152960 NHTSA-98-3588-145

An Evaluation of Fatal and Incapacitating Injuries to Drivers of Passenger Vehicles that Experienced Post-Crash Fires in North Carolina (1991-1996)

by

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April 2001

Notice: This work was funded by GM pursuant to an agreement between GM and the U.S. Department of Transportation

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INTRODUCTION

Between 1991 and 1996, some 254,227 drivers of passenger vehicles in the State of North Carolina were involved in single-vehicle crashes. 1,954 (0.76 percent) of these drives were riding in vehicles that experienced post-crash fires. Of these 1,954 drivers, 88 (4.50 percent) were killed and another 249 (12.74 percent) sustained A-level ("incapacitating") injuries. For the 252,273 drivers who were riding in passenger vehicles that did not experience post-crash fires, 1,736 (0.69 percent) were killed and another 13,026 (5.16 percent) sustained A-level injuries. See Figure 1.

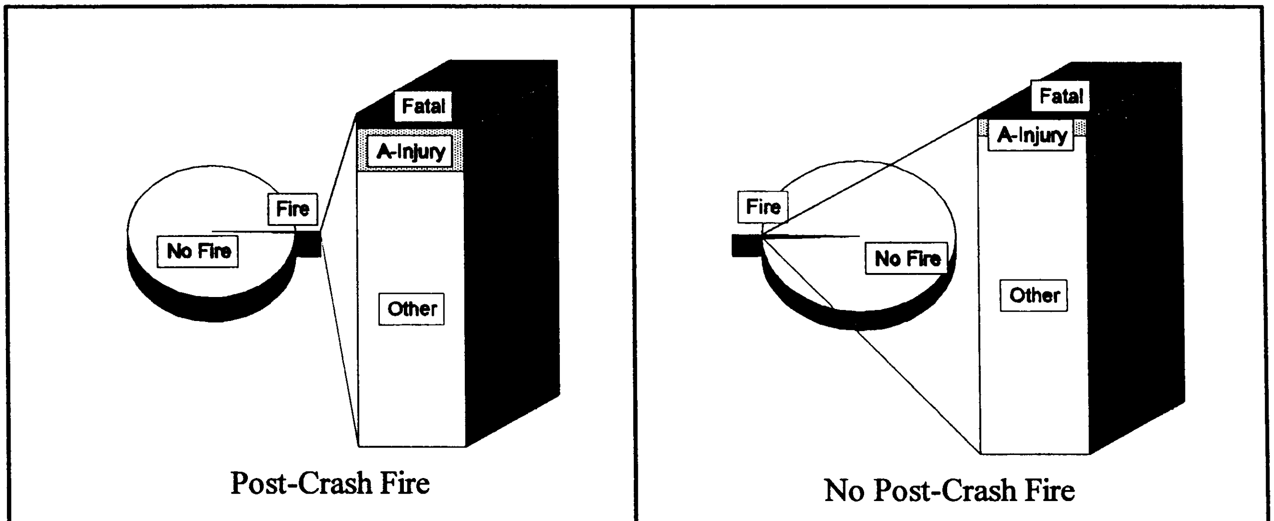

Figure 1: Fatal and A-Level Injuries Sustained by Drivers Riding in Passenger Vehicles that Did and Did Not Experience Post-Crash Fires in Single Vehicle Crashes (North Carolina, 1991-1996)

During the same time period in North Carolina (1991-1996), 1,606,370 drivers of passenger vehicles were involved in multi-vehicle crashes. 5,851 (0.36 percent) of these drivers who were riding in passenger vehicles that experienced post-crash fires. Ninety (1.54 percent) of these 5,851 drivers were killed and another 171 (2.92 percent) sustained A-level injuries. Of the remaining drivers who were riding in vehicles that did not experience post-crash fires, 2,178 (0.14 percent) were killed and 25,999 (1.62 percent) sustained A-level injuries. See Figure 2.

If the statistics presented in the previous two paragraphs are taken at face value, it would appear that the relative risk of a driver being killed while riding in a passenger vehicle that experienced a post-crash fire in a single vehicle crash are about 6.5 to 1 (4.50/0.69), when compared to drivers whose vehicles did not experience post-crash fires. For A-level injuries, the relative risk is about 2.5 to 1 (12.74/5.16). In multi-vehicle crashes, the relative risk of a passenger vehicle driver being killed if his or her vehicle experiences a post-crash fire is about 11 to 1 (1.54/0.14), when compared to drivers whose vehicles did not experience post-crash fires. For A-level injuries the relative risk is about 1.8 to 1 (2.92/1.62).

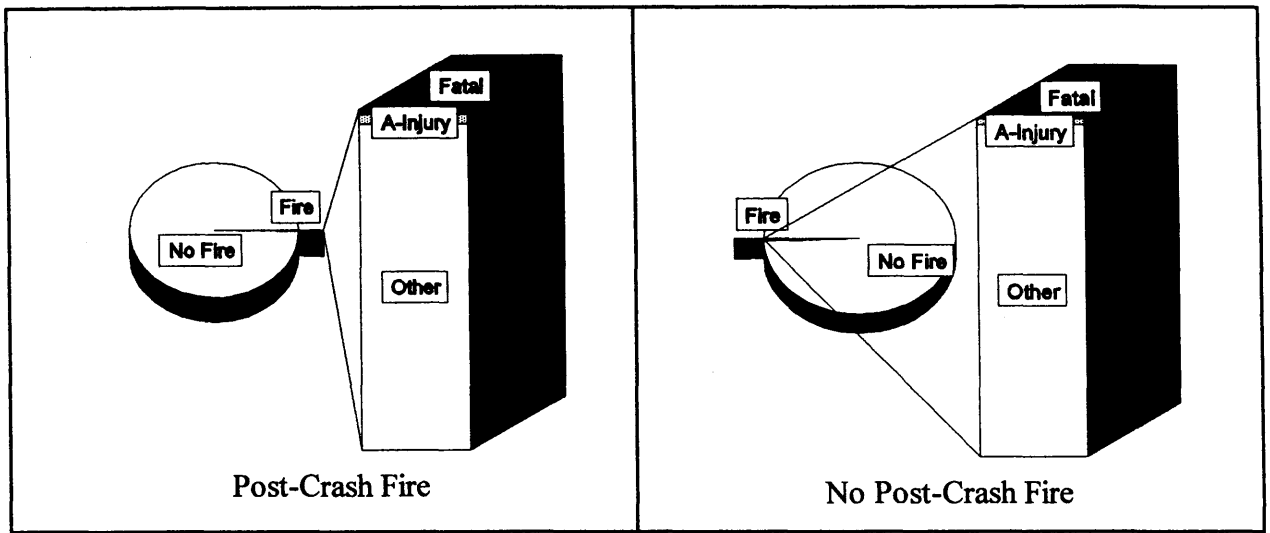

Figure 2: Fatal and A-Level Injuries Sustained by Drivers Riding in Passenger Vehicles that Did and Did Not Experience Post-Crash Fires in Multi-Vehicle Crashes (North Carolina,1991-1996)

Before these estimates of heightened injury risk associated with passenger vehicles that experience post-crash fires are given any credence, it should be pointed out that those vehicles that experience post-crash fires are generally involved in more severe crashes than vehicles that do not experience post-crash fires. Therefore, any direct comparison of the injuries sustained by drivers whose vehicles experienced post-crash fires—versus the injuries sustained by drivers whose vehicles had not experienced post-crash fires—is misleading and an exaggeration of injuries associated with vehicles experiencing post-crash fires.

The balance of this paper is devoted to estimating those injuries that are associated with post-crash fires after the data have been adjusted to account for differences in crash conditions and severity for passenger vehicles that did and did not experience post-crash fires.

PROCEDURE

Crash Data

Six years of North Carolina accident data (1991-1996) were purchased from the University of North Carolina's Highway Safety Research Center (HSRC). The crash-involved vehicles contained in this six-year data set were screened to include only passenger vehicles—some 2,033,360 vehicles. Passenger vehicles were defined to be any one of six vehicle types: 1 (2,4 Door Sedan); 2 (SW-Passenger); 3 (SW-Truck); 11 (Taxicab); 23 (Pickup Truck); or 25(Van). These 2,033,360 passenger vehicles were then divided into two groups: vehicles involved in single vehicle crashes (276,597) and vehicles involved in multi-vehicle crashes (1,756,763). Single passenger vehicle crashes included those crashes in which the number of units involved in the crash equaled one, but excluded those crashes involving pedestrians, mopeds, and bicyclists. Passenger vehicles involved in multi-vehicle crashes were defined on two variables: "number of units" in the crash (> 1) and "region of impact":

6 (Head On); 7 (Front vs Rear); 8 (Rear vs Rear); 9 (Front vs Side); 10 (Rear vs Side); 11 (Side vs Side); 12 (Two Vehicles, Other); and 13 (More Than 2 Vehicles).

For each of the 2,033,360 passenger vehicles in the reduced data set, driver injury and post-crash fire experience were recorded, as shown in Table 1. Note that of the initial 2,033,360 vehicles in the reduced data set, 172,763 records (8.5 percent) were lost, i.e., driver injury and/or post-crash fire information was unavailable for 172,763 of these 2,033,360 records.

