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AIRBAG FATALITIES APPROXIMATION FOR THE PASSENGER CAR FLEET

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FINAL REPORT

The University of Michigan

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16. Abstract

Effects of airbags in the passenger car fleet were estimated by comparing fatality rates per registered passenger car. Fatalities, by seating position, were obtained from the 1992 Fatal Accident Reporting System data file, car registrations from the R. L. Polk National Vehicle Population Profile, and New Car Registration files.

Driver, and right front-seat occupant, fatality rates in airbag-equipped and other cars were compared to estimate the effects of airbags relative to safety belts, as used in 1992. Corrections for vehicle age were made. Occupants of airbag-equipped cars had 30 to 33 percent lower fatality rates.

Initially, heavier cars were equipped with airbags. Therefore, their occupant fatality rate would be lower, possibly by as much as 25 percent. An attempt to correct for this was not successful. Thus, the estimated airbag effects may be upwardly biased.

Seventy-five percent of the airbag effect appeared in frontal impacts, the rest in side impacts; 95 percent were in nonrollover crashes.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

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AIRBAG FATALITIES APPROXIMATION FOR THE PASSENGER CAR FLEET

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Objective

This study estimates the number of front-seat, passenger-car fatalities that would have occurred in 1992 if the entire passenger car fleet had been equipped with driver and right, front-seat airbags. Separate estimates are provided by seating position, and by crash direction and type.

General Approach

The estimates are based on fatality rates per registered vehicle year. Rates for vehicles with airbags are compared with those for vehicles without airbags; the differences are interpreted as effects of airbags. Such rates are confounded by many factors. A major factor is vehicle mass: occupants of lighter cars face a higher fatality risk than occupants of heavier cars. Since initially heavier cars were equipped with airbags, mass effects confound estimates of airbag effectiveness. Vehicle age is another confounding factor: annual mileage decreases with increasing vehicle age, the accident mix changes, and the risk of fatal accidents also changes. The presence of a right, front-seat passenger may also vary with the size—related to mass—of a car, and/or its age. If so, fatality rates for right, front-seat passengers will be confounded.

There are many more factors that influence the fatality risk, which may be related to the presence or absence of an airbag in the current fleet: driver age, urban/rural, alcohol, environment, and type of traffic, to name some. To control for most of these factors is practically impossible. However, the available data allow one to control for effects of vehicle age, and, to some extent, for correlated factors. It also appeared that they might allow to control for effects of vehicle mass, and, to some extent, for correlated factors. This was attempted, but did not succeed.

Fatality information was obtained from the 1992 FARS file, from which passenger car occupant fatalities, and information on their vehicles, were extracted.

Vehicle information was obtained from R. L. Polk data files on NHTSA's computer. The National Vehicle Population Profile provides information on all passenger cars registered on 7/1/1992. It does not give information on airbag availability. The New Car Registration file gives information on new cars registered in each calendar year, beginning in 1987. It contains information on airbag availability.

Three levels of analysis were performed. In the basic level, fatality rates per registered car are calculated for cars without and with airbags. The latter rates are applied to the entire fleet to estimate fatalities in an all airbag fleet. This analysis does not account for any confounding factors, and the result is likely to be biased toward a low estimate.

The second level analysis includes vehicle age. Cars are stratified by age, and comparisons between airbag and other cars are made only within the same age groups. They give a factor by which airbags reduce the fatality risk, and this factor is applied to other age groups, where no direct comparison is possible.

The third level stratifies by vehicle mass and age. Again, comparisons between airbags and other cars were attempted only within the same strata. While this approach is conceptually the soundest, problems with data compatibility lead to implausible results.

Estimates are subject to uncertainties and errors from several sources. An unavoidable source is the random variability of accidents. Other sources are errors in the data files, which are not recognized as such, and missing information, which is obvious. Some missing information prevents an exact match between accident and registration files, which affects the calculated rates. Missing information may not have the character of random errors. Therefore, only simple heuristic error estimates were attempted. They are intended to give an idea of the magnitude of uncertainties to be expected, not to be interpreted as precise statistical error estimates.

