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A REVIEW OF CRASH DATA ANALYSIS IN A DEFECT AND RECALL INVESTIGATION OF THE GENERAL MOTORS C/K PICKUP TRUCKS

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Abstract—In the process of assessing the safety of the fuel-containment system of the 1973–1987 General Motors C/K truck, the National Highway Traffic Safety Administration and General Motors Corporation have written and submitted numerous documents to a public file between October 1992 and April 1993. Five substantial reports have been issued by the National Highway Traffic Safety Administration and General Motors Corporation describing data analysis of crashes recorded on state and federal databases. Both the National Highway Traffic Safety Administration and General Motors Corporation have used crash data, in some cases the same data, to examine the claim that a defect in the fuel system design of General Motors Corporation C/K trucks poses an unreasonable risk of death or injury. The comparative analysis presented in this paper demonstrates how crash databases and their summary statistics can be used to support opposed positions in a safety dispute. Understanding differences in the analysis is fundamental to obtaining an insight into the role of field crash data, including its relevance and shortcomings, in defect and recall investigations.

Keywords—Crash databases, NHTSA, Defects investigation, Fuel system design, General Motors Corporation

INTRODUCTION

Under the National Traffic and Motor Vehicle Safety Act of 1966 (National Traffic and Motor Vehicle Safety Act 1966), the National Highway Traffic Safety Administration (NHTSA) has the authority to force the remedy of vehicular "defects" effecting "motor vehicle safety." Prerequisites to recalling a vehicle, in this case the General Motors (GM) C/K truck, are finding a defect and concurrently finding a relationship between the defect and unreasonable risk to motor vehicle safety. The focus of this paper is the description of part of the analysis, in particular, the data analysis, used by NHTSA and GM in their efforts to establish or refute the existence of a defect and its relationship to motor vehicle safety.

A defect includes "any defect in performance, construction, components, or materials in motor vehicles or motor vehicle equipment." According to the Act, "... 'motor vehicle safety' means the performance of motor vehicles or motor vehicle equipment in such a manner that the public is protected against unreasonable risk of accidents occurring as a result of design, construction, or performance of motor vehicles, and is also protected against unreasonable risk of death or injury to persons in the event accidents do occur..." Using their authority to remedy a defect, NHTSA may require the manufacturer to recall a vehicle, thus resulting in vehicle repairs, vehicle replacements, or refunds on the purchase price. Under the Act, it would be possible for the NHTSA to determine that a defect exists in a motor vehicle or motor vehicle equipment, but without an "unreasonable risk" to motor vehicle safety, no recall would be warranted.

The defect investigation in the GM C/K pickup truck was initiated when the Center for Auto Safety and the Public Citizen petitioned NHTSA in August 1992, claiming that the fuel system design was defective and posed an unreasonable safety risk (Ditlow 1992). During the period between October 1992 and April 1993, GM issued three reports and NHTSA issued two reports based on crash data for the public file. Due to the sensitivity of this type of investigation and the potential for litigation in any defect/recall investigation, public disclosure by all parties of all analyses and their interpretations is unlikely. Determining the existence of a defect and its effect on safety is not limited to crash database analysis; rather, legal, engineering, and testing analyses apparently form an important portion of each party's position. Nevertheless, there is considerable value in understanding how and why GM and NHTSA diverge in their publicly disclosed statistical analyses of the GM C/K pickup truck performance as recorded in databases of vehicular crashes. As will become clear in the following discussion, there are numerous ways to quantify and examine actual vehicle crash performance. Understanding differences in the analysis is fundamental to obtaining an insight into the role of field crash data, including its relevance and shortcomings, in defect and recall investigations.

DATA

Both NHTSA and GM describe the performance of GM C/K 1973–1987 pickup trucks using crash data from NHTSA's Fatal Accident Reporting System (FARS) for the years 1975–1990 (FARS 1988). FARS contains information on a census of fatal traffic crashes in the U.S., including information about the crash, the vehicle(s) involved in the crash, the driver(s), and any additional occupants. In the formulation of their analyses, both NHTSA and GM select a subset of this census data to assess the safety risk of the 1973–1987 GM C/K truck fuel-containment system. From 1973 through 1980, the GM C/K trucks were equipped with a standard fuel tank on the right side. In 1981, the standard fuel tank was switched to the left side, as illustrated in Fig. 1. During both design periods, purchasers of GM C/K trucks could optionally request dual fuel tanks, one on each side. None of the accident databases is equipped with information about the optional fuel tank; however, GM estimates that less than half of the 1973–1987 GM C/K trucks had auxiliary fuel tanks (General Motors Corporation 1993a).

In addition, GM summarizes a subset of crashes reported in 12 state databases for various time periods*. Information is included in each state's crash database using different criteria about the accident (e.g. minimum vehicular damage of $250). Since there are no uniform criteria, and since the state crash data are drawn from different years and various locations, the aggregation of the state data can be considered to be a database of crashes, but it does not necessarily represent all crashes over a fixed time period in the nation.

