Driver Death Rates by Vehicle Make and Series with Adjustments for Driver Age and Gender

Charles M. Farmer

October 2001

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

1005 N. GLEBE RD. ARLINGTON, VA 22201-4751
PHONE 703/247-1500 FAX 703/247-1678
website http://www.highwaysafety.org

ABSTRACT

Driver death rates per million registered vehicles per year were calculated for 161 passenger vehicle models for sale in 1997. Rates ranged from 18 to 308 deaths per million registrations per year. Station wagons, passenger vans, and luxury cars had driver death rates significantly lower than those for other vehicle types. Within vehicle type, larger vehicles generally had lower driver death rates than smaller vehicles. To account for potential differences in driver exposure by age and gender, which can affect motor vehicle crash and injury experience, an imputational method was used to standardize these rates to a common distribution of women drivers ages 25-64 (42 percent). These adjusted rates ranged from 15 to 286 deaths per million registrations per year, and the relative differences among vehicle types were lessened considerably. Within each vehicle market class, however, drivers were reasonably homogeneous with regard to age and gender, and the adjustments had little effect on the relative differences between rates.

INTRODUCTION

Periodically since 1989 the Insurance Institute for Highway Safety (IIHS) has calculated and published driver death rates per registered vehicle. Such rates provide an indication of the overall risk to drivers, including both the likelihood of being in a crash and of being fatally injured in that crash. Assuming similar amounts and types of driving per year, comparisons can be made among the various vehicle models. Such exposure, however, may vary widely across vehicle models for a number of reasons, including vehicle cost and marketing, geography, and economic conditions. Driver characteristics, especially age and gender, affect both the likelihood of crash involvement and the likelihood of injury in a crash. For example, young drivers are overinvolved in crashes, and elderly drivers are more likely to be killed if they are in crashes.

To compensate for the differences in exposure, many other published statistics on real-world crash injury experience standardize the injury rates to a common age and gender distribution of involved drivers. For example, standardized relative injury rates per reported crash have been published in Australia (Newstead et al., 1998), Britain (Grove and Wilding, 1995), Finland (Tapio et al., 1995), and Sweden (Gustafsson et al., 1984). Standardized relative injury rates per insured vehicle have been published in the United States (Highway Loss Data Institute, 1999).

Similar standardization of fatal crash rates for age and gender has not been possible. There is no national database of all reported motor vehicle crashes in the United States, so it is not possible to calculate driver death rates per crash. And, although there is a database of all fatal crashes and a corresponding database of all registered vehicles — so that it is possible to calculate driver death rates per registered vehicle for each vehicle model (IIHS, 2000) — the vehicle registration database does not include information on driver age and gender. Absent information on the exposure of each vehicle model by driver age and gender, driver death rates cannot be directly standardized to a common driver age and gender distribution.

One indirect method of lessening the effect of driver differences is to group vehicle models by size and body style. The driver population within each resulting vehicle group is likely to be much more homogeneous than the overall driver population. Therefore, comparisons among cars within a market group should be less affected by driver differences. Nevertheless, comparisons between vehicles in different market groups still are affected by driver differences.

A mathematical adjustment of death rates based on vehicle wheelbase and the proportion of occupant deaths in cars with male drivers or drivers under age 30 was included as part of the first few IIHS evaluations (IIHS, 1989). In addition to occupant death rates per 10,000 vehicle registrations, the differences between actual death rates and those predicted based on wheelbase, driver age, and gender were presented. About one-sixth of vehicles evaluated had actual death rates more than 40 percent lower or higher than those predicted by the mathematical model. These vehicles were then rated as performing much better or much worse than expected. In subsequent years the parameters of the mathematical model became unstable and the assumptions underpinning the methodology were suspect. The adjustment for wheelbase, age, and gender was abandoned.

This paper presents driver death rates per million registrations per year by vehicle model for model years 1994-97 during calendar years 1995-98. A new method is discussed for adjusting the rates to account for differences in driver age and gender. This adjustment makes comparisons of vehicles more meaningful by standardizing each vehicle's driver death rate to a population with a common proportion of 25-64-year-old female drivers — i.e., the group of drivers with the lowest fatality rate. Because the true proportion of 25-64-year-old female drivers for a given vehicle is unknown, the standardization procedure is indirect, based on an adaptation of the mathematical relationship between overall and group-specific driver death rates developed by IIHS (1989). One goal of the adjustment is to determine how the driver death rates of individual vehicle models are affected by driver differences. In addition, the adjustment is an attempt to refine the comparison of risk across vehicle size and market classes.

METHOD

Driver death rates: Counts of driver deaths for each make and series of 1994-97 passenger vehicles were obtained from the U.S. Department of Transportation's Fatality Analysis Reporting System (FARS), an annual census of fatal motor vehicle crashes. Vehicle make, series, and model year were determined by decoding vehicle identification numbers using the VINDICATOR software (Highway Loss

Data Institute, 1999). A vehicle series is defined as the combination of vehicle model and body style (e.g., the two-door and four-door Chevrolet Cavalier are different series).

Counts of registered vehicles for each make and series were obtained from the National Vehicle Population Profile (NVPP), a compilation of data from state registration files (The Polk Company, 1999). NVPP registration counts are a snapshot of vehicles registered as of July 1 of each year, so they tend to misrepresent annual registrations of the current model year. For example, registration counts on July 1, 1998, did not include any of the yet unsold 1998 models, nor did they provide information on how many months any new vehicle had been registered. In this analysis counts of both driver deaths and vehicle registrations for each model year were restricted to calendar years later than the model year. Nearly all such vehicles registered on July 1 would have been on the road for the whole year. Also, because NVPP does not include government-owned vehicles, driver deaths in police vehicles or vehicles with government tags were excluded from the analysis.

For each vehicle series, driver deaths and registrations were summed over all model years not significantly different in design from the 1997 model year. Design changes include changes in engineering design, such as the dimensions or weight of the vehicle, or the addition of driver or side airbags. For example, the Ford Taurus four-door car was redesigned in 1996, so only model years 1996-97 were included in this analysis. There were 25 driver deaths and 334,474 registrations for 1996 model Taurus cars during 1997, 30 driver deaths and 331,194 registrations for 1996 models during 1998, and 28 driver deaths and 353,031 registrations for 1997 models during 1998. Thus, the totals for the 1996-97 Taurus cars were 83 driver deaths and 1,018,699 registration-years.

Driver death rates were computed by dividing reported deaths by registered vehicle-years (in millions). Exact 95 percent confidence limits were computed assuming that the number of driver deaths for each vehicle series follows a Poisson distribution (Hahn and Meeker, 1991).