FARS Data

From the 1992 FARS file, records for passenger car occupants and their vehicles were extracted. A total of 14,095 driver fatalities, 4919 right, front-seat occupant fatalities, and 2213 other occupant fatalities were found. They were identified by vehicle body type (1 to 9), occupant type, occupant seating position, and injury severity (all fatalities). Table 1 shows the counts of occupant fatalities by model year and airbag availability.

For the cars, the VIN, weight, model year, rollover, and initial impact point were extracted. The initial and not the primary impact point was selected, because the initial impact triggers the airbag.

NHTSA's program AOPVIN was used to decode the VIN for airbag availability in cars of 1985 or later model year. The information was aggregated into three categories, driver side only airbag, driver and passenger side airbag, and other or no restraint. There were 310 out of 7885 drivers' cars that could not be decoded; they were treated as having no airbag.

For the initial impact point, the clock positions 1 to 12 were distinguished; all other impact codes were aggregated into an "other" category. In addition, aggregated impact codes were defined, "front" (11, 12, 1), "right" (2, 3, 4), "rear" (5, 6, 7), "left" (8, 9, 10). Rollover, as the first or subsequent event was combined versus no rollover or unknown.

Vehicle weight was recoded into the categories under 2500, 2500 to 3400, and 3500 (due to the rounding convention for weight, the actual classes are < 2450, 2450 to 3449, > 3449).

Table 1. Fatalities by airbag status and model year.

Model Year	Drivers No bag	Drivers Airbag	Right Front Seat No bag	Right Front Seat Airbag	Other Occupants No bag	Other Occupants One	Other Occupants Two bags
pre-78	1,332	0	433	0	180	0	0
78	542	0	178	0	63	0	0
79	650	0	206	0	91	0	0
80	594	0	214	0	97	0	0
81	661	0	221	0	109	0	0
82	661	0	226	0	116	0	0
83	750	0	231	0	119	0	0
84	1,020	0	348	0	155	0	0
85	1,085	1	373	0	175	0	0
86	1,161	3	409	0	178	1	0
87	1,076	5	375	0	161	2	0
88	1,102	8	390	0	136	0	0
89	975	28	391	1	161	1	0
90	666	185	311	2	117	31	0
91	658	249	348	4	103	60	2
92	408	240	239	6	88	55	3
93	20	15	6	1	5	3	1
Total	13,361	740	5011	14	2,054	153	6

Registration Data

Data from the R. L. Polk's National Vehicle Population Profile (NVPP), and New Car Registration files were processed on NHTSA's computers, and summary tabulations produced.

The 1992 NVPP contains all cars registered in the U.S. on 7/1/1992. The following variables were used: series abbreviation, curb weight, NVPP make year (model year), and car count. For each series and model year, an average weight was calculated, and categorized as in the FARS data. NVPP does not contain information on restraint type provided. Table 2 shows the car counts by model year and weight class.

Table 2. Car registrations in thousands as of 7/1/92 by model year and weight class. Light = <2450 lbs., medium = 2450 -.3449, heavy = >3449

Model	Vehicle and Weight Group				
Year	Light	Medium	Heavy	Unknown	Total
Pre '78				11383	11,383
78	551	1,334	1,772	368	4,025
79	797	1,448	1,574	988	4,989
80	999	2,400	940	108	4,447
81	1,521	2,338	1,017	12	4,888
82	1,729	2,318	1,018	12	5,077
83	1,957	2,577	1,420	45	5,999
84	2,799	3,975	1,687	106	8,567
85	3,095	4,466	1,556	98	9,215
86	3,364	5,414	846	128	9,752
87	3,057	5,871	706	6	9,640
88	2,673	6,229	812	46	9,761
89	2,381	5,902	1,022	5	9,309
90	1,506	5,831	1,031	3	8,372
91	1,673	5,241	1,183	4	8,100
92	847	3,226	952	204	5,226
Unknown				1,750	1,750

The New Car Registration file for year y contains monthly counts of registrations for cars of model year y+1, y, and y-1 (relatively few). Its information differs from that of the NVPP. Variables used were model year, restraining device code, series code, and month count. The new car registration count file does not contain information on car weight.

