AN EVALUATION OF FMVSS 301

FUEL SYSTEM INTEGRITY

Report Number UM-HSRI-79-12

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March, 1979

Prepared under Contract DOT-HS-7-01755

National Highway Traffic Safety Administration
Department of Transportation
Washington, D. C. 20590

Interim Report

Technical Report Documentation Page

1. Report No. UM-HSRI-79-12	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle An Evaluation of FMVSS-301--Fuel System Integrity		5. Report Date March 1979
		6. Performing Organization Code
7. Author(s) Jairus D. Flora, Paula Beitler, Nancy Goldstein, Judith Bromberg		8. Performing Organization Report No. UM-HSRI-79-12
9. Performing Organization Name and Address Highway Safety Research Institute, University of Michigan, Ann Arbor, Michigan 48109		10. Work Unit No.
		11. Contract or Grant No. DOT-HS-7-01755
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration, Department of Transportation, Washington, D.C. 20590		13. Type of Report and Period Covered Interim 10/77 - 10/78
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Fire department data and police accident data from six states were used to estimate the possible effects on post-crash passenger car fires of FMVSS 301--Fuel System Integrity. The one-year study used data from two years of accident statistics.

The study concluded that existing data are inadequate to provide a definitive evaluation of FMVSS 301. A survey of data available from 48 states was conducted. Large data sets having the required data elements were used. In all data sets, the missing data rate was much larger than the reported rate of crash fires. Thus, all results are subject to potential bias errors of an order of magnitude greater than the phenomena themselves.

The frequency of post-crash fires is estimated to be on the order of one fire per thousand crashes. This varies by model year of car, type of crash, speed, and data set. Newer model years of cars exhibited lower crash fire rates than older ones. This finding was consistent in all data sets and is probably qualitatively valid, although hard to quantify. While this reduction is consistent with a beneficial effect of FMVSS 301, it could also be due to a deterioration of the fuel system with age.

17. Key Words Crash fires; Fuel Systems; Passenger Car Crashes	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 75	22. Price

SUMMARY

This is an interim report detailing the findings and results from the first year's efforts on a project entitled "Evaluation of the Effectiveness of Federal Motor Vehicle Safety Standard 301--Fuel System Integrity, Passenger Cars." The project is sponsored by the National Highway Traffic Safety Administration (Contract No: DOT-HS-7-01755).

The project first determined the availability and applicability of data from several sources. Police accident data and fire department data were considered. A summary of the data available and applicable by each state is presented in the report as Table 4.1.

Passenger car fires following a crash are rare. However, when they do occur, they substantially increase the risk to the occupants and the amount of damage. In order to evaluate the FMVSS 301 standard, post-crash fire rates by model year--and hence by version of the standard--were estimated and compared. In order to do this, data sets must provide a minimum amount of information: the presence or absence of fire in crash and the model year of the vehicle for accident data; the occurrence or non-occurrence of a crash and the model year of the vehicle for fire department data. In addition, in order for comparisons to be meaningful, a large number of fire crashes must be anticipated in each data set. This last consideration restricted attention to state-wide files, while the former restricted attention to those which contained the required data elements.

In the report, data from the states of Illinois, Washington, Missouri, Maryland, Michigan, and New York are considered. In addition, data from a special study in California are utilized and preliminary data from the NCSS are mentioned.

One major finding was that none of the existing data sources is adequate to definitively evaluate the effect of FMVSS 301. In part this is a consequence of the type of data and the fact that information on crash fires is only available for at most a few years, while the original standard went into effect in 1968. However, aside from the known limits of the data, the quality was found to be quite low. All data sources had missing data rates on the key data elements which were

much higher than the estimated rate of crash fires. For example, the variable to indicate whether a fire occurred in a crash might indicate that no fire occurred in 70.0% of the crashes, that a fire did occur in 0.4% of the crashes, and be missing for the remaining 29.6% of the crashes. In Fire department data, model year was often missing for 20-30% of the car fires. Generally, the assumption has been made that the missing data are unbiased--that they contain the same distributions of fires and non-fires that the other data do. This is probably not true, but there does not seem to be much alternative.

A second major finding is that crash fires are rare. The different data sources disagree on the proportion of crashes which result in fires. In addition, the amount of missing data makes any such estimate uncertain. The level varies from about 3 fires per thousand crashes (in the Illinois data) to about 0.3 fires per thousand crashes (in Washington and New York data). The most defensible figure is about 3 fires per thousand towaway crashes from the preliminary data from the NCSS. A frequency of about one fire per thousand police reported crashes seems a reasonable estimate, although, as mentioned, the missing data make this uncertain.

A third major finding is that the crash fire rates are lower in the more recent models. This effect is apparent consistently in all of the data sets. However, in some of the smaller data sets, the rates are not significantly different from a constant rate for each model year of car. It is not possible to ascribe these lower crash fire rates in newer models directly to the more stringent versions of FMVSS 301, or even to any version of FMVSS 301. The data generally show crash fire rates which increase relatively smoothly with the age of the car. Thus, the lower fire rates could be due to a gradual deterioration of the car with age. It is possible that the lower rates for newer models could be due to yearly improvements in the fuel system in response to the early version of FMVSS 301 or in anticipation of the more stringent versions of FMVSS 301 later. The data are not adequate to distinguish between these alternatives.

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1. INTRODUCTION

This is an interim report detailing the findings and results from the first year's effort on a project entitled "Evaluation of the Effectiveness of Federal Motor Vehicle Safety Standard 301--Fuel System Integrity, Passenger Cars." The project is sponsored by the National Highway Traffic Safety Administration (Contract no. DOT-HS-7-01755).

Passenger car fires following a crash are rare events. However, when they do occur, they are spectacular and potentially lethal, and as a consequence, particularly newsworthy. In an effort to reduce the fatalities and injuries associated by post-crash fires, the FMVSS 301 was formulated. The original version of the standard became effective on January 1, 1968. Subsequently the requirements of the standard were made more stringent effective for the 1976 model year passenger cars and more recently modified again for the 1977 model year passenger cars. These latter versions of the standard were broadened to include light trucks. However, this report restricts attention to passenger cars.

The purpose of this report is to estimate any changes in post-crash passenger car fires which may have occurred as a result of the standard in its various forms. Practical considerations have reduced this estimate of the effectiveness of the standard to estimating the post-crash fire rates experienced by different model year passenger cars in recent years' crashes. By attempting to relate observed differences in the post crash fire rates to the standard, one can obtain a measure of the standard's effectiveness.

2. APPROACH

The general approach to estimating the effect that FMVSS 301 has had on passenger car post-crash fires is to try to determine the rate of occurrence of post-crash fires in accidents involving cars of different model year's manufacture. These fire rates by model year are then related to the version of the standard in effect at the time of the car's manufacture. The differences which are found may be attributable to the effects of the standard.

There are a number of complications to this method, of course. It is possible that any observed differences may be due to a number of factors instead of or in addition to the standard. Attempts were made to identify such confounding factors. When they were found, the magnitude and presumed direction of the bias they introduce was estimated. To the extent that this could be done, then these factors were adjusted for or controlled for in an attempt to remove their influence from the differences in fire rates. It may well be that not all of these potential confounding factors were eliminated. In that case, differences in fire rates may be related to the standard or to the confounding factors, or both.

2.1 Evolution of the Standard

The first version of FMVSS 301 went into effect on January 1, 1968. It called for the fuel systems to retain their integrity (not leak fuel) after a crash and affected the fuel tank, filler pipe, and fuel line connections. Compliance was to be judged or demonstrated by a 30 miles per hour perpendicular frontal crash into a fixed barrier following which fuel leakage was to be less than one ounce per minute.

The FMVSS 301 was upgraded effective with the 1976 model year of passenger cars, following some postponements of the initially proposed effective date. The main change in the standard was that following a 30 mph frontal barrier crash, the car should not leak more than the one ounce per minute in any of four final resting positions--on its wheels, on its roof, or on either side.

The current version of the standard was effective for the 1977 model year vehicles. In addition to the previous requirements, the current version specifies testing in two alternative modes--moving barrier rear collision and angle side impacts. Following any of the collision types, the vehicle should not leak more than the one ounce per minute in any of the four resting positions. The 1976 and 1977 versions of the standard also covered more vehicles than the 1968 version. In addition, the details of the testing procedure are somewhat different and more completely specified. Exact details of the standard in its three versions may be found in 32 F.R. 2416, February 3, 1967, 38 F.R. 22397, August 20, 1973, and 40 F.R. 48352, October 15, 1975, respectively.

2.2 Timing of Design Changes

Although the dates of the standard's three versions are given above, it is not clear whether these dates are actually the dates when cars first met the standards. In fact, it seems quite unlikely to be so. It seems generally accepted that most passenger cars--at least those made in the U.S.--required little or no modification in order to comply with the first version of the standard. If a make or model did require some modification in order pass the test specified in the 1968 version of the standard, such a modification would almost surely have been introduced with the first of the new (1968) model year rather than in the midst of the model year (for those cars built after January 1, 1968). Thus, it is a reasonable assumption that the first version of the standard was actually effective for the entire 1968 model year rather than beginning on January 1, 1968. This is fortunate, since identifying the date of manufacture of a car in existing data is next to impossible.

Since the later versions of the standard were postponed from proposed earlier effective dates, it is possible that some manufacturers upgraded the fuel systems of some models to meet the anticipated standard in advance of the date that was finally established. Again, one would expect car makers to modify models (when such modifications were needed to meet the standard) at the time when other design changes or styling changes were to be incorporated. One would hope that such modifications would pre-date the actual effective date of the standard. However, it is possible that if it was borderline or questionable whether a particular model would meet the standard, and if that model was to have major design changes shortly after the anticipated effective date of a new version of the standard, that any modifications to that model might be postponed until the scheduled model change. It should be emphasized that there is no evidence that this was the case, it is merely a possibility.

To the extent that such phasing in of models which complied with the new standard took place, any effects of the standard would appear as a reduction in fire rates over two or three years rather than a sudden drop in fire rates coincident with the timing of the standard.

2.3 Different Effects of Standard Revisions by Crash Severity.

The standard specifies performance in terms of crash tests at 30 mph (later versions have some tests at 20 mph). As always, there is difficulty in relating a barrier crash at 30 mph to an equivalent crash in a real traffic situation. However, a 30 mph barrier crash should be approximately equivalent to a delta V of 30 mph in a frontal collision. Preliminary data from the NCSS (National Crash Severity Study) (O'Day, et. al., 1978, p. 69) shows that an estimated 90+ % of tow-away crashes have a calculated delta V of less than 30 mph. The relationship of the 20 mph testing modes to delta V is less clear. However, an estimated 80+ % of the towaway crashes had calculated delta V's less than 20 mph. Thus, the speeds specified in the standard would seem to encompass most of the crashes which are observed in practice. (The non-towaway crashes would typically occur at lower speeds than the towaways.)

It should be noted, however, that there will still be some crashes at low speeds which will result in fuel leakage, and, possibly, in fire. On the other hand, many of the crashes at higher speeds will not result in either fuel leakage or fire. The chance of fuel spillage in an accident increases with the speed of impact. Presumably there is not a sudden increase at the speed specified in the standard, but a more or less continuous one.

The key point to keep in mind is that the potential effect of the standard is to affect different crashes differently depending on the speed of impact or the energy in the crash. The standard should reduce the chance of fuel spillage in "low" speed crashes (those below the limits specified in the crash test), but may do little if anything to the chance of fuel spillage in high speed crashes. The effect in the crash population is then dependent on the mix of speeds as well as on the efficacy of the standard at each speed. Thus, the different distribution of speeds might cover up a true effect or suggest one which does not actually exist.

2.4 Age Effects

One conceptual difficulty in evaluating FMVSS 301 by using data on accidents which occurred relatively recently is that cars built to different versions of the standard were of different ages when their accidents occurred. It is conceivable that the aging of a car results in the deterioration of its fuel system and makes it more likely to spill fuel in a crash. To the extent that this is so, age is a factor confounded with the effect of the standard. It cannot be completely separated, but the fact that the 1968 version of the standard has vehicles of several model years (and hence ages) provides the opportunity to estimate whether aging is a factor. If it is, then one may attempt to model it as a smoothly increasing probability of post-crash fire and look for possible effects of the standard above the smooth trend seen in the rates as functions of the age of the vehicle.

2.5 Rarity of Crash-Related Fires

Post-crash fires are often spectacular and lethal. As a result, they often rate considerable news coverage. This attention may make them seem to be more frequent than they actually are. The different data sources investigated in this report disagree considerably on the relative frequency of fire in crashes. Data from the state of Illinois show an overall average rate of 1.954 fires per thousand crashes (if missing data on fires are assumed to be non-fires) over a two year period. On the other hand, data from Washington state show a two-year average rate of 0.375 fires per thousand crashes. Data from New York estimate a crash fire rate of 0.288 per thousand crashes. It should be noted that in all these data sets the proportion of missing data is much larger than the estimated fire rates. Perhaps the best (in terms of data quality) estimate of crash fire rates comes from the preliminary data of the NCSS. Based on the preliminary data reported in O'Day et. al. (1978), an estimated crash fire rate of 3.137 fires per thousand tow-away crashes is obtained. It should be noted that this refers to tow-away crashes, while the other estimates refer to all police reported crashes. While it is not known exactly how many police reported crashes occurred in the NCSS sites during the period when the tow-away data were collected, the number of non-tow-away crashes was larger than the number of tow-away crashes. Presumably the fire rate in non-towaway crashes is nearly zero—much lower than in the tow-away population. In fact, the occurrence of a post-crash fire would likely result in damage which would require towing even if other damage in the crash did not.

In any event, it is clear that the occurrence of post-crash fires is quite a rare event. They occur at the rate of at most about three fires per thousand towaway crashes, and perhaps about one or less fire per thousand police reported crashes.

Although post-crash fires are rare in general accident data, they are much more frequent among fatal accidents. Data from the Fatal Accident Reporting System (FARS) show that in fatal accidents, somewhere between two and three percent of the accidents which resulted in a death involved a post-crash fire. Post crash fires increase the chance of a fatality. In addition to the indirect evidence from the FARS, the fatality rate in cars involved in post-crash fires in Washington was 0.195 persons per car. For all crashes, the fatality rate was only 0.0034 persons killed per vehicle. Of course, the crashes in which fire occurred were more severe crashes than those without fire, so in part the increased fatality rate reflects this in addition to the additional hazards posed by the fire.

The rarity of the post crash fire event makes studying the fire rates difficult. In addition, the fire rates differ by nearly a factor of ten in data from different sources. Almost all data sources have missing data rates (on the fire variable, or on the model year variable) which are much larger than the calculated fire rates. Thus, if missing data are associated with fires, very large biases could be present in the estimated rates.

3. METHODS

Two general types of data sets were expected to be useful in this study. One type of data includes all the crashes in a given geographical (or other defined population) region for a given time and, in addition, identifies which of those crashes resulted in a post-crash fire. An example of this sort of data set is the police accident data from the state of Illinois. These data can be used to calculate fire rates (the numerator is a proper subset of the denominator).

The second general type of data encountered consists of data about crash fires from one source, and data about crashes from another source. This is the case if fire department records are used to determine the crash fires in passenger cars by model year, while police accident data are used to give the number of passenger car crashes by model year. Data from the state of Michigan are of this type. These data can be used to calculate fire ratios (the numerator is not necessarily a subset of the denominator).

The advantage of the first type of data is that they include the same definition of crash whether or not a fire occurs. In addition, the variability associated with a rate is generally smaller than that of a ratio. The disadvantages of the second type are the larger variability (minor), and more seriously, the fact that the definition of crash in the fire data may differ substantially from that in the police accident data. These disadvantages are offset by some other considerations. First, fires may not be reported in accident data. Then using data of the second type can add significantly to the total amount of data available for study. Second, since fires are a rare event, a system which reports all or nearly all of the fires may be advantageous. Unfortunately, fire department data consists predominantly of non-car fires. Most of the data elements were designed with fires occurring in fixed property in mind, so that data about the vehicle are quite limited, and data about the accident are almost non-existent. Further, since car fires are a small portion of the fire data, data quality problems exist. These include problems of missing data and inaccurate data as well as questions about completeness of reporting.

3.1 Police Accident Data Which Report Fire

For a variety of reasons, it is better if all data come from the same data system. In addition to alleviating data quality problems by reducing them to a single system, interpretation of the rates is more direct when the data come from a single set. In some states, the police accident data records the occurrence or non-occurrence of a fire in each police reported crash. In Illinois, the police accident report form has included an item to check for fire or no fire for each vehicle involved in a crash since 1975. The data from New York report fire as one of the possible "second adverse events" in a crash. Since many crashes—particularly the more severe ones in which fires are more likely to occur—involve multiple collisions, this could result in severe under-reporting as fires would have to compete with second collisions for recording. However,the instructions require that if a fire occurs, it takes precedence over any other second adverse events. Thus, if the instructions are followed, this variable should be a valid indicator of the occurrence of crash fires. Data from Washington state include a multiple response variable with fire as one of the responses for additional adverse events. Up to three additional events are coded. Data about fires are abstracted from the narrative of the police report and then coded at the state level. Thus, these fires would only be reported if they were significant and recorded by the investigating office in his narrative.