Exposure

Both NHTSA and GM select subsets of crashes from the databases based on relevant crash exposure and other types of vehicles' performance to be contrasted to the C/K pickups. Crash exposure refers to those variables present within a database from which an analyst can choose the type and severity of crashes to be studied. For analysis of the data in the FARS, both GM and NHTSA agree that side impacts are those crashes coded with a principal impact at the 2–4 and 8–10 o'clock positions (12 o'clock is at the center front of a vehicle). GM's criteria for side impact

*The 12 states and corresponding years analyzed are Alabama, 1983–1989; Arkansas, 1987–1988; Florida, 1986–1990; Idaho, 1980–1991; Illinois, 1981–1990; Maryland, 1977–1990; Michigan, 1982–1990; New York, 1975–1991; North Carolina, 1986–1990; Pennsylvania, 1989–1989; Texas, 1978–1990; Washington, 1970–1990.

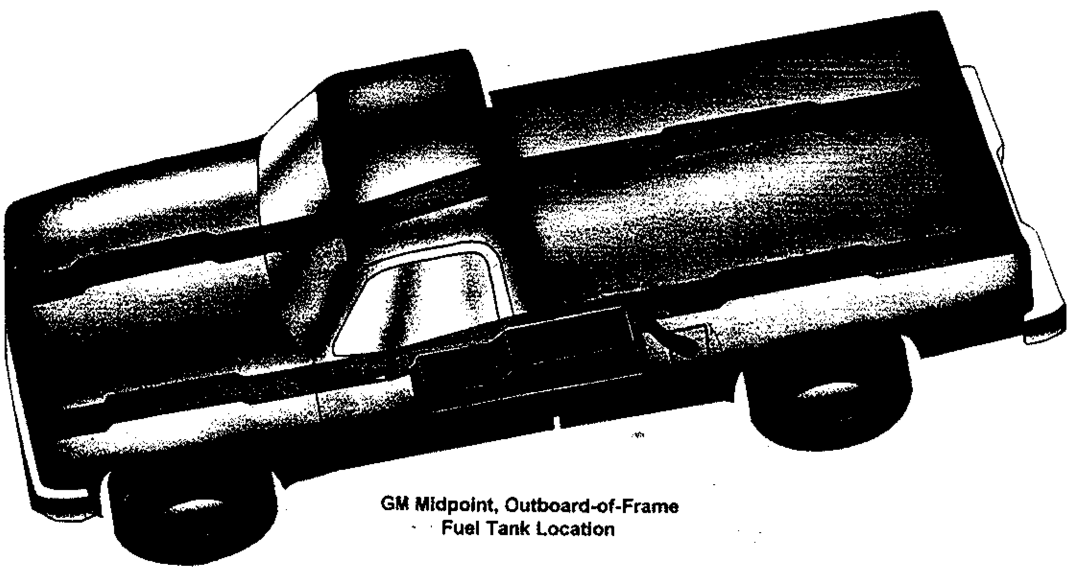

Fig. 1. GM C/K pickup truck fuel tank location.

in its analysis of state crash data appears similar, except that the description of the o'clock position changes from principal impact to principal damage. Confusion about these terms exists. For example, in a right side offset front crash which produced deep crush along the right side of a truck, one might code the principal impact as 12 or 1 o'clock, yet the principal damage might include the 2 o'clock position. GM performs its own principal damage position coding for crashes with truck fires of state police crash reports for data analyzed from Texas, Washington, and Pennsylvania.

A second important difference between GM and NHTSA's data selection is the treatment of principal side impacts with rollover. NHTSA includes all principal side impacts (2–4, 8–10 o'clock) with or without rollover, and GM excludes crashes with a principal side impact and a rollover. The treatment of rollovers highlights a fundamental difference in the exposure analyzed by the respective parties. GM excludes rollover based upon its belief that, "Collisions with rollovers are substantially different from those with planar impacts only, both in terms of the risk of occupant injury or fatality and in terms of fuel system integrity" (General Motors Corporation 1993c). NHTSA presumably includes rollovers consistent with the post-crash rollover requirements of FMVSS 301, Fuel System Integrity (Code of Federal Regulations 1980).

Differences also exist in how GM and NHTSA quantify crashes based on exposure. In studying fire/burn events, GM counts vehicles in which there was a fire reported. NHTSA prefers to count fatalities in crashes when there was a fire or when the state FARS analyst attributed the most harmful event of a crash to be death by fire.