New car registrations for three years were combined to obtain complete information on one model year (e.g., 1988, 89 and 90 to obtain information on the 1989 model year). The restraint information in the New Car Registration file was aggregated into the same categories as for the FARS data: driver side only airbag, driver and passenger side airbag, and other or unknown. Table 3 shows the counts of new car registration by restraint type and model year.

Table 3. New car registrations in thousands by model year and restraint type.

Model Year	Driver Airbag Only	Driver + Passenger Airbag	Other Restraint	Unknown
87	131	0	10305	207
88	195	0	9636	731
89	440	61	9114	287
90	2321	144	6237	4
91*	3017	36	5395	1
92*	2495	227	2288	1
93*	110	25	89	0

* Cars registered during 1992 are weighted proportional to time registered in 1992.

Comparing the count of new cars of a certain model year with the number of cars of the same model year registered on 7/1/92 allows one to calculate survival rates. They are shown in table 4.

Table 4. Survival rates to 7/1/92.

Model year	87	88	89	90	91
Survival rate	.906	.924	.940	.962	.959

Cars registered in 1992 were weighted according to the registration month, to account for varying exposure during this year. A car registered in January was counted as 11.5/1, a car registered in December as 0.5/12, etc. For cars of model years 1992 and 93, no attrition was assumed.

To obtain numbers of cars in use in 1992, by restraint type, data on pre-1987 model years were taken from the NVPP, assuming no airbags[1]; for later model years, the new registration counts were used and the survival rates of Table 4 applied.

This approach may possibly underestimate the availability of airbags: survival rates differ among car classes. If more expensive and/or heavier cars had higher survival rates, airbag-equipped cars would also show higher survival rates.

For analyses requiring stratification by weight and model year, we tried to infer car weight in the New Car Registration file from the model series code. Car weight is available in the NVPP by model series. However, the model series code for about half the cars in the New Car Registration file could not be matched with the series code in the NVPP. To overcome this limitation, we tried two approaches.

[1]This is not completely correct, in the model year 1986, approximately 79,000 new cars with airbags were produced, and a small number of cars had airbags much earlier.

The first approach assumed that the weight distribution for all cars in a restraint class was the same as for those cars that could be matched. While this gave correct distributions of restraint type, the resulting weight distributions, for all cars, often differed greatly from those in the NVPP for the corresponding model years. Also, fatality rates by restraint type and weight class showed large fluctuations and implausible patterns.

The other approach used iterative proportional fitting, using the cross-tabulation of restraint class by weight class, and adjusted to the margins of restraint distribution in the New Car Registration file and weight distribution in the NVPP. While this resulted in correct distributions of restraint types and weight, fluctuations of fatality rates remained large and still showed implausible patterns.

Therefore, we could not adjust for the fact that current airbag-equipped cars are heavier than the average car, and, therefore, have an inherently lower occupant fatality risk.

A Basic Estimate

In 1992, 13,361 drivers were killed in cars without airbags, 730 in cars with airbags (this excludes four drivers with airbags in pre-1987 cars). Registered years for vehicles where absence of airbags was known or assumed totalled 109,839,000; for vehicles known to have had airbags, 8,926,000. This gives a fatality rate of 0.122 per 1,000 for cars without airbags; 0.082 for cars with airbags. This represents a reduction of the fatality risk by 33 percent. Applying the lower rate of 0.082 to the cars without airbags gives a hypothetical figure of 9,713 driver deaths in an all air-bag fleet, compared with an actual number of 14,091.

An additional 4,905 right front seat occupants were killed in cars without passenger side airbags, 14 in cars with passenger side airbags. There were 118,282,000 registered years of cars without passenger side airbags, 403,000 of cars with such airbags. The fatality rates are 0.0415 and 0.0290, respectively, per 1,000 registration years. The reduction in risk is 30 percent, and the hypothetical estimate of right front seat passenger fatalities is 3,442, compared with an actual figure of 4,919.

