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# **Development of Test Scenarios for Off-Roadway Crash Countermeasures Based on Crash Statistics**

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13. ABSTRACT (Maximum 200 words) This report presents the results from an analysis of off-roadway crashes and proposes a set of crash-imminent scenarios to objectively test countermeasure systems for light vehicles (passenger cars, sport utility vehicles, vans, and pickup trucks) based on crash statistics. This analysis was conducted in support of the roadway departure research area of the U.S. Department of Transportation's Intelligent Vehicle Initiative. The first harmful event in target off-roadway crashes occurs off the roadway after a vehicle departs the road due to loss of control or crossing the edge of the roadway. Approximately 992,000 such crashes occurred in the U.S. in 1998 based on the National General Estimates System (GES) crash database—93 percent of these crashes involved light vehicles. These crashes were grouped into six pre-crash scenarios based on vehicle movements and critical events and were described in terms of their physical settings, contributing factors, and post-roadway departure events. Based on 1998 GES statistics, 85 percent of these off-roadway crashes occurred on non-freeways, 66 percent in rural areas, 82 percent away from junctions, 59 percent on two lanes of travel, and 61 percent below 55 mph speed limit. Speeding was cited as a contributing factor to the cause of the crash in 24 percent of these crashes, whereas alcohol was reported in 19 percent of these crashes. Moreover, inclement weather conditions or driver inattention/distraction might have contributed to about 44 percent of these crashes. After leaving the roadway, vehicles struck other parked vehicles (21 percent) and signposts (14 percent); some form of injury resulted in about 37 percent of off-roadway crashes. Finally, eight test scenarios were proposed and described in terms of roadway type, junction, number of lanes, curvature, shoulder, travel speed, and environmental conditions.					
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## PREFACE

The National Highway Traffic Safety Administration (NHTSA), in conjunction with the Research and Special Programs Administration Volpe National Transportation Systems Center (Volpe Center), is conducting an analysis of off-roadway crashes in support of the Intelligent Vehicle Initiative (IVI). The IVI accelerates the development and deployment of vehicle-based and vehicle-infrastructure cooperative crash countermeasures using intelligent technologies over seven problem areas: rear-end, off-roadway, lane change, crossing paths, driver impairment, reduced visibility, and vehicle instability crashes.

This report presents the results obtained for the analysis of off-roadway crashes based on statistics from the 1998 National Automotive Sampling System (NASS)/General Estimates System crash data base and a sample of crashes from the 1993 NASS Crashworthiness Data System. Approximately 1,350,000 vehicles were involved in police-reported off-roadway crashes in the United States in 1998.

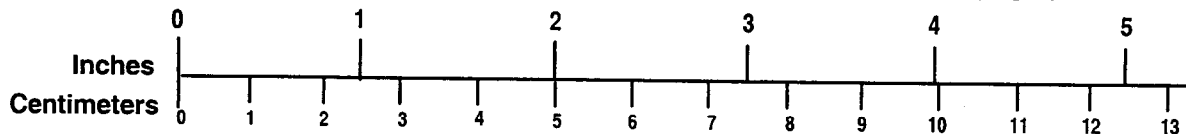
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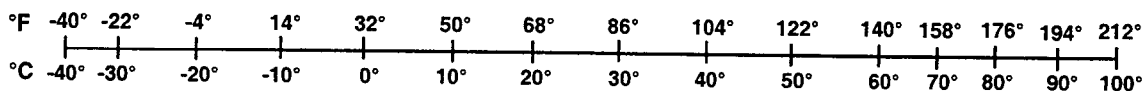
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## EXECUTIVE SUMMARY

This report defines the problem of off-roadway crashes and provides a basis for related future research in the U.S. Department of Transportation's Intelligent Vehicle Initiative, proposing a set of crash-imminent scenarios based on crash data to objectively test countermeasure systems at the vehicle-system level. Off-roadway crashes are defined as vehicular crashes in which the first harmful event happened off the travel portion of the roadway. Crash-imminent scenarios refer to driving situations that require certain action (e.g., warning signal) by the countermeasure system.

This report presents the results from an analysis of off-roadway crashes based on data from the National Highway Traffic Safety Administration National Automotive Sampling System/General Estimates System (GES) crash data base. In 1998, police-reported off-roadway crashes involved nearly 1,350,000 vehicles. This report targets approximately 992,000 crashes with the critical event characterized by roadway edge departure or control loss, excluding crashes resulting from evasive maneuvers and vehicle control loss due to vehicle failure. Six pre-crash scenarios were identified and described in terms of their physical setting, contributing factors, and post roadway departure events. Information on pre-crash scenarios and their physical setting, contributing factors, and environmental conditions help to develop performance guidelines and objective test procedures for crash avoidance systems. This report analyzed causal (speeding, alcohol or drugs, hit and run, impairment, distraction) and environmental factors (daylight/dark) that might have contributed to 62 percent and 38 percent, respectively, of target off-roadway crashes.

The 1998 GES statistics and a sample of crashes from the 1993 Crashworthiness Data System were utilized to develop a set of crash imminent scenarios to objectively test potential off-roadway crash countermeasure systems for intelligent light vehicle applications. Pre-crash scenarios formed the basis for these test scenarios that were then distinguished by roadway type (freeway/non-freeway), number of lanes (two), and relation to junction (non-junction/intersection). This report also recommended test values for the radius of roadway curvature and the width of shoulder. In addition, a range of vehicle travel speeds and environmental conditions were proposed to better describe these scenarios. Objective test procedures normally include crash imminent test scenarios and operational scenarios. The former scenarios are used to assess the capability of countermeasures to take action in driving situations that require a system response. The latter scenarios are devised to evaluate the capability of countermeasures to not react in driving situations that do not lead to imminent crashes. This report did not address operational scenarios that remain to be investigated in future research.



# 1. INTRODUCTION

This report presents the results from an analysis of off-roadway crashes based on data from the National Automotive Sampling System (NASS)/General Estimates System (GES) crash data base of the National Highway Traffic Safety Administration (NHTSA). These results form the basis for the development of crash-imminent scenarios to test applicable off-roadway crash countermeasure systems. Off-roadway crashes are defined in this report as those where the first harmful event occurs off the roadway after a vehicle in transport departs the travel portion of the roadway. Crash-imminent scenarios refer to driving situations that require certain action (e.g., warning signal) by the countermeasure system. This report consists of two major parts. The first part defines the problem of off-roadway crashes and provides a basis for related future research in the U.S. Department of Transportation's Intelligent Vehicle Initiative (IVI). The second part proposes a set of crash-imminent scenarios based on crash data to objectively test countermeasure systems at the vehicle-system level (i.e., driver condition not included).

The IVI is focused on solving traffic safety problems through the development and deployment of vehicle-based and vehicle-infrastructure cooperative countermeasure systems using advanced technologies (Reference 1). There are seven problem areas under consideration in the IVI including rear-end, off-roadway, lane change, crossing paths, driver impairment, reduced visibility, and vehicle instability crashes. Research in these crash problem areas is being performed in the context of four vehicle platforms that include light vehicles (passenger cars, sport utility vehicles, vans, and pickups), commercial vehicles (large trucks—medium and heavy trucks), transit vehicles (buses, but not school buses), and emergency vehicles (police, fire, ambulance, snow plows, and other roadway maintenance vehicles). The first part of this report provides crash statistics for all vehicles involved in off-roadway crashes. Appendices A and B contain off-roadway crash statistics for light and commercial vehicles, respectively. It should be noted that light vehicles comprise almost 93% of all vehicles in the U.S. vehicle fleet and thus off-roadway crash statistics for all and light vehicles are often very similar. This report does not include statistics on off-roadway crashes involving transit and emergency vehicles due to the very small relative frequency of this crash type in both vehicle platforms.

The first part of this report analyzes off-roadway crashes for all vehicles and focuses on a selected portion (target) of these crashes to enable the development of concepts, functional requirements, performance guidelines, and test procedures as well as the safety assessment of potential off-roadway crash avoidance systems. This analysis of off-roadway crashes began with the selection of target crashes and followed with the breakdown of these crashes into common pre-crash scenarios that represented vehicle dynamics prior to leaving the roadway. These scenarios formed the foundation to statistically describe the physical setting of these target off-roadway crashes, the factors that might have contributed to the cause of the crash, and post roadway departure events such as departure side of the road, first harmful event, and maximum injury severity. The combination of causal factors and pre-crash scenarios allows the development of crash countermeasure concepts and essential functional requirements (Reference 2, 3). Information on pre-crash scenarios and their physical setting helps to develop performance guidelines and objective test procedures (including test scenarios) for crash avoidance systems (Reference 4, 5). Such information also guides researchers to collect the appropriate data on

driver performance with and without the assistance of crash avoidance systems. Such data are essential to the design of effective warning algorithms and driver-vehicle interfaces, and estimation of safety benefits for crash avoidance systems (Reference 6). Finally, the first harmful event and injury severity statistics support the projection of safety benefits in terms of injury severity reduction that might be accrued by the use of off-roadway crash countermeasure systems (Reference 7).

