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An Analysis of Motor Vehicle Rollover Crashes and Injury Outcomes

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16. Abstract

Rollover crashes can have serious consequences. In 2004, 33% of passenger vehicle occupant fatalities were in vehicles that rolled over. This report analyzes data related to passenger vehicle rollovers, including rollover propensity and injury outcomes. The report uses the Fatality Analysis Reporting System and National Automotive Sampling System General Estimates System databases to tabulate data on passenger vehicles and their occupants by a variety of variables and performs logistic analysis of the data. Tabulations focus on years 1994, 2003, and 2004; logistic analysis pools data for years 2000 through 2004. We specifically analyze factors that (a) were associated with vehicle rollovers in single-vehicle crashes of passenger vehicles; and (b) were associated with ejection status and varying degrees of injury severity of occupants of passenger vehicles that rolled over in single-vehicle crashes. Among other things, we also analyze the relationship between various anthropomorphic characteristics, such as the Body Mass Index, and seat belt effectiveness for drivers of passenger vehicles that were in single-vehicle rollovers. This report may be useful to other researchers and may provide a starting point for further analysis of vehicle rollovers and injury outcomes.

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1. Executive Summary

Objective. The primary purpose of this technical report is to provide descriptive characteristics on vehicles that have rolled over and on injuries to occupants of these vehicles. The data is provided by categories that are thought to be of interest to the customers of NHTSA's National Center for Statistics and Analysis (NCSA), both internal and external. In particular, we focus on passenger vehicles that were in single-vehicle crashes and rollovers, and on injuries of occupants of passenger vehicles that were in single-vehicle rollovers.

Methods. We provide simple analyses in the form of tables of counts and percentages, as well as more sophisticated multivariate analyses. Following the Introduction, five sections of the report provide tabulated data on vehicles that rolled over and on vehicle occupants in vehicles that rolled over. These tables give both counts and percentages. These are given for 2004, the latest year for which data is available; for 2003, the previous year; and for 1994, which is 10 years prior to 2004, or for the earliest year for which data is available, if it is later than 1994.

Note that counts of vehicles and of nonfatally injured occupants are estimated. Calculation of standard errors and confidence intervals is discussed in the Introduction. On the other hand, counts of fatally injured occupants come from a census.

We use logistic regression to model the propensity of vehicles in single-vehicle crashes to roll over, as well as the propensity of occupants in single-vehicle rollovers to be fatally injured. We also provide a brief discussion on the interpretation of the results of logistic regression.

Results. Considering rollovers in all types of crashes, in 2004 2.7% of occupants who were in passenger vehicles that rolled over were fatally injured, compared to 0.2% of occupants killed who were in passenger vehicles that crashed but did not roll over. The same year, 33% of passenger vehicle occupant fatalities were in vehicles that rolled over. The rollover rates were higher for light trucks, as opposed to passenger cars; and for males and for younger drivers.

Considering the probability that a vehicle rolled over given involvement in a single-vehicle crash, we find the following. We generally find that sport utility vehicles (SUVs) were more likely to have rolled over than pickups, which in turn were more likely to roll over than either vans or passenger cars. Vehicles that were more likely to roll over were older, were driven by younger, unbelted drivers, had more occupants, and were in speed-related crashes on roads with higher speed limits, in nonintersection areas. Alcohol involvement increased the probability of rollover. Vehicles that were more likely to roll over were passing as opposed to turning prior to the crash, and the drivers in such vehicles attempted to steer when they realized that the crash was imminent; the first harmful event in the crash was either the rollover itself or striking an embankment.

In single-vehicle rollovers, SUVs had the highest rate of total ejection. Unrestrained occupants had more severe injuries and were totally ejected at a higher rate than restrained occupants. Older occupants had a higher fatality rate than younger ones; males had a higher fatality rate than females.

In single-vehicle rollovers, occupants who weighed more and who had a higher Body Mass Index (BMI) appeared to have received fewer benefits from seat belts. People who weighed less, were taller, and had a lower BMI tended to be overrepresented in fatalities as compared to the general population, regardless of seat belt use. Thus, while heavier individuals received fewer benefits from seat belts, they might also have been at a lower risk of fatality given involvement in a single-vehicle rollover regardless of seat belt use.

In 2004, for the United States as a whole, 31,693 passenger vehicle occupants were fatally injured in crashes of all types, 10,553 were fatally injured in rollovers, and 8,565 were fatally injured in single-vehicle rollovers. This means that 33% of passenger vehicle occupant fatalities were in vehicles that rolled over. State-by-State, this percentage ranged from 10% for the District of Columbia to 67% for Montana.

There were some factors that increased both the probability that a vehicle rolls over given that it is involved in a single-vehicle crash and the probability of an occupant fatality given that the occupant was in a vehicle that rolled over, while other factors increased the probability of one while decreasing the probability of the other. For example, if a vehicle was turning as opposed to going straight right before the single-vehicle crash occurred, that decreased the probability that the vehicle rolled over, and it also decreased the probability of occupant fatality if it did roll over. The same was true for the speed limit. A higher speed limit both increased the probability that a vehicle rolled over given that it was in a single-vehicle crash and it increased the probability of occupant fatality given that the occupant was in a vehicle that was in a single-vehicle rollover.

On the other hand, light trucks had a higher probability of rolling over than passenger cars, but being an occupant in a light truck decreased the probability of a fatal injury given a single-vehicle rollover. Similarly, higher vehicle occupancy increased the probability of a vehicle rolling over given involvement in a single-vehicle crash, but at the same time it decreased the probability of occupant fatality given that the vehicle was involved in a single-vehicle rollover.

Conclusion. This report provides a general overview of the different factors related to passenger vehicle rollovers. It might prompt more detailed research into specific areas that are deemed to be interesting. For example, one potentially interesting area for further research is the effect of seat belts on injury outcomes as a function of occupant characteristics, such as body weight. Other potentially interesting areas for research would include investigating further the use of the driver restraint use variable as a proxy for driver safety and studying the relationship between rollover propensity observed in actual crashes and certain vehicle characteristics, such as the Static Stability Factor (SSF).

The report uses both the Fatality Analysis Reporting System (FARS) database and the National Automotive Sampling System General Estimates System (NASS GES) database. It could be extended with additional databases, such as the National Automotive Sampling System Crashworthiness Data System (NASS CDS). CDS contains variables relevant to rollovers that are not present in either FARS or GES, such as the number of quarter turns that a vehicle has rolled over. Previous studies of rollovers, such as Eigen (2005), have used this database.

2. Introduction

Purpose. The primary purpose of this technical report is to provide descriptive characteristics on vehicles that have rolled over and on injuries to occupants of these vehicles. The data is provided by categories that are thought to be of interest to the customers of NHTSA's National Center for Statistics and Analysis, both internal and external. The report builds and expands upon Strashny (2005), which was written in response to a specific data request by NHTSA's Office of Vehicle Safety Planning and Analysis. Certainly, for many of the topics discussed in this report, the discussion could be greatly expanded. The research as presented in the report was conducted to balance between breadth and depth of coverage of the various topics related to vehicle rollovers.

By tabulating the data and by performing some regression analysis, this report explores the various factors associated with vehicle rollovers and with varying degrees of occupant injury in a rollover. Keep in mind that no retrospective statistical analysis can establish causality. Thus, when a strong association is found, the matter should be investigated further to determine if there was an actual causal relationship. The Haddon matrix is a useful framework for organizing the different aspects of crashes that is commonly used in the field of traffic safety (see Haddon, 1980). In terms of the Haddon matrix, the report analyzes pre-event and event phases of the human, vehicle, and environmental factors. This report analyzes variable associations not only for 2004, the latest year for which data is available, but also for selected previous years.

Data. The data is limited to passenger vehicles, which consist of passenger cars and light trucks. When the category of light trucks is divided into subcategories, these are vans, pickups, sport utility vehicles, and other light trucks. Note that the analysis is only on vehicles and their occupants, and excludes nonmotorists. For brevity, extraneous categories such as "unknown" and "other" have been removed from the tabulated counts. When percentages are shown, they are based on all the categories, including ones that have been removed.

The initial few tables show annual data for years 1994 through 2004, the latest year for which data is available. Subsequent tables show annual data for 2004, 2003, the previous year, and for 1994, which is 10 years prior to 2004, or for the earliest year for which data is available, if it is later than 1994. Regression analysis combines years 2000 through 2004.

The data on occupants who were fatally injured are from the Fatality Analysis Reporting System database. According to Tessmer (2002), FARS "is a collection of files documenting all qualifying fatal crashes since 1975 that occurred within the 50 States, the District of Columbia, and Puerto Rico. To be included in this census of crashes, a crash had to involve a motor vehicle traveling on a trafficway customarily open to the public, and must result in the death of a person (occupant of a vehicle or a nonmotorist) within 30 days of the crash." Note that following standard NCSA practice, we exclude Puerto Rico from all national-level counts and analyses; it is only included in the State-by-State analysis in the Fatalities Only section. FARS data for 2004 is from the preliminary Annual Report File (ARF), while data from all the previous years is from the Final files.

The data on all vehicle crashes, including fatal crashes, and on occupants who survived the crashes in which they were involved, come from the National Automotive Sampling System

General Estimates System database. According to NHTSA c (2004), "the GES obtains its data from a nationally representative probability sample selected from the estimated 6.2 million police-reported crashes which occur annually. These crashes include those that result in a fatality or injury and those involving major property damage."

When considering data at the vehicle level, we only use the GES database. When considering data at the occupant level, we take the data on fatally injured occupants from FARS, and data on all occupants who were not fatally injured from GES.

The data on vehicle miles traveled is from the Federal Highway Administration, as revised by NHTSA; the data on registered passenger cars and light trucks is from R.L. Polk & Co.; the data on licenses drivers is from the Federal Highway Administration.

For some variables, GES provides the variable together with its imputed version. Some analysts assume that the imputed versions of variables are better and automatically use them in their analysis. However, Shelton (1993), which discusses the imputation procedures used to create the imputed versions of variables in GES, states that these imputed versions of variables should only be used in univariate tables. Since almost all the tables in this report involve at least two variables, we do not use the imputed versions of variables.

Note that GES is a probability sample that provides estimated rather than exact quantities. Estimation of the standard errors for these estimated quantities is discussed in NHTSA c (2004). In particular, let X be the estimate of a quantity obtained from GES. Then the estimated standard error of this quantity is $\exp\left(a + b(\ln X)^2\right)$. The values of the coefficients a and b vary by year and depend on whether the estimated quantity is at the crash level, vehicle level, or person level. The latest year for which NHTSA c (2004) provides values of a and b is 2003, though the values seem to have varied little from year to year. For 2003, for vehicle-level estimates, $a = 4.2724$ and $b = 0.03553$; for person-level estimates, $a = 4.3572$ and $b = 0.03399$. For example, Table 1 lists the estimated number of passenger vehicles that have rolled over, by year. In 2003, the estimated number of passenger vehicles that rolled over was 278,442. The standard error of this estimate is thus $\exp\left(4.2724 + 0.03553(\ln 278{,}442)^2\right) = 19{,}089$. From this, the 95% confidence interval for the number of passenger vehicles that rolled over in 2003 is $278{,}442 \pm 1.96 * 19{,}089 =$ 241,029 to 315,855. From Table 2, in 2003, there were an estimated 389,800 occupants of passenger vehicles that had rolled over. Thus, the standard error of this estimate is 21,811; the 95% confidence interval for the number of occupants is 347,051 to 432,549.

NCSA maintains a number of databases that are representative probability samples. Some NCSA publications round counts obtained from such databases to the nearest thousand. For example, NHTSA e (2006) rounds estimated counts to the nearest thousand. This is done to emphasize the fact that these counts are estimates rather than true counts. However, such rounding might imply that the estimate is at least accurate to the nearest thousand, which may or may not be the case. For example, consider the sample calculations of standard errors presented above. In the previous two examples, the standard error is around 20,000, which means that the estimates in the examples are certainly not accurate to the nearest thousand. Instead, the range of the

confidence interval is around 75,000 in the first example and around 85,000 in the second example. Thus, other NCSA publications do not round counts obtained from representative probability samples. They discuss the standard errors of the estimates and present the estimates themselves without rounding. See, for example, NHTSA a (1999). In this publication, consistent with the practice, we have discussed the calculation of standard errors, and we present all counts without rounding them to the nearest thousand.

Another issue that makes rounding problematic is that when the counts are relatively small calculating percentages based on rounded and unrounded counts produces very different results. Thus, presenting rounded counts could be confusing or misleading. For example, consider Table 12, which tabulates vehicles with two occupants in single-vehicle crashes by vehicle type, driver and passenger age, and rollover status, in the years 1994, 2003, and 2004. As with most other tables in this report, the first part of the table shows counts whereas the second part of the table shows percentages. Consider, for example, pickups with drivers who were 24 and younger and passengers who were 25 and older in 2004. There were an estimated 1,032 such vehicles in single-vehicle crashes, of which an estimated 508 rolled over. Thus, the probability of rollover for pickups with a younger driver and an older passenger in 2004 was an estimated 49% (= [508 ÷ 1,032]). However, if we performed rounding of the counts to the nearest thousand, we would state that there were an estimated 1,000 relevant pickups, of which an estimated 1,000 rolled over. This would make it appear that 100% of such pickups rolled over, which was certainly not the case.

Particular caution should be taken when estimated counts are relatively small. The standard error of an estimated count as a percent of that count is a decreasing function of the estimated count. For example, consider 2003 person-level standard error estimates. If the estimated count was 10,000, then its standard error was about 1,395, or 14% (= [1,395 ÷ 10,000]) of the estimated count. However, if the estimated count was 1,000, the standard error was 395, or 40% of the estimated count; if the estimated count was 100, then its estimated standard error was 160, or more than one and a half times of the estimated count itself. In other words, when estimated counts are relatively low, they, and the estimates of percentages that are based on them, are very inexact. For example, consider again Table 12. According to the table, of the sport utility vehicles with younger drivers and older passengers that were in single-vehicle crashes, an estimated 25% rolled over in 2003 but only an estimated 8% rolled over in 2004. Looking at the counts, we see that these percentages are based on an estimated 224 vehicle rollovers in 2003 and 153 rollovers in 2004. As these estimated counts are so low, the estimates are inexact, which explains the great variability in the estimated percentages calculated using these estimated counts.

Methods. The report presents both tabulated data as well as results of logistic regression analyses. When the analysis is at the vehicle level, all the data are from the GES database. When the analysis is at the occupant level, data on fatally injured occupants are from the FARS database and data on the occupants who were not fatally injured are from the GES database. Analyzing FARS rather than GES fatalities is standard practice since GES is a probability sample of all crashes while FARS is a census of fatal crashes. (For additional discussion, see NHTSA c (2004), p. 216.)

To perform logistic regressions, we use an SAS procedure called PROC SURVEYLOGISTIC. This procedure is new in version 9 of SAS. In performing logistic analysis, when the value of an explanatory variable for a particular observation is unknown, SAS drops the whole observation. To remedy this, we proceed as follows: if the variable is categorical, we follow the procedure used by Le Breton and Vervialle (2005) and use "Unknown" as its own category. This makes sense since the fact that the value of a particular variable was unknown may have been related to the event being modeled, such as rollover propensity or injury outcome. If the variable is interval, we replace unknown values with the average of that variable taken over all known values. This makes sense since a regression measures how the variability of explanatory variables around their averages is associated with the variability of the dependent variable. Setting an explanatory variable for a particular observation equal to its average means that, from the point of view of the regression model, the variable for that particular observation has no effect on the dependent variable. Replacing unknown interval scale variables in this way ensures that all of the available data is used, thus making the estimates more exact. Note however that we do not account for uncertainty due to these unknowns. Doing so would require performing multiple imputations for every interval scale variable that had an unknown value for at least one observation. Such a project is outside the scope of this report, requiring its own report. For an example of a report on the topic, see Subramanian (2002), which describes the multiple imputations procedure for the blood alcohol concentration variable in the FARS database.

Report Structure. This report consists of the following sections, in order: Executive Summary, Introduction, Introductory Tables, Crash Avoidance, Rollover Propensity, Injury Outcomes, Fatalities Only, Logistic Analysis, and References. The Executive Summary section, at the front of this report, is a brief summary of all of the report's findings. The Introduction, this section, familiarizes the reader with the purpose of this report, the databases used, and the methodology employed. The Introductory Tables section gives tables with counts of passenger vehicles that have rolled over, of occupants of such vehicles, and of injury outcomes of such vehicle occupants. The Crash Avoidance section gives rates for passenger vehicles that had rolled over, as well as for drivers of such vehicles; the Rollover Propensity section gives tables that show rollover rates in single-vehicle crashes. The section is subdivided into the Vehicle-Related Factors subsection, the Driver-Related Factors subsection, and the Other Factors subsection. The Injury Outcomes section shows injury outcomes and total ejection statuses of occupants who were in passenger vehicles that rolled over in single-vehicle crashes; the Fatalities Only section has tables for data on fatally injured occupants rather than all occupants in crashes. The reason that nonfatally injured occupants are not included is that the variables tabulated in this section were not present in the GES database. The section has two sub-sections. The first subsection tabulates the weight, height, and Body Mass Index of fatally injured drivers in single-vehicle rollovers. The second subsection tabulates rollover fatalities by State; the Logistic Analysis section describes the results of multivariate analysis of the data; the Rollover Propensity subsection models the propensity of vehicles to roll over given involvement in a single-vehicle crash. The Injury Outcomes subsection models the odds of occupant fatality given involvement in a single-vehicle rollover. The Discussion subsection compares the results of the two logistic models. Finally, the Appendix subsection briefly discusses the interpretation of logistic regression estimates; the Conclusion section provides concluding remarks; the References section lists references and acknowledgements.

3. Introductory Tables

This section contains some introductory tables to familiarize the reader with the data and with the general extent of the rollover issue as it existed from 1994 to 2004. The tables show annual data for years 1994 through 2004, the latest year for which data are available. Vehicle-level data in Table 1 are from the GES database, whereas occupant-level data in Tables 2 and 3 are from a combination of the FARS and the GES databases. Specifically, the data on occupants who were fatally injured is from the FARS database, while the data on occupants who were not fatally injured is from the GES database.

Vehicles. In 2004, an estimated 275,637 passenger vehicles rolled over, as compared to 237,504 vehicles in 1994, an increase of 16% (= [275,637 - 237,504] ÷ 237,504). As there were an estimated 11,728,411 vehicles in crashes in 2004, 2.4% (= [275,637 ÷ 11,728,411]) of the vehicles in crashes rolled over, as shown in Table 1. Although the results could be due to sampling error, it appears that both the number of rollovers and the rollover rate per total vehicles in crashes have increased over the years.

In 2004, passenger vehicles traveled 2,719 billion vehicle miles (Vehicle Miles Traveled - VMT). This means that there were an estimated 10.1 vehicles that have rolled over per 100 million VMT. This rollover rate has *decreased* by 7.3% (= [10.9 – 10.1] ÷ 10.9) since 1994. Since 1994, 2004 had the lowest rollover rate per VMT. There were 223,214,000 registered passenger vehicles in 2004, making the rollover rate an estimated 123 vehicles that have rolled over per 100,000 registered vehicles. This rate, again, was the lowest since 1994. Finally, there were a total of 198,889,000 licensed drivers, making an estimated 139 passenger vehicles that have rolled over per 100,000 licensed drivers in 2004. Unlike the rollover rates per VMT and 100,000 registered vehicles, the licensed driver roll rate was slightly higher than that in 1994.

Table 1
Passenger vehicle crashes and rollovers (regardless of the number of vehicles in the crash), 1994-2004

Year	Rolled over	Total vehicles in crashes	% Rolled over	VMT (billions)	Rolled over per 100 million VMT	Registered vehicles (thousands)	Rolled over per 100,000 registered vehicles	Licensed drivers (thousands)	Rolled over per 100,000 licensed drivers
1994	237,504	11,684,680	2.0	2,171	10.9	181,483	131	175,403	135
1995	243,431	12,171,372	2.0	2,228	10.9	185,763	131	176,628	138
1996	268,901	12,273,601	2.2	2,286	11.8	190,052	141	179,539	150
1997	259,158	12,008,921	2.2	2,353	11.0	191,960	135	182,709	142
1998	252,098	11,547,388	2.2	2,418	10.4	195,749	129	184,861	136
1999	275,207	11,371,434	2.4	2,470	11.1	200,013	138	187,170	147
2000	295,369	12,198,795	2.4	2,523	11.7	203,913	145	190,625	155
2001	294,729	12,020,364	2.5	2,572	11.5	207,720	142	191,276	154
2002	273,022	11,990,929	2.3	2,625	10.4	211,993	129	194,602	140
2003	278,442	11,987,190	2.3	2,656	10.5	216,730	128	196,166	142
2004	275,637	11,728,411	2.4	2,719	10.1	223,214	123	198,889	139

Source: NHTSA, NCSA, GES, R.L. Polk, 1994-2004.