Finally, 2,213 other passenger car occupants were killed. These occupants were seated somewhere other than the driver or right front seat position. Their fatality risk should not have been affected by the availability of airbags. However, it is worthwhile to perform similar calculations as for drivers and right front seat occupants to see whether airbag equipped cars have lower fatality risks than other cars, due to factors other than the airbag. Such a comparison, however, can be only suggestive, not conclusive, because it deals mainly with rear seat occupants, which face very different physical risks than front seat occupants.

There were 2,054 other car occupants killed in cars without airbags, 153 in cars with driver-side airbags, and six in cars with dual airbags. The corresponding rates are 0.0187, 0.0181, and 0.0124. The first two rates are practically identical. The last appears to be lower, but one must consider that the numerator (six) is small. If this number of deaths were a Poisson variable with an expected value of nine, which would make the rate equal to the others, a value of six or less would have a probability of 21 percent; thus, the low value may likely be due to chance. This suggests that there maybe no difference in the fatality risk to the occupant between airbag and other cars.

To summarize the findings: for drivers and right, front-seat occupants, airbag-equipped cars have a 30 to 33 percent lower fatality rate per car year. The total number of car occupant deaths in an all airbag fleet would be 15,368, compared to 21,223 in the 1992 fleet. The reduction of 28 percent is smaller than the 30 to 33 percent reduction of the fatality rates, because a substantial number of cars already had airbags in 1992.

Estimates Considering Vehicle Age

The fatality rates for drivers and right, front-seat passengers show a peculiar pattern with age as shown in Fig. 1, where age is reflected by the model year. The newest model years show a sharp increase in the fatality rate. This may reflect a real increase in risk in the first few months of use, or a lag in recording the new car registration data.

To account for possible age-related effects, airbag and non-airbag cars were compared only in matched age groups. In cars of the model years 1987-93, when both airbags and non-airbag cars were available, 730 drivers were killed in airbag cars, and 4,905 drivers in non-airbag cars. With the corresponding registration figures of 8,926,000 and 41,497,000, rates of .082 and .118 per 1,000 result. The rate for airbag cars is 31 percent lower.

In cars of model years before 1987, 8,456 drivers were killed, which with 68,342,000 registrations gives a rate of .124 per 1,000. This is higher than the rate for the more recent non-airbag cars and suggests that a comparison between airbag cars and all non-airbag cars without accounting for age would be biased.

For this estimate, simple error estimates can be made. Data are stratified by model year, x_i being the number of deaths in, y_i that of registered cars of model year *i*. An estimate of the standard error of the estimated rate

