AN EVALUATION OF FMVSS 301
FUEL SYSTEM INTEGRITY

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by

Jairus D. Flora, Jr.,
Paula Beitler,
Judith Bromberg,
Nancy Goldstein,
James O'Day

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48109

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16. Abstract

Police and fire department data from 10 states were used to estimate the effects of FMVSS 301--Fuel System Integrity--on the crash population. The 18-month study used data from 1 to 3 years of accident statistics. Data on fatalities showed reductions corresponding to the introduction of FMVSS 301, but were too limited to provide firm conclusions. Data on non-fatal injuries were not available. Only limited information on fuel leakage was found and most of the effort dealt with estimating effect on post-crash fire rates.

The study concluded that fire department data were of limited use because they could not be related to the occurrence of a crash. They also contained very large amounts of missing data. Although fire department data were analyzed, the police accident data provided a better source of information.

Post-crash fires are rare events. Their rate of occurrence depends on the definition of a crash, but appears to be on the order of 2 per 1000 in police-reported accidents and about 3 per 1000 in towaway crashes.

A 16% reduction in post-crash fires occurred coincident with the first promulgation of FMVSS 301 in 1968. An additional 14% reduction occurred with the strengthened version of 1976, for a total reduction of 25% from pre-standard models to current. However, causality cannot be imputed to the standard, and the reductions could be due, in part, to the younger ages of cars produced since the standard was changed.

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SUMMARY

This is a final report detailing the findings and results from efforts on a project entitled "Evaluation of the Effectiveness of Federal Motor Vehicle Safety Standard 301--Fuel System Integrity, Passenger Cars." The project was 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, Idaho, Ohio, Oklahoma, Oregon, 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 all of the effects 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 show 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 5 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 from one to two fires per thousand police reported crashes seems a reasonable estimate, although, as mentioned, the missing data make this uncertain. Estimated fire rates by version of the standard and data source are presented in Table 3.1.

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. However, the police data do estimate significant reductions in passenger car post-crash fire rates which coincided with the versions of the standard. A combined estimate from the data indicates a 16% reduction coincident with the 1968 version of FMVSS 301. A further reduction of 14% was estimated for the revised standard (1976). (No difference between the 1976 and 1977 versions was discernable.) Overall there was a 25% reduction in passenger car crash fire rates from pre-1968 models to post-1975 models.

Only one source of fuel leakage data was found to be adequate. This was from Michigan police accident data for 1978. These data estimated a 47% reduction in leakage rates coincident with the 1968 version of FMVSS 301, a further 50% reduction coincident with 1976 models, and an overall reduction of 74% from pre-1968 models to post-1975 models. However, there was some evidence that this may have been more associated with the age of the vehicle than with the standard.

No adequate data were found to try to estimate the reduction in non-fatal injuries. The FARS data were combined with accident data from several states in an attempt to estimate the effect on the fatalities in accidents with fire. The number of fire-associated fatalities proved to be too low to obtain reliable estimates of the possible effects of FMVSS 301 on fatalities. One would need crash data by model years from essentially all the states to combine with the FARS data to estimate an effect on fatalities. Even if that could be obtained, the effects observed could be caused in part by other factors. In addition, many of the fatalities in crashes with fire may not be related to the fire. To determine the number of fire-caused fatalities would require an autopsy investigation of all the fatalities in crashes with fires.

Police accident data proved to be quite inconsistent in the variables reported. In addition, the practical definition of a crash fire differed among the states, as did the criteria for a reportable passenger car crash. Future effort to obtain consistent reporting of fires and crashes and other crash variables among states would be necessary to improve the data if a better estimate of effectiveness of FMVSS 301 is to be developed.

Statewide fire department data in NFIRS proved of limited use in determining the number of passenger cars involved in crash fires. The current NFIRS data do not identify a passenger car fire with a crash reliably. In addition, there are such magnitudes of differences in reporting of variables among states, that one must conclude that some states are interpreting the instructions and definitions of variables differently. The current data structure of NFIRS requires linking records in two or three different files to identify a fire in a passenger car and to determine the model year of the car. A further link would be required to obtain injury information. The matching of records results in a loss of some information. Further, typically 20 to 30 percent of the records have no model year information. Even if these problems are resolved and an identification of crash is provided, it seems unlikely that much crash information would be included. As a result, the best use would be as a potential identification of cases for further study.

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1. INTRODUCTION

This is the final report detailing the findings and results from a project entitled "Evaluation of the Effectiveness of Federal Motor Vehicle Safety Standard 301--Fuel System Integrity, Passenger Cars." The project was 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, fuel leakage, and resulting injuries that may have occurred as a result of the standard in its various forms. Practical considerations have reduced most of the effort to an estimate of the effectiveness of the standard by 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. Data on fuel leakage were very limited. What data were available are detailed in Section 5.4.2 and Section 5.10. The sparsity of data precluded any conclusions based on injuries or fatalities. Information on injuries or fatalities is mentioned in each section as applicable, but is mostly of an anecdotal nature.

2. APPROACH

The genproach to estimating the effect of FMVSS 301 was to estimate thef occurrence of post-crash fires or fuel spillages in accidents in cars of different model year's manufacture. Either fire rates by year or fuel spill rates by model year were then related to thion of the standard in effect at the time of the car's manufac The differences found may be attributable to the effects of thdard.

There arenber of complications to this method, of course. It is possible th observed differences may be due to a number of factors insteaor in addition to the standard. Attempts were made to identify confounding factors. When they were found, the magnitude and umed direction of the bias they introduce was estimated. To xtent that this could be done, these factors were adjusted for or rolled for in an attempt to remove their influence from the differe in rates. It may well be that not all of these potential confong factors were eliminated. In that case, differences in or fuel spillage rates may be related to the standard or to thonfounding factors, or both.

2.1 Evolution of Standard

The first vebn of FMVSS 301 went into effect on January 1, 1968. It called for the systems to retain their integrity (not leak fuel) after a crash and acted the fuel tank, filler pipe, and fuel line connections. Complire was to be judged or demonstrated by a 30 miles per hour perpendicular frontal crash into a fixed barrier following which fuel leakage wasto 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 applied to 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 with 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 or fuel spillage 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 3.54 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 0.38 fires per thousand crashes. Data from New York estimate a crash fire rate of 0.29 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. Police accident data from 1978 in

Michigan give a rate of 2.32 fires per thousand crashes. Fuel leakage occurred in 13.10 cases per thousand vehicles. 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 3.30 fires per thousand tow-away crashes is obtained. It should be noted that the NCSS data refer 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. The NCSS estimate seems consistent with that from Michigan, and that from Illinois if a higher reporting threshold (nearly equivalent to towaway crashes) were assumed in Illinois.

Ratios of fire department reported car fires to crashes are even more variable, ranging from about 0.3 to 12.3 per thousand crashes.

In any event, it is clear that the occurrence of post-crash fires is quite a rare event. They occur at the rate of about two or three fires per thousand 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.

Estimation of the rate of fuel spillage in accidents proved quite difficult. Most of the accident data sets do not include any information about fuel spillage. The only exceptions were the NCSS data and the 1978 Michigan data. Fire department data were considered as a possible source for information on fuel spillage. However, it appears that fire departments are generally not called to accidents unless there is a fire. Small amounts of gasoline spilled are not reported. The only types of crashes where fire departments appear to be summoned are those which involved a large amount of fuel--generally tank trucks. The situation found variable--hazardous condition--in fire department data which would indicate a call to a crash where there was no fire, did not occur with passenger cars as the type of property to any great extent. Thus, the fire department data were not useful for estimating rates of fuel spillage. The estimates of fuel spillage are based on the NCSS data, which includes a rather limited number of cases of fuel spillage, and the 1978 Michigan data. These latter data indicated that fuel spillage without fire is approximately 5 times as frequent as fire in a crash. Overall, the fuel spillage rate (including fires) in the NCSS data was 3.78 per thousand vehicles. In the 1978 Michigan data, the rate (including fires) was 13.10 per thousand. Cases of fuel spillage without fire occurred in about 12.34 cases per thousand vehicles.

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 Missouri exemplify 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 are not reported in some 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 that indicates which vehicle fires 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 7,850 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. Several possible identifications of the fires with crashes in those data were considered. One was to include only codes 71 and 41. Another was to exclude arsons and other known non-crash causes. Both resulted in the inclusion of some non-crash car fires and the exclusion of 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 were 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 were similar for both. The analysis consisted of defining an appropriate crash fire rate (or ratio) and then calculating these estimated rates. These crash fire rates were (at a minimum) estimated separately for each model year back to about 1961. The rates were then analyzed to look for age effects within versions of the standard, and differences among different versions of the standard. When possible--in police accident data--rates were 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 made the data too tenuous to include many variables (in addition to model year) at once. Hence, it was 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 was generally 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 resulted 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, two rates were considered. One 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. The second approach was to use all fire department fires excluding the obviously non-crash fires, but retaining the essentially unknown causes.

3.3.2 Relation of Rates to Standard. Once an 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 mostly 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	5.17	4.33	3.96	4.95	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	4.91	2.29	0.97	0.75	0.88
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
Michigan Police						
Leaks	1978	27.17	15.18	7.18	6.80	6.92
Fires	1978	3.14	2.51	1.72	1.83	1.80
Missouri Fire/Police	1977	7.92	3.74	1.35	1.02	1.20
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 Towaways	1977					
Leaks		5.40	2.82	6.89	4.92	5.95
Fires		3.81	3.09	3.86	3.38	3.63
Idaho Police	1976	0.59	1.11	0.32		0.33
	1977	1.50	1.05	0.93	1.89	1.34
	comb	1.00	1.06	0.70	1.81	1.05
Oklahoma[1] Police	1977	0.44	0.70	0.41		0.41
Ohio Fires/Police	1977	2.17	0.84	0.23	0.23	0.23
Oregon	1977	0.77	0.57	0.29		0.29
FARS (Fatal) Fires/Regis	3-Yrs	18.4	21.1	23.2	22.8	

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[1] Model year ranges for Oklahoma are pre 1971, 1972-1975, 1976 and later.

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:

$$EP_i = B_0 + B_1X_{1i} + B_2X_{2i} + B_3X_{3i} + B_4X_{4i}.$$

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 if 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. The state police accident data files that contained useful fire information were Illinois, Michigan, New York, Oklahoma, Idaho, and Washington. In addition, some states had fire department data. These were Michigan, Missouri, Ohio, Oregon, New York, and Maryland. In addition, a small set of data from a special highway patrol study in California are analyzed. Some data from the NCSS and the FARS 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.

Table 4.1
Status of State Fire and Accident Records

State	Police Data		Comments	Fire Data
	Fire	Model Year		
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 . .	Yes*	Yes	*Coded from narrative	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.

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. If missing data are assumed to be non-fires, the average fire rate in the 1976 data is 3.93 fires per thousand vehicles in crashes, while for 1977 the average fire rate is 2.88 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 the crash occurred. This difference in missing data rate from 1976 to 1977 accounts for half 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 were 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 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.

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 . .	158	26,364	5.99	0.477
1977 . .	4	20	200.00	100.000
1978 . .	--	--	--	--
Others .	0	10	--	--

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 5.2 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 1976 and later are grouped, the combined rate is 4.0 per 1000. The associated standard errors are estimated as 0.228, 0.088, 0.231, and

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	10,225	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	--	--

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 standard as compared to those built with the 1968 standard. An additional 7.4% reduction is observed with the 1976 standard. (An

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	5.174
1968-1975	4.333
1976	3.964
1977+	4.845

apparent 22% increase 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 due to the fact that rear end crashes are generally less severe--i.e. happen at lower speeds--than do head-on crashes, rollovers, or

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

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 ± 0.546/1000

Slope for age = 0.15 ± 0.0399/1000

Estimate of effect with 1977 models = 1.03 + 0.491/1000

Estimate of effect with 1976 models = 0.20 ± 0.290/1000

Estimate of effect with 1968 models = 0.36 ± 0.359/1000

Only the overall mean and the slope 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 model s. The parameters estimated for this model are:

Mean for 1976 and 1977 model years
= 4.14 ± 0.203/1000

Linear trend for 1968-1975 models
= 0.16 ± 0.041/1000

Intercept for linear trend
= 3.72 ± 0.181/1000

Mean for pre-1968 models
= 5.02 + 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 estimated reduction of 0.32 fires per thousand vehicles in crashes from the mid-1968-1975 standard to the current. This reduction, however, is not significantly different from zero (p=0.16). The

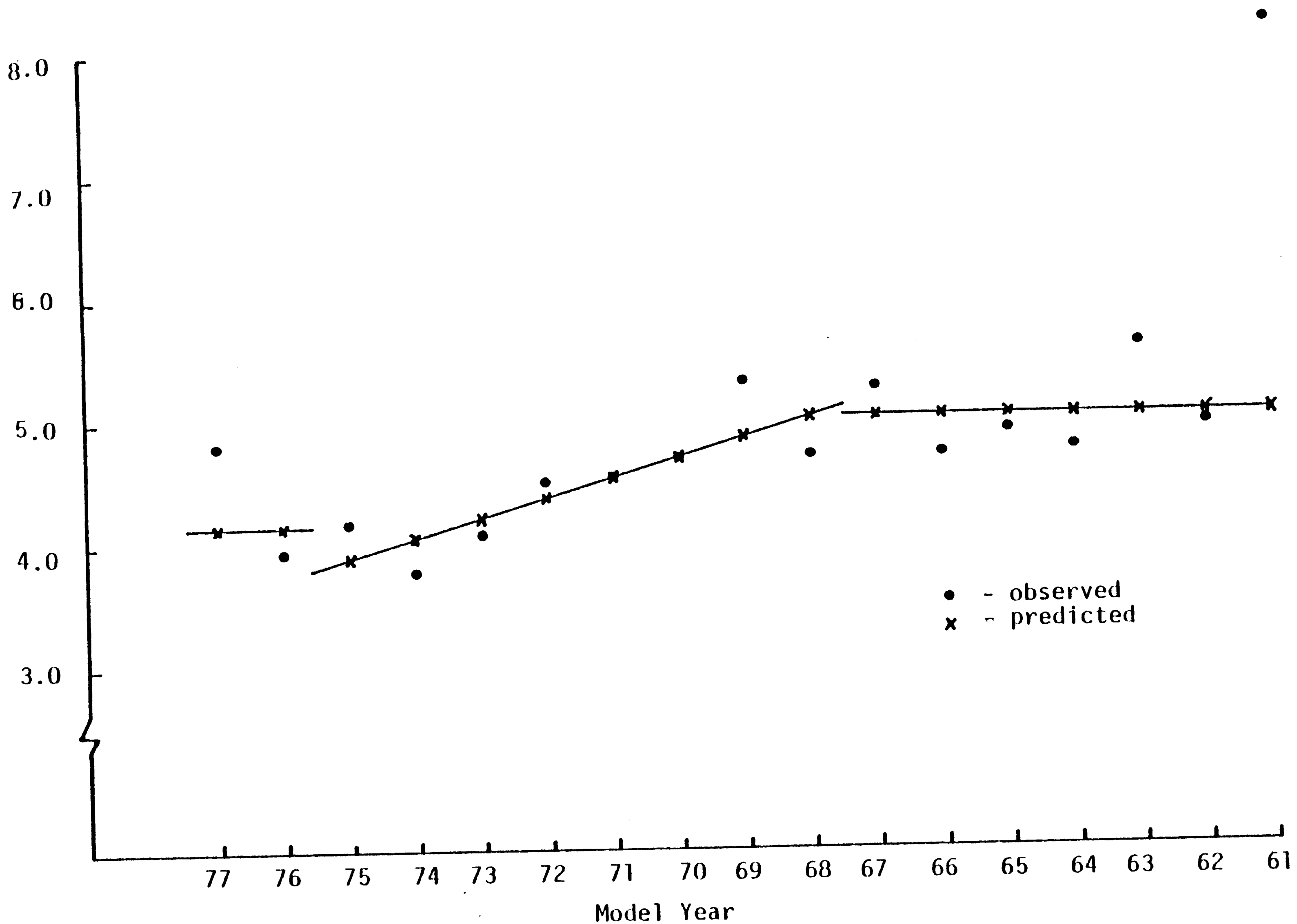


Figure 5.1.1 Observed and Predicted Crash Fire Ratios--Illinois

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

estimated reduction from pre-1968 to 1968-1975 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.

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. Table 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. This would tend to artificially reduce the observed fire rates in older cars relative to those in newer cars.

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

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.

later models have higher rates than the other two groups. It should be 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			All Stds.
	Pre-1968	1968-1975	1976+	
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 th usand. 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 severe 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

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

Washington data. In general all models showed a good fit to the data. However, in general only the overall mean effect was significant. That 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 crashes and 0.42 crash fires per thousand vehicles in 1977 crashes.

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,

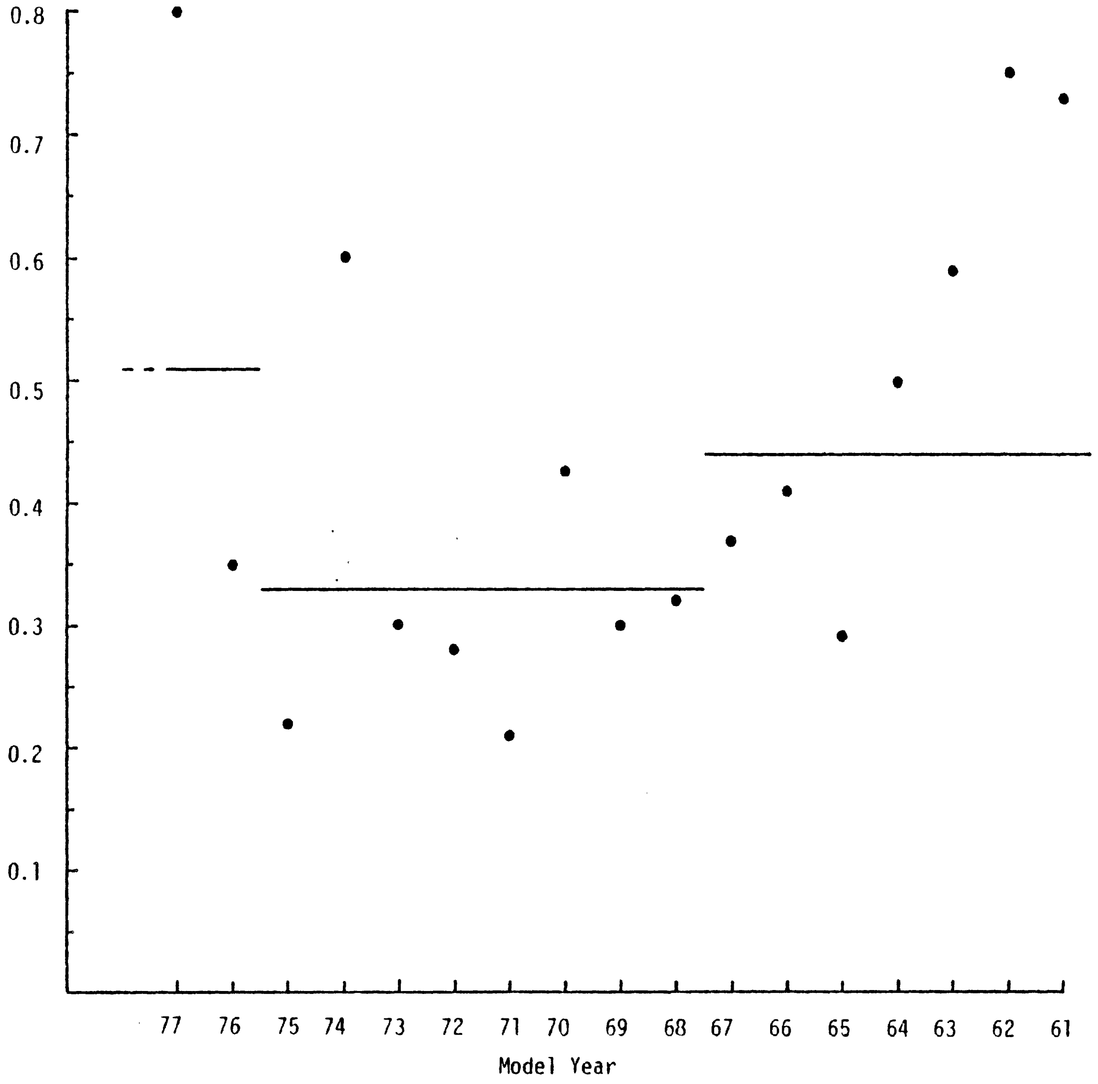


Figure 5.2.1

Observed and Predicted Crash Fire Rates
Washington

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

the rates would have been reduced by about one-third).