A variety of levels of fire reporting are found among police accident data. It should be noted, that to be useful, the police data must also contain the model year of the car as well as whether or not a fire occurred. A number of police accident data sets included non-crash fires. This was recorded if a police officer stopped to assist a motorist whose car had caught on fire without being involved in a crash (from a carburetor fire, wiring, etc.). Such incident reports do not involve crashes. They appear to be more common than crash fires, but generally result only in property damage and are the result of mechanical problems rather than accidents.

3.2 Fire Department Data

The National Fire Administration (NFA) collects data from several states' fire departments. These data are collected on a uniform form and use common instructions and definitions. The collection of these state data files forms the National Fire Incident Reporting System (NFIRS). This is the largest set of data from fire departments.

3.2.1 Identification of Crash Fires. Unfortunately for the purpose of evaluating FMVSS 301, this data set (NFIRS) does not clearly identify a fire incident involving a motor vehicle with a crash or traffic accident involving that motor vehicle. Some information is available, which indicates vehicle fires which are likely to have resulted from crashes. For example, the variable "ignition factor" has one code value (code 71) for "collision, overturn, knockdown", which would appear to include motor vehicle crashes. However, this comes under the general category of operational deficiency. An alternative general category which might apply is "mechanical failure, malfunction." Several other codes could be used for ignition factor for fires resulting from a motor vehicle crash, for example, "41--fuel spilled, released accidentally, 51--part failure, leak or break, 53--manual control failure, 61--design deficiency," as well as a number of general categories such as "70--operational deficiency, insufficient information to classify further." These latter categories, which are essentially "unknowns," contain a relatively large number of the cases. They include some of the crashes but many other, non-crash events. Other variables could give supporting information toward deciding if a fire resulted from a crash, for example, the area of fire origin, the form of heat of ignition, the type of material ignited, the location.

3.2.2 Development of a Crash Surrogate. To determine how accurate or inaccurate identification of a car fire as resulting from a crash was, three months' of data from the Michigan fire data were obtained as hard copies of the original data forms. There were approximately 62,700 forms, each containing the record of a "fire incident." These were reviewed manually to select those which involved passenger cars and fire, resulting in approximately 7,846 fires involving passenger cars. These were read and based on the coded values, the written entries, and the optional narratives, were classified as having definitely resulted from a crash, having not resulted from a crash, a possible crash, or unknown. There were 55 cases which could definitely be identified as resulting from a crash, and 9 cases which were probably crashes, the rest being non-crashes or probably non-crashes. Various combinations of the variables in the computerized data file were tried to see which did the best at identifying the crash fires while excluding the non-crashes. In checking these surrogates, it was discovered that not all of the cases in the computer file could be matched with the hard copies. Most of the promising surrogates identified 3 to 6 cases from the computer file which were not located in the hard copies.

There were 5 surrogate combinations which did about the same at identifying crash fires in the fire department data. These differed only slightly in the number of cases found and also in the definition, usually differing only by the inclusion of one additional code value. The one selected as best identified 52 cases from the computer file. Of these, 17 were non-crashes and 5 were missing. The remaining 30 were either definite or probable crashes. Of the crashes the computerized surrogate identified 24 of the 55 definite and 6 of the 9 probable crashes--or 30 of 64 probable crash fires.

While other combinations of variables did slightly differently, it was not possible to find substantially more of the crashes without including an unacceptably large number of non-crashes. For example, in order to include 34 of the 55 crashes, 100 non-crashes would be included. Thus, identification of crash fires in the fire department data is quite difficult. We have used the surrogate variable for the Michigan data, since it is somewhat better than just using the code 71--collision, overturn, knockdown, but it does not seem justified to use it in other fire department data. Identification of the fire with a crash in those data is simply by the most likely code--71. This will result in the inclusion of some not-crash car fires and will exclude some car fires which resulted from crashes. However, the size of this discrepancy is not known. It is likely to differ for each state's data, since the data are collected by local fire departments in each state and assembled by the state Fire Marshall's office. The exact definition of the surrogate used in the Michigan data is given in Appendix A.

3.3 Analytic Methods

Although there are two general types of data sources, the basic analytical techniques are similar for both. The analysis consists of defining an appropriate crash fire rate (or ratio) and then calculating these estimated rates. These crash fire rates are (at a minimum) estimated separately for each model year back to about 1961. The rates are then analyzed to look for aging effects within versions of the standard, and differences among different versions of the standard. When possible—in police accident data—rates are calculated and analyzed by other variables as well. Examples include type of crash, posted speed limit, etc. Even in the largest data sets, the rarity of fires makes the data too tenuous to include many variables (in addition to model year) at once. Hence, it is difficult to look for interactions among the various variables.

3.3.1 Definition and Calculation of Crash Fire Rates. For data which come from the same reporting system, the definition of crash fire rates is straightforward. One simply determines the number of fires for, say, a given model year, and the number of vehicles of that model year, involved in crashes, and divides the number of vehicles involved in crashes which caught on fire by the total number of such vehicles involved in crashes. These rates may be calculated separately for each model year of vehicle, for types of crashes, or for categories of other variables in the data. Because of the rarity of the fires, if one calculates these rates for combinations of other variables, the rates become unreliable. That is, the numerator becomes either zero or one or two, so that little information is gained.

An alternative to using the number of crashes as the denominator would be to use the number of registered vehicles as the denominator. One would then have a rate of crash fires per registered vehicle rather than of fires per crashes. While the rate of fires per registered vehicle has some relevance, the fires per crash rate is more directly relevant to FMVSS 301, and is the rate of choice. The two rates are highly related, the crash fires per registered vehicle being about one tenth that of the fires per crash. The fires per crash rate is that used in this study.

When the data on fires come from the fire department records while the accident data come from police department records, the definition of rates is not as clear cut. Conceptually, the ratio of crash fires to crashes would still be preferred. However, with the difficulty of identifying crashes among the fire department records of car fires, this ratio is open to question. A number of alternatives were considered.

One alternative would be to use all car fires divided by the number of registered vehicles. Such a rate would be calculated for each model year. Since fire department data do not contain any information about the crash--if there was one--further subdivision of the rates is not possible. The rationale for this rate is that if FMVSS 301 improved the integrity of the fuel system, this may well have had the effect of reducing the likelihood of car fires in general, not just those which result from a crash. There are a number of refinements of this rate which would appear useful. Arson and suspected arson cases should be eliminated as irrelevant. In addition, cases which do not involve fuel should be eliminated. While elimination of the arson cases is fairly reliable, when other types of fires are considered--electrical versus fuel-fed, for example, one encounters large amounts of missing data. That is, should one only include fires for which fuel is given as the substance first ignited, or should one exclude the non-fuel sources, leaving a large amount of missing data? In trying to exclude the non-relevant car fires, one is soon left with trying to develop a crash surrogate as described in Section 3.2.2. As a result of these considerations, the approach selected was to use the fire department data which seemed to correspond to crash fires as the numerator, and to use the crashes as the denominator. (One exception to this is the data from Maryland, for which we have not obtained crash data for the denominator as yet. For this set, registration data were used for the denominators.)

3.3.2 Relation of Rates to Standard. Once the appropriate rate was defined, these rates were calculated for each model year of passenger car from the most recent back to about 1961. Earlier models were excluded or combined into a single group for two reasons. First, the number of such vehicles was very small, leading to unreliable fire rates. Second, cars more than 15 years old are not generally in regular use--they tend to become antiques or special use vehicles--and so are not relevant to the evaluation of the standard. Tables showing the fire rates by model year are presented in Section 5, in the sub-section corresponding to each data set.

Averaging the fire rates over all model years corresponding to a single version of the standard gives an average rate for that version of the standard. These rates are summarized in Table 3.1.

As can be seen in Table 3.1 most of the fire rates show a tendency to be lower for the more recent versions of the standard. This is consistent with a beneficial effect of the standard in terms of reducing the incidence of post-crash fires. However, this is also consistent with an increase in the post-crash fire rates with the age of the vehicle. Thus, there is a plausible, alternate explanation for the lower fire rates among the more recent model years. This point is discussed further in the Section 5. Findings. It is also of interest to note that the estimated fire rates differ by an order of magnitude among the different data sets. Further, the different data sets show some disagreements with respect to the trends or patterns of the rates also.

3.3.3 Adjustment of Rates for Confounding Factors. It has been pointed out that the age of the vehicle is one factor which is confounded with effect of the standards. This confounding cannot be completely eliminated, since the data are restricted to crashes which occurred in 1976 and 1977. During this time period, the cars manufactured under the first version of the standard were already from one to nine years old, while those built prior to the standard (pre 1968 models) were at least ten years old. Similarly cars built after the later versions were new--or at most two years old. To eliminate this confounding, one would need data for the earlier cars crash fire rates when they were new--data which are not available.

Table 3.1

Average Fire Rates by Standard and Data Source
(All Rates are per thousand cars)

Data Source	Date	Standard				
		None (Pre 1968)	301 1968-75	301-75 1976	301-76 1977	Post 1975 combined
Illinois	1976	5.90	5.30	6.00	—	6.14
	1977	3.90	3.50	2.90	4.00	3.25
	comb	5.07	4.33	3.96	4.85	4.01
Washington	1976	0.42	0.22	0.37	--	0.47
	1977	0.50	0.46	0.34	0.79	0.53
	comb	0.44	0.33	0.35	0.87	0.51
New York Police	1976	0.30	0.29	0.35	0.00	0.34
	1977	0.44	0.26	0.31	0.22	0.27
	comb	0.37	0.28	0.33	0.21	0.29
New York Fire/Police	1977	3.48	1.62	0.62	0.75	0.67
Michigan Fire/Police	1976	0.71	0.31	0.06	--	0.06
	1977	1.00	0.44	0.13	0.15	0.14
	comb	0.82	0.37	0.09	0.15	0.11
Missouri Fire/Police	1977	6.94	3.29	1.38	0.51	0.99
Maryland Fire/Regis.	1977	0.41	0.17	0.15	0.08	0.12
California Spec. Study	1976	1.93	1.62	1.09	7.43	1.31
NCSS Singl Veh. Towaways)	1977	1.63	1.31	2.02	1.12	1.55

One method to try to eliminate at least one of the confounding factors is to adopt a model fitting approach. In this approach, a smooth (e.g.,linear or quadratic) age effect is postulated and estimated from the data within a given version of the standard. To this generalized linear model for the fire rates are then added indicator variables which introduce as differences in intercepts the effects of the various versions of the standard. If the coefficients of the variables which indicate the different versions of the standard are significant, (after the age effect has been estimated) then this would indicate an effect associated with the introduction of the standard above that which is likely to be due to aging of the vehicle.

Let P_i denote the fire rate for model year i. Let X_{1i} be the age of a vehicle of model year i. Let X_{2i} be 1(0) according as model year i is later than 1967 (1967 or earlier); X_{3i} be 1(0) according as model year i is later than 1975 (1975 or earlier), and let X_{4i} be 1(0) according as model year i is later than 1976 (1976 or earlier). Then one can fit the model:

$$EP_i = B_0 + B_iX_{1i} + B_2X_{2i} + B_3X_{3i} + B_4X_{4i}.$$

That is the expected value of the fire rate is a constant (B_0) plus a linear age effect. In addition, (B_2) represents an estimated effect on the expected fire rate coincident with the 1968 standard, while (B_3) estimates an additional effect coincident with the 1976 change, and (B_4) estimates the additional effect on the average fire rate coincident with the 1977 standard.

The model exemplified here is only one of similar models which were considered. It assumes a linear age effect throughout the data with the same slope. Linear effects with different slopes in the pre 1968 and 1968-75 ranges can be fitted. Polynomials or other functions of age can also be considered, but generally proved unnecessary.

Interpretation of the effects of the standard as estimated by the coefficients of the indicator variables in the model is somewhat conservative. That is, an effect of the standard is estimated only if it is apparent over and above any effect which could be explained by a smooth aging effect. If there were no aging effect, but three different levels of the rates corresponding to three different versions of the standard, some effect of aging would be estimated by the model. Thus, in such a situation, the model would underestimate the effectiveness of the standard. If an effect of the standard is found using the model described above, then one can be reasonably certain that such an effect occurred at the same time as the change in the standard. This does not imply casualty, of course, since conceivably other factors could have occurred to cause or partially cause such a change at the same time.

If the coefficients of the indicator variables in the above model are not significant, it does not necessarily mean that no standard effect was present--merely that a decrease in the mean fire rate was not found significantly more than a general decreasing trend in fire rates with newer model years. It seems likely that rather small design changes would be anticipated to meet the standard. In addition, many models may not have required any design changes. Finally, in some models for which design changes were necessary to meet the standard, these may have been introduced prior to the final promulgation of the standard. All of these factors may operate to make an effect of the standard fairly small in magnitude. In addition, such an effect might be of the form of a sharply decreasing trend in fire rates over 2 or 3 model years instead of a sudden drop at the model year coinciding with the introduction of the standard.

Whatever the type of effect, one should (eventually) see a lower average fire rate for model years subject to the more stringent versions of the standard if the standard was beneficial. If this is the case, but it the lower fire rates show a smooth trend over the model years, that is, if fire rates generally increase for older cars, then while the pattern would be consistent with a beneficial effect of the standard, it could also be due to simple aging of the cars. This alternative explanation could not be ruled out. Thus, it is possible that a beneficial effect may appear, but that it may not be identifiable as caused by the standard in the sense that alternative, plausible explanations for the observed changes may be available.

4. DATA SOURCES AND USEABILITY CRITERIA

In order to be useful, data sets must contain several key elements. These data elements must enable one to determine that a vehicle was involved in a post-crash fire and what the model year of the vehicle involved in the fire was. For police accident data, this requirement implies that one must be able to determine the model year of each vehicle involved in a crash and whether or not that vehicle was also involved in a post-crash fire. Fire department data must identify the model year of each vehicle involved in a fire and also whether the fire resulted from a crash (traffic accident) or some other cause. In addition, it must be possible to relate the post-crash car fires identified through fire department data to accident data.

Thus, the minimal data requirements are the following. For a defined accident population, using either police accident data, fire department data, or both, one must be able to determine how many vehicles of each model year were involved in post-crash fires and how many vehicles of each model year were involved in crashes.

In addition to containing the minimal data elements needed to ensure identifiability of post crash fires by model year, the data sets must be fairly large. That is, the population of accidents covered by the data source must contain enough crash fires so that the calculated fire rates by model years will be reasonably stable. Using a Poisson approximation, the standard error of a fire rate is approximately proportional to the square root of the number of fires (the numerator). Thus, in order to have standard errors of 10% of the estimated rates, one would need to be able to expect about 100 crash fires for each model year (or for each rate to be calculated). For a 20% relative error 25 crash fires should be expected, etc. Combined with the rarity of crash fires, this means that data sets from geographical areas smaller than a state are not likely to be of much practical use. Indeed, data from relatively small states will be of limited use. A post crash fire rate of between one and five fires per thousand crash-involved vehicles would produce only an expected 100-500 crash fires in a state with 100,000 crashes in a year.

In addition to the minimal data needed in order to calculate fire rates by model year (and hence by version of the FMVSS 301 standard), other data would be useful. In particular, information about the type of crash, the severity (or speed) of the crash, the make and manufacturer of the car, and any injuries would be particularly useful. Of course, these must be related to the crash fires in order to be used. In practice, these data are available and usable only in police accident files which also contain fire information.

4.1 Data Analyzed

Based on the considerations of the data elements and the population size needed several statewide data files were obtained and analyzed. Three state police accident data files contained useful fire information. These were Illinois, New York, and Washington. Two additional states had fire department data. These were Michigan and Missouri. New York also has state-wide fire department data. Fire department data from Maryland are used in conjunction with registration data. (Accident data were not received in time for the present analysis, but will be used in the final report.) In addition, a small set of data from a special highway patrol study in California are analyzed. Some limited, preliminary data from the NCSS are also analyzed.

4.2 Data Sets Found Not Useful

Police accident data from the 48 contiguous states were investigated for use in this project. The accident reporting forms were reviewed. In addition, telephone contacts with each state were made in order to investigate the availability and utility of the data. State fire marshall's offices were contacted for information about availability and applicability of fire department data. In addition the National Fire Administration's National Fire Incident Reporting System (NFIRS) was utilized.

Table 4.1 summarizes the results of this data investigation. In a number of cases police accident data have a variable labeled "fire" which turned out to be non-crash fires only. That is, fire was one of several non-crash events which could lead to an incident report in the police data file. Other state data files did not include the model year of the vehicle.

4.3 Data to be Analyzed in the Future

Some of the smaller or apparently less useful data sets were added to the project late at the request of the sponsor. These data will be reported in the final report. They include data from the state police accident files of Oklahoma, Idaho, and New Hampshire.

Data from the state of Mississippi were to have been included. These records included a variable for fire but not for model year in the computerized file. However model year was available on the hard copies. A computer search revealed only five cases of crash fires. Copies of these accident reports have been obtained, but there are too few fires in the Mississippi data for meaningful rates to be calculated.