$$R = \Sigma x_i / \Sigma y_i$$

is

$$S = \sqrt{((\Sigma(x_i - Ry_i)^2 / n(n-1))} / y_o$$

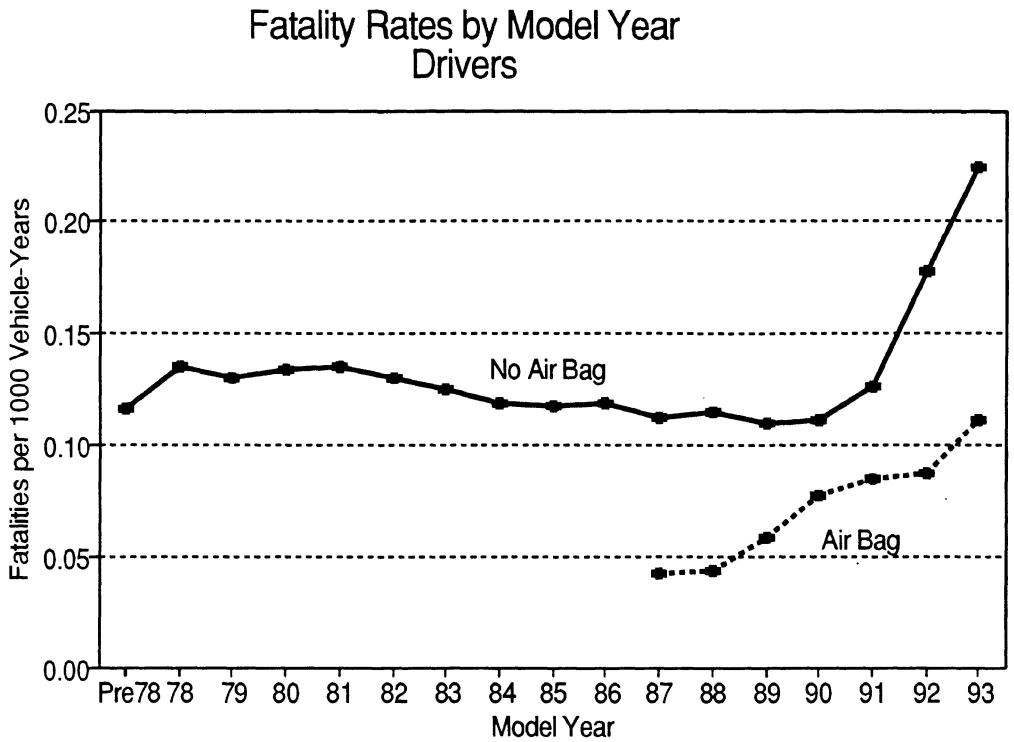

Figure 1

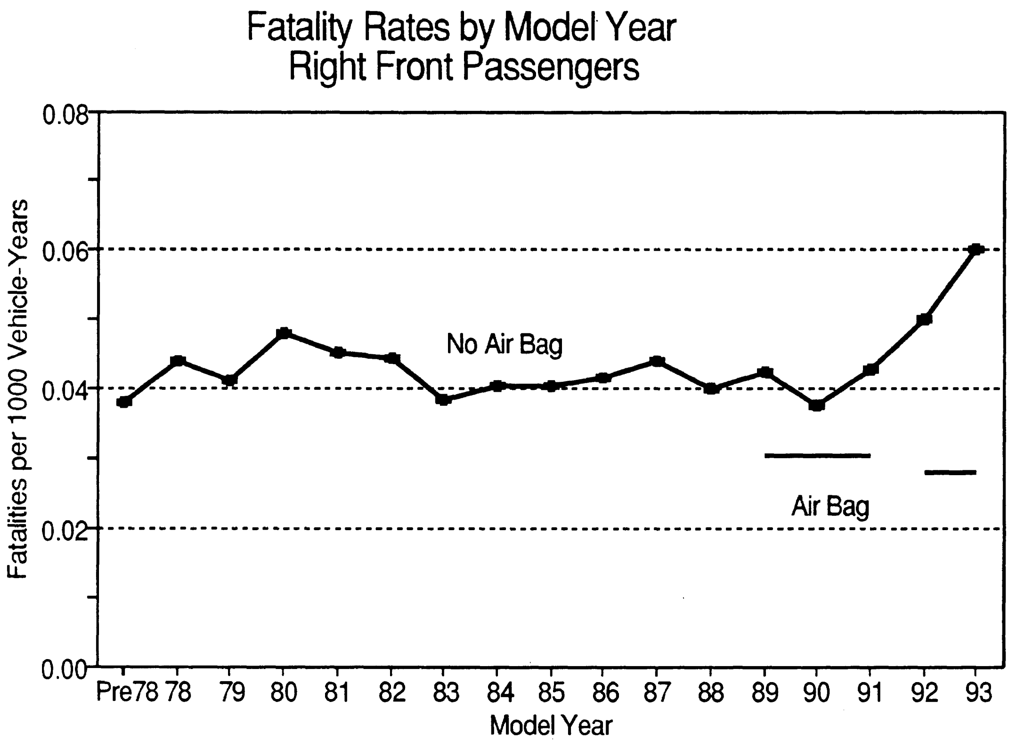

Figure 2

where y_o is the average of the y_i per model year, and n the number of model years used. This formula weights according to the varying sales in different model years.

The resulting standard errors are 0.003 for the rates of airbag cars, 0.005 for recent non-airbag cars, and 0.003 for the older non-airbag cars. With such errors the difference between the rates for the earlier and more recent non-airbag cars, 0.118 and 0.124, may well be due to chance.

The ratio of two rates, r=p/q, reflecting the apparent effect of the airbag, has a standard error given by

$$s(r)^2 = (s(p)^2+r^2s(q)^2-2r\rho s(p)s(q))/q^2$$

where s(p) and s(q) are the standard errors of p and q, and ρ the correlation coefficient between p and q, which in this case is 0.81. The resulting s(r) is 0.03 for the ratio r = 0.69.