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

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

When models were fit to the data for each year separately, no adequate fits were found. The small number of fires and the relatively 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 ± 0.051
1968-1975	0.276 ± 0.018
1976	0.328 ± 0.055
1977	0.210 ± 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 report fire department records. Again, the cases reported are all the car fires excluding arson, natural, and electrical sources 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 38% 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 0.75, 0.97, 2.29, and 4.91 per thousand crashes from the current version to the pre-standard models. The estimated standard errors associated with these are 0.130, 0.137, 0.074, and 0.206, 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.The ratios by model year are presented in Table 5.3.5.

If the data are averaged over all model years, 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 to 0.65/1000 the 1976 models show a reduction to 0.97/1000 the 1968 to 1975 models show a rate of 2.02/1000, while the pre-standard models have a larger ratio of 4.78/1000. The reductions of the mean ratios for the 1976 and later models are significant--that is, these models (1976 and 1977) had

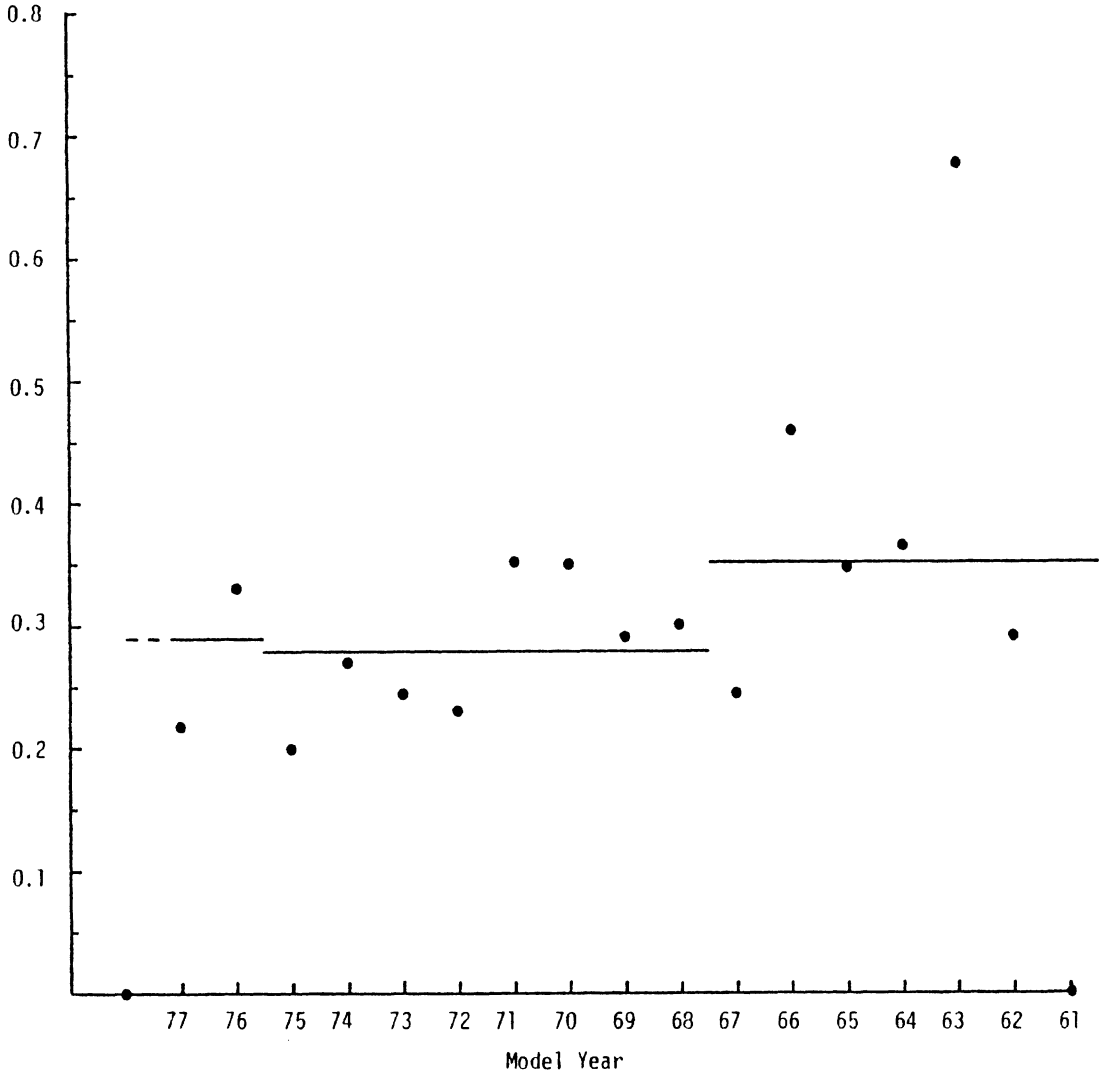


Figure 5.3.1

Observed and Predicted Crash Fire Rates
--New York (Police Data)

Table 5.3.4

Passenger Car Fires and Crash Frequencies
New York 1977

Model Year	All Fires	Code 41	Code 71	Exclusion Surrogate	Crashes
1978 .	3	0	0	1	1,231
1977 .	86	1	2	32	40,030
1976 .	140	0	5	60	61,578
1975 .	172	2	3	76	50,154
1974 .	223	1	3	97	60,759
1973 .	270	2	8	111	69,119
1972 .	279	0	0	111	61,487
1971 .	323	4	1	133	53,486
1970 .	326	3	2	136	48,994
1969 .	305	1	2	151	41,671
1968 .	305	3	3	141	32,719
1967 .	200	3	2	88	20,672
1966 .	145	3	2	73	14,490
1965 .	122	1	1	52	10,556
1964 .	65	1	2	33	5,465
1963 .	33	0	0	13	2,961
1962 .	24	0	2	10	1,376
1961 .	11	0	0	7	710
Missing	1,913	9	16	861	
Total .	4,973	34	54	2,022	577,458

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.

As noted, models fitting mean effects only were not adequate. The lack of fit chi-square was 118.5 with 14 degrees of freedom. 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 marginally

Table 5.3.5

Fire/Crash Ratios
New York 1977

Model Year	Ratio	Standard Deviation
1978	0.812	0.812
1977	0.799	0.137
1976	0.974	0.126
1975	1.515	0.174
1974	1.596	0.162
1973	1.606	0.152
1972	1.805	0.171
1971	2.487	0.136
1970	2.776	0.141
1969	3.624	0.295
1968	4.309	0.363
1967	4.257	0.454
1966	5.038	0.590
1965	4.926	0.683
1964	6.038	1.051
1963	4.390	1.218
1962	7.267	2.298
1961	9.859	3.726
Pre-1968	4.908	0.296
1968-75	2.285	0.074
1976	0.974	0.137
1977+	0.746	0.1300
1976-on	0.879	0.091

adequately. (Chi-square for error was 25.15 with 13 df, P=0.02). This model showed a significant effect for the linear term in age. The parameters were estimated as:

$u = 0.601 \pm 0.521/1000$

$B_1 = 0.343 \pm 0.036/1000$ per year

$B_2 = 0.020 \pm 0.178/1000$

$B_3 = 0.1614 \pm 0.191/1000$

$B_4 = -0.474 \pm 0.381/1000$

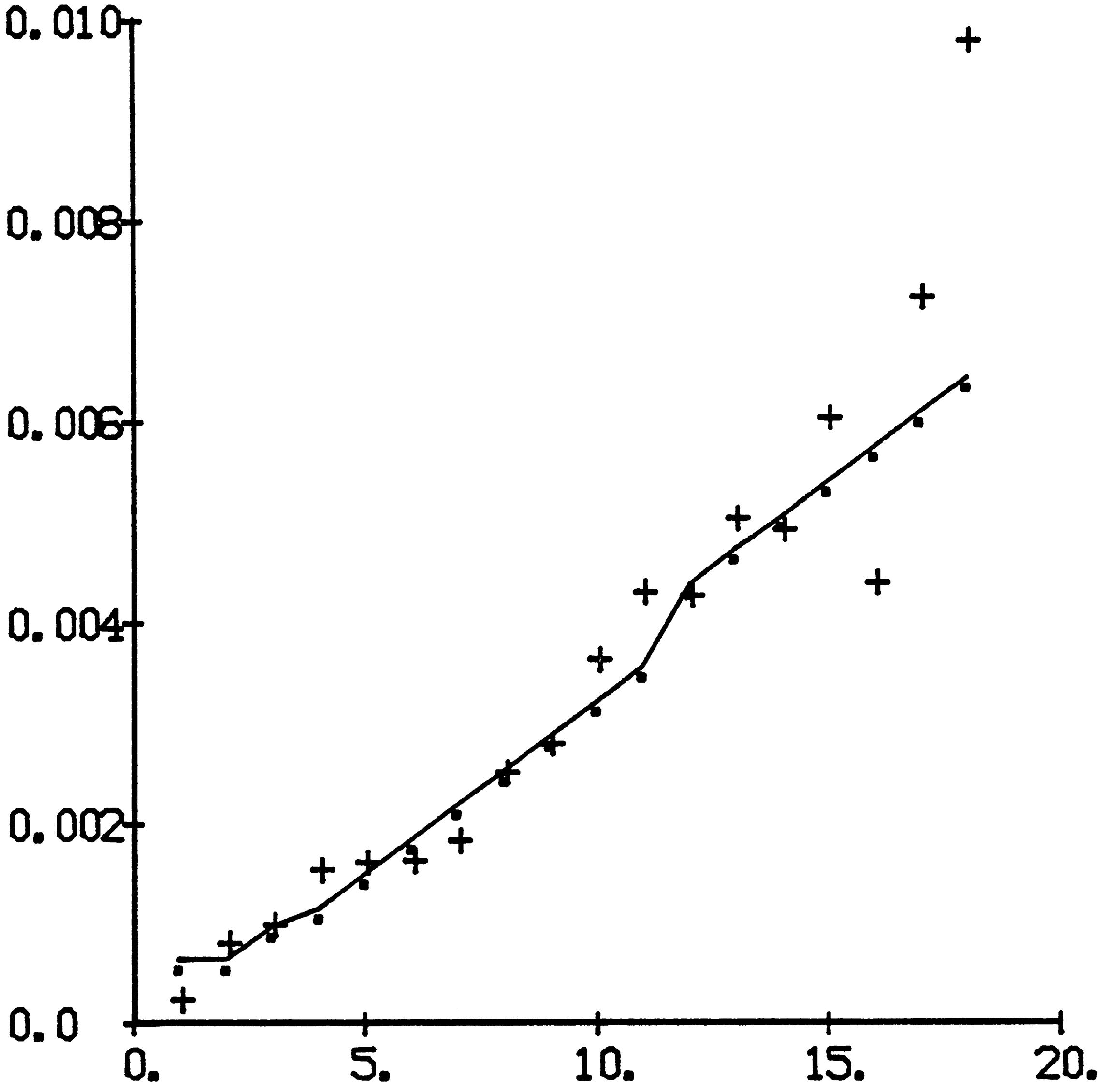
where the parameters and their estimated standard deviations are both in terms of thousands of crashes.

Viewed collectively, there is little evidence that the effects of the various versions of the standard were significant. The X^2 for testing this was 4.18 with 3 df, giving a P=0.243. Thus, these data indicate no differences among models subject to different versions of the standard (including no standard) which are significant at the 5% level after a linear effect for age has been removed. 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 small increase and the 1977 models showed a very small increase. None of these individual parameters reaches statistical significance at the 5% level, however.

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, most of the differences can be explained by a linear effect increasing with the age of the car. There was no indication that significant differences among the versions of the standard persisted after adjustment for age. After adjusting for age, the 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 large amount of missing data (38% 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

5.4.1 Fire Department Data In Michigan passenger car fires were identified through the statewide fire department reporting system, while crashes were 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.



NEW YORK FIRE CRASH RATIOS [1977]

Figure 5.3.2

Observed and Predicted Fire Crash Rates
--New York (Fire Data)

(If a vehicle burned following a crash, this might be noted in the narrative of the police report, but the information was not computerized an' so would not be accessible without manually reading all of the accident reports.) The 1978 crash data are analyzed in Section 5.4.2.

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 ratios for the data from Michigan from 1976 and 1977 respectively. Table 5.4.3 presents these data combined. Ratios are presented by model year of the car involved.

Inspection of the ratios 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 ratios by version of the standard for the combined data, one obtains ratios 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 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 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

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

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:

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

were

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

$B_1 = 0.046/1000 \pm 0.0117/1000$ per year

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

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

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

where the numbers following the "±" are the estimated standard errors of the parameter.

The data from 1977 showed more variation of the crash-surrogate fire ratios 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 or 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

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

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, Fire Department 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.

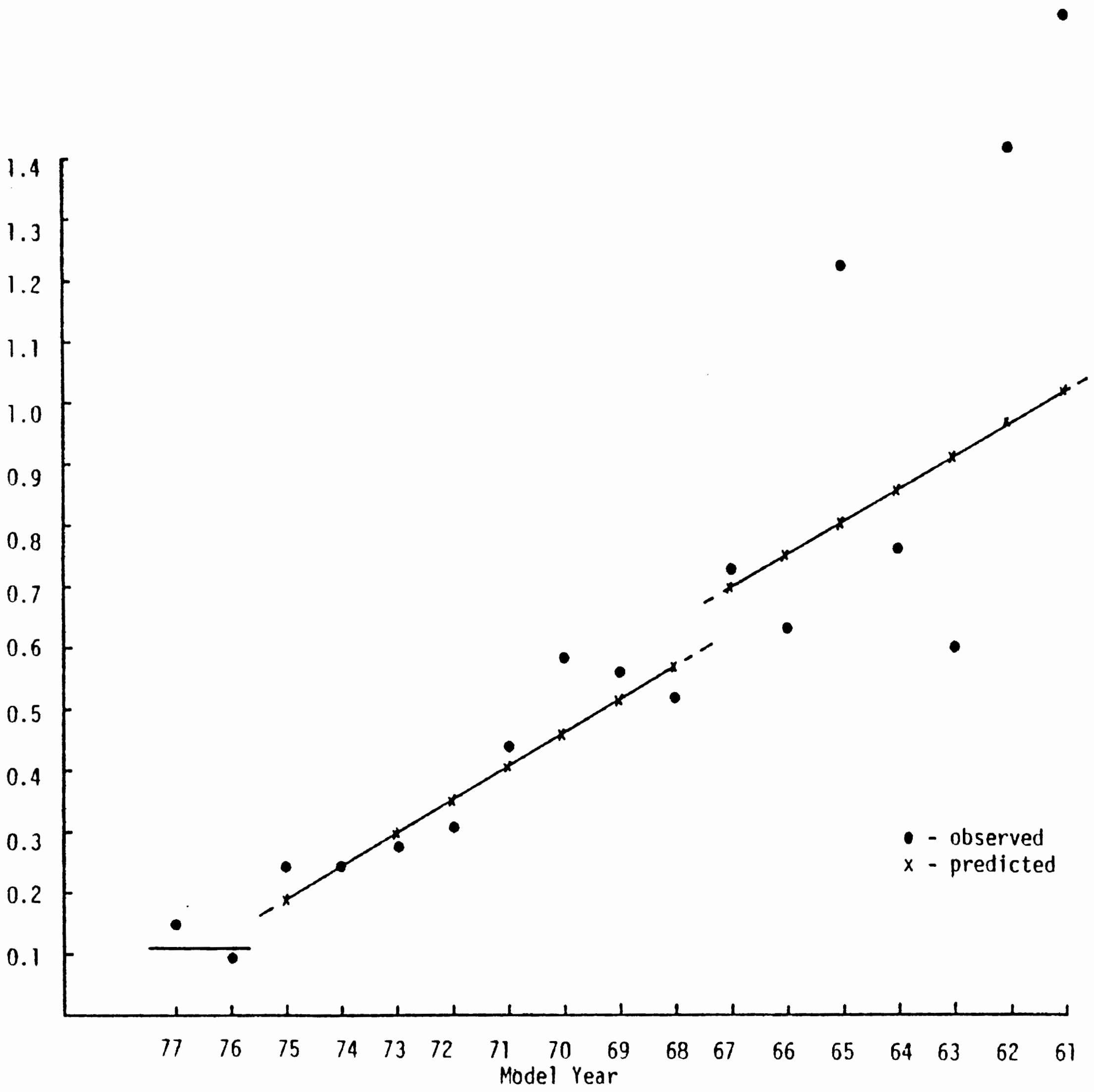


Figure 5.4.1

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

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.

5.4.2 Police Data From Michigan

5.4.2.1 Fires. Beginning in 1978, the State Police accident reporting form (UD-10) was revised. The new form included several additional questions, two of which dealt with fuel leakage and fire in crashes. One question related to fuel leakage. Officers were to mark a box for yes or no, depending on whether the vehicle leaked fuel in the crash. The instructions were: "Enter an 'X' on the box marked 'Y' where the engine (or auxiliary engine) fuel supply tank, lines, or carburetor, leaked fuel at the accident scene. Otherwise, enter an 'X' in the box marked 'N.' This does not include a truck's cargo after being involved in an accident."