Table 1: Crash-Involved Passenger Vehicles by Crash Type (Single Vehicle vs. Multi-Vehicle) and Driver Injury (North Carolina, 1991-1996)

	Single Vehicle Crashes		Multi-Vehicle Crashes		All Crashes	
Driver Injury	Post-Crash Fire	No Post-Crash Fire	Post-Crash Fire	No Post-Crash Fire	Post-Crash Fire	No Post-Crash Fire
Fatal	88	1,736	90	2,178	178	3,914
A-Level	249	13,026	171	25,999	420	39,025
Other	1,617	237,511	5,590	1,572,342	7,207	1,809,853
Total	1,954	252,273	5,851	1,600,519	7,805	1,852,792
	254,227		1,606,370		1,860,597	

The 1,860,597 crash-involved passenger vehicles shown in Table 1, were further categorized by location and severity of impact through use of the Traffic Accident Data (TAD) codes provided by the investigating officers. TAD codes consist of an alphabetic code that defines the location of vehicle impact and a numeric code (ranging from 1 to 7) that defines the severity of the impact. A TAD numeric code of 1 is minimal damage; a code of 7 is maximal damage.[1] To simplify the analyses that follow, the 19 TAD alphabetic codes (impact locations) were collapsed into five abbreviated locations, as shown in Table 2. Of the 1,860,597 driver/vehicles in Table 1, another 111,701 cases (another 2.3 percent of the initial 2,033,360 cases) were lost, i.e., for 111,701 of the driver/vehicles represented in Table 1, TAD data were not available. Of the 243,109 passenger vehicles involved in single vehicle crashes, 1,840 (0.76 percent) experienced post-crash fires. Another 1,505,787 passenger vehicles were involved in multi-vehicle crashes. Some 5,413 (0.36 percent) of these experienced post-crash fires.[2]

[1]Investigating officers in North Carolina may submit up to three TAD alpha and numeric codes for each crash-involved vehicle. Only the first TAD alpha (TAD1) and numeric (TADSEV1) codes recorded for each passenger vehicle were used in the analyses that follow.

[2]Because so few data were available for top-damaged passenger vehicles involved in multi-vehicle (221 cases), these cases were dropped from the data set and not further analyzed. See the shaded area in Table 2.

Table 2: Passenger Vehicles in Single Vehicle and Multi-Vehicle Crashes that Did or Did Not Experience Post-Crash Fires (North Carolina 1991-1996)					
Impact Locations (TAD1)	Collapsed Locations	Single Vehicle Crashes		Multi-Vehicle Crashes	
		No Fire	Fire	No Fire	Fire
Front Distributed Front Concentrated Front Left Front Right	Front	13,163	792	665,999	2,367
Right Front Quarter Right Passenger Right Distributed, Right Side Swipe Right Back Quarter Right and Top	Right	52,666	497	254,249	969
Back Distributed Back Concentrated Back Left Back Right	Back or Rear	6,159	39	310,989	1,169
Left Front Quarter Left Passenger Left Distributed, Right Side Swipe Left Back Quarter Left and Top	Left	50,500	503	268,918	906
Top	Top	581	9	219	2
Total		241,269	1,840	1,500,374	5,413
		243,109		1,505,787	
		1,748,896			

Tables 3 and 4 show the percent of drivers who sustained fatal (K) or A+K injuries in single vehicle and multi-vehicle crashes in vehicles that did or did not experience post-crash fires, by impact location (Table 3) and impact severity (Table 4). With the exception of top-damaged vehicles involved in single vehicle crashes, driver injury is greater—and often substantially greater—in those vehicles that experienced post-crash fires.

Table 3: Percent of Drivers Who Sustained Fatal (K) and A+K Injuries in Passenger Vehicles that Did and Did Not Experience Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Impact Location (TAD1) (North Carolina, 1991-1996)

Impact Location	Single Vehicle Crashes				Multi-Vehicle Crashes			
	Fatal (K) Injuries		A+K Injuries		Fatal (K) Injuries		A+K Injuries	
TAD1	No Fire	Fire	No Fire	Fire	No Fire	Fire	No Fire	Fire
Front	0.49	6.31	5.48	20.08	0.15	2.20	2.23	7.01
Right	0.88	4.63	6.51	15.90	0.12	1.44	1.45	3.72
Back	0.24	2.56	2.57	12.82	0.02	0.51	0.77	1.11
Left	1.10	2.19	6.64	15.71	0.27	1.66	2.30	3.64
Top	2.07	-	9.29	-	-	-	-	-

Table 4: Percent of Drivers Who Sustained Fatal (K) and A+K Injuries in Passenger Vehicles that Did and Did Not Experience Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Severity of Impact (TADSEV1) (North Carolina, 1991-1996)

Impact Severity	Single Vehicle Crashes				Multi-Vehicle Crashes			
	Fatal (K) Injuries		A+K Injuries		Fatal (K) Injuries		A+K Injuries	
TADSEV1	No Fire	Fire	No Fire	Fire	No Fire	Fire	No Fire	Fire
1	0.12	0.65	1.39	4.19	0.00	0.07	0.22	0.26
2	0.17	1.19	2.02	5.97	0.01	0.07	0.69	0.37
3	0.34	1.53	4.26	8.26	0.05	0.51	1.89	2.88
4	0.74	3.36	8.02	19.03	0.14	3.03	4.36	9.47
5	1.28	4.37	13.62	22.27	0.60	2.01	9.07	15.44
6	2.90	11.88	20.75	38.75	1.66	11.72	15.86	40.69
7	6.04	17.36	29.52	46.45	5.93	27.46	27.66	58.03

In Table 5, the driver/vehicle cases shown in Table 2 were subdivided into four vehicle categories (cars and station wagons, truck based station wagons, pickups, and vans). To better assess just what kinds and types of vehicles were included in the four vehicle categories shown in Table 5, the VINDICATOR program developed by the Highway Loss Data Institute was used to further characterize these vehicles. Approximately one thousand vehicle identification numbers (VINs) were systematically selected from each of the four vehicle categories developed for this study by taking every n^{th} case in each of the four categories. No attempt was made to edit or modify the VINS that were contained in the data sets that were received from HSRC. The results of this analysis are shown in Table 6.

Table 5: Passenger Vehicles Involved in Single Vehicle and Multi-Vehicle Crashes, by Category (North Carolina, 1991-1996)			
NC Vehicle Type	Vehicle Category	Single Vehicle Crashes	Multi-Vehicle Crashes
1 (2,4 Door Sedan) 2 (SW-Passenger) 11 (Taxicab)	Cars and Station Wagons	191,189	1,255,378
3 (SW-Truck)	Truck Based SWs	3,452	16,207
23 (Pickup Truck)	Pickups	41,012	176,441
25 (Van)	Vans	7,456	57,761
Total		243,109	1,505,787
		1,748,896	

Table 6: Vehicle Categories Used in the Present Study Compared to Vehicle Categories Based on Vehicle Identification Numbers (North Carolina, 1991-1996)				
VINDICATOR Vehicle Categories Based on VINs	Vehicle Categories for the Present Study			
	Cars and Station Wagons	Truck Based Station Wagons	Pickups	Vans
Passenger Car	532	4	1	10
Utility	26	560	5	5
Pickup Truck	8	15	504	4
Passenger Van	7	14	0	295
Cargo Van	1	13	0	231
No Match/Missing VIN	419	394	483	447

"Cars and station wagons," as defined in this study, are predominantly "passenger cars," as defined by VINDICATOR. Truck based station wagons are predominantly utility vehicles, pickups are predominantly pickup trucks, and vans include both passenger vans and cargo vans, in roughly equal measure.

Statistical Methodology

Step 1: Twelve separate analyses were performed in this study, as outlined in Table 7. Each analysis began by developing a logit function or model to represent the raw data. Conceptually, the logit models developed in these analyses might be thought of as three-dimensional figures that are five columns wide (TAD location = Front, Left, Back, Right, or Top), by seven rows tall (TAD severity values from 1 to 7), by two layers deep (Post-Crash Fire; No Post-Crash Fire). Within each of the 70 (5 x 7 x 2) cells in this three-dimensional figure, the expected probability that a driver received a severe injury [i.e., a fatal (K) injury or an "incapacitating" or fatal (A+K) injury] is calculated.

Table 7: Outline of the Twelve Analyses Performed in this Study			
Analysis	Dependent Variable	Vehicle Category	Crash Type
1	(A + K) ÷ (0,B,C)	All Passenger Vehicles	Single Vehicle Crashes
2	K ÷ (0,C,B,A)		
3	(A + K) ÷ (0,B,C)	Passenger Cars and Station Wagons	
4	K ÷ (0,C,B,A)		
5	(A + K) ÷ (0,B,C)	Pickups	
6	K ÷ (0,C,B,A)		
7	(A + K) ÷ (0,B,C)	All Passenger Vehicles	Multi-Vehicle Crashes
8	K ÷ (0,C,B,A)		
9	(A + K) ÷ (0,B,C)	Passenger Cars and Station Wagons	
10	K ÷ (0,C,B,A)		
11	(A + K) ÷ (0,B,C)	Pickups	
12	K ÷ (0,C,B,A)		

To make this explanation more concrete, data from the first of the 12 analyses outlined in Table 7 will used. The data set for the first analysis contains some 243,109 passenger vehicles and drivers that had been involved in single vehicle crashes. For each vehicle/driver included in the analysis, four pieces of information were of interest: driver injury [A+K or lesser injury (0,C,B)], TAD location (Front, Right, Back, Left, Top), TAD severity (1 through 7), and post-crash fire (Yes or No). The first four columns in Table 8 depict the raw data for this first analysis.

From the first row in Table 8 we see that 11 drivers (Col 2) whose vehicles sustained frontal, minor (TAD severity = 1) damage in single vehicle crashes—and whose vehicles experienced post-crash fires—suffered A- or K-level injuries. Another 173 (Col 1) suffered lesser injuries [C-level (possible) injuries, B-level (non-incapacitating) injuries] or no injuries at all (0). Expressing these frequencies as probabilities, we see that the probability of an A+K injury is 0.05978 (11/184) while the probability of a 0-C-B injury is 0.94022 (173/184).