The same procedure was applied to right, front-seat occupants. In cars of the model years 1989-93 when passenger side airbags became available, 14 right front seat occupants were killed in cars with airbags for them, 1,301 in cars with no or only driver side airbags. With registrations of 483,000 and 30,539,000, rates of .029 and .043 result, with a ratio of .68. In cars of earlier model years, 3,604 right front seat passengers were killed; with 87,744,000 registrations, the rate is 0.041.

Error estimates were made for drivers, giving .002 for the non-airbag cars, and 0.009 for the airbag cars; the latter high value is due to the low number of deaths and registrations. Due to this, and to the fact that the correlation coefficient between the two rates is practically zero, the ratio of .68 has a standard error of .21. This means that the apparent reduction of 31 percent for right front passengers is very uncertain.

These figures allow one to estimate occupant fatalities for an all airbag fleet. For drivers,

$$730 + 0.69*(4905 + 8456) = 9949$$

results, where the first term reflects the fatalities in airbag cars that are not changed in an all-airbag fleet. This is a reduction by 4810. For right front seat occupants, the estimate is:

$$14 + 0.68*(1301 + 3604) = 3349$$

The figure of 2,213 for other occupants remains unchanged. The total is 14,843, which compared with 21,173 is a 30% reduction.

Since we could estimate standard errors for the ratios 0.64 and 0.68, we can also estimate the standard error for the hypothetical total. It is

$$\sqrt{(.03^2*(4905+8456)^2+0.21^2*(1301+3554)^2} = 1106$$

The magnitude of the error is mainly due to the uncertainty of the estimate for right front seat occupants, 1020. For drivers only, the standard error is much smaller, 400.

Consideration of Car Mass

It is well established that a car occupant's risk of dying in a crash decreases with increasing mass of his car. It does not necessarily follow that the rate of occupant deaths per registered car similarly declines, because the probability of getting into a crash is influenced by many factors, some of which may be correlated with vehicle mass.

Only a negligible fraction of cars of model years before 1987 had airbags. For cars of the model years 1978-86, mass information could be extracted from the NVPP file, the percentage of cars with mass information ranging from 80 percent to 99.8 percent. Three car classes were distinguished: <2450, 2450 to 3449, and >=3450.

The resulting driver fatality rates are shown in Table 5 in the first row labelled 1978-1986. This trend with severity is as one would expect. The rate for heavy cars is 0.75 of the average rate 0.130 for all cars (which is only coincidentally the same as that for medium cars). This means that if some heavy cars were equipped with an ineffective device, and their fatality rate be compared with that of all cars, one would notice a reduction of 25 percent associated with the device, even though it is actually ineffective. Since similar comparisons have to be made in the case of the airbag, some control for car weight is desirable.

Table 5. Comparison of driver fatality rates per 1000 registered vehicles by model year, restraint type, and method of weight imputation. Standard errors are in parenthesis.

	No Airbag			Airbag		
	Light	Medium	Heavy	Light	Medium	Heavy
1978-1986	.152 (.009)	.130 (.009)	.098 (.009)			
1987-93 Weight distributed proportionally	.112* (.019)	.105 (.006)	.176 (.037)	.079* (.026)	.101 (.010)	.085 (.068)
1987-93 Weight distributed by iterative proportional fitting	.189* (.031)	.092 (.005)	.185 (.072)	.107* (.032)	.084 (.005)	.076 (.022)

* Excluding model years 1987 and 88 when no light cars with airbags were offered.

This cannot be directly done because car mass is given only in the NVPP file, not in the New Car Registration file. Restraint type is given only in the New Car Registration file, but not in the NVPP. To merge information from the two files, one needs a unique identifier of the car classes used in these two files. Different characteristics are used to classify cars in these files. The finest common classification is by series. However, for only

50 to 60%—varying among the model years—of the cars in the New Car Registration file could a matching series be found in the NVPP, and a weight assigned (an average weight for all cars of each series was used). Therefore, imputation of the missing car weight for each restraint class was attempted.