A similar question was used for vehicle fire. The instructions for this question were: "Enter an 'X' on the box marked 'Y' where any part of the vehicle, vehicle attachments, trailer, or cargo caught fire (open flame) before or after impact. Otherwise, enter an 'X' on the box marked 'N'."

In coding the data, four codes were used. One was for a "yes" on the fuel leakage question; "no" on the fire question. Code two was "yes" on fire, "no" on fuel leakage. Code three was both "yes" and code four was both "no." In the coding, cases where neither box was marked were coded as "no" on that variable. There was consequently no provision for estimating the amount of missing data. No "unknown" box was included on the form in order to force the investigating officers to make a determination. Past experience indicated that inclusion of an "unknown" response resulted in loss of much information. Cases with code "2" (fire, yes; fuel leak, no) are cases where either there was complete involvement of the vehicle so that the officer could not determine whether fuel leaked or not, or cases where there was no evidence of fires spreading on the ground from leaked fuel. Table 5.4.4 presents the frequencies of each code in the Michigan 1978 data for passenger cars.

Table 5.4.4.
Fuel Leakage and Fire Frequencies, Michigan 1978

Year	Leak	Fire	Fire and Leak	None	Total
1979 . .	11	7	2	2501	2521
1978 . .	295	64	21	44719	45099
1977 . .	383	71	37	62019	62509
1976 . .	334	61	25	49578	49998
1975 . .	312	64	31	37835	38242
1974 . .	507	94	33	46746	47380
1973 . .	667	94	38	53869	54668
1972 . .	690	78	34	47502	48304
1971 . .	593	52	32	35576	36253
1970 . .	572	40	31	28527	29170
1969 . .	489	40	28	22430	22987
1968 . .	393	32	19	17018	17462
1967 . .	228	17	10	10332	10587
1966 . .	169	14	9	6321	6513
1965 . .	130	8	2	4199	4339
1964 . .	61	4	4	1975	2044
1963 . .	39	2	2	1012	1055
1962 . .	17	0	4	531	552
1961 . .	6	1	0	192	199
pre-1960	17	1	3	486	507
Total .	5913	744	365	472,056	479,078

Table 5.4.5 tabulates the rates of fires and fuel leakage in crash-involved passenger cars in Michigan 1978. Overall there were about 12.3 cases of fuel leakage per thousand vehicles. About 2.3 fires occurred per thousand vehicles, and either fire or fuel leakage occurred in about 14.6 per 1000 of the crash-involved vehicles.

Table 5.4.5
Fuel Leakage and Fire Rates, Michigan 1978
(per thousand crash-involved passenger cars)

Year	Leak Only	Fire Only	Fire and Leak	Leaks	Fires	All
1979 . .	4.36	2.78	0.79	5.16	3.57	7.93
1978 . .	6.54	1.42	0.46	7.01	1.88	8.42
1977 . .	6.13	1.14	0.59	6.72	1.73	7.86
1976 . .	6.68	1.22	0.50	7.18	1.72	8.40
1975 . .	8.16	1.67	0.81	8.96	1.48	10.64
1974 . .	10.70	1.98	0.70	11.40	2.68	13.38
1973 . .	12.20	1.72	0.70	12.90	2.41	14.62
1972 . .	14.28	1.61	0.70	14.99	2.32	16.60
1971 . .	16.36	1.43	0.88	17.24	2.32	18.67
1970 . .	19.61	1.37	1.06	20.67	2.43	22.04
1969 . .	21.27	1.74	1.22	22.49	2.96	24.23
1968 . .	22.51	1.83	1.09	23.59	2.92	25.43
1967 . .	21.54	1.61	0.94	22.48	2.55	24.09
1966 . .	25.95	2.15	1.34	27.33	3.53	29.48
1965 . .	29.96	1.84	0.46	30.42	2.30	32.27
1964 . .	29.84	1.96	1.96	31.80	3.91	33.76
1963 . .	38.54	1.98	1.98	40.51	3.95	42.49
1962 . .	30.80	0.00	7.25	38.04	7.25	38.04
1961 . .	30.15	5.03	0.00	30.15	5.03	35.18
pre-60 .	33.53	1.97	5.92	39.45	7.89	41.42
post-75	6.39	1.27	0.53	6.92	1.80	8.19
post-76	6.26	1.29	0.54	6.80	1.83	8.09
1976 . .	6.68	1.22	0.50	7.18	1.72	8.40
68-75 .	14.34	1.68	0.84	17.65	2.51	19.32
61-67 .	25.70	1.82	1.22	26.93	3.04	28.75
pre-1961	33.53	1.97	5.92	39.45	7.89	41.42
Totals .	12.34	1.55	0.76	13.10	2.31	14.68

A model which included different mean fire rates in the four groups of model years corresponding to the versions of the standard was fit to the police accident data from Michigan. The resulting means and associated standard errors were:

Post-1976	1.81 ± 0.128/1000
1976	1.72 ± 0.185/1000
1968-1975	2.50 ± 0.092/1000
Pre-1968	2.91 ± 0.335/1000

For this analysis, all fires were used. The model fit the data well. The chi-squared for lack of fit was 13.20 with 16 degrees of freedom; P = 0.66. The fire rates for the 1976 vehicles did not differ significantly from that for the later vehicles (that is, the rates of 1.8/1000 and 1.7/1000 can be regarded as equal except for chance variation). Both the 1976 and post-1976 rates differed significantly at the 1 percent level from the earlier rates. However, the difference in the pre-1968 and 1968-1975 rates was not statistically significant. (The chi-squared statistic was 1.43 and 1 df, P = 0.23).

The Michigan police data include a variable, TAD, that is a measure of the severity of the crash. Although this measure is based on the damage to the car, and thus may be a different scale for cars of different sizes or constructions, it does provide a useful measure of crash severity. It is a seven point scale, with increasing amounts of damage for larger values of the variable. The crash fire rates by TAD level and standard version are given in Table 5.4.6. A general increasing trend in the rates with increasing TAD level is seen within each version of the standard. The highest TAD level has substantially higher fire rates than any of the others.

If model years of cars corresponding to different versions of the standard had different distributions of crash severity, this could confuse the comparisons of the standards. This would be particularly the case if one set of model years had crashes which had a significantly different proportion of TAD-7 type crashes. To investigte this possibility, adjusted fire rates were computed by the direct method. The adjustment was for TAD severity and the standard population was taken as the distribution of all passenger cars in Michigan 1978 crashes. The adjusted rates and estimated standard errors were:

Table 5.4.6
Fire Rates by TAD Level, Michigan 1978 Rates per Thousand Crashes

TAD Level	Pre-1968	Standard 301-68	301:76	All
1 .	0.91	1.43	1.20	1.32
2 .	2.17	1.53	1.19	1.45
3 .	2.96	1.39	1.32	1.45
4 .	3.82	1.90	1.93	2.02
5 .	3.81	4.04	2.08	3.40
6 .	6.38	6.43	3.96	5.66
7 .	21.63	29.53	21.22	26.72
All	3.14	2.51	1.80	2.31

Pre-1968	2.90 ± 0.326	per thousand vehicles
301-1968	2.48 ± 0.091	per thousand vehicles
301-1976	1.91 ± 0.113	per thousand vehicles

The difference in the adjusted rates between the pre-1968 and the 1968-1975 models was not significant, however, the other two comparisons were. The adjusted rates correspond to a 14.5% reduction with the first version of FMVSS 301, a further 22.9% reduction with the 1976 (and later) version of FMVSS 301, and a 34.1% reduction in the fire rate from the pre-standard models to the current (post-1975) models. Thus, there was a drop in the fire rates after adjusting for possible different crash severities as measured by the TAD scale. Inspection of Table 5.4.6 shows that similar reductions in the rates occur within most of the TAD levels, although there are more fluctuations there.

To test whether there was a linear increase in the fire rates which could be a result of age, a model was fit that included age as a covariate, and effects for the different versions of the standard. This model also fit the data very well. The chi-squared statistic to test for lack of fit was 12.75 with 15 degrees of freedom; P = 0.62. The estimated parameters and standard errors of this model were:

u = 2.52 ± 0.6776/1000
b(age) = 0.030 ± 0.0450/1000
b(1976+) = 0.133 ± 0.2342/1000
b(1976) = 0.661 ± 0.2700/1000
b(1968+) = -0.229 ± 0.4476/1000

The observed and fitted values are plotted in Figure 5.4.2.

The model estimated a slight trend for the fire rates to increase with age. However, the slope was not significantly different from zero. ($P = \geq 0.5$.) Including the age as a covariate, the model estimated a reduction in the fire rate of 0.23 of a fire per 1000 crash involved-passenger cars for models newer than 1968. This indicates a drop in the fire rate concurrent with the models that FMVSS 301 first applied to this drop was not significantly different from zero ($X^2 = 0.26$, $P = 0.61$).

A reduction in the fire rate concurrent with the 1976 model was also estimated. This reduction was estimated as 0.89 fires per 1000 crash-involved passenger cars. This approached significance ($X^2 = 2.25$, $P = 0.13$). Finally, a reduction for the 1977 and later models was estimated as 0.76 fires per thousand passenger cars. This did not reach significance ($X^2 = 1.44$, $P = 0.23$).

Taken together, the three standard effects were just significant at the 10 percent level ($X^2 = 6.35$, 3 df, $P = 0.096$). Thus, there is evidence at the 10 percent level to conclude that reductions in the final rates occurred coincident with each version of FMVSS 301 after adjusting for age as a covariate. These reductions were small (0.23, 0.89, and 0.70 fires per 1000). However, they compare to an average of 2.52 fires per thousand.

Thus, in the Michigan data, an all means model is adequate. Significant reductions in the fire rate were observed concurrent with the models affected by FMVSS 301-68 and FMVSS 301-76 (no additional change was noted for 1977 models). Even if age is included as a covariate (its slope is not significantly different from zero) reductions concurrent with the two main versions of the standard were observed. These reductions were significant at the 10 percent level. Thus, while these data do not imply causality, it is reasonable to assume that the 1968 version of the standard reduced the post-crash fire rate by about one fire for every four thousand crashes (0.23/1000). Likewise, the strengthening of the standard for 1976 and later models is associated with an additional reduction of about two fires for three thousand crashes (0.66/1000).

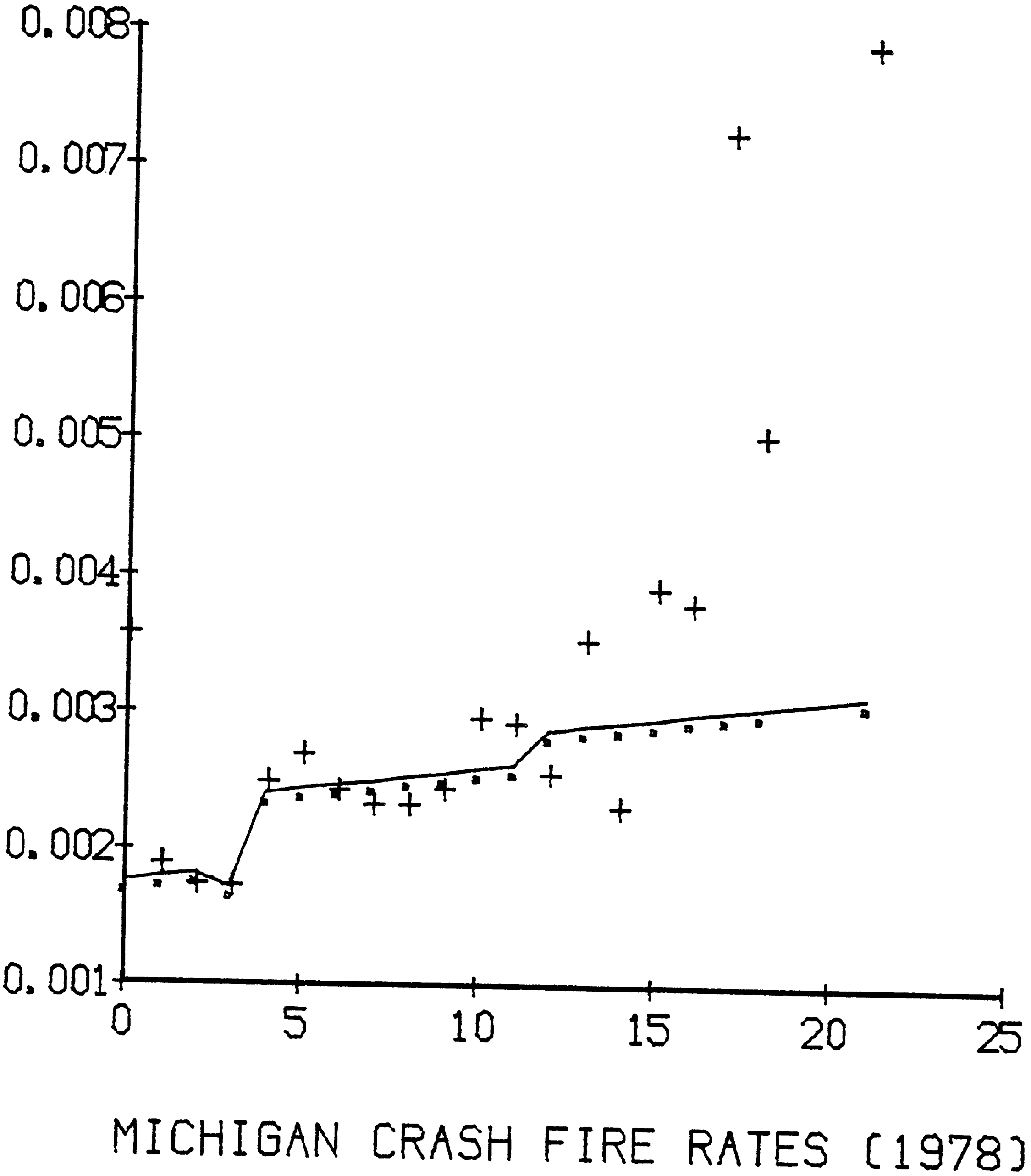

0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
5
10
15
20
25
MICHIGAN CRASH FIRE RATES [1978]

Figure 5.4.2

5.4.2.2. Leaks. In analyzing the fuel leakage, all cases with fuel leakage marked "yes" were used. This included a small percentage of leaks where fire also occurred. The all means model had a significant lack of fit. The means and standard errors were estimated as:

Post-76	6.79 ± 0.247/1000
1976	7.18 ± 0.378/1000
1961-75	13.94 ± 0.216/1000
Pre-1968	26.42 ± 0.998/1000

The means for post-76 and 1976 models clearly were not significantly different. Both of these rates differed significantly from the 1968-1975 rate and from the pre-1968 model rate. In addition, the 1968-75 rate differed significantly from the pre-1968 rate.

Age was incorporated as a covariate to try to improve the fit and to see whether the differences in means could be explained by the different ages of the groups. The incorporation of a linear age effect improved the fit substantially (X^2 for lack of fit was reduced from 399.8 to 31.1, 16 and 15 df, respectively), but the lack of fit was still significant at about the 1 percent level (P = 0.009).

The estimated parameters and standard errors were:

u = -0.516 ± 1.7214/1000
E(age) = 2.059 ± 0.1072/1000 per year
T(1976+) = 2.605 ± 0.4777/1000
T(1976) = 0.096 ± 0.5625/1000
T(1968+) = 1.425 ± 1.2519/1000

The slope was highly significant indicating a definite trend for the fuel leakage rate to increase with the age of the vehicle. This effect was so strong that the estimated group effects corresponding to the different standards were all positive, indicating that the fuel leakage rates for these models were higher than would be predicted on the basis of the age trend. The observed and fitted rates are plotted in Figure 5.4.3.

None of the estimated standard effects was significant at the 5 percent level. However, the latest one was barely significant at the 10 percent level. The conclusion is that the differences in crash fuel leakage rates among model years is best explained by a linear trend for those rates to be larger for older vehicles. While this is consistent

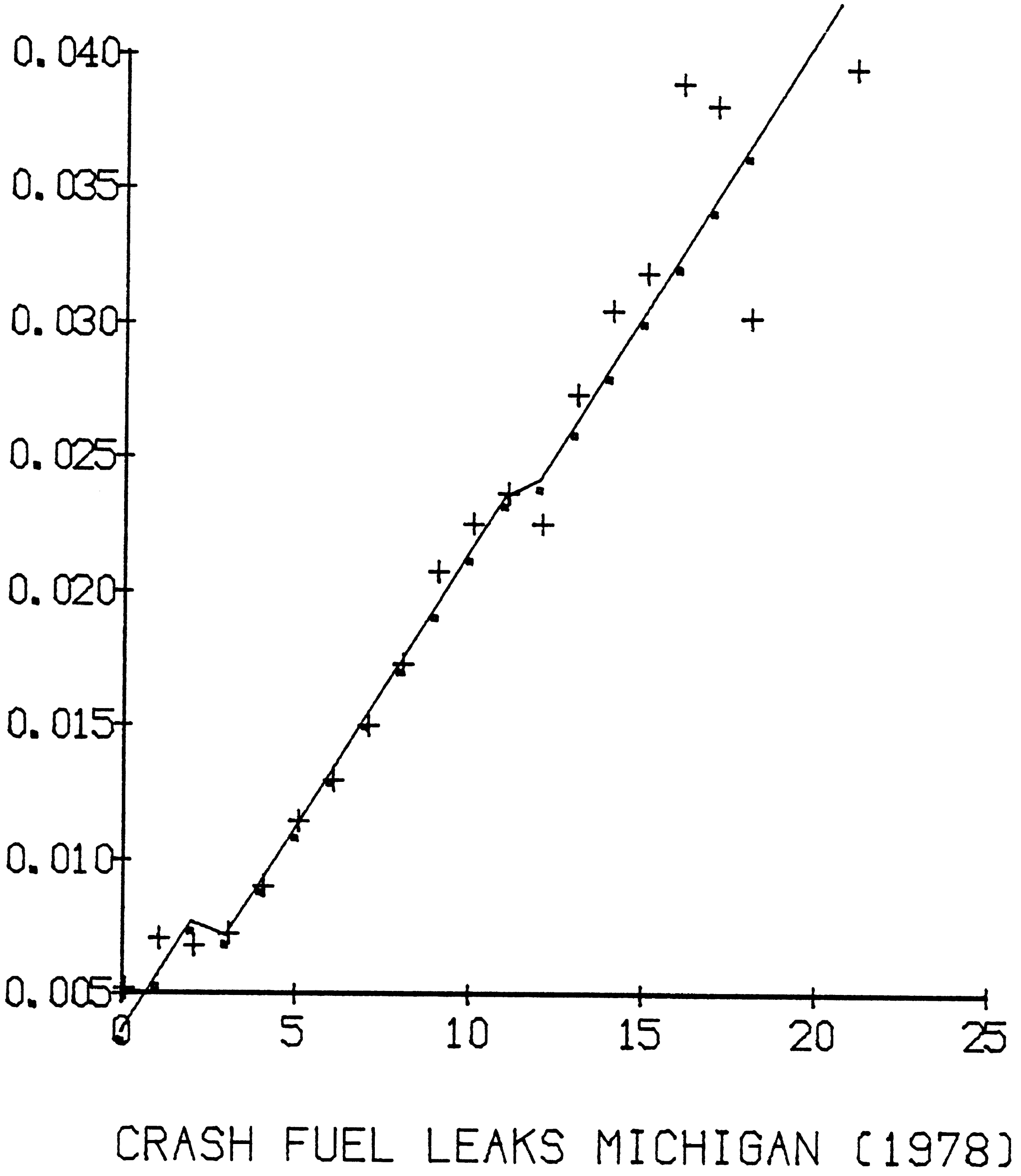

0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0
5
10
15
20
25
CRASH FUEL LEAKS MICHIGAN [1978]

Figure 5.4.3

with a beneficial effect of FMVSS 301, it is also consistent with an aging effect, or different crash characteristics for older cars. As a result, while the Michigan data show reductions in fire rates associated with FMVSS 301, they do not show corresponding reductions in fuel leakage rates. Since the mechanism of fire reduction was to be by reductions in fuel leakage, this casts serious doubts on attributing causality for the reduction in fire rates to the standard.