Occupants. Now, consider the same information at the occupant level rather than the vehicle level. In 2004, there were an estimated 393,545 occupants in passenger vehicles that rolled over, as compared to 358,933 occupants in 1994, a 9.6% increase, as shown in Table 2. Since there were an estimated 14,099,883 occupants in passenger vehicles that crashed, 2.8% of occupants in crashes were in vehicles that rolled over. There were an estimated 14.5 occupants in vehicles that rolled over per 100 million VMT, 176 per 100,000 registered vehicles, and 198 per 100,000 licensed drivers. In 2004, the rates per VMT and per registered vehicles were the lowest that they have been since 1994. The last column of Table 2 uses information presented in Table 1 to calculate the average number of occupants per rollover. Thus, for example, in 2004, there were an estimated 1.43 (= [393,545 ÷ 275,637]) occupants per rollover.

Table 2
Passenger vehicle occupants in vehicles that crashed and in vehicles that rolled over, 1994-2004

Year	Occupants in vehicles that rolled over	Occupants in all vehicles that crashed	% in vehicles that rolled over	VMT (billions)	In vehicles that rolled over per 100 million VMT	Registered vehicles (thousands)	In vehicles that rolled over per 100,000 registered vehicles	Licensed drivers (thousands)	In vehicles that rolled over per 100,000 licensed drivers	Occupants per rollover
1994	358,933	15,578,690	2.3	2,171	16.5	181,483	198	175,403	205	1.51
1995	363,025	16,362,004	2.2	2,228	16.3	185,763	195	176,628	206	1.49
1996	394,434	16,496,950	2.4	2,286	17.3	190,052	208	179,539	220	1.47
1997	375,439	16,049,187	2.3	2,353	16	191,960	196	182,709	205	1.45
1998	354,473	15,386,637	2.3	2,418	14.7	195,749	181	184,861	192	1.41
1999	392,307	14,826,683	2.6	2,470	15.9	200,013	196	187,170	210	1.43
2000	415,418	14,789,760	2.8	2,523	16.5	203,913	204	190,625	218	1.41
2001	410,494	14,477,919	2.8	2,572	16	207,720	198	191,276	215	1.39
2002	390,958	14,427,318	2.7	2,625	14.9	211,993	184	194,602	201	1.43
2003	389,800	14,394,424	2.7	2,656	14.7	216,730	180	196,166	199	1.40
2004	393,545	14,099,883	2.8	2,719	14.5	223,214	176	198,889	198	1.43

Source: NHTSA, NCSA, FARS, GES, R.L. Polk., 1994-2004.

Injury Outcomes. As Table 3 shows, in 2004, of the estimated 393,545 occupants who were in passenger vehicles that rolled over, 10,553 occupants were fatally injured. Thus, the probability of death given involvement in a rollover was an estimated 2.7% (= [10,553 ÷ 393,545]). The number of occupants killed in passenger vehicles that rolled over increased from an estimated 8,981 in 1994 by 17.5% (= [10,553 - 8,981] ÷ 8,981). By comparison, when a passenger vehicle did not roll over in a crash, the probability of fatality was an estimated 0.2%. The number of those killed in vehicles that crashed but did not roll over has actually *decreased* by 3.6% from 1994 to 2004.

In 2004, an estimated 15,312 occupants in vehicles that rolled over were totally ejected from their vehicles. This constitutes 3.9% (= [15,312 ÷ 393,545]) of all the occupants who were in vehicles that rolled over were completely ejected from the vehicles. By contrast, of the occupants who were in vehicles that crashed but did not roll over, only an estimated 6,207 occupants were

totally ejected. There were thus 2.5 times (= [15,312 ÷ 6,207]) as many total ejections in vehicles that rolled over as there were in vehicles that crashed but did not roll over.

Table 3
Passenger vehicle occupants
by rollover status, injury severity, and ejection status, 1994-2004

Year	Rolled Over (#)					
	Fatal	Incapacitating Injury	Other Injury	No Injury	Total**	Total Ejection
1994	8,981	51,457	147,170	151,324	358,933	*
1995	9,537	46,690	165,680	141,118	363,025	12,431
1996	9,624	51,553	178,288	154,969	394,434	12,626
1997	9,527	46,741	170,910	148,261	375,439	12,332
1998	9,773	47,572	165,369	131,759	354,473	12,729
1999	10,140	54,081	182,049	146,037	392,307	17,922
2000	9,959	62,997	190,781	151,681	415,418	20,994
2001	10,157	54,280	192,638	153,419	410,494	17,989
2002	10,729	50,913	181,700	147,616	390,958	16,246
2003	10,442	47,734	189,402	142,222	389,800	16,457
2004	10,553	47,284	184,408	151,301	393,545	15,312

Source: NHTSA, NCSA, FARS, GES, R.L. Polk., 1994-2004.
** Total ejection data are available starting in 1995.*
*** Total includes unknowns.*

Year	No Rollover (#)					
	Fatal	Incapacitating Injury	Other Injury	No Injury	Total	Total Ejection
1994	21,920	307,798	2,846,108	12,043,931	15,219,758	*
1995	22,454	320,857	3,248,940	12,406,727	15,998,978	8,285
1996	22,813	310,358	3,084,905	12,684,439	16,102,516	7,024
1997	22,921	312,025	3,042,019	12,296,782	15,673,748	6,961
1998	22,126	291,464	3,018,988	11,699,586	15,032,164	7,081
1999	21,987	286,760	2,827,114	11,298,515	14,434,376	10,323
2000	22,266	270,973	2,728,433	11,352,670	14,374,342	9,849
2001	21,886	252,468	2,639,305	11,153,766	14,067,425	6,785
2002	22,114	248,073	2,594,276	11,171,898	14,036,361	7,321
2003	21,829	214,664	2,594,172	11,173,959	14,004,625	7,189
2004	21,140	206,156	2,478,897	11,000,145	13,706,338	6,207

Source: NHTSA, NCSA, FARS, GES, R.L. Polk., 1994-2004.
** Total ejection data are available starting in 1995.*

Year	Rolled Over (%)				
	Fatal	Incapacitating Injury	Other Injury	No Injury	Total Ejection
1994	2.5	14.3	41.0	42.2	*
1995	2.6	12.9	45.6	38.9	3.4
1996	2.4	13.1	45.2	39.3	3.2
1997	2.5	12.4	45.5	39.5	3.3
1998	2.8	13.4	46.7	37.2	3.6
1999	2.6	13.8	46.4	37.2	4.6
2000	2.4	15.2	45.9	36.5	5.1
2001	2.5	13.2	46.9	37.4	4.4
2002	2.7	13.0	46.5	37.8	4.2
2003	2.7	12.2	48.6	36.5	4.2
2004	2.7	12.0	46.9	38.4	3.9

Source: NHTSA, NCSA, FARS, GES, R.L. Polk., 1994-2004.
** Total ejection data are available starting in 1995.*

Year	No Rollover (%)				
	Fatal	Incapacitating Injury	Other Injury	No Injury	Total Ejection
1994	0.1	2.0	18.7	79.1	*
1995	0.1	2.0	20.3	77.5	0.1
1996	0.1	1.9	19.2	78.8	0.0
1997	0.1	2.0	19.4	78.5	0.0
1998	0.1	1.9	20.1	77.8	0.0
1999	0.2	2.0	19.6	78.3	0.1
2000	0.2	1.9	19.0	79.0	0.1
2001	0.2	1.8	18.8	79.3	0.0
2002	0.2	1.8	18.5	79.6	0.1
2003	0.2	1.5	18.5	79.8	0.1
2004	0.2	1.5	18.1	80.3	0.0

Source: NHTSA, NCSA, FARS, GES, R.L. Polk., 1994-2004.
** Total ejection data are available starting in 1995.*

4. Crash Avoidance

The tables in this section show annual vehicle-level data on vehicles that rolled over in 2004, the latest year for which data is available, in 2003 (except Table 6), the previous year, and in 1994, which is 10 years prior to 2004. As discussed previously in the Introductory Tables section, the vehicle-level data come from the GES database, not from the FARS database.

Vehicles by Type. Table 4 gives counts and rates of vehicles that have rolled over by two vehicle types: passenger car and light truck. Light trucks include vans, pickups, sports utility vehicles, and other light trucks. In 2004, of the two types, light trucks had the higher number of rollovers at an estimated 150,802 rollovers – 59% of the passenger vehicles that rolled over were light trucks. They also had the higher increase in rollovers from 1994 to 2004: 57%, as compared to a *decrease* of 15% for passenger cars. In 2004, light trucks also had the higher rate of rollovers per 100 million VMT at an estimated 13.8 as compared to 6.5 for passenger cars. The rate for light trucks was 2.1 times as much as it was for passenger cars. In 1994, the rate for light trucks was 1.6 times of what it was for passenger cars. This increase in the rates ratio is primarily due to a decrease in the rate for passenger cars, as the rate for light trucks has remained about the same.

Table 4
Passenger vehicles in rollovers
by vehicle type, 1994, 2003, 2004

Year	Vehicles that have rolled over				VMT (billions)		Rollovers per 100 million VMT	
	Passenger car		Light Truck		Passenger car	Light Truck	Passenger car	Light Truck
	#	%	#	%				
1994	124,187	56	96,082	44	1,459	712	8.5	13.5
2003	110,265	42	149,651	58	1,612	1,044	6.8	14.3
2004	105,994	41	150,802	59	1,624	1,096	6.5	13.8

Source: NHTSA, NCSA, GES, R.L. Polk., 1994, 2003, 2004.

Drivers by Sex. As seen in Table 5, in 2004, an estimated 251,804 passenger vehicle drivers with known sex were in vehicles that rolled over. Of these, an estimated 159,808, 63% of the total, were male, and 91,996, or 37%, were female. In 2004, of the drivers of passenger vehicles that crashed but did not roll over, an estimated 5,406,097, or only 56%, were male. There were 99,571,000 licensed male drivers, which makes the rate in 2004 an estimated 160 male drivers (= [100 * 159,808 ÷ 99,571]) in rollovers per 100,000 licensed male drivers. By contrast, there were only an estimated 93 female drivers in vehicles that rolled over per 100,000 licensed female drivers. Note that to obtain these rates, we are dividing the number of passenger vehicle drivers in rollovers by the number of licensed drivers of all vehicle types.

Table 5
Passenger vehicle drivers
by rollover status and sex, 1994, 2003, 2004

Year	Drivers in rollovers				Drivers in non-rollovers				Licensed drivers (thousands)		Drivers in rollovers per 100,000 licensed drivers	
	Male		Female		Male		Female					
	#	%	#	%	#	%	#	%	Male	Female	Male	Female
1994	143,295	67	71,388	33	5,921,537	59	4,193,046	41	89,194	86,210	161	83
2003	162,225	64	91,435	36	5,514,335	56	4,288,424	44	98,228	97,937	165	93
2004	159,808	63	91,996	37	5,406,097	56	4,252,755	44	99,571	99,318	160	93

Source: NHTSA, NCSA, GES, R.L. Polk., 1994, 2003, 2004.

Drivers by Age. Considering drivers who were in vehicles that rolled over by age groups, of the age groups considered in Table 6, the group with the highest number of drivers in 2004 is the 16- to 20-year-old group, with an estimated 67,366 drivers. Let us consider the rate of drivers of passenger vehicles that rolled over per 100,000 licensed drivers by age group. For example, in 2004, there were 12,485,000 licensed drivers between the ages of 16 and 20, making the rate for this group an estimated 540. The rate decreased with increasing age. Thus, for drivers 75 or older, the rate in 2004 was only 22, about 25 times less.

Table 6
Passenger vehicle drivers in rollovers
by age, 1994, 2004

Age	1994			2004		
	Drivers in rollovers	Licensed drivers (thousands)	Drivers in rollovers per 100,000 licensed drivers	Drivers in rollovers	Licensed drivers (thousands)	Drivers in rollovers per 100,000 licensed drivers
16 to 20	66,457	11,729	567	67,366	12,485	540
21 to 24	29,065	13,143	221	38,367	13,722	280
25 to 34	52,412	38,991	134	53,809	36,065	149
35 to 44	33,392	38,958	86	41,559	40,758	102
45 to 54	16,843	28,713	59	25,395	39,192	65
55 to 64	6,821	19,020	36	13,951	27,665	50
65 to 74	4,293	15,755	27	4,898	16,365	30
75 and older	2,105	9,037	23	2,806	12,611	22

Source: NHTSA, NCSA, GES, R.L. Polk., 1994, 2004.

Discussion. The crash avoidance tables show that, in the years under consideration, light trucks were more likely to roll over than passenger cars. They also show that male drivers were more

likely to be in vehicles that rolled over than female drivers, and that drivers who were younger were more likely to be involved than drivers who were older.

5. Rollover Propensity

This section considers passenger vehicles that have rolled over given that they were in a single-vehicle crash. Single-vehicle crashes are crashes that involve only a single vehicle in transport, not counting legally parked vehicles. The reason that we only consider single-vehicle crashes is that we wish to study the propensity of each vehicle itself to roll over. Single-vehicle crashes are often considered in studies of rollover propensity. See, for example, Dalrymple (2003). Also, a vehicle characteristic used by NHTSA, called the Static Stability Factor (SSF), has been found to highly correlate with the probability that a vehicle rolls over given that it is involved in a tripped single-vehicle crash (Walz, 2005; Committee for the Study of a Motor Vehicle Rollover Rating System, 2002). Thus, focusing on single-vehicle crashes makes the data more relevant to studies related to SSF.

The tables in this section show annual data for 2004, the latest year for which data is available, 2003, the previous year, and 1994, which is 10 years prior to 2004. The data in all the tables come from the GES database. Note that the percentage tables in this section show the proportion of vehicles that have rolled over as a percent of all vehicles that were in single-vehicle crashes. Thus, the percentages in the tables do not, and are not intended to, add up to 100%.

Vehicle-Related Factors

Vehicles by Type. As Table 7 shows, in 2004, an estimated 980,463 passenger cars were in single-vehicle crashes, of which an estimated 94,836 passenger cars rolled over. This means that in 2004, the probability of rollover for passenger cars given involvement in such a crash was 10% (= [94,836 ÷ 980,463]). In 2004, the highest probability of rollover given involvement in a single-vehicle crash was for sport utility vehicles at 23%. This probability was 2.3 times (= [23% ÷ 10%]) as great as for passenger cars. Likewise, the probability of rollover for pickups was 1.7 times higher than the probability of rollover for passenger cars. From 1994 to 2004, the probability of rollover for passenger cars had remained about the same at 10%, but had decreased slightly for light trucks. For example, for pickups, it went from 19% in 1994 to 17% in 2004. Note that, to improve readability, the table omits years 1995 through 2002.

Table 7
Vehicles in single-vehicle crashes
by vehicle type and rollover status, 1994, 2003, 2004

Vehicles Type/Rollover Status (#)		1994	2003	2004
Passenger car	**Rolled Over**	114,116	97,962	94,836
	Total	1,174,709	1,036,538	980,463
Van	**Rolled Over**	9,942	11,408	11,116
	Total	100,986	129,757	118,678
Pickup	**Rolled Over**	52,123	49,078	48,933
	Total	276,363	291,675	292,625
Sport Utility Vehicle	**Rolled Over**	18,154	57,686	56,962
	Total	73,469	227,770	246,221
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.				

Vehicles Type/Rollover Status (%)		1994	2003	2004
Passenger car	**Rolled Over**	10	9	10
Van	**Rolled Over**	10	9	9
Pickup	**Rolled Over**	19	17	17
Sport Utility Vehicle	**Rolled Over**	25	25	23
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.				

Vehicles by Age. Since vehicle age is not given in the databases, we follow Morgan (1999) and define vehicle age as the difference between the year in which the crash occurred and the model year of the vehicle. Note that this does not give the exact vehicle age as some vehicles may be sold as early as the year prior to their model year. This fact can result in a negative vehicle age, as measured by this calculation.

According to Table 8, in 2004, an estimated 27,905 passenger cars that were less than 5 years old rolled over when they were in single-vehicle crashes, compared to an estimated 66,687 that were 5 years old or older. For all four vehicle types, the probability of rollover for the older vehicles was slightly higher than for the newer vehicles. For example, the probability for older sport utility vehicles was 26%, compared to 20% for newer sport utility vehicles.

Table 8
Vehicles in single-vehicle crashes
by vehicle type, vehicle age, and rollover status, 1994, 2003, 2004

Vehicle Type/Vehicle Age/Rollover Status (#)			1994	2003	2004
Passenger car	**Less than 5 Years**	**Rolled Over**	37,539	28,271	27,905
		Total	422,226	342,638	311,480
	5 Years or More	**Rolled Over**	76,577	69,565	66,687
		Total	752,483	669,174	646,712
Van	**Less than 5 Years**	**Rolled Over**	3,885	3,150	3,338
		Total	47,472	41,265	39,806
	5 Years or More	**Rolled Over**	6,057	8,258	7,778
		Total	53,514	83,796	75,671
Pickup	**Less than 5 Years**	**Rolled Over**	16,855	18,479	19,037
		Total	104,010	117,073	114,646
	5 Years or More	**Rolled Over**	35,268	30,599	29,843
		Total	172,353	169,229	171,696
Sport Utility Vehicle	**Less than 5 Years**	**Rolled Over**	6,681	21,960	22,356
		Total	30,621	102,371	110,789
	5 Years or More	**Rolled Over**	11,473	35,727	34,606
		Total	42,848	120,795	131,799
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Vehicle Type/Vehicle Age/Rollover Status (%)			1994	2003	2004
Passenger car	**Less than 5 Years**	**Rolled Over**	9	8	9
	5 Years or More	**Rolled Over**	10	10	10
Van	**Less than 5 Years**	**Rolled Over**	8	8	8
	5 Years or More	**Rolled Over**	11	10	10
Pickup	**Less than 5 Years**	**Rolled Over**	16	16	17
	5 Years or More	**Rolled Over**	20	18	17
Sport Utility Vehicle	**Less than 5 Years**	**Rolled Over**	22	21	20
	5 Years or More	**Rolled Over**	27	30	26
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Driver-Related Factors

Speed-Related. If speed is judged by the police to be a contributing factor to the cause of the crash, the crash is called speed-related. We use the GES variable SPEEDREL and the classification in Lindsey (2006) to determine if the crash was speed-related. As Table 9 shows, in 2004, an estimated 249,151 single-vehicle car crashes were speed-related. In these crashes, an estimated 40,744 passenger cars rolled over. This made the probability of passenger car rollover in speed-related crashes 16%, compared to 8% for crashes that were not speed-related. Passenger cars were 2 times (= [16 ÷ 8]) as likely to roll over in speed-related crashes as in non-speed-related crashes. This probability ratio was highest for vans, at 3.1 (= [22 ÷ 7]).

Table 9
Vehicles in single-vehicle crashes
by vehicle type, whether the crash was speed-related, and rollover status, 1997, 2003, 2004

Vehicle Type/Speed-Related Crash/Rollover Status (#)			1997	2003	2004
Passenger car	**Speed-related**	**Rolled Over**	51,973	45,075	40,744
		Total	257,623	259,045	249,151
	Not speed-related	**Rolled Over**	52,567	48,992	50,611
		Total	730,642	704,305	667,204
Van	**Speed-related**	**Rolled Over**	4,691	4,271	3,702
		Total	15,649	20,579	17,161
	Not speed-related	**Rolled Over**	6,269	6,896	6,852
		Total	79,676	98,276	92,882
(Continued on Next Page)					

Vehicle Type/Speed-Related Crash/Rollover Status (#)			1997	2003	2004
Pickup	Speed-related	Rolled Over	23,154	21,498	21,888
		Total	72,840	70,814	71,663
	Not speed-related	Rolled Over	26,215	26,055	25,851
		Total	185,670	205,037	205,493
Sport Utility Vehicle	Speed-related	Rolled Over	6,457	25,510	23,375
		Total	18,834	66,115	66,745
	Not speed-related	Rolled Over	15,224	30,833	31,409
		Total	61,692	149,177	165,935

Source: NHTSA, NCSA, GES, 1997, 2003,2004
Note: Speed-related data available starting in 1997

Vehicle Type/Speed-Related Crash/Rollover Status (%)			1997	2003	2004
Passenger car	Speed-related	Rolled Over	20	17	16
	Not speed-related	Rolled Over	7	7	8
Van	Speed-related	Rolled Over	30	21	22
	Not speed-related	Rolled Over	8	7	7
Pickup	Speed-related	Rolled Over	32	30	31
	Not speed-related	Rolled Over	14	13	13
Sport Utility Vehicle	Speed-related	Rolled Over	34	39	35
	Not speed-related	Rolled Over	25	21	19

Source: NHTSA, NCSA, GES, 1997, 2003,2004
Note: Speed-related data available starting in 1997

Driver Restraint Use. Restraint use is the police-reported use of available vehicle restraints. It may reflect self-reporting by occupants of vehicles that crashed, and might thus be a biased estimate of actual restraint use.

According to Table 10, across all vehicle types and years, vehicles of restrained drivers that were involved in a single-vehicle crash were less likely to roll over than vehicles of unrestrained drivers. One possible interpretation of this data is that the drivers who chose to use restraints also chose to drive safer. These safer drivers could have been less likely to have been in vehicles that crashed, and also could have been less likely to have been in a vehicle that rolled over if it was in a crash. Another possible interpretation of the data is that given that a vehicle is involved in a crash, restrained drivers may be in a better position to mitigate rollovers by retaining better control over their vehicles.