The second part of this report utilizes national crash statistics to devise crash-imminent scenarios for objective testing of IVI off-roadway crash countermeasure systems. Moreover, this approach is applied to develop a set of scenarios to objectively test potential IVI off-roadway countermeasures for light vehicles based on their respective crash statistics. It is noteworthy that crash-imminent test scenarios are generally platform specific since crash characteristics may be different among vehicle platforms. Pre-crash scenarios and their physical setting, vehicle speed, and environmental conditions constitute the fundamental pieces of information required for the development of crash-imminent test scenarios.

## 1.1 PREVIOUS WORK

Previous studies have used the NHTSA's GES and NASS Crashworthiness Data System (CDS) crash data bases to analyze single vehicle roadway departure crashes. The 1991 GES was used to assess the problem size and describe the conditions of these crashes (Reference 8). This crash type was defined as a single vehicle departing the roadway and then crashing off the roadway, excluding single vehicles backing up prior to roadway departure and single vehicles hitting a pedestrian or animal off the roadway. The size of these crashes was determined from the GES using codes 01–12 and 14–16 of the *Accident Type* variable and codes 2–4 of the *Relation to Roadway* variable. The *Accident Type* variable categorizes the pre-crash situation. The *Relation to Roadway* variable indicates the location of the first harmful event. Based on 1991 statistics, the single vehicle roadway departure crash accounted for 1,270,000 crashes or 20.8% of all U.S. police-reported crashes.

Using the same definition mentioned above, single vehicle roadway departure crashes were analyzed to derive functional requirements of potential countermeasures as part of a project to develop performance specifications for vehicle-based run-off-road crash countermeasure systems (Reference 9). Based on 1992 GES estimates, this crash type totaled 1,210,000 crashes or 20.2% of all U.S. police-reported crashes. In addition, primary causal factors were identified for these target crashes based on a detailed analysis of 201 crash cases drawn from the 1993 CDS crash data base (Reference 9). Causal factors were arranged in six distinct categories: driver inattention, driver relinquished steering control, evasive maneuver, lost directional control, vehicle failure, and vehicle speed. These causal categories constituted the off-roadway crash scenarios that were further described using variables such as attempted avoidance maneuver, road horizontal alignment (curve or straight), road surface condition, and lighting condition. A similar causal factor analysis of single vehicle off-roadway crashes was conducted in an earlier project based on 100 crash cases selected from the 1991 CDS (Reference 10). Primary causal factors were also grouped under the same six categories, mentioned above, and delineated by the road horizontal alignment.

This report enhances the analysis of off-roadway crashes in comparison to past analyses by providing platform specific and infrastructure-based crash statistics to enable the development of vehicle-based and cooperative vehicle-infrastructure countermeasure systems for the various IVI vehicle platforms. In addition, this new analysis differs from past analyses by describing off-roadway crashes based on distinct pre-crash scenarios that deal with vehicle movements immediately prior to departing the road. Finally, this report adopts a new approach based on deductive reasoning to determine dominant factors that might have contributed to the cause of the crash. This approach is an alternative to the primary causal factors obtained by past analyses that used small, non-representative samples of crash cases from the CDS.

## **1.2 ANALYSIS DATA BASES**

This analysis utilized the 1998 GES crash data base to define and statistically describe the problem of off-roadway crashes for all and light vehicles (Reference 11,12). The 1996–1998 GES crash data bases were used to statistically describe off-roadway crashes that involved commercial vehicles. Three years of GES data were needed to attain a large enough sample of commercial vehicle crash cases to produce representative values in all categories. The GES constitutes a part of NHTSA's NASS crash data collection. Providing data about all types of crashes involving all types of vehicles, the GES is used to identify highway safety problem areas, supply a foundation for regulatory and consumer information initiatives, and form the basis for cost and benefit analyses of highway safety initiatives. The GES is a nationally representative sample of police reported crashes collected from about 400 police agencies within 60 geographical sites in the U.S. Each year, about 50,000 police accident reports are selected and coded directly in the GES by trained personnel who check the data for validity and consistency.

In addition to the GES, a sample of 201 crash files from the 1993 CDS was used to obtain information about the radius of roadway curvature and characteristics of roadway shoulders. Such information was needed in the second part of this report to describe a set of crash imminent test scenarios for light vehicle off-roadway crash countermeasure systems. This analysis did not generalize the national profile of crash statistics about roadway curvature and shoulder characteristics from the 1993 CDS sample. The CDS is a nationally representative sample of 5,000 police-reported crashes involving at least one light vehicle that was towed from the crash scene due to damage from the crash. The CDS crash cases provide a rich body of data that enable researchers to reconstruct crashes, identify the exact details of the surrounding environment, and analyze causal factors. Generally, CDS cases include police accident reports, driver and witness statements, scaled schematic diagrams depicting crash events and physical evidence generated during the crash sequence, and slides documenting vehicles, damage sustained, and other physical evidence.





## 2. DEFINITION OF OFF-ROADWAY CRASHES

The universe of off-roadway crashes is defined as all vehicular crashes in which the first harmful event happened off the roadway. The roadway refers to the portion of the highway normally used for vehicular travel (the travel lanes). The *Relation to Roadway* variable identifies such crashes in the GES crash data base. Off-roadway crash locations include the shoulder or parking lane, the median, the channel island, and any location that is not in the travel lanes of a roadway. Islands refer to the areas between traffic lanes for control and guidance of vehicle movements, which may be provided for separation and special control of turning maneuvers. Based on 1998 GES statistics, the universe of police-reported off-roadway crashes involved about 1,350,000 vehicles or 12% of all vehicles involved in the entire 1998 crash population. National estimates produced from GES data may differ from the true values because they are based on a probability sample of crashes and not a census of all crashes. The size of these differences may vary depending on which sample of crashes was selected. Generalized standard errors for estimates of totals are provided in Reference 11. The standard error of an estimate is a measure of the precision or reliability with which an estimate from the GES sample approximates the results of a census. The 1998 GES crash standard error is 400 for a vehicle estimate of 1,000 and 63,200 for a vehicle estimate of 1,000,000. The 95% confidence interval for the estimate of 1,350,000 vehicles involved in off-roadway crashes would be approximately 1,183,000 to 1,517,000 vehicles in 1998.

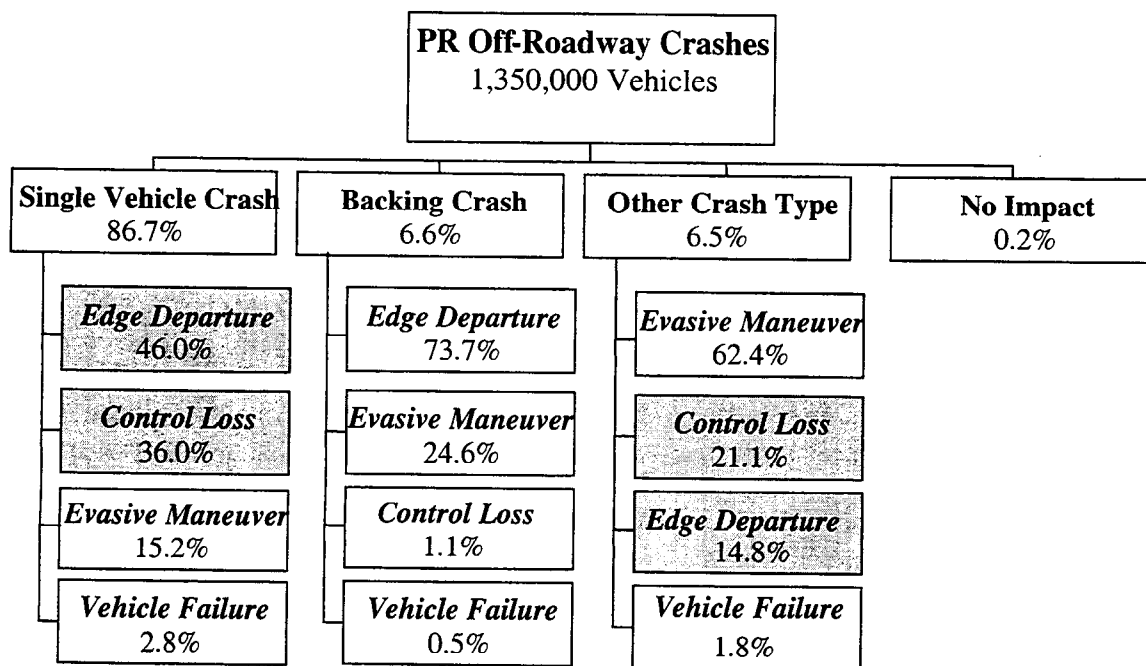
### 2.1 TARGET CRASH POPULATION

Figure 1 shows the distribution of the off-roadway crash universe based on the GES *Accident Type* and *Critical Event* variables. The *Critical Event* variable identifies the critical event that made the crash imminent. Figure 1 identifies four major crash categories by arranging the codes of the *Accident Type* variable as follows:

- No impact: Code 00
- Single vehicle crash: Codes 01 - 16
- Backing crash: Codes 92 - 93
- Other crash type: Remaining codes

The “no impact” crash category identifies non-collision events such as fire or immersion. The “single vehicle crash” category involves a collision between a vehicle in transport and an object. A collision involving two vehicles in transport is excluded from this crash category. The “backing crash” involves a vehicle that backs into another vehicle or object. The “other crash type” category encompasses all remaining crash categories defined in the *Accident Type* variable such as rear-end, lane change, crossing paths, and untripped rollover crashes. Based on 1998 GES estimates, about 1,170,000 vehicles involved in off-roadway crashes, or 86.7% of these crashes as seen in Figure 1, belonged to the “single vehicle crash” category, while 88,000 or 6.5% were coded as being “other crash type.” A total of 1,170,000 light vehicles were involved in “single vehicle” and “other” off-roadway crashes, or 93.5% of all light vehicles reported in off-roadway crashes in 1998 as indicated in Figure A-1. On the other hand, commercial vehicles were involved in about 186,000 “single vehicle” and “other” off-roadway crashes over a 3-year

period from 1996-1998 based on GES data. Thus, commercial vehicles experienced an annual average of about 62,000 single vehicle and other off-roadway crashes in 1996-1998 as shown in Figure B-1.