Adjustments for driver gender and age: IIHS (1989) expressed the relationship between the overall driver death rate per vehicle registration for the entire population (D) and the driver death rate for female drivers (D_1) as:

$$D_1 = D[1 + (R - 1)P_1] / R, \tag{1}$$

where P_1 is the proportion of driver deaths that were female and R is the ratio of driver death rates for males compared with females. The driver death rate for male drivers (D_2) can be expressed as:

$$D_2 = R\, D_1. \tag{2}$$

The relationships follow from basic rules of probability and certain algebraic identities (see Appendix). Equation 1 cannot be directly used to compute D_1 because the death rate ratio (R) is unknown, but it is useful if an estimate of R is available. Noting that R is expected to be large, IIHS suggested approximating the right side of Equation 1 by its limit as R approaches infinity, i.e.,

$$D_1 \cong D\,P_1. \tag{3}$$

In reality, however, the right side of Equation 3 is too small whenever $P_1 < 1$. Furthermore, this approximation is especially poor when P_1 is close to zero.

An alternative means of using Equation 1 is to estimate R by the ratio of driver death rates per licensed driver. For example, in 1998 there were 14,975 male and 6,651 female passenger vehicle driver deaths in the United States. According to the Federal Highway Administration (2000), there were 93,040,202 male and 91,820,767 female licensed drivers in 1998. Thus, there were approximately 161 deaths per million licensed male drivers and 72 deaths per million licensed female drivers, yielding a rate ratio of 2.2.

The death rate per registration for female drivers of any particular vehicle series would then be estimated as the death rate for both genders combined multiplied by $(1 + 1.2\,P_1) / 2.2$, where P_1 is the proportion of females among drivers dying in that vehicle series. Now suppose we wanted to predict the overall death rates if each vehicle series had the same proportion of female drivers. The adjusted overall driver death rate of a vehicle series, assuming W is the proportion of the driving population who were female, would be $D_S = W\,D_1 + (1 - W)\,D_2$. In other words,

$$D_S = [W + (1 - W)\,R\,]\,D_1 \tag{4}$$

Although W could be any chosen proportion, it is convenient to define it as the estimated proportion of females among the drivers of all vehicles combined. In this way the adjusted driver death rate for all vehicles combined is defined to be equal to the unadjusted rate. The constant W is computed as the overall driver death rate for all vehicles combined times the proportion of females among all drivers dying divided by the estimated female driver death rate.

Note that the adjusted driver death rate can also be expressed as the raw driver death rate multiplied by an adjustment factor (combine Equations 1 and 4). The adjustment factor is an increasing linear function of P_1, so death rates based on a low percentage of female drivers are adjusted down whereas those based on many female drivers are adjusted up. For vehicles series where P_1 equals exactly the proportion of females among all driver deaths in the study, the driver death rate would not be adjusted at all.

Driver death rates depend on driver age as well as driver gender. Even among female drivers, death rates per licensed driver age 25-64 are only half those of drivers younger than 25 or those 65 or older. Equation 1 can be used to adjust for gender and age simultaneously by defining P_1 to be the proportion of females ages 25-64 among the fatally injured drivers. According to FARS and the Federal Highway Administration (2000), there were 3,827 driver deaths and 66,186,373 licensed drivers in 1998 that were females ages 25-64. Thus, there were approximately 58 deaths per million licensed female drivers ages 25-64. For all other driver classifications, there were 17,799 deaths and 118,674,596 licensed drivers, yielding a rate of 150 deaths per million licensed drivers. The estimated rate ratio (R) was 2.6.

For each vehicle series, the death rate per registration for female drivers ages 25-64 was estimated as the overall driver death rate multiplied by $(1 + 1.6\ P_1) / 2.6$, where P_1 was the proportion of females ages 25-64 among drivers dying in that vehicle series. The estimated proportion of females ages 25-64 in the overall driving population of vehicles in this study (W) was 0.42, so the adjusted driver death rate for each vehicle series was estimated as the female age 25-64 driver death rate multiplied by 1.93 (see Equation 4). Approximate 95 percent confidence limits for the adjusted death rates were computed as two standard deviations to either side of D_S (see Appendix for the derivation of the variance of D_S).

RESULTS

Table 1 lists driver death rates for all vehicle series with either 20 or more driver deaths or at least 120,000 vehicle registration-years of exposure. Death rates for vehicle series not meeting these criteria were considered too imprecise to provide useful information. Vehicle series are arranged by vehicle type, size class, and body style and ordered from highest to lowest driver death rate. Also listed are adjusted driver death rates.

Car sizes are defined in terms of both wheelbase and overall length. Cars with a wheelbase greater than 115 inches or an overall length greater than 210 inches are classified as very large. All cars not meeting the very large criteria, but with either a wheelbase greater than 110 inches or an overall length greater than 195 inches, are classified as large. All cars not meeting the large or very large criteria, but with either a wheelbase greater than 105 inches or an overall length greater than 180 inches, are classified as midsize. All cars not meeting the midsize, large, or very large criteria, but with either a wheelbase greater than 100 inches or an overall length greater than 165 inches, are classified as small. All remaining cars are classified as mini. Light truck sizes are defined in terms of curb weight of the four-wheel-drive version: less than 3,000 pounds; 3,000-3,999 pounds; 4,000-4,999 pounds; and 5,000 pounds or more.

The adjustment for driver age and gender tended to lessen differences in driver death rates between vehicles. For example, among small four-door cars, the Saturn SL and Toyota Corolla, each with approximately 1.9 million registration-years, had overall driver death rates of 73 and 86, respectively. However, the SL had a higher proportion of 25-64-year-old females among the fatally injured drivers (36 percent) than did the Corolla (30 percent). Therefore, the driver death rate for the SL was adjusted more than that for the Corolla. The adjusted driver death rates for the SL and Corolla were 86 and 95 per million registration-years, respectively.