5.5 Data from the State of Missouri.

The data from Missouri consist of passenger car fires from fire department data (NFIRS) and police accident data from the Missouri Department of Transportation. Table 5.5.1 presents the frequencies by model year of all passenger car fires, those coded as caused by fuel spillage (code 41), by collision, accident, or overturn (code71) and by the exclusion surrogate. In these data, very few of the passenger car fires had either code 41 or code 71 as the cause of the fire. While it is possible that the fire to crash ratios are much smaller in Missouri than elsewhere, it seems more likely to be a difference in recording. As a result, the primary analysis uses the exclusion surrogate ratios, which are more consistent with other data sets. The overall ratio of surrogate fires to crashes is 3.90 per thousand.

There were a total of 11 fatalities reported among the passenger car fires, only five of which could be matched to specific model years. There were thus 0.036 fire-associated fatalities per crash. There were an additional 50 injuries, 36 of which could be matched to specific model years. This gives a ratio of 0.164 (non-fatal) fire-associated injuries per crash. Grouping the model years corresponding to three different versions of the standard gives the fire associated fatalities to crash ratios of 0.018/1000 (current), 0.015/1000 (1968-1975) crashes and 0.023/1000 (pre-1968). The corresponding ratios for injuries are 0.088/1000, 0.103/1000, and 0.227/1000, respectively. Although these ratios show reductions corresponding to the later versions of the standard, the small number of fatalities and injuries together with the difficulty in matching them to model years and to crashes means that little importance should be attached to them.

Table 5.5.1

Passenger Car Fires and Crash Frequencies
Missouri 1977

Model Year	All Fires	Code 41	Code 71	Exclusion Surrogate	Crashes
1978	2	0	0	2	1,195
1977	32	0	2	24	24,336
1976	66	3	3	42	31,149
1975	83	2	2	59	24,114
1974	107	1	1	72	29,088
1972	132	6	5	95	33,511
1971	126	3	3	99	23,474
1970	137	4	5	110	23,178
1969	143	9	3	112	23,084
1968	150	4	2	115	17,989
1967	91	4	1	79	13,288
1966	115	5	4	92	10,971
1965	78	0	1	66	8,573
1964	68	2	2	53	5,580
1963	49	1	1	38	3,479
1962	25	0	0	20	2,068
Missing	606	17	17	10	---
Total	2,123	66	54	1188	304,516

Table 5.5.2 presents the fire to crash ratios by model year. When these are grouped by version of the standard, these ratios show reductions by each version of the standard. When an all means model was fit to the data, the parameters and their standard errors were estimated as:

Post-1976	1.00	± 0.198/1000
1976	1.35	± 0.208/1000
1968-1975	3.38	± 0.128/1000
pre 1967	7.56	± 0.411/1000

fires per crash. The post 1976 and the 1976 ratios are not significantly different. All other pairwise differences are significant at the 1% level. This model showed a substantial lack of fit (x^2=84.14

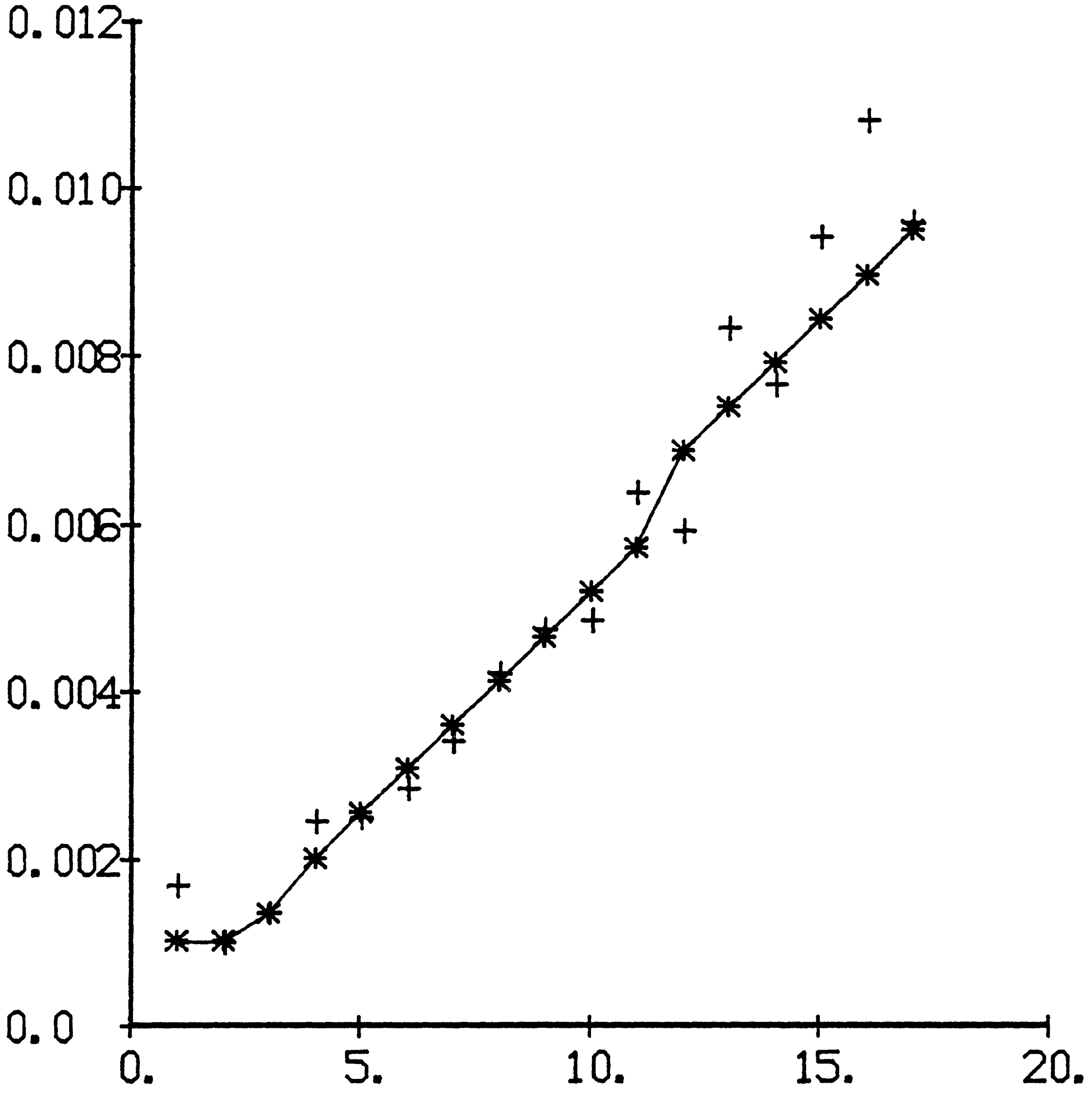
Table 5.5.2

Fire/Crash Ratios
Missouri 1977
(per 1000 Crashes)

Model Year	All Fires	Code 41	Code 71	Surrogate	Codes 41771
1978	1.67	0.00	0.00	1.67	0.00
1977	1.31	0.00	0.08	0.99	0.08
1976	2.12	0.10	0.10	1.35	0.19
1975	3.44	0.08	0.08	2.45	0.17
1974	3.68	0.03	0.03	2.48	0.07
1973	3.94	0.18	0.15	2.83	0.33
1972	4.21	0.17	0.07	3.40	0.24
1971	5.37	0.13	0.13	4.22	0.26
1970	5.91	0.17	0.22	4.75	0.39
1969	6.19	0.39	0.13	4.85	0.52
1968	8.34	0.22	0.11	6.39	0.33
1967	6.85	0.30	0.08	5.95	0.38
1966	10.48	0.46	0.36	8.39	0.82
1965	9.10	0.00	0.12	7.70	0.12
1964	12.19	0.36	0.36	9.50	0.72
1963	14.08	0.29	0.29	10.92	0.57
1962	12.09	0.00	0.00	9.67	0.00
Post75	1.76	0.05	0.09	1.20	0.14
1968-75	4.92	0.17	0.11	3.74	0.28
pre1967	9.69	0.27	0.21	7.92	0.48
Total	7.01	0.22	0.18	3.90	0.39

with 13 degrees of freedom). This indicates that there was a large amount of variability in the ratios within standard groups-more than could be explained by random variations.

An additional model was fit, which used the age of the vehicle as a covariate, and included changes in level corresponding to the changes in the standard (model years 1968, 1976, and 1977). This model fit the data well. (X^2 due to error 10.1 with 12 degrees of freedom, P = 0.61). The observed ratios (+) and the fitted values (*)are plotted in Figure 5.5.1, where the abscissa represents the age and the ordinate, the fires to crash ratio.



MISSOURI FIRE CRASH RATIOS 1977

Figure 5.5.1

The parameters of this model were estimated as

mean	1.05	± 0.861/1000
slope(age)	0.53	± 0.061/1000
t (77)	0.19	± 0.293/1000
t (76)	-0.13	± 0.329/1000
t (68)	-0.63	± 0.596/1000

Of these, only the slope--the linear trend in age--was significantly different from zero. That is, all of the differences in ratios among the model years can be described adequately by a linear increase with the age of the car. The estimated effects of the standards after adjusting for this trend were:

1968 standard	-0.626	± 0.596/1000
1976 standard	-0.758	± 0.758/1000
1977 standard	-0.572	± 0.832/1000

where the negative signs indicated a reduction in the ratios from those predicted by the linear trend. However, none of these reductions is significantly different from zero. While the linear trend could result in whole or in part from the standard, it could also be a result of the deterioration of the vehicle with age, or other factors associated with the age of the vehicle.

The data from Missouri are thus best described by a fire to crash ratio smoothly increasing in a linear fashion with the age of the vehicle. Although reductions in addition to this occurred corresponding to each version of the standard, none of these was significant. At most the standard appears to reduce the fire rate by about three-fourths of a fire per thousand crashes. Most of this possible reduction was associated with the first version of the standard smaller reductions with the later two versions. Thus, the Missouri data indicate little or no effect.

5.6 Data from Idaho

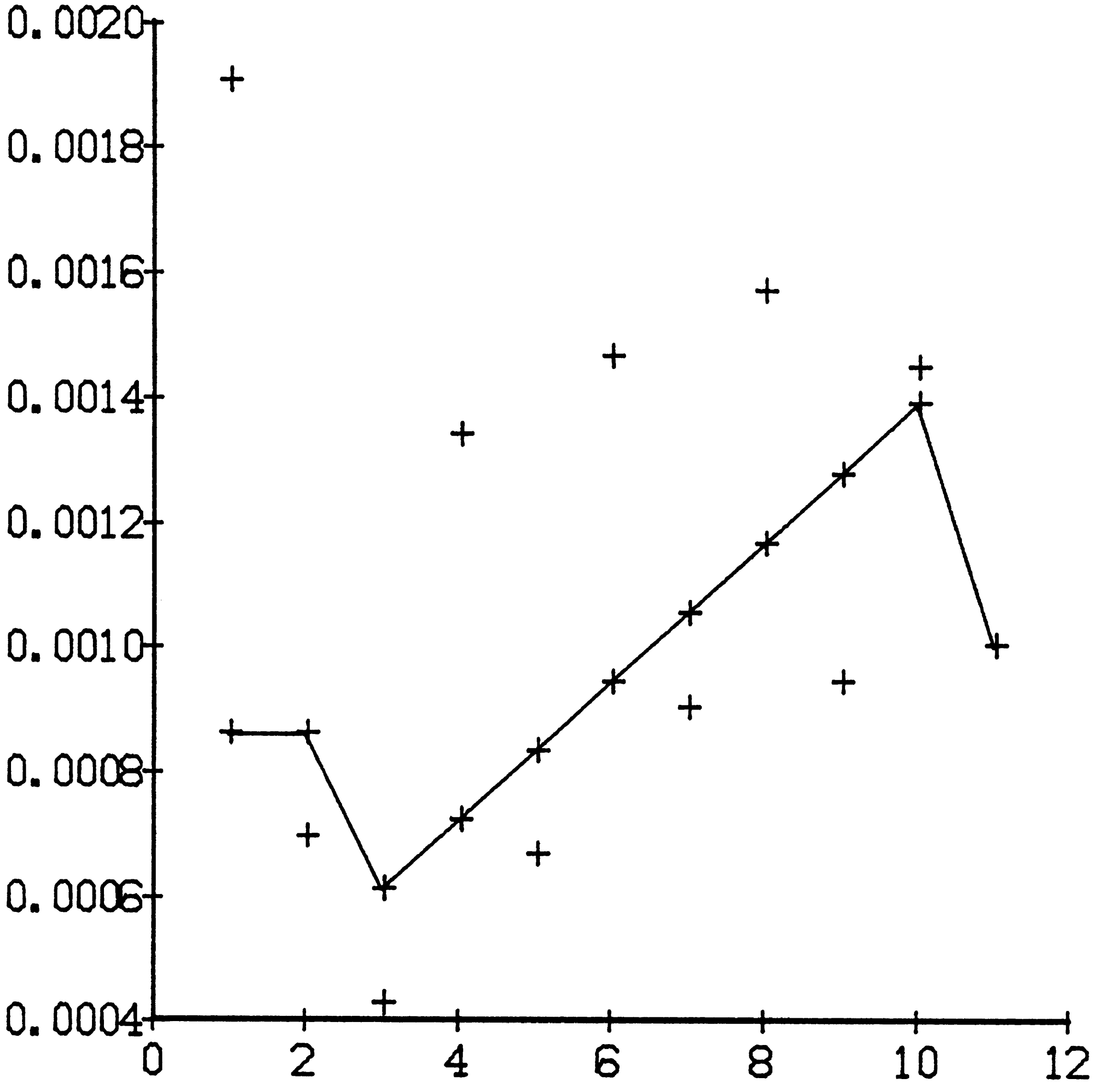
The data from Idaho are police accident data: Crashes which involve fire are reported by a variable checked on the accident reporting form. There were a total of 41 fires reported among 44,602 crashes in 1976, for an overall fire rate of 0.92 fires per thousand crashes. In the 1977 data, a total of 54 fires were reported among 45,240 crashes for a rate of 1.19 fires per thousand crashes (see Figure 5.6.1). Tables 5.6.1 and 5.6.2 give the frequencies of crash fires and crashes by model year for the 1976 and 1977 data, respectively. The crashes are separately reported for fatal crashes, personal crashes, and property damage crashes, as well as the total. Combined data are presented in Table 5.6.3.

The three means model fit the data from Idaho adequately (the lack of fit chi-squared was 12.44 with 8 degrees of freedom, P=0.13). The means were estimated as 0.86 fires per thousand (current) 0.90 fires per thousand (1968-1975) and 1.00 fires per thousand (pre-1968 standard). There were thus only very slight differences in the mean crash fire rates by the different version of the standard. The standard errors associated with the three means were were 0.289/1000, 0.125/1000, and 0.213/1000, respectively. There were no significant differences among the three means.

A second model was fit to the data. This model included a linear effect for age, an overall intercept or mean, and level effects for the two versions of the standard (starting in 1968 and 1976). The parameters and their associated standard error were estimated as:

Mean = 1.00 $\pm$ 0.213/1000
Slope = 0.11 $\pm$ 0.056/1000 per year
1968 Standard = -0.50 $\pm$ 0.399/1000
1976 Standard = 0.36 $\pm$ 0.374/1000

This model also fit well (X^2 = 8.47, 7 df, P = 0.29). However, only the slope and the overall mean are significantly different from zero. The model estimates that the fire rate dropped 0.139 fires per thousand crashes with the 1976 standard. However, this is not statistically significantly different from zero. Its standard error is 0.3588 per 1000 crashes, so that the change could easily be the result of chance



IDAHO CRASH FIRE RATES (1977)

Figure 5.6.1

Table 5.6.1

Crash and Fire Frequencies
Idaho 1976

Model Year	Fatals		Personal Injury		Property Damage		Total	
	Fires	Crashes	Fires	Crashes	Fires	Crashes	Fires	Crashes
1977	0	0	0	20	0	118	0	138
1976	0	21	0	514	1	2,347	1	2,882
1975	0	16	1	749	0	2,859	1	3,624
1974	0	15	1	800	4	3,502	5	4,317
1973	1	25	0	848	2	3,766	3	4,639
1972	2	21	1	751	3	3,379	6	4,151
1971	0	9	1	594	2	2,848	3	3,451
1970	0	16	1	619	2	2,648	3	3,283
1969	0	9	1	562	3	2,667	4	3,238
1968	0	11	2	506	6	2,392	8	2,909
1967	0	56	1	2,288	6	9,629	7	11,970
Total	3	202	9	8,260	29	36,181	41	44,643
Rate(per 1000)	14.85		1.09		0.80		0.92	
Standard Error	8.58		0.36		0.15		0.14	

Table 5.6.2

Crash and Fire Frequencies
Idaho 1977

Model Year	Fatals		Personal Injury		Property Damage		Total	
	Fires	Crashes	Fires	Crashes	Fires	Crashes	Fires	Crashes
1978	0	0	0	26	0	143	0	169
1977	0	19	3	596	3	2,394	6	3,009
1976	0	25	1	861	3	3,426	4	4,312
1975	1	18	0	721	1	2,653	2	3,398
1974	1	20	1	74	4	3,154	6	3,895
1973	0	15	1	867	2	3,470	3	4,352
1972	0	22	2	788	4	3,240	6	4,050
1971	0	17	1	580	2	2,609	3	3,206
1970	0	15	1	566	6	2,510	7	3,091
1969	0	21	1	566	1	2,536	2	3,123
1968	0	20	0	478	0	2,123	0	2,621
1968	0	40	4	2,005	11	7,961	15	10,014
Total	2	232	16	8,781	36	36,222	54	45,240
Rate(per 1000)	8.547		1.819		0.993		1.192	
Standard Error	6.044		0.455		0.165		0.162	

fluctuation.