Fire department data from the NFIRS for Oregon and Ohio have been received. Oregon's computerized accident data contains a variable for "fire" but not for model year. We have attempted to arrange to sample nard copies to estimate the crash distribution by model year and to review all accident reports for the crash fires. To date, (February), we have been unable to complete these arrangements. Preliminary indications are that crash fires may be extremely rare—on the order of a dozen. If that is the case reviewing the crash fires would not be useful. Registration data would then provide more cost-effective denominator data for car fires estimated from the fire department data. The computer record system for Ohio was changed in mid 1977. As a consequence, model year distributions of crashes may not be available. If that proves to be the case, registration would be suggested for use with Ohio fire department data also.

Analysis of the available data from NCSS will be included in the final report.

Some states may change their accident reporting forms to include information about post-crash fires in the future. Michigan instituted a new form in 1978 which includes this variable. However, the statewide data for 1978 will not be available until mid-1979. In addition, data from the first year of a new system tend to contain more errors than data from an on-going system.

Table 4.1

Status of State Fire and Accident Records

State	Police Data: Fire	Police Data: Model Year	Comments	Fire Data
Alabama . . .	No*	Yes	*Fire as primary event	No
Arizona . . .	No	Yes		No
Arkansas . . .	No	No		No
California . .	No*	Yes	*Spec. study	NFIRS/no model year
Colorado . . .	No	Yes		No
Connecticut .	No	Yes		No
Delaware . . .	No	Yes		No
Florida . . .	No*	Yes	*Fire as primary event only	No
Georgia . . .	No	No		No
Idaho	Yes*	Yes	*Code as second harmful event	No
Illinois . . .	Yes	Yes	In house	No
Indiana . . .	No*	Yes	*Fire as first event only	No
Iowa	No	Yes		No
Kansas	No	Yes		No
Kentucky . . .	No	Yes		No
Louisiana . .	No	No		No
Maine	No*	Yes	*Fire as primary event only	No
Maryland . . .	No	Yes		Yes since Jan. 1977
Massachusetts	No	No		No
Michigan . . .	No*	Yes	In house (yes beg. 1978)	Yes
Minnesota . .	No	No		Yes, since jan. 1977
Mississippi .	Yes	No	No model year (5 fires)	No
Missouri . . .	No	Yes*		Yes, since 1975
Montana . . .	No*	Yes	*First harmful event only	Yes,but no model year
Nebraska . . .	No	Yes		No
Nevada	No	No		No
New Hampshire	No*	Yes	Fire as primary event only *burn injury noted	In process—no expected date
New Jersey . .	No*	No**	**License plate #	No
New Mexico . .	No	No		No
New York . . .	Yes	Yes	In house fire coded as second event	Yes
North Carolina	No	Yes		No
North Dakota .	Yes	No*	*has license plate number	No
Ohio	No	Yes	New 7/77 pd data	Yes
Oklahoma . . .	Yes	Yes	In house	No
Oregon	Yes	No	(12 fires)	yes, since 1966
Pennsylvania .	No	Yes	only since July 1977	No
Rhode Island .	No	No		No
South Carolina	No*	Yes	*1st harmful event only	No
South Dakota .	No	No		Since Jan. 1978
Tennessee . .	No	Yes		No
Texas	No	Yes		No
Utah	No	Yes		only since Jan.1978
Vermont . . .	No	No		No
Virginia . . .	No	Yes	Changed computer at Mar. 1977	No
Washington . .	No	Yes		No
West Virginia	No	Yes		In process
Wisconsin . .	No	Yes		No
Wyoming . . .	No*	No	*primary event only	No

5. RESULTS

The results presented in this section are presented separately for each data set. Since the data sets generally consist of data from a state for one or more years, the sections are identified with the state's data. Within each subsection, the quality of the data and the results from analysis of the data from that source are discussed. Results from different data sets are somewhat different, and this should be borne in mind by the reader.

5.1 Data from the State of Illinois

5.1.1 Characteristics of the Data. The data from Illinois are police accident data. They represent accidents which occurred during calendar 1976 and the first three quarters of 1977. At the time the data were obtained, only the first three quarters of data from 1977 crashes were available. Recently the complete data for 1977 were received and will be included in the final report.

In the Illinois data, a variable is coded as "fire" or "no fire". This is a vehicle-identified variable, so it refers to the presence or absence of a crash fire in each vehicle in a multiple vehicle accident. Data from vehicle one and vehicle two were used. The vehicle numbers refer to an arbitrary number assigned in the accident report. (Single vehicle accidents have no data for vehicle two.) These were combined into a vehicle file for analysis. Thus, the rates reported in the tables in this section refer to crash fires per vehicle involved in a crash.

There are two key variables for analysis. The first is the fire variable, while the second is the model year of the vehicle. In the 1976 data, 3.3% of the accidents were missing the model year information. In the 1977 data, 3.2% of the accidents were missing model year information. In addition, 0.6% of the accidents were for model years earlier than 1960 or had unknown or "wild" codes (e.g., model year 86). Thus, the model year variable was missing in about 4% of the crashes.

The fire variable was present less often. In the 1976 data, the fire variable was unknown in 31.4% of the vehicles, while in the 1977 data, the fire variable was unknown in 22.8% of the vehicles. (These figures refer to the missing data on vehicle one). In calculating the crash fire rates, only definitely present data were used. That is, the fire rates were calculated as the number of crash fires divided by the number of crash fires plus the number of non-fires. The cases with "unknown" on the fire variable were not included. This probably biases the rates in the upward direction. That is, it is clear that most of the unknown were non-fires. In fact, it is possible that they all were non-fire crashes. If this were the case it would account for much of the difference in level in the two years' data. The average fire rate in the 1976 data is 3.53 fires per thousand vehicles in crashes, while for 1977 the average fire rate is 2.44 fires per thousand vehicles in crashes.

In considering the crash fire rates for data from Illinois, it should be borne in mind that data on the occurrence of fire is missing or unknown in 20 to 30 percent of the vehicles, depending on the year. This difference in missing data rate from 1976 to 1977 seems likely to account for much of the difference in estimated crash fire rates. While the missing data rates do not appear to be associated with the different model years, the large amount of missing data introduces a great deal of uncertainty into any conclusions from the Illinois data.

5.1.2 Crash Fire Rates. The crash fire rates are calculated excluding missing data on the variable which indicates whether or not a fire occurred. Data from both vehicle one and two were combined so that the rates reported are in terms of vehicles involved in crashes rather than in terms of accidents. Rates are expressed per thousand vehicles.

5.1.2.1 Fire Rates by Model Year Tables 5.1.1 and 5.1.2 present the crash fire rates by model year of the vehicle for crashes which occurred in 1976 and 1977 in Illinois, respectively. The last column gives the approximate standard error associated with each rate. Data for both years combined are presented in Table 5.1.3.

It should be noted that in each case, the crash fire rate for the current model year is based on fewer crashes than the rates for the immediately preceding years. This refers, for example, to the model year 1976 in the year 1976. The reason for this is that 1976 vehicles

Table 5.1.1

Illinois 1976 Fires
by Model Year

Model year	# With Fire	# Without Fire	# with Fire/ #without Fire x 1000	Approx. Std. error of rate
Missing	554	77,011	7.19	0.306
Pre 1961	19	2,405	7.90	1.812
1961 . .	8	805	9.94	3.513
1962 . .	12	2,063	5.82	1.679
1963 . .	23	3,521	6.53	1.362
1964 . .	32	6,035	5.30	0.937
1965 . .	60	10,592	5.66	0.731
1966 . .	71	14,128	5.03	0.596
1967 . .	122	18,346	6.65	0.602
1968 . .	141	24,211	5.82	0.490
1969 . .	187	29,749	6.29	0.460
1970 . .	180	30,694	5.86	0.437
1971 . .	192	33,890	5.67	0.409
1972 . .	234	42,530	5.50	0.360
1973 . .	227	48,923	4.64	0.308
1974 . .	204	46,530	4.38	0.307
1975 . .	196	40,258	4.87	0.348
1976 . .	2158	26,364	5.99	0.477
1977 . .	4	20	200.00	100.000
1978 . .	--	--	--	--
Others .	0	10	--	--

are sold throughout the year and are thus subject to less than a full year's traffic exposure. This results in the lower number of crashes. The rates presented are based on those vehicles involved in crashes. However, the smaller number of crashes should be considered. Very few Crashes involving the newest model (1977 in 1976; 1978 in 1977) were included in the file.

5.1.2.2 Fire Rates by Standard Table 3.1 summarized the fire rates by the versions of the standard for all data sources. Reference to it shows that for the two years combined, there is an estimated 5.1 crash fires per 1000 vehicles for the pre-1968 models, a rate of 4.3 per 1000 for the 1968-1975 models, a rate of 4.0 per 1000 for the 1976 models and a rate of 4.8 per 1000 for the 1977 and later models. If the

Table 5.1.2

Illinois 1977 Fires
by Model Year

Model Year	# With Fire	# Without Fire	# with Fire/ #without Fire x 1000	Approx. Std. Error
Missing	346	76,288	4.54	0.244
Pre 1961	12	1735	6.92	1.997
1961 . .	3	526	5.70	3.293
1962 . .	5	1,355	3.69	1.650
1963 . .	10	2,328	4.30	1.358
1964 . .	16	4,046	3.95	0.989
1965 . .	28	7,296	3.84	0.725
1966 . .	44	1,225	4.30	0.649
1967 . .	48	13,731	3.50	0.505
1968 . .	65	19,280	3.37	0.418
1969 . .	103	24,593	4.19	0.413
1970 . .	93	27,470	3.39	0.351
1971 . .	103	30,929	3.33	0.328
1972 . .	137	39,408	3.48	0.297
1973 . .	162	45,788	3.54	0.278
1974 . .	134	42,511	3.15	0.272
1975 . .	128	37,027	3.46	0.306
1976 . .	137	48,058	2.85	0.244
1977 . .	102	25,563	3.99	0.395
1978 . .	0	10	0	106.200
Others .	2	22	--	--

1976 and later are grouped, the combined rate is 4.0 per 1000. The associated standard errors are estimated as 0.230, 0.231, and 0.435, respectively, or, if the 1976 and later models are grouped, the associated standard error for the combined rate is 0.205.

Thus, there is some evidence that the crash fire rates are less for cars built under the later versions of the standard. There is an apparent increase (non-significant) for the fire rates associated with models built under the latest version of the standard. However, this is based on rather scanty data, and may well be an artifact. If the three versions (no standard, 1968, and 1976 and later) are considered, the crash fire rates show a steady downward progression. This amounts to a 14.6% reduction in the crash fire rate for cars built prior to the 1968

Table 5.1.3

Illinois Fires by Model Year
1976 and 1977 Data Combined

Model Year	Fires	Crashes	Rates/ 1000
1978 . .	0	10	0.0
1977 . .	124	25,583	4.847
1976 . .	295	74,422	3.964
1975 . .	324	77,285	4.192
1974 . .	338	89,041	3.796
1973 . .	389	94,711	4.107
1972 . .	371	81,938	4.528
1971 . .	295	64,819	4.551
1970 . .	273	58,164	4.694
1969 . .	290	54,342	5.337
1968 . .	206	43,491	4.737
1967 . .	170	32,077	5.300
1966 . .	115	24,353	4,722
1965 . .	88	17,888	4.919
1964 . .	48	10,081	4.761
1963 . .	33	5,849	5.642
1962 . .	17	3,418	4.973
1961 . .	11	1,331	8.264
Pre 1961	31	4,140	7.487
Missing	900	153,299	5.871

Pre 1968	5.074
1968-1975	4.333
1976	3.964
1977+	4.845

standard as compared to those built with the 1968 standard. An additional 7.4% reduction is observed with the 1976 standard. (An apparent 22% increased relative to 1976 model rates occurred with the 1977 and later models, but this is based on sparse data.)

5.1.2.3 Fire Rates by Other Factors. Tables 5.1.4 and 5.1.5 present estimated fire rates by type of accident. Again the rates are per 1000 vehicles involved in each listed crash type. In terms of the rates, the fire rate is highest in head-on collisions, followed by collisions with railroad trains, rollovers, and crashes into fixed objects. These are, of course, the most severe types of crashes. For comparison, the fire rate for non-collision cases (i.e., non-crash fires in the police data) is also presented. This rate indicates that fire was the cause of the report in about 19 per thousand of the non-crash reports filed.

Table 5.1.4

Illinois 1976 Fires
By Type of Crash

Crash Type	# With Fire	# Without Fire	# With Fire/# Without Fire x 1000 (Rate per thousand)
Overturned . .	49	3,870	12.66
Rear-end . . .	319	54,211	5.88
Head-on . . .	31	1,597	19.41
Sideswipe . .	111	27,218	4.06
Angle	111	27,207	4.08
Turning . . .	206	49,089	4.20
Parked car . .	103	27,879	3.69
Pedestrian . .	3	2,822	1.06
Railroad train	7	419	16.71
Pedal cyclist	4	2,581	1.55
Animal	6	1,504	3.99
Fixed Object .	245	23,518	10.42
Other Object .	5	842	5.94
Other non collision	108	5,718	18.89
Other	4	520	7.69

In the 1977 data, head-on crashes still have the highest rate, followed by overturns, and fixed objects. Crashes involving railroad trains are rather rare, and had the fourth highest crash fire rate in 1977.

Although head-on crashes had the highest rate of fire, they are relatively rare. Many other crash types resulted in more fires, although they were less likely to result in a fire in a given crash. Rear-end crashes produced the largest number of fires; however, the rate of fire per thousand vehicles was relatively low. This is presumably

Table 5.1.5

Illinois 1977 Fires
by Type of Crash

Crash Type	# With Fire	# Without Fire	# With Fire/# Without Fire x 1000 (rate per thousand)
Overturned . .	28	3,947	7.09
Rear-end . . .	185	55,725	3.32
Head-on . . .	27	2,138	12.63
Sideswipe . .	105	29,225	3.59
Angle	77	26,197	2.94
Turning . . .	108	47,146	2.29
Parked Car . .	66	27,133	2.43
Pedestrian . .	5	2,603	192
Railroad train	2	437	4.58
Pedalcyclist .	1	2,047	0.49
Animal	2	1,488	1.34
Fixed object .	153	23,705	6.45
Other object .	3	998	3.01
Other non collision	75	5,677	13.21
Other	2	504	3.97

due to the rear end crashes are generally less severe--i.e. happen at lower speeds--than do head-on crashes, rollovers, or single vehicle into fixed object crashes.

From the differences in fire rates by type of crash, it is evident that different distributions of crash types could either cover up differences in fire rates by model year, or show apparent differences where none really exist. That is, if distributions of crash types are different, this could cause apparent differences in crash fire rates. The data are too sparse to calculate meaningful fire rates by crash type and by model year. However, distribution of crash types by model year did not reveal any apparent large differences.

5.1.3 Modeling Crash Fire Rates. A number of different models were fit to the Illinois data to try to separate out the possible standard effects from possible effects due to aging of the cars. An "all means" model did not fit the data adequately. That is, estimating a constant fire rate within each version of the standard did not fit the data well. There was evidence that a linear effect for age was needed, at least over the middle range of ages of vehicles. In both the 1976 and 1977 data, a model with a linear effect for age of car fit the data well, with the coefficient for age being significantly different from zero.

When effects for the different versions of the standard were added to the model, however, they were all non-significantly different from zero. Thus, while there is a tendency for fire rates to be lower in newer vehicles, this can be explained by a linearly increasing fire rate increasing with the age of the vehicle somewhat better than by steps upward corresponding to the timing of different versions of the standard. In the 1977 data, the estimated standard effects, while not significantly different from zero, were in the logical direction. That is, they indicated downward shifts in addition to the general downward trend in the fire rates for the newer models. However, in the 1976 data, this was not the case. The estimates of the effects of the standard were to predict increases in the fire rates with the later versions of the standard. These were also non-significant, and emphasize that the differences from zero could result from chance fluctuations.

In the hope of reducing the fluctuations somewhat, the data from the two years were combined. The model with a linear effect for age fit well (x^2=17.4, 15 df, p=0.297). The parameters were estimated as an intercept of 3.757 fires per thousand, and a slope of 0.106 fires per thousand increase with each year's increase in age. These parameters were both significantly different from zero. Thus, a model which fits the data from Illinois well is:

$$P = 3.757 + 0.106 \text{ (Age)}$$

where P is the predicted rate per thousand vehicles, and the age of the vehicle is in years with 1977 models taken to be one year old.

The model which assumes a constant fire rate within each version of the standard did not fit well (Lack of fit x^2=25.96 with 13 df, P=0.017). This model estimates the mean fire rates to be 4.82/1000 for the current version, 3.948/1000 for 1976, 4.350/1000 for 1968 to 1975, and 5.015/1000 for the pre-1968 versions. The standard deviations associated with these rates are 4.320/1000, 2.294/1000, 0.875/1000, and 2.286/1000, respectively. The only pairwise difference which is significant is from the pre-1968 to the 1968-1975 standards, which is a reduction significant at P=0.007).