**Figure 1. Distribution of Off-Roadway Crashes Involving All Vehicles (Based on 1998 GES)**

Similarly, the codes of the *Critical Event* variable were grouped into four categories as indicated in Figure 1:

- Vehicle failure: Codes 010 - 040
- Control loss: Codes 050 - 060
- Edge departure: Codes 100 - 199
- Evasive maneuver: Remaining codes

The “vehicle failure” event category refers to a vehicle component failure leading to control loss, such as blow out/flat tire or stalled engine. The “control loss” event category indicates speed-related control loss crashes due to excessive speed or speeding on poor road conditions. Vehicles traveling over the right or left edge of the roadway or simply departing an end of a roadway (T-shape) are included in the “edge departure” category. The “evasive maneuver” event category consists of situations where a driver attempted to avoid another vehicle, object, animal, pedestrian, or pedalcyclist on the roadway and deliberately drove off the road. As observed in Figure 1, the “edge departure” and “control loss” events were reported in 82.0% of the “single vehicle” crash category. The “edge departure” event was dominant at 73.7% of the

“backing” crash category. Conversely, the “evasive maneuver” event was the most prevalent and comprised 62.4% of the “other crash type” category, while “control loss” and “edge departure” accounted for 21.1% and 14.8% respectively.

In this analysis, the target population of off-roadway crashes was restricted to crashes where the involved vehicle was moving in the forward direction and the critical event was characterized by roadway edge departure or control loss, as indicated in the shaded blocks of Figure 1. This analysis excluded off-roadway crashes that resulted from control loss due to “vehicle failure” from the target population because this type of control loss might be amenable to IVI crash countermeasures under consideration in the vehicle instability problem area. Potential countermeasures for crashes caused by vehicle failure would encompass vehicle component diagnostic systems such as tire pressure monitors. In addition, off-roadway crashes due to an “evasive maneuver” were removed from the target crash population since the driver, in these cases, is deliberately moving off the roadway in order to avoid an obstacle on the road. Off-roadway crashes preceded by a backing maneuver were also excluded since the backing crash type is not part of the IVI. With these restrictions, the target crash population was estimated at 992,000 vehicles or 73.5% of all vehicles involved in off-roadway crashes based on 1998 GES estimates. The target crash population of light vehicles amounted to about 925,000 vehicles or 73.9% of all light vehicles involved in off-roadway crashes in 1998 as deduced from Figure A-1. Similarly, Figure B-1 provides an estimate of 136,000 target off-roadway vehicle crashes or 64.5% of all commercial vehicles involved in off-roadway crashes between 1996 and 1998, averaging about 45,000 crashes yearly over this 3-year period.

## 2.2 PRE-CRASH SCENARIOS

The target crash population was divided into six pre-crash scenarios based on a combination of the GES *Critical Event*, *Movement Prior to Critical Event*, and *Imputed Roadway Alignment* variables. The *Movement Prior to Critical Event* variable records the attribute that best describes the 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 to attempt any evasive maneuver. The *Imputed Roadway Alignment* variable indicates the horizontal alignment of roadway in the immediate vicinity of the first harmful event, excluding “unknown” values. These scenarios qualitatively represent the dynamics of the vehicle immediately prior to leaving the roadway. Table 1 defines the most common scenarios of off-roadway crashes involving all vehicles and shows statistics in a descending order concerning their frequency of occurrence and their frequency relative to the total target crash population.

Approximately 956,000 vehicles, or 96.3% of the target crash population, were involved in six most common off-roadway pre-crash scenarios based on 1998 GES statistics. These crashes are referred to as “target off-roadway crashes” for the remainder of this report. Table 2 provides the 95% confidence bounds on GES estimates of crash counts for each of the six pre-crash scenarios. The classification of these six pre-crash scenarios is needed as a basis for the development of performance guidelines and objective test procedures for appropriate countermeasure systems, and for the collection of driver performance data with and without the assistance of these systems to design better warning algorithms and driver-vehicle interfaces and to assess their impact on safety.

**Table 1. Target Off-Roadway Pre-Crash Scenarios for All Vehicles  
(Based on 1998 GES)**

Pre-Crash Scenario	Frequency	Relative Frequency*	Cumulative Frequency	Cumulative Relative Frequency*
Going straight and departed road edge	348,000	35.1%	348,000	35.1%
Going straight and lost control	218,000	21.9%	566,000	57.0%
Negotiating a curve and lost control	162,000	16.3%	728,000	73.3%
Negotiating a curve and departed road edge	111,000	11.2%	839,000	84.6%
Initiating a maneuver and departed road edge	66,000	6.6%	905,000	91.2%
Initiating a maneuver and lost control	51,000	5.1%	956,000	96.3%

\*Scenario crash frequency relative to the frequency of target crash population (992,000)

Note: Frequency values are rounded to the nearest 1,000.

**Table 2. 95% Confidence Bounds of Target Off-Roadway Pre-Crash Scenario Counts for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Frequency	Lower 95 % Confidence Bound	Upper 95 % Confidence Bound
Going straight and departed road edge	348,000	301,000	395,000
Going straight and lost control	218,000	187,000	249,000
Negotiating a curve and lost control	162,000	138,000	186,000
Negotiating a curve and departed road edge	111,000	93,000	129,000
Initiating a maneuver and departed road edge	66,000	54,000	78,000
Initiating a maneuver and lost control	51,000	41,000	61,000
Total	956,000	837,000	1,075,000

The largest frequency reported for the vehicle's movement prior to the critical event was simply "going straight," which accounted for about 57.0% of all target off-roadway crashes as seen in Table 1. The next most common movement was "negotiating a curve" that was reported in about 27.5% of all target off-roadway crashes. About 11.7% of all target off-roadway crashes involving all vehicles were grouped together by pre-event vehicle movement as "initiating a maneuver." Table 3 indicates that approximately 75,000 vehicles in 64.3% of all target "initiating a maneuver" crashes were making a turn before departing the road edge or losing control based on 1998 GES statistics. Moreover, about 27,000 vehicles in 22.8% of these crashes ran off the road while overtaking another vehicle, changing lanes, merging, or decelerating in a traffic lane. About 14,000 vehicles in 12.8% of these crashes were reported to depart the roadway in 1998 while initiating maneuvers to enter or leave a parking space or start in a traffic lane.

**Table 3. Distribution of Vehicle Movements in “Initiating a Maneuver” Pre-Crash Scenarios (Based on 1998 GES)**

Pre-Crash Scenario	Vehicle Maneuver						Total	Cumulative Total
	Turning	Passing or Changing Lanes	Parking	Slowing or Stopping	Merging	Starting		
Initiating a maneuver and departed road edge	65.1%	9.6%	19.6%	3.8%	0.7%	1.2%	100.0%	66,000
Initiating a maneuver and lost control	63.3%	20.8%	1.0%	10.7%	2.8%	1.4%	100.0%	51,000
Average	64.3%	14.4%	11.5%	6.8%	1.6%	1.3%	100.0%	
Cumulative Total	75,000	17,000	13,000	8,000	2,000	1,000		116,000

## 2.3 PHYSICAL SETTING

The physical setting of the six most common scenarios of target off-roadway crashes was described in terms of the roadway type (freeway/non-freeway), land use (rural/urban), relation to a junction, number of travel lanes, and posted speed limit using variables that were available in the 1998 GES. These combined variables describe the physical circumstances of the crash, insofar as this is possible using available GES variables.

### 2.3.1 ROADWAY TYPE

The GES *Trafficway Flow* and *Hotdeck Imputed Speed Limit* variables were utilized to identify the location of off-roadway crashes on freeways and non-freeways. Unfortunately, the 1998 GES does not contain any variable that directly identifies the roadway type such as freeway or arterial. Freeways were then defined in this report as divided highways (e.g., median strip or barrier) with posted speed limits greater than or equal to 55 mph. The *Trafficway Flow* variable indicates whether or not the roadway was divided. The *Hotdeck Imputed Speed Limit* variable refers to the statutory speed limit posted for the roadway, excluding “unknown” speed limits. Based on our freeway definition, 14.6% of all target off-roadway crashes occurred on freeways (see Table 4). Approximately 58.1% of target off-roadway crashes on freeways were reported on “interstate highways.” This information was obtained from the GES *Interstate Highway* variable that indicates whether or not the crash occurred on an interstate highway based on a *Federal Highway Administration* classification. The remaining 41.9% of target off-roadway crashes on freeways occurred on state or local freeways.