The first imputation was straightforward. The distribution of weights in each restraint class, obtained from the matched series, was used to assign weights to the other cars in the same restraint class in the same proportions. The result was not fully satisfactory because the resulting weight distributions for all cars differed sometimes widely from that in the NVPP.

Nevertheless, these imputed weights were used to classify cars and calculate fatality rates, that are shown in table 5 in the second row. For the light and medium weight cars, the rates are lower than those for the earlier model years, but for the heavy cars, the rate is much higher than for the heavy cars of earlier model years, and higher than for the lighter cars of the same model years; the standard error is also large. These results makes this imputation of weights unsatisfactory.

Therefore, an alternative imputation was also tried. The tabulation of restraint type by weight, for the cars that could be matched, was used as interaction table. The distribution of restraint types in the model year from the New Car Registration file, was used as one margin, and the distribution of weight for that model year from the NVPP was used as the other margin. By iterative proportional fitting, a table of restraint type by weight was obtained that retained the interactions from the matched tabulations, and also satisfied the distribution of restraint classes, and of car weights, thus avoiding the obvious shortcoming of the first imputation.

The result of this imputation was also used to calculate fatality rates, which are shown in the last row table 5. The value for heavy cars does not differ much from that obtained by the first imputation, and its standard error is even larger. The values for light and medium cars differ much more than in the pre-1987 model year, which are fairly reliable. Thus, this imputation is not satisfactory either.

Though both imputations are not satisfactory, we also show the rates for airbag equipped cars obtained using them. In both cases, the values for airbag cars are lower than for the other cars. The pattern, however, is puzzling: differences for medium weight cars are very small, for light cars large, and for heavy cars even larger.

The conclusion is that weight has an appreciable effect on the fatality rates, and that it biases comparisons that ignore weight differences between airbag-equipped cars and others to an unknown extent. The information in the data files used does not readily allow one to control for these differences.

Analysis by Initial Impact

Because airbags are triggered by the initial impact (except if it is so weak that a stronger second impact is needed to trigger it), the initial impact variable is used to determine impact type. Impacts are indicated by clock position. For the analysis, they are aggregated: 11, 12, 1 into "front," 2, 3, 4 into "right," 5, 6, 7 into "rear", 8, 9,10 into "left," and all other codes into "other."

Table 6 shows the driver fatality rates by impact site, and car and restraint class. As noted before, rates for the more recent model cars without airbags are lower than those for the pre-1987 cars. The ratio of the rates for the recent cars with and without seatbelts is 0.63 for frontal impacts, suggesting a 37 percent fatality risk reduction for these cars. Interestingly, for both left and right side impacts, the ratio is 0.76, suggesting a 24 percent fatality risk reduction. Possible explanations for this effect are that even a side impact can decelerate a car in its direction of travel, and can also deform the body so as to be sensed like a frontal impact by the trigger mechanism. For rear impacts, other impacts, and no impact crashes, airbags have slightly higher driver fatality rates. Table 7 shows the data in greater detail.

Table 6. Driver fatality rates by car class, and initial impact.

	Initial Impact				
Car Class	Front	Right	Left	Rear	Other
Pre-1987 Models	.0705	.0138	.0233	.0039	.0128
Later models					
no airbag	.0623	.0127	.0227	.0030	.0099
airbag	.0391	.0097	.0172	.0032	.0102
ratio	.63	.76	.76	1.07	1.03

Table 7. Driver fatalities and fatality rates by initial impact. Initial impact is indicated by clock position. Airbag factor is the ratio of rates for cars with and without airbags, of the same model years.