When standard effects were estimated in addition to a linear term for the age of the car, the following model was obtained.

Overall mean = 3.08 $\pm$ 0.546/1000

Slope for age = 0.15 $\pm$ 0.0399/1000

Estimate of effect with 1977 models = 1.03 $\pm$ 0.491/1000

Estimate of effect with 1976 models = 0.20 $\pm$ 0.290/1000

Estimate of effect with 1968 models = 0.36 $\pm$ 0.359/1000

Only the overall mean and the slopes are significantly different from zero. The model shows a generally decreasing trend in the fire rates with the newer models as evidenced by the significant slope for the age. This estimates that there was on the average a reduction of about 0.16 fire per thousand vehicles in crashes each year. However, the slope is somewhat too steep—that is, the average rates for the pre-68 models are less than the linear trend shows, while those for the other years are somewhat greater. All of these differences are non-significant. The reason for this appears to be that there is a definite slope only during the model years 1968-1975. Most of the data are in these years also. Thus, the slope is essentially set there and extrapolated for the earlier models and the later models.

Taking this into account, a model was fit which allowed for different linear trends in the pre-1968 data and the 1968-75 models. The estimated trend in the pre-1967 models was almost zero (not significantly different from zero and very small in absolute value) so this term was deleted and the data were modeled as a constant rate for 1976 and 1977 models years, a linear trend from 1968-1975 models, and a constant rate for the pre-1968 models.

This model seems to be the best in terms of fitting adequately and being interpretable. It fits a constant rate in 1976 and 1977, a linearly decreasing rate from 1968 to 1975, and a constant rate for the pre 1968 models. The parameters estimated for this model are:

Mean for 1976 and 1977 model years
$= 4.14 \pm 0.203/1000$

Linear trend for 1968-1975 models
$= 0.16 \pm 0.041/1000$

Intercept for linear trend
$= 3.72 \pm 0.181/1000$

Mean for pre-1968 models
$= 5.02 \pm 0.229/1000$

The chi-squared statistics for testing lack of fit for this model was 13.26 with 13 degrees of freedom, indicating a satisfactory fit.

This model can be interpreted as follows. For models prior to 1968, the first version of FMVSS 301, there is a relatively high crash fire rate. The crash fire rates decrease with newer models from 1968 to 1975. This decrease can be described by a linear trend; however, inspection of the rates shows that the model years 1968 and 1969 could easily be included with the pre-1968 models while the last two or three models in this period could be included with the 1976 and 1977 models. That is, the decrease in fire rates from about 5 per thousand to about 4 per thousand occurred over a 3 or 4 model year period somewhat after the first promulgation of FMVSS 301 and somewhat before the promulgation date of the revised versions of the standard. While this is consistent with a beneficial effect due to the standard, the data are insufficient to attribute this effect to the standard.

Figure 5.1.1 plots the observed and predicted fire rates by model year, where the predicted rates are estimated from this model. Table 5.1.6 gives the observed and predicted rates together with the estimated standard errors of the predicted rates.

Using this model, there is an estimated reduction of 0.875 fires per thousand vehicles in crashes from the pre-1968 models to the current models. This is statistically significant (x^2=8.20, p=0.004). There is also an estimate reduction of 0.32 fires per thousand vehicles in

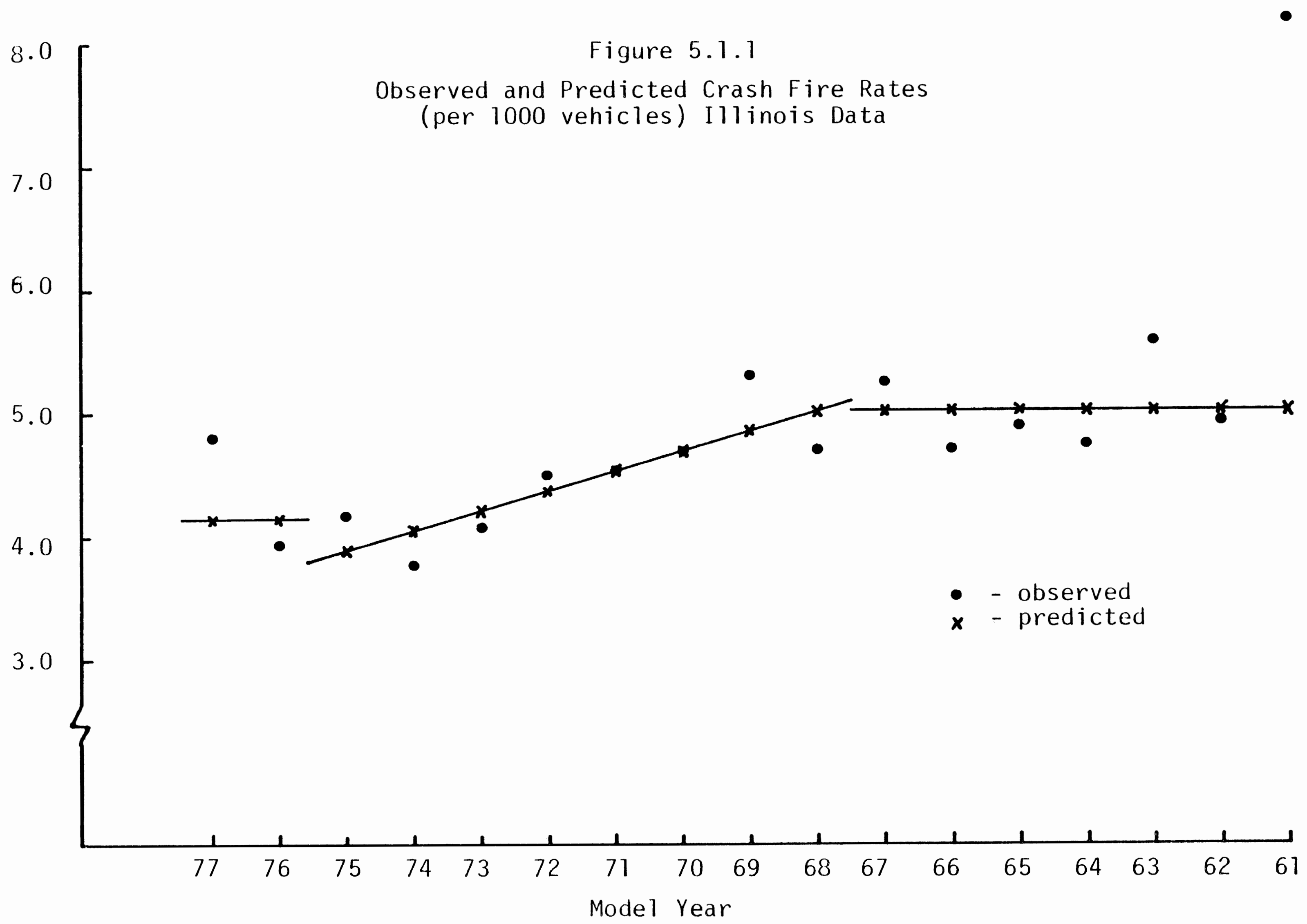


Figure 5.1.1

Observed and Predicted Crash Fire Rates (per 1000 vehicles) Illinois Data crashes from the mid-1968-1975 standard to the current. This reduction, however, is not significantly different from zero (p=0.16). The estimated reduction from pre:1968 to 198-1975 models is 0.555 fires per thousand vehicles in crashes, which is significant.

In summary, the data from Illinois show a reduction in the crash fire rates for newer vehicles. Most of the reduction seems to be associated with the model years for about 1970 to about 1974, with rates for both later models and earlier models being approximately level as functions of model year. This reduction is associated with models some years after the standard was first published, and a few years before the effective date of the current standard. Thus, while the data are consistent with a beneficial effect of the standard, the changes are not associated directly with a change in the standard. As a result, other explanations of the reduction are as valid as a result of the standard.

Table 5.1.6

Smoothed Fire Rates
Illinois Combined Data

Model Year	Observed Rate	Predicted Rate	Std. error of predicted rate
1977	4.82	4.14	0.203
1976	3.95	4.14	0.203
1975	4.17	3.88	0.146
1974	3.78	4.05	0.116
1973	4.09	4.21	0.094
1972	4.51	4.37	0.088
1971	4.53	4.54	0.099
1970	4.67	4.70	0.124
1969	5.31	4.87	0.156
1968	4.71	5.03	0.192
1967	5.27	5.02	0.229
1966	4.70	5.02	0.229
1965	4.90	5.02	0.229
1964	4.74	5.02	0.229
1963	5.61	5.02	0.229
1962	4.95	5.02	0.229
1961	8.20	5.02	0.229

5.2 Washington State Police Data

5.2.1 Nature and Characteristics of the Data. The data from the state of Washington consist of police reported accidents which occurred in 1976 and 1977. There is no question on the data form which inquires whether a fire occurred or not. Instead, there are variables which indicate occurrences subsequent to the initial crash. One such possible occurrence is a post-crash fire. Up to three post crash events are recorded. A fire could be noted in any one of three responses. Data for this variable come from the narrative of the police report. At the state level, the narrative of each report is read and used to code values for these crash sequelae. As a consequence, in order for a fire to be reported in the Washington data, it must have been noted in the narrative of the police accident report.

Thus, presumably the fires reported in the Washington data are those which involved the entire car or which resulted in additional damage or injury. However, many crash fires may have been missed. Probably all of the car fires reported are of the "spectacular" type which involve the entire vehicle. Most such fires are probably reported. It seems likely that many of the smaller, easily extinguished fires would not be mentioned in the narrative and would not appear in the data. This would certainly be true if the fire was extinguished before the police arrived.

5.2.2 Crash Fire Rates. Tables 5.2.1 presents the fire rates per thousand vehicles for the 1976 and 1977 data. The rates for the combined data are presented in Table 5.2.2, which also presents the estimated standard errors. The rates are presented for each model year of the vehicle.

In general, the rates are quite small—approximately a tenth of the rates in the Illinois data. This low level of the rates is likely due to underreporting. That is, the method of reporting the data might not include many car fires, although when a fire is noted, it is probably correct. There appears to be relatively little difference in the rates by standard. The general impression is that the rates show a considerable amount of variation from year to year, but no very outstanding trend. The post 1968 rates are somewhat lower than the pre

Table 5.2.1

Washington Crash Fire Rates

	1976			1977		
Model Year	Fires	Crashes	Rate/ 10,000	Fires	Crashes	Rate/ 10,000
1978				1	399	25.1
1977	1	325	15.4	6	8449	7.1
1976	3	8228	3.7	4	11839	3.4
1975	1	9319	1.1	3	8994	3.3
1974	6	12638	4.8	9	12092	7.4
1973	2	12754	1.5	6	13420	4.5
1972	4	14781	2.7	4	13988	2.9
1971	2	12087	1.7	3	11523	2.6
1970	1	11936	0.8	9	11478	7.8
1969	2	13768	1.5	6	12718	4.7
1968	4	13121	3.1	4	11721	3.4
1967	2	11490	1.7	6	10211	5.9
1966	5	10718	4.7	3	8760	3.4
1965	2	9513	2.1	3	7759	3.9
1964	4	6786	5.9	2	5289	3.8
1963	3	4844	6.2	2	3684	5.4
1962	3	3042	9.9	1	2264	4.4
1961	1	1545	6.5	1	1178	4.3

Rate by standard	1976	1977
Pre 1968	4.2	4.6
1968-75	2.2	4.6
1976	3.7	3.4
1977-	15.4	7.9

1968 models' rates. Detailed comparisons are made in the analysis section which follows.

One possible explanation for the slight differences in rates by different versions of the standard is a possible confounding with other variables. Table 5.2.3 presents the average fire rates grouped by standard and by the posted speed limit of the road where the crash occurred. No fires occurred where the posted speed was 15 mph or less. One can note an increase in the fire rates with the posted speed limit--presumably this corresponds to higher speeds for the crashes. In addition, there is some indication that older vehicles had a greater

Table 5.2.2

Washington Crash Fires
1976 and 1977 crashes combined

Model Year	Fires	Crashes	Rate/1000
1978	1	399	2.521
1977	7	8,774	0.798
1976	7	20,067	0.349
1975	4	18,313	0.218
1974	15	24,730	0.607
1973	8	27,174	0.294
1972	8	28,769	0.278
1971	5	23,610	0.212
1970	10	23,414	0.427
1969	8	26,486	0.302
1968	8	24,842	0.322
1967	8	21,701	0.369
1966	8	19,478	0.411
1965	5	17,272	0.289
1964	6	12,075	0.497
1963	5	8,528	0.586
1962	4	5,306	0.754
1961	2	2,723	0.734

pre 1968	0.4363
1968-1975	0.3345
1976	0.3488
1977	0.8721

proportion of their crashes where posted speeds were lower. Pre-1968 models had 82.5% of their crashes where the posted speed was 45 mph or less. Models from 1968-1975 had 80.0% of their crashes on such roads, while models later than 1976 had only 77.4% of their crashes on such roads.

Table 5.2.4 presents the rates by standard and posted speed for the combined (1976 and 1977) crash data. There is a definite trend for the crash fire rates to increase with the higher posted speeds. In all speeds, the 1968-1975 models show a lower fire rate than the pre-1968 models. In the 16-30 speed group, the 1976 and later models have a still lower rate. However, for posted speeds over 30 mph, the 1976 and later models have higher rates than the other two groups. It should be

Table 5.2.3

Fire Rates by Model Year and Posted Speed
Fires/10,000 Crashes
Washington Data

	1976			1977		
Speed	1961-1967	1968-1975	1976+	1961-1967	1968-1975	1976+
1-15	0.0	0.0	0.0	0.0	0.0	0.0
16-30	3.13	1.66	0.0	3.74	3.39	1.65
31-45	7.72	3.84	0.0	3.65	5.69	9.77
46+ .	15.02	5.71	16.81	17.23	1.71	2.02

Note: These rates do not correspond exactly to those in Table 5.2.1 because of missing data on posted speeds.

noted that the amount of data for the 1976 and later models is rather small. Thus, the rates estimated for the cars built after this version of the standard was promulgated are subject to large errors. The table presents three figures for each combination of posted speed and standard version. The first is the ratio of crash fires to crashes (in terms of vehicles). The second is the rate per thousand vehicles, and the third is an estimate of the standard error of the crash fire rate. For the case of zero observed rates, the estimated standard error was obtained by calculating a 95% confidence interval for the fire rate, then using the midpoint of that interval as the rate in a Poisson distribution to estimate the standard error of the fire rate. For example, in the pre-1978 models no fires in 261 crashes were observed at posted speeds of less than 15 mph. The upper 95% confidence limit is found from the equation

$$261 \ln(1-P) = \ln(0.95),$$

where ln stands for the natural logarithm. From this, P is found to be 0.1964/1000. This is the upper limit of the 95% confidence interval. The midpoint is 0.0982/1000. Multiplying this by 261, taking the square root, and dividing by 0.261 gives 0.6134/1000 as the estimated standard error.

Table 5.2.4

Crash Fire Rate by Standard and Posted Speed
Washington Data

Posted Speed	Standard Pre-1968	Standard 1968-1975	Standard 1976+	All Stds.
0-15 mph				
Fires/Crashes	0/261	0/499	0/82	0/842
Rate(per 1000)	0.00	0.00	0.00	0.00
Std.Error	0.613	0.320	1.952	0.269
16-30 mph				
Fires/Crashes	10/29,326	15/59,689	1/8,427	26/97,442
Rate(per 1000)	0.341	0.251	0.119	0.267
Std.Error	0.108	0.065	0.119	0.053
31-45 mph				
Fires/Crashes	10/17,275	18/37,553	4/5,686	32/60,514
Rate(per 1000)	0.579	0.479	0.704	0.529
Std.Error	0.183	0.113	0.352	0.093
45+ mph				
Fires/Crashes	16/9,968	27/24,531	8/3,885	51/38,384
Rate(per 1000)	1.605	1.101	2.059	1.329
Std.Error	0.401	0.212	0.728	0.186
All speeds				
Fires/Crashes	36/56,569	60/121/773	13/17,998	
Rate(per 1000)	0.636	0.493	0.722	
Std.Error	0.106	0.064	0.200	

The crashes which were followed by fires were more severe than those without fire. They also resulted in a higher risk of fatality. In 1976, 9 persons were killed in the 47 vehicles which were involved in post-crash fires, for a rate of 0.192 deaths per fire. In all, 517 persons were killed in the 165,872 vehicles in crashes for a rate of 3.1 fatalities per thousand vehicles in crashes. In 1977 the corresponding figures were 15 deaths in the 76 post-crash fire vehicles for a rate of 0.197 fatalities per fire, while 590 deaths occurred in the 162,312 vehicles in crashes for a rate of 0.0036. In 1976 reported crash fire rate was 0.283 per thousand vehicles, while in 1977 it was 0.468 per thousand. The combined data estimate a rate of 0.195 deaths per post crash fire reported, while in all crashes the fatality rate is only 0.00337 deaths per crash (or 3.37 deaths per thousand crashes). This indicates that the fires reported in the Washington data were much more evere crashes than the average. It is unlikely that the increased risk of fatality is due solely to the presence of fire in these crashes. Further, as noted before, the reporting system would tend to only report the conflagration type of fires, which would be the more serious.