In the 2004 single-vehicle car crashes in passenger cars that had a driver, an estimated 766,349 drivers used restraints while an estimated 51,861 did not. In those cases when the driver used restraints, there were 76,642 passenger car rollovers. The probability of passenger car rollover

with a restrained driver was thus 10% (= [76,642 ÷ 766,349]), compared to 17% when the driver was unrestrained. Note that in sport utility vehicles with unrestrained drivers, the rollover probability was 40%.

Table 10
Vehicles in single-vehicle crashes
by vehicle type, driver restraint use, and rollover status, 1994, 2003, 2004

Vehicle Type/Restraint Use/Rollover Status (#)			1994	2003	2004
Passenger car	Restrained	Rolled Over	78,839	71,186	76,642
		Total	806,536	789,117	766,349
	Unrestrained	Rolled Over	21,178	14,263	8,855
		Total	137,251	68,248	51,861
Van	Restrained	Rolled Over	7,502	9,177	9,267
		Total	71,593	95,490	91,444
	Unrestrained	Rolled Over	1,264	1,316	916
		Total	8,015	6,618	3,644
Pickup	Restrained	Rolled Over	30,723	35,623	38,083
		Total	173,977	221,790	230,913
	Unrestrained	Rolled Over	13,973	8,662	6,357
		Total	54,306	27,113	21,436
Sport Utility Vehicle	Restrained	Rolled Over	12,145	46,297	47,636
		Total	50,327	181,396	199,896
	Unrestrained	Rolled Over	3,914	6,937	6,262
		Total	8,880	14,983	15,645

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Restraint Use/Rollover Status (%)			1994	2003	2004
Passenger car	Restrained	Rolled Over	10	9	10
	Unrestrained	Rolled Over	15	21	17
Van	Restrained	Rolled Over	10	10	10
	Unrestrained	Rolled Over	16	20	25
Pickup	Restrained	Rolled Over	18	16	16
	Unrestrained	Rolled Over	26	32	30
Sport Utility Vehicle	Restrained	Rolled Over	24	26	24
	Unrestrained	Rolled Over	44	46	40

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Younger Drivers. Following Kindelberger and Eigen (2003), we define younger drivers as those drivers who were 24 or younger at the time of the crash. As seen in Table 11, of the passenger car drivers in cars that were in single-vehicle car crashes in 2004, an estimated 372,920 were

between 16 and 24, while an estimated 533,328 were 25 or older. Of these older passenger car drivers, 41,937, or 8%, were in vehicles that rolled over. On the other hand, 13% of the younger passenger car drivers were in vehicles that rolled over.

Table 11
Vehicles in single-vehicle crashes
by vehicle type, driver age, and rollover status, 1994, 2003, 2004

Vehicle Type/Age/Rollover Status (#)			1994	2003	2004
Passenger car	16 to 24	Rolled Over	56,504	52,329	49,524
		Total	402,779	394,802	372,920
	25 and older	Rolled Over	51,606	40,819	41,937
		Total	665,787	559,863	533,328
Van	16 to 24	Rolled Over	2,413	2,172	2,455
		Total	13,946	16,930	16,261
	25 and older	Rolled Over	7,365	8,910	7,859
		Total	75,635	100,163	92,657
Pickup	16 to 24	Rolled Over	21,702	17,762	18,253
		Total	80,872	77,817	78,168
	25 and older	Rolled Over	28,359	29,014	28,921
		Total	172,555	195,594	197,074
Sport Utility Vehicle	16 to 24	Rolled Over	6,474	21,181	21,725
		Total	23,064	66,100	69,326
	25 and older	Rolled Over	11,327	34,930	33,351
		Total	45,798	146,988	162,509

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Age/Rollover Status (%)			1994	2003	2004
Passenger car	16 to 24	Rolled Over	14	13	13
	25 and older	Rolled Over	8	7	8
Van	16 to 24	Rolled Over	17	13	15
	25 and older	Rolled Over	10	9	8
Pickup	16 to 24	Rolled Over	27	23	23
	25 and older	Rolled Over	16	15	15
Sport Utility Vehicle	16 to 24	Rolled Over	28	32	31
	25 and older	Rolled Over	25	24	21

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Younger Drivers and Passengers. Here, we consider single-vehicle crashes in those cases in which the vehicle had two occupants, including the driver; we consider the crashes by the age of

both the driver and the passenger. Note that younger drivers and younger passengers are defined slightly differently. As before, younger drivers are defined as driver between 16 and 24, inclusive. Younger passengers are any passengers who were 24 or younger.

According to Table 12, the presence of a younger passenger did not seem to have a clear association with the rollover rate. Consider the situation with older passenger car drivers. In 2004, when the passenger was younger, the rollover rate was an estimated 13% whereas when the passenger was older, the rate was an estimated 7%. Thus, in this case, younger passengers were associated with a higher rollover rate. However, in 2003, the relationship was reversed, with a 7% rate with younger passengers and 9% rate with older passengers.

Note the high variability in some of the percentages shown in Table 12. For example, for sport utility vehicles with younger drivers and older passengers, the rollover rate was an estimated 25% in 2003 and an estimated 8% in 2004. As discussed in the Introduction, such high variability is due to the low estimated counts, which makes the standard error of the estimate high relative to the estimate itself. For instance, in 2003, an estimated 224 sport utility vehicles with younger drivers and older passengers rolled over. The standard error of this estimate is 203, or 91% of the estimate. If the estimate had been 10 times as large, then its standard error would have been only 27% of the estimate.

Table 12
Vehicles with two occupants in single-vehicle crashes
by vehicle type, driver and passenger age, and rollover status, 1994, 2003, 2004

Vehicle Type/Driver and passenger age/Rollover Status (#)			1994	2003	2004
Passenger car	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	11,635	8,494	7,330
		Total	70,119	57,665	52,204
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	1,139	1,496	836
		Total	9,057	9,521	7,400
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	3,353	2,140	3,168
		Total	30,269	30,257	23,675
	Driver 25 and older/ Passenger 25 and older	Rolled Over	5,990	3,893	2,901
		Total	56,112	41,232	42,986
Van	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	213	52	463
		Total	1,235	1,948	1,965
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	0	78	141
		Total	0	1,157	909
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	76	346	334
		Total	4,083	4,148	5,741
	Driver 25 and older/ Passenger 25 and older	Rolled Over	642	807	889
		Total	5,116	8,257	7,613

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Vehicle Type/Driver and passenger age/Rollover Status (#)			1994	2003	2004
Pickup	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	5,018	3,169	3,175
		Total	16,587	10,858	12,202
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	1,019	360	508
		Total	2,302	1,211	1,032
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	1,657	1,365	1,320
		Total	6,681	7,582	5,875
	Driver 25 and older/ Passenger 25 and older	Rolled Over	2,924	3,052	3,588
		Total	15,136	15,234	18,944
Sport Utility Vehicle	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	1,051	4,337	3,955
		Total	2,984	11,196	9,926
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	200	224	153
		Total	547	893	1,873
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	1,074	2,462	1,740
		Total	1,801	8,601	6,349
	Driver 25 and older/ Passenger 25 and older	Rolled Over	1,936	3,832	3,460
		Total	3,855	12,373	12,633

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Driver and passenger age/Rollover Status (%)			1994	2003	2004
Passenger car	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	17	15	14
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	13	16	11
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	11	7	13
	Driver 25 and older/ Passenger 25 and older	Rolled Over	11	9	7
Van	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	17	3	24
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	-	7	16
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	2	8	6
	Driver 25 and older/ Passenger 25 and older	Rolled Over	13	10	12

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Vehicle Type/Driver and passenger age/Rollover Status (%)			1994	2003	2004
Pickup	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	30	29	26
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	44	30	49
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	25	18	22
	Driver 25 and older/ Passenger 25 and older	Rolled Over	19	20	19
Sport Utility Vehicle	Driver 24 and younger/ Passenger 24 and younger	Rolled Over	35	39	40
	Driver 24 and younger/ Passenger 25 and older	Rolled Over	37	25	8
	Driver 25 and older/ Passenger 24 and younger	Rolled Over	60	29	27
	Driver 25 and older/ Passenger 25 and older	Rolled Over	50	31	27
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Sex. In 2004, an estimated 52,824 of the estimated 534,279 male drivers of passenger cars that were in single-vehicle car crashes were in cars that rolled over, which means that the rollover rate for male passenger car drivers was 10%. The rollover rate for female passenger car drivers was, likewise, 10%. From the numbers in Table 13, there did not seem to be a clear relationship between driver sex and the rollover rate.

Table 13
Vehicles in single-vehicle crashes
by vehicle type, driver sex, and rollover status, 1994, 2003, 2004

Vehicle Type/Sex/Rollover Status (#)			1994	2003	2004
Passenger car	Male	Rolled Over	65,072	55,407	52,824
		Total	660,456	552,622	534,279
	Female	Rolled Over	45,251	39,017	40,030
		Total	447,327	429,926	400,122
Van	Male	Rolled Over	5,666	7,326	7,190
		Total	59,813	74,292	69,505
	Female	Rolled Over	4,276	3,968	3,336
		Total	34,896	46,868	42,446
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Vehicle Type/Sex/Rollover Status (#)			1994	2003	2004
Pickup	Male	Rolled Over	42,476	40,394	40,669
		Total	228,134	240,530	236,890
	Female	Rolled Over	8,033	7,104	7,159
		Total	33,689	39,285	44,394
Sport Utility Vehicle	Male	Rolled Over	12,379	32,628	32,730
		Total	48,311	130,162	133,431
	Female	Rolled Over	5,774	24,058	23,376
		Total	21,770	88,002	105,284
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Vehicle Type/Sex/Rollover Status (%)			1994	2003	2004
Passenger car	Male	Rolled Over	10	10	10
	Female	Rolled Over	10	9	10
Van	Male	Rolled Over	9	10	10
	Female	Rolled Over	12	8	8
Pickup	Male	Rolled Over	19	17	17
	Female	Rolled Over	24	18	16
Sport Utility Vehicle	Male	Rolled Over	26	25	25
	Female	Rolled Over	27	27	22
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Alcohol. Whether alcohol was involved in the crash is derived from police-reported alcohol involvement. If any driver, pedestrian, cyclist, or other nonmotorist who was in a crash used alcohol, the crash was classified as having alcohol involvement. Note that simply because a crash had alcohol involvement does not mean that alcohol use caused the crash.

In 2004, there were an estimated 106,934 passenger cars in single-vehicle car crashes in which alcohol was involved. Of these, an estimated 15,618 passenger cars rolled over. In 2004, the passenger car rollover rate when alcohol was involved was thus 15%. When alcohol was not involved, the rate was 9%. This relationship that alcohol involvement was associated with higher incidence of rollover, held for all vehicle types considered in Table 14.

Table 14
Vehicles in single-vehicle crashes
by vehicle type, alcohol involvement, and rollover status, 1994, 2003, 2004

Vehicle Type/Alcohol Involvement/Rollover Status (#)			1994	2003	2004
Passenger car	Involved	Rolled Over	20,652	17,356	15,618
		Total	132,969	105,693	106,934
	Not Involved	Rolled Over	88,740	69,988	72,312
		Total	970,416	802,783	765,542
Van	Involved	Rolled Over	690	1,202	1,293
		Total	4,872	9,225	7,070
	Not Involved	Rolled Over	8,870	9,369	8,944
		Total	89,430	101,318	96,450
Pickup	Involved	Rolled Over	10,246	9,755	9,418
		Total	45,655	35,498	37,825
	Not Involved	Rolled Over	39,002	35,087	35,889
		Total	215,657	224,900	228,828
Sport Utility Vehicle	Involved	Rolled Over	2,814	8,000	8,298
		Total	8,038	23,400	25,375
	Not Involved	Rolled Over	15,066	46,064	44,467
		Total	60,589	182,124	195,817

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Alcohol Involvement/Rollover Status (%)			1994	2003	2004
Passenger car	Involved	Rolled Over	16	16	15
	Not Involved	Rolled Over	9	9	9
Van	Involved	Rolled Over	14	13	18
	Not Involved	Rolled Over	10	9	9
Pickup	Involved	Rolled Over	22	27	25
	Not Involved	Rolled Over	18	16	16
Sport Utility Vehicle	Involved	Rolled Over	35	34	33
	Not Involved	Rolled Over	25	25	23

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Maneuver Prior to Critical Event. Vehicle maneuver prior to critical event describes a vehicle's activity prior to the driver's realization of an impending critical event, or just prior to impact if the driver took no action or had no time to attempt any evasive maneuvers.

As seen in Table 15, by far, most vehicles rolled over while going straight. For example, in 2004, an estimated 56,124 passenger cars rolled over while going straight, compared to an estimated 30,424 passenger car rollovers while negotiating a curve. However, the highest rate of rollover occurred while passing. For example, in 2004, 28% of passenger cars that were passing before a single-vehicle crash rolled over in that crash. For sport utility vehicles, the rate was 58%. The vehicle maneuver associated with the lowest rollover rate was turning. In 2004, only 3% of passenger cars that were turning prior to a single-vehicle crash rolled over in that crash. Note that the table shows the probability of rollover given involvement in a single-vehicle crash, by type of crash. In other words, the table does not say that passing leads to more rollovers than going straight. Rather, it says that if a vehicle is involved in a single-vehicle crash while passing, it is more likely that it rolls over than if it was involved in a single-vehicle crash while going straight.

Table 15
Vehicles in single-vehicle crashes
by vehicle type, maneuver prior to critical event, and rollover status, 1994, 2003, 2004

Vehicle Type/Vehicle Maneuver/Rollover Status (#)			1994	2003	2004
Passenger car	Going Straight	Rolled Over	87,500	59,712	56,124
		Total	884,766	668,273	625,433
	Passing	Rolled Over	1,391	1,597	1,615
		Total	7,120	7,403	5,685
	Changing Lanes	Rolled Over	1,892	2,188	2,300
		Total	10,723	17,035	15,870
	Negotiating a Curve	Rolled Over	13,467	30,257	30,424
		Total	64,266	179,800	168,204
	Turning	Rolled Over	3,801	2,291	2,045
		Total	82,044	76,547	71,818
Van	Going Straight	Rolled Over	8,027	8,014	7,866
		Total	72,686	80,968	77,573
	Passing	Rolled Over	0	0	0
		Total	427	1,063	761
	Changing Lanes	Rolled Over	326	287	223
		Total	869	981	1,042
	Negotiating a Curve	Rolled Over	676	2,722	2,388
		Total	2,362	11,647	9,302
	Turning	Rolled Over	290	102	144
		Total	6,429	9,883	7,524

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Vehicle Type/Vehicle Maneuver/Rollover Status (#)			1994	2003	2004
Pickup	Going Straight	Rolled Over	40,700	29,578	30,887
		Total	204,781	191,851	196,088
	Passing	Rolled Over	434	661	610
		Total	1,168	2,617	1,700
	Changing Lanes	Rolled Over	649	348	661
		Total	2,706	2,968	2,966
	Negotiating a Curve	Rolled Over	6,742	16,688	13,355
		Total	19,145	52,126	40,852
	Turning	Rolled Over	1,355	666	1,775
		Total	15,230	15,591	18,868
Sport Utility Vehicle	Going Straight	Rolled Over	13,129	37,425	35,787
		Total	54,059	149,284	156,340
	Passing	Rolled Over	309	510	1,050
		Total	469	1,519	1,805
	Changing Lanes	Rolled Over	358	985	847
		Total	875	2,722	3,145
	Negotiating a Curve	Rolled Over	2,190	16,379	15,336
		Total	3,883	37,756	39,243
	Turning	Rolled Over	1,045	1,169	2,367
		Total	4,025	16,465	18,147

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Vehicle Maneuver/Rollover Status (%)			1994	2003	2004
Passenger car	Going Straight	Rolled Over	10	9	9
	Passing	Rolled Over	20	22	28
	Changing Lanes	Rolled Over	18	13	14
	Negotiating a Curve	Rolled Over	21	17	18
	Turning	Rolled Over	5	3	3
Van	Going Straight	Rolled Over	11	10	10
	Passing	Rolled Over	0	0	0
	Changing Lanes	Rolled Over	38	29	21
	Negotiating a Curve	Rolled Over	29	23	26
	Turning	Rolled Over	5	1	2

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Vehicle Type/Vehicle Maneuver/Rollover Status (%)			1994	2003	2004
Pickup	Going Straight	Rolled Over	20	15	16
	Passing	Rolled Over	37	25	36
	Changing Lanes	Rolled Over	24	12	22
	Negotiating a Curve	Rolled Over	35	32	33
	Turning	Rolled Over	9	4	9
Sport Utility Vehicle	Going Straight	Rolled Over	24	25	23
	Passing	Rolled Over	66	34	58
	Changing Lanes	Rolled Over	41	36	27
	Negotiating a Curve	Rolled Over	56	43	39
	Turning	Rolled Over	26	7	13
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Corrective Action Attempted. Corrective action attempted describes actions taken by the driver of a vehicle in response to the impending danger. Of the three actions considered in Table 16, none, braking, and steering, "none" (meaning no corrective action) was associated with the lowest rollover rate given involvement in a single-vehicle crash while steering was associated with the highest rollover rate. For example, in passenger cars in single-vehicle crashes in 2004, no corrective action was associated with a rollover rate given involvement in a single-vehicle crash of an estimated 7%, whereas steering was associated with a rate of an estimated 21%, 3 times as high. In sport utility vehicles, steering was associated with a 40% probability of rollover given involvement in a single-vehicle crash.

Note however that these results do not imply that taking no corrective action decreased the probability of rollover whereas steering increased it. For example, it is possible that drivers chose to steer when, in their judgments, the impending crash had a high severity; and that it is these crashes of high perceived severity that were associated with a high rollover rate.

Table 16
Vehicles in single-vehicle crashes
by vehicle type, corrective action attempted, and rollover status, 1994, 2003, 2004

Vehicle Type/Crash Avoidance Maneuver/Rollover Status (#)			1994	2003	2004
Passenger car	None	Rolled Over	66,935	4,407	9,623
		Total	856,770	84,320	146,810
	Braking	Rolled Over	19,106	3,483	3,788
		Total	106,721	47,218	43,336
	Steering	Rolled Over	18,773	26,308	29,726
		Total	108,707	155,434	141,971
(Continued on Next Page)					

Vehicle Type/Crash Avoidance Maneuver/Rollover Status (#)			1994	2003	2004
Van	None	Rolled Over	6,910	169	1,474
		Total	82,584	13,255	18,539
	Braking	Rolled Over	792	521	404
		Total	4,218	3,594	2,637
	Steering	Rolled Over	1,963	2,556	2,146
		Total	6,758	12,311	12,406
Pickup	None	Rolled Over	31,941	1,991	4,107
		Total	207,529	22,994	40,975
	Braking	Rolled Over	8,533	2,060	1,607
		Total	27,188	12,004	13,536
	Steering	Rolled Over	7,694	11,288	12,555
		Total	22,417	40,376	41,689
Sport Utility Vehicle	None	Rolled Over	12,570	3,034	7,094
		Total	52,275	17,329	36,146
	Braking	Rolled Over	1,790	3,434	1,835
		Total	6,544	10,303	7,926
	Steering	Rolled Over	2,298	13,794	13,864
		Total	7,557	34,212	35,051

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Crash Avoidance Maneuver/Rollover Status (%)			1994	2003	2004
Passenger car	None	Rolled Over	8	5	7
	Braking	Rolled Over	18	7	9
	Steering	Rolled Over	17	17	21
Van	None	Rolled Over	8	1	8
	Braking	Rolled Over	19	14	15
	Steering	Rolled Over	29	21	17
Pickup	None	Rolled Over	15	9	10
	Braking	Rolled Over	31	17	12
	Steering	Rolled Over	34	28	30
Sport Utility Vehicle	None	Rolled Over	24	18	20
	Braking	Rolled Over	27	33	23
	Steering	Rolled Over	30	40	40

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Other Factors

Vehicle Occupancy. According to Table 17, in 2004 an estimated 825,888 passenger cars in single-vehicle car crashes had one or two occupants, counting the driver. Of these, an estimated 81,509 passenger cars rolled over, making the passenger car rollover rate given involvement in a single-vehicle crash when there were one or two occupants 10%. When there were three to five occupants, again, counting the driver, the rate increased to 13%. For all vehicle types under consideration, higher occupancy was associated with a higher rollover rate. For example, pickups with six or more occupants had a probability of 54% of rolling over given involvement in a single-vehicle crash. The result that higher occupancy is associated with higher probability of rollover in a single-vehicle crash is confirmed by multivariate analysis later in this report, as well as by other analyses, such as Subramanian (2005). One possible reason for this is that higher occupancy raises the vehicle's center of mass, which makes it less stable.