Table 1
Driver Death Rates by Vehicle Make and Series with Adjustments for Driver Age and Gender

				Driver Deaths					Driver Death Rates per Million Registrations					
										95 Percent Confidence Limits			95 Percent Confidence Limits	
Make	**Series**	**Model Years**	**Vehicle Registrations**	**Ages <25**	**Ages 65+**	**Males Ages 25-64**	**Females Ages 25-64**	**Total**	**Raw**	**Lower**	**Upper**	**Adjusted**	**Lower**	**Upper**
Mini Two-Door Cars														
Geo	Metro	1995-97	249,025	12	9	13	18	52	**209**	156	274	**241**	167	316
Hyundai	Accent	1995-97	135,255	16	0	5	3	24	**177**	114	264	**158**	88	229
Ford	Aspire	1994-97	273,084	18	2	9	17	46	**168**	123	225	**199**	134	264
Toyota	Tercel	1995-97	284,462	19	4	7	12	42	**148**	106	200	**160**	105	215
Size/style total			1,045,500	72	16	36	53	177	**169**	145	196	**186**	155	217
Mini Four-Door Cars														
Geo	Metro	1995-97	183,656	13	5	8	13	39	**212**	151	290	**242**	156	328
Ford	Aspire	1994-97	133,451	9	4	3	12	28	**210**	139	303	**263**	153	372
Hyundai	Accent	1995-97	138,025	8	2	5	6	21	**152**	94	233	**165**	85	245
Size/style total			545,658	35	13	18	32	98	**180**	146	219	**203**	157	249
Small Two-Door Cars														
Ford	Probe	1994-97	560,361	45	2	24	14	85	**152**	121	188	**142**	108	177
Dodge/Plymouth	Neon	1995-97	328,350	22	4	12	9	47	**143**	105	190	**139**	94	184
Mitsubishi	Eclipse	1995-97	301,622	23	3	8	6	40	**133**	95	181	**122**	80	165
Nissan	200SX	1995-97	184,720	11	4	2	5	22	**119**	75	180	**121**	63	178
Acura	Integra	1994-97	474,384	20	1	9	6	36	**76**	53	105	**71**	45	98
Toyota	Celica	1994-97	218,211	7	1	5	3	16	**73**	42	119	**71**	32	110
Honda	Civic coupe	1996-97	310,002	6	1	6	8	21	**68**	42	104	**81**	42	120
Size/style total			2,874,067	164	19	86	62	331	**115**	103	128	**111**	98	125
Small Four-Door Cars														
Kia	Sephia	1995-97	148,691	11	1	2	8	22	**148**	93	224	**174**	91	256
Dodge/Plymouth	Neon	1995-97	1,392,371	67	25	44	44	180	**129**	111	150	**134**	111	156
Geo	Prizm	1994-97	911,277	35	14	28	37	114	**125**	103	150	**141**	112	171
Nissan	Sentra	1995-97	639,798	20	4	20	20	64	**100**	77	128	**112**	80	143
Ford	Escort	1997	242,260	6	3	5	9	23	**95**	60	143	**115**	62	168
Toyota	Corolla	1994-97	1,919,876	44	27	44	50	165	**86**	73	100	**95**	78	111
Mazda	Protege	1995-97	379,839	8	2	8	11	29	**76**	51	110	**91**	54	129
Saturn	SL	1994-97	1,899,963	33	19	37	50	139	**73**	62	86	**86**	69	102
Volkswagen	Jetta III	1994-97	661,002	24	1	17	5	47	**71**	52	95	**62**	42	81
Acura	Integra	1994-97	179,309	6	2	2	2	12	**67**	35	117	**63**	23	103
Honda	Civic	1996-97	383,758	2	3	3	10	18	**47**	28	74	**66**	32	99
Volkswagen	Golf III	1994-97	128,006	1	2	2	1	6	**47**	17	102	**44**	4	84
Size/style total			9,162,764	266	107	222	254	849	**93**	87	99	**102**	94	110
Small Station Wagons														
Saturn	SW	1994-97	173,697	0	6	0	5	11	**63**	32	113	**81**	27	135
Size/style total			323,171	2	13	5	8	28	**87**	58	125	**94**	54	133

Table 1 — continued

									Driver Death Rates per Million Registrations					
				Driver Deaths						95 Percent Confidence Limits			95 Percent Confidence Limits	
		Model	Vehicle	Ages	Ages	Males Ages	Females Ages							
Make	**Series**	**Years**	**Registrations**	**<25**	**65+**	**25-64**	**25-64**	**Total**	**Raw**	**Lower**	**Upper**	**Adjusted**	**Lower**	**Upper**
Midsize Two-Door Cars														
Pontiac	Sunfire	1995-97	283,112	27	2	10	19	58	**205**	156	265	**232**	164	300
Oldsmobile	Achieva	1994-97	128,585	9	1	4	7	21	**163**	101	250	**186**	96	277
Chevrolet	Cavalier	1995-97	712,520	46	4	18	27	95	**133**	108	163	**144**	111	177
Pontiac	Grand Am	1994-97	848,997	45	6	40	21	112	**132**	109	159	**127**	101	154
Dodge	Avenger	1995-97	201,086	12	1	10	3	26	**129**	85	190	**114**	65	163
Oldsmobile	Cutlass Supreme	1994-97	270,435	6	5	11	10	32	**118**	81	167	**132**	80	184
Mazda	MX-6	1994-97	147,889	6	0	6	3	15	**101**	57	167	**100**	42	157
Chrysler	Sebring	1995-97	154,469	7	1	4	1	13	**84**	45	144	**70**	29	112
Honda	Accord	1994-97	472,043	6	5	6	5	22	**47**	29	71	**47**	25	70
Chrysler	Sebring convertible	1996-97	147,543	1	0	3	2	6	**41**	15	89	**46**	4	88
Size/style total			3,594,722	171	28	120	103	422	**117**	107	129	**121**	108	135
Midsize Four-Door Cars														
Pontiac	Sunfire	1995-97	130,991	11	3	3	10	27	**206**	136	300	**244**	140	348
Hyundai	Sonata	1995-97	129,789	1	0	12	9	22	**170**	106	257	**208**	110	307
Chevrolet	Cavalier	1995-97	542,635	32	15	17	19	83	**153**	122	190	**155**	117	193
Buick	Skylark	1994-97	426,333	5	21	8	19	53	**124**	93	163	**145**	101	190
Pontiac	Grand Am	1994-97	1,375,388	53	10	51	51	165	**120**	102	140	**133**	110	156
Mercury	Mystique	1995-97	313,103	8	5	11	12	36	**115**	81	159	**131**	82	180
Ford	Contour	1995-97	910,346	26	21	30	25	102	**112**	91	136	**116**	90	142
Mitsubishi	Galant	1994-97	578,499	20	5	24	12	61	**105**	81	135	**103**	74	132
Dodge/Plymouth	Stratus/Breeze	1995-97	573,398	11	11	21	9	52	**91**	68	119	**86**	60	113
Oldsmobile	Cutlass Supreme	1994-97	609,937	12	11	21	10	54	**89**	67	116	**85**	60	111
Oldsmobile	Achieva	1994-97	317,872	7	4	8	8	27	**85**	56	124	**93**	53	133
Mazda	Millenia	1995-97	170,678	4	1	7	2	14	**82**	45	138	**75**	31	119
Toyota	Avalon	1995-97	374,726	3	7	8	12	30	**80**	54	114	**98**	58	137
Nissan	Altima	1994-97	1,374,770	31	10	36	30	107	**78**	64	94	**84**	66	102
Buick	Regal	1994-97	669,315	5	23	11	8	47	**70**	52	93	**66**	45	88
Chrysler	Cirrus	1995-97	288,379	1	10	6	2	19	**66**	40	103	**57**	29	86
Honda	Accord	1994-97	2,891,832	51	31	49	47	178	**62**	53	71	**65**	54	76
Mazda	626	1994-97	841,411	11	0	21	18	50	**59**	44	78	**70**	48	91
Nissan	Maxima	1995-97	878,939	10	8	15	9	43	**49**	35	66	**49**	32	65
Volvo	850	1995-97	232,115	1	0	5	3	9	**39**	18	74	**44**	11	77
Toyota	Camry	1997	355,158	4	1	5	3	13	**37**	20	63	**37**	14	60
Size/style total			14,640,145	310	203	378	327	1,219	**83**	79	88	**88**	83	94
Midsize Station Wagons														
Subaru	Legacy/Outback 4WD	1995-97	338,780	1	11	7	6	25	**74**	48	109	**76**	42	110
Size/style total			576,079	2	13	10	7	32	**56**	38	78	**56**	34	78
Midsize Luxury Cars														
Mercedes	C class four-door	1994-97	230,028	3	1	3	5	12	**52**	27	91	**65**	23	106
Infiniti	J30 four-door	1994-97	153,114	0	1	2	0	3	**20**	4	57	**15**	0	31
Size/style total			954,272	14	2	22	9	47	**49**	36	66	**48**	32	63