Table 5.2.5 presents fire rates by type of crash for the Washington data, for the 1976, 1977, and combined data. Again, the frequencies are presented, followed by the rate per thousand vehicles and the standard error estimated for that rate, again in terms of a per thousand vehicle rate. Rollovers have the highest rate, followed by single vehicle into fixed object crashes. Two car crashes have considerably lower fire rates, while the rear-end collisions have the lowest rate reported, although it is not much different from the other two-car crash fire rates.

In these data, single vehicle crashes have much higher fire rates than do multiple vehicle crashes. The observed rate for single vehicle crashes is over 15 times that for multiple vehicle crashes. The single vehicle crashes tend to be more severe than multiple vehicle crashes. The fixed object struck type of crash would be approximated by the frontal barrier test specified in the standard. Rollovers are very difficult to approximate in a crash testing situation. The low rate for the rear end impacts may raise the question of the advantage of the rear impact part of the standard. However, it should be remembered that these fires represent the more severe fires. Further, the single vehicle into fixed object type of crash is typically preceded by a loss of control. As a result, the vehicle may be skidding at the time of the impact and could hit the fixed object with any portion of the vehicle, possibly the rear.

5.2.3 Analysis of Rates A number of models were fit to the Washington data. In general all models showed a good fit to the data. However, in general only the overall mean effect was significant. That

Table 5.2.5

Fire Rates by Type of Crash (Washington)

Type of Crash	1976	1977	Combined
Fixed object struck			
Fires/Crashes	22/17,407	35/17,126	57/34,533
Rate(per 1000)	1.26	2.04	1.65
Std.Error	0.269	0.345	0.219
Rollover			
Fires/Crashes	8/2,723	10/3,032	18/5,755
Rate(per 1000)	2.94	3.30	3.13
Std.Error	1.039	1.043	0.737
Two Cars(one at angle)			
Fires/Crashes	4/36,262	6/36,588	10/72,850
Rate(per 1000)	0.11	0.16	0.14
Std.Error	0.055	0.067	0.043
Rear End	1/30,197	5/29,422	6/59,619
Rate(per 1000)	0.033	0.17	0.10
Std.Error	0.033	0.076	0.041

is, no significant differences were found among the rates for different versions of the standard, and no significant age effect was found. Thus, the data can be adequately summarized by a single mean. The sampling variability expected with data such as these is large enough to account for the observed variation about this mean. Inclusion of separate means in the versions of the standard does not reduce this variability significantly; neither does a linear trend in age.

The model which fits a separate mean in the model years corresponding to the different versions of the standard gives the means listed by standard at the bottom of Tables 5.2.1 (separately by year of crash) and 5.2.2 (for the data combined). The differences in these mean crash fire rates were not significant. Thus, except for random fluctuations, the data can be viewed as a constant fire rate by model year of 0.20 fires per thousand vehicles in 1976 and 0.42 crash fires per thousand vehicles in 1977.

The model with only the average rate is not interesting. The more complex model was fit which estimated different means in the different versions of the standard and includes age effects fit separately in the 1968-75 models and the 1967 and earlier models. While this model fit adequately (e.g., $X^2 = 8.70$, P=.79 for lack of fit in 1977 data, better in 1976), the age coefficients were not significantly different from zero, and none of the differences among the means corresponding to different standards was significantly different from zero. In the 1976 data, the age effect in the pre-1967 models approached significance (P=0.085), and also in the 1976 data, the difference between the means for the pre-1967 models and the mean for the 1976 and later models approached significance (P=0.084). However, this latter difference would indicate that the newer models had a higher fire rate. These questionable parameters were quite different in the 1977 data where they did not approach significance. The difference in the pre-67 and post-75 fire rates was in the opposite direction in 1977 data. As a result, no significant differences were observed.

Since no age effect was found, but some indication of newer cars having crashes at higher posted speeds, the data in Table 5.2.4 were analyzed to determine whether this difference was covering up an effect of the standard. Inspection of the rates in Table 5.2.4 shows that there was a strong linear trend for the fire rates to increase with the posted speed. Within the speeds from 16 to 30 mph, there is a decreasing fire rate with each version of the standard. In the higher speeds, the 1968-1975 models show lower rates than those for which no standard was in effect, but the latest version has somewhat high fire rates. Overall, there is a significant difference in the fire rates for different posted speeds, and the fire rates for some version of the standard (i.e. since 1968) are significantly lower than for no version of the standard.

As a general conclusion from the Washington data, there is some evidence that the first version of the standard reduced crash fire rates somewhat; however, there is no indication that the later, more stringent standard had any additional effect. The data are quite sparse, particularly for cars built after the effective date of the strengthened standard. This has resulted in small differences and large estimated standard errors, so few significant effects were found. One of the difficulties is the under-reporting of the minor crash fires. On the other hand, the type of crash fire reported in the Washington data is the type it is most important to prevent--the large, spectacular fire which engulfs the entire vehicle. The small, almost inconsequential fires are not reported in these data--except for their potential to get larger, they do not have very serious consequences. Little effect on the reduction of these large fires was found. However, with the limited size of the data set, reductions would have to have been dramatic to appear. Figure 5.2.1 plots the observed rates by model year.

5.3 New York Data

5.3.1 Police Data. Data from the state of New York reported in this Section consist of police accident data.

The police accident data from New York include a "second adverse event" variable. This variable includes fire as one of its codes. In the instructions, officers are told to code this variable as fire if a fire is present. That is, if a crash fire occurs, this is to be reported as the second adverse event no matter how many events occur. Thus, if instructions are followed, multiple impact crashes followed by fire would be reported as crash fires.

The data from 1976 crashes and from 1977 crashes are reported in Tables 5.3.1 and 5.3.2, respectively. In each table, the number of fires, number of crashes and fire rate is reported separately for each model year from 1961 models to the current. These rates are rather low. The overall rate for 1976 is 0.296/1000 crashes and for 1977 it is 0.278/1000 crashes, giving a combined rate of 0.288/1000 crashes. This is similar to the rate reported from Washington state, and is approximately an order of magnitude lower than that reported for Illinois. (It should be recalled, however, that in calculating the Illinois rate, crashes with the fire variable missing were excluded rather than counted as non-fire. Had they been counted as non-fires, the rates would have been reduced by about one-third).

Fire rates for the 1976 and 1977 crashes combined are reported in

Figure 5.2.1

Observed and Predicted Crash Fire Rates
(per 1000 vehicles) Washington Data

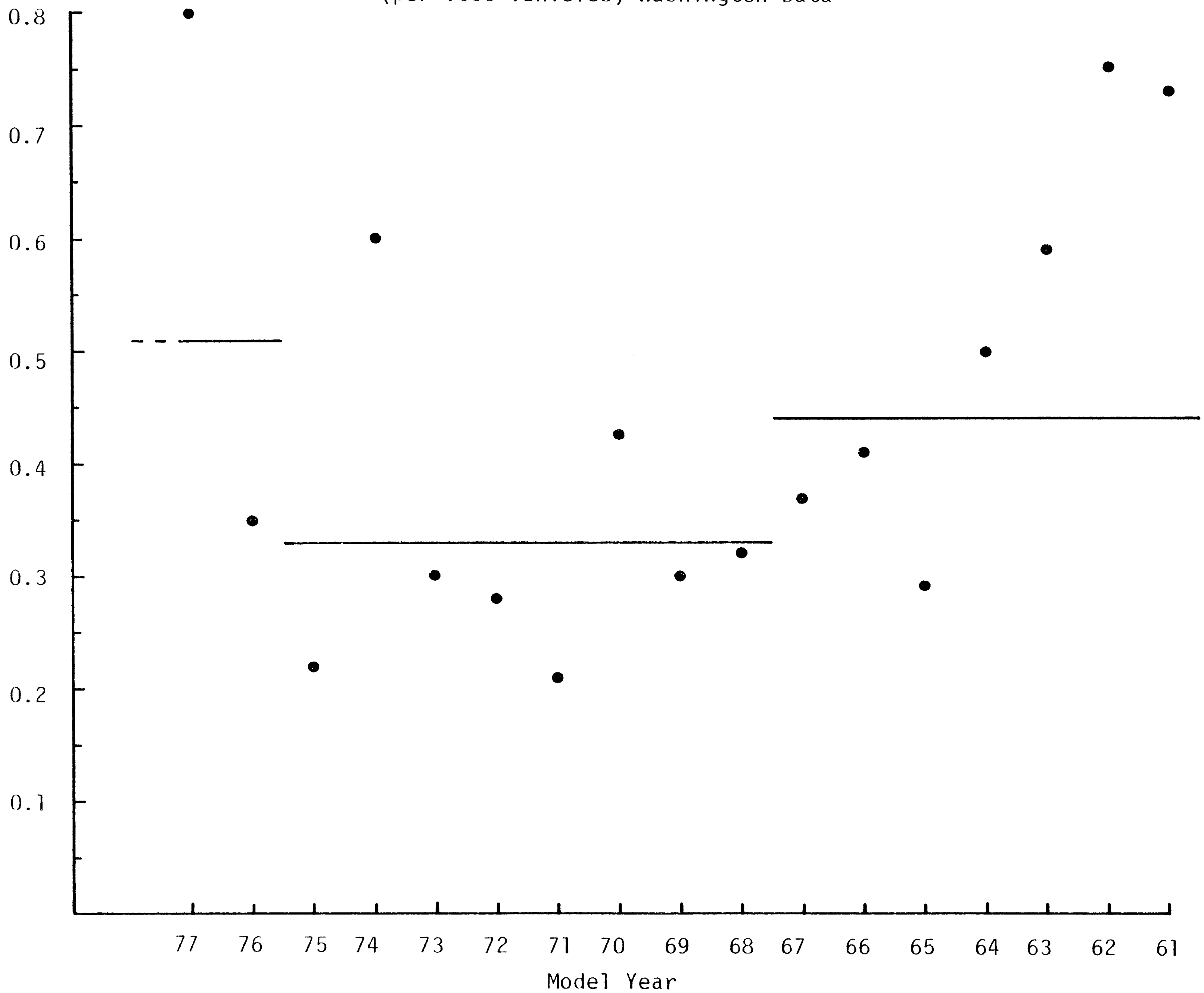


Table 5.3.1

New York, 1976

Model Year	No. of Fires	No. of Crashes	Fire rate per 10,000 crashes
1978	--	--	--
1977	0	1,498	0
1976	16	45,198	3.54
1975	12	57,434	2.09
1974	19	69,036	2.75
1973	16	77,026	2.08
1972	16	67,929	2.36
1971	29	60,334	4.81
1970	22	57,581	3.82
1969	13	51,425	2.53
1968	14	42,798	3.27
1967	6	28,313	2.12
1966	6	21,587	2.78
1965	6	15,475	3.88
1964	2	8,248	2.42
1963	4	4,443	9.01
1962	0	2,124	0
1961	0	932	0

Source: New York State Department of Motor Vehicles

Table 5.3.3. Standard errors for those rates by model years are also estimated and reported in this table. Generally, the rates show little trend with age (or model year). The average rate for the current version of the standard is 0.21 fires per 1000 crashes; for the 1976 models, the rate was 0.33 fires per thousand crashes; for the 1968-1975 models, the rate was 0.28/1000; and for the pre-1968 models, the rate was 0.35/1000. If the current version is combined, the 1976 and later models show an average crash fire rate of 0.29 per thousand. Thus considering the four standards, there is a drop in the fire rate of from about 0.35/1000 to about 0.28/1000 corresponding to models built before the 1968 standard as compared to those since. Little or no change has been observed with the later versions of the standard.

When models were fit to the data for each year separately, no adequate fits were found. The small number of fires and the relatively

Table 5.3.2

New York, 1977

Model Year	No. of Fires	No. of Crashes	Fire rate per 10,000 Crashes
1978	0	1,231	0
1977	9	40,030	2.25
1976	19	61,578	3.09
1975	9	50,154	1.79
1974	16	60,759	2.63
1973	20	69,119	2.89
1972	14	61,487	2.28
1971	11	53,486	2.06
1970	15	48,994	3.06
1969	14	41,671	3.36
1968	9	32,719	2.75
1967	6	20,672	2.90
1966	11	15,490	7.10
1965	3	10,556	2.84
1964	3	5,465	5.49
1963	1	2,961	3.38
1962	1	1,376	7.27
1961	0	710	0

Source: New York State Department of Motor Vehicles

large variation among model years precluded describing the data adequately with a model with only a few parameters. Neither the all means model, nor the model which included a linear effect in age fit adequately, nor did more complex models with an aging effect and separate effects estimated for the different versions of the standard.

When the data were pooled for the two years, much of the variability was smoothed out. Considering the combined data,the all means model fit adequately (x^2=12.87 with14 df, P=0.536, for lack of fit). However, none of the differences among the fire rates were significant. No pair of the rates differed significantly, nor did the 1976 and later rate differ from the earlier rates, nor did the average rate for 1968 and later models differ from the pre-1968 model rate significantly.

If a model with a linear effect for age is considered, it, too fits adequately. However, the age effect is barely significant (x^2=4.06, 1 df, P=0.0438). Thus,there are few differences if any in the combined data which cannot reasonably be ascribed to random fluctuations.

Table 5.3.3

New York Fires by Model Year
1976 and 1977 data combined

Model Year	Fires	Crashes	Rate/1000	Std.Dev.
1978	0	1,231	0.000	0.130
1977	9	41,528	0.217	0.072
1976	35	106,776	0.328	0.055
1975	21	107,588	0.195	0.043
1974	35	129,795	0.270	0.046
1973	36	146,145	0.246	0.041
1972	30	129,416	0.232	0.042
1971	40	113,820	0.351	0.056
1970	37	106,575	0.347	0.057
1969	27	93,096	0.290	0.056
1968	23	75,517	0.305	0.064
1967	12	48,985	0.245	0.071
1966	17	37,077	0.459	0.111
1965	9	26,031	0.346	0.115
1964	5	13,713	0.365	0.163
1963	5	7,404	0.675	0.302
1962	1	3,500	0.286	0.286
1961	0	1,642	0.000	0.097

pre 1968	0.374	$\pm$ 0.051
1968-1975	0.276	$\pm$ 0.018
1976	0.328	$\pm$ 0.055
1977	0.210	$\pm$ 0.070

If the model with age (linear) and step function effects at the time of the standard changed is used, age is barely significant (P is between 0.01 and 0.05). Above the general decreasing trend with newer models (or increasing trend with age), the 1977 and later models show a drop compared to what the linear effect would predict. The 1976 models were higher than predicted, as were the 1968-1975 models. However, none of these differences were significantly different from zero even at the 10% level. Further, none of the differences in effects estimated among the different versions of the standard was significantly different from zero. Figure 5.3.1 plots the rates by model year.

In summary, the New York police data are consistent with a constant fire rate for all model years. There is slight evidence for somewhat lower rates with newer models and with later versions of the standard, but nothing reached statistical significance at the 10% level.

5.3.2 New York Fire Department Data. In addition to the fire information in the police accident data in New York, data are available from the NFIRS for the state of New York. These data are from the first three quarters of 1977 and report fire department records. Again, the cases reported are all the car fires with code 71 (collision, etc.) for the source of ignition. Table 5.3.4 presents the number of fires by model year as well as the fires to crashes ratio. The crashes are the same as reported in Table 5.3.2. It should be noted that over 30% of the car fires had no reported model year and so become missing data. Any conclusions could obviously be affected by this amount of missing data.

The average ratios by version of the standard are 0.749, 0.617, 1.443, and 2.332 per thousand crashes from the current version to the pre-standard models. The estimated standard errors associated with these are 0.136, 0.100, 0.0586, and 0.244, respectively. These average ratios are significantly different from each other, but there is still significantly more variation among ratios for model years within standards than could be expected from random variation. That is, different mean effects corresponding to different versions of the standard are not an adequate description of the data.

If the data are considered slightly differently, the average fire/crash ratio is 1.562/1000. The models corresponding to the current (1977 and later) version of the standard show a reduction of 0.814/1000; the 1976 models show a reduction of 0.946/1000, the 1968 to 1975 models show a reduction from this mean of the 1976 and 1977 versions of the standard are significant--that is, these models (1976 and 1977) had significantly fewer fires than average, while the older (pre-1968) models had significantly more than average. The 1968-1975 models did not differ significantly from the average.