Similarly the model estimated a reduction of 0.502 fires per thousand crashes associated with the 1968 standard. While this is also not significant, it approaches significance at the 10 percent level ($X^2 = 2.47$, $P = 0.116$). The estimated standard error is 0.3192 fires per thousand crashes. The slope estimates that the fires per crash increases about 0.1 fire per thousand crashes for every year of age of the vehicle. The slope was just significant at the 5 percent level ($X^2 = 3.97$, $P = 0.0463$). The observed and predicted values were plotted in Figure 5.6.1.

All of the possible effects of the standards on the Idaho data may be judged not significant. Fitting a single mean to the fire rates for all models gave an estimated crash fire rate of 0.92 fires per thousand crashes, with a standard error of 0.101 per thousand. There was little evidence of lack of fit in this model ($X^2 = 12.65$, 10 df, $P = 0.244$).

Although the standard may have reduced the fire rates in the Idaho data, the data were insufficient to conclude that the small differences observed were not due to chance. Thus although the data show slight beneficial changes in rates associated with the timing of the standard, they are insufficient to conclude that these changes are real; that is, not simply due to chance. Of course, even if these were real, one could not conclude that they were caused by the standard. The observed difference (0.86, 0.90, 1.00 of a fire per thousand crashes) are so small that one may question their practical importance even if they were real and were the result of the standard.

5.7 Data from the State of Ohio

Passenger car fires were identified in the statewide fire department data from Ohio as reported to the NFIRS. There were 67,633 records of mobile property in the NFIRS file. Of these, 54,931 were not passenger cars or were missing data. There remained 12,702 records of passenger car fires in the incident file, and 12,469 records in the equipment file. (The equipment file contains the data describing the car type--that is, the model year.) Of the records in the incident file, 541 had no matching cases in the equipment files, and of those in

Table 5.6.3

Crash Fire Rates
Idaho (1976 and 1977)

Model Year	Rate	Standard Error
1978	0.00	7.210
1977	1.91	0.778
1976	0.70	0.311
1975	0.43	0.247
1974	1.34	0.404
1973	0.67	0.272
1972	1.46	0.422
1971	0.90	0.368
1970	1.57	0.496
1969	0.94	0.385
1968	1.45	0.511
<1968	1.00	0.213
post-1976	1.809	0.739
post-1975	1.047	0.316
1976	0.699	0.311
1968-75	1.064	0.136
pre-1968	1.001	0.213

the equipment file, 308 had no matching records in the incident file. There were a total of 12,161 complete records of passenger car fires available in the Ohio data from 1977.

The data on crashes were supplied to HSRI from the Ohio Department of Traffic Safety. A distribution of the number of passenger cars o each model year which were involved in police reported crashes was supplied. As a result, the data from Ohio have been used to construct ratios of car fires to cars in crashes for 1977.

Not all of the passenger car fires also involved a crash. Three possibilities were considered to try to relate car fires to crashes. Code 71 indicates that the source of ignition was a collision, overturn, or knockdown, while code 41 indicates that fuel spillage was the cause. (These are mutually exclusive.) Both of these had very few cases. An additional possibility that was used to exclude cases which were clearly not crash related and consider the rest relative to the crash distribution. For the exclusion surrogate arson and suspected arson, natural, electrical, etc., causes were excluded, and the remaining cases considered as possible crash-related fires. Table 5.7.1 presents the frequencies of all passenger car fires, code 41 fires, code 71 fires, and the exclusion surrogate fires as well as the distribution of crashes. The fire/crash ratios are presented in Table 5.7.2. While it is clear that codes 41 and 71 do not contain all of the crash-related fires, and while those codes may contain non-crash-related fires, the magnitude of the ratio of codes 41+71 fires to crashes is more consistent with ratios from other data sources than the other possible ratios.

Table 5.7.1

Passenger Car Fires and Crash Frequencies
Ohio 1977

Model Year	All Fires	Code 41	Code 71	Exclusion Surrogate	Crashes
1978	20	0	0	13	2,376
1977	222	6	5	138	44,186
1976	390	6	7	242	57,083
1975	511	15	3	317	46,135
1974	885	41	18	544	62,375
1973	988	42	3	654	70,911
1972	1006	41	16	698	64,054
1971	1044	51	16	774	53,868
1970	1198	57	12	875	52,726
1969	1309	61	15	1,026	47,236
1968	1154	58	17	922	38,670
1967	882	60	7	704	26,182
1966	733	35	5	588	19,668
1965	567	29	7	453	13,936
1964	336	18	3	285	7,649
1963	164	10	2	131	4,215
1962	121	4	1	89	2,150
<1962	238	7	1	164	1,364
Missing	1267	39	16	842	---
Total	13,010	580	159	9,461	614,784

Table 5.7.2

Passenger Car Fire/Crash Ratios
Ohio 1977 (Per 1000 Crashes)

Model Year	All Fires	Code 71	Code 41	Exclusion Surrogate	Code 41 & 71
1978	8.42	0.00	0.00	5.47	0.00
1977	5.02	0.11	0.14	3.12	0.25
1976	6.83	0.12	0.11	4.24	0.23
1975	11.08	0.07	0.33	6.87	0.39
1974	14.19	0.29	0.66	8.72	0.95
1973	13.93	0.04	0.59	9.22	0.63
1972	15.71	0.25	0.64	10.89	0.89
1971	19.38	0.30	0.95	14.37	1.24
1970	22.72	0.23	1.08	16.60	1.31
1969	27.71	0.32	1.29	21.72	1.61
1968	29.84	0.44	1.50	23.84	1.94
1967	33.69	0.27	2.29	26.89	2.56
1966	37.27	0.25	1.78	29.90	2.03
1965	40.69	0.50	2.08	32.51	2.58
1964	43.93	0.39	2.35	37.26	2.75
1963	38.91	0.47	2.37	31.08	2.85
1962	56.28	0.47	1.86	41.40	2.33
<1962	174.49	0.73	5.13	120.23	5.87
1976+	6.12	0.12	0.12	3.81	0.23
1968-1975	18.57	0.23	0.84	13.33	1.07
pre-1968	38.01	0.35	2.17	30.51	2.51
Total	21.16	0.26	0.94	15.39	1.20

The fire department data indicated a total of 24 fatalities which could be identified with particular model year of vehicles. In addition, there were 114 injuries identified by model year of car. These were distributed by version of the standard as follows: 1976 and later, 2 fatalities and 7 injuries; 1968-1975, 13 fatalities and 79 injuries; pre 1968 models, 9 fatalities and 28 injuries. These injury data are probably not complete. However, it is instructive to consider the ratios of fatalities and injuries reported in the passenger car fires by the fire department data to fatal crashes, injury crashes, or all crashes. The relevant data are summarized in Table 5.7.3 All of the ratios show a favorable improvement for each successive version of the standard. The ratios are reduced by about a factor of two to one for each version of the standard. For example, the ratio of either a fatality or an injury per thousand crashes was 0.49/1000 in the pre-standard cars, 0.021/1000 the 1968-1975 models, and 0.087/1000 in the post 1975 models. While there is probably a considerable amount of underreporting, there is no obvious reason to indicate that this should bias the rates.

The fires/crashes ratios were modeled in two ways. The first was a four means model. This model estimates the mean ratio in each of four groups of model years, associated with the various versions of the standard. The estimated parameters and standard errors were:

1977 on	0.247 ± 0.0727/1000
1976	0.228 ± 0.0631/1000
1968-1975	0.870 ± 0.0446/1000
pre-1968	2.414 ± 0.1796/1000.

This model showed a significant lack of fit (X^2=88.79 with 14 d f). This means that there were significant differences among model years within groups. Even with the lack of fit it is clear that no significant difference lies between the 1976 and later models. Allowing for the lack of fit, there is evidence at the 5% significant level, that 1976 and later models have lower fire ratios than do the 1968-75 or the pre-1968 models.

A second model was fit which included a linear trend in age, an overall intercept, and additive effects for the different standards. The parameters and their standard errors were estimated as:

a(intercept) =0.118 ± 0.323/1000

b(age) =0.186 ± 0.022/1000

77+) =0.205 ± 0.099/1000

(76+) =-0.012 ± 0.107/1000

(68+) =-0.251 ± 0.239/1000

This model fit the data well. The X^2 for lack of fit was 15.9 with 13

Table 5.7.3

Fire Injuries and Fatalities
Ohio 1977

Standard Version	Fires		Crashes		All
	Fatals	Injuries	Fatals	Injuries	
1976+	2	7	286	26,711	103,645
1968-1975	13	79	1,199	110,855	435,975
pre-1968	9	28	277	20,778	75,164

Ratios

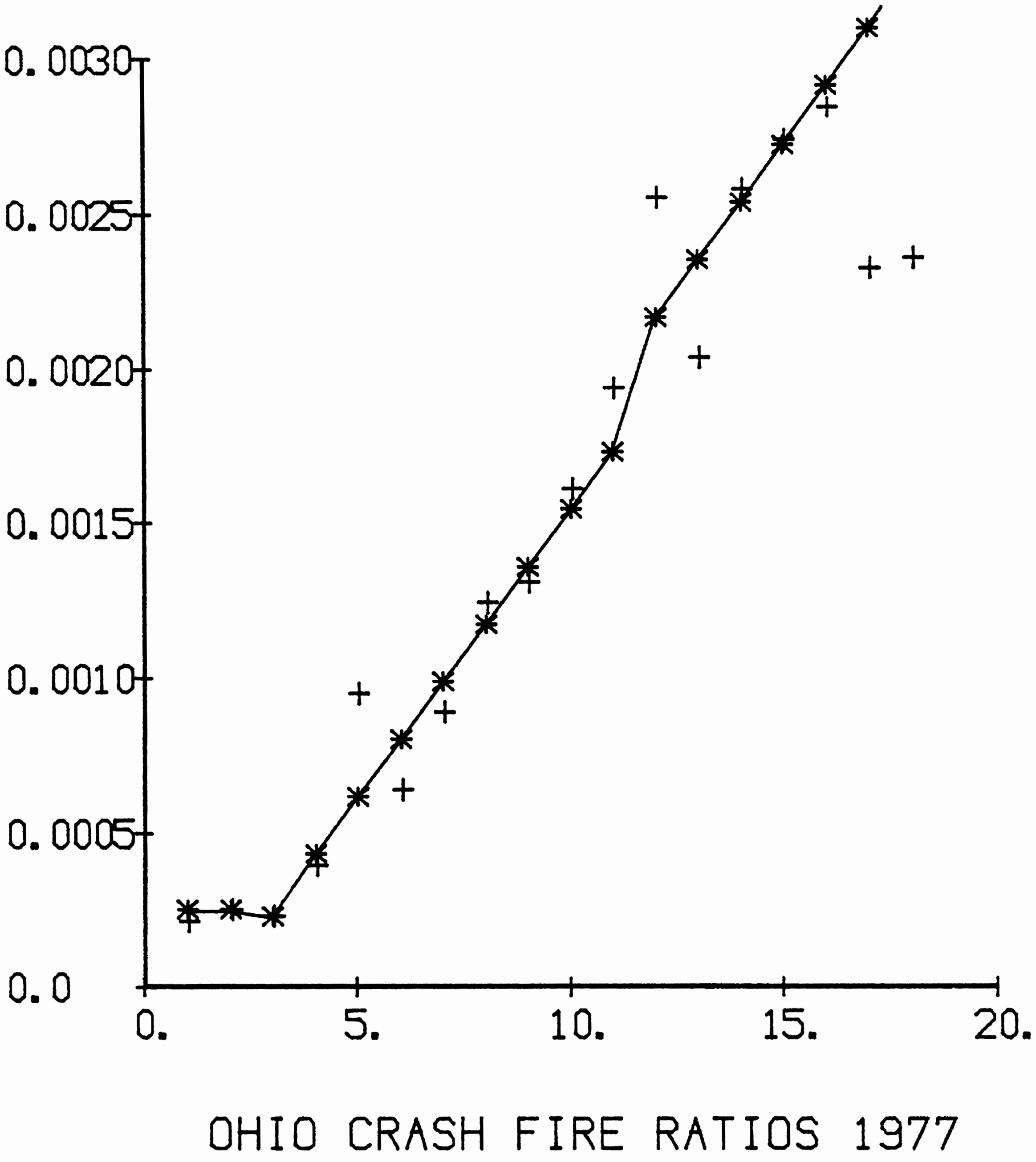
	Fire Fatals/ All Fatals	Fatals/ Crashes	Fire Injuries/ All Injuries	Fire Injuries/ All Crashes	Inj.+Fatals/ All Crashes
1976+	0.00699	0.0193/1000	0.262/1000	0.0675/1000	0.0868/1000
1968-78	0.01084	0.0198/1000	0.713/1000	0.1812/1000	0.2110/1000
pre-1968	0.03249	0.1197/1000	1.1348/1000	0.3725/1000	0.4923/1000

degrees of freedom (P=0.25). The linear effect was highly significant. Viewed collectively, the standard effects were significant only at the 10% level (P=0.068). The observed ratios (+) and the fitted values (* connected by lines) are presented in Figure 5.7.1. As can be seen in the figure, there is a noticeable drop in level corresponding to the 1968 model year. The ratios for 1976, 1977, and 1978 are essentially flat - 1976 is slightly lower. (The abscissa of the Figure is the age of the cars).

In this model, the linear effect for age was highly significant. Viewed collectively, the three standard effects were marginally significant (P=0.068). Each of the incremental effects is at best marginally significant. The estimated effects of the three versions of the standard, after adjusting for a linear age trend, were: 1968 version -0.251/1000; 1975 version -0.263/1000; and 1976 version -0.058/1000. These are reductions in the fire/crash ratios corresponding to the different versions of the standard.

It seems somewhat inconsistent that the most recent standard -the most stringent- shows the smallest beneficial effect. The most likely explanation for this is that some of the linear trend in age is a result of the standard. With the strong linear trend and the small ratios for new cars, little additional effect could be estimated. There is no way to completely separate the possible aging effect from the effect of the standard. The strong increasing trend of the ratios for older cars and the fact that the ratio must remain positive may make the estimated effect for the most recent version an artifact.

The conclusion from the Ohio data is that the newer model year passenger cars have substantially lower fire to crash ratios. However, this is primarily a linear trend in the age of the vehicle. There is some evidence of a change in intercept concurrent with the versions of the standard, but this did not reach significance at the 5% level. While the smooth trend in age could be partly an effect of FMVSS 301, it could also represent a more general age effect as well.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OHIO CRASH FIRE RATIOS 1977

Figure 5.7.1

5.8 Data from the State of Oklahoma

The Oklahoma police accident records include information about whether each vehicle involved in a crash caught fire or not. These data also include the age of the vehicle (in years) at the time of the crash. The accidents in the data file occurred during calendar 1977. The coding convention was that the current model year was assigned age "0", 1977 models were coded age "1", etc. The ages were grouped after seven years, so that all model years 1971 and earlier were combined. Since the first version of FMVSS 301 was effective for the 1968 models, this means that the pre-1968 standard and the post-1968 standard cannot be clearly distinguished. However, about half of the cars in the 1971 and earlier would be pre-standard vehicles.

Only a total of 54 fires out of 95,330 records were observed. Two of these fires had missing model years, while overall, model year was missing on 954 non-fire vehicles. Five of the vehicles that caught fire were involved in a fatal crash, 10 additional vehicles that caught fire were involved in a crash which resulted in personal injury, and 37 resulted in property damage only. Thus, of the vehicles that caught fire a a result of the crash, 9.6% were involved in fatal crashes, 19.2% were involved in personal injury crashes, and the remaining 71.2% were involved in property damage crashes.

Of the vehicles that did not catch fire after their crash, only 0.5% were involved in fatal crashes. 16.2% were involved in personal injury crashes, and the remaining 83.3% were involved only in property damage crashes. This over involvement of the fire crashes with fatal crashes and personal-injury crashes suggests that fire poses a substantial additional hazard to the occupants. However, such a conclusion may not be warranted from these data. Forty of the 52 fires occurred in single-vehicle crashes, which tend to be more severe than multiple-vehicle crashes. In addition, 45 of the fires occurred on roads where the legal speed limit was more than 45 mph (i.e. 50 or 55), suggesting that almost all of the fires occurred in rural or freeway crashes.

Table 5.8.1 presents the crash fire rates by model year for the Oklahoma crashes which occurred in 1977. An unusually large number of

Table 5.8.1

Crash Fire Rates
Oklahoma 1977

Model Year	Fires	Crashes	Rate (per 1000)	Standard Error
1977	0	10,696	0.00	0.094
1976	7	6,865	1.02	0.385
1975	6	8,496	0.63	0.258
1974	8	8,397	0.95	0.337
1973	2	9,008	0.22	0.157
1972	9	8,742	1.03	0.343
<1972	20	41,065	0.49	0.109
Missing	2	1,007	1.99	1.404
Total	54	95,276	0.57	0.077
1976 & later	7	17,561	0.409	0.151
1972-75	25	35,643	0.70	0.140
1971 & earlier	20	41,065	0.49	0.109

Table 5.8.2

Oklahoma Crash Fire Ratio by
Speed and Standard

Standard Version	0 MPH	1-29 MPH	30-45 MPH	46+ MPH	
1976	2/998 2.00	0/4255 0.00	0/8348 0.00	5/4012 1.25	0.40
1972-75	1/2224 0.45	0/8888 0.00	1/16,749 0.06	23/7791 2.95	0.70
pre-1972	1/3051 0.33	0/10,787 0.00	2/18,273 0.11	17/8956 1.90	0.49
	4/6486 0.62	0/24,185 0.00	3/32,734 0.07	45/20,879 2.16	

Table 5.8.3
Crash Fire Rates in Single- and Multiple-Vehicle Crashes
(Posted Speed Greater than 45 mph)--Oklahoma 1977

Model Year	Single			Multiple		
	Fires	Crashes	Rate	Fires	Crashes	Rate
1977	0	1037	0.00	0	1019	0.00
1976	4	1054	3.80	0	1019	0.00
1975	6	1005	5.97	1	889	1.13
1974	7	1082	6.47	0	878	0.00
1973	1	1123	0.89	1	860	1.16
1972	7	1088	6.43	0	837	0.00
<1972	16	5591	2.86	2	3348	0.60
Total	41	11,980	3.42	3	8,850	0.34
post-1976	4	2091	1.91	0	2031	0.00
1972-75	21	4298	4.89	2	3464	0.58
pre-1972	16	5591	2.86	2	3348	0.60

crashes involving new (1977) vehicles is noted. These apparently were mostly minor crashes, for when the data were filtered on posted speed or speed at or before impact, the number of 1977 vehicles reported is approximately equal to the number of 1976 model vehicles.