Table 1 — continued

Make	Series	Model Years	Vehicle Registrations	Driver Deaths Ages <25	Driver Deaths Ages 65+	Driver Deaths Males Ages 25-64	Driver Deaths Females Ages 25-64	Driver Deaths Total	Driver Death Rates per Million Registrations Raw	Raw 95 Percent Confidence Limits Lower	Raw 95 Percent Confidence Limits Upper	Adjusted	Adjusted 95 Percent Confidence Limits Lower	Adjusted 95 Percent Confidence Limits Upper
Large Two-Door Cars														
Chevrolet	Monte Carlo	1995-97	495,248	16	2	23	17	58	**117**	89	151	**128**	90	165
Ford	Thunderbird	1994-97	1,033,971	14	19	29	26	88	**85**	68	105	**93**	71	115
Mercury	Cougar	1994-97	556,812	6	13	9	11	39	**70**	50	96	**76**	49	103
Buick	Riviera	1995-97	166,408	0	2	2	2	6	**36**	13	79	**41**	4	78
Size/style total			2,252,439	36	36	63	56	191	**85**	73	98	**93**	78	108
Large Four-Door Cars														
Oldsmobile	Eighty-Eight	1994-97	659,951	1	34	12	18	65	**98**	76	126	**106**	76	135
Chevrolet	Lumina	1995-97	1,342,526	20	36	40	25	121	**90**	75	108	**89**	71	107
Ford	Taurus	1996-97	1,018,699	11	19	35	18	83	**81**	65	101	**82**	62	102
Buick	LeSabre	1994-97	1,356,008	3	86	13	7	109	**80**	66	97	**66**	53	79
Mercury	Sable	1996-97	299,850	2	10	5	7	24	**80**	51	119	**87**	48	127
Pontiac	Grand Prix	1994-97	713,711	11	6	19	18	54	**76**	57	99	**86**	60	112
Chrysler	Concorde	1994-97	562,761	6	18	10	8	42	**75**	54	101	**72**	48	97
Dodge	Intrepid	1994-97	1,350,746	10	13	37	19	79	**58**	46	73	**60**	45	75
Eagle	Vision	1994-97	188,273	2	0	5	4	11	**58**	29	105	**69**	23	115
Pontiac	Bonneville	1994-97	780,276	3	8	14	9	34	**44**	30	61	**46**	28	64
Size/style total			8,429,135	70	231	191	134	626	**74**	69	80	**74**	68	81
Large Station Wagons/Passenger Vans														
Ford	Aerostar	1994-97	441,945	3	4	24	9	40	**91**	65	123	**91**	59	124
GMC	Safari	1994-97	198,432	1	2	9	4	16	**81**	46	131	**84**	37	131
Ford	Aerostar ext.	1994-97	305,628	1	5	8	3	17	**56**	32	89	**53**	25	81
Dodge/Plymouth	Caravan/Voyager	1996-97	540,365	1	12	7	6	26	**48**	31	71	**49**	28	70
Mercury	Villager	1994-97	564,501	1	4	16	5	26	**46**	30	68	**45**	25	64
Chrysler	Town & Country	1996-97	245,450	1	8	0	2	11	**45**	22	80	**43**	14	72
Chevrolet	Astro	1994-97	553,379	3	5	9	7	24	**43**	28	65	**47**	26	69
Honda	Odyssey	1995-97	146,056	1	1	3	1	6	**41**	15	89	**39**	4	74
Ford	Windstar	1995-97	1,352,448	3	9	18	14	44	**33**	24	44	**36**	24	49
Chevrolet	Astro 4WD	1994-97	121,687	0	0	2	1	3	**25**	5	72	**28**	0	64
Dodge/Plymouth	Grand Caravan/Voyager	1996-97	826,451	1	5	10	2	18	**22**	13	34	**19**	9	29
Nissan	Quest	1994-97	491,537	1	0	1	7	9	**18**	8	35	**31**	9	52
Size/style total			6,464,887	20	60	125	69	274	**42**	38	48	**44**	38	50
Large Luxury Cars														
Lincoln	Mark VIII two-door	1994-97	202,670	2	3	9	6	20	**99**	60	152	**109**	54	163
Chrysler	LHS four-door	1994-97	409,702	0	6	11	7	24	**59**	38	87	**64**	35	93
Cadillac	Eldorado two-door	1994-97	221,440	0	6	4	2	12	**54**	28	95	**51**	18	84
Oldsmobile	Aurora four-door	1995-97	200,356	1	4	2	1	8	**40**	17	79	**36**	8	63
Lincoln	Continental four-door	1995-97	180,187	0	7	0	0	7	**39**	16	80	**29**	7	51
Cadillac	Seville four-door	1994-97	363,884	1	5	4	2	12	**33**	17	58	**31**	11	51
Size/style total			1,966,252	4	39	36	21	100	**51**	41	62	**51**	39	62