The majority, or 85.4% of all target off-roadway crashes happened on non-freeways. Of these non-freeway crashes, about 90.1% occurred on undivided roadways based on 1998 GES statistics. Divided roadways with posted speed limits below 55 mph were reported in the remaining 9.9% crashes. The distinction between freeways and non-freeways is important for the development of the sensory element and effectiveness of target off-roadway crash countermeasure systems. Countermeasure systems might require more sophisticated sensors and more robust operation on non-freeways than freeways because, generally, the geometric design and lane delineation are inferior on non-freeways. Moreover, the maintenance of the roadway surface and the travel advisories are usually better on freeways than non-freeways.

**Table 4. Distribution of Target Off-Roadway Pre-Crash Scenarios by Roadway Type for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Non-Freeway		Freeway	
	Frequency	Relative Frequency	Frequency	Relative Frequency
Going straight and departed road edge	307,000	37.6%	41,000	29.4%
Going straight and lost control	159,000	19.5%	59,000	42.1%
Negotiating a curve and lost control	141,000	17.3%	21,000	15.1%
Negotiating a curve and departed road edge	104,000	12.7%	8,000	5.4%
Initiating a maneuver and departed road edge	63,000	7.7%	3,000	2.0%
Initiating a maneuver and lost control	42,000	5.2%	8,000	6.0%
Total	816,000	100.0%	139,000	100.0%

As seen in Table 4, the ranking order of the six most common target off-roadway crash scenarios in terms of their frequency of occurrence is different between non-freeways and freeways. The most dominant pre-crash scenario on non-freeways was “going straight and departed road edge” while the “going straight and lost control” pre-crash scenario was the most prevailing on freeways. About 58.0% of all vehicles involved in target off-roadway crashes on non-freeways departed the road edge while the remaining 42.0% lost control. On the contrary, about 63.2% of all vehicles involved in target off-roadway crashes on freeways lost control while the remaining 36.8% departed the road edge. This discrepancy in the results between freeways and non-freeways might be due to higher vehicle travel speeds on freeways.

### 2.3.2 LAND USE AND RELATION TO JUNCTION

Crash statistics on land use (rural and urban locations) and relation to junction were derived from the 1998 GES *Land Use* and *Imputed Relation to Junction* variables. The former variable is based on the population figures of the jurisdiction in which the crash occurred, taken from the 1994 County and City Data Book published by the U.S. Census. Areas with population of 50,000 and more were coded as “urban” for this study. Areas with population of less than 50,000 (including areas not listed in the County and City Data Book) were coded as “rural.” Rural/urban crashes were further divided based on their location relative to junction based on the GES *Imputed Relation to Junction* variable. This variable indicates whether or not the location of the first harmful event occurred within or outside the boundaries of an interchange. The term “junction” includes intersections, intersection approaches, driveways, ramps, and similar areas (Reference 12). This report classifies non-junctions that were not part of interchanges as “non-junction,” combines intersection and intersection-related into the “intersection” category, keeps driveways and expressway entrance and exit ramps as separate categories, and groups all remaining categories as “other.”

Based on 1998 GES estimates, approximately 535,000, or 65.6% of all target off-roadway crashes on non-freeways occurred in rural areas. In contrast, about 213,000, or 26.0% of all target off-roadway crashes on non-freeways happened in urban areas. The remaining 8.4% of all target off-roadway crashes on non-freeways were coded as “unknown.” Table 5 breaks down the six most common off-roadway pre-crash scenarios on non-freeways by rural/urban locations and relation to junction. Non-junction locations were reported in about 82.1% of all target off-roadway crashes on non-freeways. On the other hand, about 14.0% of all target off-roadway

crashes on non-freeways occurred at intersections. Generally, the four most common pre-crash scenarios tend to occur in rural areas away from junctions. Target off-roadway crash scenarios characterized by “initiating a maneuver” exceptionally tend to happen at rural intersections. This makes sense because vehicles were attempting turning maneuvers in the majority of such crashes.

**Table 5. Distribution of Target Off-Roadway Pre-Crash Scenarios on Non-Freeways by Land Use and Relation to Junction for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenarios	Land Use	Relationship to Junction					Total
		Non-Junction	Intersection	Driveway	Ent/Exit Ramp	Other	
Going Straight and Departed Road Edge (307,000)	Rural (55.6%)	88.9%	8.4%	0.5%	0.6%	1.6%	100.0%
	Urban (38.6%)	91.2%	8.1%	0.0%	0.4%	0.3%	100.0%
	Unknown (5.8%)	90.7%	7.7%	0.0%	0.0%	1.6%	100.0%
Going Straight and Lost Control (159,000)	Rural (72.5%)	88.5%	7.5%	0.3%	0.5%	3.2%	100.0%
	Urban (18.4%)	79.6%	14.1%	0.0%	1.4%	4.9%	100.0%
	Unknown (9.1%)	91.0%	6.2%	0.7%	0.0%	2.0%	100.0%
Negotiating a Curve and Lost Control (141,000)	Rural (75.4%)	92.4%	3.8%	0.1%	2.0%	1.8%	100.0%
	Urban (9.8%)	75.8%	9.7%	0.0%	13.1%	1.5%	100.0%
	Unknown (14.8%)	92.9%	0.8%	0.4%	5.9%	0.0%	100.0%
Negotiating a Curve and Departed Road Edge (104,000)	Rural (78.3%)	96.1%	2.3%	0.2%	0.5%	0.9%	100.0%
	Urban (12.3%)	86.0%	6.7%	0.6%	4.2%	2.5%	100.0%
	Unknown (9.4%)	96.8%	0.5%	0.0%	2.8%	0.0%	100.0%
Initiating a Manuever and Departed Road Edge (63,000)	Rural (53.5%)	30.7%	58.4%	10.8%	0.0%	0.0%	100.0%
	Urban (42.6%)	38.0%	54.6%	6.7%	0.1%	0.6%	100.0%
	Unknown (3.9%)	3.2%	83.0%	13.0%	0.0%	0.8%	100.0%
Initiating a Manuever and Lost Control (42,000)	Rural (65.8%)	23.7%	67.1%	4.7%	2.8%	1.7%	100.0%
	Urban (27.3%)	11.9%	77.9%	5.7%	1.4%	3.2%	100.0%
	Unknown (6.9%)	17.9%	75.1%	3.8%	0.0%	3.1%	100.0%
Average		82.1%	14.0%	1.1%	1.2%	1.6%	100.0%
Cumulative Total		670,000	114,000	9,000	10,000	13,000	816,000

**Table 6. Distribution of Target Off-Roadway Pre-Crash Scenarios on Freeways by Land Use and Relation to Junction for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Land Use	Relationship to Junction					Total
		Non-Junction	Intersection	Driveway	Ent/Exit Ramp	Other	
Going Straight and Departed Road Edge (41,000)	Rural (54.0%)	94.3%	0.3%	0.0%	3.2%	2.2%	100.0%
	Urban (30.0%)	92.5%	0.0%	0.0%	5.5%	2.0%	100.0%
	Unknown (16.0%)	93.8%	1.6%	0.0%	2.4%	2.2%	100.0%
Going Straight and Lost Control (59,000)	Rural (58.4%)	81.3%	1.9%	0.0%	6.6%	10.2%	100.0%
	Urban (25.9%)	84.9%	1.1%	0.0%	9.1%	5.0%	100.0%
	Unknown (15.7%)	95.3%	0.0%	0.0%	0.4%	4.3%	100.0%
Negotiating a Curve and Lost Control (21,000)	Rural (48.6%)	46.5%	0.9%	0.0%	51.3%	1.3%	100.0%
	Urban (33.0%)	61.6%	3.5%	0.0%	27.7%	7.3%	100.0%
	Unknown (18.4%)	65.3%	6.7%	0.0%	28.0%	0.0%	100.0%
Negotiating a Curve and Departed Road Edge (8,000)	Rural (51.4%)	70.3%	6.3%	0.0%	18.6%	4.7%	100.0%
	Urban (39.4%)	49.3%	3.1%	0.0%	45.1%	2.5%	100.0%
	Unknown (9.2%)	98.0%	0.0%	0.0%	2.0%	0.0%	100.0%
Initiating a Manuever and Departed Road Edge (3,000)	Rural (33.8%)	79.1%	14.2%	0.0%	6.7%	0.0%	100.0%
	Urban (48.4%)	70.5%	17.4%	0.0%	12.1%	0.0%	100.0%
	Unknown (17.8%)	95.9%	0.0%	0.0%	4.1%	0.0%	100.0%
Initiating a Manuever and Lost Control (8,000)	Rural (49.6%)	62.8%	12.1%	6.3%	16.6%	2.2%	100.0%
	Urban (40.8%)	64.7%	16.5%	0.0%	16.3%	2.4%	100.0%
	Unknown (9.6%)	61.6%	28.7%	0.0%	9.8%	0.0%	100.0%
Average		79.9%	2.9%	0.0%	12.2%	5.0%	100.0%
Cumulative Total		111,000	4,000	*	17,000	7,000	139,000

\* refers to a crash count below 500

Based on 1998 GES statistics, approximately 75,000, or 54.2% of all target off-roadway crashes on freeways occurred in rural areas. On the other hand, about 42,000, or 30.2% of all target off-roadway crashes on freeways happened in urban areas. The remaining 15.6% on freeways were coded as “unknown” in the 1998 GES *Land Use* variable. Table 6 breaks down the six most common off-roadway pre-crash scenarios on freeways for all vehicles by rural/urban locations and relation to junction. Approximately 79.9% of all target off-roadway crashes on freeways occurred away from junctions. Entrance and exit ramps experienced about 12.2% of all target off-roadway crashes on freeways. It should be noted that about 4,000, or 2.9% of all target off-roadway crashes on freeways occurred at intersections (see Table 6). Clearly, this statistic shows a very small error in our attempt to identify freeway road type using the variables that are



available in the 1998 GES as explained earlier in this report. As a result, it is recommended for future analyses that the definition of freeways also excludes intersection and driveway locations when using the GES.