Table 5.8.2 presents the crash rates by posted speed and standard. In this table, model years 72-75 have been combined as the second version of the standard, and models prior to 1972 have been considered as the pre-standard models. This is clearly not exactly the case, but models prior to 1972 cannot be distinguished in the Oklahoma data. The zero category in the table consists of two types of crashes. One type is parked vehicles and the other is missing data on posted legal speed. Essentially all of the fires occurred where the posted speed was greater than 45 mph.

Since virtually all of the fires occurred where the posted speed was greater than 45 mph. Table 5.8.3 presents the crash fire rates by model year for single- and multiple-vehicle accidents, for which the posted speed was greater than 45 mph. In considering the subset of single vehicle crashes, the post-76 models have the lowest fire rate, 1.91/1000. The 72-75 models have the highest rate, 4.89/1000, while the pre-71 models have a rate of 2.86/1000.

It is difficult to attach too much meaning to these rates, since the two earlier rates do not correspond with model years when the standard changed. The data suggest that the post-1975 models have lower fire rates than the earlier models, although the single year 1976 is rather high. Whether these lower rates are a result of FMVSS 301 or of the aging of the vehicles being associated with higher crash fire rates is problematical.

There are too few data to support much model fitting, and there is no evident trend in the rates. Considering the three groups (pre 1972, 1972-1975, and post 1975), the differences in the crash fire rates are not significant (X^2=2.51, 2 degrees of freedom, P>01). However, if 1976 is included as a separate group, then the four rates do differ significantly ($X^2 = 10.4$, 3 degrees of freedom, $0.01<P<0.05$). Obviously the fact that all seven of the fires reported for post-1975 model year vehicles occurred in 1976 models accounts for the difference. The rates are not monotonic as would be expected if the increasingly stringent versions of FMVSS 301 were having progressively more effect. In fact, the 1976 models' rate is the highest. This is probably best viewed as a sampling artifact of the relatively small numbers. If the rates for the single-vehicle crashes which occurred where the posted speed was greater than 45 mph are considered, there are no significant differences among the rates, whether the 1976 model is considered separately or combined with the 1977 models ($X^2 = 6.87$, 3 df, or $X^2 = 4.58$, 2 df, $P>0.1$).

In conclusion, the data from Oklahoma do not show any statistically significantly differences among fire rates for model year groupings corresponding to the versions of the standard. Data limitations on the model year variable make it impossible to distinguish between cars built before and shortly after the first (1968) version of the standard. The 1976 models had the highest fire rates, followed by the 1972-1975 models. The pre-1972 models were relatively low, and no fires were observed in crashes involving 1977 models. The best conclusion seems to be that the FMVSS 310 standard had no effect observed in the data from Oklahoma. Although a 43% reduction in crash fires was reported comparing 1972-1975 models with 1976-1977 models, if the 1976 models were considered separately, a 46% increase for 1976 was observed, followed by a 100% decrease for 1977.

5.9 Data from the State of Oregon

Police accident data in Oregon contained fire as a crash variable. However, the model year of the vehicle was not included in the list of variables included in the computerized data. As a result, in order to determine the model year of a vehicle involved in a crash fire, one would have to match the case number to a file of the original hard copies of the accident report. Further, in order to obtain a distribution of the model years of passenger cars involved in crashes, one would have to sample the file of hard copies to record the model years. Because of confidentiality considerations, any work with the hard copies would have to be done by employees of the State of Oregon's Department of Transportation.

A computer search for the vehicles in the accident file which were involved in a crash followed by fire was done by Mr. Crawford Godsey of the Oregon Department of Transportation. This resulted in only twelve (12) cases of post-crash fires being identified in the 1976 and 1977 data. This number of cases is too small to add anything to the analysis. As a result, no further use was made of the Oregon crash data.

Fire department data from Oregon were obtained from the NFIRS. Table 5.9.1 gives the frequencies of car fires by model year. The table also gives passenger car registration for 1977. These latter data were supplied to HSRI directly from the state of Oregon through the kind assistance of Mr. Wayne Ivie, Operations Manager, Motor Vehicles Division, Oregon Department of Transportation.

The fire department data were used in two ways. The column headed "crash or spill" consists of those passenger car fires where the cause of ignition was either code 71 or code 41. Nearly all of these are thought to be post-crash fires. However, it is thought that these will substantially under-report the crash-fires. The column headed "surrogate" contains passenger car fires after removing those that were clearly not crash related (e.g. arson, natural causes). These data contain substantial numbers of cases where the crash relation is uncertain. For example "design defects" is included. It is likely that many of the fires reported here are not crash-related. The data did not permit a more definitive determination of crash-fires. (See discussion of attempts to derive a surrogate in Section 3.2.2.)

Table 5.9.1

Fire Department Data
Oregon 1977
Passenger Cars

Model Year	Car Fires	Crash or Spill	Surrogate	Registrations
1976 and later	80	8	70	279,833
1975	54	3	41	132,093
1974	65	3	52	149,398
1973	93	2	78	144,689
1972	107	7	86	114,348
1971	105	5	91	107,012
1970	135	10	124	116,457
1969	204	9	181	100,495
1968	228	13	209	87,672
1967	212	7	183	85,707
1966	185	7	166	77,956
1965	182	8	160	61,553
1964	189	6	160	46,560
1963	113	3	95	32,083
pre-1963	236	7	208	122,111
Missing	161	11	129	
Total	2349	109	2033	1,657,967

Table 5.9.2 presents the fire rates per 10,000 registered vehicles in Oregon. (The choice of 10,000 makes these rates approximately on the same scale as rates per 1000 crashes.) For the three versions of the standard, the crash fire rates are 0.77 per 10,000 cars (no standard)

Table 5.9.2

Fire Rates - Oregon 1977
(Rates per 10,000)

Model Year	Crash Fires	Standard Errors	Surrogate Fires	Standard Errors
post-1975	0.29	0.101	2.50	0.299
1975	0.23	0.131	3.10	0.485
1974	0.20	0.116	3.48	0.483
1973	0.14	0.098	5.39	0.610
1972	0.61	0.231	7.52	0.811
1971	0.47	0.209	8.50	0.891
1970	0.86	0.171	10.65	0.956
1969	0.90	0.299	18.01	1.339
1968	1.48	0.411	23.84	1.649
1967	0.82	0.309	21.35	1.578
1966	0.90	0.339	21.29	1.653
1965	1.30	0.460	25.99	2.055
1964	1.29	0.526	34.36	2.717
1963	0.94	0.540	29.61	3.038
1963	0.57	0.217	17.03	1.181
Total	0.66	0.063	12.26	0.272
Post-75	0.29	0.101	2.50	0.299
1968-75	0.57	0.077	9.05	0.308
pre-68	0.77	0.135	22.82	0.732

0.57 per 10,000 cars (1968-1975) and 0.29 per 10,000 cars (1976 and later). These rates are too low in actual value, but, since they are consistently defined for all model years, should indicate trends or differences.

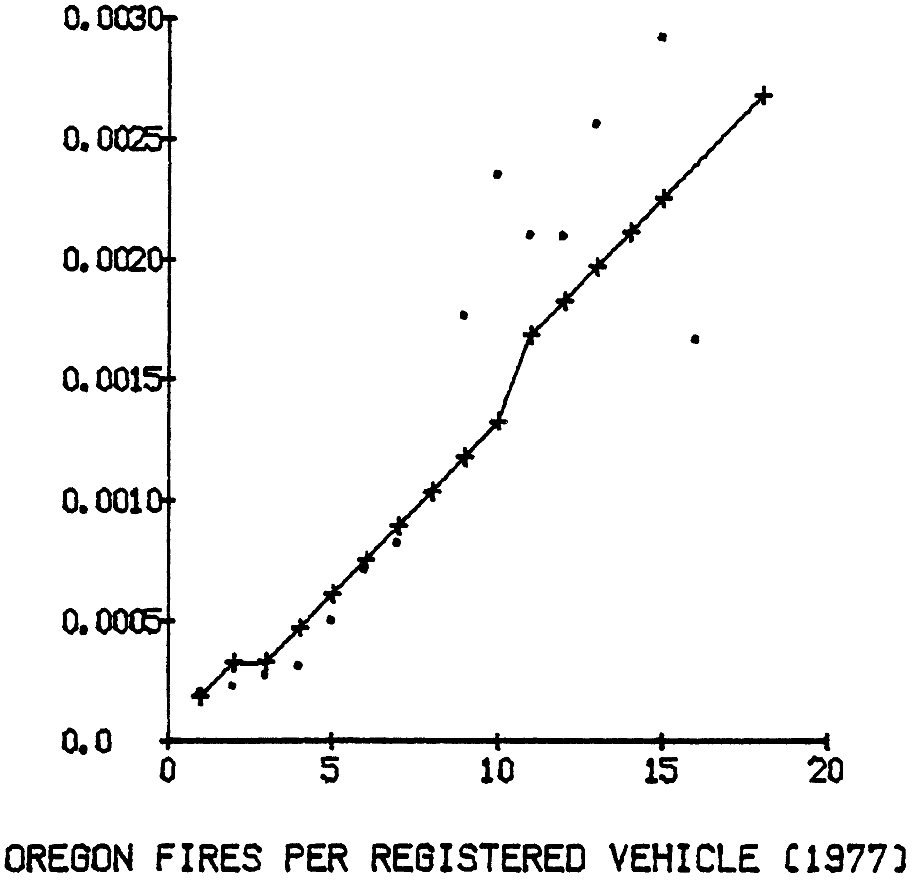
If only the obviously non-applicable car fires are excluded, the rates by version of the standard are 22.82 per 10,000 cars (no standard) 9.0 per 10,000 cars (68-75 version), and 2.5 per 10,000 cars (1976 and later version). The actual values of these rates are too high for crash-related fires, but again should correctly indicate trends or differences.

The surrogate rates are plotted as a function of the age or model year of the car in Figure 5.9.1. As can be seen in the figure, the differences in rates do not correspond simply to different levels coinciding with different versions of the standard. There are substantial differences among model years within a given version of the standard. Although there are fluctuations, there appears to be a general trend for the rates to increase with the age of the car. This trend is particularly apparent for model years 1968-1975. Older models rates appear constant (but with large variability). Thus there is the question of how much of the difference in rates relates to the standard and how much is simply a matter of the aging of the vehicle.

The three means model was fit to the data from Oregon. These data are ratios of fires (from fire department data) to registered passenger cars. Thus, the ratios do not directly address the question of crash fires. In this setting, registered vehicles are used as an approximate surrogate for crashes. The resulting ratios are approximately one tenth of what they would be with crashes as the denominator. However, crashes could not be identified with model years of cars in the Oregon data.

The estimated means were 0.249/1000, 0.594/1000, and 2.168/100 registered vehicles corresponding to post-75 models, 1968-1975 models, and pre-1968 models, respectively. The standard errors associated with these were, respectively: 0.02985, 0.02498, and 0.07126 per thousand. The lack of fit was highly significant. In part this reflects the fact that there was also a linear trend in the fire rates. However, part of the significant lack of fit is caused by the use of registration data as denominators. The extremely large numbers cause relatively small differences in the rates to be declared statistically significant, the model had an R^2 of 0.81, implying that 81 percent of the variability in the rates was explained by the three means. It was evident that the last mean was significantly larger than the first two. That is, pre-1968 models had a significantly higher fire rate than either the post-75 models, and the 1968-1975 models was not clearly significant.

A second model was fit which included a linear trend in age as well as differential effects for the two versions of the FMVSS 301 (beginning with the 1968 and 1976 models, respectively). The R^2 for this model was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20
OREGON FIRES PER REGISTERED VEHICLE [1977]

Figure 5.9.1

0.90, indicating that it explained 90 percent of the year-to-year variation of the fire rates. The lack of fit was still significant. However, no other trend or explanatory variable was found. The large lack of fit is presumed to be a result of the use of the large registration numbers of the denominator. The parameters of the model and their estimated standard errors were:

Mean = 0.256 ± 0.1703/1000
1975 = 0.145 ± 0.0556/1000
1968 = -0.219 ± 0.1331/1000
Slope = 0.143 ± 0.0115/1000 per year.

This model estimates that the fires per registered vehicle increases with the age of the car at approximately 0.14 fires per thousand registered vehicles per year of age. In addition, the model estimates that in addition to this trend with age, there was a drop of about 0.22 fires per thousand registered vehicles concurrent with the 1968 standard. However, this drop is not statistically significant. In addition, there was also a drop of 0.074 fires per thousand registered vehicles concurrent with the current (1976) version of the standard. However, this drop was also not statistically significantly different from zero. The observed and predicted rates are plotted in Figure 5.9.1.

The data from Oregon show a pattern which could be consistent with a beneficial effect of the FMVSS 301. However, the data are insufficient to conclude that such an effect is really there. While there are clearly differences in the average fire rates grouped by the model years affected by different versions of the standard, these differences are largely related to a smooth increase in the fire rates with the age of the vehicle. If age is used as a covariate, only very small, non-significant differences are observed. The numerator data are fire department data and are not clearly identified with crashes. The denominator data are registrations of passenger cars rather than crashes. As a result, while the data from Oregon do not contradict a possible beneficial effect of FMVSS 301, they do not add much evidence of such an effect.

5.10 Fatal Accident Reporting System (FARS) Data and National Crash Severity Study (NCSS) Data

5.10.1 Data From FARS

In the Fatal Accident Reporting System coders in each state are asked to note whether or not a fire occurred for each crash and for each vehicle involved. In addition to the notation of the presence or absence of fire, the FARS file contains information about the accident configuration, the points of initial and principal impact for each vehicle, the vehicle model year, etc. Given the FARS data alone it is possible to count the number of fire fatal involvements in any of several categories, and to compute the ratio of fire involvements to all involvements.

Three years of FARS data have been used in this study--data from calendar years 1976, 1977, and 1978. In tables 5.10.1 through 5.10.5 data from the three years have been combined and displayed for (1) rear-damaged cars, (2) front-damaged cars, (3) side-damaged cars, (4) cars in which a fatality occurred, and (5) all passenger cars involved in fatal accidents. Actual counts of fire occurrence and vehicle involvement, as well as the ratio of these two, are shown for each model year in these tables. At the bottom of each table the data are grouped into the periods covered by various versions of the standard.

In each of these categories, the ratio of fires to involvements is relatively constant with model year, and, in fact, is generally slightly higher for newer cars than for older ones. If improvement in fuel containment were the only factor responsible for changes in this ratio in successive model years, one would have to conclude that there is little evidence of improvement. For rear-damaged cars (Table 5.10.1) there is a slight reduction, but for other configurations (and for the totals) there is an increase for the newer model years.

An exception to this general pattern is that for rear-damaged cars. For rear-damaged cars there appears to be a reduction for the 1976 and later versions of the standard. This would be logical, since this latest version of the standard included a rear impact test as part of the demonstration of compliance. It is also interesting to note that the rate of fires in fatal cars that were rear-damaged is two or three

Table 5.10.1

Rear-Damaged Passenger Cars in
Fatal Crashes--FARS 1976-78

Passenger Car Model Year	Number of Cars With Fires	Number of Cars in Fatal Crashes	Ratio of Fires to Total Cars
1961	3	73	0.0411
1962	6	38	0.1579
1963	6	77	0.0779
1964	6	109	0.0550
1965	10	132	0.0758
1966	21	204	0.1029
1967	14	226	0.0619
1968	20	291	0.0687
1969	21	391	0.0537
1970	31	399	0.0777
1971	39	395	0.0987
1972	40	482	0.0830
1973	43	527	0.0816
1974	42	459	0.0915
1975	24	353	0.0680
1976	24	421	0.0570
1977	21	334	0.0629
1978	10	159	0.0629

Std. Version	Ratio(fires to cars)
pre-1968	.0768
1968-75	.0789
1976	.0570
1977-78	.0629

times the corresponding rate for fatal cars with other types of damage. This is probably indicative of interactions of several factors. In general fatalities are unlikely in rear impacts--unless a fire occurs.

An alternative explanation for the findings, however, would be that newer cars are less often involved in fatal accidents (perhaps because of many design improvements), and that fire, while a constant ratio with fatal involvements, is actually much less frequent because all fatal involvements are reduced. This cannot be tested without some exposure data such as vehicle miles traveled (by model year), and perhaps inclusion of other factors in an analysis as well. As a substitute for complete exposure data, it is possible to use data from the National

Table 5.10.2

Front-Damaged Passenger Cars in Fatal Crashes--FARS 1976-78

Passenger Car Model Year	Number of Cars With Fires	Number of Cars in Fatal Crashes	Ratio of Fires to Total Cars
1961	5	250	0.0200
1962	3	160	0.0187
1963	4	287	0.0139
1964	4	382	0.0105
1965	9	635	0.0142
1966	17	827	0.0206
1967	6	894	0.0067
1968	18	1182	0.0152
1969	18	1387	0.0130
1970	13	1387	0.0094
1971	14	1428	0.0098
1972	21	1642	0.0128
1973	34	1725	0.0197
1974	26	1627	0.0160
1975	23	1177	0.0195
1976	35	1473	0.0238
1977	27	1147	0.0235
1978	8	568	0.0141

Std. Version	Ratio(fires to cars)
pre-1968	.0140
1968-75	.0145
1976	.0238
1977-78	.0204

Crash Severity Study to estimate total (towaway) crash involvement by model year, and thus to compute the ratio of fatal involvements or fatal fire involvements to "all" crash involvement.

This has been done by computing the proportion of each car model year with fatal fire involvements, the proportion of each model year in the NCSS reconstructed population, and taking the ratio of the two proportions. This ratio is plotted as Figure 5.10.1, and shows a definite trend of improvement with newer model years. If the NCSS model year distribution represents the national population well, one may infer that newer cars are less likely to involve a fire, given that they have been involved in a "towaway" crash.

Table 5.10.3

Side-Damaged Passenger Cars in Fatal Crashes--FARS 1976-78

Passenger Car Model Year	Number of Cars With Fires	Number of Cars in Fatal Crashes	Ratio of Fires to Total Cars
1961	7	357	0.0196
1962	2	243	0.0082
1963	3	367	0.0082
1964	9	565	0.0159
1965	13	814	0.0160
1966	9	1027	0.0088
1967	27	1241	0.0218
1968	24	1589	0.0151
1969	37	1845	0.0201
1970	37	2024	0.0183
1971	43	2035	0.0211
1972	34	2242	0.0152
1973	28	2471	0.0113
1974	27	2255	0.0120
1975	40	1763	0.0227
1976	31	2011	0.0154
1977	26	1521	0.0171
1978	13	751	0.0173

Std. Version	Ratio(fires to cars)
pre-1968	.0152
1968-75	.0166
1976	.0154
1977-78	.0172

Such an interpretation must be made with some caution at this writing, since the NCSS data may not truly be representative of the national population. A stronger inference should be possible once the NASS data become available, and their combination with FARS information in the manner shown here should certainly be planned.