Again, from the first row in Table 8, we see another 483 drivers (Col 4) who suffered A+K injuries in single vehicle crashes in which their vehicles sustained frontal, minor (TAD severity = 1) damage—but their vehicles did <u>not</u> experience post-crash fires. Another 32,824 drivers (Col 3) suffered 0-C-B injuries. Or, the probability of an A+K injury (in vehicles that did not experience post-crash fires) is 0.014501 (483/33,307) while the probability of a 0-C-B injury is 0.985499 (32,824/33,307). In similar fashion, the raw data from Table 6 can be used calculate the probability

Table 8: Raw and Fitted Data Used in the First Analysis

		Raw Data				Fitted Data from a Logit Model			
		Post Crash Fire		No Fire		Post Crash Fire		No Fire	
		Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8
TAD Values		O-C-B	A + K	O-C-B	A + K	O-C-B	A + K	O-C-B	A + K
Front	1	173	11	32824	483	176.19	7.81	32813.28	493.72
	2	136	11	37290	815	138.06	8.94	37285.66	819.34
	3	124	14	27162	1241	121.11	16.89	27118.76	1284.24
	4	72	27	14180	1327	77.54	21.46	14174.99	1332.01
	5	53	22	6827	1164	49.95	25.05	6828.45	1162.55
	6	29	28	3492	1026	30.97	26.03	3514.74	1003.26
	7	46	46	2384	1148	39.18	52.82	2423.13	1108.87
Right	1	60	0	10649	144	58.47	1.53	10655.08	137.92
	2	93	5	12359	252	94.39	3.61	12377.02	233.98
	3	76	4	10378	457	73.91	6.09	10410.86	424.14
	4	77	11	6892	549	75.64	12.36	6884.46	556.54
	5	56	16	4282	634	55.55	16.45	4287.96	628.04
	6	28	16	2539	605	29.40	14.60	2524.16	619.84
	7	28	27	2140	786	30.64	24.36	2099.47	826.53
Back	1	8	0	1852	16	7.84	0.16	1857.00	11.00
	2	5	0	1498	17	4.85	0.15	1502.00	13.00
	3	5	0	1112	19	4.69	0.31	1110.29	20.71
	4	7	1	710	23	7.07	0.93	706.84	26.16
	5	5	1	41	23	4.85	1.15	59.98	4.02
	6	3	1	230	24	2.86	1.14	228.33	25.67
	7	1	2	188	36	1.84	1.16	189.80	34.20
Left	1	56	2	10144	134	56.64	1.36	10139.09	138.91
	2	79	4	12372	226	80.18	2.82	12351.06	246.94
	3	93	9	9988	446	94.82	7.18	10003.00	461.00
	4	59	12	6600	564	61.72	9.28	6599.74	564.26
	5	63	12	3922	616	58.94	16.06	3929.33	608.67
	6	37	17	2264	583	37.07	16.93	2260.04	586.96
	7	37	23	1857	784	34.63	25.37	1864.63	776.37
Top	1	0	0	108	4	-	-	110.32	1.68
	2	2	0	101	1	2.00	-	99.78	2.22
	3	2	0	92	5	2.00	-	92.56	4.44
	4	2	0	75	17	2.00	-	84.00	8.00
	5	1	0	71	9	1.00	-	68.23	11.77
	6	1	0	49	7	1.00	-	43.43	12.57
	7	1	0	31	11	1.00	-	28.61	13.39
Total		1518	322	227073	14196	1518.00	322.00	227073.00	14196.00
		243109				243109			

of an A+K (or 0-C-B) injury in each of the 70 combinations of TAD location by TAD severity by Post-Crash Fire experience.

The raw data from Table 8 (columns 1-4) were then entered into the CATMOD procedure in SAS (the Statistical Analysis System)[3] to develop the most parsimonious logit equation that accurately modeled (matched) the raw data.

The first logit model considered in this first analysis included the effects of all three main predictor variables [TAD location (TAD1), TAD severity (TADSEV1), and fire experience (POSTFIRE)], as well as all possible interactions. That is to say, the first logit model considered in this analysis was a saturated model. Simpler logit models were then explored by sequentially removing non-significant interactions from the saturated model one term at a time while maintaining the hierarchical nature of the candidate models.

The simplest logit model that could be found to adequately fit the raw data in the first four columns in Table 8 is presented in Table 9. All three main effects are included in this model (TAD1, TADSEV1, POSTFIRE), as well as an interaction between POSTFIRE and TAD1. Note that POSTFIRE by itself is not significant ($\chi^2 = 0.01$, with one degree of freedom; pr = 0.9153). This term was kept in the model, nevertheless, to maintain the hierarchical nature of the model, i.e., POSTFIRE is a component of the interaction between POSTFIRE and TAD1 which is significant ($\chi^2 = 11.75$, with four degrees of freedom; pr = 0.0193). Note also that this model provided a good fit to the data, i.e., the likelihood ratio chi-square at the bottom of the table is not significant ($\chi^2 = 54.94$, with 53 degrees of freedom; pr = 0.4011), which means, in essence, that the fitted values from the model do not differ significantly from the raw data.

Table 9: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Developed in the First Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	0.39	0.5309
POSTFIRE	1	0.01	0.9153
TAD1	4	31.61	0.0000
TADSEV1	6	13740.28	0.0000
POSTFIRE*TAD1	4	11.75	0.0193
LIKELIHOOD RATIO	53	54.94	0.4011

The maximum-likelihood parameter estimates for the logit model (equation) depicted in Table 9 are provided in Table 10. From these parameter estimates, the fitted or expected frequencies

[3]For more detail, see, for example, Stokes, Maura E., Davis, Charles S., and Koch, Gary G., *Categorical Data Analysis Using the SAS System*, Cary, NC: SAS Institute Inc., 1995, 499 pp.

depicted in columns 5 through 8 in Table 8 were calculated. Now, working with the fitted data from the first row we estimate the probability of an A+K injury to be 0.042446 (7.81/184) [rather than 0.059783 (11/184)] for drivers experiencing post-crash fires. And, similarly, we estimate the probability of an A+K injury to be 0.014823 (493.72/33,307) [rather than 0.014501 (483/33,307)] for drivers whose vehicles did not experience post-crash fires.

Table 10: Maximum-Likelihood Parameter Estimates for the Logit Model Developed for the First Analysis

Effect	Parameter	Estimate	Standard Error	Chi-Square	Prob
INTERCEPT	1	-3.2461	5.1799	0.39	0.5309
POSTFIRE	2	-0.5512	5.1799	0.01	0.9153
TAD1	3	1.3240	5.1801	0.07	0.7983
	4	0.9853	5.1802	0.04	0.8491
	5	0.4831	5.1838	0.01	0.9257
	6	0.9717	5.1802	0.04	0.8512
TADSEV1	7	-1.7344	0.0317	2984.54	0.0000
	8	-1.3557	0.0253	2860.05	0.0000
	9	-0.5879	0.0208	797.95	0.0000
	10	0.0974	0.0200	23.77	0.0000
	11	0.6917	0.0206	1125.57	0.0000
	12	1.2085	0.0221	2993.66	0.0000
POSTFIRE*TAD1	13	1.0914	5.1801	0.04	0.8331
	14	0.9031	5.1802	0.03	0.8616
	15	1.1824	5.1838	0.05	0.8196
	16	0.8335	5.1802	0.03	0.8722

From a statistical point of view, these fitted ("smoothed") values constitute better estimates of driver injury than the raw data shown in columns 1 through 4. Note, however, that <u>within the rows</u> in Table 6: (Col 1 + Col 2) = (Col 5 + Col 6) and (Col 3 + Col 4) = (Col 7 + Col 8).

Step 2: Look once again at Table 8—at the sums at the bottom of the table. Here we see that the probability of an A+K injury is 0.058839 (14,196/241,269) for drivers who did <u>not</u> experience post-crash fires. Now, if we apply this coefficient (0.058839) to the 1,840 drivers who were riding in vehicles that did experience post-crash fires, we would estimate or predict that 108.26 drivers riding in vehicles that experienced post-crash fires would have suffered A+K injuries <u>**if**</u> post-crash fires have no effect on driver injury. Since 322 drivers riding in vehicles that experienced post-crash fires suffered A+K injuries, we calculate that there were 2.97 times as many A+K injuries (322/108.26) in vehicles that experienced post-crash fires as anticipated.

It should immediately be pointed out that this estimate of 2.97 is biased. It fails to account for any differences in the vehicle-damage (TAD location and severity) to which drivers of vehicles that do, and do not, experience post-crash fires are exposed.

From the fitted data in the first row in Table 8, we estimate that 0.014823 (493.72/33,307) of the 184 drivers (i.e., 2.73 drivers) riding in vehicles experiencing post-crash fires should have suffered A+K injuries if post-crash fires were of no consequence in the production of A+K injuries. For the second row in Table 8, we estimate that 3.16 drivers riding in vehicles that experience post-crash fires should have suffered A+K injuries. For the third row we estimate 6.24. And so on for all 35 rows in the Table 8. These 35 estimates of A+K injuries are shown in the last column in Table 11.

The sum of the estimated A+K injuries to drivers (if post-crash fires do not contribute to the production of drivers' A+K injuries) is 172.53. The observed (and fitted) number of drivers suffering A+K injuries while riding in vehicles that experienced post-crash fires is 322—149.47 more than estimated (not 213.74 more than estimated), or, 1.87 times as many A+K injuries associated with post-crash fires as expected (not a 2.97 times as many). This estimate of injuries associated with post-crash fires does take into account differences in the impact locations and impact severities recorded for passenger vehicles that do and do not experience post-crash fires.

Table 11: Driver Injuries in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)							
Region and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Estimated A+K Based on Vehicles that Did Not Experience Post Crash Fires
Front	1	184	173	11	7.81	2.73
	2	147	136	11	8.94	3.16
	3	138	124	14	16.89	6.24
	4	98	72	27	21.46	8.50
	5	75	53	22	25.05	10.91
	6	57	29	28	26.03	12.66
	7	92	46	46	52.82	28.88
Left	1	60	60	0	1.53	0.77
	2	98	93	5	3.61	1.82
	3	80	76	4	6.09	3.13
	4	88	77	11	12.36	6.58
	5	72	56	16	16.45	9.20
	6	44	28	16	14.60	8.67
	7	55	28	27	24.36	15.54
Back	1	8	8	0	0.16	0.05
	2	5	5	0	0.15	0.04
	3	5	5	0	0.31	0.09
	4	8	7	1	0.93	0.29
	5	6	5	1	1.15	0.38
	6	4	3	1	1.14	0.40
	7	3	1	2	1.16	0.46
Right	1	58	56	2	1.36	0.78
	2	83	79	4	2.82	1.63
	3	102	93	9	7.18	4.21
	4	71	59	12	9.28	5.59
	5	75	63	12	16.06	10.06
	6	54	37	17	16.93	11.13
	7	60	37	23	25.37	17.64
Top	2	2	2	0	-	0.04
	3	2	2	0	-	0.09
	4	2	2	0	-	0.17
	5	1	1	0	-	0.15
	6	1	1	0	-	0.22
	7	1	1	0	-	0.32
		1,847	1,525	322	322.00	172.53

RESULTS

Appendices A (Single Vehicle Crashes) and B (Multi-Vehicle Crashes) provide the basic data from which the summaries provided in this section were developed. These appendices include the raw data used in all 12 analyses and the simplest logit model that could be accurately fit to the data.