Figure 5.3.1

Observed and Predicted Crash Fire Rates (per 1000 vehicles) New York Police Data

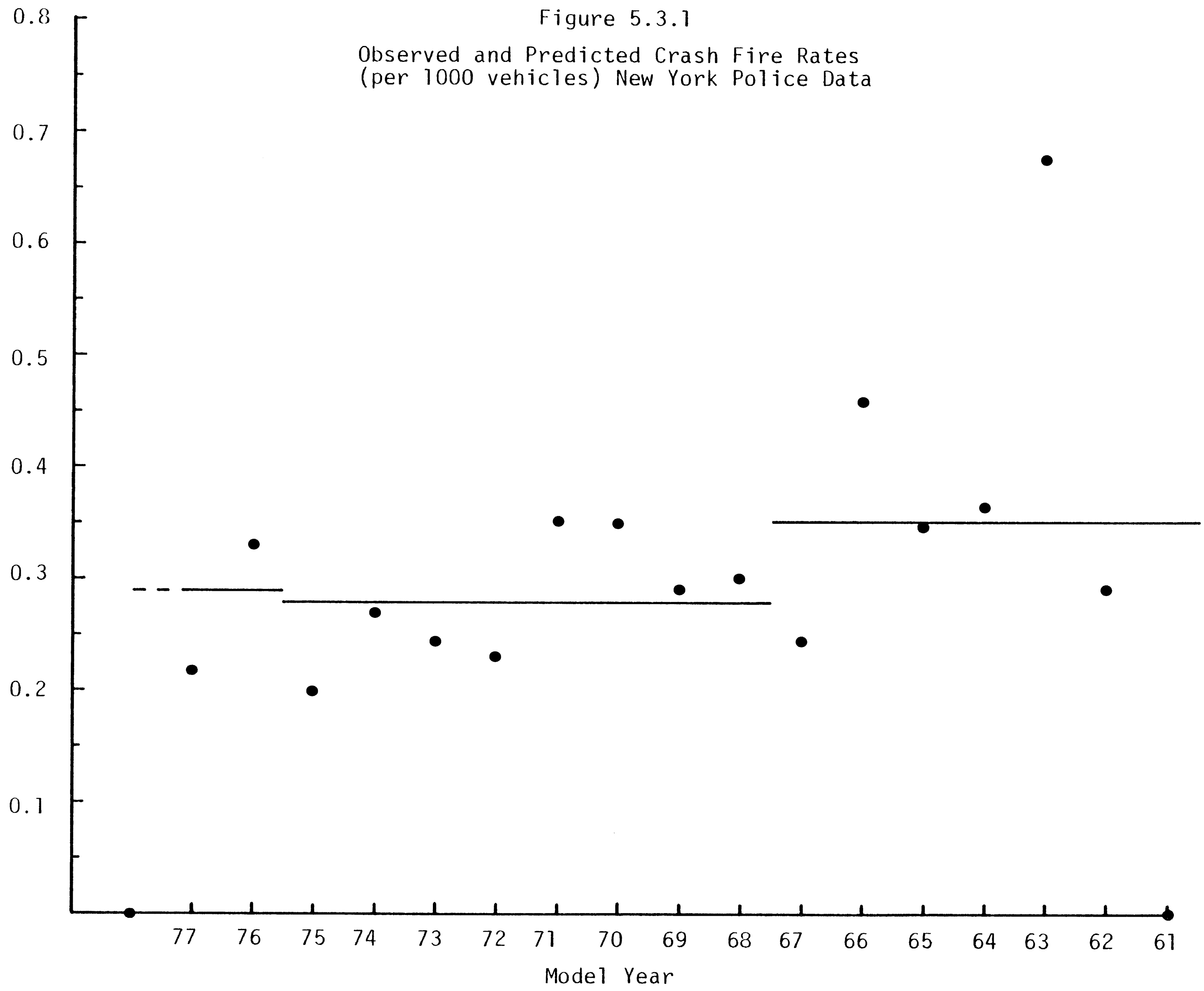


Table 5.3.4

New York Fires (Fire Department Data)
Crash Ratios 1977

Model Year	Fires (FD)	Crashes (PD)	Rate (per 1000)	Std. Dev.
1977	30	40,030	0.749	0.137
1976	38	61,578	0.617	0.100
1975	56	50,154	1.117	0.149
1974	55	60,759	0.905	0.122
1973	93	69,119	1.346	0.140
1972	86	61,487	1.399	0.151
1971	101	53,486	1.888	0.188
1970	100	48,994	2.041	0.204
1969	112	41,671	2.688	0.254
1968	74	32,719	2.262	0.263
1967	74	20,672	3.579	0.416
1966	48	15,490	3.099	0.447
1965	36	10,556	3.410	0.568
1964	22	5,465	4.026	0.858
1963	11	2,961	3.715	1.120
1962	5	1,376	3.634	1.625
1961	3	710	4.225	2.440

pre 68	3.477
68-75	1.618
76	0.617
77	0.749

A caution to be kept in mind is that the 1977 models were not subject to the entire year's exposure for fires, but were represented by a year's crashes. Thus, the ratio for 1977 is somewhat questionable.

As noted, models fitting mean effects only were not adequate. There was a significant age effect in the data—at least, a linear term increasing with the age of the vehicles improved the fit significantly. The model

$$R = u + B_1(\text{age}) + B_2(1977) + B_3(1976) + B_4(1968),$$

where R is the ratio, u is a mean, and the age is treated as a linear term, while the standards—denoted by the first year of the model affected—are taken as changes in level, fit the data well. (Chi-square for error was 12.26 with 12 df, P=0.42). This model showed a significant effect for the linear term in age. The parameters were estimated as:

$u = 0.643 \pm 0.432/1000$

$B_1 = 0.227 \pm 0.029/1000$

$B_2 = 0.360 \pm 0.172/1000$

$B_3 = -0.024 \pm 0.154/1000$

$B_4 = -0.458 \pm 0.319/1000$

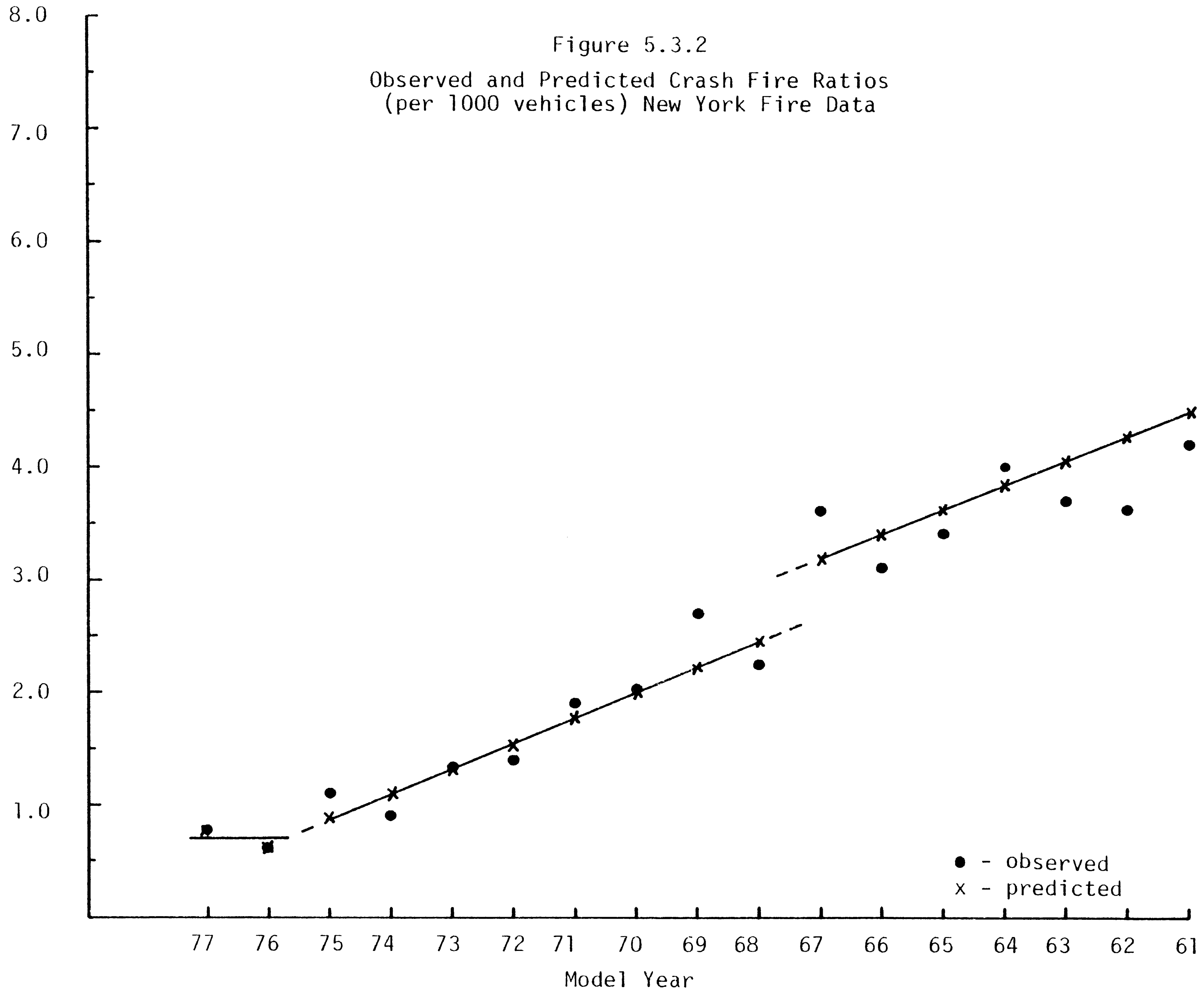
where the parameters and their estimated standard deviations are both in terms of thousands of crashes.

Viewed collectively, there is some evidence that the effects of the various versions of the standard are significant. The X^2 for testing this was 8.43 with 3 df, giving a P=0.0379. Thus, these data indicate differences among models subject to different versions of the standard (including no standard) which are significant at the 5% level even after a linear effect for age has been removed. These are somewhat difficult to interpret, however. The parameters estimated indicate that the models from 1968-1975 showed the largest reduction from what would be expected from age alone. The 1976 showed a very small reduction and the 1977 models showed a small increase. None of these individual parameters reaches statistical significance at the 5% level, however. There is an indication that the 1968-1975 models had a difference from the average level of the other years which was nearly significant. However, in testing several of these differences, one must remember that they are not independent and that the significance levels will be affected by the multiple tests. In addition, the questions regarding the 1977 data add caution to any conclusions.

In summary, the fire department data indicate that there were differences in the fire data to crash ratios for models subject to different versions of FMVSS 301. The newer models have lower fire to crash ratios. However, much of the differences can be explained by a linear effect increasing with the age of the car, although there is some indication that significant differences among the versions of the standard persist after adjustment for age. After adjusting for age, the

Figure 5.3.2

Observed and Predicted Crash Fire Ratios
(per 1000 vehicles) New York Fire Data



indication is that the 1968-1975 models had the best fire to crash rates, however, this is not statistically significantly different from the others. In addition, the partial data for 1977 models, the sparsity of data for later models, and the large amount of missing data (30+% on the model year in the fire department data) preclude any firm conclusions. Figure 5.3.2 plots the ratios from the New York Fire Department data.

5.4 Data from Michigan

In Michigan passenger car fires are identified through the statewide fire department reporting system, while crashes are found through the police accident reporting system. Beginning in 1978, police accident reports also have a check box to report whether fire was involved in each vehicle. Also included on the new reports is a variable to record whether fuel spillage occurred. However, prior to 1978—the data reported here—no information about fire in crashes was available from the computerized accident report. (If a vehicle burned following a crash, this might be noted in the narrative of the police report, but the information was not computerized and so would not be accessible without manually reading all of the accident reports.)

From the passenger car fires reported in the fire department data, a combination of code values for various variables was used to try to identify which fires resulted from crashes. The development of this crash surrogate was discussed in Section 3.2.2. Although the crash surrogate developed there has serious limitations, it appears to be the best variable available, and was used as the numerator for calculating the rates. Although it appears that it selects about the right number of cases, about half of the cases selected may not be crashes. Thus, one must remember that it is only a surrogate. The fires it selects are those involving passenger cars, which occurred on a highway or public street, etc. The complete list of variables is presented in Appendix A.

Tables 5.4.1 and 5.4.2 present the fires, crashes and crash-surrogate fire rates for the data from Michigan from 1976 and 1977 respectively. Table 5.4.3 presents these data combined. Rates are presented by model year of the car involved.

Table 5.4.1

Crash Surrogate Fire Rates
Michigan 1976

Model Year	Fire	Crashes	Fire rate per 10,000 Crashes
1978	--	--	--
1977	--	--	--
1976	3	52,500	0.5714
1975	8	56,100	1.4260
1974	16	68,540	2.3344
1973	22	77,180	2.8505
1972	19	68,400	2.7778
1971	16	53,960	2.9652
1970	21	46,000	4.5652
1969	21	47,110	4.4577
1968	18	37,780	4.7644
1967	17	26,140	6.5034
1966	14	19,240	7.2765
1965	10	13,060	7.6570
1964	4	7,100	5.6338
1963	2	3,140	6.3694
1962	3	1,880	15.9574
1961	1	860	11.6279

Inspection of the rates presented in Tables 5.4.1 - 5.4.3 shows that there is a tendency for these to be lower with the newer models. If one calculates the rates by version of the standard for the combined data, one obtains rates of 0.148, 0.093, 0.368, and 0.817 per thousand crashes for the versions of the standard running from current to no standard (pre-1968 models). The estimated standard errors associated with these are 0.0558, 0.0293, 0.0201, and 0.0822 per thousand crashes,respectively. These differences in rates are consistent with a beneficial effect of the various versions of the standard.

Linear models were fit to the rates for each year of data separately. The results differed. The data from1976 showed relatively little variability. A model with a linear effect for age and with three standard effects fit quite well (x^2=3.08, 12 df, p=.99 for lack of fit). However, the only coefficient which was significantly different from

Table 5.4.2

Crash Surrogate Fire Rate
Michigan 1977

Model Year	Fires	Crashes	Fire rate per 10,000 Crashes
1978	--	--	—
1977	7	47,374	1.4776
1976	7	55,303	1.2658
1975	16	42,020	3.8077
1974	14	52,259	2.6790
1973	12	60,775	1.9745
1972	19	54,645	3.4770
1971	27	43,956	6.1425
1970	28	37,588	7.4492
1969	24	33,271	7.2135
1968	15	25,740	5.7826
1967	14	16.346	8.5648
1966	5	10,901	4.5867
1965	15	7,379	20.3280
1964	4	3,353	11.9296
1963	1	1,874	5.3362
1962	1	945	10.5820
1961	1	364	27.4725

zero was that for age. A model with only a linear effect for age also fit the data adequately. Thus, the 1976 data are best explained by a linear increase in the fire rate with the age of the vehicle. Although this does not rule out an effect of the standard, such an effect was not noticeable over a linear effect of increasing fire rates with increasing age of the vehicle (decreasing fire rates with newer model years). The estimated parameters for the later versions of the standard were negative, indicating a reduction, but did not reach statistical significance. The estimated parameters for the model:

$$P = u + B_1(\text{age}) + B_2(\text{1976 and later}) + B_3(\text{1968–1975}),$$

where:

$$u = 0.175/1000 \pm 0.194/1000$$

$$B_1 = 0.046/1000 \pm 0.0117/1000 \text{ per year}$$

Table 5.4.3

Fires by Model Year
1976 and 1977 Combined

Model Year	Fires	Crashes	Rate/ 1000
1978 . .	--	--	--
1977 . .	7	47,374	0.148
1976 . .	10	107,803	0.093
1975 . .	24	98,120	0.245
1974 . .	30	120,799	0.248
1973 . .	34	137,955	0.275
1972 . .	38	123,045	0.309
1971 . .	43	97,916	0.439
1970 . .	49	83,588	0.586
1969 . .	45	80,381	0.560
1968 . .	33	63,520	0.520
1967 . .	31	42,486	0.730
1966 . .	19	30,141	0.630
1965 . .	25	20,439	1.223
1964 . .	8	10,453	0.765
1963 . .	3	5,014	0.598
1962 . .	4	2,825	1.416
1961 . .	2	1,224	1.634
pre 1968	92	112,582	0.8172
1968-1975	296	805,324	0.3676
1976 . .	10	107,803	0.0928
1977 . .	7	47,321	0.1479

$B_2 = -0.059/1000 \pm 0.057/1000$

$B_3 = -0.105/1000 \pm 0.129/1000$

where the numbers following the "$\pm$" are the estimated standard errors of the parameter.

The data from 1977 showed more variation of the crash-surrogate fire rates by model year. None of the models fit the data adequately (the best had a X^2=23.79 with 12 df, P=0.022 for lack of fit). This indicates that either some parameter has been omitted from the model of that the data are more variable than would be predicated from the binomial error structure. No systematic variation could be deduced, although powers of age were tried as well as different age effects within standard versions. Even within the limitations of the fit of the model, it was clear that there is a significant effect of age—fire rates increasing for older cars. Further, it was evident that above a linear age effect, the estimated effects of the standard were not significant. (The estimate of the effect of the 1968 version was a reduction of 0.52/100 while that of the 1976 version was an increase of 0.021/1000, but neither approached statistical significance).

In the hope of smoothing the variability of the rates, the two years data were combined, as in Table 5.4.3. The model which estimated a different mean in each version of the standard did not fit adequately (X^2=40.27 13 df), indicating that there was substantial variability in the rates within model year corresponding to each version of the standard. In view of the strong age effect observed in each year's data, this was not surprising. The model did indicate that there was not sufficient evidence to conclude that the mean for the 1977 models was significantly different (higher) than for the 1976 models. However, the mean rate for the 1976 and 1977 models was significantly lower than for the 1968-1975 models or for the pre-1968 models.