Initial	Drivers Fatalities			Rate per 1000			Airbag
impact clock position	pre-87 cars	Later cars without airbag	Later cars with airbag	Pre-87 cars	Later cars without airbag	Later cars with airbag	factor
11	832	461	76	.0055	.0044	.0036	.82
12	3,574	2,040	247	.0122	.0104	.0083	.80
1	416	260	37	.0061	.0059	.0040	.68
2	177	135	28	.0026	.0030	.0030	1.00
3	714	396	55	.0104	.0089	.0060	.67
4	53	33	6	.0008	.0007	.0007	1.00
5	58	17	1	.0008	.0004	.0001	.25
6	153	87	18	.0022	.0020	.0020	1.00
7	56	31	8	.0008	.0007	.0009	1.28
8	68	39	9	.0010	.0009	.0010	1.11
9	1,155	771	116	.0169	.0174	.0126	.72
10	373	196	33	.0055	.0099	.0102	1.03
Other or None	827	439	94	.0121	.0099	.0102	1.03

Table 8 shows how driver fatalities by impact would be changed if the rates in non-airbag cars were changed by the airbag factor, corresponding to an all airbag fleet. It shows that of the total reduction in fatalities, 75 percent would occur in frontal impacts, 10% in right side impacts, and 17 percent in left side impacts. This sums to more than 100 percent, because fatalities in the other impacts and no impact crashes would increase by 2 percent.

Table 8. Driver fatalities by car class and initial impact, and hypothetical reductions in an all-airbag fleet.

	Initial Impact				
Car Class	Front	Right	Left	Rear	Other
Pre-1987 Models	4,822	944	1,596	267	827
Later models					
no airbag	2,761	564	1,006	135	439
airbag	360	89	158	29	94
hypothetical reduction for an all airbag fleet	2,806	362	624	-28	-38
percent of total reduction	75	10	17	-1	-1

Because of the low number of right front seat occupants killed in cars with passenger side bags, no meaningful analysis can be performed. For frontal impact, a reduction of 69 percent appears, but for right side impacts an increase of 71 percent.

Analysis by Crash Type

As crash types, we distinguish those without rollover, and those with rollover, whether as primary or secondary event, because one would not expect an effect of an airbag in a rollover. Table 9 shows the corresponding analysis of the data. In nonrollover accidents, the airbag factor is 0.56 for driver and 0.62 for right front seat occupants, which is the same, considering the low number of right front seat occupant fatalities. In rollover crashes, the factor is much larger, .94 and .91, suggesting little, if any, effect in rollover accidents. 95% of the hypothetical savings in an all-airbag fleet are obtained in non-rollover crashes.

Table 9. Fatalities and fatality rates per 1000, by rollover strata, person type, and model year/restraint class.

Driver	No Rollover		Rollover	
	Fatalities	Fatality Rate	Fatalities	Fatality Rate
Pre-87 cars	6547	.0958	1909	.0279
Later cars, no airbag	3850	.0928	1055	.0254
airbag	500	.0518	230	.0238
Airbag factor		.56		.94
Hypothetical saving	4575		178	
Right front seat occupants				
Pre-89 cars	2914	.0332	690	.00786
Later cars, no airbag	1023	.0335	278	.00910
airbag	10	.0207	4	.00828
Airbag factor		.62		.91
Hypothetical saving	1496		87	

Summary

Comparison of fatality rates per registered vehicle between cars with and without airbags show that cars with airbags have 30-33 percent lower driver fatality rates, and 30-32 percent lower right front passenger fatality rates. A conceptually limited standard error estimate for the first figures is 3 percent, for the last figures, 21 percent.

In 1992, 14,091 drivers were killed in passenger cars. Using the above estimates of airbag effectiveness, in an all airbag fleet 9,300 to 9,700 drivers would have been killed, indicating a reduction of 4,400 to 4,800 deaths. A conceptually limited standard error estimate for these figures is 400.

Approximately 75% of the reduction occurred in crashes with frontal impacts, 17% in left impacts, and 10% in right impacts. Fully 95% of the reduction occurred in crashes with no rollover and only 5% in crashes with rollover as first or second event.

There were 4,919 right front seat passenger car occupants killed in 1992. In an all-airbag fleet, 3,300 to 3,400 would have been killed. This corresponds to a reduction of 1,500 to 1,600. The standard error of this figure, however, is 1020.

In 1992, cars with airbags were, on the average, heavier than the average. Such cars have lower occupant fatality rates than lighter cars. The available data did not allow separation of this effect from that of the airbags, and the above estimates may be upwardly biased.