturers in the sample design is based on their respective sales volumes: GM (5 entries), Ford (3 entries), Chrysler (3 entries), AMC (1 entry), VW (1 entry), and Mercedes (1 entry). Mercedes was chosen because they have repositioned their fuel tank to a more interior position over the rear axle. To decide which car model to choose within a particular market/class cell, the highest sales volume model may be used. Although this yields a biased estimate of average cost, the variance of the estimate will be minimized and it should be the better estimate if the sales volume of the chosen model is significant. If two or more models have the highest volume, a randomization scheme should be used.

Data should be collected for the:

- Model year preceding the Standard (1968)
- Model year of first major application of the Standard (1969)
- Model year of major upgrading of the Standard (1976).

The derivation of this sampling scheme can be found in Appendix D.

4.4 References for Section 4.0

1. Robertson, S.H., *A New Look at Fuel System Design Criteria*, Proceedings of the Tenth STAPP Car Crash Conference, Society of Automotive Engineers,Inc., November 1966.

2. Severy, D.M., H.M. Brink, and J.D. Baird, *Postcrash Fire Studies Show Need for Rear-Seat Fire Wall and Rupture-Proof Fuel Tank,* SAE Journal, July 1969.

3. Severy, D.M., D.M. Balisdell, and J.T. Kerkhoff, *Automotive Collision Fires,* Proceedings of the Eighteenth STAPP Car Crash Conference, Society of Automotive Engineers, Inc., December 1974.

4. Anonymous, *1970 Car Shop Manual, Volume II, Engine,* Ford Marketing Corporation, 1970.

5. Anonymous, *1974 Car Shop Manual, Volume II, Engine,* Ford Marketing Corporation, 1974.

6. Anonymous, *Fuel System Integrity Standard #301-75, You can Live With It, Don't Panic,* Distributors News, 76-7, October 1976.

7. General Accounting Office, *Effectiveness, Benefits, and Costs of Federal Safety Standards for Protection of Passenger Car Occupants, Report to the Committee on Commerce,* U.S. Senate, CED-16-121, July 1976.

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

9. 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 301 is divided into a total of four tasks. The fourth task is an analysis of costs to the consumer for implementation of FMVSS 301. The work to be conducted under each of the first three evaluation tasks is basically 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 work plan is formulated such that all tasks are initiated at the start of the study. The first task requires the collection of new data from towaway accidents while the other two evaluation tasks make use of historical data. Thus, the first task requires the longest period of time for completion of the work.

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.

It is recognized that the estimated costs of conducting the evaluation of FMVSS 301 are high, especially in terms of manpower. This is directly a result of the lack of a readily-available data base which can be used for evaluating the Standard. Task 1 involves the costly acquisition of new data. Task 2 and Task 3 are based on historical data, but the data must be manually extracted and assembled into a suitable data base. Thus, the estimated resources for accomplishing the four tasks to evaluate the effectiveness and costs of the Standard are 11 person-years, $10,000 for computer processing and analysis and $33,000 for miscellaneous expenses including preparation of data forms, training and travel costs.

5.1 Task 1 - Fuel Systems Rupture Analysis

Task 1 is concerned with the collection of new data on fuel system rupture. The data would be collected by trained investigators or technicians during a 12-month period in selected locations in the United States. The fuel rupture data will be obtained by inspection and testing of towaway-involved vehicles by the investigator. A total of 3 person-years has been estimated for this collection effort which will also include acquiring supplementary information from police accident records. The analysis of these data is designed to (1) determine whether spillage occurs when the conditions of the Standard are approximately realized in a crash situation and (2) investigate what the effects of the Standard are in higher speed and/or concentrated (corner)