Analyses 1 and 2 (Single Vehicle Crashes; All Passenger Vehicles)

Some 243,109 passenger vehicles were included in these analyses—1,840 (0.76 percent) experienced post-crash fires and 241,269 (99.24 percent) did not. Driver injuries were distributed as shown in Table 12. Of the 14,518 drivers who sustained A+K injures in these crashes, 322 (2.22 percent) were riding in vehicles that experienced post-crash fires; of the 1,776 drivers who were killed, 85 (4.79 percent) died in vehicles that experienced post-crash fires.

Table 12: Driver Injury in Passenger Vehicles Involved in Single Vehicle Crashes, by Post-Crash Fire Experience

	Driver Injury			
	K	A	0-C-B	Total
Post-Crash Fire	85	237		
	322		1,518	1,840
No Post-Crash Fire	1,691	12,505		
	14,196		227,073	241,269
Total	1,776	12,742		
	14,518		228,591	243,109

After controlling for impact location and severity, drivers riding in passenger vehicles that experienced post-crash fires were associated with 1.87 times as many A+K injuries and 3.44 times as many fatal (K) injuries as expected, when compared to drivers riding in passenger vehicles that did not experience post-crash fires. Without controlling for impact location and severity, post-crash fires were associated with 2.97 times as many A+K injuries and 6.59 times as many fatal (K) injuries as expected.

Analyses 3 and 4 (Single Vehicle Crashes; Passenger Cars and Station Wagons)

Some 191,189 passenger cars and station wagons were included in these analyses—1,431 vehicles (0.75 percent) experienced post-crash fires and 189,758 (99.25 percent) did not. Driver injuries were distributed as shown in Table 13. Of the 11,329 drivers who sustained A+K injures in these crashes, 243 (2.14 percent) were riding in vehicles that experienced post-crash fires; of the 1,327 drivers who were killed, 61 (4.60 percent) died in vehicles that experienced post-crash fires.

Table 13: Driver Injury in Passenger Cars and Station Wagons Involved in Single Vehicle Crashes, by Post-Crash Fire Experience

	Driver Injury			
	K	A	O-C-B	Total
Post-Crash Fire	61	182		
	243		1,188	1,431
No Post-Crash Fire	1,266	9,820		
	11,086		178,672	189,758
Total	1,327	10,002		
	11,329		179,860	191,189

After controlling for impact location and severity, drivers riding in vehicles that experienced post-crash fires were found to have 1.80 times as many A+K injuries and 3.22 times as many fatal (K) injuries as expected. Had impact location and severity not been controlled for, post-crash fires would have been associated with 2.91 times as many A+K injuries and 6.39 times as many fatal (K) injuries as expected.

Analyses 5 and 6 (Single Vehicle Crashes; Pickup Trucks)

Some 41,012 pickup trucks were included in these analyses—308 (0.75 percent) experienced post-crash fires and 40,704 (99.25 percent) did not. Driver injuries were distributed as shown in Table 14. Of the 2,650 drivers who sustained A+K injuries in these crashes, 65 (2.45 percent) were riding in vehicles that experienced post-crash fires; of the 372 drivers who were killed, 21 (5.65 percent) died in vehicles that experienced post-crash fires.

After controlling for impact location and severity, drivers riding in vehicles that experienced post-crash fires were found to have 2.54 times as many A+K injuries as expected. After controlling for impact severity, drivers riding in vehicles that experienced post-crash fires were found to have 4.73 times as many fatalities (K) as expected. Without controlling for impact location and severity, post-crash fires appear to be associated with 3.32 times as many A+K injuries as expected. Without controlling for impact severity, post-crash fires appear to be associated with 7.91 times as many fatal (K) injuries as expected. [Note in Analysis 6 in the first appendix that the most parsimonious logit model that fit the data did not include impact location (TAD1).]

<table>
<tr><th colspan="5">Table 14: Driver Injury in Pickup Trucks Involved in Single Vehicle Crashes, by Post-Crash Fire Experience</th></tr>
<tr><td rowspan="2"></td><td colspan="4">Driver Injury</td></tr>
<tr><td>K</td><td>A</td><td>0-C-B</td><td>Total</td></tr>
<tr><td rowspan="2">Post-Crash Fire</td><td>21</td><td>44</td><td rowspan="2">243</td><td rowspan="2">308</td></tr>
<tr><td colspan="2">65</td></tr>
<tr><td rowspan="2">No Post-Crash Fire</td><td>351</td><td>2,234</td><td rowspan="2">38,119</td><td rowspan="2">40,704</td></tr>
<tr><td colspan="2">2,585</td></tr>
<tr><td rowspan="2">Total</td><td>372</td><td>2,278</td><td rowspan="2">38,362</td><td rowspan="2">41,012</td></tr>
<tr><td colspan="2">2,650</td></tr>
</table>

Analyses 7 and 8 (Multi-Vehicle Crashes; All Passenger Vehicles)

Some 1,505,566 passenger vehicles were included in these analyses—5,411 vehicles (0.36 percent) experienced post-crash fires and 1,500,155 (99.64 percent) did not. Driver injuries were distributed as shown in Table 15. Of the 27,333 drivers who sustained A+K injures in these crashes, 248 (0.91 percent) were riding in vehicles that experienced post-crash fires; of the 2,204 drivers who were killed, 87 (3.95 percent) died in vehicles that experienced post-crash fires.

<table>
<tr><th colspan="5">Table 15: Driver Injury in Passenger Vehicles Involved in Multi-Vehicle Crashes, by Post-Crash Fire Experience</th></tr>
<tr><td rowspan="2"></td><td colspan="4">Driver Injury</td></tr>
<tr><td>K</td><td>A</td><td>0-C-B</td><td>Total</td></tr>
<tr><td rowspan="2">Post-Crash Fire</td><td>87</td><td>161</td><td rowspan="2">5,163</td><td rowspan="2">5,411</td></tr>
<tr><td colspan="2">248</td></tr>
<tr><td rowspan="2">No Post-Crash Fire</td><td>2,117</td><td>24,968</td><td rowspan="2">1,473,070</td><td rowspan="2">1,500,155</td></tr>
<tr><td colspan="2">27,085</td></tr>
<tr><td rowspan="2">Total</td><td>2,204</td><td>25,129</td><td rowspan="2">1,478,233</td><td rowspan="2">1,505,566</td></tr>
<tr><td colspan="2">27,333</td></tr>
</table>

After controlling for impact location and severity, drivers riding in vehicles that experienced post-crash fires were found to have 1.93 times as many A+K injuries as expected and 5.66 times as many fatalities (K) as expected. Without controlling for impact location and severity, post-crash fires appear to be associated with 2.54 times as many A+K injuries as expected and 11.39 times as many fatal (K) injuries as expected.

Analyses 9 and 10 (Multi-Vehicle Crashes; Passenger Cars and Station Wagons)

Some 1,255,199 passenger cars and station wagons were included in these analyses—4,423 vehicles (0.35 percent) experienced post-crash fires and 1,250,776 (99.65 percent) did not. Driver injuries were distributed as shown in Table 16. Of the 23,272 drivers who sustained A+K injures in these crashes, 198 (0.85 percent) were riding in vehicles that experienced post-crash fires; of the 1,830 drivers who were killed, 63 (3.44 percent) died in vehicles that experienced post-crash fires.

Table 16: Driver Injury in Passenger Cars and Station Wagons Involved in Multi-Vehicle Crashes, by Post-Crash Fire Experience

	Driver Injury			
	K	A	O-C-B	Total
Post-Crash Fire	63	135	4,225	4,423
	198			
No Post-Crash Fire	1,767	21,307	1,227,702	1,250,776
	23,074			
Total	1,830	21,442	1,231,927	1,255,199
	23,272			

After controlling for impact location and severity, drivers riding in vehicles that experienced post-crash fires were found to have 1.89 times as many A+K injuries as expected and 5.15 times as many fatalities (K) as expected. Without controlling for impact location and severity, post-crash fires appear to be associated with 2.43 times as many A+K injuries as expected and 10.08 times as many fatal (K) injuries as expected.

Analyses 11 and 12 (Multi-Vehicle Crashes; Pickup Trucks)

Some 176,416 pickups were included in these analyses—618 vehicles (0.35 percent) experienced post-crash fires and 175,798 (99.65 percent) did not. Driver injuries were distributed as shown in Table 17. Of the 3,014 drivers who sustained A+K injures in these crashes, 34 (1.13 percent) were riding in vehicles that experienced post-crash fires; of the 289 drivers who were killed, 16 (5.54 percent) died in vehicles that experienced post-crash fires.

After controlling for impact location and severity, drivers riding in vehicles that experienced post-crash fires were found to have 2.21 times as many A+K injuries as expected and 8.33 times as many fatalities (K) as expected. Without controlling for impact location and severity, post-crash fires appear to be associated with 3.25 times as many A+K injuries as expected and 16.67 times as many fatal (K) injuries as expected.

Table 17: Driver Injury in Pickups Involved in Multi-Vehicle Crashes, by Post-Crash Fire Experience				
	Driver Injury			
	K	A	O-C-B	Total
Post-Crash Fire	16	18	584	618
	34			
No Post-Crash Fire	273	2,707	172,818	175,798
	2,980			
Total	289	2,725	173,402	176,416
	3,014			

Summary

From the 1991-1996 North Carolina data used in the analyses performed herein, about 0.76 percent of all passenger vehicles involved in single vehicle crashes (243,109) experienced post-crash fires. About 0.36 percent of all passenger vehicles involved in multi-vehicle crashes (1,505,566) experienced post-crash fires. The percentages of passenger cars and pickups that experienced post-crash fires in single vehicle and multi-vehicle crashes are equal. See Table 18.