Table 17
Vehicles in single-vehicle crashes
by vehicle type, number of vehicle occupants, and rollover status, 1994, 2003, 2004

Vehicle Type/Number of Vehicle Occupants/Rollover Status (#)			1994	2003	2004
Passenger car	1 or 2	Rolled Over	96,499	82,307	81,509
		Total	1,047,772	864,373	825,888
	3 to 5	Rolled Over	16,603	10,425	10,526
		Total	116,418	87,006	78,110
	6 or more	Rolled Over	937	112	502
		Total	4,910	1,813	1,526
Van	1 or 2	Rolled Over	7,456	8,463	7,994
		Total	85,994	99,746	89,756
	3 to 5	Rolled Over	2,065	2,294	1,918
		Total	13,037	14,174	15,223
	6 or more	Rolled Over	421	378	597
		Total	1,772	1,852	2,380
Pickup	1 or 2	Rolled Over	47,178	43,518	43,474
		Total	256,645	256,536	256,325
	3 to 5	Rolled Over	4,240	3,380	3,812
		Total	16,133	16,505	15,712
	6 or more	Rolled Over	705	109	136
		Total	1,562	401	250
Sport Utility Vehicle	1 or 2	Rolled Over	15,776	48,311	47,449
		Total	65,449	187,154	203,131
	3 to 5	Rolled Over	2,288	6,948	8,086
		Total	7,697	22,267	24,800
	6 or more	Rolled Over	90	724	467
		Total	235	1,475	1,070

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Number of Vehicle Occupants/Rollover Status (%)			1994	2003	2004
Passenger car	1 or 2	Rolled Over	9	10	10
	3 to 5	Rolled Over	14	12	13
	6 or more	Rolled Over	19	6	33
Van	1 or 2	Rolled Over	9	8	9
	3 to 5	Rolled Over	16	16	13
	6 or more	Rolled Over	24	20	25
Pickup	1 or 2	Rolled Over	18	17	17
	3 to 5	Rolled Over	26	20	24
	6 or more	Rolled Over	45	27	54
Sport Utility Vehicle	1 or 2	Rolled Over	24	26	23
	3 to 5	Rolled Over	30	31	33
	6 or more	Rolled Over	38	49	44
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Speed Limit. As Table 18 shows, in 2004 when the speed limit was 30 mph or less, there were an estimated 201,660 single-vehicle car crashes, an estimated 6,889 of which resulted in a rollover. Thus, at these speed limits, the probability of passenger car rollover given involvement in a single-vehicle crash was 3%. The probability increased with increasing speed limits. At a speed limit of 60 mph or higher, the probability for passenger cars was 16%, which is 5.3 times (= [16% ÷ 3%]) as much as it was at 30 mph or less. At a speed limit of 30 mph or less, the probability of rollover given involvement in a single-vehicle crash for utility vehicles was 15%, which was about twice as high as it was for pickups (at 7%), almost four times as high as it was for vans (at 4%), and five times as high as it was for passenger cars (at 3%).

Table 18
Vehicles in single-vehicle crashes
by vehicle type, posted speed limit, and rollover status, 1994, 2003, 2004

Vehicle Type/Speed Limit/Rollover Status (#)			1994	2003	2004
Passenger car	30 mph or less	Rolled Over	10,581	8,000	6,889
		Total	280,396	220,262	201,660
	35 to 55 mph	Rolled Over	80,019	58,595	57,598
		Total	616,563	491,210	466,218
	60 mph or more	Rolled Over	6,894	20,349	20,784
		Total	38,588	125,140	126,227
Van	30 mph or less	Rolled Over	282	1,313	855
		Total	23,640	30,600	23,817
	35 to 55 mph	Rolled Over	6,212	5,856	5,695
		Total	47,705	53,156	53,706
	60 mph or more	Rolled Over	1,866	3,451	3,484
		Total	5,186	15,548	13,508
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Vehicle Type/Speed Limit/Rollover Status (#)			1994	2003	2004
Pickup	30 mph or less	Rolled Over	2,897	3,812	3,962
		Total	57,817	53,932	54,877
	35 to 55 mph	Rolled Over	39,543	30,060	28,146
		Total	173,613	158,684	160,338
	60 mph or more	Rolled Over	3,225	11,134	12,683
		Total	10,716	45,319	42,082
Sport Utility Vehicle	30 mph or less	Rolled Over	2,518	7,493	7,978
		Total	18,342	47,264	51,764
	35 to 55 mph	Rolled Over	12,163	31,350	29,209
		Total	38,985	117,039	127,285
	60 mph or more	Rolled Over	1,359	16,171	16,416
		Total	2,875	40,636	40,951
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Vehicle Type/Speed Limit/Rollover Status (%)			1994	2003	2004
Passenger car	30 mph or less	Rolled Over	4	4	3
	35 to 55 mph	Rolled Over	13	12	12
	60 mph or more	Rolled Over	18	16	16
Van	30 mph or less	Rolled Over	1	4	4
	35 to 55 mph	Rolled Over	13	11	11
	60 mph or more	Rolled Over	36	22	26
Pickup	30 mph or less	Rolled Over	5	7	7
	35 to 55 mph	Rolled Over	23	19	18
	60 mph or more	Rolled Over	30	25	30
Sport Utility Vehicle	30 mph or less	Rolled Over	14	16	15
	35 to 55 mph	Rolled Over	31	27	23
	60 mph or more	Rolled Over	47	40	40
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Road Type. As seen in Table 19, in 2004, most single-vehicle car rollovers occurred on undivided two-way trafficways, with an estimated 59,962 rollovers. The highest rollover rate, however, was on divided highways, with an estimated 12% of all single-vehicle car crashes involving a rollover. This higher probability of rollover on divided highways could have been due to several reasons. It could have been due to the road type itself, or due to some other variable. For instance, it could have been due to the fact that divided highways generally have higher speed limits. Another interesting issue is the high rollover rate that occurred on one-way roads. For example, in 2004, the rate for sport utility vehicles was 31%. Addressing these two

issues requires multivariate analysis, such as logistic analysis presented later in this report. See there for a further discussion.

Table 19
Vehicles in single-vehicle crashes
by vehicle type, road type, and rollover status, 1994, 2003, 2004

Vehicle Type/Type of Road/Rollover Status (#)			1994	2003	2004
Passenger car	Undivided Two-Way	Rolled Over	72,558	60,963	59,962
		Total	656,551	586,269	568,469
	Divided Highway	Rolled Over	24,830	24,460	24,951
		Total	197,615	204,495	203,790
	One-way	Rolled Over	3,599	3,631	2,225
		Total	37,805	44,366	36,253
Van	Undivided Two-Way	Rolled Over	4,850	5,788	6,057
		Total	48,415	66,264	67,253
	Divided Highway	Rolled Over	3,121	4,244	4,025
		Total	16,859	22,934	22,899
	One-way	Rolled Over	347	255	257
		Total	2,862	4,849	2,433
Pickup	Undivided Two-Way	Rolled Over	35,894	33,960	29,211
		Total	173,271	182,687	183,342
	Divided Highway	Rolled Over	8,328	10,064	13,584
		Total	36,871	55,313	57,497
	One-way	Rolled Over	1,486	1,185	1,723
		Total	6,258	8,756	8,116
Sport Utility Vehicle	Undivided Two-Way	Rolled Over	10,088	32,326	31,149
		Total	41,079	128,952	144,820
	Divided Highway	Rolled Over	4,197	19,980	18,716
		Total	13,307	56,525	58,817
	One-way	Rolled Over	777	1,933	2,473
		Total	3,239	6,750	7,933

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Type of Road/Rollover Status (%)			1994	2003	2004
Passenger car	**Undivided Two-Way**	**Rolled Over**	11	10	11
	Divided Highway	**Rolled Over**	13	12	12
	One-way	**Rolled Over**	10	8	6
Van	**Undivided Two-Way**	**Rolled Over**	10	9	9
	Divided Highway	**Rolled Over**	19	19	18
	One-way	**Rolled Over**	12	5	11
Pickup	**Undivided Two-Way**	**Rolled Over**	21	19	16
	Divided Highway	**Rolled Over**	23	18	24
	One-way	**Rolled Over**	24	14	21
Sport Utility Vehicle	**Undivided Two-Way**	**Rolled Over**	25	25	22
	Divided Highway	**Rolled Over**	32	35	32
	One-way	**Rolled Over**	24	29	31
Source: NHTSA, NCSA, GES, 1994, 2003, 2004.					

Relation to junction. By "relation to junction," we mean whether the first harmful event of the crash occurred in an interchange and whether it occurred in an intersection. These categories are based on the REL_JCT variable in GES. The variable is classified into the interchange/non-interchange and intersection/non-intersection categories following NHTSA c (2004) and Lindsey (2006). In particular, NHTSA c (2004) classifies some values of the variable as referring to an interchange and others as referring to a non-interchange area. Lindsey classifies "intersection" and "intersection-related" as intersection, and all other values that are not unknown as non-intersection. Interchange is an area with roadways on different levels, such as a cloverleaf; non-interchange is an area in which all roadways are on the same level. An intersection consists of two or more roadways that intersect at the same level.

According to Table 20, given involvement in a single-vehicle crash, rollovers were more likely to occur in non-intersections as opposed to intersections. For example, in 2004, the rollover rate for passenger cars given involvement in a single-vehicle crash in non-interchange intersections was only an estimated 3%; compare this to an estimated 11% rate on non-interchange non-intersections.

Table 20
Vehicles in single-vehicle crashes
by vehicle type, relation to junction, and rollover status, 1994, 2003, 2004

Vehicle Type/Relation to Junction/Rollover Status (#)			1994	2003	2004
Passenger car	Non-Interchange Non-Intersection	Rolled Over	104,953	87,873	88,088
		Total	998,578	842,440	808,669
	Non-Interchange Intersection	Rolled Over	5,270	4,637	3,328
		Total	147,829	145,877	131,339
	Interchange Non-Intersection	Rolled Over	2,902	4,986	3,182
		Total	19,297	38,892	31,034
	Interchange Intersection	Rolled Over	409	92	52
		Total	3,128	1,259	984
Van	Non-Interchange Non-Intersection	Rolled Over	9,129	10,192	10,121
		Total	87,505	105,612	101,996
	Non-Interchange Intersection	Rolled Over	536	818	427
		Total	11,751	19,058	13,568
	Interchange Non-Intersection	Rolled Over	184	397	568
		Total	776	4,192	2,154
	Interchange Intersection	Rolled Over	93	0	0
		Total	93	0	0
Pickup	Non-Interchange Non-Intersection	Rolled Over	49,019	45,511	44,372
		Total	245,035	257,371	253,231
	Non-Interchange Intersection	Rolled Over	1,971	1,771	2,985
		Total	25,750	24,963	30,440
	Interchange Non-Intersection	Rolled Over	796	1,699	1,345
		Total	4,018	8,364	6,713
	Interchange Intersection	Rolled Over	244	0	0
		Total	436	0	0
Sport Utility Vehicle	Non-Interchange Non-Intersection	Rolled Over	16,372	52,197	50,048
		Total	61,990	192,066	208,439
	Non-Interchange Intersection	Rolled Over	1,341	2,847	3,472
		Total	9,335	26,464	25,919
	Interchange Non-Intersection	Rolled Over	441	2,430	3,016
		Total	1,642	6,846	9,118
	Interchange Intersection	Rolled Over	0	0	142
		Total	0	0	377

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/Relation to Junction/Rollover Status (%)			1994	2003	2004
Passenger car	Non-Interchange Non-Intersection	Rolled Over	11	10	11
	Non-Interchange Intersection	Rolled Over	4	3	3
	Interchange Non-Intersection	Rolled Over	15	13	10
	Interchange Intersection	Rolled Over	13	7	5
Van	Non-Interchange Non-Intersection	Rolled Over	10	10	10
	Non-Interchange Intersection	Rolled Over	5	4	3
	Interchange Non-Intersection	Rolled Over	24	9	26
	Interchange Intersection	Rolled Over	100	-	-
Pickup	Non-Interchange Non-Intersection	Rolled Over	20	18	18
	Non-Interchange Intersection	Rolled Over	8	7	10
	Interchange Non-Intersection	Rolled Over	20	20	20
	Interchange Intersection	Rolled Over	56	-	-
Sport Utility Vehicle	Non-Interchange Non-Intersection	Rolled Over	26	27	24
	Non-Interchange Intersection	Rolled Over	14	11	13
	Interchange Non-Intersection	Rolled Over	27	35	33
	Interchange Intersection	Rolled Over	-	-	38

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

First Harmful Event. The first harmful event is the first property-damaging or injury-producing event in a crash as judged by GES coders based on police crash reports.

In 2004, there were an estimated 37,953 passenger cars in single-car crashes for which the first harmful event was a rollover. Considering the other first harmful events shown in Table 21, the highest rollover rate for passenger cars given involvement in a single-vehicle crash was associated with striking an embankment, at an estimated 30%, followed by hitting a culvert, curb, or ditch, at an estimated 17%. Striking an embankment had the highest rollover rate for the other vehicle types as well. For example, for pickups in 2004, striking an embankment was associated with a rollover rate given involvement in a single-vehicle crash of 52%. The lowest rollover rates were for other non-collisions and for striking an object not fixed. It is also interesting to note striking a guard rail or a barrier as the first harmful event resulted in a higher rollover rate for pickups (an estimated 13%) and utility vehicles (15%) than for passenger cars (5%) and vans (8%).

Table 21
Vehicles in single-vehicle crashes
by vehicle type, first harmful event, and rollover status, 1994, 2003, 2004

Vehicle Type/First Harmful Event/Rollover Status (#)			1994	2003	2004
Passenger car	Rollover	Rolled Over	49,725	37,003	37,953
		Total	49,725	37,003	37,953
	Other Non-collision	Rolled Over	291	9	127
		Total	19,176	9,611	7,763
	Object Not Fixed	Rolled Over	1,073	4,242	2,055
		Total	484,832	403,789	372,402
	Bridge	Rolled Over	545	562	230
		Total	9,163	10,502	8,933
	Guard Rail/Barrier	Rolled Over	5,733	7,390	6,079
		Total	96,756	109,781	110,789
	Fence	Rolled Over	1,598	1,425	1,908
		Total	34,428	28,240	29,010
	Pole/Post	Rolled Over	5,038	9,353	6,079
		Total	129,699	140,256	117,962
	Culvert/Curb/Ditch	Rolled Over	27,810	17,869	20,788
		Total	135,820	118,639	119,031
	Embankment	Rolled Over	9,745	9,363	8,964
		Total	39,601	35,514	29,993
	Shrubbery/Tree	Rolled Over	6,065	6,036	5,687
		Total	89,311	87,350	87,060
Van	Rollover	Rolled Over	5,418	6,123	6,163
		Total	5,418	6,123	6,163
	Other Non-collision	Rolled Over	83	0	0
		Total	2,392	0	0
	Object Not Fixed	Rolled Over	142	578	206
		Total	58,596	75,595	71,001
	Bridge	Rolled Over	0	95	0
		Total	0	533	0
	Guard Rail/Barrier	Rolled Over	893	373	606
		Total	5,788	6,763	7,870
	Fence	Rolled Over	219	113	123
		Total	1,487	3,906	1,284

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Vehicle Type/First Harmful Event/Rollover Status (#)			1994	2003	2004
Van	Pole/Post	Rolled Over	229	755	685
		Total	10,198	12,224	8,883
	Culvert/Curb/Ditch	Rolled Over	1,663	2,311	1,783
		Total	6,286	8,485	6,451
	Embankment	Rolled Over	889	370	846
		Total	2,083	1,918	2,517
	Shrubbery/Tree	Rolled Over	81	475	514
		Total	3,386	7,120	6,472
Pickup	Rollover	Rolled Over	26,391	23,278	25,391
		Total	26,391	23,278	25,391
	Other Non-collision	Rolled Over	99	951	52
		Total	9,623	8,732	8,667
	Object Not Fixed	Rolled Over	224	765	427
		Total	94,415	113,372	111,193
	Bridge	Rolled Over	189	254	448
		Total	3,473	2,268	2,450
	Guard Rail/Barrier	Rolled Over	1,651	3,229	3,492
		Total	15,893	26,886	26,007
	Fence	Rolled Over	491	1,236	995
		Total	9,730	9,318	9,915
	Pole/Post	Rolled Over	1,963	2,868	2,305
		Total	27,945	31,672	32,822
	Culvert/Curb/Ditch	Rolled Over	9,894	8,786	6,858
		Total	29,351	28,056	27,614
	Embankment	Rolled Over	5,606	3,814	4,804
		Total	11,321	10,271	9,160
	Shrubbery/Tree	Rolled Over	2,302	2,258	2,942
		Total	23,631	24,584	24,992
Sport Utility Vehicle	Rollover	Rolled Over	9,549	29,310	31,830
		Total	9,549	29,310	31,830
	Other Non-collision	Rolled Over	236	87	95
		Total	1,042	2,811	4,028
	Object Not Fixed	Rolled Over	412	1,137	1,729
		Total	26,944	81,180	83,789
	Bridge	Rolled Over	73	803	142
		Total	1,245	3,471	2,593

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Vehicle Type/First Harmful Event/Rollover Status (#)			1994	2003	2004
Sport Utility Vehicle	Guard Rail/Barrier	Rolled Over	825	4,711	4,047
		Total	5,141	21,030	26,477
	Fence	Rolled Over	6	356	870
		Total	1,400	3,724	5,468
	Pole/Post	Rolled Over	720	2,573	2,840
		Total	8,916	24,034	25,131
	Culvert/Curb/Ditch	Rolled Over	3,603	10,847	7,105
		Total	7,193	25,873	23,085
	Embankment	Rolled Over	1,610	3,645	3,105
		Total	2,775	7,829	8,626
	Shrubbery/Tree	Rolled Over	192	2,213	2,844
		Total	3,982	17,297	22,012

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Vehicle Type/First Harmful Event/Rollover Status (%)			1994	2003	2004
Passenger car	Rollover	Rolled Over	100	100	100
	Other Non-collision	Rolled Over	2	0	2
	Object Not Fixed	Rolled Over	0	1	1
	Bridge	Rolled Over	6	5	3
	Guard Rail/Barrier	Rolled Over	6	7	5
	Fence	Rolled Over	5	5	7
	Pole/Post	Rolled Over	4	7	5
	Culvert/Curb/Ditch	Rolled Over	20	15	17
	Embankment	Rolled Over	25	26	30
	Shrubbery/Tree	Rolled Over	7	7	7
Van	Rollover	Rolled Over	100	100	100
	Other Non-collision	Rolled Over	3	-	-
	Object Not Fixed	Rolled Over	0	1	0
	Bridge	Rolled Over	-	18	-
	Guard Rail/Barrier	Rolled Over	15	6	8
	Fence	Rolled Over	15	3	10
	Pole/Post	Rolled Over	2	6	8
	Culvert/Curb/Ditch	Rolled Over	26	27	28
	Embankment	Rolled Over	43	19	34
	Shrubbery/Tree	Rolled Over	2	7	8

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Vehicle Type/First Harmful Event/Rollover Status (%)			1994	2003	2004
Pickup	Rollover	Rolled Over	100	100	100
	Other Non-collision	Rolled Over	1	11	1
	Object Not Fixed	Rolled Over	0	1	0
	Bridge	Rolled Over	5	11	18
	Guard Rail/Barrier	Rolled Over	10	12	13
	Fence	Rolled Over	5	13	10
	Pole/Post	Rolled Over	7	9	7
	Culvert/Curb/Ditch	Rolled Over	34	31	25
	Embankment	Rolled Over	50	37	52
	Shrubbery/Tree	Rolled Over	10	9	12
Sport Utility Vehicle	Rollover	Rolled Over	100	100	100
	Other Non-collision	Rolled Over	23	3	2
	Object Not Fixed	Rolled Over	2	1	2
	Bridge	Rolled Over	6	23	5
	Guard Rail/Barrier	Rolled Over	16	22	15
	Fence	Rolled Over	0	10	16
	Pole/Post	Rolled Over	8	11	11
	Culvert/Curb/Ditch	Rolled Over	50	42	31
	Embankment	Rolled Over	58	47	36
	Shrubbery/Tree	Rolled Over	5	13	13

Source: NHTSA, NCSA, GES, 1994, 2003, 2004.

Discussion. The rollover propensity tables show the probability that a vehicle rolled over given that it was involved in a single-vehicle crash. These tables generally show that, given involvement in a single-vehicle crash, sport utility vehicles were more likely to roll over than pickups, which in turn were more likely to roll over than either vans or passenger cars. Vehicles that were more likely to roll over were older, were driven by younger unbelted drivers, had more occupants, and were in speed-related crashes on divided highways with higher speed limits, in non-intersection areas. Alcohol involvement increased the probability of rollover. Vehicles that were more likely to roll over (a) were passing as opposed to turning prior to the single-vehicle crash; (b) had drivers who attempted to steer when they realized that the crash was imminent; and (c) had the first harmful event in the single-vehicle crash of either rollover or striking an embankment.

6. Injury Outcomes

This section considers injury severity and ejection status of occupants who were in vehicles that rolled over in single-vehicle crashes. The tables show annual data for 2004, the latest year for which data are available, 2003, the previous year, and 1994, which is 10 years prior to 2004, or the earliest year available if it is later than 1994. Since all the data in this section is occupant-level, it comes from a combination of the FARS and the GES databases. Specifically, the data on occupants who were fatally injured is from the FARS database, while the data on occupants who were not fatally injured is from the GES database.