5.10.2 Data from NCSS. Data from the NCSS were used to estimate the approximate fire rate and fuel leakage rate in the towaway crashes investigated in the NCSS. The data reported here are from the first two years of NCSS. The data have been weighted with the inverse of the sampling fraction to reconstruct the population rates. All of the data

Table 5.10.4

Fatal Passenger Cars in
Fatal Crashes--FARS 1976-78

Passenger Car Model Year	Number of Cars With Fires	Number of Cars in Fatal Crashes	Ratio of Fires to Total Cars
1961	37	1176	0.0315
1962	19	685	0.0277
1963	21	1155	0.0182
1964	31	1730	0.0179
1965	69	2550	0.0271
1966	78	3250	0.0240
1967	92	3632	0.0253
1968	129	4422	0.0292
1969	155	5059	0.0306
1970	163	5421	0.0301
1971	173	5588	0.0310
1972	188	6212	0.0303
1973	191	6426	0.0297
1974	188	5932	0.0317
1975	171	4440	0.0385
1976	194	5273	0.0368
1977	149	3991	0.0373
1978	69	2167	0.0318

Std. Version	Ratio(fires to cars)
pre-1968	.0245
1968-75	.0312
1976	.0368
1977-78	.0354

from the different teams have been pooled. No attempt has been made here to weight the different teams' data separately to obtain a more nationally representative number. Copies of the fire and fuel spillage forms were obtained from James Hedlund. These were used to identify the vehicles which had been reported to have post-crash fires and/or fuel spillage. The computerized data were then used together with the subset identified to be involved in fuel leakage or fires.

A total of 70 vehicles were reported to have post-crash fires, and 85 vehicles were reported to have post-crash fuel spillage. Most of the fuel spillage cases were also fire cases. Fourteen of the vehicles which were involved in a post-crash fire were not reported to have had

Table 5.10.5

All Passenger Cars in
Fatal Crashes--FARS 1976-78

Passenger Car Model Year	Number of Cars With Fires	Number of Cars in Fatal Crashes	Ratio of Fires to Total Cars
1961	40	1578	0.0253
1962	20	984	0.0203
1963	23	1653	0.0139
1964	38	2589	0.0147
1965	77	3946	0.0195
1966	95	5039	0.0189
1967	103	5714	0.0180
1968	146	7302	0.0200
1969	176	8715	0.0202
1970	187	9110	0.0205
1971	191	8967	0.0213
1972	220	10417	0.0211
1973	224	11441	0.0196
1974	221	10262	0.0215
1975	195	7877	0.0248
1976	214	9211	0.0232
1977	164	6899	0.0238
1978	71	3390	0.0209

Std. Version	Ratio(fires to cars)
pre-1968	.0184
1968-75	.0211
1976	.0232
1977-78	.0228

fuel leakage. After weighting with the sample weights, the NCSS data reported a total of 132 fires and 149 cases of fuel leakage. The rates become 3.35 post-crash fires per thousand towaway crashes, and 3.78 fuel spillage cases per thousand towaway crashes. It is important to note that the NCSS data are restricted to towaway crashes, while other data sets have reported all police-reported crashes. Much of the differences in reported rates may be caused by different reporting thresholds in different states. The overall fire rate reported from the NCSS seems to agree fairly well with that from Michigan or Illinois.

Table 5.10.6 gives the (weighted) frequencies of fires and fuel spillage as well as the (weighted) crashes by model year for the NCSS

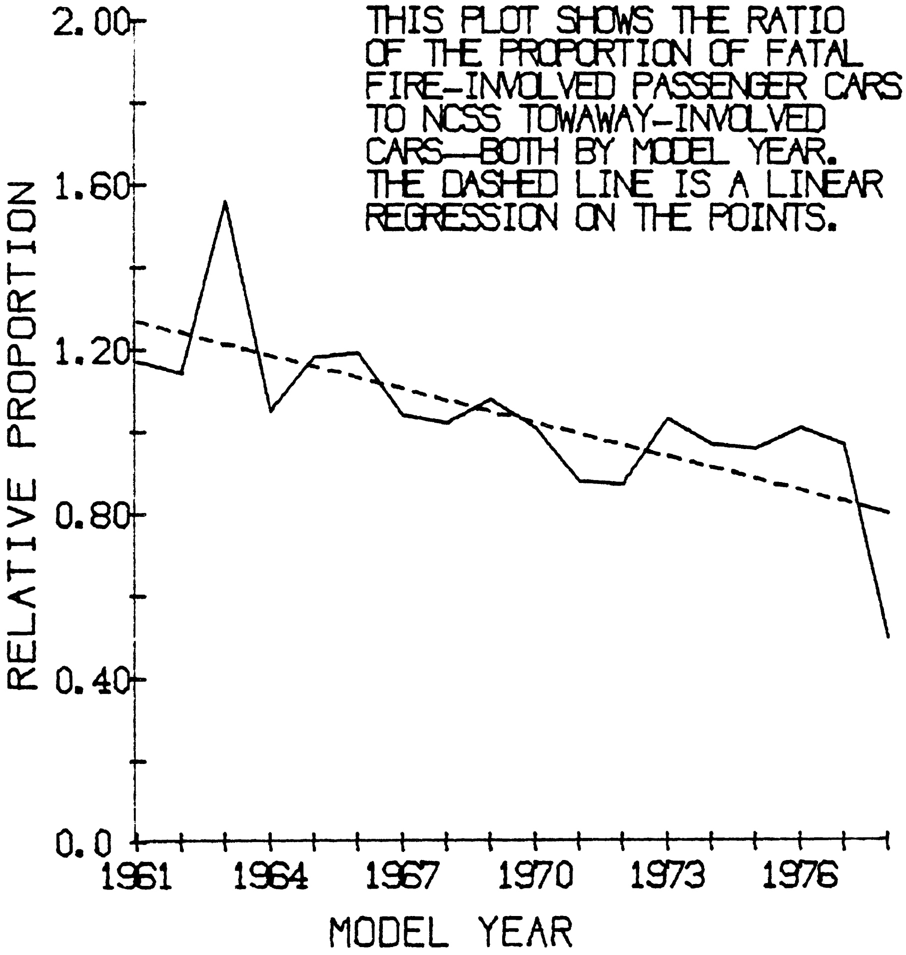

Figure 5.10.1

Ratio of Fatal Fire Involved Cars to
Crash Involved Cars

data. Inspection of the rates by model year shows considerable year-to-year variation. In addition, the weighting factors have very noticable effects on the number of fires and fuel leakages. All of the model years where the estimated number of fires or fuel spills was more than ten included one crash that had a sample weight of 10--that is, was a vehicle in which no one was injured. In general, the overall fire rate may be fairly reliable, but the individual years' rates are subject to such large fluctuations that no particular import should be imparted to them. The fire data seem to be fairly reliable. However, the fuel spillage data are open to question. Since the NCSS did not include on-scene investigation, the fuel leakage information was inferred by the investigators viewing the car after it had been removed to a different location. Consequently, fuel spillage information was obtained from the physical condition of the car--that is--were there holes in the fuel tank, were fuel lines broken, etc. While this should reveal any large spills, or fuel tank punctures or ruptures, it seems likely that small spills--say, 2 or 3 ounces per minute--would escape detection in this system. This may account for the large difference in the rate compared to the Michigan police data from 1978. Presumably, fuel spillage rates should tend to be larger in towaway accidents than in all police-reported accidents. However, the Michigan police data report on-scene investigations, while the NCSS are after the car has been towed. This may account for the higher rate of leakage observed in the Michigan data.

Model fitting was attempted with the NCSS data. Fitting a four means model to the spillage data resulted in the estimates of the mean rates by version of the standard as:

Pre-1967	1.05 ± 0.406 per thousand
1968-1975	2.39 ± 0.301 per thousand
1976	6.84 ± 1.363 per thousand
Post-1976	4.39 ± 1.156 per thousand.

The standard errors reported do not include any design effect, and were calculated on the basis of the weighted numbers. They are thus clearly too small. This model did not fit the data adequately (the X^2 for lack of fit was 40.37 with 11 df). The model with a linear term in the age of the vehicle was also fit. However, it did not fit as well.

Table 5.10.6
Crash Fire Rates From NCSS (per 1000)

Model Year	Fires	Crashes	Spills	Fire Rate	Spill Rate
1978 . .	1	334	4	2.99	11.83
1977 . .	11	2920	12	3.75	4.09
1976 . .	14	3631	25	3.84	6.84
1975 . .	11	2879	10	3.81	3.46
1974 . .	5	3675	8	1.36	2.17
1973 . .	7	3796	6	1.84	1.58
1972 . .	8	4074	10	1.96	2.45
1971 . .	6	3379	6	1.77	1.77
1970 . .	16	3137	7	5.07	2.23
1969 . .	14	2846	13	4.90	4.55
1968 . .	14	2468	14	5.64	5.64
1967 . .	8	1841	18	4.33	9.68
1966 . .	1	1432	1	0.70	0.70
1965 . .	15	1094	14	13.53	12.64
Pre-1965	1	1932	1	0.52	0.52
Total .	132	39,438	149	3.35	3.78

In addition, the linear term was non-significant and very close to zero. As a consequence, the parameters are not reported. The best interpretation of the lack of fit here seems to be that the variability of the rates is simply larger than the binomial variation would be. This seems to mostly be a result of the sampling design. No design effect has been reported for the NCSS data. This model suggests that for this variable such a design effect might be about four. If that design effect is assumed, none of the pairwise differences in fuel spillage rates by version of the standard were significant. (Only the latest to the pre-1967 version would be significant if the design effect of one were assumed. Such differences in fuel spillage rates as there were observed in NCSS, indicated higher spillage rates for the more recent versions of the standard.) The conclusion from the NCSS about fuel spillage is that no differences among model years corresponding to different versions of the standard were significant. In addition, the data collection system seems likely to under-report the cases of fuel spillage. Much more data would be needed before comparisons among model years based on NCSS data would be meaningful.

The fire data from NCSS seems likely to be more complete than the fuel spillage data. However, since the cars were not inspected on the scene, there is the possibility that some small fires wcould have been extinguished and would not be reported. However, the fire data can be considered fairly complete.

Inspection of the fire rates in Table 5.10.6 shows considerable variability by model year. No particular trend is observed. If the models are grouped by version of the standard, the fire rates are higher for the more recent versions of the standard. The model which fits a mean to each version of the standard gave the following estimated means and standard errors for fire rates:

Pre-1967	1.01 ± 0.398 per thousand
1968-1975	2.36 ± 0.299 per thousand
1976	3.84 ± 1.025 per thousand
Post-1976	3.66 ± 1.056 per thousand

Again, it should be noted that the estimated standard errors are based on the assumed binomial variances within model years and do not include the sampling design effect, which is clearly greater than one, and might be about four for this variable. There is a significant lack of fit for the model; however, it is improved only marginally by inclusion of a trend in age. Bearing in mind that the standard errors must be inflated to account for a design effect, none of the pairwise differences in the above means was statistically significant. The rates do appear to be worse for cars corresponding to the newer versions of the standard. However, these differences appear most reasonably to be sampling artifacts and/or sampling variation. The large rates all correspond to model years where at least one vehicle with a sample weight of 10 (no injuries in the crash) was included. This appears to produce artifacts in the numerators where the frequencies are of the order of 5 to 10.

The model which included a trend for age had the following estimated parameters and standard errors (with the same caution that these latter do not include the design effect):

Intercept	-2.57 ± 2.037 per thousand
Slope (age)	0.27 ± 0.152 per thousand per year
1968+	3.37 ± 1.232 per thousand
1976	2.50 ± 1.208 per thousand
1977+	0.12 ± 1.481 per thousand

The lack of fit was significant. It appears to be essentially caused by an excessive amount of variation in the year-to-year rates. This is an artifact of the sampling weights and the small amount of data for the rates. The estimated effect of the current (1977) version of the standard is an increase of 5.99 per thousand with an estimated standard error of 3.76 per thousand, and the estimated effect of the 1968 standard was 3.37 per thousand with an estimated standard error of 2.29 per thousand. All of these effects are changes in the fire rate above a linear trend in the age of the vehicle. The slope for the age was estimated as 0.27 per thousand per year with an estimated standard error of 2.83 per thousand. Thus, the model estimates a linear trend for the fire rates to increase with age. However, the standard effects are estimated as increases in level above that linear trend. None of these increases is statistically significantly different from zero. The significance of the linear trend is also in doubt.

Although the NCSS data show mean fire rates that increase with the later versions of the standard, these differences are not statistically significant. Similarly, the estimated standard effect above age as a covariate do not show any statistical significance. The general conclusion from the NCSS data is that no significant effect of the FMVSS 301 has been observed. Because of the sampling fluctuations, considerably more data from NCSS would be needed before meaningful comparisons of fire rates by model years could be made. However, the overall estimate of the fire rate may be reasonably accurate.

5.11 Supplemental Data

5.11.1 Data From Maryland.

Data on passenger car fires in Maryland come from the NFIRS. They represent fire department data. Since distribution of crashes by model year for Maryland 1977 accidents was unavailable, registration data were used for denominators. The rates reported are thus passenger car fires per 10,100 registered vehicles. There were only 15 passenger car fires with source of ignition codes 41 and 71 (fuel spillage and collision) so the exclusion surrogate was used to filter the passenger car files for the numerator data. That is, arsons, suspected arson, natural, and other obviously non-crash causes were eliminated. The remainder, however, include many "not otherwise specified" categories, and so probably include many non-crash fires.

The frequencies of fires, registrations, fire rates (per 10,000 registered vehicles), and estimated standard errors are reported in Table 5.11.1. The overall rate was 2.71 fires per 10,000 registered vehicles. This would approximately correspond to 2.71 fires per thousand crashes, assuming that there are about one tenth as many crashes as registered vehicles. The fire rates show a general tendency to be larger for the earlier model years.

Table 5.11.1
Fire Rates per Registered Vehicles, Maryland 1977.

Model Year	Fires (Exclusion Surrogate)	Registrations	Rate (per 10,000)	Standard Error
1977 . .	12	161,408	0.74	0.215
1976 . .	22	191,692	1.15	0.245
1975 . .	16	141,565	1.13	0.283
1974 . .	27	178,839	1.51	0.291
1973 . .	23	198,259	1.16	0.242
1972 . .	27	162,482	1.66	0.320
1971 . .	17	138,226	1.23	0.298
1970 . .	30	122,621	2.45	0.447
1969 . .	32	109,094	2.93	0.519
1968 . .	21	89,011	2.36	0.515
1967 . .	25	63,892	3.91	0.783
1966 . .	27	54,199	4.98	0.959
1965 . .	14	37,061	3.78	1.010
1964 . .	14	27,387	6.25	1.366
1963 . .	6	13,001	4.62	1.884
1962 . .	7	6,911	10.13	3.828
Pre-62 .	8	16,185	4.94	1.748
Missing	135			
Total .	463	1,706,833	2.71	0.126
Pre-1968	101	200,635	4.73	0.501
68-75 .	193	1,153,098	1.87	0.120
76 . . .	22	191,692	1.15	0.245
77 . . .	12	161,408	0.74	0.215
Post-75	34	353,100	0.96	0.165

A model that fit different mean rates in three groups of model years corresponding to the different versions of the standard was fit to the data. The estimated means and standard errors were:

1976-1977	0.919 ± 0.1613 per 10,000 registered vehicles
1968-1975	1.520 ± 0.1155 per 10,000 registered vehicles
Pre-1968	4.447 ± 0.4508 per 10,000 registered vehicles

The three means model fit the data only marginally. The chi-squared statistic for testing lack of fit was 24.94 with 14 degrees of freedom, giving a P-value of 0.035. This indicates that there is evidence of a lack of fit at the 5% level. Even with the marginal fit accounted for, there is evidence that there are significant differences among the three means. The current mean is lower than either of the two previous means. The difference between the current mean and the rate for the 1968-1975 models was significant at the 5% level, but not at the 1% level. The other pairwise differences were significant well beyond the 1% level. Thus, there is evidence that the models corresponding to the current version of the standard have the lowest fire rate, while those corresponding to the first version of the standard have a fire rate significantly lower than those corresponding to the pre-standard era. However, it is possible that these differences could be merely a result of the age of the car.

To investigate the possible age effect, and to try to improve the fit, a model which included a linear term in age and step effects for the different versions of the standard was fit. The estimated parameters and associated standard errors were as follows:

mean = 11..916 ± 0.8443/10,000
slope B (age) = 0.200 ± 0.0565/10,000 per year
1976+ T = 0.230 ± 0.3070/10,000
1968 T = -1.514 ± 0.6126/10,000

The estimated effect of the current standard is a net reduction of 1.284 (±0.794) per 10,000 registered vehicles in the fire rate. This is of borderline significance (X^2 = 2.62, P = 0.106). The estimated effect of the 1968 version of the standard was a reduction of 1.51/10,000 registered vehicles in the fire rate. This was significant at the 1% level (X^2 = 6.11, 1 df). These estimates of effects are in addition to an estimated age effect. The estimate of the age effect is an increase of 0.2 per 10,000 in the fire rate for each year of age of the vehicle. The goodness of fit of this model was quite satisfactory ($X^2 = 12.37$, 13 df, $P = 0.497$). The age effect was highly significant.

Thus, much of the difference in the means and the lack of fit of the all means model is explained by a linear age effect in the fire rates. However, even after a linear term for the age effect is included, there is still some evidence of a beneficial standard effect. This effect is only of borderline significance--at the 10% level. In addition, most of the estimated effect occurred corresponding to the first (1968) version of the standard. The estimated additional effect of the 1976 version of the standard is not significantly different from zero ($P = 0.45$) and is positive, indicating a slight upward shift. Of course, the standard could cause a linear decrease in the rates for the newer models, so the age effect cannot be separated from a possible standard effect, unless the age and standard effects are assumed to be of different forms.

While it is clear that there were smaller fire rates in newer model cars in the Maryland data, given the nature of the data--fire department reported passenger car fires per registered vehicle, it would be presumptious to ascribe these differences to the effects of the standard. Although some beneficial effects above a linear trend can be observed, these did not reach significance. Coupling the difficulty of identifying the crash-fires and the marginal effects after adjusting for age, the best conclusion seems to be that no significant standard effect was observed in the Maryland data. The data with a smooth quadratic effect in age are plotted in Figure 5.11.1.