In general, the exposure of a vehicle to collision, or exposure of an occupant to injury, death, or burns is dependent upon a vast array of variables. These variables include characteristics of the vehicle environment (rural vs urban driving, single vs multi-lane road, etc.), dimensional characteristics of the vehicle (wheelbase, ride height, weight, etc.), design and safety-related characteristics of a vehicle (air bags, side-impact protection, controllability, etc.), and driver characteristics (propensity for risk taking). To illustrate, the crash exposure (crashes) represented by FARS is a subset of the exposure envelope (population of all crashes) which is the most severe–fatality-producing, usually with high speed and great vehicle damage. Contrast the FARS exposure to that of GM's analysis of the 12 state databases that have an exposure not limited to the most severe crashes. Furthermore, single vs multi-vehicle crashes and crashes with rollovers vs crashes without rollovers probably represent fundamentally different crash and occupant exposures (crash severities, risks of fuel system failures, and risk of occupant injuries).

Comparison vehicles

Other vehicles, including peer vehicles, are used for comparison in the GM and NHTSA statistical analyses when assessing risk of injury and death—by burns or other means. Peer trucks, used by both GM and NHTSA, include the 1973–1987 Ford F series. For Dodge peer trucks, GM uses the 1973–1987 D/W series; whereas, NHTSA excludes the 1973 and 1974 D/W series because these trucks had in-cab fuel tanks. While NHTSA claims to compare GM C/K trucks only to peer trucks with fuel tanks located between the truck frame rails, GM demonstrates that some Dodge trucks used in NHTSA's counts for model years later than 1974 continue to have in-cab fuel tanks. An illustration of peer truck fuel-tank positions is shown in Fig. 2. As will be shown in the following section of this paper on measurements, the differences in selection criteria for peer vehicles do not appear to have a major impact on the computed rates for Dodge.

As shown below, GM also compares vehicles other than peer trucks to fire and death/injury rates of its C/K truck. NHTSA provides comparisons only to peer trucks.

MEASUREMENTS

Selecting the measurements to be used to summarize the effect of vehicle design on safety is central to the evaluation performed by NHTSA and GM. Several measurements or rates were proposed by the two parties. Typically, these rates are derived by forming a ratio of the number of incidents (e.g. the number of crashes or crashes with fires or fatalities) and the number of vehicles registered, as provided by R.L. Polk and Co. Registered vehicles represents the number of 'opportunity vehicles' (RVY). The numerator in these ratios summarizes incidents based on vehicle counts, occupant counts, or number of collisions. Table 1 provides a brief description of measurements that will be used to quantify and contrast vehicle performance and safety.

Based rates

Two rates, used by both GM and NHTSA, provide a unique opportunity to compare the effects of definitions of exposure and peer vehicles on the data analyses and, consequently, the conclusions. These rates are the fatal vehicle rate and the fatal-fire vehicle rate.

Difference between GM and NHTSA in the fatal vehicle and fatal-fire vehicle rates, as demonstrated in Table 2, is primarily attributable to the exclusion/

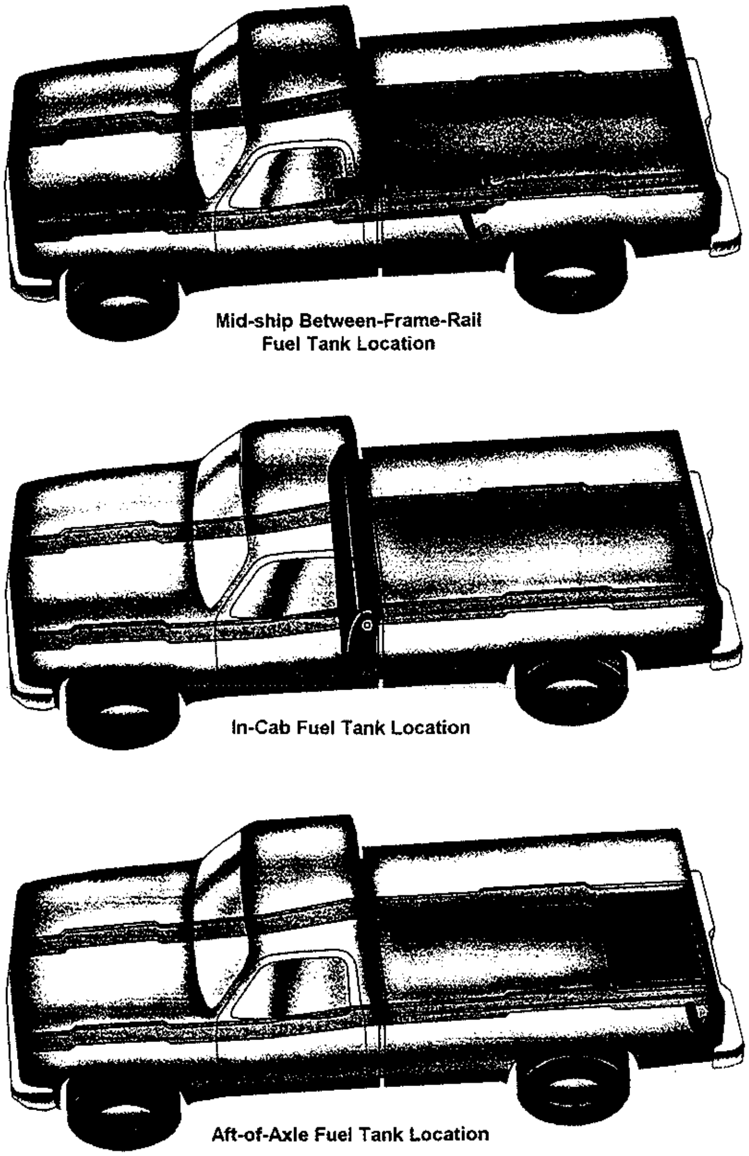

Fig. 2. Fuel tank location of peer pickup truck.