Rather than considering occupants in single-vehicle rollovers, one logical possibility was to consider occupants in crashes in which rollover was classified as the most harmful event. The most harmful event is the most severe property-damaging or injury-producing event for each vehicle as judged by FARS analysts and GES coders based on police crash reports. However, Griffin et al. (2002), which studied vehicle fires, found that the most harmful event variable in FARS was coded very inconsistently across States. For example, the paper found that in some States, whenever a vehicle fire occurred, the most harmful event was classified as fire; whereas in other States, the most harmful event was never classified as fire, even though there were plenty of vehicles in the FARS database for that State in which fires have occurred. The paper concluded that such extreme variation across States was most probably due to variations in the reporting procedures related to the most harmful event variable. It is for this reason that we do not use the most harmful event variable.

In the FARS and GES databases, injury severity, as taken from Police Accident Reports (PARs), is given on the KABCO scale. In the tables and discussions below, fatality corresponds a K ("Fatal Injury") on the scale, incapacitating injury to an A ("Incapacitating Injury"), other injury to a B ("Non-incapacitating Evident Injury"), C ("Possible Injury"), or U ("Injured, Severity Unknown"), and no injury to an O ("No Injury").

Note that the percentage tables in this section show the proportion of people with each possible type of injury. Thus, the percentages in the tables do add up to 100%.

Injury Severity by Vehicle Type. As Table 22 shows, in 2004, for the vehicle types considered, passenger cars had the highest number of occupants killed in single-vehicle rollovers, at 3,640 occupants. The next highest fatality count was for sport utility vehicles, at 2,331. The fatality rate given involvement in a single-vehicle rollover was similar for all four vehicle groups, between 2% and 3%. However, the rate of no injuries was higher in pickups and sport utility vehicles than it was in passenger cars and vans. For example, the "no injury" rate given involvement in a single-vehicle rollover in sport utility vehicles was an estimated 43%, compared to an estimated 39% for passenger cars.

Table 22
Occupants of vehicles in single-vehicle rollovers by vehicle type and injury severity, 1994, 2003, 2004

Vehicles Type/Injury Severity (#)		1994	2003	2004
Passenger car	Fatal	4,072	3,752	3,640
	Incapacitating Injury	27,644	15,731	16,374
	Other Injury	79,692	74,940	66,079
	No Injury	76,349	47,560	54,460
	Total	187,756	141,983	140,553
Van	Fatal	434	521	487
	Incapacitating Injury	1,555	2,722	1,985
	Other Injury	6,033	9,819	10,957
	No Injury	11,266	7,922	8,238
	Total	19,288	20,984	21,667
Pickup	Fatal	1,969	2,130	2,100
	Incapacitating Injury	9,616	7,556	7,817
	Other Injury	30,927	29,874	30,074
	No Injury	37,738	28,257	29,268
	Total	80,250	67,817	69,259
Sport Utility Vehicle	Fatal	841	2,120	2,331
	Incapacitating Injury	4,486	11,653	11,381
	Other Injury	11,244	39,208	38,324
	No Injury	13,409	39,222	39,284
	Total	29,980	92,203	91,320

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.

Vehicles Type/Injury Severity (%)		1994	2003	2004
Passenger car	Fatal	2	3	3
	Incapacitating Injury	15	11	12
	Other Injury	42	53	47
	No Injury	41	33	39
Van	Fatal	2	2	2
	Incapacitating Injury	8	13	9
	Other Injury	31	47	51
	No Injury	58	38	38
Pickup	Fatal	2	3	3
	Incapacitating Injury	12	11	11
	Other Injury	39	44	43
	No Injury	47	42	42

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Vehicles Type/Injury Severity (%)		1994	2003	2004
Sport Utility Vehicle	Fatal	3	2	3
	Incapacitating Injury	15	13	12
	Other Injury	38	43	42
	No Injury	45	43	43
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.				

Injury Severity in Fatal Single-Vehicle Rollovers by Vehicle Type. In Table 23, we consider the same information as above, but restrict it only to fatal crashes. A fatal crash is defined as a crash that involves at least one fatality, whether occupant or nonoccupant. It may be of interest to consider fatal crashes as opposed to all crashes since fatal crashes are more severe. One should be cautious when considering probabilities of injury in fatal crashes, since, by definition, the probability of death in a fatal single-vehicle crash with a single occupant and no nonoccupant fatalities is 100%. As vans might have generally had more occupants than other vehicle types, it is not surprising that the probability of death in a fatal crash was lower for vans than it was for other vehicle types.

In 2004, 4,777 occupants were in passenger cars that were involved in fatal single-vehicle rollovers. Of these, 3,640, or 76%, were fatally injured. By contrast, the fatality rate given involvement in a fatal single-vehicle rollover in vans was 43%. Since this table only uses the FARS database, it contains actual counts, not estimates. Note that a few of the counts of non-fatally injured occupants were zero. This is simply because the table is restricted to fatal rollovers. As we see from the percentages, the overwhelming majority (in the case of passenger cars and pickups) or at least a very sizable minority (for vans and sport utility vehicles) of occupants died in such rollovers.

Table 23 Occupants of vehicles in fatal single-vehicle rollovers by vehicle type and injury severity, 1994, 2003, 2004

Vehicles Type/Injury Severity (#)		1994	2003	2004
Passenger car	Fatal	4,072	3,752	3,640
	Incapacitating Injury	1,826	406	626
	Other Injury	415	574	471
	No Injury	71	10	40
	Total	6,384	4,742	4,777
Van	Fatal	434	521	487
	Incapacitating Injury	0	629	280
	Other Injury	321	75	271
	No Injury	321	3	86
	Total	1,076	1,229	1,124
Pickup	Fatal	1,969	2,130	2,100
	Incapacitating Injury	578	446	335
	Other Injury	131	306	191
	No Injury	0	5	64
	Total	2,678	2,887	2,689
Sport Utility Vehicle	Fatal	841	2,120	2,331
	Incapacitating Injury	568	670	1,109
	Other Injury	386	1,312	927
	No Injury	0	27	151
	Total	1,796	4,129	4,518
Source: NHTSA, NCSA, FARS, 1994, 2003, 2004.				

Vehicles Type/Injury Severity (%)		1994	2003	2004
Passenger car	**Fatal**	64	79	76
	Incapacitating Injury	29	9	13
	Other Injury	6	12	10
	No Injury	1	0	1
Van	**Fatal**	40	42	43
	Incapacitating Injury	0	51	25
	Other Injury	30	6	24
	No Injury	30	0	8
Pickup	**Fatal**	74	74	78
	Incapacitating Injury	22	15	12
	Other Injury	5	11	7
	No Injury	0	0	2
Sport Utility Vehicle	**Fatal**	47	51	52
	Incapacitating Injury	32	16	25
	Other Injury	22	32	21
	No Injury	0	1	3
Source: NHTSA, NCSA, FARS, 1994, 2003, 2004.				

Ejection Status by Vehicle Type. Ejection status considers whether an occupant was totally ejected from the vehicle. For years 1990 – 1994, GES does not code total ejections. Therefore, all tables involving ejection status begin in 1995 rather than 1994.

As seen in Table 24, in 2004, an estimated 91,320 occupants were in sport utility vehicles that were in single-vehicle rollovers. Of these, an estimated 5,050 occupants were totally ejected from their vehicles, making the total ejection rate given involvement in single-vehicle rollover for sport utility vehicle occupants 6%.

Table 24
Occupants of vehicles in single-vehicle rollovers
by vehicle type and ejection status, 1995, 2003, 2004

Vehicles Type/Ejection Status (#)		1995	2003	2004
Passenger car	**Total Ejection**	5,075	5,775	5,280
	Total	178,075	141,983	140,553
Van	**Total Ejection**	833	806	680
	Total	20,187	20,984	21,667
Pickup	**Total Ejection**	3,156	3,710	2,855
	Total	78,112	67,817	69,259
Sport Utility Vehicle	**Total Ejection**	1,627	4,206	5,050
	Total	33,823	92,203	91,320

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Vehicles Type/Ejection Status (%)		1995	2003	2004
Passenger car	**Total Ejection**	3	4	4
Van	**Total Ejection**	4	4	3
Pickup	**Total Ejection**	4	5	4
Sport Utility Vehicle	**Total Ejection**	5	5	6

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Restraint Use by Vehicle Type. Restraint use is as reported by the police. It may reflect self-reporting by occupants of vehicles that crashed, and might thus be a biased estimate of actual restraint use.

According to Table 25, the rate of restraint use has gone up over the years in all four vehicle types under consideration. For example, in 1994, an estimated 64% of occupants of passenger cars in single-vehicle crashes used restraints. This rate was an estimated 77% in 2004. It is interesting to compare these restraint use rates for occupants of vehicles involved in single-vehicle rollovers to restraint use rates for occupants of all vehicles. According to Glassbrenner and Ye (2006), which uses the National Occupant Protection Use Survey (NOPUS) database, in 1994, an estimated 58% of vehicle occupants across the United States used vehicle restraints. In 2003, the use rate was an estimated 79%; in 2004, it was an estimated 80%.

Table 25
Occupants of vehicles in single-vehicle rollovers by vehicle type and restraint use, 1994, 2003, 2004

Vehicles Type/Restraint Use (#)		1994	2003	2004
Passenger car	**Restrained**	119,299	102,463	108,748
	Total	187,756	141,983	140,553
Van	**Restrained**	12,404	17,370	17,435
	Total	19,288	20,984	21,667
Pickup	**Restrained**	41,951	48,181	51,134
	Total	80,250	67,817	69,259
Sport Utility Vehicle	**Restrained**	18,186	72,586	71,943
	Total	29,980	92,203	91,320
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.				

Vehicles Type/Restraint Use (%)		1994	2003	2004
Passenger car	**Restrained**	64	72	77
Van	**Restrained**	64	83	80
Pickup	**Restrained**	52	71	74
Sport Utility Vehicle	**Restrained**	61	79	79
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.				

Injury Severity by Occupant Restraint. As Table 26 shows, in single-vehicle rollovers in 2004, 949 passenger car occupants who used restraints were killed. As there were an estimated 108,748 restrained passenger car occupants in single-vehicle rollovers, the fatality rate for restrained occupants was 1%. By contrast, 2,487 unrestrained passenger car occupants were fatally injured in single-vehicle rollovers; the fatality rate for unrestrained passenger car occupants was thus an estimated 13%.

Table 26
Occupants of vehicles in single-vehicle rollovers by vehicle type, restraint use, and injury severity, 1994, 2003, 2004

Vehicle Type/Restraint Use/Injury Severity (#)			1994	2003	2004
Passenger car	Restrained	Fatal	852	1,037	949
		Incapacitating Injury	12,373	9,458	10,593
		Other Injury	52,136	52,122	49,113
		No Injury	53,938	39,847	48,093
		Total	119,299	102,463	108,748
	Unrestrained	Fatal	2,972	2,499	2,487
		Incapacitating Injury	13,758	5,244	4,888
		Other Injury	18,635	12,004	9,349
		No Injury	8,186	4,136	2,974
		Total	43,552	23,883	19,698
Van	Restrained	Fatal	63	116	105
		Incapacitating Injury	966	1,881	1,201
		Other Injury	3,553	8,487	8,552
		No Injury	7,823	6,886	7,577
		Total	12,404	17,370	17,435
	Unrestrained	Fatal	346	372	360
		Incapacitating Injury	589	774	508
		Other Injury	2,209	773	1,574
		No Injury	1,867	738	405
		Total	5,011	2,657	2,847
Pickup	Restrained	Fatal	209	357	440
		Incapacitating Injury	2,752	3,765	4,970
		Other Injury	16,484	19,824	21,846
		No Injury	22,506	24,235	23,879
		Total	41,951	48,181	51,134
	Unrestrained	Fatal	1,665	1,684	1,586
		Incapacitating Injury	6,045	3,604	2,424
		Other Injury	10,124	5,327	5,340
		No Injury	7,873	2,946	2,171
		Total	25,707	13,561	11,522

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Vehicle Type/Restraint Use/Injury Severity (#)			1994	2003	2004
Sport Utility Vehicle	Restrained	Fatal	159	520	605
		Incapacitating Injury	2,116	7,562	7,197
		Other Injury	7,067	29,558	29,671
		No Injury	8,844	34,946	34,470
		Total	18,186	72,586	71,943
	Unrestrained	Fatal	646	1,499	1,634
		Incapacitating Injury	1,985	3,661	3,697
		Other Injury	3,601	6,194	5,884
		No Injury	2,049	2,257	3,035
		Total	8,280	13,611	14,250

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.

Vehicle Type/Restraint Use/Injury Severity (%)			1994	2003	2004
Passenger car	Restrained	Fatal	1	1	1
		Incapacitating Injury	10	9	10
		Other Injury	44	51	45
		No Injury	45	39	44
	Unrestrained	Fatal	7	10	13
		Incapacitating Injury	32	22	25
		Other Injury	43	50	47
		No Injury	19	17	15
Van	Restrained	Fatal	1	1	1
		Incapacitating Injury	8	11	7
		Other Injury	29	49	49
		No Injury	63	40	43
	Unrestrained	Fatal	7	14	13
		Incapacitating Injury	12	29	18
		Other Injury	44	29	55
		No Injury	37	28	14

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Vehicle Type/Restraint Use/Injury Severity (%)			1994	2003	2004
Pickup	Restrained	Fatal	0	1	1
		Incapacitating Injury	7	8	10
		Other Injury	39	41	43
		No Injury	54	50	47
	Unrestrained	Fatal	6	12	14
		Incapacitating Injury	24	27	21
		Other Injury	39	39	46
		No Injury	31	22	19
Sport Utility Vehicle	Restrained	Fatal	1	1	1
		Incapacitating Injury	12	10	10
		Other Injury	39	41	41
		No Injury	49	48	48
	Unrestrained	Fatal	8	11	11
		Incapacitating Injury	24	27	26
		Other Injury	43	46	41
		No Injury	25	17	21
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.					

Ejection Status by Occupant Restraint. The contrast between restrained and unrestrained occupants was even greater when considered by ejection status rather than fatality outcome. As seen in Table 27, in 2004 single-vehicle rollovers, an estimated 1% of the restrained passenger car occupants were totally ejected, as compared to an estimated 22% of the unrestrained occupants. In sport utility vehicles, a very small percentage of the restrained occupants were totally ejected; the rate for unrestrained sport utility vehicle occupants was 33%. Note also that the total ejection rate for unrestrained occupants has increased dramatically for all vehicle types from 1995 to 2003. For example, in 1995, the rate for van occupants was an estimated 10%, while in 2003, it was an estimated 24%.

Table 27
Occupants of vehicles in single-vehicle rollovers by vehicle type, restraint use, and ejection status, 1995, 2003, 2004

Vehicle Type/Restraint Use/Ejection Status (#)			1995	2003	2004
Passenger car	Restrained	Total Ejection	648	679	660
		Total	117,418	102,463	108,748
	Unrestrained	Total Ejection	4,058	4,706	4,327
		Total	42,732	23,883	19,698
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Vehicle Type/Restraint Use/Ejection Status (#)			1995	2003	2004
Van	Restrained	Total Ejection	227	164	12
		Total	12,297	17,370	17,435
	Unrestrained	Total Ejection	592	625	655
		Total	6,223	2,657	2,847
Pickup	Restrained	Total Ejection	224	154	99
		Total	42,568	48,181	51,134
	Unrestrained	Total Ejection	2,784	3,457	2,677
		Total	21,574	13,561	11,522
Sport Utility Vehicle	Restrained	Total Ejection	19	328	239
		Total	21,143	72,586	71,943
	Unrestrained	Total Ejection	1,432	3,649	4,662
		Total	9,992	13,611	14,250

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Vehicle Type/Restraint Use/Ejection Status (%)			1995	2003	2004
Passenger car	Restrained	Total Ejection	1	1	1
	Unrestrained	Total Ejection	9	20	22
Van	Restrained	Total Ejection	2	1	0
	Unrestrained	Total Ejection	10	24	23
Pickup	Restrained	Total Ejection	1	0	0
	Unrestrained	Total Ejection	13	25	23
Sport Utility Vehicle	Restrained	Total Ejection	0	0	0
	Unrestrained	Total Ejection	14	27	33

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Ejection Status in Fatal Crashes by Occupant Restraint. According to Table 28, even in fatal crashes, ejection status was strongly associated with restraint use. In fatal single-vehicle rollovers that occurred in 2004, 5% of the restrained passenger car occupants were totally ejected, as compared to 55% of the unrestrained passenger car occupants. Likewise, the total ejection rate for restrained sport utility vehicle occupants was 9%, compared to 65% for unrestrained sport utility vehicle occupants.

Table 28
Occupant of vehicles in fatal single-vehicle rollovers by vehicle type, restraint use, and ejection status 1995, 2003, 2004

Vehicle Type/Restraint Use/Ejection Status (#)			1995	2003	2004
Passenger car	Restrained	Total Ejection	121	140	74
		Total	1,891	1,779	1,560
	Unrestrained	Total Ejection	1,972	1,593	1,642
		Total	3,518	2,649	2,976
Van	Restrained	Total Ejection	8	69	12
		Total	942	578	573
	Unrestrained	Total Ejection	260	443	249
		Total	1,081	611	519
Pickup	Restrained	Total Ejection	12	17	24
		Total	424	565	659
	Unrestrained	Total Ejection	1,299	1,377	1,049
		Total	2,053	2,234	1,887
Sport Utility Vehicle	Restrained	Total Ejection	19	52	162
		Total	391	1,197	1,848
	Unrestrained	Total Ejection	785	1,587	1,503
		Total	960	2,771	2,313

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Vehicle Type/Restraint Use/Ejection Status (%)			1995	2003	2004
Passenger car	Restrained	Total Ejection	6	8	5
	Unrestrained	Total Ejection	56	60	55
Van	Restrained	Total Ejection	1	12	2
	Unrestrained	Total Ejection	24	73	48
Pickup	Restrained	Total Ejection	3	3	4
	Unrestrained	Total Ejection	63	62	56
Sport Utility Vehicle	Restrained	Total Ejection	5	4	9
	Unrestrained	Total Ejection	82	57	65

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Injury Severity by Ejection Status and Occupant Restraint. Following Digges and Eigen (2003) and Eigen (2005), we consider injury severity by both ejection status and occupant restraint. This allows us to consider the effects of restraint use on injury outcome controlling for ejection status. Alternatively, it allows us to consider the effects of total ejection on injury outcome controlling for restraint use.

As Table 29 shows, in 2004, among occupants of passenger cars that rolled over in single-vehicle crashes, of those who used restraints and were not totally ejected, one percent were fatally injured. Of the occupants who did use restraints but who were nevertheless totally ejected, the fatality rate was 11%. Of the occupants who were not totally ejected even though they did not use restraints, 7% were fatally injured. Finally, of the passenger car occupants who did not use restraints and were totally ejected, the fatality rate was 35%. These results illustrate that there was an interaction effect between restraint use and ejection status in determining injury outcomes. In particular, even if an occupant was totally ejected, being restrained decreased the probability of fatality.