Table 1 — continued

Make	Series	Model Years	Vehicle Registrations	Driver Deaths: Ages <25	Ages 65+	Males Ages 25-64	Females Ages 25-64	Total	Driver Death Rates per Million Registrations: Raw	95 Percent Confidence Limits: Lower	Upper	Adjusted	95 Percent Confidence Limits: Lower	Upper
Very Large Four-Door Cars														
Ford	Crown Victoria	1994-97	845,692	5	31	22	7	65	**77**	59	98	**67**	49	85
Mercury	Grand Marquis	1994-97	948,237	0	52	10	10	72	**76**	59	96	**69**	51	87
Size/style total			1,793,929	5	83	32	17	137	**76**	64	90	**68**	55	81
Very Large Luxury Cars														
Lincoln	Town Car four-door	1994-97	1,025,666	5	44	19	11	79	**77**	61	96	**70**	53	87
Size/style total			1,075,942	5	44	20	11	80	**74**	59	93	**67**	51	84
Mini Sports Cars														
Honda	Civic Del Sol	1994-97	142,325	6	0	3	3	12	**84**	44	147	**88**	31	144
Mazda	MX-5 Miata	1994-97	187,026	2	0	6	3	11	**59**	29	105	**63**	21	105
Size/style total			388,214	9	0	13	6	28	**72**	48	104	**72**	42	102
Small Sports Cars														
Size/style total			215,908	8	0	18	3	29	**134**	90	193	**116**	70	163
Midsize Sports Cars														
Chevrolet	Camaro two-door	1994-97	845,042	121	2	96	41	260	**308**	271	347	**286**	247	326
Chevrolet	Camaro convertible	1994-97	89,704	9	0	13	4	26	**290**	189	425	**269**	153	385
Pontiac	Firebird two-door	1994-97	374,420	42	2	38	18	100	**267**	217	325	**256**	199	312
Ford	Mustang two-door	1994-97	887,117	61	3	41	17	122	**138**	114	164	**125**	100	150
Ford	Mustang convertible	1994-97	383,341	13	2	17	5	37	**97**	68	133	**87**	56	119
Size/style total			2,669,261	249	9	208	86	552	**207**	190	225	**192**	174	210
Large Vans														
Ford	E-350 Club Wagon	1995-97	131,658	3	3	6	1	13	**99**	53	169	**82**	34	131
Chevrolet	Astro cargo	1994-97	321,212	2	1	11	4	18	**56**	33	89	**56**	27	86
Dodge	Ram Van 2500	1995-97	252,352	1	0	9	3	13	**52**	27	88	**52**	20	85
Ford	E-150 Econoline	1994-97	585,265	1	1	17	5	24	**41**	26	61	**41**	22	59
Ford	E-250 Econoline	1994-97	373,244	1	1	12	0	14	**38**	21	63	**28**	13	43
Size/style total			2,273,720	10	13	94	17	134	**59**	49	70	**53**	43	63
Small 2WD Pickups														
Toyota	Tacoma	1995-97	123,438	2	3	15	6	26	**211**	138	309	**214**	121	308
Ford	Ranger	1995-97	713,453	46	11	53	13	123	**172**	143	206	**150**	121	179
Nissan	Standard bed	1996-97	141,166	8	1	15	0	24	**170**	109	253	**127**	75	178
Toyota	Tacoma Xtra Cab	1995-97	145,433	4	4	11	3	22	**151**	95	229	**137**	73	201
Ford	Ranger super cab	1995-97	489,536	11	6	18	8	43	**88**	64	118	**85**	56	113
Size/style total			1,973,828	81	35	128	36	280	**142**	126	160	**127**	111	144

Table 1 — continued

				Driver Deaths					Driver Death Rates per Million Registrations					
						Males	Females			95 Percent Confidence Limits			95 Percent Confidence Limits	
Make	Series	Model Years	Vehicle Registrations	Ages <25	Ages 65+	Ages 25-64	Ages 25-64	Total	Raw	Lower	Upper	Adjusted	Lower	Upper
Midsize 2WD Pickups														
Chevrolet	S10	1995-97	575,227	38	15	54	6	113	**196**	162	236	**159**	127	190
GMC	S15 ext. cab	1995-97	134,722	3	2	15	2	22	**163**	102	247	**139**	75	203
Chevrolet	S10 ext. cab	1995-97	473,003	26	3	26	4	59	**125**	95	161	**103**	74	131
GMC	1500 series	1995-97	178,669	10	5	7	0	22	**123**	77	186	**92**	53	131
Chevrolet	1500 series	1995-97	479,915	17	8	32	2	59	**123**	94	159	**96**	70	122
Dodge	Ram 1500	1994-97	704,341	19	11	43	7	80	**114**	90	141	**96**	73	119
Ford	F-150	1997	150,979	2	3	7	2	14	**93**	51	156	**85**	35	134
Size/style total			2,941,960	121	49	201	24	395	**134**	121	148	**110**	98	121
Midsize 4WD Pickups														
Ford	Ranger super cab 4WD	1995-97	135,089	8	4	6	0	18	**133**	79	211	**99**	52	146
Toyota	Tacoma Xtra cab 4WD	1995-97	203,594	8	0	15	2	25	**123**	80	181	**103**	59	147
Size/style total			752,295	35	11	59	8	113	**150**	124	181	**124**	99	149
Large 2WD Pickups														
GMC	1500 ext. cab	1995-97	246,551	4	1	10	5	20	**81**	50	125	**84**	42	127
Ford	F-150 super cab	1997	248,381	3	2	11	3	19	**76**	46	120	**71**	35	107
Chevrolet	1500 ext. cab	1995-97	681,642	7	5	33	7	52	**76**	57	100	**69**	48	90
Dodge	Ram 1500 club cab	1995-97	306,170	1	1	17	4	23	**75**	48	113	**71**	38	104
Dodge	Ram 2500	1994-97	134,556	0	1	8	0	9	**67**	31	127	**50**	17	83
Ford	F-250 super cab	1994-97	184,072	2	0	8	1	11	**60**	30	107	**51**	18	84
Ford	F-250	1994-97	252,411	0	1	10	0	11	**44**	22	78	**32**	13	52
Size/style total			2,618,653	24	18	139	21	202	**77**	67	89	**67**	57	77
Large 4WD Pickups														
Chevrolet	1500 series 4WD	1995-97	241,381	14	3	23	0	40	**166**	118	226	**123**	84	162
Ford	F-250 4WD	1994-97	279,663	8	2	18	4	32	**114**	78	162	**102**	63	142
Dodge	Ram 1500 4WD	1994-97	386,460	7	3	28	4	42	**109**	78	147	**93**	62	124
Chevrolet	1500 ext. cab 4WD	1995-97	707,227	10	5	49	3	67	**95**	73	120	**76**	56	95
Ford	F-150 super cab 4WD	1997	168,198	2	1	11	0	14	**83**	46	140	**62**	29	95
Dodge	Ram 2500 4WD	1994-97	246,110	4	1	13	1	19	**77**	47	121	**62**	32	92
Dodge	Ram 1500 club cab 4WD	1995-97	224,524	3	0	12	1	16	**71**	41	116	**58**	27	89
GMC	1500 ext. cab 4WD	1995-97	227,081	3	0	13	0	16	**70**	40	114	**52**	26	79
Chevrolet	2500 series 4WD	1994-97	173,548	3	1	2	2	8	**46**	20	91	**48**	10	86
Chevrolet	2500 ext. cab 4WD	1994-97	232,426	0	1	8	0	9	**39**	18	74	**29**	10	48
Size/style total			3,283,431	60	17	204	19	300	**91**	81	102	**75**	66	84
Very Large 2WD Pickups														
Ford	F-350 crew cab	1994-97	214,886	1	0	7	1	9	**42**	19	80	**37**	10	63
Size/style total			453,131	6	0	23	2	31	**68**	47	97	**56**	35	78
Very Large 4WD Pickups														
Ford	F-250 super cab 4WD	1994-97	311,811	5	7	27	1	40	**128**	92	175	**99**	67	132
Ford	F-350 crew cab 4WD	1994-97	129,560	3	1	6	0	10	**77**	37	142	**57**	21	94
Size/style total			863,610	21	9	62	2	94	**109**	88	133	**84**	66	101