inclusion of rollovers*. Using the GM definition of exposure, i.e. excluding crashes with rollovers from NHTSA's counts of incidents, Table 3 shows that the NHTSA rates are very close to GM's. While not a large effect here, GM's exclusion of side impacts with rollovers and the associated lower rates will affect estimates of additional burn fatalities per year associated with the GM C/K fuel containment system design, as will be described below.

*The data are compiled from the NHTSA April report (Partyka 1993a), Appendix A1 using FARS 1975–1990 and GM Report, Part III, Appendix J12 documentation using FARS 1975–1991 (General Motors Corporation 1993c). The Reconciliation Appendix of Part III also contains information about other minor differences in vehicle counts.

When viewing the results shown in Table 2 and Table 3, it is noteworthy that even with the elevated frequency of fire, the GM pickups' overall fatal-vehicle rate is very similar to that of other pickups. Using the assumption that vehicle-based rates are not sensitive to the number of occupants in a vehicle, GM uses these rates to reach conclusions about occupant risk. GM provides further analysis of the fatal vehicle rate by comparing its C/K truck to vehicles other than peer trucks†. A summary of this analysis is shown in Table 4.

The terms, burn fatal vehicles and nonburn fatal

†Data are compiled from GM Report Part III, Appendix J1 documentation; FARS 1975–1991.

Table 1. Rate descriptions

	Vehicle-based rates
Fatal vehicle rate:	The number of vehicles in FARS with at least one occupant fatality divided by the number of corresponding registered vehicle-years (in millions).
Fatal-fire vehicle rate:	The number of vehicles in FARS with at least one fatality and a reported fire occurence divided by the number of corresponding registered vehicle-years (in millions).
	Fatality-based rates
Burn fatal vehicles:	The number of vehicles in which the most harmful event was a fire and there was a fatality.
Burn/nonburn ratio:	The number of vehicles in which the most harmful event was a fire and there was a fatality divided by the number of vehicles in which the most harmful events was not a fire and there was a fatality.
Fire-related fatality rate:	The number of occupant fatalities in vehicles in which a fire occurred divided by the corresponding registered vehicle-years (in millions).
Burn fatality rate:	The number of occupant fatalities in vehicles in which a fire occurred and fire was designated as the most harmful event divided by the corresponding registered vehicle-years (in millions).
	Collision-based rate
Fatal or major injury vehicle rate:	The number of vehicles in which an occupant died or sustained a major injury per 1000 collisions of the vehicles of interest in the database.

Table 2. Comparison of FARS rates for side impacts between NHTSA and GM

	Fatal vehicle rates		Fatal-fire vehicle rates	
Vehicle	NHTSA	GM	NHTSA	GM
Dodge trucks	23.2	20.3	0.6	0.6
Ford trucks	26.6	19.3	1.0	0.8
GM C/K trucks	29.0	20.5	2.5	1.9

Table 3. Comparison of FARS rates between NHTSA and GM when rollovers are excluded from counts of side impacts

	Fatal vehicle rates		Fatal-fire vehicle rates	
Vehicle	NHTSA	GM	NHTSA	GM
Dodge trucks	18.1	20.3	0.3	0.6
Ford trucks	19.2	19.3	0.8	0.8
GM C/K truck	20.5	20.5	2.0	1.9

Table 4. FARS fatal vehicle rates for side impacts of small pickups as compiled by GM in Report III

Comparison vehicles	Fatal vehicle rates
GM C/K trucks	20.5
Small pickups	
Dodge	33.6
Ford	38.3
Toyota	32.0
Nissan	32.1
Average passenger car	46.5

vehicles, play a key role in NHTSA's analysis*. Based on this concept, NHTSA forms a ratio used to measure safety. A comparison of NHTSA's burn/nonburn ratio, which is an attempt to normalize for variables that contribute to a vehicle's fatality exposure, to GM's vehicle-based rates is shown in Table 5†. Using the burn/nonburn ratio to provide a comparative measure of the risk of fatality-producing fire in all fatal accidents, as NHTSA states, the highest ratio occurs in fatality-producing side impacts to the standard tank side (Partyka 1993a). However, GM remarks that while their data show evidence that the incidence of fire in fatal crashes is higher when the impact is on the side of the standard fuel tank, the fatal vehicle rates for later model year (1981–1987) trucks compared to earlier trucks (1973–1980) suggest that the fuel tank position may have been saving lives(General Motors Corporation 1993a). That is, the left-side impact fatality vehicle rates decreased from 10.54 to 9.89.