Table 29
Occupants of vehicles in single-vehicle rollovers
by vehicle type, restraint and ejection status, and injury severity, 1995, 2003, 2004

Vehicle Type/Restraint and Total Ejection Status/Injury Severity (#)			1995	2003	2004
Passenger car	Total Ejection/Unrestrained	Fatal	1,877	1,519	1,512
		Incapacitating Injury	2,001	1,895	1,548
		Other Injury	180	1,292	1,267
		Total	4,058	4,706	4,327
	No or Partial Ejection/Unrestrained	Fatal	1,183	974	962
		Incapacitating Injury	7,790	3,218	2,980
		Other Injury	19,521	9,289	7,204
		No Injury	10,047	4,136	2,974
		Total	38,541	17,616	14,119
	Total Ejection/Restrained	Fatal	121	88	74
		Incapacitating Injury	237	236	379
		Other Injury	290	355	207
		Total	648	679	660
	No or Partial Ejection/Restrained	Fatal	785	949	873
		Incapacitating Injury	12,132	8,402	9,298
		Other Injury	53,726	46,212	43,433
		No Injury	50,123	39,847	48,093
		Total	116,766	95,410	101,697

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Vehicle Type/Restraint and Total Ejection Status/Injury Severity (#)			1995	2003	2004
Van	Total Ejection/Unrestrained	Fatal	260	267	238
		Incapacitating Injury	242	340	180
		Other Injury	89	17	237
		Total	592	625	655
	No or Partial Ejection/Unrestrained	Fatal	90	101	122
		Incapacitating Injury	1,198	353	322
		Other Injury	2,617	621	1,047
		No Injury	1,724	738	343
		Total	5,629	1,813	1,835
	Total Ejection/Restrained	Fatal	8	14	12
		Incapacitating Injury	219	55	0
		Other Injury	0	95	0
		Total	227	164	12
	No or Partial Ejection/Restrained	Fatal	55	102	92
		Incapacitating Injury	1,130	1,314	1,035
		Other Injury	4,971	6,860	6,114
		No Injury	5,914	6,443	7,577
		Total	12,070	14,718	14,819
Pickup	Total Ejection / Unrestrained	Fatal	1,169	1,097	1,028
		Incapacitating Injury	927	1,544	845
		Other Injury	688	816	803
		No Injury	0	0	4
		Total	2,784	3,457	2,680
	No or Partial Ejection / Unrestrained	Fatal	658	582	555
		Incapacitating Injury	2,837	1,573	1,207
		Other Injury	10,053	3,716	3,415
		No Injury	5,235	2,946	2,167
		Total	18,782	8,817	7,344
	Total Ejection / Restrained	Fatal	12	17	24
		Incapacitating Injury	212	43	75
		Other Injury	0	95	0
		Total	224	154	99
	No or Partial Ejection / Restrained	Fatal	176	340	418
		Incapacitating Injury	3,408	3,252	4,077
		Other Injury	18,619	14,558	16,722
		No Injury	20,141	24,235	23,879
		Total	42,343	42,385	45,096

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Sport Utility Vehicle	**Total Ejection/Unrestrained**	**Fatal**	590	1,132	1,223
		Incapacitating Injury	559	1,595	2,021
		Other Injury	154	922	1,418
		No Injury	130	0	0
		Total	1,432	3,649	4,662
	No or Partial Ejection/Unrestrained	**Fatal**	172	359	405
		Incapacitating Injury	1,230	1,568	1,669
		Other Injury	5,135	3,796	3,191
		No Injury	2,021	2,257	3,035
		Total	8,557	7,980	8,301
	Total Ejection/Restrained	**Fatal**	19	48	39
		Incapacitating Injury	0	119	165
		Other Injury	0	161	35
		Total	19	328	239
	No or Partial Ejection/Restrained	**Fatal**	160	471	565
		Incapacitating Injury	776	6,775	5,859
		Other Injury	9,348	25,488	24,925
		No Injury	10,840	34,946	34,470
		Total	21,124	67,679	65,818

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.
Note: Ejection Status data available starting in 1995

Vehicle Type/Restraint and Total Ejection Status/Injury Severity (%)			1995	2003	2004
Passenger car	Total Ejection/Unrestrained	Fatal	46	32	35
		Incapacitating Injury	49	40	36
		Other Injury	4	27	29
		No Injury	0	0	0
	No or Partial Ejection/Unrestrained	Fatal	3	6	7
		Incapacitating Injury	20	18	21
		Other Injury	51	53	51
		No Injury	26	23	21
	Total Ejection/Restrained	Fatal	19	13	11
		Incapacitating Injury	37	35	57
		Other Injury	45	52	31
		No Injury	0	0	0
	No or Partial Ejection/Restrained	Fatal	1	1	1
		Incapacitating Injury	10	9	9
		Other Injury	46	48	43
		No Injury	43	42	47
Van	Total Ejection/Unrestrained	Fatal	44	43	36
		Incapacitating Injury	41	55	27
		Other Injury	15	3	36
		No Injury	0	0	0
	No or Partial Ejection/Unrestrained	Fatal	2	6	7
		Incapacitating Injury	21	19	18
		Other Injury	46	34	57
		No Injury	31	41	19
	Total Ejection/Restrained	Fatal	4	9	100
		Incapacitating Injury	96	34	0
		Other Injury	0	58	0
		No Injury	0	0	0
	No or Partial Ejection/Restrained	Fatal	0	1	1
		Incapacitating Injury	9	9	7
		Other Injury	41	47	41
		No Injury	49	44	51

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Vehicle Type/Restraint and Total Ejection Status/Injury Severity (%)			1995	2003	2004
Pickup	Total Ejection/Unrestrained	Fatal	42	32	38
		Incapacitating Injury	33	45	32
		Other Injury	25	24	30
		No Injury	0	0	0
	No or Partial Ejection/Unrestrained	Fatal	4	7	8
		Incapacitating Injury	15	18	16
		Other Injury	54	42	46
		No Injury	28	33	30
	Total Ejection/Restrained	Fatal	5	11	24
		Incapacitating Injury	95	28	76
		Other Injury	0	61	0
		No Injury	0	0	0
	No or Partial Ejection/Restrained	Fatal	0	1	1
		Incapacitating Injury	8	8	9
		Other Injury	44	34	37
		No Injury	48	57	53
Sport Utility Vehicle	Total Ejection/Unrestrained	Fatal	41	31	26
		Incapacitating Injury	39	44	43
		Other Injury	11	25	30
		No Injury	9	0	0
	No or Partial Ejection/Unrestrained	Fatal	2	4	5
		Incapacitating Injury	14	20	20
		Other Injury	60	48	38
		No Injury	24	28	37
	Total Ejection/Restrained	Fatal	100	15	16
		Incapacitating Injury	0	36	69
		Other Injury	0	49	15
		No Injury	0	0	0
	No or Partial Ejection/Restrained	Fatal	1	1	1
		Incapacitating Injury	4	10	9
		Other Injury	44	38	38
		No Injury	51	52	52

Source: NHTSA, NCSA, FARS, GES, 1995, 2003, 2004.

Note: Ejection Status data available starting in 1995

Injury Severity by Occupant Age. According to Table 30, in 2004, the fatality rate of single-vehicle rollover occupants 4 years old and younger was an estimated 1%. The rate increased with age. For example, for occupants 35 to 44 years old, the fatality rate was an estimated 3%; for occupants 75 and older, the fatality rate was 10%.

Table 30
Occupants of vehicles in single-vehicle rollovers
by occupant age and injury severity, 1994, 2003, 2004

Age/Injury Severity (#)		1994	2003	2004
4 and Younger	Fatal	119	113	111
	Incapacitating Injury	855	317	603
	Other Injury	2,333	3,237	3,672
	No Injury	4,246	3,412	3,461
	Total	7,553	7,079	7,848
5 to 9	Fatal	55	91	114
	Incapacitating Injury	431	732	625
	Other Injury	1,715	3,044	3,247
	No Injury	2,820	2,150	2,677
	Total	5,021	6,017	6,663
10 to 15	Fatal	314	324	276
	Incapacitating Injury	3,286	1,632	1,880
	Other Injury	8,516	8,409	9,741
	No Injury	7,264	5,551	6,797
	Total	19,379	15,915	18,693
16 to 20	Fatal	1,545	1,710	1,746
	Incapacitating Injury	12,257	10,841	9,845
	Other Injury	41,489	43,932	40,545
	No Injury	42,157	36,361	37,182
	Total	97,448	92,844	89,317
21 to 24	Fatal	1,060	1,184	1,209
	Incapacitating Injury	5,934	4,349	5,233
	Other Injury	14,077	20,739	18,864
	No Injury	15,790	17,126	19,158
	Total	36,862	43,398	44,464

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Age/Injury Severity (#)		1994	2003	2004
25 to 34	Fatal	1,691	1,617	1,647
	Incapacitating Injury	9,509	6,905	7,061
	Other Injury	25,008	24,530	24,869
	No Injury	24,739	21,229	23,877
	Total	60,947	54,281	57,454
35 to 44	Fatal	1,095	1,355	1,287
	Incapacitating Injury	5,229	5,513	5,385
	Other Injury	14,632	19,818	18,426
	No Injury	13,415	15,697	14,412
	Total	34,370	42,382	39,510
45 to 54	Fatal	648	984	1,015
	Incapacitating Injury	2,915	4,221	3,531
	Other Injury	6,572	9,739	11,020
	No Injury	8,196	10,660	8,826
	Total	18,330	25,603	24,391
55 to 64	Fatal	344	554	575
	Incapacitating Injury	1,040	1,895	1,648
	Other Injury	3,088	5,488	6,525
	No Injury	3,267	4,787	4,290
	Total	7,739	12,724	13,038
65 to 74	Fatal	287	324	312
	Incapacitating Injury	740	818	1,102
	Other Injury	2,159	2,599	2,391
	No Injury	2,354	1,491	2,235
	Total	5,540	5,232	6,040
75 and older	Fatal	178	259	247
	Incapacitating Injury	670	434	478
	Other Injury	1,055	2,073	1,330
	No Injury	93	963	412
	Total	1,996	3,729	2,467

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.

Age/Injury Severity (%)		1994	2003	2004
4 and younger	Fatal	2	2	1
	Incapacitating Injury	11	4	8
	Other Injury	31	46	47
	No Injury	56	48	44
5 to 9	Fatal	1	2	2
	Incapacitating Injury	9	12	9
	Other Injury	34	51	49
	No Injury	56	36	40
10 to 15	Fatal	2	2	1
	Incapacitating Injury	17	10	10
	Other Injury	44	53	52
	No Injury	37	35	36
16 to 20	Fatal	2	2	2
	Incapacitating Injury	13	12	11
	Other Injury	43	47	45
	No Injury	43	39	42
21 to 24	Fatal	3	3	3
	Incapacitating Injury	16	10	12
	Other Injury	38	48	42
	No Injury	43	39	43
25 to 34	Fatal	3	3	3
	Incapacitating Injury	16	13	12
	Other Injury	41	45	43
	No Injury	41	39	42
35 to 44	Fatal	3	3	3
	Incapacitating Injury	15	13	14
	Other Injury	43	47	47
	No Injury	39	37	36
45 to 54	Fatal	4	4	4
	Incapacitating Injury	16	16	14
	Other Injury	36	38	45
	No Injury	45	42	36
55 to 64	Fatal	4	4	4
	Incapacitating Injury	13	15	13
	Other Injury	40	43	50
	No Injury	42	38	33

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Age/Injury Severity (%)		1994	2003	2004
65 to 74	Fatal	5	6	5
	Incapacitating Injury	13	16	18
	Other Injury	39	50	40
	No Injury	42	28	37
75 and older	Fatal	9	7	10
	Incapacitating Injury	34	12	19
	Other Injury	53	56	54
	No Injury	5	26	17
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.				

Use of Child Safety Seats. In looking at child safety seats, we follow NHTSA b (2004) and only consider occupants who were 4 years old or younger. According to Lindsey (2006), historically, NCSA typically classified a child safety seat used improperly as a child safety seat not used; however, starting in mid 2003, NCSA typically classifies a child safety seat used improperly as a child safety seat used. We follow the more recent practice and classify "child safety seat used improperly" as a child safety seat used for all the years under consideration.

As with general restraint use, child safety seat use has gone up since 1994. For example, as Table 31 shows, in 1994 single-vehicle rollovers, an estimated 56% of the children 4 years old or younger who were occupants in passenger cars used child safety seat. This rate has increased to an estimated 78% in 2004.

Table 31
Occupants 4 years old or younger of vehicles in single-vehicle rollovers by vehicle type and use of child safety seat, 1994, 2003, 2004

Vehicles Type/Use of Child Safety Seat (#)		1994	2003	2004
Passenger car	Used	2,689	1,937	2,784
	Total	4,836	2,333	3,551
Van	Used	280	770	716
	Total	922	1,268	952
Pickup	Used	332	92	478
	Total	1,134	218	695
Sport Utility Vehicle	Used	322	2,840	1,669
	Total	659	3,260	2,546
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.				

Vehicles Type/Use of Child Safety Seat (%)		1994	2003	2004
Passenger car	**Used**	56	83	78
Van	**Used**	30	61	75
Pickup	**Used**	29	42	69
Sport Utility Vehicle	**Used**	49	87	66
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.				

Injury Severity by Use of Child Safety Seats. As seen in Table 32, in 2004, of the children 4 years old or younger who were occupants in passenger cars that rolled over in a single-vehicle crash, an estimated 2,784 were using a child safety seat while an estimated 652 were not using such a seat. Of those children who were using a child safety seat, 1% was fatally injured, while of those who were not using such a seat, 3% were fatally injured.

Table 32
Occupants 4 years old and younger of vehicles in single-vehicle rollovers by vehicle type, use of child safety seats, and injury severity, 1994, 2003, 2004

Vehicle Type/Use of Child Safety Seat/Injury Severity (#)			1994	2003	2004
Passenger car	**Used**	**Fatal**	15	35	22
		Incapacitating Injury	212	17	168
		Other Injury	706	1,084	1,354
		No Injury	1,756	800	1,240
		Total	2,689	1,937	2,784
	Not used	**Fatal**	53	18	20
		Incapacitating Injury	195	11	86
		Other Injury	997	106	300
		No Injury	848	143	246
		Total	2,093	279	652
Van	**Used**	**Fatal**	4	3	6
		Incapacitating Injury	151	143	0
		Other Injury	0	78	229
		No Injury	125	546	481
		Total	280	770	716
	Not used	**Fatal**	9	11	8
		Incapacitating Injury	94	20	0
		Other Injury	0	378	213
		No Injury	377	89	14
		Total	481	497	235
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Vehicle Type/Use of Child Safety Seat/Injury Severity (#)			1994	2003	2004
Pickup	Used	Fatal	4	2	2
		Incapacitating Injury	0	0	0
		Other Injury	73	0	0
		No Injury	255	90	476
		Total	332	92	478
	Not used	Fatal	15	3	13
		Incapacitating Injury	203	0	4
		Other Injury	114	123	133
		No Injury	470	0	67
		Total	802	126	216
Sport Utility Vehicle	Used	Fatal	5	13	13
		Incapacitating Injury	0	39	112
		Other Injury	201	1,181	887
		No Injury	116	1,607	657
		Total	322	2,840	1,669
	Not used	Fatal	11	24	21
		Incapacitating Injury	0	87	195
		Other Injury	190	210	408
		No Injury	137	98	154
		Total	337	419	778

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.

Vehicle Type/Use of Child Safety Seat/Injury Severity (%)			1994	2003	2004
Passenger car	Used	Fatal	1	2	1
		Incapacitating Injury	8	1	6
		Other Injury	26	56	49
		No Injury	65	41	45
	Not used	Fatal	3	6	3
		Incapacitating Injury	9	4	13
		Other Injury	48	38	46
		No Injury	41	51	38

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Vehicle Type/Use of Child Safety Seat/Injury Severity (%)			1994	2003	2004
Van	Used	Fatal	1	0	1
		Incapacitating Injury	54	19	0
		Other Injury	0	10	32
		No Injury	45	71	67
	Not used	Fatal	2	2	3
		Incapacitating Injury	20	4	0
		Other Injury	0	76	91
		No Injury	79	18	6
Pickup	Used	Fatal	1	2	0
		Incapacitating Injury	0	0	0
		Other Injury	22	0	0
		No Injury	77	98	100
	Not used	Fatal	2	2	6
		Incapacitating Injury	25	0	2
		Other Injury	14	98	61
		No Injury	59	0	31
Sport Utility Vehicle	Used	Fatal	2	0	1
		Incapacitating Injury	0	1	7
		Other Injury	62	42	53
		No Injury	36	57	39
	Not used	Fatal	3	6	3
		Incapacitating Injury	0	21	25
		Other Injury	56	50	52
		No Injury	41	23	20

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.

Injury Severity by Sex. According to Table 33, in 2004 there were an estimated 76,517 male occupants of passenger cars and an estimated 59,111 female occupants of passenger cars who were in single-vehicle rollovers. The fatality rate for males was 3% whereas for females it was 2%. On the other hand, 42% of all males suffered no injury, while only 33% of all females did not have any injuries.

Table 33
Occupants of vehicles in single-vehicle rollovers by vehicle type, sex, and injury severity, 1994, 2003, 2004

Vehicle Type/Sex/Injury Severity (#)			1994	2003	2004
Passenger car	Male	Fatal	2,706	2,527	2,437
		Incapacitating Injury	16,113	8,767	7,895
		Other Injury	41,505	37,066	34,054
		No Injury	40,705	29,979	32,130
		Total	101,029	78,338	76,517
	Female	Fatal	1,362	1,225	1,203
		Incapacitating Injury	11,530	6,964	8,427
		Other Injury	33,804	34,543	30,169
		No Injury	26,322	15,855	19,313
		Total	73,018	58,587	59,111
Van	Male	Fatal	277	320	321
		Incapacitating Injury	660	1,459	1,308
		Other Injury	3,068	4,968	6,196
		No Injury	5,919	5,582	5,558
		Total	9,923	12,330	13,383
	Female	Fatal	157	201	166
		Incapacitating Injury	895	1,254	676
		Other Injury	2,871	4,747	4,152
		No Injury	4,788	2,008	2,628
		Total	8,711	8,210	7,623
Pickup	Male	Fatal	1,637	1,779	1,740
		Incapacitating Injury	7,157	5,954	6,118
		Other Injury	23,712	21,403	21,823
		No Injury	25,649	23,309	23,309
		Total	58,155	52,445	52,990
	Female	Fatal	332	351	360
		Incapacitating Injury	2,459	1,597	1,698
		Other Injury	5,719	6,944	7,211
		No Injury	7,998	3,900	4,350
		Total	16,507	12,793	13,620

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Vehicle Type/Sex/Injury Severity (#)			1994	2003	2004
Sport Utility Vehicle	Male	Fatal	587	1,314	1,439
		Incapacitating Injury	2,734	5,481	5,526
		Other Injury	6,411	20,441	21,485
		No Injury	9,113	22,327	22,058
		Total	18,845	49,562	50,508
	Female	Fatal	254	806	892
		Incapacitating Injury	1,752	6,172	5,851
		Other Injury	4,833	17,990	15,982
		No Injury	3,599	15,391	14,452
		Total	10,438	40,359	37,177

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004.

Vehicle Type/Sex/Injury Severity (%)			1994	2003	2004
Passenger car	Male	Fatal	3	3	3
		Incapacitating Injury	16	11	10
		Other Injury	41	47	45
		No Injury	40	38	42
	Female	Fatal	2	2	2
		Incapacitating Injury	16	12	14
		Other Injury	46	59	51
		No Injury	36	27	33
Van	Male	Fatal	3	3	2
		Incapacitating Injury	7	12	10
		Other Injury	31	40	46
		No Injury	60	45	42
	Female	Fatal	2	2	2
		Incapacitating Injury	10	15	9
		Other Injury	33	58	54
		No Injury	55	24	34
Pickup	Male	Fatal	3	3	3
		Incapacitating Injury	12	11	12
		Other Injury	41	41	41
		No Injury	44	44	44
	Female	Fatal	2	3	3
		Incapacitating Injury	15	12	12
		Other Injury	35	54	53
		No Injury	48	30	32

(Continued on Next Page)

Vehicle Type/Sex/Injury Severity (%)			1994	2003	2004
Sport Utility Vehicle	Male	Fatal	3	3	3
		Incapacitating Injury	15	11	11
		Other Injury	34	41	43
		No Injury	48	45	44
	Female	Fatal	2	2	2
		Incapacitating Injury	17	15	16
		Other Injury	46	45	43
		No Injury	34	38	39
Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004..					

Injury Severity by Vehicle Age. As Table 34 shows, in 2004 the fatality rate for occupants of passenger cars that were less than 5 years old and that were in single-vehicle rollovers was an estimated 2%; for older passenger cars, the fatality rate was an estimated 3%. The fatality rates were either 2% or 3% for all four vehicle types under consideration, both for newer and older vehicles, in 1994, 2003, and 2004. Thus, there appears to have been no association between vehicle age and fatal injury outcomes.

Table 34
Occupants of vehicles in single-vehicle rollovers
by vehicle type, vehicle age, and injury severity, 1994, 2003, 2004

Vehicle Type/Vehicle Age/Injury Severity (#)			1994	2003	2004
Passenger car	Less than 5 Years	Fatal	1,270	1,124	996
		Incapacitating Injury	9,856	4,552	5,167
		Other Injury	26,026	21,689	17,728
		No Injury	23,414	14,450	17,764
		Total	60,565	41,815	41,655
	5 Years or More	Fatal	2,802	2,621	2,628
		Incapacitating Injury	17,788	11,169	11,207
		Other Injury	53,666	53,018	48,351
		No Injury	52,935	33,101	36,453
		Total	127,191	99,909	98,639
(Continued on Next Page)					

Vehicle Type/Vehicle Age/Injury Severity (#)			1994	2003	2004
Van	Less than 5 Years	Fatal	190	153	126
		Incapacitating Injury	1,004	876	576
		Other Injury	2,482	2,271	2,854
		No Injury	4,287	1,969	3,050
		Total	7,963	5,270	6,605
	5 Years or More	Fatal	244	368	361
		Incapacitating Injury	551	1,846	1,409
		Other Injury	3,551	7,548	8,103
		No Injury	6,980	5,952	5,188
		Total	11,326	15,715	15,061
Pickup	Less than 5 Years	Fatal	598	811	780
		Incapacitating Injury	3,062	3,441	3,525
		Other Injury	8,753	10,910	11,952
		No Injury	12,035	11,114	10,161
		Total	24,448	26,275	26,419
	5 Years or More	Fatal	1,371	1,316	1,316
		Incapacitating Injury	6,554	4,115	4,291
		Other Injury	22,173	18,965	17,962
		No Injury	25,703	17,143	19,107
		Total	55,801	41,539	42,676
Sport Utility Vehicle	Less than 5 Years	Fatal	331	895	845
		Incapacitating Injury	1,970	4,685	3,861
		Other Injury	3,617	14,753	15,485
		No Injury	6,087	15,534	14,906
		Total	12,006	35,867	35,097
	5 Years or More	Fatal	510	1,224	1,478
		Incapacitating Injury	2,516	6,968	7,521
		Other Injury	7,627	24,455	22,839
		No Injury	7,322	23,688	24,378
		Total	17,974	56,335	56,215

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004..