### 2.3.3 NUMBER OF TRAVEL LANES

The *Number of Travel Lanes* variable in the 1998 GES was utilized to obtain information on the actual number of lanes of travel on freeways and non-freeways. This variable indicates the number of all the lanes regardless of their direction of travel if the trafficway is not divided, and only the number of lanes in the direction of travel if the trafficway is divided. Crash statistics on the number of travel lanes may influence the design of vehicle-based countermeasure systems that track vehicle position within the roadway boundaries and thus may affect their sensor's field of view.

Tables 7 and 8 present statistics on the distribution of the number of travel lanes in target off-roadway crashes that occurred respectively on undivided and divided non-freeways. About 63.9% of all target off-roadway crashes on undivided non-freeways were associated with two lanes of travel (one lane in each direction) based on 1998 GES estimates, as listed in Table 7. However 28.0% of all target off-roadway crashes on undivided non-freeways were coded as "unknown" in the 1998 GES *Number of Travel Lanes* variable. As a result, the relative frequency of crashes associated with two lanes of travel could be as high as 89% of all target off-roadway crashes on undivided non-freeways if "unknown" cases were excluded. On the other hand, only 36.2% of all target off-roadway crashes on divided non-freeways were linked to 2 lanes of travel (two lanes in same direction) as shown in Table 8. This percentage could be as high as 49% of all target off-roadway crashes on divided non-freeways if 25.2% of crash cases with "unknown" values were excluded. Table 8 also indicates that one and three lanes of travel were related to substantial 14.5% and 18.9% of all target off-roadway crashes on divided non-freeways, respectively. Also, the two lanes of travel were the most dominant in each of the six target off-roadway pre-crash scenarios on undivided and divided non-freeways. In addition, the one lane of travel was second most dominant in "negotiating a curve" crash scenarios while three lanes of travel were second most dominant in "going straight" and "initiating a maneuver" pre-crash scenarios on divided non-freeways with the exception of "initiating a maneuver and lost control."

**Table 7. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Undivided Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	>7	unk.		
Going straight and departed road edge	0.7%	54.7%	2.0%	4.6%	1.6%	0.2%	0.0%	36.0%	100.0%	277,000
Going straight and lost control	0.8%	70.2%	2.1%	3.6%	1.4%	0.2%	0.3%	21.2%	100.0%	144,000
Negotiating a curve and lost control	0.3%	77.4%	1.5%	1.5%	0.1%	0.0%	0.1%	19.2%	100.0%	128,000
Negotiating a curve and departed road edge	0.0%	78.5%	0.8%	1.6%	0.1%	0.1%	0.0%	18.9%	100.0%	98,000
Initiating a maneuver and departed road edge	0.8%	40.6%	3.9%	6.7%	3.6%	0.9%	0.5%	43.0%	100.0%	53,000
Initiating a maneuver and lost control	0.6%	54.4%	5.4%	4.9%	5.4%	1.0%	1.5%	26.8%	100.0%	36,000
Average	0.6%	63.9%	2.1%	3.7%	1.4%	0.2%	0.2%	28.0%	100.0%	
Cumulative Total	4,000	469,000	15,000	27,000	11,000	2,000	1,000	206,000		735,000

**Table 8. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Divided Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	>7	unk.		
Going straight and departed road edge	12.1%	35.3%	19.8%	6.0%	0.3%	1.2%	0.0%	25.2%	100.0%	30,000
Going straight and lost control	6.6%	45.1%	22.2%	4.7%	0.4%	0.0%	0.0%	21.1%	100.0%	15,000
Negotiating a curve and lost control	30.3%	30.0%	13.3%	2.0%	0.6%	0.0%	0.0%	23.8%	100.0%	13,000
Negotiating a curve and departed road edge	20.6%	43.8%	10.4%	1.6%	0.0%	0.0%	0.0%	23.7%	100.0%	6,000
Initiating a maneuver and departed road edge	7.6%	32.4%	24.9%	2.3%	0.9%	0.0%	0.0%	31.9%	100.0%	10,000
Initiating a maneuver and lost control	17.6%	32.0%	17.0%	5.4%	0.0%	0.0%	0.0%	27.9%	100.0%	7,000
Average	14.5%	36.2%	18.9%	4.3%	0.4%	0.5%	0.0%	25.2%	100.0%	
Cumulative Total	12,000	30,000	15,000	3,000	*	*	*	21,000		82,000

\* refers to a crash count below 500

Table 9 provides statistics on the distribution of the number of travel lanes in target off-roadway crashes that occurred on freeways based on 1998 GES estimates. About 48.3% of all target off-roadway crashes on freeways were connected to two lanes of travel (two lanes in same direction). Unlike non-freeway crashes, only 4.8% of all target off-roadway crashes on freeways were coded as “unknown” in the 1998 GES *Number of Travel Lanes* variable. High frequencies with at least 10,000 target off-roadway crashes were observed in one, three, and four lanes of travel on freeways as seen in Table 9. The two lanes of travel were also the most dominant in each of the six target off-roadway pre-crash scenarios on freeways. The one lane of travel was the second most dominant in the “negotiating a curve” pre-crash scenario while the three lanes of travel was the second most prevalent in “going straight” and “initiating a maneuver and lost control” pre-crash scenarios.

**Table 9. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	>7	unk.		
Going straight and departed road edge	4.3%	57.6%	20.0%	8.2%	5.9%	0.4%	0.0%	3.6%	100.0%	41,000
Going straight and lost control	4.5%	48.3%	23.3%	13.6%	3.8%	1.3%	0.8%	4.3%	100.0%	59,000
Negotiating a curve and lost control	27.2%	37.8%	18.8%	7.0%	1.6%	0.0%	0.0%	7.6%	100.0%	21,000
Negotiating a curve and departed road edge	28.4%	42.3%	17.7%	7.1%	0.1%	0.0%	0.0%	4.3%	100.0%	8,000
Initiating a maneuver and departed road edge	6.6%	52.3%	12.4%	16.0%	6.3%	3.1%	0.0%	3.4%	100.0%	3,000
Initiating a maneuver and lost control	8.7%	33.9%	27.3%	16.3%	5.5%	0.0%	0.0%	8.3%	100.0%	8,000
Average	9.5%	48.3%	21.4%	10.9%	4.0%	0.7%	0.3%	4.8%	100.0%	
Cumulative Total	13,000	67,000	30,000	15,000	6,000	1,000	*	7,000		139,000

\* refers to a crash count below 500

### 2.3.4 POSTED SPEED LIMIT

Another physical setting investigated was the posted speed limit of the road segment where the crash occurred, so as to infer whether target off-roadway crashes were coupled with high vehicle speeds. The *Hotdeck Imputed Speed Limit* variable in the 1998 GES provides such information. Table 10 presents a distribution of posted speed limits in target off-roadway crashes on non-freeways based on 1998 GES statistics. This report does not provide such information for

freeways since, by our definition, target off-roadway crashes on freeways occurred at speed limits greater than or equal to 55 mph.

The 55 mph speed limit was the most dominant at approximately 24.7% of all target off-roadway crashes on non-freeways. This was followed by about 21.2% of all target off-roadway crashes on non-freeways at locations posted with 25 mph. The 35 mph posted speed limit was the third most dominant, associated with 16.5% of all target off-roadway crashes on non-freeways. As seen in Table 10, the 55 mph posted speed limit was the most prevalent (> 30%) in “going straight and lost control” and “negotiating a curve” pre-crash scenarios. In contrast, the 25 mph posted speed limit dominated at greater than 24% in “going straight and departed road edge” and “initiating a maneuver” pre-crash scenarios. This last result is expected for “initiating a maneuver” pre-crash scenarios because they mostly occur at intersections. It is interesting, though, that the most dominant speed limit in the “going straight and departed road edge” pre-crash scenario was much lower than that of the “going straight and lost control” and “negotiating a curve” pre-crash scenarios.