Occupant based rates

NHTSA focuses most of its analysis on rates based on the number of occupant fatalities. One such rate, the fire-related fatality rate, is dependent on information in the FARS record that indicates that a fire, regardless of the fire's severity, has occurred in the vehicle. It was not until 1979 that the FARS record was augmented with the variable labeled "most harmful event (MHE)". When MHE is recorded as a fire, then NHTSA uses it as an indication of cause of death. "The FARS variable 'Most Harmful Event' can be used to identify vehicles with at least one occupant fatality attributed to the fire (in the judgement of the state FARS analyst, based on the Police Accident Report and other supporting state documents available at the time)" (Partyka 1993a).

If the FARS record indicates that a fire has occurred, and the MHE is identified as a fire, then NHTSA uses this information to define a burn fatality rate. Both of these occupant-based fatality rates generated by NHTSA and displayed in Table 6 are substantially different in absolute and relative magnitude.

While from a design or "defect" evaluation perspective, it may be more interesting to describe a vehicle's post-crash fires by calculating vehicle fire rates (the method GM chose), NHTSA studies fire-related fatality and burn fatality rates presumably based on its charge in the National Traffic and Motor

*Partyka sometimes uses the term "burn fatalites" in the context of this analysis interchangeably with burn fatal vehicles (Partyka 1993a).

†GM data are based on Appendix J14 of Report I and its documentation found in Report III; FARS 1979–1991 and model years 1973–1991. Only very few left-side tank vehicles were made during 1988–1991.

Table 5. Comparison of rates and ratios of C/K pickup trucks from FARS by tank location

	Left side impact		Right side impact	
	Not standard tank side	Standard tank side	Standard tank side	Not standard tank side
GM data and rates				
Model years	1973-80	1981-87	1973-80	1981-87
(1) Fatal vehicle rate	10.54	9.89	10.09	10.03
(2) Fatal-fire vehicle rate	0.63	1.28	1.25	0.76
NHTSA data and rates				
Model years	1973-80	1981-87	1973-80	1981-89
(3) Burn/nonburn ratio	0.02	0.06	0.05	0.04

Table 6. FARS fatality rates for side impacts with fire compiled by NHTSA

Vehicle	Fire-related fatality rate	Burn fatality rate
Dodge D/W trucks	1.01	0.25
Ford F trucks	1.16	0.42
GM C/K trucks	2.83	1.47

Vehicle Safety Act of 1966 to reduce traffic accidents and death and injury* (National Traffic and Motor Vehicle Safety Act 1966).

According to NHTSA, the difference in the burn fatality rate between Ford and GM trucks translates into a projected 4.9 additional burn fatalities due to GM's higher rate. That is, the difference $(1.47-0.42=1.05)$ times the expected number of registered GM C/K trucks $(4.7 \text{ million} \times 1.05=4.9)$. Adding to this projection, the estimated 0.5 fatalities, which was calculated in a similar manner from the FARS data, of occupants of other vehicles involved in accidents with GM trucks $(4.9+0.5=5.4)$, NHTSA concludes that five to six additional burn fatalities will occur in 1993 because of the higher burn rate of GM C/K trucks (Partyka 1993a). GM's exclusion of side impact with rollover will affect estimates of the additional burn fatality per year associated with the GM C/K fuel containment system design.

Collision based rates

Unlike the FARS rates based on registered-vehicle-years, in their analysis of state recorded crashes, GM formulates the fatal or major injury vehicle rate based on the number of collision vehicles. GM compiles these rates for the different side impacts and the locations of the fuel tank for 6 of the 12 states. The 6 states and the years analyzed are Alabama (1983–1989), Arkansas (1987–1988), Florida (1986–1990), Maryland (1977–1990), Michigan (1982–1990), and North Carolina (1986–1990). It is our understanding that these databases are included because they contain the detailed information necessary to compute the rate and exposure as defined by GM. The results, shown on Table 7, again are consistent with GM's position that having the fuel tank moved to the driver's side in 1981 reduced the rate (i.e. from 25.3 to 23.5). However, it is noteworthy that in most cases this reduction occurred on both sides of the vehicles in the later models.

*The comment is based on a discussion with Charles Gauthier and Susan Partyka of NHTSA on 23 March 1994.

INTERPRETATION

In an effort to address the possibility that the overall fatality rate difference between GM and Ford trucks is indicative of vehicle use, NHTSA proposes an adjusted rate based on a comparison of the burn fatal vehicles to the nonburn fatal vehicles.