Table 18: Passenger Vehicles Involved in Single Vehicle and Multi-Vehicle Crashes that Experienced Post-Crash Fires, by Type of Vehicle (North Carolina, 1991-1996)

	Single Vehicle Crashes		Multi-Vehicle Crashes	
Type of Vehicle	N	Percent	N	Percent
Passenger Cars and Station Wagons	1,431	0.75	4,423	0.35
Pickups	308	0.75	618	0.35
Other Passenger Vehicles	101	0.93	370	0.50
Total	1,840	0.76	5,411	0.36

In Table 19 observed and expected driver fatalities (K) derived from the logit models developed in analyses 2, 4, 6, 8 , 10, and 12 are shown. "Expected fatalities" are estimates of the numbers of drivers who would have died in vehicles that experienced post-crash fires if their vehicles had not experienced post-crash fires. When expected (or estimated) fatalities are divided by observed fatalities, that proportion of driver deaths that can be explained by the models that were developed (i.e., by impact location and severity, TAD1 and TADSEV1) is calculated.

Of the 61 passenger car/station wagon drivers who were killed in single vehicle crashes while riding in vehicles that experienced post-crash fires, it is estimated (based on the developed model) that 18.93 would have died if their vehicles had not experienced post-crash fires. Or, 0.31 of the 61 driver fatalities (18.93) recorded in these fire-related crashes would have been expected due to crash circumstances (i.e., impact location and severity), if the vehicles had not experienced post-crash fires.

$$P = \left(\frac{\text{Expected Fatalities}}{\text{Observed Fatalities}}\right) = \left(\frac{18.93}{61}\right) \approx 0.31$$

Where, P equals the proportion of the fatalities (K) explained by the models.

In single vehicle crashes in which passenger vehicle drivers are killed in vehicles that experience post-crash fires, it is estimated that 0.29 (of 85 drivers) would have been lost even if their vehicles had not experienced post-crash fires. For multi-vehicle crashes, the corresponding proportion is 0.18 (of 87 drivers). Or, of the 172 fatalities shown in Table 19, about 23 percent can be explained in terms of impact location and severity.

Table 19: Observed and Expected Driver Fatalities (K) in Passenger Vehicles that Experienced Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Type of Vehicle (North Carolina, 1991-1996)

	Single Vehicle Crashes			Multi-Vehicle Crashes		
Type of Vehicle	Observed K	Expected K	Proportion of Fatalities (K) Explained by Models	Observed K	Expected K	Proportion of Fatalities (K) Explained by Models
Passenger Cars and Station Wagons	61	18.93	0.31	63	12.24	0.19
Pickups	21	4.44	0.21	16	1.92	0.12
All Passenger Vehicles	85	24.71	0.29	87	15.37	0.18

Table 20 is structurally equivalent to Table 19, but depicts A+K injuries rather than fatalities (K). Table entries come from analyses 1, 3, 5, 7, 9, and 11. In multi-vehicle crashes in which passenger vehicle drivers sustain A+K injuries in vehicles that experience post-crash fires, it is estimated that 0.54 (of 322 drivers) would have sustained A+K injuries even if their vehicles had not experienced post-crash fires. For multi-vehicle crashes, the corresponding percentage is 0.52 (of 248 drivers). Of, of the 570 A+K injuries shown in Table 20, about 53 percent can be accounted for in term of impact location and severity.

Table 20: Observed and Expected Driver A+K Injuries in Passenger Vehicles that Experienced Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Type of Vehicle (North Carolina, 1991-1996)						
	Single Vehicle Crashes			Multi-Vehicle Crashes		
Type of Vehicle	Observed A+K	Expected A+K	Proportion of A+K Injuries Explained by Models	Observed A+K	Expected A+K	Proportion A+K Injuries Explained by Models
Passenger Cars and Station Wagons	243	134.74	0.55	198	104.56	0.53
Pickups	65	25.62	0.39	34	15.41	0.45
All Passenger Vehicles	322	172.53	0.54	248	128.20	0.52

The reciprocals of the proportions shown in Tables 19 and 20 are simple measure of the "injury penalty" associated with vehicles that experienced post-crash fires. See Table 21. Looking at the top, left cell: 3.22 times as many deaths were recorded for passenger car/station wagon drivers involved in single vehicle crashes as expected. 3.22 is the reciprocal of 0.31 (shown in Table 19).

Table 21: Over Representation of Fatal (K) and A+K Injuries for Drivers Experiencing Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Type of Vehicle (North Carolina, 1991-1996)				
	Single Vehicle Crashes		Multi-Vehicle Crashes	
Type of Vehicle	Fatal (K) Injury	A+K Injury	Fatal (K) Injury	A+K Injury
Passenger Cars and Station Wagons	3.22	1.80	5.15	1.89
Pickups	4.73	2.54	8.33	2.21
All Passenger Vehicles	3.44	1.87	5.66	1.93

DISCUSSION

When a passenger car driver is killed or seriously injured in a crash in which his or her vehicle experiences a post-crash fire, the proximal cause of death (K) or serious (A-level) injury may be the fire (e.g., thermal trauma, asphyxiation, etc.) or some other factor (e.g., mechanical trauma). To the extent that the circumstances surrounding drivers whose vehicles experience post-crash fires differ from those whose vehicles do not experience post-crash fires—and to the extent that these circumstances are associated with the likelihood of death or serious injury—these differences must be accounted for in assessing the injury penalty associated with post-crash fires.

Table 20: Observed and Expected Driver A+K Injuries in Passenger Vehicles that Experienced Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Type of Vehicle (North Carolina, 1991-1996)						
	Single Vehicle Crashes			Multi-Vehicle Crashes		
Type of Vehicle	Observed A+K	Expected A+K	Proportion of A+K Injuries Explained by Models	Observed A+K	Expected A+K	Proportion A+K Injuries Explained by Models
Passenger Cars and Station Wagons	243	134.74	0.55	198	104.56	0.53
Pickups	65	25.62	0.39	34	15.41	0.45
All Passenger Vehicles	322	172.53	0.54	248	128.20	0.52

The reciprocals of the proportions shown in Tables 19 and 20 are simple measures of the association between driver injury and post-crash fires. See Table 21. Looking at the top, left cell: 3.22 times as many deaths were recorded for passenger car/station wagon drivers involved in single vehicle crashes as expected. 3.22 is the reciprocal of 0.31 (shown in Table 19).

Table 21: Over Representation of Fatal (K) and A+K Injuries for Drivers Experiencing Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Type of Vehicle (North Carolina, 1991-1996)				
	Single Vehicle Crashes		Multi-Vehicle Crashes	
Type of Vehicle	Fatal (K) Injury	A+K Injury	Fatal (K) Injury	A+K Injury
Passenger Cars and Station Wagons	3.22	1.80	5.15	1.89
Pickups	4.73	2.54	8.33	2.21
All Passenger Vehicles	3.44	1.87	5.66	1.93

DISCUSSION

When a passenger car driver is killed or seriously injured in a crash in which his or her vehicle experiences a post-crash fire, the proximal cause of death (K) or serious (A-level) injury may be the fire (e.g., thermal trauma, asphyxiation, etc.) or some other factor (e.g., mechanical trauma). To the extent that the circumstances surrounding drivers whose vehicles experience post-crash fires differ from those whose vehicles do not experience post-crash fires—and to the extent that these circumstances are associated with the likelihood of death or serious injury—these differences must be accounted for in assessing the association between driver injury and post-crash fires.

The likelihood that a driver will be killed or seriously injured in a single vehicle or multi-vehicle crash is a function of many variables: crash factors (e.g., impact location and severity, post-crash fire, etc.), driver factors (e.g., age, gender, health, use of seat belts, etc.), vehicle factors (e.g., make, model, curb weight, air bags, etc.) In this study, differences in crash circumstances for passenger vehicles that did and did not experience post-crash fires were modeled for single vehicle and multi-vehicle crashes using the Traffic Accident Data (TAD) scale. The TAD scale is an alpha-numeric scale used to document impact location (Front, Right, Back, Left, and Top) and severity [as measured along a seven-point (i.e., 1-7), ordinal scale of increasing vehicle deformation].

A Comparison of Present Study Results to Previous Findings

In Table 19 some 172 passenger vehicle drivers died in North Carolina between 1991 and 1996 in vehicles that experienced post-crash fires. Based on the analyses performed in this study, 0.23 (of these 172 drivers) might have been expected to die if the vehicles in which they were riding had not experienced post-crash fires. Or, the drivers who were riding in vehicles that experienced post-crash fires were 4.29 times as likely to die as expected—4.29 times as likely to die as drivers involved in comparable crashes (as defined by TAD1 and TADSEV1), but whose vehicles did not experience post-crash fires.

Stated in slightly different terms, of the 172 decedents considered in the previous paragraph, 40 might have been expected based on the locations and severities of vehicle impacts sustained, i.e., 40 of these 172 driver deaths would have been expected even if their vehicles had not experienced post-crash fires. The remaining 132 deaths were "unexpected," i.e., not accounted for by the likelihood of death in passenger vehicles that did not experience post-crash fires. Although these 132 deaths were "unexpected," it should not be assumed that they were caused by post-crash fires. Other explanations for the occurrence of these 132 deaths will be explored shortly. The fact remains, however, that 132 (77 percent) of 172 deaths in vehicles experiencing post-crash fires could not be accounted for in terms of impact location and severity.

In a recently completed study (Davies and Griffin), medical examiner information on 102 decedents (drivers and passengers) who died in passenger vehicles that experienced post-crash fires were clinically reviewed to determine if post-crash fire was (or was not) the proximal cause of death in each case. These 102 deaths were recorded in North Carolina in 1995 and 1996.