Vehicle Type/Vehicle Age/Injury Severity (%)			1994	2003	2004
Passenger car	Less than 5 Years	Fatal	2	3	2
		Incapacitating Injury	16	11	12
		Other Injury	43	52	43
		No Injury	39	35	43
	5 Years or More	Fatal	2	3	3
		Incapacitating Injury	14	11	11
		Other Injury	42	53	49
		No Injury	42	33	37
Van	Less than 5 Years	Fatal	2	3	2
		Incapacitating Injury	13	17	9
		Other Injury	31	43	43
		No Injury	54	37	46
	5 Years or More	Fatal	2	2	2
		Incapacitating Injury	5	12	9
		Other Injury	31	48	54
		No Injury	62	38	34
Pickup	Less than 5 Years	Fatal	2	3	3
		Incapacitating Injury	13	13	13
		Other Injury	36	42	45
		No Injury	49	42	38
	5 Years or More	Fatal	2	3	3
		Incapacitating Injury	12	10	10
		Other Injury	40	46	42
		No Injury	46	41	45
Sport Utility Vehicle	Less than 5 Years	Fatal	3	2	2
		Incapacitating Injury	16	13	11
		Other Injury	30	41	44
		No Injury	51	43	42
	5 Years or More	Fatal	3	2	3
		Incapacitating Injury	14	12	13
		Other Injury	42	43	41
		No Injury	41	42	43

Source: NHTSA, NCSA, FARS, GES, 1994, 2003, 2004..

Discussion. This section considered injury outcomes in single-vehicle rollovers. The data show that sport utility vehicles had the highest total ejection rate. Unrestrained occupants had more severe injuries and were totally ejected at a higher rate than restrained occupants. There was an interaction effect between restraint use and ejection status in determining injury outcomes. In

particular, even if an occupant was totally ejected, being restrained decreased the probability of fatality. Older male occupants had a higher fatality rate than younger female occupants.

7. Fatalities Only

The data used in this section is exclusively from the FARS database and not from the GES database. This is because the variables discussed in this section appear only in FARS and not in GES. Thus, this section only considers fatally injured occupants, and does not consider occupants who were not fatally injured. Data on non-fatally injured occupants from FARS is not used. The tables show annual data for 2004, the latest year for which data are available, and 2003, the previous year. The tables in the Weight, Height, and Body Mass Index subsection also show data for year 1998, the earliest year for which data is available; the tables in the Fatalities by State subsection also show data for 1994, which is 10 years prior to 2004.

Weight, Height, and Body Mass Index

This subsection considers weight, height, and Body Mass Index (BMI) of fatally injured drivers in single-vehicle rollovers. It considers drivers rather than all occupants because only the data on drivers are available. BMI is a function of weight and height, and is defined below. One reason to consider these variables is that it might be thought that they influence the effectiveness and the use of seat belts. In particular, people who weigh more, are shorter, or both (that is, those with a higher Body Mass Index) are sometimes thought to receive less benefit from using a seat belt and are thought to use seat belts less frequently.

McDowell et al. (2005) tabulates various anthropometric characteristics of the U.S. population as it existed between 1999 and 2002. Specifically, it gives certain percentiles of weight, height, and BMI for adults 20 and older, by sex. Likewise, the following tables show fatalities by sex, and only if they were 20 or older at the time of the crash. The tables use ranges such that each range contained 25% of the general population between 1999 and 2002.

Every year from 1998, the first year on which weight and height of fatally injured drivers was collected, until 2004 there have been about 5,000 fatally injured drivers 20 or older in single-vehicle rollovers. The following tables only show the drivers with known seat belt use and known weight and/or height, as appropriate.

Weight. According to NHTSA d (2004), either the driver licensing files or the coroner's report may be used to determine driver weight. Table 35 shows fatally injured drivers 20 or older in single-vehicle rollovers by sex, restraint use, and body weight. In such fatalities, there was a tendency for restrained drivers to be heavier than unrestrained drivers. For example, in 2004, of the male drivers who were restrained, 17% were over 212 lbs, while of those unrestrained, only 14% were over 212 lbs.

Regardless of restraint use, these fatally injured drivers tended to be lighter than the general population. For example, among unrestrained female driver fatalities in 2004, 32% were 132 lbs or less; by contrast, only 25% of the general female population was 132 lbs or less.

Table 35
Fatally injured drivers 20 years old or older in single-vehicle rollovers by sex, restraint use, and weight, 1998, 2003, 2004

Female Drivers				
Restraint Use/Weight (lbs) (#)		**1998**	**2003**	**2004**
Restrained	**<= 132.5 (25% of population)**	102	119	119
	132.5 - 154.8 (25% of population)	109	146	170
	154.8 - 184.6 (25% of population)	52	72	76
	> 184.6 (25% of population)	18	55	57
	Total	281	392	422
Unrestrained	**<= 132.5 (25% of population)**	305	268	255
	132.5 - 154.8 (25% of population)	312	320	321
	154.8 - 184.6 (25% of population)	94	126	124
	> 184.6 (25% of population)	60	90	88
	Total	771	804	788
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Female Drivers				
Restraint Use/Weight (lbs) (%)		**1998**	**2003**	**2004**
Restrained	**<= 132.5 (25% of population)**	36	30	28
	132.5 - 154.8 (25% of population)	39	37	40
	154.8 - 184.6 (25% of population)	19	18	18
	> 184.6 (25% of population)	6	14	14
Unrestrained	**<= 132.5 (25% of population)**	40	33	32
	132.5 - 154.8 (25% of population)	40	40	41
	154.8 - 184.6 (25% of population)	12	16	16
	> 184.6 (25% of population)	8	11	11
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Male Drivers				
Restraint Use/Weight (lbs) (#)		**1998**	**2003**	**2004**
Restrained	**<= 162.3 (25% of population)**	165	197	181
	162.3 - 184 (25% of population)	266	331	358
	184 - 212.1 (25% of population)	145	179	208
	> 212.1 (25% of population)	74	111	151
	Total	650	818	898
Unrestrained	**<= 162.3 (25% of population)**	715	692	661
	162.3 - 184 (25% of population)	1,095	1,117	1,087
	184 - 212.1 (25% of population)	548	569	552
	> 212.1 (25% of population)	289	351	381
	Total	2,647	2,729	2,681
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Male Drivers				
Restraint Use/Weight (lbs) (%)		**1998**	**2003**	**2004**
Restrained	**<= 162.3 (25% of population)**	25	24	20
	162.3 - 184 (25% of population)	41	40	40
	184 - 212.1 (25% of population)	22	22	23
	> 212.1 (25% of population)	11	14	17
Unrestrained	**<= 162.3 (25% of population)**	27	25	25
	162.3 - 184 (25% of population)	41	41	41
	184 - 212.1 (25% of population)	21	21	21
	> 212.1 (25% of population)	11	13	14
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Height. According to NHTSA d (2004), either the driver licensing files or the coroner's report may be used to determine driver height. Among male drivers who were fatally injured in single-vehicle rollovers, restrained drivers tended to be taller than unrestrained drivers. For example, as seen in Table 36, in 2004, 33% of the male restrained fatalities were over 71 inches (5 feet 11 inches), compared to 29% of the unrestrained fatalities. This pattern appears to have been weak or nonexistent among female fatalities.

Regardless of restraint use, fatally injured drivers in single-vehicle rollovers tended to be taller than the general population. For example, in 2004, 38% of the female restrained fatalities were taller than 65 inches (5 feet 5 inches), compared to 25% of such females in the general population.

Table 36
Fatally injured drivers 20 years old or older in single-vehicle rollovers by sex, restraint use, and height, 1998, 2003, 2004

Female Drivers				
Restraint Use/Height (in) (#)		**1998**	**2003**	**2004**
Restrained	**<= 62 (25% of population)**	67	83	101
	62 - 63.8 (25% of population)	39	55	58
	63.8 - 65.6 (25% of population)	81	99	101
	> 65.6 (25% of population)	94	155	162
	Total	281	392	422
Unrestrained	**<= 62 (25% of population)**	176	210	188
	62 - 63.8 (25% of population)	129	112	96
	63.8 - 65.6 (25% of population)	203	218	210
	> 65.6 (25% of population)	263	264	294
	Total	771	804	788
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Female Drivers				
Restraint Use/Height (in) (%)		**1998**	**2003**	**2004**
Restrained	**<= 62 (25% of population)**	24	21	24
	62 - 63.8 (25% of population)	14	14	14
	63.8 - 65.6 (25% of population)	29	25	24
	> 65.6 (25% of population)	33	40	38
Unrestrained	**<= 62 (25% of population)**	23	26	24
	62 - 63.8 (25% of population)	17	14	12
	63.8 - 65.6 (25% of population)	26	27	27
	> 65.6 (25% of population)	34	33	37
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Male Drivers				
Restraint Use/Height (in) (#)		**1998**	**2003**	**2004**
Restrained	**<= 67.3 (25% of population)**	135	189	168
	67.3 - 69.3 (25% of population)	143	183	226
	69.3 - 71.3 (25% of population)	164	195	206
	> 71.3 (25% of population)	208	251	298
	Total	650	818	898
Unrestrained	**<= 67.3 (25% of population)**	526	587	526
	67.3 - 69.3 (25% of population)	652	715	690
	69.3 - 71.3 (25% of population)	663	652	683
	> 71.3 (25% of population)	806	775	782
	Total	2,647	2,729	2,681
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Male Drivers				
Restraint Use/Height (in) (%)		**1998**	**2003**	**2004**
Restrained	**<= 67.3 (25% of population)**	21	23	19
	67.3 - 69.3 (25% of population)	22	22	25
	69.3 - 71.3 (25% of population)	25	24	23
	> 71.3 (25% of population)	32	31	33
Unrestrained	**<= 67.3 (25% of population)**	20	22	20
	67.3 - 69.3 (25% of population)	25	26	26
	69.3 - 71.3 (25% of population)	25	24	25
	> 71.3 (25% of population)	30	28	29
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Body Mass Index. Body Mass Index is defined as follows. If weight is measured in kilograms and height in meters, it is the ratio of weight divided by height squared. If weight is measured in pounds and height in inches, then it is 703.07 times the ratio.

$$BMI = \frac{weight(kg)}{height(m)^2} = 703.07\frac{weight(lbs)}{height(in)^2}.$$

Among fatally injured drivers in single-vehicle rollovers, restrained fatalities tended to have a higher BMI than unrestrained fatalities. For example, according to Table 37, in 2004, 16% of the male restrained fatalities had a BMI of greater than 30.4, compared to 13% of the unrestrained male fatalities. Regardless of restraint use, drivers who were fatally injured tended to have a lower BMI than the general population. For example, in 2004, 39% of the female unrestrained drivers had a BMI of 23.1 or less, compared to 25% of such females in the general population.

The male unrestrained drivers had the same tendency (28% vs. 24.8%). Finally, drivers with a higher BMI appeared to receive more benefits from wear

Table 37
Fatally injured drivers 20 years old or older in single-vehicle rollovers by sex, restraint use, and Body Mass Index, 1998, 2003, 2004

Female Drivers				
Restraint Use/BMI (#)		**1998**	**2003**	**2004**
Restrained	**<= 23.1 (25% of population)**	118	143	140
	23.1 - 26.8 (25% of population)	102	145	170
	26.8 - 32 (25% of population)	42	56	66
	> 32 (25% of population)	19	48	46
	Total	281	392	422
Unrestrained	**<= 23.1 (25% of population)**	333	305	311
	23.1 - 26.8 (25% of population)	302	310	299
	26.8 - 32 (25% of population)	92	115	106
	> 32 (25% of population)	44	74	72
	Total	771	804	788
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Female Drivers				
Restraint Use/BMI (%)		**1998**	**2003**	**2004**
Restrained	**<= 23.1 (25% of population)**	42	36	33
	23.1 - 26.8 (25% of population)	36	37	40
	26.8 - 32 (25% of population)	15	14	16
	> 32 (25% of population)	7	12	11
Unrestrained	**<= 23.1 (25% of population)**	43	38	39
	23.1 - 26.8 (25% of population)	39	39	38
	26.8 - 32 (25% of population)	12	14	13
	> 32 (25% of population)	6	9	9
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Male Drivers				
Restraint Use/BMI (#)		**1998**	**2003**	**2004**
Restrained	**<= 24.2 (25% of population)**	186	210	211
	24.2 - 27.1 (25% of population)	292	376	385
	27.1 - 30.4 (25% of population)	101	125	157
	> 30.4 (25% of population)	71	107	145
	Total	650	818	898
Unrestrained	**<= 24.2 (25% of population)**	812	767	757
	24.2 - 27.1 (25% of population)	1,147	1,173	1,111
	27.1 - 30.4 (25% of population)	438	427	457
	> 30.4 (25% of population)	250	362	356
	Total	2,647	2,729	2,681
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Male Drivers				
Restraint Use/BMI (%)		**1998**	**2003**	**2004**
Restrained	**<= 24.2 (25% of population)**	29	26	23
	24.2 - 27.1 (25% of population)	45	46	43
	27.1 - 30.4 (25% of population)	16	15	17
	> 30.4 (25% of population)	11	13	16
Unrestrained	**<= 24.2 (25% of population)**	31	28	28
	24.2 - 27.1 (25% of population)	43	43	41
	27.1 - 30.4 (25% of population)	17	16	17
	> 30.4 (25% of population)	9	13	13
Source: NHTSA, NCSA, FARS, 1998, 2003, 2004; McDowell et al. (2005).				

Discussion. One finding of this section is that among fatally injured drivers, those who were restrained tended to weigh more, be taller, and have a higher BMI than those who were unrestrained. Another interesting finding is that drivers who weighed less, were taller, and had a lower BMI tended to be overrepresented in single-vehicle fatal rollovers. Thus, while heavier individuals received fewer benefits from seat belts, they might also have been at a lower risk of fatality given involvement in a single-vehicle rollover. On the other hand, this overrepresentation of lighter, taller, and lower BMI drivers could be related to age and its relationship to risk-taking.

Fatalities by State

Table 38 shows the number of fatally injured passenger vehicle occupants by State. The first part of the table shows fatality counts for occupants in single-vehicle rollovers, occupants in all rollovers, and passenger vehicle occupants in all crashes. The second part of the table shows the amount of single-vehicle rollover occupant fatalities as a percent of all rollover occupant fatalities and the amount of all rollover occupant fatalities as a percent of all occupant fatalities.

The row marked "USA" shows the quantities pooled for the 50 States plus the District of Columbia, but excluding Puerto Rico. The rows marked "Average," "Standard Deviation," "Minimum," and "Maximum" show these summary statistics taken, again, over all the 50 States plus the District of Columbia. Thus, for example, in 2004, in the United States 33% of all passenger vehicle occupant fatalities were rollover fatalities. However, the average of this percentage across the States was 35%.

In 2004, the States with the highest amounts of single-vehicle rollover fatalities as a percentage of all rollover fatalities were Mississippi (at 99%), North Dakota (94%), and Montana (92%). The States with the lowest percents of single-vehicle rollover fatalities as compared to all rollover fatalities were the District of Columbia (50%), Hawaii (63%), and New Jersey (68%). The States with the highest amount of rollover occupant fatalities as a percent of all occupant fatalities were Montana (67%), Wyoming (66%), and Idaho (56%). The States with the lowest percents were the District of Columbia (10%), Puerto Rico (12%), and New Jersey and Mississippi (18% each).

Table 38
Fatally injured occupants of passenger vehicles
in single-vehicle rollovers, in all rollovers, and in all crashes
by State (plus Puerto Rico), 1994, 2003, 2004

Occupant fatalities	1994			2003			2004		
	Single-vehicle rollover	Rollover	All	Single-vehicle rollover	Rollover	All	Single-vehicle rollover	Rollover	All
Alabama	215	250	921	230	285	836	282	343	951
Alaska	28	28	61	23	24	64	25	29	69
Arizona	205	253	622	289	377	800	344	415	797
Arkansas	119	149	506	170	196	513	156	187	565
California	766	982	2,869	841	1,086	2,937	850	1,068	2,786
Colorado	185	230	465	180	228	497	185	228	492
Connecticut	38	48	204	49	63	222	41	58	193
Delaware	15	19	82	24	31	110	20	25	104
Dist of Columbia	10	12	41	1	3	41	1	2	21
Florida	261	380	1,812	458	582	2,105	459	627	2,080

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Occupant fatalities	1994			2003			2004		
	Single-vehicle rollover	Rollover	All	Single-vehicle rollover	Rollover	All	Single-vehicle rollover	Rollover	All
Georgia	236	290	1,147	275	356	1,247	316	397	1,279
Hawaii	20	26	62	20	22	84	19	30	82
Idaho	92	101	217	110	123	244	102	114	205
Illinois	235	308	1,118	254	309	1,063	216	273	985
Indiana	156	186	775	99	121	644	145	164	712
Iowa	102	113	399	105	112	349	81	92	305
Kansas	110	118	376	144	168	392	112	147	390
Kentucky	161	189	667	172	203	760	203	245	793
Louisiana	162	213	661	201	254	714	165	202	705
Maine	38	43	143	45	46	168	51	61	152
Maryland	64	75	468	61	80	456	83	113	450
Massachusetts	49	64	305	63	74	324	63	82	309
Michigan	175	239	1,092	172	219	960	145	185	875
Minnesota	126	150	518	166	215	520	129	157	452
Mississippi	97	98	662	124	128	764	139	141	778
Missouri	267	322	925	331	391	994	321	396	948
Montana	88	93	164	125	143	228	115	125	186
Nebraska	53	74	231	77	95	250	72	88	214
Nevada	101	116	206	108	126	255	109	131	262
New Hampshire	26	30	91	25	27	91	32	37	123
New Jersey	71	98	530	56	76	510	56	82	451
New Mexico	169	189	331	175	200	325	169	210	396
New York	167	218	1,094	164	194	923	165	200	948
North Carolina	246	318	1,127	309	395	1,230	315	395	1,185
North Dakota	28	35	75	30	36	82	34	36	82
Ohio	144	200	1,077	185	255	988	201	263	981
Oklahoma	182	229	579	167	206	549	186	238	602
Oregon	120	145	373	124	137	399	93	110	343
Pennsylvania	184	234	1,090	242	294	1,169	231	279	1,110
Rhode Island	7	11	36	16	17	74	19	21	65
South Carolina	128	152	639	223	250	763	250	295	826
South Dakota	53	56	106	91	95	169	67	79	155
Tennessee	251	312	1,018	261	310	966	315	378	1,067
Texas	616	721	2,476	795	1,002	2,893	695	876	2,707
Utah	116	117	263	108	121	241	105	121	218
Vermont	21	22	66	12	14	55	18	25	76

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Occupant fatalities	1994			2003			2004		
	Single-vehicle rollover	Rollover	All	Single-vehicle rollover	Rollover	All	Single-vehicle rollover	Rollover	All
Virginia	214	243	739	163	192	763	166	201	730
Washington	132	157	489	122	154	445	124	144	414
West Virginia	83	95	288	74	88	313	103	114	324
Wisconsin	129	145	571	196	245	653	194	238	620
Wyoming	80	85	124	74	74	129	78	86	130
USA	**7,341**	**8,981**	**30,901**	**8,529**	**10,442**	**32,271**	**8,565**	**10,553**	**31,693**
Puerto Rico	26	33	333	32	36	266	26	30	249

Source: NHTSA, NCSA, FARS, 1994, 2003, 2004.

	Single-vehicle rollover fatalities as percent of all rollover fatalities			Rollover fatalities as percent of all occupant fatalities		
	1994	2003	2004	1994	2003	2004
Alabama	86	81	82	27	34	36
Alaska	100	96	86	46	38	42
Arizona	81	77	83	41	47	52
Arkansas	80	87	83	29	38	33
California	78	77	80	34	37	38
Colorado	80	79	81	49	46	46
Connecticut	79	78	71	24	28	30
Delaware	79	77	80	23	28	24
Dist of Columbia	83	33	50	29	7	10
Florida	69	79	73	21	28	30
Georgia	81	77	80	25	29	31
Hawaii	77	91	63	42	26	37
Idaho	91	89	89	47	50	56
Illinois	76	82	79	28	29	28
Indiana	84	82	88	24	19	23
Iowa	90	94	88	28	32	30
Kansas	93	86	76	31	43	38
Kentucky	85	85	83	28	27	31
Louisiana	76	79	82	32	36	29
Maine	88	98	84	30	27	40
Maryland	85	76	73	16	18	25

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	Single-vehicle rollover fatalities as percent of all rollover fatalities			Rollover fatalities as percent of all fatalities		
	1994	2003	2004	1994	2003	2004
Massachusetts	77	85	77	21	23	27
Michigan	73	79	78	22	23	21
Minnesota	84	77	82	29	41	35
Mississippi	99	97	99	15	17	18
Missouri	83	85	81	35	39	42
Montana	95	87	92	57	63	67
Nebraska	72	81	82	32	38	41
Nevada	87	86	83	56	49	50
New Hampshire	87	93	86	33	30	30
New Jersey	72	74	68	18	15	18
New Mexico	89	88	80	57	62	53
New York	77	85	83	20	21	21
North Carolina	77	78	80	28	32	33
North Dakota	80	83	94	47	44	44
Ohio	72	73	76	19	26	27
Oklahoma	79	81	78	40	38	40
Oregon	83	91	85	39	34	32
Pennsylvania	79	82	83	21	25	25
Rhode Island	64	94	90	31	23	32
South Carolina	84	89	85	24	33	36
South Dakota	95	96	85	53	56	51
Tennessee	80	84	83	31	32	35
Texas	85	79	79	29	35	32
Utah	99	89	87	44	50	56
Vermont	95	86	72	33	25	33
Virginia	88	85	83	33	25	28
Washington	84	79	86	32	35	35
West Virginia	87	84	90	33	28	35
Wisconsin	89	80	82	25	38	38
Wyoming	94	100	91	69	57	66
USA	**82**	**82**	**81**	**29**	**32**	**33**
Average	**83**	**83**	**81**	**33**	**34**	**35**
Standard Deviation	**8**	**10**	**8**	**12**	**12**	**12**
Minimum	**64**	**33**	**50**	**15**	7	**10**
Maximum	**100**	**100**	**99**	**69**	**63**	**67**
Puerto Rico	79	89	87	10	14	12

Source: NHTSA, NCSA, FARS, 1994, 2003, 2004.