Exposure characteristics

For all accidents in FARS for the years 1979–1990, NHTSA's recorded rates are GM nonburn fatal vehicle rate = 156.97, Ford nonburn fatal vehicle rate = 133.44, GM burn fatal vehicle rate = 4.80, and Ford burn fatal vehicle rate = 2.95 (Partyka 1993a). NHTSA suggests that the difference in nonburn fatal vehicles rate reflects two possible interpretations: either there are differences in vehicle use (i.e. crash speed and occupant exposure) or overall crashworthiness (Partyka 1993a). The adjusted rate is formulated on the assumption that the ratio of GM to Ford rates should be the same if the difference in

Table 7. Fatal or major injury vehicle rates from a six-state database for side impacts by tank location

Accident type	All	Single vehicle	Multiple vehicle
Model years 1973-80			
Tank side impact (passenger side)	21.6	40.2	16.3
Not tank side impact (driver side)	25.3	43.9	22.1
Model years 1981-87			
Tank side impact (driver side)	23.5	39.9	20.1
Not tank side impact (passenger side)	20.8	30.3	17.9

nonburn fatal involvement rate reflects crash severity differences. Based on the adjusted rate, the GM C/K expected burn fatal vehicle rate equals the number of GM nonburn fatal vehicle rate divided by the Ford nonburn fatal vehicle rate multiplied by the Ford burn fatal vehicle rate.

Using this concept, the rate equals

$$\frac{156.99}{133.44}*2.95=3.47 \text{ GM C/K vehicles with burn fatalities}$$

Since the actual rate (4.80) exceeds the expected rate (3.47), then the NHTSA implication is that the difference reflects lower overall crashworthiness of GM trucks (Partyka 1993a).

GM, in its Part III Report, states that "the 'burn' to 'nonburn' fatality [vehicle rate] ratio will not be the same in two groups of vehicles of similar crashworthiness but different driver characteristics (aggressiveness). Rather, the group of vehicles with the more aggressive drivers and more severe crashes will have a higher ratio of 'burn' to 'nonburn' fatalities" (General Motors Corporation 1993c).

Some of the initial analysis performed by NHTSA and reported in April 1993 studies the notion of differences in driver and accident characteristics of GM C/K pickups vs those of other manufacturers. NHTSA investigated the following characteristics: single vs multiple vehicle accidents, posted speed limit, lighting conditions at the accident scene, rural vs urban areas, damaged side (of vehicle), rollover occurrence, fire or explosion occurrence, age of vehicle, driver age, gender of driver, alcohol involvement, and use of seat belt.

Based on the data analyzed, NHTSA concluded that there were differences in certain GM driver and crash characteristics compared to the experiences of Ford driver fatalities. However, the differences describe experiences in fatal crashes only, and they do not necessarily reflect differences in the pickup-truck-driving population as a whole or difference in the relative crashworthiness of the various pickup trucks by crash type (Partyka 1993a).

Composite measures

GM performed additional analysis of driver and crash characteristics. The research focused on the percentage of drivers or crashes falling into 22* categories. For example, in Part I of the GM Report, it is reported that 47.01% of the GM C/K pickup drivers are 29 years old or younger compared to 42.89% of the Ford drivers.

Data on individual driver and accident characteristics reported by NHTSA are similar to those reported by GM. GM changes the driver and accident characteristics analysis, however, by forming a composite measure. GM names its composite measure the 'Aggressive Driver Demographic Index', which sums the individual percent occurrence of the 22 driver and accident characteristics (General Motors Corporation 1993c).

In examining FARS (vehicle-based) and some state (collision- based) data rates, GM concludes that the observed difference in the C/K and Ford FARS rates used by NHTSA is "attributable in major part and perhaps altogether to demographic differences between the driver groups for each vehicle" (General Motors Corporation 1993c).

In its November 1993 report, NHTSA presents burn/nonburn ratio data in which the driver or crash characteristics are held constant, rather than holding the vehicles constant (Partyka 1993b). NHTSA provides data on four characteristics: [a] speed limit, [b] land use, [c] age of driver, and [d] drinking involved. They found that for each of the characteristics investigated, when examined individually (GM uses a composite index), the C/K pickups always had a higher fire rate than the Ford pickups (Partyka 1993a).

Design vs exposure characteristics

In the GM Reports, Part II and III, data on the analysis of corporate twins is provided. "These 'twins' share the same platform and have virtually the same major systems including chassis, frame, and for purposes of this analysis, fuel systems" (General Motors Corporation 1993b). GM illustrates two points using corporate twins. The first is related to the estimation of the expected burn fatality rate. Given that FARS has information on both twins of the sets, then GM applies the NHTSA method of calculating expected burn fatality rates to one of the twins and finds inaccurate estimates for five out of the six matching twin of the sets. Table 8 illustrates several examples of this analysis.