> Of the 102 cases included in the North Carolina sample, fire-related injuries (e.g., burns, smoke inhalation, and/or asphyxiation) appeared to be responsible for 17 of the deaths. These 17 individuals would likely have survived their crashes had their passenger vehicles not experienced fires.
>
> Mechanical trauma appeared to be the proximal cause of death for 66 of the 102 persons in the North Carolina sample. These individuals would likely have died even if the passenger vehicles in which they were riding had not experienced fires. For the remaining 19 cases, the proximal cause of death was not determined from a review

of the available information.

Discarding the 19 cases for which the proximal cause of death was unclear, 17 of 83 decedents (21 percent) appeared to have succumbed to fire and 66 of 83 (79 percent) appeared to have succumbed to some other cause (e.g., mechanical trauma).[4]

The North Carolina data for the current study and the previous study were comparable, but not identical. The previous study included both drivers and passengers involved in crashes in North Carolina in 1995 and 1996; the current study includes only drivers involved in crashes in North Carolina between 1991 and 1996. Furthermore, the methodologies employed in the two studies (clinical evaluation and statistical modeling) are obviously different. Nevertheless, the differences in the findings from these two studies are marked:

- Previous Study (Davies and Griffin): 21 percent of the deaths in passenger vehicles that experience post-crash fires result from the fire; 79 percent result from some other factor, e.g., mechanical trauma.

- Current Study: 77 percent of the passenger vehicle drivers who were killed in vehicles experiencing post-crash fires could not be accounted for by crash circumstances (impact locations and severities); 23 percent could be accounted for by impact locations and severities.

Threats to the Validity of the Current Study

1. In the current study, an attempt was made to control for (i.e., adjust for) the crash circumstances surrounding those vehicles that did and did not experience post-crash fires on the basis of impact location (TAD1) and severity (TADSEV1). If other factors (i.e., crash, vehicle, and driver factors) exist that discriminate between vehicles that do and do not experience post-crash fires, and if these factors also correlate with the probability of driver death and serious (A-level) injury, then the models developed in this study may be deficient. They may not fully accounted for other consequential "non-fire-related" differences between those vehicles and drivers that did and did not experience post-crash fires.

2. Impact location and severity were obvious factors to include in the logit models that were developed, but the reliability and validity of the location (TAD1) and severity (TADSEV1)

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[4]Interestingly, in the same study (Davies and Griffin) a review of medical examiner information for 104 drivers and passengers who were killed in passenger vehicles that experienced post-crash fires in Texas between 1990 and 1992 indicated that 32 decedents succumbed to fire-related causes while 45 died of other causes. For 27, no determination could be made based upon the available data. Or, discarding the unknowns, 42 percent of the decedents (32 of 77) appeared to have succumbed to fire-related causes while 58 percent (45 of 77) appeared to have succumbed to other causes.

codes used in these analyses can always be questioned. TAD codes by their very nature are subjective, particularly the severity codes. These analyses assume that officers' judgements of impact locations and severities are both reliable and valid, i.e., consistently applied and truly reflective of crash circumstances. These analyses also assume that judgements of impact location and severity are independent of the presence or absence of a post-crash fire. That is to say, the severity of a level seven (7) frontal impact to a vehicle that experiences a post-crash fire is equivalent to the severity of a level seven (7) frontal impact to a vehicle that does not experience a post-crash fire—save for the effects of the fire.

Recall that only the first of three possible TAD codes provided by the investigating officers were used in these analyses. The first TAD code is assumed to provide a reliably and valid portrayal of crash circumstances. This assumption may be questioned.

Recall also that individual impact location codes were collapsed into front, left, back, right, and top impacts. For example, front-left, front-right, front-concentrated, and front-distributed impact locations were collapsed into a unitary, "front" impact location. In this collapsing process, front-right, level seven (7) impact is tacitly equated to a front-concentrated, level seven (7) impact. This assumption may be questioned.

Finally, in the logit analyses that were performed, it was assumed, in effect, that the severity ratings were comparable regardless of impact location. That is to say, a frontal, level three (3) impact is comparable in severity to a left-side, level three (3) impact. This assumption may be questioned.

3. All of the North Carolina crash data that were used in these analyses (not just the TAD data) were assumed to be both reliable and valid: vehicle type (i.e., passenger vehicles, passenger cars and station wagons, pickups, etc.), driver injury level (K- and A-level injuries), and presence or absence of post-crash fires are all reliably and validly coded.

    - A spot check of the vehicle identification numbers recorded for vehicles included in this study tended to confirm that vehicle type (as defined for purposes of this study) was fairly reliably coded (except for vans).

    - It seems reasonable to believe that driver fatalities are validly coded by investigating officers. A-level injuries, however, may be somewhat more subjectively coded.

    - Earlier work with the Fatality Analysis Reporting System (FARS) has indicated that some states may not be reliably coding the presence and absence of post-crash fires (Griffin, 1997 and 1998). Table 22 shows the relative percentages of passenger vehicles involved in single vehicle and multi-vehicle crashes that experienced post-crash fires in North Carolina, by year (1991-1996). In 1991 some 148 passenger vehicles involved in single vehicle crashes experienced post-crash fires: 0.47 percent. By 1996, 519 passenger vehicles involved in single vehicle crashes experienced post-crash fires: 1.07 percent. Some 438 passenger vehicles involved in multi-vehicle crashes in 1991 experienced post-crash fires: 0.22 percent. By 1996, some 1,517 passenger vehicles involved in multi-vehicle crashes experienced post-crash fires: 0.53 percent. The year-to-year variation in these data (particularly the single vehicle data) is disturbing.

Table 22: Passenger Vehicles Experiencing Post-Crash Fires in Single Vehicle and Multi-Vehicle Crashes, by Year (North Carolina, 1991-1996)

	Single Vehicle Crashes				Multi-Vehicle Crashes			
	No Fire		Fire		No Fire		Fire	
Year	N	Percent	N	Percent	N	Percent	N	Percent
1991	31,517	99.53	148	0.47	194,959	99.78	438	0.22
1992	36,490	99.17	304	0.83	223,937	99.67	748	0.33
1993	39,499	98.95	421	1.05	243,059	99.67	801	0.33
1994	41,203	99.49	212	0.51	264,503	99.71	777	0.29
1995	44,467	99.47	236	0.53	288,905	99.61	1,130	0.39
1996	48,093	98.93	519	1.07	284,792	99.47	1,517	0.53
Total	241,269		1,840		1,500,155		5,411	

CONCLUDING COMMENT

The current study indicates, not surprisingly, that passenger vehicles that experience post-crash fires are involved in more severe crashes than those vehicles that do not experience post-crash fires. About 23 percent of driver deaths and 53 percent of driver A+K injuries recorded in passenger vehicles experiencing post-crash fires can be explained in terms of impact location and severity.

A previous study (Davies and Griffin) suggests that the current attempt to control for "non-fire-related" differences between passenger vehicles that do and do not experience post-crash fires may be wanting. Threats to the validity of the analyses performed, and possible explanations for the "under correcting" of "non-fire-related" differences between passenger vehicles that do and do not experience post-crash fires, were offered in the last section.

The results from the previous study (Davies and Griffin) cannot be taken unreservedly as superior to those generated in the current study, but given the quality of the available data for this study, the predictor variables included in the statistical models, and the enabling assumptions used in the analyses, it seems likely that the estimates provided in this study "under correct" for "non-fire-related" differences between passenger vehicles that do and do not experience post-crash fires.

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Appendix A: Analyses of Single Vehicle Crashes

Analysis 1: Driver Injuries (A+K) in Passenger Vehicles in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	184	173	11	7.81	2.73
	2	147	136	11	8.94	3.16
	3	138	124	14	16.89	6.24
	4	99	72	27	21.46	8.50
	5	75	53	22	25.05	10.91
	6	57	29	28	26.03	12.66
	7	92	46	46	52.82	28.88
RIGHT	1	60	60	0	1.53	0.77
	2	98	93	5	3.61	1.82
	3	80	76	4	6.09	3.13
	4	88	77	11	12.36	6.58
	5	72	56	16	16.45	9.20
	6	44	28	16	14.60	8.67
	7	55	28	27	24.36	15.54
BACK	1	8	8	0	0.16	0.05
	2	5	5	0	0.15	0.04
	3	5	5	0	0.31	0.09
	4	8	7	1	0.93	0.29
	5	6	5	1	1.15	0.38
	6	4	3	1	1.14	0.40
	7	3	1	2	1.16	0.46
LEFT	1	58	56	2	1.36	0.78
	2	83	79	4	2.82	1.63
	3	102	93	9	7.18	4.21
	4	71	59	12	9.28	5.59

Analysis 1: Driver Injuries (A+K) in Passenger Vehicles in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	75	63	12	16.06	10.06
	6	54	37	17	16.93	11.13
	7	60	37	23	25.37	17.64
TOP	2	2	2	0	-	0.04
	3	2	2	0	-	0.09
	4	2	2	0	-	0.17
	5	1	1	0	-	0.15
	6	1	1	0	-	0.22
	7	1	1	0	-	0.32
		1,840	1,518	322	322.00	172.53

Analysis 1: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the First Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	0.39	0.5309
POSTFIRE	1	0.01	0.9153
TAD1	4	31.61	0.0000
TADSEV1	6	13740.28	0.0000
POSTFIRE*TAD1	4	11.75	0.0193
LIKELIHOOD RATIO	53	54.94	0.4011

Analysis 2: Driver Fatalities (K) in Passenger Vehicles in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	184	182	2	1.47	0.20
	2	147	145	2	1.58	0.22
	3	138	135	3	2.93	0.41
	4	99	92	7	4.38	0.62
	5	75	72	3	5.48	0.80
	6	57	44	13	8.79	1.39
	7	92	72	20	25.37	4.56
RIGHT	1	60	60	0	0.30	0.08
	2	98	96	2	0.66	0.18
	3	80	79	1	1.07	0.29
	4	88	87	1	2.48	0.67
	5	72	68	4	3.39	0.93
	6	44	41	3	4.51	1.29
	7	55	43	12	10.59	3.26
BACK	1	8	8	0	0.02	-
	2	5	5	0	0.02	-
	3	5	5	0	0.04	0.01
	4	8	8	0	0.13	0.02
	5	6	6	0	0.17	0.03
	6	4	4	0	0.25	0.04
	7	3	2	1	0.37	0.07
LEFT	1	58	58	0	0.12	0.10
	2	83	83	0	0.23	0.20
	3	102	101	1	0.57	0.48
	4	71	70	1	0.83	0.71