**Table 10. Distribution of Posted Speed Limit in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Posted Speed Limit (mph)											Total	Cumulative Total
	≤20	25	30	35	40	45	50	55	60	65	>65		
Going straight and departed road edge	3.2%	28.1%	12.7%	16.0%	5.2%	11.1%	2.7%	17.8%	0.8%	1.6%	0.9%	100.0%	307,000
Going straight and lost control	1.2%	14.7%	7.4%	14.7%	4.8%	13.2%	6.5%	34.4%	0.4%	1.9%	0.9%	100.0%	159,000
Negotiating a curve and lost control	2.5%	11.8%	9.7%	18.0%	6.6%	14.0%	3.1%	32.9%	0.4%	0.9%	0.1%	100.0%	141,000
Negotiating a curve and departed road edge	4.3%	12.9%	8.3%	15.4%	5.9%	15.6%	1.6%	33.7%	0.9%	0.8%	0.6%	100.0%	104,000
Initiating a maneuver and departed road edge	5.1%	36.0%	13.5%	21.6%	5.6%	8.7%	2.3%	5.8%	0.5%	0.3%	0.6%	100.0%	63,000
Initiating a maneuver and lost control	5.9%	24.4%	8.8%	17.1%	8.4%	14.1%	2.9%	17.2%	0.2%	0.7%	0.5%	100.0%	42,000
Average	3.1%	21.2%	10.4%	16.5%	5.7%	12.5%	3.3%	24.7%	0.6%	1.3%	0.7%	100.0%	
Cumulative Total	25,000	173,000	185,000	135,000	46,000	102,000	27,000	202,000	5,000	10,000	6,000		816,000

## 2.4 CRASH CONTRIBUTING FACTORS

This analysis relied on 1998 GES variables to identify factors that may have contributed to the cause of target off-roadway crashes. It is noteworthy that the GES does not contain variables that indicate the primary cause of the crash. Thus, some 1998 GES variables were investigated that point to a number of crash contributing factors including the *Hotdeck Imputed Police Reported Alcohol Involvement*, *Person’s Physical Impairment*, *Driver Distracted By*, *Speed Related*, and *Imputed Hit and Run* variables. The *Hotdeck Imputed Police Reported Alcohol Involvement* variable indicates that a driver had consumed an alcoholic beverage. The *Person’s Physical Impairment* variable attempts to identify driver physical impairments that may have contributed to the cause of the crash such as illness, blackouts, drowsiness, fatigue, or impairment due to previous injury. The *Driver Distracted By* variable attempts to capture distractions that may have influenced driver performance and contributed to the cause of the crash. These distractions include passengers, vehicle instrument display, phone, other internal distractions, other crash, or external distractions. The *Speed Related* variable captures whether or not vehicle speed was a factor in the crash. The *Imputed Hit and Run* variable is coded when a motor vehicle in transport or its driver departs from the scene of the crash. If the driver leaves the scene, with or without the vehicle, the police accident report typically contains little information about the drivers’ actions, and therefore contributing factors are generally unknown.

However, very few cases of hit and run crashes in the GES might contain information on whether or not the driver was drunk or impaired typically reported by eyewitnesses.

This analysis deducted one dominant contributing factor for each crash based on a priority scheme that ranked contributing factors in descending order:

- Alcohol or drugs
- Driver impairment
- Driver distraction
- Speeding
- Hit and run

First, this analysis determined the portion of target off-roadway crashes that involved alcohol or drugs and then adopted a process of elimination to quantify the involvement of other factors. Thus, the remaining target off-roadway crashes were examined to identify the portion of crashes that were attributed to driver impairment. After, the involvement of each of the other factors (driver distraction, speeding, and hit and run) was sequentially determined from the remaining crashes. Finally, the remaining crashes, not linked to any of these contributing factors, were separated by various environmental factors to establish other circumstances that might have potentially contributed to target off-roadway crashes. Thus, this approach is an attempt to identify dominant factors that might have contributed to the cause of the crash by deductive reasoning and not to describe the environmental circumstances of the crash. This analysis considered the combination of the *Imputed Light Condition*, *Imputed Atmospheric Conditions*, and *Imputed Roadway Surface Condition* variables from the 1998 GES. The *Imputed Light Condition* variable denotes general light conditions at the time of the crash, taking into consideration the existence of external roadway illumination fixtures. All non-daylight conditions, including dark but lighted, dusk, and dawn, were grouped as “dark.” The *Imputed Atmospheric Conditions* variable points to general atmospheric conditions at the time of the crash such as clear or adverse weather. All adverse weather conditions—rain, sleet, snow, fog, and smog—were categorized as “adverse.” The *Imputed Roadway Surface Condition* variable identifies whether the roadway surface is dry or slippery at the time of the crash. Slippery surfaces consist of wet, snowy, icy, or oily roadways. The combination of lighting and weather conditions constitute another important crash contributing factor, both of which may make it difficult to see the edge of the road or upcoming curves. In addition, slippery road conditions make some control loss crashes more likely.

#### **2.4.1 NON-FREEWAYS**

Speeding was the most dominant contributing factor in 22.6% of all target off-roadway crashes on non-freeways according to 1998 GES, as listed in Table 11. This percentage of crashes excludes cases that involved speeding in combination with alcohol or drugs, driver impairment, driver distraction, or hit and run. Alcohol or drugs contributed to about 19.7% of all target off-roadway crashes on non-freeways. Driver distraction was cited in only about 6.2% of all target off-roadway crashes on non-freeways. The GES generally underestimates driver distraction as a contributing factor because distraction is rarely noted in police accident reports. The CDS usually reports higher rates of driver inattention/distraction than the GES. For instance, such a

factor might have caused about 18% of all crashes based on 1997 CDS. Driver impairment was reported in about 5.2% of target off-roadway crashes on non-freeways in 1998. As seen in Table 11, alcohol or drugs was the most dominant factor in target crash scenarios associated with “departed road edge” as the critical event. On the other hand, speeding was the most prevalent factor in target crash scenarios characterized by “lost control” as the critical event.

The driver did not hit an object and fled the scene of the crash, was not drunk, impaired, distracted, or speeding in about 308,000 or 37.8% of all target off-roadway crashes on non-freeways, noted as “other” in Table 11. Environmental conditions were explored in an attempt to deduce whether these conditions played a role in “other” crashes. The results showed that about 195,000 or 63.2% of “other” target off-roadway crashes on non-freeways occurred in adverse weather, slippery surface, or dark conditions as indicated in Table 12. The remaining 113,000 or 36.8% of these crashes happened in clear weather, in daylight, and on dry roadway surface. Thus, one may assume that driving inexperience or some sort of inattention or distraction contributed to the cause of these 113,000 target off-roadway crashes on non-freeways.

**Table 11. Distribution of Contributing Factors in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Contributing Factors/Driver Circumstance						Total	Cumulative Total
	Alcohol or drugs	Driver impaired	Driver Distracted	Speeding	Hit/Run	Other		
Going straight and departed road edge	23.4%	9.0%	9.3%	10.2%	15.8%	32.3%	100.0%	307,000
Going straight and lost control	17.9%	2.4%	3.2%	29.1%	3.3%	44.1%	100.0%	159,000
Negotiating a curve and lost control	14.4%	1.7%	4.1%	42.0%	1.2%	36.6%	100.0%	141,000
Negotiating a curve and departed road edge	23.4%	6.6%	6.9%	25.8%	3.9%	33.5%	100.0%	104,000
Initiating a maneuver and departed road edge	13.7%	1.3%	3.9%	9.9%	14.8%	56.5%	100.0%	63,000
Initiating a maneuver and lost control	16.7%	1.2%	2.6%	34.6%	3.7%	41.1%	100.0%	42,000
Average	19.7%	5.2%	6.2%	22.6%	8.6%	37.8%	100.0%	
Cumulative Total	160,000	42,000	50,000	185,000	70,000	308,000		816,000

Slippery roadway conditions were reported in about 126,000 or 41.2% of all “other” target off-roadway crashes on non-freeways. Such conditions hinder the ability of the driver to maintain control of the vehicle, especially when negotiating a curve or initiating a maneuver. Dark lighting conditions and adverse weather conditions accounted for 122,000 or 39.6% and 85,000 or 27.9% of these crashes, respectively. These two conditions affect visibility that may cause drivers to run off the road. As seen in Table 12, “other” target pre-crash scenarios on non-freeways in which the vehicle simply departed the road edge were more likely to occur in clear weather, in daylight, and on dry roadway surface than in any other combination of environmental conditions. On the other hand, “other” crashes that belong to “going straight and lost control” and “negotiating a curve and lost control” pre-crash scenarios were more likely to occur in

adverse weather, in daylight, and on slippery roadway surface than in any other combination of environmental conditions on non-freeways.