8. Logistic Analysis

Rollover propensity

In this subsection, we model the probability that a passenger vehicle rolls over given that it is in a single-vehicle crash. The dependent variable is a categorical variable that indicates whether a vehicle had rolled over. We consider all the passenger vehicles (all passenger cars and light trucks) that were in single-vehicle crashes between 2000 and 2004, inclusive, and that had a driver at the time of the crash. All the data are from the GES database. We consider the following explanatory variables:

Categorical variables: vehicle type, driver restraint use, driver sex, alcohol involvement, vehicle maneuver prior to critical event, corrective action attempted, road type, and whether the crash was speed-related.

Interval variables: driver age, speed limit, vehicle occupancy, and vehicle age.

One interpretation of the driver restraint use variable is that it is a proxy for driver behavior in relation to traffic safety. It is possible that drivers who chose not to wear seat belts also chose to drive unsafely, which in turn could have lead to a higher probability that their vehicle rolled over given that it was involved in a crash. The results of the regression are consistent with such an interpretation. As Table 39 shows, the odds ratio of a single-vehicle crash being a rollover for unrestrained drivers as compared to restrained drivers was significantly greater than 1, indicating that unrestrained drivers did indeed have a higher probability of being in vehicles that rolled over in single-vehicle crashes than did restrained drivers. As not wearing a seat belt was a symptom of unsafe driving, simply having forced an otherwise unsafe driver to wear a seat belt might not have changed the probability of rollover for that driver.

Whether alcohol was involved in the crash was derived from police-reported alcohol involvement. If any driver, pedestrian, cyclist, or other nonmotorist who was involved in a crash used alcohol, the crash was classified as having alcohol involvement. Note that simply because a crash had alcohol involvement does not mean that alcohol use caused the crash. Nevertheless, as the results of the logistic analysis show in Table 39, all other things being equal, if there was alcohol involvement, or if alcohol involvement was unknown, the odds of a vehicle rolling over were higher than if there was no alcohol involvement.

Vehicle occupancy is the number of occupants that were present in the vehicle at the time of the crash.

Table 39 shows results of the logistic analysis. For categorical variables, results are presented as odds ratios of the odds that the vehicle rolled over for the given category divided by the odds that it rolled over for the reference category. Recall that the odds of an event is the probability that the event occurs divided by the probability that it does not occur; see the Appendix for a further discussion. For example, all other things being equal, the odds that a sport utility vehicle rolled over are 3.60 times the odds that a passenger car rolled over.

For interval scale variables, estimated coefficients are shown. A coefficient is the approximate percent change in the odds of rollover for a unit increase in the explanatory variable, provided that none of the other explanatory variables change. Thus, for example, all other things being equal, every additional vehicle occupant increased the odds of rollover by about 10.5%.

The confidence intervals shown in the table were generated by the SAS software. The p-values for all the explanatory variables presented in the table are well below 1%. The only exception is Driver Sex, the p-value for which is 15%, which means that it is not statistically significant. Note that the variable has three categories – male, female, and unknown. The odds ratio of unknown versus male is not statistically significant, while the odds ratio of female versus male is, in fact, statistically significant. For this reason, we leave the Driver Sex variable in the model.

Also note that for some categorical variables, the difference between two particular categories is not statistically significant. Nevertheless, the variables are overall statistically significant. One example of such a variable is "Driver restraint use" – there is no statistically significant difference between the "unknown" and "restrained" categories, however, the variable overall is, in fact, statistically significant.

Table 39
Logistic analysis of vehicle rollover given involvement in a single-vehicle crash, 2000-2004

Parameter		Estimate	95% Confidence Interval	
		Odds Ratios		
Vehicle type	Other Light Truck vs Passenger Car	1.85	1.39	2.46
	Pickup vs Passenger Car	1.95	1.80	2.11
	Sport Utility Vehicle vs Passenger Car	3.60	3.32	3.90
	Van vs Passenger Car	1.38	1.21	1.57
Driver restraint use	Unknown vs Restrained	0.88	0.72	1.08
	Unrestrained vs Restrained	1.84	1.66	2.05
Driver sex	Unknown vs Male	1.00	0.78	1.27
	Female vs Male	1.06	1.00	1.13
Alcohol involvement	Unknown vs No	1.20	1.06	1.36
	Yes vs No	1.71	1.56	1.89
Maneuver prior to critical event	Unknown vs Going Straight	0.53	0.38	0.74
	Changing Lanes vs Going Straight	1.23	1.03	1.47
	Negotiating a Curve vs Going Straight	1.88	1.70	2.08
	Other vs Going Straight	0.48	0.40	0.58
	Passing vs Going Straight	1.95	1.49	2.55
	Turning vs Going Straight	0.47	0.39	0.55

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Corrective action attempted	**Unknown vs None**	1.33	1.18	1.51
	Braking vs None	1.16	0.97	1.40
	Other vs None	2.19	1.57	3.05
	Steering vs None	3.03	2.62	3.50
Road type	**Unknown vs Divided Highway**	0.65	0.49	0.86
	One-way vs Divided Highway	0.84	0.72	0.99
	Undivided Two-Way vs Divided Highway	1.24	1.03	1.47
Speed-related	**Unknown vs No**	1.20	1.01	1.43
	Yes vs No	2.31	2.04	2.62
		Coefficients		
Driver age	**(years)**	-0.015	-0.017	-0.012
Speed limit	**(mph)**	0.040	0.033	0.047
Vehicle occupancy	**(persons)**	0.105	0.068	0.143
Vehicle age	**(years)**	0.017	0.012	0.022
Source: NHTSA, NCSA, GES, 2000-2004				

Kindelberger and Eigen (2003) modeled rollover of SUVs in crashes as a function of driver age, driver sex, and vehicle age. They found a negative relationship between probability of rollover and driver age, as did we. They found a positive and statistically significant relationship between the driver being male, as opposed to female, and probability of rollover. We found the opposite relationship. Finally, the paper found that, other things being equal, a one-year increase in vehicle age increased the odds of rollover by 3%. We found the increase in odds to be 1.7%.

Subramanian (2005) used NHTSA's State Data System (SDS) database to model rollover of passenger vehicles in single-vehicle crashes as a function of vehicle occupancy, speed limit, and a number of other variables. It found that, other things being equal, the addition of a single occupant increased the odds of rollover by a value between 6% (for passenger cars) and 19% (for sport utility vehicles). We found the increase across all vehicle types to be 11%. The paper also found that high speed limit is statistically significant and was correlated with a higher probability of rollover, as did we.

Qualitatively, the results of the multivariate analysis tell basically the same story as the tables presented earlier in the Rollover Propensity section. For example, Table 8 shows that rollover rate increased with increasing vehicle age. This is confirmed by the positive Vehicle Age coefficient in Table 39.

One important exception to this is the road type. Table 19 considers three types of roads: divided highway, undivided two-way street, and one-way street. The table indicates that single-vehicle crashes that occurred on divided highways had the highest rollover rate. It also shows that for light trucks, single-vehicle crashes on one-way streets had a higher rollover rate than crashes on undivided two-way streets. The multivariate analysis tells a different story. According to the logistic table, crashes that occurred on undivided two-way streets had the highest rollover rate,

followed by divided highways, then one-way streets, and then streets of unknown type, in that order.

Results differ between the simple tabulation and the multivariate analysis for the following reason. Multivariate analysis considers the impact of each variable given that all the other explanatory variables in the analysis remain constant. In this particular case, it compares different road types at a fixed speed limit. In other words, the multivariate analysis says that *if* all road types had the same speed limit, then undivided two-way streets would have had the highest rollover propensity. The simple tabulation, on the other hand, reports past rollover incidence without controlling for other potentially confounding variables. One possible reason that divided highway had the highest rollover incidence is that divided highways tend to have higher speed limits and, as we see from both the tabulation and the multivariate analysis, higher speed limit is associated with a higher rollover rate.

Injury Outcomes

In this subsection, we model the probability that a passenger vehicle occupant was fatally injured given involvement in a single-vehicle rollover. The dependent variable is a categorical variable that indicates whether or not a vehicle occupant was fatally injured. We consider all the occupants of passenger vehicles that were involved in single-vehicle rollovers between 2000 and 2004, inclusive. The data are from a combination of the FARS and the GES databases. Specifically, the data on occupants who were fatally injured is from the FARS database, while the data on occupants who were not fatally injured is from the GES database. We consider the following explanatory variables:

Categorical variables: vehicle type, ejection status, restraint use, occupant sex, maneuver prior to critical event, corrective action attempted, road type, and whether the crash was speed-related.

Interval variables: occupant age, vehicle age, speed limit, and vehicle occupancy.

Ejection status indicates whether the occupant was totally ejected.

We follow Lindsey (2006) in defining the speed-related variable for the observations taken from the FARS database. In particular, we consider the crash to have been speed-related if the driver in the crash either (a) had a speeding-related driver-related factor; or (b) had a speeding-related violation charged.

When the regression was performed with all of the above explanatory variables, the speed-related variable had a p-value of 57% and the vehicle age variable had a p-value of 19%, indicating that these variables are not statistically significant. Because we had no strong *a priori* basis for thinking that these variables belong in the model, we removed them from the model. In the resultant model, maneuver prior to critical event has a p-value of 3%; all other explanatory variables have a p-value that is well below 1%.

Table 40 shows results of the logistic regression analysis. As before, for categorical variables, odds ratios are given. For example, all other things being equal, the odds of fatality were 10.53 times higher if an occupant was totally ejected than if he was not ejected or not totally ejected. For interval variables, coefficients are given. For example, all other things being equal, an increase in the speed limit by 1 mile per hour increased the odds of fatality in single-vehicle rollovers by about 2.0%.

Table 40
Logistic analysis of occupant fatality given involvement in a single-vehicle rollover, 2000-2004

Parameter		Estimate	95% Confidence Interval	
		Odds Ratios		
Vehicle type	Other Light Truck vs Passenger Car	0.07	0.02	0.24
	Pickup vs Passenger Car	0.73	0.57	0.92
	Sport Utility Vehicle vs Passenger Car	0.72	0.60	0.87
	Van vs Passenger Car	0.64	0.44	0.94
Restraint use	Unknown vs Restrained	2.86	2.02	4.03
	Unrestrained vs Restrained	7.18	5.93	8.69
Ejection status	Unknown vs No or Partial Ejection	0.12	0.07	0.22
	Total Ejection vs No or Partial Ejection	10.53	8.10	13.69
Sex	Unknown vs Male	0.00	0.00	0.01
	Female vs Male	0.79	0.70	0.89
Maneuver prior to critical event	Unknown vs Going Straight	0.92	0.35	2.48
	Changing Lanes vs Going Straight	1.19	0.77	1.84
	Negotiating a Curve vs Going Straight	0.93	0.73	1.18
	Other vs Going Straight	1.92	1.16	3.19
	Passing vs Going Straight	1.14	0.73	1.79
	Turning vs Going Straight	0.34	0.15	0.74
Corrective action attempted	Unknown vs None	0.00	0.00	0.00
	Braking vs None	0.38	0.29	0.50
	Other vs None	13.20	9.19	18.97
	Steering vs None	0.26	0.22	0.32
Road type	Unknown vs Divided Highway	0.25	0.16	0.38
	One-way vs Divided Highway	0.13	0.07	0.26
	Undivided Two-Way vs Divided Highway	1.31	1.00	1.71
		Coefficients		
Occupant age	(years)	0.034	0.030	0.038
Speed limit	(mph)	0.020	0.008	0.032
Vehicle occupancy	(persons)	-0.098	-0.162	-0.033

Source: NHTSA, NCSA, FARS, GES, 2000-2004

Note that for some variables, for unknown categories, the estimated odds ratios are zero or very close to it. For example, for unknown as opposed to male occupant sex, the estimated odds ratio

of fatality is 0.003 (shown as 0.00 in the table); for unknown as opposed to no corrective action attempted, the odds ratio of fatality is estimated to be very close to 0. These estimates are very curious since an odds ratio of zero means that the probability of fatality is also zero. Here is the explanation for why these estimates are zero. The variables in question are never or very rarely coded as unknown for fatalities but are coded as unknown with some frequency for non-fatally injured occupants. This could be because of differences in data collection procedures applied to fatalities as opposed to non-fatally injured occupants. Recall that in this report, data on fatalities comes from the FARS database, while data on other occupants comes from the GES database. So this difference in coding could reflect a difference in procedures between the two databases. In any event, because of the difference in coding, when the value of the variable is unknown, that is an almost sure indication that the observation is on a non-fatally injured occupant. This results in an estimate of the odds ratio of zero or very close to zero.

Treacy et al. (2002) modeled injury outcomes in single-vehicle rollovers that occurred in 1996 and 1997 in a particular area of Australia. Rather than modeling the probability of fatality, as we did, Treacy et al. modeled the probability of "major injury." They found a positive relationship between the probability of "major injury" and total ejection, not wearing a seat belt, and a high vehicle speed. We likewise found a positive relationship between the probability of fatality and total ejection, not wearing a seat belt, and a high speed limit.

Khattak et al. (2003) modeled injury outcomes of occupants of large trucks that rolled over in single-vehicles crashes in North Carolina from 1996 to 1998. Note that we modeled injury outcomes of passenger vehicle occupants rather than large truck occupants. They used ordered probit to model all injury outcomes possible on the KABCO scale. They found a positive relationship between injury severity and travel speed; we found a positive relationship between the probability of fatality and a high speed limit. However, they found that increased vehicle occupancy increased the probability of higher injury severity, whereas we found that it decreases it.

Qualitatively, the results of the multivariate analysis are consistent with the tables presented earlier in the Injury Outcomes section. For example, Table 26 shows that unrestrained occupants were more likely to die in a single-vehicle rollover than restrained occupants. Multivariate analysis confirms this since in Table 40, the odds ratio for "Restraint Use: Unrestrained versus Restrained" is greater than 1.

One exception to this is the vehicle type variable. According to Table 22, the probability of fatality given involvement in a single-vehicle rollover for passenger cars, pickups, and sport utility vehicles was about 3%; for vans, it was about 2%. In other words, according to the table, the probability was about the same for all four vehicle types. However, according to the results of the multivariate analysis shown in Table 40, the probability of fatality in a passenger car was significantly higher than the probability for each of the other vehicle types.

Results differ between the simple tabulation and the multivariate analysis for the following reason. Multivariate analysis considers the impact of each explanatory variable given that all the other explanatory variables in the analysis remained constant. In this particular case, it compares the impact on probability of fatality of different vehicle types at a fixed ejection status, vehicle

occupancy, and so on. In other words, the multivariate analysis says that *if* the ejection status, vehicle occupancy, and the other explanatory variables did not change as the vehicle type changed, then passenger car occupants would have had the highest propensity to die given involvement in a single-vehicle rollover. The simple tabulation, on the other hand, reports fatality incidence without controlling for other potentially confounding variables. As Table 24 shows, the probability of total ejection changed with vehicle type. Thus, ejection status might be one confounding factor.

Discussion

Considering the two logistic models above, we see that there are some factors that both increased the probability of a vehicle rolling over and increased the probability of occupant fatality given that the occupant was in a vehicle that rolled over, while other factors increased the probability of one while decreasing the probability of the other. For example, if a vehicle was turning as opposed to going straight immediately before the single-vehicle crash occurred, that decreased the probability that the vehicle rolled over (odds ratio is 0.47 < 1), and it also decreased the probability of occupant fatality if a rollover did occur (odds ratio is 0.34 < 1). The same is true for the speed limit. A higher speed limit was both correlated with an increased probability of rollover given involvement in a single-vehicle crash (coefficient is 0.04 > 0) and it was correlated with an increased probability of fatality given involvement in a single-vehicle rollover (coefficient is 0.02 > 0).

On the other hand, all light trucks had a higher probability of rollover as compared to passenger cars (odds ratio for sport utility vehicles is 3.6 > 1), but being an occupant in a light truck decreased the probability of a fatal injury given a single-vehicle rollover (odds ratio for sport utility vehicles is 0.72 < 1). Similarly, higher vehicle occupancy increased the probability of rollover given involvement in a single-vehicle crash (coefficient is 0.11 > 0), but at the same time it decreased the probability of a fatality given involvement in a single-vehicle rollover (coefficient is -0.10 < 0).

Appendix: Interpretation of Logistic Tables

A logistic regression models the odds of a particular event as a function of explanatory variables. Let p be the probability than an event occurs before we observe whether or not the event has actually occurred. For example, this could be the probability that a vehicle rolls over given involvement in a crash, or the probability that an occupant is fatally injured given involvement in a rollover. Then $o = \frac{p}{1-p}$ is the odds of the same event. Table 41 shows the relationship between probabilities and odds.

Table 41
Relationship between probabilities and odds.

Probability	Odds
0.9	9.00
0.8	4.00
0.7	2.33
0.6	1.50
0.5	1.00
0.4	0.67
0.3	0.43
0.2	0.25
0.1	0.11

Explanatory variables are of two types: categorical and interval. A categorical variable can take on two or more values that represent categories. An interval variable can take on any number of values that represent quantities. For categorical variables, the logistic regression tables give estimates of the odds ratios; for interval variables, the tables give estimates of the coefficients.

An odds ratio describes the change in the odds of the event that is being modeled given a change in the categorical variable and given that none of the other explanatory variables that are present in the model change their values. A coefficient describes the change in the odds of the event given a small increase in the interval variable and given that none of the other explanatory variables that are present in the model change their values. For example, suppose we are modeling rollover given involvement in a single-vehicle crash (Table 39). The odds ratio "Vehicle Type: Pickup versus Passenger Car" describes the change in the odds of rollover given involvement in a single-vehicle crash given that the vehicle type was changed from a passenger car to a pickup and given that none of the other variables shown in the table changed their values. The coefficient "Driver Age (years)" describes the change in the odds of rollover given involvement in a single-vehicle crash given that the driver's age increased by a small number of years and that none of the other variables shown in the table changed their values.

If a categorical variable can represent C categories, then a logistic table gives $C-1$ odds ratios for it. The odds ratios are for $C-1$ categories relative to a particular category, called the reference category. For example, in Tables 39 and 40, Passenger Car is the reference category for the Vehicle Type variable. The odds ratio is the ratio of odds of the event being modeled given a particular category divided by the odds of the same event given the reference category. For example, in Table 39, the odds ratio "Vehicle Type: Pickup versus Passenger Car" is the odds of rollover given involvement in a single-vehicle crash given that the vehicle is a pickup divided by the odds of rollover given involvement in a single-vehicle crash given that the vehicle is a passenger car. Odds ratios greater than 1.0 indicate that the category was associated with a higher probability of the event relative to the reference category. Odds ratios of less than 1.0 indicate the opposite, that the category was associated with a lower probability of the event relative to the reference category. For example, considering Table 39, the estimated odds ratio on

"Vehicle Type: Pickup versus Passenger Car" is 1.95, indicating that pickups had a higher probability of rollover given involvement in a single-vehicle crash than did passenger cars; the odds ratio on "Road Type: One-way versus Divided Highway" is 0.84, indicating that rollovers in single-vehicle crashes were less likely on one-way roads than they were on divided highways.

The coefficients given for interval variables are the approximate percent changes in the odds of the event being modeled given a small increase in the interval variable. Positive coefficients indicate a positive relationship between the event being modeled and the explanatory variable; negative coefficients indicate a negative relationship. For example, in Table 39, the estimated coefficient for "Driver Age (years)" is -0.015. This means that as the driver age increased, the probability of rollover given involvement in a single-vehicle crash tended to decrease. More precisely, if driver age was increased by one year, the odds of rollover given involvement in a single-vehicle crash would be decreased by approximately 1.5%.

9. Conclusion

This report provides a general overview of the different factors related to passenger vehicle rollovers. It might prompt more detailed research into specific areas that are deemed to be interesting. For example, one potentially interesting area for further research is the effect of seat belts on injury outcomes as a function of occupant characteristics, such as body weight. Other potentially interesting areas for research would include investigating further the use of the driver restraint use variable as a proxy for driver safety and studying the relationship between rollover propensity observed in actual crashes and certain vehicle characteristics, such as the Static Stability Factor.

The report uses both the FARS database and the NASS GES database. It could be extended with additional databases, such as the NASS CDS. CDS contains variables relevant to rollovers that are not present in either FARS or GES, such as the number of quarter turns that a vehicle has rolled over. Previous studies of rollovers, such as Eigen (2005), have used this database.

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