The column labeled percent underestimate in Table 8 shows that the actual burn fatality rate is nearly always greater than the expected burn fatality rate. GM states that the lack of agreement between actual and expected burn fatalities in its corporate twin data set is the result of "the aggressiveness of their drivers and the severity of their crashes" (General Motors Corporation 1993c). The GM conclusion is consistent with the NHTSA suggestion that, if an

*[a] driver age 29 years or younger, [b] driving too fast, [c] driver ran off road, [d] driver's license suspended/revoked/cancelled, [e] drunk driver, [f] male driver, [g] driver manual restraint not used, [h] one or more drinking drivers (multiple vehicle crashes), [i] one or more previous accidents, [j] one or more previous driver's license suspensions, [k] one or more previous DWI convictions, [l] one or more previous speeding convictions, [m] posted speed limit 55 mph or greater, [n] single vehicle accident, [o] vehicle role is striking, [p] vehicle speed 55 mph or greater and, [q] the types of violations charged being alchol, reckless driving, speeding and alcohol, suspended license or other.

Table 8. Partyka method: expected "burn fatality rate" from GM Report III

Vehicle pairs		Nonburn fatality rate		Burn fatality rate		Partyka method: expected vehicle B rate	Fraction
Vehicle A	Vehicle B	Vehicle A [1]	Vehicle B [2]	Vehicle A[3]	Vehicle B[4]	Burn fatality rate [5] {[2]/[1]} × [3]	Underestimate {[4]-[5]} ÷ [4]
Ford	GM	133.44	156.97	2.95	4.8	3.47	0.3
Volare	Aspen	175.84	176.57	2.34	2.65	2.35	0.1
Corsica	Baretta	175.35	267.05	0.00	1.43	0.00	1.0
Cimarron	Cavalier	130.98	222.31	0.00	1.37	0.00	1.0
Cougar	T-Bird	153.32	214.05	0.71	2.39	1.00	0.6
Cougar	T-Bird	165.49	188.01	1.47	1.68	1.67	0.0
Caravan	Voyager	78.33	79.08	0.44	0.93	0.44	0.5

expected burn fatality rate is less than an actual burn fatality rate, then a vehicle's performance may demonstrate differences in crash speed and/or occupant exposure. In the "twins" analysis performed by GM, significant differences in crashworthiness are not possible.

The second point illustrated by the GM analysis of corporate twins is an association of differences in the aggressive driver demographic factor index and fatal-fire vehicle rate for individual vehicles of a twin set. GM states, that by examining corporate twins, it is holding "all vehicle factors constant". Thus, if there are performance differences, then these differences must be attributable to driver and accident demographics.

Figure 3 displays a small sample of the type of data presented by GM. The "positive" slope of the lines connecting the Ford pickup and the C/K pickup as well as the slope of the line connecting the Dodge Aspen and the Plymouth Volare are meant to show a causal link between the aggressive driver demographic factors and fatal-fire vehicle rates.

DISCUSSION

Although engineering design and testing analysis are probably more useful in evaluating defects in the GM C/K truck fuel containment system design, statistics that show elevated rates of fires, fire-related injury, death, and burns in overall and side-impact crash configurations are also useful in examining the "defect" issue. In particular, for fuel-containment system-related failures, the differences in fire and burn rates have importance because of the relatively low counts of post-crash fires in any crash population. Statistical analysis presented by GM, including corporate twins and the aggressive driver demographic factor index, is an attempt to explain differences in fire, fire-related injury, death, and burns by factors other than vehicle crashworthiness.

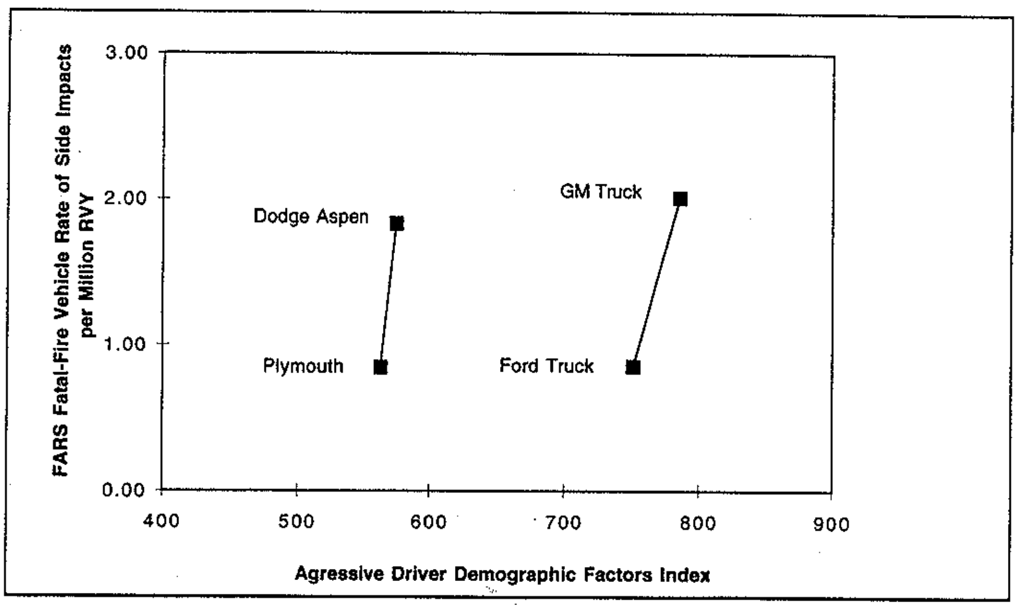

Fig. 3. FARS fatal-fire vehicle rate of side impact per MRVY vs aggressive drive demographic factors index.