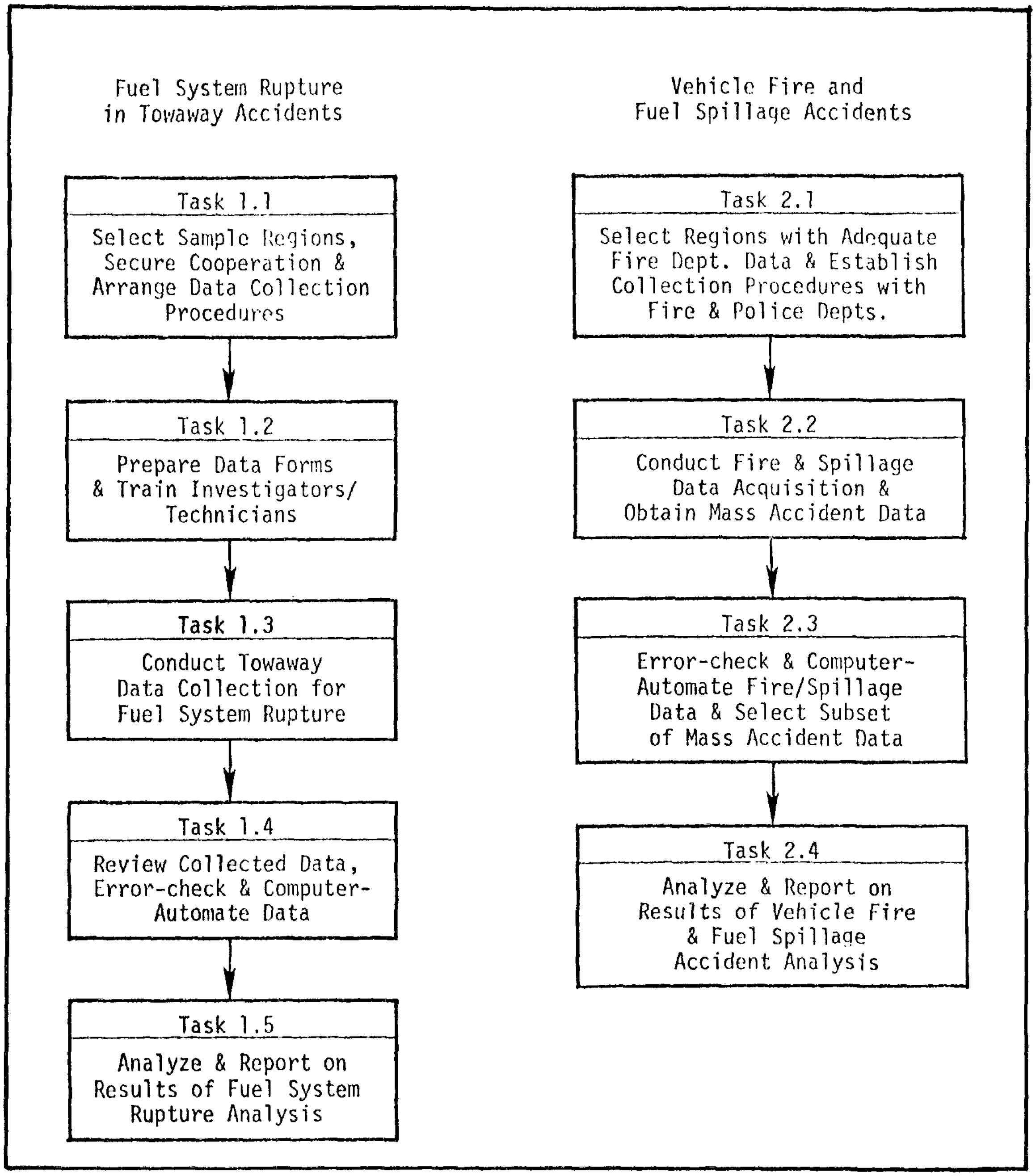


Figure 5-1. Flow chart for study to evaluate FMVSS 301.