Analysis 2: Driver Fatalities (K) in Passenger Vehicles in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	75	72	3	1.49	1.27
	6	54	51	3	2.42	2.06
	7	60	57	3	5.34	4.59
TOP	2	2	2	0	-	0.01
	3	2	2	0	-	0.01
	4	2	2	0	-	0.03
	5	1	1	0	-	0.02
	6	1	1	0	-	0.05
	7	1	1	0	-	0.11
		1,840	1,755	85	85.00	24.71

Analysis 2: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Second Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	0.39	0.5348
POSTFIRE	1	0.00	0.9699
TAD1	4	8.88	0.0642
TADSEV1	6	2628.75	0.0000
POSTFIRE*TAD1	4	27.88	0.0000
LIKELIHOOD RATIO	53	51.25	0.5426

Analysis 3: Driver Injuries (A+K) in Passenger Cars and Station Wagons in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	151	142	9	6.13	2.19
	2	120	112	8	6.94	2.51
	3	115	105	10	13.72	5.17
	4	81	59	22	17.17	6.92
	5	54	40	14	17.79	7.88
	6	48	24	24	21.55	10.59
	7	69	33	36	39.70	22.08
RIGHT	1	47	47	.	1.09	.58
	2	67	64	3	2.23	1.19
	3	61	57	4	4.31	2.34
	4	64	56	8	8.40	4.71
	5	54	43	11	11.68	6.84
	6	30	18	12	9.41	5.81
	7	46	27	19	19.88	13.14
BACK	1	4	4	.	.09	.02
	2	4	4	.	.13	.03
	3	4	4	.	.28	.08
	4	7	6	1	.91	.26
	5	5	4	1	1.07	.33
	6	4	3	1	1.24	.42
	7	3	1	2	1.28	.49
LEFT	1	41	40	1	.86	.55
	2	63	62	1	1.90	1.22
	3	81	73	8	5.20	3.38
	4	52	46	6	6.24	4.14

Analysis 3: Driver Injuries (A+K) in Passenger Cars Station Wagons in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	61	52	9	12.16	8.33
	6	40	27	13	11.69	8.31
	7	49	29	20	19.95	14.88
TOP	2	1	1	.	.	.01
	3	1	1	.	.	.02
	4	2	2	.	.	.09
	5	1	1	.	.	.08
	7	1	1	.	.	.14
		1431	1188	243	243.00	134.74

Analysis 3: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Third Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	0.26	0.6078
POSTFIRE	1	0.01	0.9291
TAD1	4	26.60	0.0000
TADSEV1	6	11019.77	0.0000
POSTFIRE*TAD1	4	12.26	0.0155
LIKELIHOOD RATIO	52	50.25	0.5429

Analysis 4: Driver Fatalities (K) in Passenger Cars and Station Wagons in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	151	150	1	1.10	.15
	2	120	119	1	.99	.14
	3	115	113	2	1.99	.28
	4	81	76	5	3.35	.48
	5	54	52	2	3.75	.56
	6	48	37	11	7.15	1.14
	7	69	54	15	18.67	3.39
RIGHT	1	47	47	.	.20	.06
	2	67	66	1	.32	.09
	3	61	60	1	.62	.18
	4	64	63	1	1.58	.46
	5	54	51	3	2.27	.66
	6	30	28	2	2.79	.85
	7	46	38	8	8.22	2.68
BACK	1	4	4	.	.01	.
	2	4	4	.	.01	.
	3	4	4	.	.03	.
	4	7	7	.	.12	.02
	5	5	5	.	.15	.03
	6	4	4	.	.27	.05
	7	3	2	1	.41	.08
LEFT	1	41	41	.	.06	.07
	2	63	63	.	.11	.12
	3	81	80	1	.31	.33
	4	52	51	1	.48	.52

Analysis 4: Driver Fatalities (K) in Passenger Cars and Station Wagons in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	61	59	2	.97	1.05
	6	40	40	.	1.45	1.57
	7	49	46	3	3.62	3.91
TOP	2	1	1	.	.	.
	3	1	1	.	.	.
	4	2	2	.	.	.01
	5	1	1	.	.	.01
	7	1	1	.	.	.02
		1431	1370	61	61.00	18.93

Analysis 4: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Fourth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	0.27	0.6030
POSTFIRE	1	0.00	0.9735
TAD1	4	7.32	0.1200
TADSEV1	6	2078.93	0.0000
POSTFIRE*TAD1	4	23.59	0.0001
LIKELIHOOD RATIO	52	47.08	0.6674

Analysis 5: Driver Injuries (A+K) in Pickups in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	24	22	2	1.11	.39
	2	22	19	3	1.53	.54
	3	19	15	4	2.37	.88
	4	11	8	3	2.51	1.01
	5	16	9	7	5.37	2.35
	6	7	4	3	3.25	1.59
	7	18	11	7	9.88	5.28
RIGHT	1	11	11	.	.46	.16
	2	23	22	1	1.43	.51
	3	14	14	.	1.58	.58
	4	15	12	3	3.12	1.23
	5	12	8	4	3.72	1.59
	6	10	7	3	4.34	2.08
	7	8	1	7	4.16	2.16
BACK	1	2	2	.	.02	.01
	2	1	1	.	.02	.01
	4	1	1	.	.07	.01
	5	1	1	.	.11	.02
LEFT	1	12	11	1	.50	.47
	2	17	14	3	1.06	1.11
	3	16	15	1	1.80	1.43
	4	13	9	4	2.7	.19
	5	12	10	2	3.72	.26
	6	12	8	4	5.22	.50
	7	8	5	3	4.16	.66

Analysis 5: Driver Injuries (A+K) in Pickups in Single Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)

Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
TOP	2	1	1	.	.09	.13
	3	1	1	.	.16	.21
	6	1	1	.	.54	.27
		308	243	65	65.00	25.62

Analysis 5: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Fifth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	330.69	0.0000
POSTFIRE	1	48.08	0.0000
TAD1	4	23.93	0.0001
TADSEV1	6	2192.67	0.0000
LIKELIHOOD RATIO	51	55.41	0.3121

Analysis 6: Driver Fatalities (K) in Pickups in Single Vehicle Crashes with Post Crash Fires, by Severity of Impact (TAD)							
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model		
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT, RIGHT, BACK, LEFT, and TOP	1	49	48	1	.48	.09
	2	64	62	2	1.09	.20
	3	50	49	1	1.58	.30
	4	40	39	1	1.76	.33
	5	41	39	2	2.85	.55
	6	30	24	6	4.44	.92
	7	34	26	8	8.80	2.04
		308	287	21	21.00	4.44

Analysis 6: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Sixth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	894.19	0.0000
POSTFIRE	1	48.39	0.0000
TADSEV1	6	455.15	0.0000
LIKELIHOOD RATIO	6	2.84	0.8283

Note: The data available to develop this model were quite sparse. Only 21 driver fatalities were recorded in pickups that experienced post-crash fires. Given the sparsity of data, we were unable to develop an acceptable logit model containing TAD1 as a predictor variable. The model shown above collapses the data across all impact locations (TAD1) and predicts the probability of driver fatality based on the presence of absence of a post-crash fire and the severity of the impact (TADSEV1) sustained, regardless of the location of impact. This model provides a good fit to the data (a likelihood ration chi-square of 2.84 with 6 degrees of freedom).

Appendix B: Multi-Vehicle Analyses

Analysis 7: Driver Injuries (A+K) in Passenger Vehicles in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	1,081	1,079	2	3.22	2.20
	2	588	587	1	2.73	4.02
	3	271	258	13	10.01	5.39
	4	134	115	19	16.29	6.38
	5	84	66	18	15.87	8.28
	6	96	57	39	43.92	15.86
	7	113	39	74	73.96	34.21
RIGHT	1	441	439	2	1.06	0.87
	2	268	267	1	0.82	1.46
	3	139	135	4	3.33	2.15
	4	39	35	4	2.80	1.27
	5	29	27	2	3.50	2.10
	6	20	12	8	6.83	2.56
	7	33	18	15	17.66	7.99
BACK	1	798	796	2	1.92	1.94
	2	227	226	1	0.77	1.69
	3	73	73	0	1.39	1.10
	4	30	30	0	1.41	0.77
	5	12	12	0	0.81	0.58
	6	13	9	4	2.27	0.89
	7	16	10	6	4.43	1.85
LEFT	1	416	415	1	0.81	1.08
	2	251	249	2	0.68	1.94
	3	107	107	0	2.27	2.34
	4	61	59	2	4.50	3.25

Analysis 7: Driver Injuries (A+K) in Passenger Vehicles in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	24	21	3	2.82	2.61
	6	16	8	8	5.99	3.46
	7	31	14	17	15.93	9.96
		5,411	5,163	248	248.00	128.20

Analysis 7: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Seventh Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	2598.48	0.0000
POSTFIRE	1	12.89	0.0003
TAD1	3	25.69	0.0000
TADSEV1	6	1336.26	0.0000
POSTFIRE*TAD1	3	8.51	0.0365
POSTFIRE*TADSEV1	6	30.48	0.0000
TAD1*TADSEV1	18	443.59	0.0000
LIKELIHOOD RATIO	18	27.09	0.0773

Analysis 8: Driver Fatalities (K) in Passenger Vehicles in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	1,081	1,081	0	0.88	0.04
	2	588	588	0	0.39	0.04
	3	271	268	3	1.25	0.10
	4	134	130	4	3.09	0.12
	5	84	81	3	1.74	0.45
	6	96	89	7	11.74	1.41
	7	113	78	35	32.91	6.53
RIGHT	1	441	440	1	0.38	0.02
	2	268	268	0	0.09	0.01
	3	139	139	0	0.60	0.05
	4	39	36	3	1.42	0.06
	5	29	29	0	0.52	0.14
	6	20	15	5	2.37	0.30
	7	33	28	5	8.62	1.71
BACK	1	798	798	0	0.40	0.01
	2	227	226	1	0.32	0.01
	3	73	73	0	0.42	0.01
	4	30	30	0	0.96	0.01
	5	12	12	0	0.17	0.01
	6	13	11	2	0.65	0.03
	7	16	13	3	3.08	0.19
LEFT	1	416	415	1	0.33	0.03
	2	251	251	0	0.19	0.04
	3	107	107	0	0.72	0.11
	4	61	60	1	2.53	0.20

Analysis 8: Driver Fatalities (K) in Passenger Vehicles in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	24	24	0	0.58	0.28
	6	16	13	3	2.25	0.51
	7	31	21	10	8.40	2.95
		5,411	5,324	87	87.00	15.37

Analysis 8: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Eighth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	2098.56	0.0000
POSTFIRE	1	104.23	0.0000
TAD1	3	17.70	0.0005
TADSEV1	6	668.23	0.0000
POSTFIRE*TAD1	3	10.11	0.0176
POSTFIRE*TADSEV1	6	13.97	0.0300
TAD1*TADSEV1	18	31.28	0.0267
LIKELIHOOD RATIO	18	31.64	0.0243

Note: Technically, the full model shown above does not fit the data. However, a reduced model eliminating the three interactions has a likelihood ratio chi-square of 83.61 with 45 degrees of freedom.