**Table 12. Distribution of Environmental Conditions in “Other” Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	51.1%	3.4%	0.8%	4.4%	29.9%	3.0%	0.8%	6.6%	100.0%	99,000
Going straight and lost control	19.0%	14.3%	0.7%	24.1%	14.7%	7.2%	1.0%	19.0%	100.0%	70,000
Negotiating a curve and lost control	15.2%	15.0%	0.0%	27.5%	10.9%	11.2%	0.3%	19.9%	100.0%	52,000
Negotiating a curve and departed road edge	46.0%	4.5%	0.1%	10.3%	27.6%	3.3%	0.4%	7.8%	100.0%	35,000
Initiating a maneuver and departed road edge	58.7%	4.6%	0.0%	6.4%	22.1%	4.1%	0.0%	4.1%	100.0%	36,000
Initiating a maneuver and lost control	27.3%	15.1%	0.5%	17.4%	10.5%	4.4%	1.2%	23.7%	100.0%	17,000
Average	36.8%	8.8%	0.5%	14.4%	21.0%	5.6%	0.6%	12.4%	100.0%	
Cumulative Total	113,000	27,000	1,000	44,000	65,000	17,000	2,000	38,000		308,000

The combination of pre-crash scenarios and contributing factors enables researchers to devise appropriate countermeasure concepts. Due to the six most common pre-crash scenarios and wide variety of major contributing factors, multiple countermeasures are needed to alleviate target off-roadway crashes. For instance, lane or road edge departure warning systems address pre-crash scenarios that are characterized by “road edge departure” as the critical event. Excessive speed warning systems dealing with the existing conditions of the driving environment may mitigate “control loss” pre-crash scenarios. Table 13 presents statistics on environmental conditions surrounding target off-roadway crashes that were attributed to speeding on non-freeways. About 47% of these crashes attributed to speeding occurred on slippery surfaces. Vision enhancement systems that improve driver vision in reduced visibility conditions and advanced vehicle stability control systems that improve vehicle handling on slippery roadway surfaces may deal with a portion of target off-roadway crashes occurring under these circumstances. The effectiveness of these systems highly depends on the physiological state of the driver. Thus, these systems may not be as effective if drivers were drunk or drowsy. In such cases, intoxicated or drowsy driver monitoring systems may be more appropriate and effective.

**Table 13. Distribution of Environmental Conditions in Target Off-Roadway Pre-Crash Scenarios Attributed to Speeding on Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	33.1%	5.1%	0.0%	12.3%	32.8%	4.8%	1.2%	10.9%	100.0%	31,000
Going straight and lost control	19.5%	15.9%	0.2%	17.6%	20.0%	10.9%	0.1%	15.8%	100.0%	46,000
Negotiating a curve and lost control	24.6%	13.9%	0.0%	19.8%	20.3%	7.8%	0.5%	13.2%	100.0%	59,000
Negotiating a curve and departed road edge	41.7%	5.8%	0.0%	9.3%	28.7%	3.2%	0.3%	11.1%	100.0%	27,000
Initiating a maneuver and departed road edge	37.8%	3.7%	0.0%	3.1%	36.6%	7.7%	0.0%	11.1%	100.0%	6,000
Initiating a maneuver and lost control	26.1%	15.6%	0.0%	22.4%	21.8%	3.1%	0.0%	11.1%	100.0%	15,000
Average	27.8%	11.5%	0.1%	16.1%	24.2%	7.0%	0.4%	12.9%	100.0%	
Cumulative Total	51,000	21,000	*	30,000	45,000	13,000	1,000	24,000		185,000

\* refers to a crash count below 500

## 2.4.2 FREEWAYS

Based on 1998 GES statistics, speeding and alcohol or drugs contributed to 34.0% and 12.8% respectively of all target off-roadway crashes on freeways as shown in Table 14. The relative frequency of speeding was higher on freeways than non-freeways. Conversely, the relative frequency of alcohol or drugs was lower on freeways than non-freeways. There were also fewer cases of hit and run on freeways. Driver impairment was connected to about 8.2% of all target off-roadway crashes on freeways and dominated in “going straight and departed road edge” pre-crash scenario. On the other hand, speeding was the most dominant in all control loss pre-crash scenarios (37.8%) and in “negotiating a curve and departed road edge” pre-crash scenario (21.2%) on freeways. Driver distraction was reported in about 4.1% of all target off-roadway crashes on freeways and prevailed in “initiating a maneuver and departed road edge” pre-crash scenario.

**Table 14. Distribution of Contributing Factors in Target Off-Roadway Pre-Crash Scenarios on Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Contributing Factors/Driver Circumstance						Total	Cumulative Total
	Alcohol or drugs	Driver impaired	Driver Distracted	Speeding	Hit/Run	Other		
Going straight and departed road edge	19.4%	21.2%	6.7%	17.4%	1.3%	34.1%	100.0%	41,000
Going straight and lost control	8.9%	1.9%	2.1%	42.5%	1.2%	43.4%	100.0%	59,000
Negotiating a curve and lost control	11.7%	1.3%	2.2%	47.7%	0.4%	36.8%	100.0%	21,000
Negotiating a curve and departed road edge	18.7%	16.2%	10.4%	21.2%	0.0%	33.4%	100.0%	8,000
Initiating a maneuver and departed road edge	4.2%	0.9%	15.6%	19.1%	3.5%	56.7%	100.0%	3,000
Initiating a maneuver and lost control	9.2%	0.0%	1.0%	38.2%	1.0%	50.7%	100.0%	8,000
Average	12.8%	8.2%	4.1%	34.0%	1.0%	39.8%	100.0%	
Cumulative Total	18,000	11,000	6,000	47,000	1,000	55,000		139,000

Table 14 indicates that the driver did not hit an object and fled the scene of the crash, was not drunk, impaired, distracted, or speeding in about 39.8% of all target off-roadway crashes on freeways. The analysis of environmental conditions in “other” target off-roadway crashes on freeways revealed that about 39,000 or 71.5% of these crashes occurred in adverse weather, slippery surface, or dark conditions, as indicated in Table 15. The remaining 16,000 crashes happened in clear weather, daylight, and on a dry roadway surface. Slippery roadway conditions were reported in about 29,000, or 50.6% of “other” target off-roadway crashes on freeways. Dark lighting conditions and adverse weather conditions accounted for 25,000 (45.7%) and 22,000 (38.8%) of these crashes, respectively. The relative frequencies of these three conditions were higher on freeways than non-freeways. As observed on non-freeways, “other” target pre-crash scenarios on freeways in which the vehicle simply departed the road edge were more likely to occur in clear weather, in daylight, and on dry roadway surface than in any other combination of environmental conditions. On the other hand, “other” crashes that belong to “going straight and lost control” pre-crash scenarios were more likely to occur in adverse weather, in dark, and on slippery roadway surface than in any other combination of environmental conditions on freeways. The “negotiating a curve and lost control” pre-crash scenario on freeways mostly occurred in adverse weather, in daylight, and on slippery roadway surface conditions. Table 16 presents statistics on environmental conditions surrounding target off-roadway crashes that were attributed to speeding on freeways based on 1998 GES. About 71% of these crashes associated with speed happened on slippery surfaces, which was higher on freeways than non-freeways.



**Table 15. Distribution of Environmental Conditions in “Other” Target Off-Roadway Pre-Crash Scenarios on Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	47.0%	0.1%	0.5%	10.3%	32.1%	3.9%	0.4%	5.7%	100.0%	14,000
Going straight and lost control	19.3%	8.5%	0.3%	22.7%	16.2%	6.8%	0.3%	26.0%	100.0%	25,000
Negotiating a curve and lost control	12.0%	8.8%	0.0%	30.9%	15.4%	9.3%	0.0%	23.6%	100.0%	8,000
Negotiating a curve and departed road edge	50.6%	2.8%	0.0%	7.7%	27.2%	6.3%	0.0%	5.4%	100.0%	3,000
Initiating a maneuver and departed road edge	24.2%	0.0%	4.0%	12.2%	23.5%	0.0%	0.0%	36.1%	100.0%	2,000
Initiating a maneuver and lost control	40.7%	15.2%	0.0%	13.0%	10.9%	4.2%	0.0%	16.0%	100.0%	4,000
Average	28.5%	6.4%	0.4%	19.0%	20.3%	6.0%	0.2%	19.2%	100.0%	
Cumulative Total	16,000	4,000	*	11,000	11,000	3,000	*	11,000		55,000

\* refers to a crash count below 500

**Table 16. Distribution of Environmental Conditions in Target Off-Roadway Pre-Crash Scenarios Cited with Speeding on Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	39.9%	2.5%	0.6%	21.1%	22.4%	0.1%	0.0%	13.4%	100.0%	7,000
Going straight and lost control	11.8%	10.8%	0.0%	36.5%	6.7%	9.8%	0.0%	24.4%	100.0%	25,000
Negotiating a curve and lost control	14.0%	13.0%	0.0%	32.8%	9.9%	9.6%	0.0%	20.8%	100.0%	10,000
Negotiating a curve and departed road edge	46.5%	0.2%	0.0%	4.6%	17.4%	0.0%	0.0%	31.3%	100.0%	2,000
Initiating a maneuver and departed road edge	36.9%	0.0%	0.0%	11.9%	51.2%	0.0%	0.0%	0.0%	100.0%	1,000
Initiating a maneuver and lost control	16.8%	9.0%	0.0%	35.0%	11.8%	5.8%	0.0%	21.6%	100.0%	3,000
Average	18.3%	9.4%	0.1%	31.9%	10.9%	7.6%	0.0%	21.8%	100.0%	
Cumulative Total	9,000	4,000	*	15,000	5,000	4,000	*	10,000		47,000

\* refers to a crash count below 500

## 2.5 POST-ROADWAY DEPARTURE EVENTS

The post-roadway departure events of the six most common pre-crash scenarios of target off-roadway crashes were described in terms of the departure side (left/right/end), first harmful event, and maximum injury severity using variables in the 1998 GES. These events were described as thoroughly as possible utilizing combinations of existing GES variables.