Table 1 — continued

Make	Series	Model Years	Vehicle Registrations	Driver Deaths: Ages <25	Ages 65+	Males Ages 25-64	Females Ages 25-64	Total	Driver Death Rates per Million Registrations: Raw	95 Percent Confidence Limits: Lower	Upper	Adjusted	95 Percent Confidence Limits: Lower	Upper
Small 2WD Utility Vehicles														
Jeep	Cherokee four-door	1995-97	188,738	3	0	4	7	14	**74**	41	125	**99**	41	157
Size/style total			311,770	7	0	7	15	29	**93**	62	134	**126**	75	177
Small 4WD Utility Vehicles														
Jeep	Cherokee four-door 4WD	1995-97	516,879	5	4	10	7	26	**50**	33	74	**53**	30	77
Size/style total			745,162	9	4	20	13	46	**62**	45	82	**67**	45	89
Midsize 2WD Utility Vehicles														
Ford	Explorer two-door	1995-97	86,663	7	1	4	8	20	**231**	141	356	**281**	142	421
Jeep	Grand Cherokee four-door	1994-97	359,612	7	2	5	14	28	**78**	52	113	**104**	61	147
Size/style total			646,983	22	4	19	33	78	**121**	95	151	**150**	113	188
Midsize 4WD Utility Vehicles														
Chevrolet	T10 Blazer two-door 4WD	1995-97	124,547	2	1	9	7	19	**153**	92	238	**180**	88	272
Toyota	4Runner four-door 4WD	1996-97	150,863	4	1	11	3	19	**126**	76	197	**117**	58	177
Ford	Explorer two-door 4WD	1995-97	158,217	2	1	7	2	12	**76**	39	133	**71**	26	117
Jeep	Grand Cherokee four-door 4WD	1994-97	1,950,535	17	8	51	25	101	**52**	42	63	**54**	42	66
Size/style total			2,647,863	30	11	85	40	166	**63**	54	73	**65**	53	76
Large 2WD Utility Vehicles														
Chevrolet	S10 Blazer four-door	1995-97	215,218	10	4	11	17	42	**195**	141	264	**239**	157	321
Isuzu	Rodeo four-door	1995-97	191,478	6	0	13	10	29	**151**	101	218	**175**	102	247
Ford	Explorer four-door	1995-97	512,275	11	6	27	9	53	**103**	78	135	**98**	68	128
Size/style total			1,029,697	29	10	54	37	130	**126**	106	150	**137**	110	163
Large 4WD Utility Vehicles														
Isuzu	Rodeo four-door 4WD	1995-97	172,284	4	1	6	6	17	**99**	58	158	**115**	53	177
Chevrolet	T10 Blazer four-door 4WD	1995-97	897,851	3	6	35	21	65	**72**	56	92	**82**	59	104
GMC	T15 Jimmy four-door 4WD	1995-97	295,445	2	1	10	7	20	**68**	41	105	**78**	39	118
Ford	Explorer four-door 4WD	1995-97	1,102,058	8	5	20	29	62	**56**	43	72	**73**	53	93
Size/style total			3,292,997	33	16	105	82	236	**72**	63	81	**83**	71	95
Very Large 2WD Utility Vehicles														
Chevrolet	Suburban 1500 four-door	1995-97	180,495	0	2	2	4	8	**44**	19	87	**59**	13	105
Size/style total			428,647	1	6	12	7	26	**61**	40	89	**65**	36	93
Very Large 4WD Utility Vehicles														
Chevrolet	Suburban 1500 four-door 4WD	1995-97	243,693	1	2	5	5	13	**53**	28	91	**64**	25	103
Chevrolet	Tahoe four-door 4WD	1995-97	331,499	0	0	13	2	15	**45**	25	75	**41**	18	64
Ford	Expedition four-door 4WD	1997	126,811	1	0	3	1	5	**39**	13	92	**39**	0	77
Size/style total			994,531	3	3	30	10	46	**46**	34	62	**46**	31	62
All Vehicle Total	**All Passenger Vehicles**		84,230,623	1,934	1,122	2,845	1,624	7,526	**89**	87	91	**89**	87	91

Size/style totals include vehicle series with too few registrations to be listed separately
2WD = two-wheel drive, 4WD = four-wheel drive

Utility vehicles on the whole had approximately 75 driver deaths per million registrations per year (Table 2). Pickups as a group had a much higher driver death rate, approximately 110 per million registrations per year. Utility vehicles, however, also had a higher proportion of females ages 25-64 among the fatally injured drivers. Among drivers dying in utility vehicles, 31 percent were females ages 25-64. Among drivers dying in pickups, only 8 percent were females ages 25-64. After adjusting for these differences in the driver populations, the driver death rates for utility vehicles and pickups were much more similar, 84 and 92, respectively.