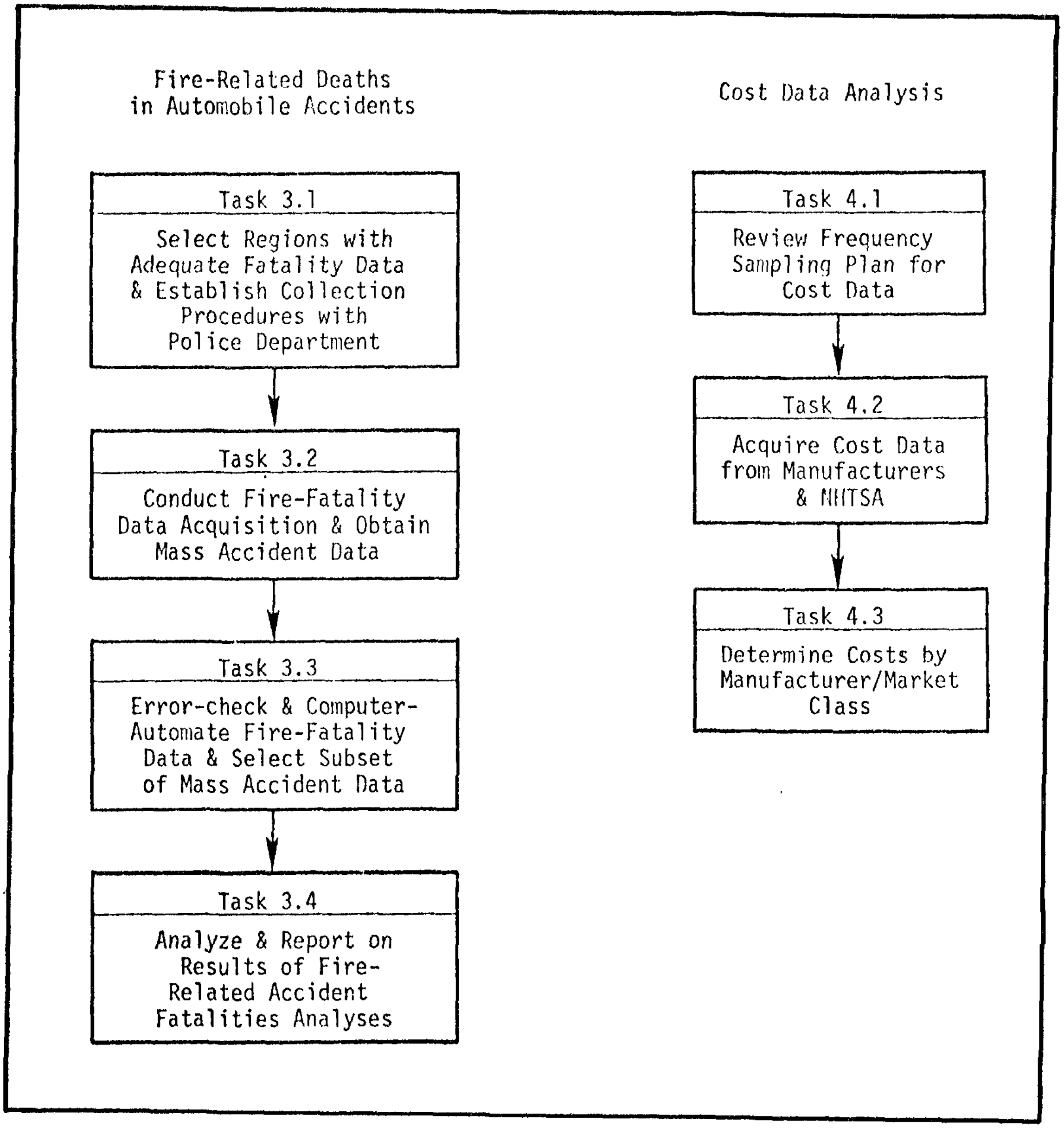


Figure 5-1 (continued).

crashes. The Task 1 effort is estimated to require 18 months for completion and about 4.5 person-years to accomplish the data collection, processing and analysis efforts. Additional resources required are estimated to be $2,000 for computer processing and $13,000 for preparation of data forms, training investigators and travel costs involved in training and data collection.

Task	Description	Months (1–18)	Resources Required: Person-Years	Resources Required: Data Processing ($K)	Resources Required: Other Costs ($K)
	Fuel System Rupture				
1.1	Select Sample Regions	1	0.2		
1.2	Prepare Forms & Train Investigators	1–3	0.4		$ 3.0
1.3	Conduct Towaway Data Collection	3–14	3.0		$ 10.0
1.4	Error-check & Automate Data	12–15	0.5	$ 1.0	
1.5	Analyze & Report Results	16–18	0.4	$ 1.0	
			4.5	$ 2.0	$ 13.0
	Vehicle Fire & Fuel Spillage				
2.1.	Select Sample Regions	1–2	0.3		
2.2	Acquire Fire Dept. Data & Mass Accident Data	3–8	1.0		$ 10.0
2.3	Error-check & Automate Data	7–9	0.6	$ 1.2	
2.4	Analyze & Report Results	10–12	0.6	$ 1.8	
			2.5	$ 3.0	$ 10.0
	Fire-Related Deaths				
3.1	Select Sample Regions	1–2	0.3		
3.2	Acquire Fire-Fatality Data & Mass Accident Data	3–8	1.5		$ 10.0
3.3	Error-check & Automate Data	7–9	0.6	$ 1.5	
3.4	Analze & Report Results	10–12	0.6	$ 2.5	
			3.0	$ 4.0	$ 10.0
	Cost Data Analysis				
4.1	Review Frequency Sampling Plan	1	0.1		
4.2	Acquire & Preprocess Data	2–4	0.3	$ 0.4	
4.3	Analyze Costs & Report Results	5–7	0.6	$ 0.6	
			1.0	$ 1.0	
	TOTAL RESOURCES REQUIRED		11.0	$10.0	$ 33.0