5.11.2 <u>Data from a Special Study in California</u>. 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

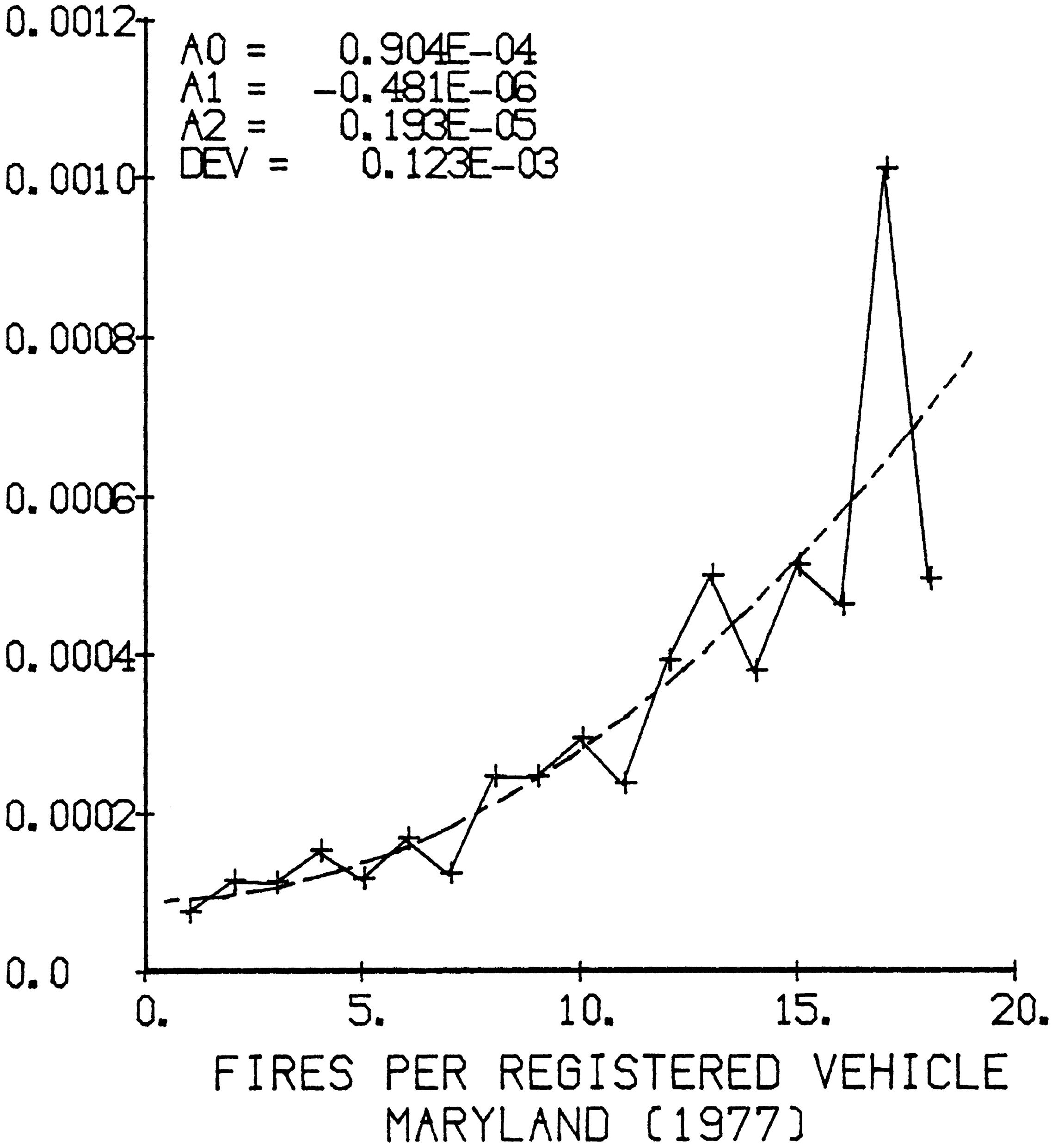
A0 = 0.904E-04
A1 = -0.481E-06
A2 = 0.193E-05
DEV = 0.123E-03
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0
0.
5.
10.
15.
20.
FIRES PER REGISTERED VEHICLE
MARYLAND (1977)

Figure 5.11.1

there has been no report published on these data.

The data are presented in Table 5.11.2. 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.

Table 5.11.2

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

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 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.

5.11.3 Data From the State of Mississippi

Police accident data in Mississippi contain a variable, vehicle condition, which indicates whether a vehicle involved in an accident caught fire or not. However, the model year of the vehicle is not computerized. The computer file was interrogated to list all of the cases for which the vehicle condition noted fire. Only eight such cases were found. Photocopies of these cases were supplied to HSRI and are summarized below. With only a total of eight cases, there are insufficient data to calculate rates, so further sampling of the hard copies of the reports to estimate distribution of model years of vehicles involved in crashes was not undertaken.

One case involved a 1970 Chevrolet passenger car travelling on I55. The driver lost control after being passed by a large truck,and ran off the roadway. The car rolled over, then caught fire. The driver and passenger were injured and taken to a hospital. The car burned completely.

The second case involved a Datsun 2+2 (year unspecified), which struck a parked 1969 Chevrolet 4-door in the left rear. Following the crash, the battery of the 1969 Chevrolet caught fire. The fire was easily extinguished and caused little additional damage. No injuries occurred.

The third case involved a 1974 truck (semi-trailer). The drive shaft came loose as the truck was going up a hill and punctured the fuel tank. The loss of control caused the truck to roll back down the hill, jack-knifing and igniting the fuel. The truck and trailer burned entirely. There were no injuries.

The other five cases involved vehicles which caught fire prior to or without a crash. One was a 1975 Buick traveling on I55 when a short in the electrical system set the car on fire. The driver stopped and summoned the fire department to extinguish the fire. Another involved a 1975 Dodge motor home traveling on I55. The vehicle suddenly burst into flames. The driver made a panic stop and the driver and passengers abandoned the vehicle. One person was injured and taken to a hospital. The vehicle was a total loss. Another case involved a 1976 Kenworth truck (semi). The driver reported it was pulling hard. He stopped and found that the right rear of the trailer was burning apparently caused by overheating of the brakes or bearings of the wheel. A 1974 Volkswagen traveling on Mississippi highways 24 and 33 caught fire in the engine area. Finally a 1972 Chevrolet truck traveling on Mississippi Highway 28 caught fire and burned.

Very little more can be said about these data. Only one of the cases involved a fuel fire after a crash. Only two of the cases were actually passenger car crashes, although one other case which involved a truck could be considered a crash. The variable which indicates fire is vehicle condition. Alternative codes are for defective brakes, steering, headlights, taillight, etc., so it may be that coding of defects which may have led to the crash receives preference over coding of fires which followed the crash. It seems likely that this system does not identify all of the vehicle fires. Further, it is evident that many of the fires reported will not be post-crash fires.

5.11.4 Data From the State of New Hampshire

Mr. Peter Klein, Head of the Office of Information Systems in New Hampshire, informed us that fire is coded as the first harmful event in the New Hampshire accident data. As a result, those cases would be very unlikely to be post-crash fires. New Hampshire filtered on their fire variable in their computerized data and sent us information about the accident reports which involved fires. There were three cases involving fire in the 1977 data, and five cases involving fire in the 1976 data. Mr. Klein stated in his letter that it was his belief that prior to 1978 they were not properly coding all of the fire accidents into their file. Also, their code for fire was a first harmful event for the crash. They presently have plans to adapt their coding system for the 1980 data so as to indicate in the file fire involvement, whether it is the first harmful event or not.

5.12 Combined Estimates of the Effects of FMVSS 301

In this section the effects of FMVSS 301 estimated separately are combined. It should be borne in mind throughout that these estimates are associational--not causal. Certain effects observed occurred at the time of introduction of the standard. These effects could plausibly have resulted from the standard; however, a number of other factors may have contributed to the effects. So the data do not justify ascribing the effects estimated to the standard.

5.12.1 Effect of FMVSS 301 on Fatalities. The best source of data on fatal crashes is in the FARS files. However, since all of the crashes in FARS resulted in a fatality, these data are not clearly useable alone. Some sort of standardization is desirable. The proportion of fires in fatal accidents differs relatively little by model year, but the slight tendency that is there shows a higher rate for newer models--contrary to what might be expected as the desirable effect of FMVSS 301. The exception to this is for rear-impacted vehicles which show lower fire rates in the more recent years in FARS. The ratio of the proportion of fire crashes (in FARS) to towaway crashes (in NCSS) by model year shows a steady decline for newer models. To the extent that the model-year distribution in NCSS reflects the national model year distribution the role of fire would appear to be reduced in fatal crashes for newer models.

It should be noted that the occurrence of a fire in a fatal accident does not mean that the fire caused the fatality. Fires are more likely to occur in more serious accidents, including fatal accidents. In a serious crash an occupant may well die from other injuries that were sustained before the fire occurred. Thus, in some fraction of fatal crashes with fire, the fire might be considered incidental. This has been discussed at length in Cooley,[1] where it was estimated that about half of the fatalities that occurred in cars that caught fire would have occurred even if there had been no fire. Some of the others might also have died without the presence of fire. The current (FARS) data do not allow one to determine with certainty whether a fatality that occurred in a car that burned after the crash would have resulted without the fire. Indeed, a detailed autopsy is often necessary to make such a determination. In this report, fatalities "with fire" are those that occurred in a car that was reported to have caught fire. No attempt has been made to separate the fire-caused fatalities from those that would have died without the presence of fire.

The fire-associated fatalities reported in the fire department data are so seldom reported and so difficult to identify with a definite crash that they were not used in estimating possible effects of the standard on fatalities. One should note, however, that the ratio of these fatalities to crashes tends to be smaller for newer car models. See the individual state sections of this report for details. Table 5.12.1 presents the ratio of fatalities in crashes with fire to police-reported crashes by grouped model years for each state for which crash distributions were available. Table 5.12.2 presents an estimated percent change in fire-associated fatalities which occurred concurrently for models of passenger cars. It should be noted that there are many other changes in cars which associate with model year--including adherence to numerous other motor vehicle standards and other design modifications. Any of these could have affected the fatality rate. Finally, note that only data from a select number of states have been used--mainly because of availability of data. This could bias the results in the sense of a national estimate.

5.12.2 Effect of FMVSS 301 on Injuries. Unlike the case for fatalities, no satisfactory source of injury information is available.

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[1] Cooley, Peter, "Fire in Motor Vehicle Accidents," An HSRI Special Report, UM-HSRI-SA-74-3, The Highway Safety Research Institute, The University of Michigan, Ann Arbor, Michigan 48109, April 1974.

Table 5.12.1

Fire Fatalities per Thousand Crashes
(1976 and 1977 FARS in Selected States)

State	Pre-301	301-1968	301-1976
Illinois .	0.191	0.164	0.259
Idaho . .	0.091	0.105	0.000
Michigan .	0.089	0.051	0.026
Missouri .	0.125	0.072	0.062
New York .	0.072	0.106	0.087
Ohio . . .	0.097	0.123	0.087
Washington	0.069	0.127	0.103

Table 5.12.2

Percent Change in Fire-Fatality Rate
(1976 and 1977 FARS Data from Selected States)

State	Pre-301 to 1968	301-1968 to current	Pre-301 to current
Illinois .	-14.1	+57.9	+35.6
Idaho . .	+15.4	-100.0	-100.0
Michigan .	-42.7	-49.0	-70.8
Missouri .	-42.4	-13.9	-50.4
New York .	+47.2	-17.9	+20.8
Ohio . . .	+26.8	-29.3	-10.3
Washington	+84.1	-18.9	+49.3

Although some passenger car fire injuries were reported in the fire department data, these were too incomplete and too difficult to relate to crashes to permit their use. As a result of this lack of data, there is no satisfactory estimate of the effect of FMVSS 301 on (non-fatal) injuries.

5.12.3 Effect of FMVSS 301 on Passenger Car Fires. In estimating the combined effect of the standard on passenger car fires, only the data from accident files were used. There were two reasons for this. First, the standard was aimed at reducing the incidence of post-crash fires. The accident data clearly identify fires in crashes; fire department data could not be adequately reduced to crash fires. Secondly, and perhaps because of the inability of the fire department data to identify crash fires, the fire department data generally showed a ratio of car fires to crashes (or registrations) which increased smoothly with the age of the vehicle. Thus the fire department data indicated differences which appeared less likely to be associated with FMVSS 301 (and more likely with a vehicle age characteristic). Further, since a covariate of age was clearly necessary for the fire department data, and, since the rates differed by more than a factor of ten among the states, no useful way to combine the data was apparent.

The accident data generally did not show a significant effect for the age of the vehicle. Even in the one state that did--Illinois--the effect was primarily a drop over only a four- or five-year period, and was also consistent with a standard effect. In order to combine the data from different states it was necessary to express the data as a percent change in the post-crash fire rate. This was required since the average fire rate varied so widely among the states--evidently depending on the state's criteria for reporting fires and upon the criteria for inclusion as a police-reported crash.

Table 5.12.3 presents the estimated percent change in crash-fire rate by state. Vehicles are considered in three groups: the pre-1968 passenger cars (called "old"), the 1968 through 1975 passenger cars (called "middle") and the 1976 to present passenger cars (called "new"). Three percentage change are shown: the "old" to "middle", the "middle to new", and the "old" to "new". Vehicles from 1976 forward have been combined, partly because there was never any significant difference in the rates associated with the 1976 and 1977 versions of the standard, and partly because there were limited data on the newer models. Presented with each change is an estimate of its standard error. These estimated standard errors were calculated by using a Taylor series approximation to the function of the difference divided by the earlier rate. In the table negative signs indicate reductions in the fire rate; positive signs indicate increases.

Table 5.12.3

Percent Changes in Fire Rates
Associated with Changes in FMVSS 301

State	Pre-1968 compared with 1968-1975		1968-1975 compared with post-1975		Pre-1968 compared with post-1975	
	Pct. Change	Std. Error	Pct. Change	Std. Error	Pct. Change	Std. Error
Illinois .	-14.7	4.14	-5.0	4.32	-19.0	5.33
Washington	-23.4	15.61	+53.4	43.98	+17.6	35.92
New York .	-19.0	12.76	+2.52	16.88	-16.9	17.26
California Spec. Study	-16.7	14.31	-18.9	26.32	-32.5	23.39
Idaho . . .	+8.03	26.81	-3.19	3.67	+4.59	38.62
Oklahoma .	+48.2	44.45	-44.74	23.62	-18.1	35.95
Michigan .	-18.1	8.17	-24.7	4.35	-38.3	6.54
NCSS . . .	-22.3	17.79	+22.4	27.59	-4.9	26.65
Combined .	-15.6	3.27	-13.9	2.91	-25.0	3.86

The individual estimated percent changes were combined into an overall estimate of the percent change using a weighted mean. The weights were inversely proportional to the variances. The overall estimate is that there was a 15.6% reduction in crash fire rates associated with the 1968-75 models as in comparison with the earlier (pre-1968) models. A further reduction of 13.9% in the crash fire rates is observed for the 1976 and later models. From the pre-FMVSS 301 models to the current (post 1975) models, a reduction of 25.0% in the post-crash fire rate was observed. The estimated standard errors of these three reductions were 3.27%, 2.91%, and 3.86% respectively.

It should be clearly noted that the limitations of the data prevent the exclusion of other factors as possible causes of these reductions. Properly one may only say that the reductions occurred and were associated with car models produced under the different versions of FMVSS 301. It is not possible to exclude other factors as contributing causes, nor to impute any causality to the standard.

Finally, it is possible that these reductions are subject to large but unknown biases. Although the combined estimate is based on data from six states (plus a special study from California and preliminary data from NCSS), the combined result is most heavily influenced by data from the states with the smallest estimated variances for the reductions. The data from two states--Michigan and Illinois--dominate the combined result. Both of these states had substantial numbers of reported crashes and of post-crash fires. Although many crashes occurred in the New York data, very few fires were reported. States such as Idaho, Washington, or Oklahoma, were simply too small to add much to the combined estimates. Similarly, the NCSS and the California Special Study were useful, but based on relatively few data. If there are regional differences in the effect of FMVSS 301--and there are regional differences in the reported fire rates--then the results will be biased toward the effect in the upper Midwest.

5.12.4 Effect of FMVSS 301 on Fuel Leakage in Crashes. Although it was hoped that the data from fire departments would aid in estimating the fuel spillage rate, this proved not to be the case. The fire department data could just not be identified with crashes. In addition, the only fuel spillage cases in the fire department data proved to be large spills--usually involving tank trucks. Thus it was not possible to identify fuel leakage in crashes from fire department data consistently enough to be useful.

Only two usable sources of fuel spillage or leakage data in crashes were found--the NCSS and the 1978 data from Michigan. The data from NCSS is of limited use, since estimates of fuel spillage are based on inspection of the vehicle after it has been towed to a location remote from the accident site. Discussions with NCSS investigators lead to the conclusion that only only obvious fuel tank punctures could be identified. While these would include cases in which the bulk of the fuel was spilled, many cases of fuel spillage which exceed the one-ounce-per-minute rate specified in the standard would be missed. Currently the best source of information is the 1978 police-reported accident data from Michigan. These data estimate a reduction in post-crash fuel spillage of 40.9% from pre-standard models to 1968-75 models. An additional 42.8% reduction in spillage rates is noted from 1968-1975 models to post-1975 models. Finally, an overall reduction of 66.2% is noted for current models compared with pre-1968 models. These estimates should be viewed with caution. They come from a single state and from a single year. In addition, other factors could be at least as influential in causing them as the standards.

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 foreseeable 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 event 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 additional 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.

The police accident data were a better source of data than the fire department data. Only one set of police accident data showed a linear trend with age that was significant. Subsequently, these data can generally be adequately modeled with different mean fire rates for the models corresponding to different versions of the standard. If this is done, a percent change must be used to make data from different sources comparable. After calculating a percent change in passenger car crash fire rates by version of the standard, the data were combined using a weighted mean. This results in a combined estimate of a 16% reduction in the fire rates corresponding to the 1968 version of 301 and a further 14% reduction corresponding to the later (1976 and 1977 combined) version of FMVSS 301. From the pre-standard to the current models, a 25% reduction in the crash fire rates was observed. The data are not sufficient to conclude that the differences were caused by the standard, but no other cause was identified.

All of the fire department data sets showed a significant linear trend in the fire rates with the age of the vehicle. This is more consistent with an aging effect than with a standard effect. In addition, the fire department data could not be identified with crashes adequately. As a result, the fire department data did not show any effect of FMVSS 301.

The possible age effect cannot be completely eliminated. The best way of attempting to do this in the future would be to collect several years of data from states' police accident data that include fire and/or fuel spillage as well as a consistent definition of a passenger car crash. One would then have data on several pre-1977 standard models and on current models for several different ages of the cars. This might separate an age effect from the standard effect.

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