Table 2
Driver Deaths per Million Vehicle Registrations per Year By Vehicle Type, Size, and Body Style

	Raw			Adjusted		
Vehicle Type/Size	**Two-Door**	**Four-Door**	**All**	**Two-Door**	**Four-Door**	**All**
Car						
Mini	169	180	173	186	203	192
Small	115	93	98	111	102	104
Midsize	117	83	90	121	88	95
Large	85	74	76	93	74	78
Very large	n/a	76	76	n/a	68	68
All cars	115	85	91	119	89	96
Station Wagon/Passenger Van						
Small			87			94
Midsize			56			56
Large			42			44
All wagons/passenger vans			45			47
Luxury Car						
Midsize			49			48
Large			51			51
Very large			74			67
All luxury cars			57			54
Sports Car						
Mini			72			72
Small			134			116
Midsize			207			192
All sports cars			186			173
	2WD	**4WD**	**All**	**2WD**	**4WD**	**All**
Pickup Truck						
Small	142	n/a	142	127	n/a	127
Midsize	134	150	138	110	124	113
Large	77	91	85	67	75	71
Very large	68	109	95	56	84	74
All pickup trucks	114	103	110	97	84	92
Utility Vehicle						
Small	93	62	71	126	67	84
Midsize	121	63	74	150	65	81
Large	126	72	85	137	83	96
Very large	61	46	51	65	46	52
All utility vehicles	109	64	75	126	70	84

2WD = two-wheel drive, 4WD = four-wheel drive

Within vehicle type, larger vehicles generally had lower driver death rates than smaller vehicles. Both the raw and adjusted driver death rates exhibited declines with increasing car size. Mini cars as a group had an overall driver death rate of 173 deaths per million registrations per year, compared with a rate of 76 for very large cars. The adjusted death rates for mini cars and very large cars were 192 and 68, respectively. Notable exceptions to the trend of lower death rates for larger vehicles were luxury and sports cars. For these types of cars, the trend was reversed — larger vehicles had higher driver death rates. For both luxury and sports cars, horsepower increases greatly as vehicles get larger, and this may account for the increasing risk of fatality.

Within each size class, four-wheel-drive pickups usually had higher driver death rates than two-wheel-drive pickups, even after adjusting for driver age and gender differences. Conversely, four-wheel-drive utility vehicles had lower driver death rates than two-wheel-drive utility vehicles.

DISCUSSION

The lowest overall driver death rate in Table 1, 18 per million registration-years, was for the Nissan Quest, a large passenger van. However, the confidence interval for this death rate overlaps those of most other passenger vans and some luxury cars. In other words, the driver death rate for the Quest was not statistically different from most other passenger vans. The driver death rates for station wagons, passenger vans, and luxury cars are significantly lower than those of any other vehicle type, even after adjusting for driver differences.

The highest overall driver death rate in Table 1, and the only one greater than 300, was for the Chevrolet Camaro two-door, a midsize sports car. However, after taking into account that nearly half the drivers who died in this vehicle were younger than 25, and two-thirds of those remaining were male, the adjusted driver death rate was similar to that for the Ford Explorer two-door, two-wheel-drive utility vehicle, 286 compared with 281. The adjustment for driver age and gender greatly reduces variability of driver death rates among vehicle types. Vehicle types popular with male drivers, such as sports cars and pickups, have adjusted death rates that are much lower than the unadjusted rates.

Within vehicle type, size, and body style, the adjustment of driver death rates had less effect. With only a few exceptions, those vehicles with the highest and lowest raw driver death rates in the class also had the highest and lowest adjusted rates. This confirms the likelihood that vehicles similar in type, size, and body style appeal to similar types of drivers. Therefore, comparisons of vehicle models with similar size and body style can be accomplished using the raw death rates.

Vehicle models built on identical platforms, but with differences in trim and nameplate, would be expected to have similar driver death rates. For example, the 1996-97 Ford Taurus and Mercury Sable four-door cars had driver death rates per million registered vehicle-years of 81 and 80, respectively. Also, the 1995-97 Chevrolet and GMC 1500 series two-wheel-drive pickups had the same driver death rate, 123 per million registered vehicle-years.

However, there were a few cases in which corporate twins had very different driver death rates. The 1995-97 Pontiac Sunfire had the highest driver death rates among midsize cars, 205 per million registered vehicle-years for the two-door version and 206 for the four-door. The 1995-97 Chevrolet Cavalier, built on the same platform as the Sunfire, had driver death rates of 133 for the two-door and 153 for the four-door. Driver age and gender did not account for the differences in death rates; the Sunfire actually had a higher proportion of 25-64-year-old females among fatally injured drivers than did the Cavalier. Thus, when large fatality rate differences exist between corporate twins, corrections for age and gender of drivers did not seem to remove them. Of course, there are driver characteristics other than age and gender that affect crash risk.

Differences in when and where vehicles are driven may lead to differences in driver death rates, even if the driver characteristics are similar. Some vehicle types may be driven more often on rural roads. Some vehicle types may be driven more often at night or in poor weather. The procedure used to adjust death rates for driver age and gender required an estimate of the relative exposure of drivers in the two groups (i.e., the number of licensed drivers). It is possible to estimate exposure of drivers to rural roads using data from the Federal Highway Administration's Highway Performance Monitoring System. Such data, however, cannot be subdivided by driver age and gender. Thus, death rates can be adjusted for either type of roadway or driver age and gender, but not both simultaneously.

The adjustment procedure described here depends upon the assumption that, for any given vehicle model, female drivers ages 25-64 are approximately 60 percent less likely than other drivers to die in motor vehicle crashes. It is possible, though unlikely, that for some vehicles the age or gender risk ratio is very different. If, for example, a particular vehicle induced speeding among males but not among females, then the death rate would not have been adjusted enough. Conversely, if the age/gender risk ratio of a vehicle was lower than that of other vehicles, then the death rate would have been adjusted too much. It is unknown to what extent such differences in the age/gender risk ratio exist.

The driver age and gender adjustment described here clarifies somewhat the differences between vehicle types and styles, with only a few anomalies. Future use of the procedure on various databases should provide evidence of its reliability, and hopefully lead to improvements. Within a market class, however, these driver characteristics appeared to be reasonably homogeneous, and adjustments for driver age and gender have little effect.

ACKNOWLEDGMENT

This work was supported by the Insurance Institute for Highway Safety.