Source	DF	Chi-Square	Prob
INTERCEPT	1	5299.25	0.0000
POSTFIRE	1	253.39	0.0000
TAD1	3	381.47	0.0000
TADSEV1	6	6311.44	0.0000
LIKELIHOOD RATIO	45	83.61	0.0000

Or, taken in aggregate the three interactions in the full model shown above are highly significant [chi-square of 51.97 (83.61 - 31.64) with 27 (45 - 18) degrees of freedom]. The full model was retained in this analysis.

Analysis 9: Driver Injuries (A+K) in Passenger Cars and Station Wagons in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	870	868	2	2.18	1.87
	2	499	498	1	1.85	3.59
	3	229	221	8	5.01	4.71
	4	121	104	17	12.50	5.85
	5	67	52	15	11.79	6.56
	6	80	49	31	32.96	13.15
	7	89	30	59	54.56	26.33
RIGHT	1	372	370	2	0.85	0.73
	2	220	219	1	0.62	1.21
	3	114	112	2	1.85	1.74
	4	29	27	2	2.04	0.94
	5	24	23	1	3.16	1.72
	6	13	7	6	4.50	1.68
	7	31	17	14	16.88	7.47
BACK	1	622	621	1	1.89	1.62
	2	175	174	1	0.69	1.35
	3	57	57	.	0.87	0.82
	4	23	23	.	1.27	0.58
	5	10	10	.	0.88	0.47
	6	10	8	2	2.03	0.67
	7	15	10	5	4.88	1.70
LEFT	1	354	353	1	1.09	0.94
	2	208	207	1	0.84	1.63
	3	93	93	.	2.27	2.13
	4	45	43	2	5.19	2.45

Analysis 9: Driver Injuries (A+K) in Passenger Cars and Station Wagons in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	16	13	3	3.16	1.78
	6	13	6	7	6.50	2.85
	7	24	10	14	15.69	8.01
		4,423	4,225	198	198.00	104.56

Analysis 9: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Ninth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	2719.50	0.0000
POSTFIRE	1	18.83	0.0000
TAD1	3	768.91	0.0000
TADSEV1	6	1122.80	0.0000
POSTFIRE*TADSEV1	6	31.27	0.0000
TAD1*TADSEV1	18	410.34	0.0000
LIKELIHOOD RATIO	21	26.19	0.1993

Analysis 10: Driver Fatalities (K) in Passenger Cars and Station Wagons in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Serious and Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	870	870	.	0.80	0.04
	2	499	499	.	0.41	0.03
	3	229	228	1	0.41	0.10
	4	121	117	4	3.36	0.15
	5	67	65	2	1.05	0.34
	6	80	77	3	5.91	1.18
	7	89	63	26	22.11	4.64
RIGHT	1	372	371	1	0.33	0.01
	2	220	220	.	0.18	0.02
	3	114	114	.	0.20	0.05
	4	29	27	2	0.79	0.04
	5	24	24	.	0.37	0.12
	6	13	9	4	0.94	0.19
	7	31	27	4	7.58	1.58
BACK	1	622	622	.	0.14	0.01
	2	175	174	1	0.04	0.00
	3	57	57	.	0.02	0.01
	4	23	23	.	0.16	0.01
	5	10	10	.	0.04	0.01
	6	10	10	.	0.19	0.04
	7	15	13	2	1.13	0.20
LEFT	1	354	353	1	0.72	0.03
	2	208	208	.	0.38	0.03
	3	93	93	.	0.37	0.09
	4	45	44	1	2.69	0.12

Analysis 10: Driver Fatalities (K) in Passenger Cars and Station Wagons in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)							
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Serious and Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	16	16	.	0.55	0.18
	6	13	11	2	1.96	0.42
	7	24	15	9	10.17	2.61
		4,423	4,360	63	63.00	12.24

Analysis 10: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Tenth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	1777.04	0.0000
POSTFIRE	1	63.54	0.0000
TAD1	3	384.08	0.0000
TADSEV1	6	644.01	0.0000
POSTFIRE*TADSEV1	6	14.57	0.0238
LIKELIHOOD RATIO	39	55.10	0.0453

Note: The reduced model shown above does not quite fit the data at $\alpha = 0.05$. The next, "fuller" model (shown below) does fit the data, but the TAD1 by TADSEV1 interaction is not significant. The reduced model shown above was selected in preference to the one below.

Source	DF	Chi-Square	Prob
INTERCEPT	1	1656.49	0.0000
POSTFIRE	1	63.74	0.0000
TAD1	3	135.40	0.0000
TADSEV1	6	526.19	0.0000
POSTFIRE*TADSEV1	6	14.76	0.0222
TAD1*TADSEV1	18	25.55	0.1106
LIKELIHOOD RATIO	21	28.24	0.1334

Analysis 11: Driver Injuries (A+K) in Pickups in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)

Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	138	138	.	0.54	0.19
	2	55	55	.	0.76	0.27
	3	25	23	2	1.07	0.38
	4	8	7	1	0.86	0.32
	5	12	10	2	2.85	1.18
	6	11	6	5	3.94	1.79
	7	16	6	10	9.45	5.37
RIGHT	1	38	38	.	0.26	0.09
	2	26	26	.	0.40	0.14
	3	14	12	2	0.62	0.22
	4	8	6	2	0.83	0.31
	5	3	2	1	0.53	0.21
	6	6	4	2	1.58	0.67
	7	1	1	.	0.52	0.27
BACK	1	100	99	1	0.53	0.19
	2	41	41	.	0.80	0.28
	3	12	12	.	0.59	0.21
	4	7	7	.	0.61	0.23
	5	2	2	.	0.29	0.11
	6	3	1	2	0.74	0.31
	7	1	.	1	0.30	0.13
LEFT	1	35	35	.	0.20	0.07
	2	26	25	1	0.52	0.19
	3	8	8	.	0.38	0.14
	4	12	12	.	1.39	0.53

Analysis 11: Driver Injuries (A+K) in Pickups in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B)	Serious and Fatal Injuries (A+K)	Fitted A+K Injuries	Expected A+K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	5	5	.	1.14	0.47
	6	2	1	1	0.81	0.38
	7	3	2	1	1.47	0.75
		618	584	34	34.00	15.41

Analysis 11: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Eleventh Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	770.10	0.0000
POSTFIRE	1	25.53	0.0000
TAD1	3	17.62	0.0005
TADSEV1	6	3225.98	0.0000
TAD1*TADSEV1	18	64.57	0.0000
LIKELIHOOD RATIO	27	28.66	0.3773

Analysis 12: Driver Fatalities (K) in Pickups in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Serious and Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
FRONT	1	138	138	.	0.05	0.00
	2	55	55	.	0.06	0.01
	3	25	23	2	0.18	0.01
	4	8	8	.	0.17	0.01
	5	12	11	1	1.02	0.09
	6	11	9	2	1.96	0.19
	7	16	11	5	7.17	1.00
RIGHT	1	38	38	.	0.01	0.00
	2	26	26	.	0.03	0.00
	3	14	14	.	0.09	0.01
	4	8	7	1	0.15	0.01
	5	3	3	.	0.23	0.02
	6	6	5	1	0.98	0.09
	7	1	1	.	0.42	0.06
BACK	1	100	100	.	0.01	0.00
	2	41	41	.	0.02	0.00
	3	12	12	.	0.03	0.00
	4	7	7	.	0.05	0.00
	5	2	2	.	0.06	0.01
	6	3	1	2	0.21	0.02
	7	1	.	1	0.22	0.02
LEFT	1	35	35	.	0.02	0.00
	2	26	26	.	0.04	0.00
	3	8	8	.	0.07	0.01
	4	12	12	.	0.32	0.03

Analysis 12: Driver Fatalities (K) in Pickups in Multi-Vehicle Crashes with Post Crash Fires, by Location and Severity of Impact (TAD) (continued)						
Location and Severity of Impact (TAD)		Driver Injuries Observed			Driver Injuries from Model	
		Total Cases	Lesser Injuries or None (O-C-B-A)	Serious and Fatal Injuries (K)	Fitted K Injuries	Expected K Based on Vehicles that Did Not Experience Post Crash Fires
LEFT	5	5	5	.	0.51	0.05
	6	2	1	1	0.42	0.04
	7	3	3	.	1.50	0.23
		618	602	16	16.00	1.92

Analysis 12: Maximum-Likelihood Analysis-of-Variance Table for the Logit Model Selected for the Twelfth Analysis

Source	DF	Chi-Square	Prob
INTERCEPT	1	657.47	0.0000
POSTFIRE	1	65.92	0.0000
TAD1	3	11.26	0.0104
TADSEV1	6	742.59	0.0000
LIKELIHOOD RATIO	45	60.54	0.0608