In this particular investigation, the "defect's" effect on "motor vehicle safety" (unreasonable risk) may be more heavily dependent on statistical analysis, rather than engineering and design analyses. In performing the overall defect investigation analysis, unreasonable risk as well as appropriate comparison vehicles and crash exposures must be determined. It appears that much of the GM focus on overall fatal vehicle rates (in general and in specific crash modes) and their comparison of the GM C/K pickup truck post-crash fire rates to vehicles beyond its peer population are aimed at evaluating the C/K truck in the context of overall motor vehicle crash performance and, therefore, safety. By contrast, the NHTSA analysis centers primarily on the peer truck population and their notion of "burn" in their efforts to quantify a comparative measure of safety and determination of vehicle crashworthiness.

If not already evident, statistical analysis of motor vehicle crash data and defect/recall investigations is not without its limitations. One important limitation is that the databases do not have coding with the specificity needed to identify precise failure, defects, and injury mechanisms. In the case of the subject analysis, coding in crash databases does not specifically identify post-crash fires resulting from fuel-tank failures that caused occupant death or injury. For example, the implicit assumption in the statistic fire-related fatality rate using FARS data is that the fire was caused by spilled gasoline from the truck's fuel tank (ignoring other possible combustibles and fuel-system component failures). NHTSA is careful to attribute death to fire only when using the most harmful event code. Similarly, NHTSA's use of the FARS variable "most harmful event" coded as a fire is based on the assumption that the FARS analyst had a clear understanding that the fire caused the fatality, a conclusion questioned by General Motors (1993a). These assumption-based limitations are not, however, unique to only one particular manufacturer's vehicles; rather, if the limitations produce errors caused by counting incidents that lie outside the assumption in the analysis, it could be assumed that all vehicles will be affected equally.

A second limitation of crash databases lies in accident reporting and coding inaccuracies. For any number of reasons, the codes associated with a particular crash in a crash database may have inaccuracies. Using reasoning that is similar to that applied to the first limitation described above, particularly for the time period prior to public knowledge of a possible defect, errors that may be produced by this limitation have been described as systematic and should not affect comparative analysis (Laurenza et al. 1988).

When considering the meaning associated with motor vehicle crash database-derived summary statistics, particularly in the context of the GM C/K truck fuel-system defect/recall analysis, an additional limitation may be resolution. In this context, resolution is defined as the ability to detect an occurrence in a vehicle crash population. For example, due to the relatively low rate of fire-related fatalities and burn fatalities associated with fuel-containment crashworthiness, the effect of five or six unexpected deaths per year in a particular vehicle may not be detectable in a general registration-based fatality rate; however, the same five or six unexpected deaths may be observable in specific fire rates associated with impact points and fuel tank locations (e.g. side, rear).

CONCLUSION

The objective of this paper was to reveal the various assumptions made by GM and NHTSA based on their respective analysis of crash data reported in the public file. It may be assumed that these public file documents represent only a small portion of the analyses performed by both parties. Nevertheless, our summary analysis clearly demonstrates that although essentially the same crash data are used, it is possible to construct numerous measures of performance supporting apparently opposing views. Only when these differences and similarities in summary measurements, as well as the limitations of the data, are well understood can the role of crash data be weighed in relationship to the engineering and design analyses in a defect investigation.

EPILOGUE

On 17 October 1994, U.S. Department of Transportation Secretary Federico Peña issued an Engineering Analysis Report and initial decision that the subject vehicles (GM C/K trucks) contain a safety-related defect (Peña 1994). The report concluded as follows:

(1) The increased risk of death and injury from fire in side-impact crashes involving the subject vehicles is a result of the design of their fuel storage system, primarily the location of the fuel tanks outside of the frame rails, supplemented by other features of the design.
(2) Given the state of the art at the time and GM's awareness of the likely consequences, it was unreasonable for GM to design the subject vehicles with fuel tanks outside the frame rails.
The increased safety risk due to post-crash fires in the subject vehicles is unreasonable (Peña 1994).

On Friday, 2 December 1994, before the Tuesday start of a required public hearing, GM and NHTSA announced an agreement which settled the dispute, ending the possibility of a recall and vacating Peña's 17 October 1994 report (U.S. Department of Transportation and Office of the Assistant Secretary of Public Affairs 1994). The terms of the agreement required GM to pay or pledge in excess of $51.355 million to current or future projects. "This settlement will save hundreds of lives— far more than could ever have been saved by proceeding with a recall or closing the case", said Peña. "The alternative was to close the case with no public benefit or to proceed with a forced recall which would have involved years of litigation, an uncertain outcome, and prevented few, if any, deaths".

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