REFERENCES

Federal Highway Administration. 2000. Highway statistics, 1998. Washington, DC. Available: http://www.fhwa.dot.gov/ohim/hs98/dlpage.htm. Last modified: October 12, 2000. Last accessed: March 5, 2001.

Grove, J. and Wilding, P. 1995. Cars: make and model; the risk of driver injury and car accident rates in Great Britain, 1994. London, England: Department of Transport.

Gustafsson, H.; Nygren, A.; and Tingvall, C. 1984. Safe cars and dangerous cars: car facts from the Folksam Insurance Group. Stockholm, Sweden: Folksam.

Hahn, G.J. and Meeker, W.Q. 1991. Statistical intervals, a guide for practitioners. New York, NY: John Wiley and Sons.

Highway Loss Data Institute. 1999. VINDICATOR 2000 user’s manual, rel. 1. Arlington, VA.

Highway Loss Data Institute. 1999. Injury, collision, and theft losses by make and model, 1996-98 models. Arlington, VA.

Insurance Institute for Highway Safety. 1989. Computing fatality rates by make and series of passenger cars. Arlington, VA.

Insurance Institute for Highway Safety. 2000. Special issue: driver death rates. *Status Report* 35(7). Arlington, VA.

Newstead, S.V.; Cameron, M.H.; and Le, C.M. 1998. Vehicle crashworthiness ratings and crashworthiness by year of vehicle manufacture: Victoria and NSW crashes during 1987-96. Report no. 128. Clayton, Victoria: Monash University Accident Research Centre.

The Polk Company. 1999. National vehicle population profile (1993-97). Detroit, MI.

Tapio, J.; Pirtala, P.; and Ernvall, T. 1995. The accident involvement and injury risk rates of car models. Oulu, Finland: University of Oulu.

APPENDIX
A Method for Adjusting Driver Death Rates for Exposure of High Risk Groups

For any events A and B such that $\Pr(A) > 0$, $\Pr(B) > 0$, and $\Pr(B \mid A) > 0$, define:

$$R = \Pr(B \mid \text{not } A) / \Pr(B \mid A).$$

Using basic laws of conditional probability:

$$\begin{aligned} R &= \Pr(B \mid \text{not } A) / \Pr(B \mid A) \\ &= [\Pr(\text{not } A \mid B)\Pr(B)] / [\Pr(\text{not } A)\Pr(B \mid A)] \\ &= \{[1 - \Pr(A \mid B)]\Pr(B)\} / \{[1 - \Pr(A)]\Pr(B \mid A)\}. \end{aligned}$$

Also,

$$\begin{aligned} 1 + (R - 1)\Pr(A \mid B) &= 1 + R\Pr(A \mid B) - \Pr(A \mid B) \\ &= 1 + R[\Pr(B \mid A)\Pr(A) / \Pr(B)] - \Pr(A \mid B) \\ &= 1 + \{[1 - \Pr(A \mid B)]\Pr(A) / [1 - \Pr(A)]\} - \Pr(A \mid B) \\ &= [1 - \Pr(A \mid B)] / [1 - \Pr(A)]. \end{aligned}$$

Dividing the two quantities gives:

$$R / [1 + (R - 1)\Pr(A \mid B)] = \Pr(B) / \Pr(B \mid A).$$

Therefore,

$$\Pr(B \mid A) = \Pr(B)\{[1 + (R - 1)\Pr(A \mid B)] / R\}.$$

For example, if A represents female drivers and B represents death in a motor vehicle crash, then the risk of crash-related death among female drivers ($\Pr(B \mid A)$) is a proportion of the risk of crash-related death among all drivers ($\Pr(B)$). The adjustment factor depends only on the proportion of female drivers among the total driver deaths ($\Pr(A \mid B)$) and the ratio of fatality risks for male and female drivers. An estimate, D_1, of $\Pr(B \mid A)$ for a given vehicle series, is:

$$\begin{aligned} D_1 &= (X / n)\{[1 + (R - 1)(Y / X)] / R\} \\ &= X / (nR) + (R - 1)Y / (nR), \end{aligned}$$

where n denotes the number of vehicle registrations, X denotes the total number of driver deaths, and Y denotes the number of deaths to drivers comprising event A (e.g., female drivers). The rate ratio, R, is assumed to be constant across vehicle series.

Suppose that the random variable X follows a Poisson distribution with mean $n\lambda$. Suppose also that the conditional distribution of Y, given $X = x$, is Binomial with mean xp_1. Then the mean and variance of Y are:

$$E(Y) = E[E(Y \mid X = x)] = E(Xp_1) = n\lambda p_1,$$

and:

$$\begin{aligned} Var(Y) &= Var[E(Y \mid X = x)] + E[Var(Y \mid X = x)] \\ &= Var(Xp_1) + E[Xp_1(1 - p_1)] \\ &= n\lambda(p_1)^2 + n\lambda p_1(1 - p_1) \\ &= n\lambda p_1. \end{aligned}$$

Also, the covariance of X and Y is

$$\begin{aligned} Cov(X,Y) &= E(XY) - E(X)E(Y) \\ &= (n\lambda + n^2\lambda^2)p_1 - n^2\lambda^2 p_1 \\ &= n\lambda p_1. \end{aligned}$$

Therefore, the mean and variance of D_1 are:

$$E(D_1) = \lambda / R + (R - 1)\lambda p_1 / R = \lambda\{[1 + (R - 1)p_1] / R\},$$

and:

$$\begin{aligned} Var(D_1) &= \lambda / (nR^2) + 2(R - 1)\lambda p_1 / (nR^2) + (R - 1)^2 \lambda p_1 / (nR^2) \\ &= \lambda\{[1 + 2(R - 1)p_1 + (R - 1)^2 p_1] / (nR^2)\}. \end{aligned}$$

By definition, the estimate, D_2, of Pr(B | not A) for a given vehicle series, is:

$$D_2 = R\, D_1.$$

So, supposing Pr(A) = W (constant across vehicle series), the risk of crash-related death among all drivers would be:

$$\begin{aligned} D_S &= W\, D_1 + (1 - W)\, D_2 \\ &= [W + (1 - W)R]\, D_1. \end{aligned}$$

The mean and variance of D_S are:

$$E(D_S) = \lambda\{[1 + (R - 1)p_1]\, [W + (1 - W)R] / R\},$$

and:

$$Var(D_S) = \lambda\{[1 + 2(R - 1)p_1 + (R - 1)^2 p_1]\, [W + (1 - W)R]^2 / (nR^2)\}.$$