The model with a linear effect for age, an overall mean, and step functions for the effectiveness of each version of the standard fit the combined data well. (X^2=11.84, 12 df, P=0.459). The model is:

$$P = u + B_1(\text{age}) + B_2(301\text{-}77) + B_3(301\text{-}76) + B_4(301\text{-}68).$$

The rate P is per thousand crashes, as usual. The estimates of the parameters and estimated standard errors were:

$u = 0.106 \pm 0.148/1000$

$B_1 = 0.054 \pm 0.010/1000$ (per year age)

$B_2 = 0.109 \pm 0.064/1000$

$B_3 = -0.045 \pm 0.050/1000$

$B_4 = -0.076 \pm 0.108/1000$

Only the coefficient for age (B_1) was significantly different from zero, although B_2 could be considered borderline (X^2=2.91, 1 df, P=0.088). Further, combining all three standard effects shows that as a group all three are non-significant (X^2=3.78, 3 df, P=0.285). So again, the differences in fire rates in the Michigan data can be explained as corresponding to a linear effect increasing with the age of the vehicle. While this is not contradictory to an effect of the FMVSS 301, it does allow the alternative explanation of aging. Changes in level above the linear age effect were not significant. Figure 5.4.1 plots the data.

In conclusion, data from the State of Michigan show significant differences in the mean post-crash fire rates with the later versions of FMVSS 301 corresponding to lower crash-fire rates. However, there is significant variability of these fire rates within models corresponding to each version of the standard—variability which can be interpreted as a linear effect increasing with the age of the car. No significant differences in the different versions of the standard remained after adjusting for a linear age effect. It was quite difficult to identify crash fires in the fire department data. A crash-surrogate was used, which is thought to give about the correct number of fires, but for which nearly half of the cases found may not be crashes. The surrogate, however, in the Michigan data, appears to be better than merely taking a single variable as indicating that a car fire was a crash—this appears to result in about ten times as many fires as were really caused by crashes.

5.5 Data from the State of Missouri

For the State of Missouri, fires were identified from the fire department data collected as part of the NFIRS. Data from only the first three-quarters of 1977 were available at the time. Cases were restricted to passenger car fires which were coded "71" on the cause of ignition—collision, overturn, or knockdown. Denominator data were obtained from the police accident data from Missouri after the entire year of 1977. The data are presented in Table 5.5.1, in which the fire rates are as usual presented by model year of the vehicle as well as averaged for the model years corresponding to the different versions of the standard FMVSS 301.

Inspection of the data from Missouri shows that the fire rates tend to increase with the older models of cars. This is particularly noticeable when the average rates by version of the standard are

Figure 5.4.1

Observed and Predicted Crash-Surrogate Fire Ratios
(per 1000 vehicles) Michigan Data

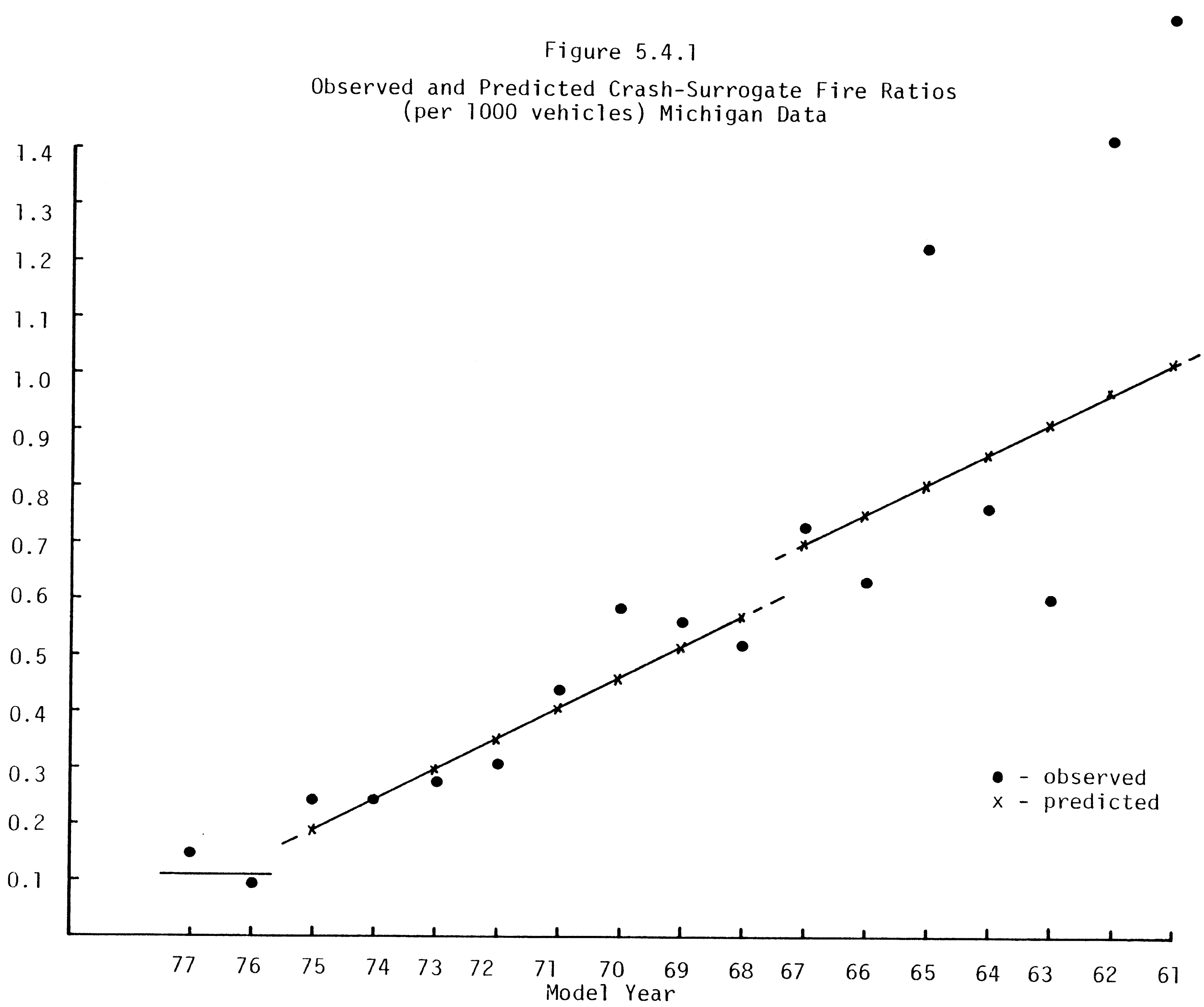


Table 5.5.1

Fire rates by model year
Missouri Data 1977
(Fires are from 9 month's data)

Model Year	Fires	Crashes	Rate per 1000 crash	Std. Dev.
1978	0	1,195	0	0.134
1977	13	24,336	0.5342	0.148
1976	43	31,149	1.3805	0.211
1975	56	24,114	2,3223	0.310
1974	71	29,088	2.4410	0.290
1973	88	33,511	2.6260	0.280
1972	82	29,439	2.7854	0.308
1971	78	23,474	3,3228	0.376
1970	98	23,178	4.2281	0.427
1969	101	23,084	4.3753	0.435
1968	97	17,989	5.3922	0.547
1967	66	13,288	4.9669	0.611
1966	80	10,971	7.2920	0.815
1965	53	8,573	6.1822	0.849
1964	49	5,580	8.7814	1.254
1963	36	3,479	10.3478	1.725
1962	21	2,068	10.1547	2.216

Average crash fire rates by standard (rates per 1000 crashes)

Pre—1968	6.94
1968-1975	3.29
1976	1.38
1977+	0.51

compared.

The model which fits four means to the data did not fit the data adequately (X^2=72.94 with 13 df for lack of fit). Thus, there was considerable variability in fire rates by model year among models corresponding to each version of the FMVSS 301. However, it can be concluded from this model that the rate for 1977 and 1977 models was not significantly different from that for 1976 models—or rather that the data are not sufficient to conclude that the rates for these later models are different from that for 1976. It seems clear from the model that the other mean rates all do differ significantly.

In order to improve the fit and to investigate the possibility of an age effect, the model with standard effects, and a linear effect for age was considered. There was some evidence that this model did not fit adequately (X^2=20.71, 12 df, P=0.055 for lack of fit), however, it did explain 96% of the variability in the rates. No other model was found to fit better, although quadratic terms, different age effects within standard, etc. were tried. With the model, the age effect is clearly significant, showing a linear increase in the crash fire rate with the age of the car. In addition, there is a significant reduction corresponding to the 1977 version of the standard—above what could be attributed to the smooth age effect. The estimated effects of the other versions of the standard are also estimated to be reductions, but neither of them reaches statistical significance. The model and its estimated parameters with standard errors is given below:

$$P = u + B_1(\text{age}) + B_2(301\text{-}77) + B_3(301\text{-}76) + B_4(301\text{-}68)$$

Where the years in parenthesis indicate the year the standard first was in effect. The parameters were estimated as:

$u = 1.304 \pm 0.812/1000$

$B_1 = 0.422 \pm 0.0584/1000$ (per year)

$B_2 = -0.682 \pm 0.241/1000$

$B_3 = -0.104 \pm 0.324/1000$

$B_4 = -0.665 \pm 0.555/1000$

As mentioned, the age effect is clearly significantly different from zero as is the parameter B_2, which corresponds to the effect of the 1977 and current version of the standard. The negative signs with the parameters B_2, B_3, and B_4 indicate that these effects are reductions in the crash fire rate. The positive sign for B_1 (age) indicates that the fire rates tend to increase with the age of the vehicle (or to decrease for the newer model years).

One additional caution needs to be kept in mind when considering these results. The fire data are for only the first 9 months (three quarters) of 1977, while the accident data are for the whole year. This means, for instance, that virtually no 1978 model cars were at risk of being involved in a fire, while 1,195 were involved in crashes. Similarly, the 1977 models were at a somewhat reduced exposure or risk to fire than to crash. As a consequence, the significance of the effect for the 1977 and 1978 models should be viewed with caution. It may be a result of this artifact in the data. The data are plotted in Figure 5.5.1.

Data from the state of Missouri are consistent with a beneficial effect of the FMVSS 301. In addition, there is a preliminary indication that there may be a demonstrated reduction in the crash fire rate with the current version of the standard which is more than would be predicted from a linear effect from the aging of the vehicles. The differences in average fire rates by versions of the standard are significant, with the more recent versions showing reductions in the fire rates. However, significant differences in fire rates by model year remain, much of which can be explained by a linear increase with the age of the vehicle. There may be a benefit of the current version which is larger than can be explained by a linear age effect. However, this should be viewed with caution because of the limited data for 1977 and later vehicles.

5.6 Data from Maryland

Data on car fires from the state of Maryland come from the NFIRS fire department data. The data reported were those car fires which occurred and were reported in the first 9 months of 1977 through the state fire department data reporting system. Only those passenger car fires which had the source of ignition listed as "collision, accident, overturn--code 71" were included as crash fires.

Since data on the number of crashes by model year were not available, registration data by model year were used as denominators. The data reported in Table 5.6.1 present only the fire rates per thousand registered vehicles. The actual number of fires, number of registered vehicles, and standard errors are not reported to preserve the confidentiality of the registration data. The authors apologize for this incomplete reporting, but see no alternative with the constraints imposed in order to use the registration data.

Figure 5.5.1

Observed and Predicted Crash Fire Ratios
(per 1000 vehicles) Missouri Data

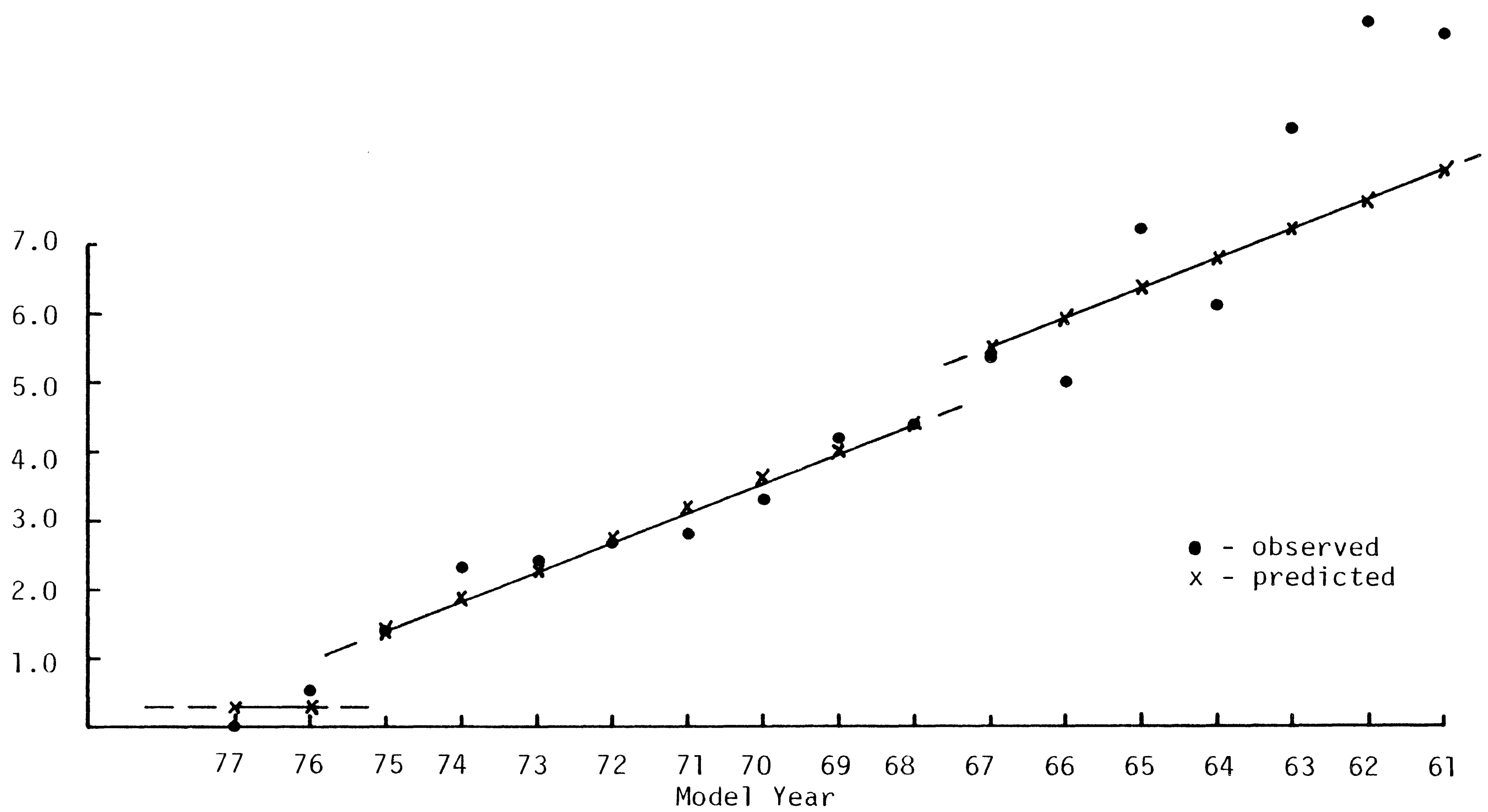


Table 5.6.1

Fire rates by model year,
Maryland Data

Model	Fire rate (fires per 10,000 veh.)
1977	0.083
1976	0.151
1975	0.104
1974	0.141
1973	0.148
1972	0.132
1971	0.152
1970	0.243
1969	0.280
1968	0.277
1967	0.320
1966	0.458
1965	0.413
1964	0.366
1963	0.391
1962	0.743
1961 and earlier	0.524

By standard version

pre 1968	0.409
68-75	0.174
76	0.151
77	0.083

The rates by standard show a decreasing progression with the later versions of the standard. The pre-1968 rate is 4.09 per 10,000 vehicles[1], 1968-1975 models have a rate of 1.74/10,000 and 1976 models had a rate of 1.51/10,000. The 1977 rate is 0.83/10,000 vehicles. However, while these fires occurred during the first three quarters of 1977, the registration data includes cars of 1977 model registered at any time during the year. Thus, the 1977 models were subject to less than a full years exposure as compared to their registrations. If a correction is made for this exposure, then an adjusted rate for the 1977

[1] These rates are based on 9 months' data. Rates per year would be approximately 1/3 larger.

models is 1.77/10,000. These rates would still indicate a progression toward improvement with later versions of the standard.

The model which fits a different mean rate for each version of the standard (the rates presented in the previous paragraph) does not fit the data adequately. That is, there is more variability within each version of the standard than random fluctuation would allow for. Inspection of the rates plotted by model year (Figure 5.6.1) reveals a general trend for the rates to decrease with the newer cars. A model which estimates a linear age effect fits the data adequately (x^2 = 15.98 with 15 degrees of freedom, P=0.383 for lack of fit), but does not test whether there is a standard effect in addition to a linear effect (which could be ascribed to age). The slope of the model is 0.223/10,000 and the intercept is 0.691/10,000. The intercept corresponds to the 1977 models predicted rate.