Figure 5-2. Schedule of tasks and required resources for evaluating FMVSS 301.

5.2 Task 2 - Vehicle Fire and Fuel Spillage Analysis

Task 2 deals with the analysis of vehicle fire and fuel spillage data. As suggested in Section 3.2, this analysis could be accomplished either with existing historical Fire Department data or from a special new ongoing collection effort at selected Police Departments. The task description given here assumes an analysis using historical data. The selection of a sample region will ideally include (1) high-quality fire department data which can be cross-referenced with police data; (2) the availability of NCSS data; and (3) the availability of mass accident data. A six-month period is allocated for the collection of vehicle fire and fuel spillage accident data. In favorable circumstances, it is possible that all or nearly all of the data can be obtained from the fire department records. It is estimated that the acquisition of these data and mass accident data requires 1 person-year of effort. It is estimated that the cost of acquiring the mass accident data,and travel and incidental costs associated with the fire and fuel spillage data extraction and compilation is about $10,000.

It is estimated that 12 months will be required for the completion of the Task 2 study. This allows two months for region selection and making required arrangements, six months for data extraction and beginning processing and four months to complete data automation and analysis. The total resources required for Task 2 are estimated to be 2.5 person-years, $3,000 for computer processing and $10,000 for data collection and acquisition costs.

5.3 Task 3 - Analysis of Fire-Related Fatalities

Task 3 is directed toward acquiring and analyzing data on fire-related motor vehicle fatalities. Mass accident data will provide the basis for overall fatality data but determination of fire-related deaths requires resorting to police accident files of fatalities. Additionally, recourse to state public health agencies may be required. Resources amounting to 1.5 person-years and $10,000 for travel and other costs have been estimated to be required for a 6-month data acquisition period. These estimates include the acquisition of mass accident data from Texas, North Carolina and New York State as well as the collection of vehicle fire fatality data.

Task 3 is scheduled to be completed within 12 months. This schedule allows two months for selection of regions, securing agency cooperation and setting up data collection procedures. Six months are allocated to data collection and acquisition. Data checking and automation will require three months time, the first two months of this period overlapping with the concluding two months of the data acquisition. Analysis of the data and reporting results are scheduled for the final three months of the 12-month study period.

It is estimated that the total resources required for Task 3 are 3.0 person-years, $4000 for computer processing, and $10,000 for fatality data and mass accident data acquisition. The computer budget for Task 3 is higher than the first two tasks because of the potentially large volume of mass accident data that will be processed.

5.4 Task 4 - Cost Data Analysis

Task 4 is directed toward the determination of direct costs to implement FMVSS 301. 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 1968 (pre-Standard), 1969 (post-Standard), and 1976 (major upgrading of Standard). 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 4 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 $1000 for computer processing.

---

*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).

APPENDIX A

DISTRIBUTION OF PRE- AND POST-FMVSS 301 VEHICLES IN FATAL ACCIDENTS BY ACCIDENT YEAR

TABLE A-1

DISTRIBUTION OF PRE- AND POST-FMVSS 301
VEHICLES IN FATAL ACCIDENTS BY ACCIDENT YEAR

Accident Year	Percent Involvement in Fatal Accidents	
	Pre-Standard	Post-Standard
1978	5	95
1977	8	92
1976	12	88
1975	18	82
1974	26	74
1973	34	66
1972	44	56
1971	55	45
1970	67	33
1969	78	22
1968	91	9
≤1967	100	0

Sources:
1. Virginia Crash Facts 1971, 1974
2. New York Mass Data Tabulations 1973
3. Estimates of CEM staff.

APPENDIX B. DISCUSSION OF CONTINGENCY TABLE ANALYSIS

Contingency table analysis is a frequently used statistical technique to investigate the relationship between two categorical variables. The contingency table approach enables one to determine if the two variables are related. Specifically, by means of the chi-square test, one can test the hypothesis that the two variables are independent of each other. The basic contingency table analysis can be traced back to Karl Pearson and his chi-square test.

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	SPEED: Fast	
Slight or None	100_{P11}	110_{P12}	210_{P1+}
Moderate or Severe	50_{P21}	80_{P22}	130_{P2+}
	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. That is, other factors or variables (e.g., type of highway, road condition, light condition, traffic density, etc.) must be introduced through sample stratification to attempt to clarify the relationship.

---

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

APPENDIX C

DISCUSSION OF PROPOSED STANDARD IMPLEMENTATION COST CATEGORIES

APPENDIX C. 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. LaHeist, 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 D: STATISTICAL DISCUSSION ON CHOOSING A PARTICULAR MAKE/MODEL WITHIN MANUFACTURER FOR COST DATA ACQUISITION

Consider any cell in the experimental design corresponding to a particular manufacturer and market class. Suppose within this cell there are K different possible cars to choose with known sales volumes $n_1, n_2, \ldots n_k$ (let $n = \sum_{i=1}^{K} n_i$). Suppose also the respective unknown costs are $c_1, c_2, \ldots c_k$.

We seek an estimate of the overall average cost

$$\bar{c} = \sum_i c_i \frac{n_i}{n} \qquad \text{based on one observation.}$$

Any decision rule may be described by a set $p_1, \ldots p_k$ where p_i is the probability of selecting the i^{th} possible car and then obtaining its cost c_i.

The risk associated with any rule, under squared error loss (obviously appropriate under variance considerations) is

$$\sum_i (c_i - \bar{c})^2 \, p_i$$

The natural inclination at this point is to attempt to minimize this risk over the p_i. The answer is set $p_i = 1$ at c_i closest to $\bar{c}$. But this is clearly worthless since the c_i are unknown. (If they were known, $\bar{c}$ would also be known and there would be no problem.)

Hence, the choice of the p_i's can only depend on the n_i. The natural approach suggests the unbiased estimator $p_i = \frac{n_i}{n}$ so that the expected value of the estimator is $\bar{c}$. The associated risk is

$$\sum_i (c_i - \bar{c})^2 \frac{n_i}{n}$$

We wish to examine which of these is the smaller. First we solve the problem if k=2 in which case $n_1/n > 1/2$.

Claim: $$(c_1 - \bar{c})^2 < (c_1 - \bar{c})^2 \frac{n_1}{n_1+n_2} + (c_2 - \bar{c})^2 \frac{n_2}{n_1+n_2}$$

Proof: Obvious: plug in $\bar{c} = c_1 \frac{n_1}{n_1+n_2} + c_2 \frac{n_2}{n_1+n_2}$ and verify.

More generally, if we write

$$\bar{c} = c_1 \frac{n_1}{n} + \frac{\sum_{i=2}^{k} n_i c_i}{n}$$

$$= c_1 \frac{n_1}{n} + c' \frac{n-n_1}{n}$$

where $c' = \sum_{i=2}^{k} \frac{n_i c_i}{n-n_i}$

In other words, $\bar{c}$ is the weighted average of c_1 with the weighted average of the remaining c_i's. Then,

$$\sum_{i=1}^{k} (c_i-\bar{c})^2 \frac{n_i}{n} = (c_1 - \bar{c})^2 \frac{n_1}{n} + \sum_{i=2}^{k} (c_i-c' + c'-\bar{c})^2 \frac{n_i}{n}$$

$$= (c_1 - c)^2 \frac{n_1}{n} + (c' - \bar{c})^2 \frac{(n-n_1)}{n} + \sum_{2}^{k} (c_i-c')^2 \frac{n_i}{n} \quad ,$$

compared with

$$(c_1 - \bar{c})^2 \quad .$$

But if $\frac{n_1}{n} > 1/2$ then $\bar{c}$ is closer to c_1 than to c'.

i.e., $$(c_1 - \bar{c})^2 < (c' - \bar{c})^2$$

or $$(c_1 - \bar{c})^2 \frac{(n-n_1)}{n} < (c' - \bar{c})^2 \frac{(n-n_1)}{n}$$

or $$(c_1 - \bar{c})^2 < (c_1 - \bar{c})^2 \frac{n_1}{n} + (c' - \bar{c})^2 \frac{(n-n_1)}{n}$$