A model was fit with a linear effect for age, and with a change in intercept estimated for the 1968 and 1976 and later versions of the standard, as well as a general intercept. This model also fit well (x_2=9.58 with 13 df, P=0.787 for lack of fit). However, the only coefficient which was significantly different from zero was the slope—the age effect. The estimated parameters were:

u = 1.156/10,000
B_1(age) = 0.235/10,000 (per year)
B_2(301-68) = -0.666/10,000
B_3(301-76) = 0.499/10,000 .

It should be noted that neither effect of the standard was significantly different from zero. In addition, although the estimated effect at the time of the 1976 and standard was an increase, that merely means that there was a decrease of less than the amount that would be predicted by a continued linear extrapolation of the trend seen from the 1961 to 1975 models/rates.

Thus, the data from Maryland indicate a significant trend toward reduction of fire rates for newer models. However, this reduction is better modeled as a linear trend than different means for the model years corresponding to different versions of the standard. The decrease in fire rates from the pre-1968 models to the 1968-1975 models is more than the linear trend would account for, but not significantly so ($p=0.23$), while the decrease from the 1968-1975 models to the 1976 and later models is less than the linear trend would predict, but again, not significantly so ($P=0.12$). As a consequence, the data are consistent with a beneficial effect of the standard, but do not show an effect of more than what can be explained by aging of the vehicles.

5.7 Supplemental Data

5.7.1 Data from a Special Study in California. The California Highway Patrol conducted a special study of car fires from June 8 to December 8, 1976. All car fires which state patrol officers were aware of were investigated, and a special data form collected. Data from the highway patrol as to the number of crashes in the same time period on roads patrolled by the highway patrol were also obtained and were recorded by model year of the vehicle. These data do not represent the entire state. Further, they are predominantly rural or freeway crashes, and thus would tend to be more severe crashes at higher speeds. To date there has been no report published on these data.

The data are presented in Table 5.7.1. In the table, only crash fires were presented. The data included a total of 393 fires, of which 165 were crash fires. The rest were cases where the car caught fire and a highway patrol officer stopped to assist, but which did not involve a crash prior to the ignition of the fire. The fire rates show relatively little variability by model year. The average rates by versions of the standard are 7.43 (1977), 1.09 (1976), 1.62 (1968-75) and 1.93 (pre 1968). All rates are per thousand crashes. The 1977 rate is based on 2 fires out of 269 reported crashes, and is presumably an artifact.

A model which fits mean effects to the different versions of the standard fits these data adequately, however there are no differences among the means which are statistically significant at the 10% level. Similarly, a model which includes age and standard effects fits well, but not even the linear age effect is significantly different from zero. In fact, these data are consistent with a constant crash fire rate for all model years—no significant lack of fit is found. Thus, although a small reduction in average rate with each version of the standard is noted (if 1976 and later are considered as one) of 1.93/1000 to

Figure 5.6.1

Observed and Predicted Fires per 1000 Registered Vehicles - Maryland Data

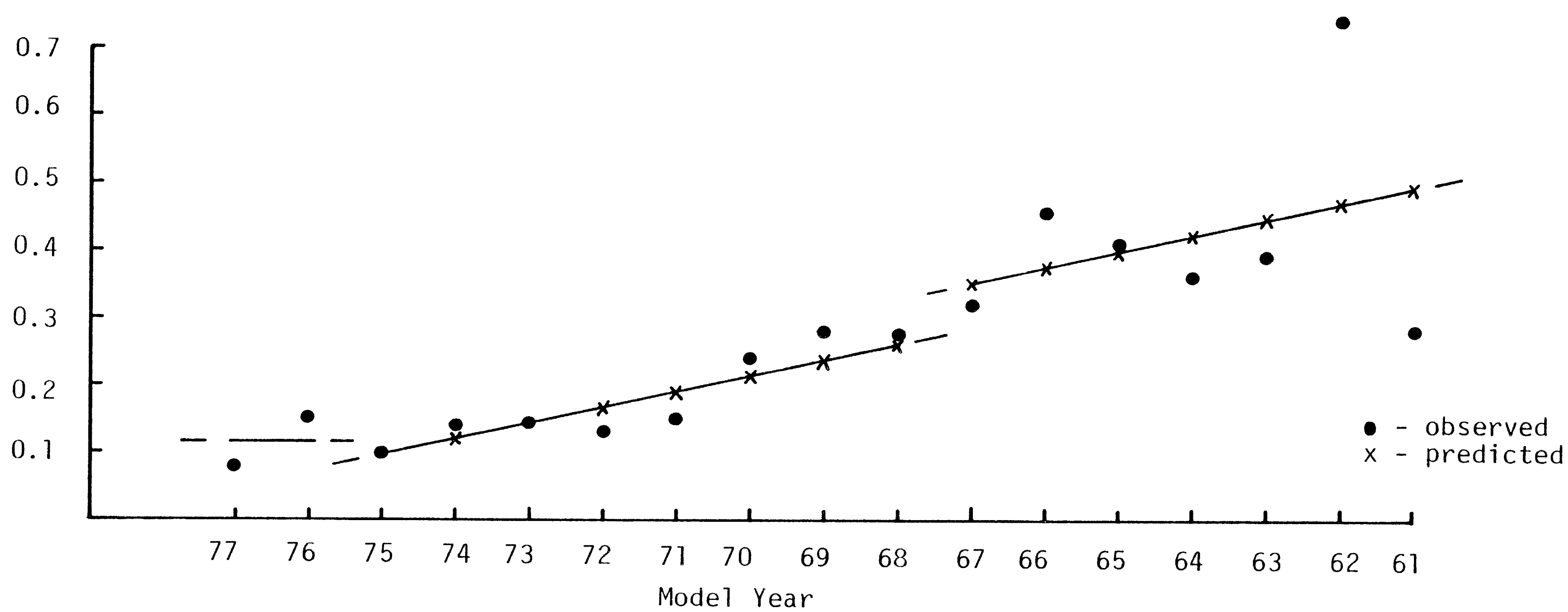


Table 5.7.1

California 6-Month Special Study

Model Year	Fires	Crashes	Rates per 1,000
1977	2	269	7.43
1976	8	7,338	1.09
1975	11	6,489	1.70
1974	13	8,402	1.55
1973	12	9,710	1.24
1972	11	9,336	1.18
1971	17	7,744	2.20
1970	12	7,585	1.58
1969	9	8,217	1.10
1968	20	7,258	2.76
1967	11	6,116	1.80
1966	12	5,511	2.18
1965	6	5,479	1.10
1964	13	3,589	3.37
1963	3	2,594	1.16
1962	3	1,545	1.94
1961	2	844	2.37

By standard

61-67	1.93
68-75	1.62
76	1.09
77	7.43

1.62/1000 with the 1968 version 1.32/1000 with the 1976 and later versions of FMVSS 301, these changes are not statistically different from zero--that is, those three average rates are not statistically significantly different. Thus, the data from California, while consistent with a small beneficial effect of FMVSS 301, are based on too limited data to conclude that such an effect exists.

5.7.2 Data from NCSS. Data from the National Crash Severity Study include information about crash fires. A one page report is collected in addition to standard NCSS data for crashes which involve fire. We have not obtained those reports yet, and they are necessary to identify the model year of the car which caught fire--the computerized NCSS data only indicate that one of the vehicles involved in a crash caught fire. From the computerized data, model year can only be determined for single vehicle accidents. The rates presented are fires in single vehicle accidents divided by all vehicles in crashes. Based on the data from the first year of the NCSS, the crash fire rates per thousand crashes in single vehicle accidents were calculated for each version of the standard. This results in an estimated 1.63 fires /1000 crash in the pre-1968 models, 1.31 fires/1000 crashes in the 1968-75 models, 2.02 fires/1000 crashes in the 1976 models and 1.12 fires/1000 crashes for the 1977 and later models. These should be regarded as preliminary results. They are restricted to single vehicle crashes and to an early portion of the NCSS data. Further use of the NCSS is planned, pending receipt of the data.

6. CONCLUSIONS

The main conclusion of this study is that existing data are not of sufficient quality to provide a definitive evaluation of FMVSS 301—Fuel System Integrity. Further, it seems unlikely that mass data reporting systems—statewide police accident data or fire department data—will be adequate for this problem in the forseeable future. In order to obtain the level of detail needed, additional investigation of the crash would be required. However, the rarity of the event of interest—post-crash fire—is such that detailed accident studies are also unlikely to find sufficient cases.

The deficiencies in the data are summarized to provide an indication of what would be needed if they were to be useful.

Police accident data often do not contain the information about whether or not a vehicle in a crash caught fire. In some cases, the data indicate the occurrence of a fire if it was an obvious one, which resulted in significant additional damage or injury, but fail to exclude the presence of minor fires. Thus, the data underreport fires, but the degree of underreporting cannot be determined. Even in cases where there is a definite variable to indicate the presence or absence of a fire, the variable is often left blank--for 20 to 30% of the vehicles. With a crash fire rate of one or two per thousand, missing data on the variable of 300 per thousand leads to extreme uncertainty. Even for those cases where the variable is checked (presumably correctly), no information is available to indicate whether the fire was related to the fuel system or not.

Fire department data at present suffer from deficiencies at least as great. First, there is a difficulty in determining whether a car fire resulted from a crash or from some other cause. Only one or two percent of passenger car fires in fire department data seem to be related to crashes. With the current data structure of the data from NFIRS, it is inconvenient to determine the model year or other information about the car—this is in a different file which must be matched—however, this can be accommodated. Unfortunately, when these data are matched, the information about the model year of the vehicle is often missing—typically for 30% of the cases. For those cases for which the model year information is present, there is still the lack of any information about the type of crash, speed, or any other crash variables. Some information about the part of car damaged, whether fuel was involved in the fire, etc., is available--at least the variables are recorded. In working with the actual data, a large proportion of the cases have codes such as unknown, or unspecified, which actually provide no additional information. This was found to be the case 30-40% of the time.

Post crash fires are quite rare. In all the data sets investigated, they appear to occur no more frequently than about five fires per thousand crashes. This appears to be about the rate for older cars in the Illinois data if missing data are excluded; including missing data as non-fires would reduce this to somewhat less than 4 fires per thousand crashes. On the other hand, data from Washington and New York show post-crash fire rates of about 0.4 fires per thousand crashes--about a tenth the rate in Illinois. These, too, are subject to missing data problems. Perhaps the data which are best for estimating the crash fire rate are those from the NCSS. The preliminary indication is that there is about a rate of 3.1 fires per thousand crashes in tow-away crashes. If all crashes were included this rate would be less--about one fire per thousand vehicles in crashes.

The rarity of the even makes it difficult to detect changes in fire rates. That is, a great amount of data is needed to provide information on enough fires so that a difference in crash fire rates could be noted. In addition, the data must be of consistently high quality. It is not tolerable to have a 1% error rate when investigating a phenomenon which occurs only in one-tenth of one percent of the cases. In all the data files, the missing data rate--on the key identification variables--has been much higher than the crash fire rate.

Crash fires occur less frequently in the newer models than in previous models. This finding was rather consistent throughout the data. A summary of this can be seen in Table 3.1. However, in Washington, New York police accident data, and in the special study in California, these reductions were not significant; those data were consistent with a constant fire rate for all model years. In the rest of the data,the reduction appeared to be primarily a linear trend, which could be caused by a gradual increase in fire risk with increasing age of the vehicle. On the other hand, such an effect could result from the standard also. On the one hand,the gradual increase in crash fire rates could be attributed to a slow deterioration with the aging of the vehicle. On the other hand, the gradually decreasing fire rates could be attributed to yearly improvements in the fuel system integrity (possibly different makes in different years) resulting from the first version of FMVSS 301 or in anticipation of the later versions of FMVSS 301. The data are inadequate to distinguish between these possibilities. Of course, the missing data are such that all of these reductions could be artifacts.

The pattern of relationship of crash fire rates to model year may be typified by the data from Illinois. Pre-1968 models had a nearly constant rate of about 5 per thousand. Models from 1968 to 1975 show a gradual, nearly linear decrease to a rate of about 4 per thousand, which is constant for model years 1975-1977. The actual model years where the form changes is not certain; the lower ate could extend as far back as to include the 1973 models, while the higher rate could include the 1969 and even possibly the 1970 models. Although these data show a reduction of crash fire rates of about 18% from the pre-1968 standard to the current, it should be borne in mind that this is rather less than one fire per thousand crashes, and that this is spread over several model years.

With the rarity of the event, it does not seem that it will be feasible to determine whether the 1976 version of FMVSS 301--which only affected one model year of production--differed in effect from the previous version of the standard or from the following version of the standard. To do so would require nearly complete data of high accuracy about crashes involving 1976 models, and might well require additinonal data about which, if any, models had modifications to their fuel systems for 1976 production. There is no way that this could be evaluated with extant data, and it would probably be prohibitively expensive to attempt.

Data on 1977 and later models are spotty and incomplete. A better evaluation of the effect of FMVSS 301--current version--could be performed when more data are available on crashes involving these models. However, improvement in data quality is a must if such an evaluation is to be definitive.

7. RECOMMENDATIONS

At present, fire department data are not well suited for identifying vehicle fires which resulted from a crash. To identify clearly whether a car fire resulted from a crash would require a change in one variable on the NFIRS form and a corresponding modification of the instructions. However, in order to obtain good data, more attention to careful completion of the form by the local fire departments would be required. The clarification to identify which car fires were associated with a crash should be suggested to the Fire Administration. Insistence on the data quality and assurance that the model year of the vehicle is obtained should also be suggested. Even with these modifications, fire department data would not contain any information about the nature of the crash. Such data are important, since the severity of the crash is a very important factor in the risk of crash fire. Adding such information to the fire reports would be too much of a burden on the system and would likely result in very poor data, and so is not recommended. It might be possible to arrange a surveillance system which would identify crash fires for investigation through fire departments, and this might be considered.

Most police accident reporting forms do not include information about occurrence of a crash fire. Even when such a variable is present, it typically only notes the presence of fire, not whether fuel was involved, the extent of the fire, whether it resulted in any additional injuries, etc. It is recommended that a variable to identify fire in crashes be suggested for addition to standard accident reporting forms. However, collection of the detailed information should not be attempted on general accident reporting forms. The event is too rare. Such an attempt would result in wasted effort. The best approach would be a surveillance type of system to identify all the crash fires for further investigation. Such a system would provide the information that no fire occurred for non-fire crashes, which could be sampled for more in-depth investigations.

The police accident reporting system provides potentially better data on crash fires than the fire department data, but requires improvements to reduce the missing data in order to consider events which occur in only one case per thousand. A linking of the police and fire department data would be advantageous--the police data provide information about the crash, while the fire department data provide information about the fire (where it originated, whether fuel or electrical, etc.)

The best hope for a relatively short-term more definitive evaluation would be with a more in-depth accident investigation effort such as the NCSS or the NASS. While there would be relatively few fires found, the data on each crash and each fire should be of sufficient quality and detail to permit some conclusions to be drawn. There would probably not be enough fires to permit consideration of fire rates separately by each model year. Thus the inherent confounding between age of vehicle and version of the standard could not be resolved. However, the detail present could assist in investigating the relationship between fire and a wide variety of crash events, and could be used to some extent to compare models built under various versions of the standard.

APPENDIX A

The Michigan fire data were obtained from tapes sent from the Michigan State Fire Marshall's office. The surrogate used to determine the number of fires due to crashes is given below. Any code listed for a given variable qualifies for inclusion. To be included, a case must have one of the listed codes for each variable listed.

V4 Situation Found
- 1. Fire, explosion with fire, crash with fire
- 3. Rescue, crash
- 4. Hazardous condition - gasoline spill

V35 Mobile Property Classification
- 11. Car, Automobile

V41 Area of Origin of Fire
- 80. ---
- 81. Mobile, Passenger Area
- 82. Mobile, Trunk or Load carrying area
- 83. Mobile, engine area, wheels, etc.
- 84. Mobile, Fuel tank
- 85. ---
- 86. ---
- 87. ---
- 88. ---
- 89. Mobile, other area
- 90. Undetermined
- 97. Multiple location

V46 Equipment involved in ignition
- 90. Undetermined
- 99. Other
- 96. Vehicle
- 66. Internal Combustion Engine

V47 Form of Heat Causing Ignition

10. Undetermined head from fuel fired or powered object
11. Spark from gas fueled equipment
12. Heat from gas fueled equipment
13. Spark from liquid fueled equipment
14. Heat from liquid fueled equipment
15. Spark from solid fueled equipment
16. Heat from solid fueled equipment
17. Spark from unknown fueled equipment
18. Heat from unknown fueled equipment
19. Other - from fuel fired or powered equipment
51. Heat or spark from friction (tire overheated)
59. Undetermined heat from hot object
49. Other heat from open flame or spark
99. Other heat

V49 Use of Material first ignited

65. Fuel
86. Accelerants, gas or liquid
60. Undetermined power transfer equipment or fuel
90. Undetermined form of material
99. Other

V50 Act or Omission

41. Fuel spilled or released accidentally
71. Accident, overturn, knockdown