### 2.5.1 DEPARTURE SIDE

The departure side of target off-roadway pre-crash scenarios was determined from the GES *Critical Event* and *Accident Type* variables. The *Critical Event* variable was first queried to provide this information, which yielded values of left, right, or end departure. End departures occur at T-type intersections. The *Accident Type* variable was only used when the *Critical Event* variable did not have departure side information for some crash cases. The departure side was entered as “unknown” in some cases when not coded in either of these two variables. Information on roadway side departure is useful to determine the field of view for vehicle-based countermeasure systems.

Table 17 shows the departure side of non-freeway off-roadway crashes for all vehicles based on 1998 GES. The right edge departure dominated in all pre-crash scenarios and captured the largest overall average with 61.3% of all off-roadway crashes on non-freeways. Vehicles involved in “control loss” pre-crash scenarios had a greater tendency to depart on the left side of the roadway than in “road edge departure” scenarios, owing to the more erratic nature of vehicle control loss. Target off-roadway crashes on non-freeways were more likely to involve right edge departure due to the general profile of the roadway sloping to the right causing lack of driver input or attention to result in drifting to the right. The departure side was unknown in 6.9% of all target off-roadway crashes on non-freeways and was particularly high in “going straight and lost control” and “initiating a maneuver and lost control” pre-crash scenarios.

**Table 17. Distribution of Departure Side in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Departure Side				Total	Cumulative Total
	Left edge	Right edge	End departure	Unknown		
Going straight and departed road edge	22.9%	66.9%	4.2%	6.0%	100.0%	307,000
Going straight and lost control	35.9%	50.4%	2.0%	11.8%	100.0%	159,000
Negotiating a curve and lost control	37.8%	56.2%	0.4%	5.7%	100.0%	141,000
Negotiating a curve and departed road edge	27.3%	69.0%	0.8%	2.9%	100.0%	104,000
Initiating a maneuver and departed road edge	26.7%	66.3%	2.1%	4.9%	100.0%	63,000
Initiating a maneuver and lost control	34.3%	52.7%	0.9%	12.1%	100.0%	42,000
Average	29.4%	61.3%	2.3%	6.9%	100.0%	
Cumulative Total	240,000	500,000	19,000	57,000		816,000

Table 18 presents the statistical breakdown of departure side in target off-roadway crashes on freeways based on 1998 GES. The obvious difference from non-freeway off-roadway crashes is the overall dominance of left edge departure that accounted for 49.2% of these crashes. Moreover, the left edge departure was the most prevalent in all pre-crash scenarios except the “going straight and departed road edge” pre-crash scenario. The general trend toward left edge departures could be due to the multi-lane nature of freeways, where vehicles traveling in the left lane have a smaller shoulder than those in the right lane and, consequently, have less recovery room.

**Table 18. Distribution of Departure Side in Target Off-Roadway Pre-Crash Scenarios on Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Departure Side				Total	Cumulative Total
	Left edge	Right edge	End departure	Unknown		
Going straight and departed road edge	46.2%	53.1%	0.3%	0.5%	100.0%	41,000
Going straight and lost control	50.4%	45.5%	0.0%	4.2%	100.0%	59,000
Negotiating a curve and lost control	49.4%	48.6%	0.0%	2.0%	100.0%	21,000
Negotiating a curve and departed road edge	50.5%	47.1%	0.0%	2.4%	100.0%	8,000
Initiating a maneuver and departed road edge	61.3%	38.7%	0.0%	0.0%	100.0%	3,000
Initiating a maneuver and lost control	50.4%	41.8%	0.0%	7.8%	100.0%	8,000
Average	49.2%	47.9%	0.1%	2.8%	100.0%	
Cumulative Total	68,000	67,000	*	4,000		139,000

\* refers to a crash count below 500

## 2.5.2 FIRST HARMFUL EVENT

The first harmful event was determined using the *Imputed First Harmful Event* variable in the 1998 GES. This variable indicates the first property damaging or injury-producing event, excluding unknown values. These events were grouped into three categories: non-collision, collision with object not fixed, and collision with fixed object. By understanding the first harmful event of crashes, countermeasures can be better designed to search for, monitor, and warn of these hazards.

Parked vehicles were the most dominant first harmful event in target off-roadway crashes on non-freeways and accounted for 23% of these crashes as shown in Table 19. The second most frequent event was crashes into signposts with 15.4%. Crashes with a culvert or ditch and trees also commanded a large number of crashes with 11.3% and 10.9%, respectively.

Table 20 illustrates the breakdown of first harmful events on freeways for all vehicles based on 1998 GES. Vehicles struck guardrails and concrete traffic barriers in 41.2% of all target off-roadway crashes on freeways. Off-road rollovers and the combined culverts or ditches, signposts, and trees accounted respectively for 11.3% and 21.0% of these crashes. Even on freeways, parked vehicles were reported struck in 5.5% of these crashes.

**Table 19. Distribution of First Harmful Events by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for All Vehicles (Based on 1998 GES)**

First Harmful Event		Pre-Crash Scenario						Average	Cumulative Total
		1	2	3	4	5	6		
Non-collision	Rollover	2.8%	10.4%	9.4%	7.6%	2.7%	6.9%	6.2%	51,000
	Immersion	0.0%	0.0%	0.1%	0.0%	0.0%	0.5%	0.1%	1,000
	Jackknife	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	*
	Other	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.1%	*
Object Not Fixed	Pedestrian	0.4%	0.0%	0.0%	0.1%	0.7%	0.0%	0.2%	2,000
	Cyclist	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	*
	Animal	0.0%	0.3%	0.2%	0.0%	0.0%	0.0%	0.1%	1,000
	Veh in Transport	0.0%	0.2%	0.1%	0.0%	0.1%	0.0%	0.1%	1,000
	Parked Vehicle	42.5%	8.3%	3.0%	8.9%	42.7%	8.9%	23.0%	188,000
	Other/Non Mot.	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Other Object	0.1%	0.5%	0.0%	0.3%	0.0%	0.3%	0.2%	2,000
Crash With Fixed Object	Ground	0.1%	0.2%	0.2%	0.1%	0.0%	0.2%	0.1%	1,000
	Building	0.6%	0.7%	0.4%	0.6%	1.2%	1.4%	0.7%	6,000
	Impact Attenuation	0.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.1%	1,000
	Bridge Structure	0.8%	1.8%	0.6%	0.7%	0.2%	1.4%	0.9%	8,000
	Guardrail	2.9%	6.1%	11.9%	6.7%	3.0%	9.1%	5.9%	48,000
	Concr Traffic Barrier	0.9%	1.6%	2.2%	0.8%	1.6%	4.2%	1.4%	12,000
	Sign Post	14.6%	15.2%	12.4%	16.6%	22.3%	19.3%	15.4%	126,000
	Culvert or Ditch	8.4%	14.9%	14.1%	15.9%	6.0%	5.2%	11.3%	92,000
	Curb	4.2%	4.3%	4.7%	2.8%	6.5%	13.8%	4.8%	39,000
	Embankment	2.5%	5.5%	13.3%	8.3%	0.5%	4.1%	5.6%	46,000
	Fence	3.3%	6.8%	4.3%	4.7%	1.8%	7.4%	4.4%	36,000
	Wall	0.9%	1.4%	0.7%	1.1%	1.0%	1.4%	1.0%	8,000
	Fire Hydrant	0.7%	1.3%	0.5%	0.7%	3.8%	1.6%	1.1%	9,000
	Shrubbery/Bush	0.7%	0.3%	0.3%	0.4%	0.7%	0.9%	0.5%	4,000
	Tree	7.5%	13.2%	15.1%	16.5%	4.0%	10.0%	10.9%	89,000
	Boulder	0.3%	0.5%	1.2%	1.4%	0.2%	0.4%	0.6%	5,000
	Pavement Irregularity	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	*
Other Fixed Object	4.9%	5.1%	4.1%	5.1%	1.0%	2.7%	4.4%	36,000	
Fix Object-No Detail	0.6%	1.3%	0.7%	0.4%	0.0%	0.6%	0.7%	5,000	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Cumulative Total		307,000	159,000	141,000	104,000	63,000	42,000		816,000

**Key to Scenarios**

1	Going straight and departed road edge
2	Going straight and lost control
3	Negotiating a curve and lost control
4	Negotiating a curve and departed road edge
5	Initiating a maneuver and departed road edge
6	Initiating a maneuver and lost control

\* refers to a crash count below 500

**Table 20. Distribution of First Harmful Events by Target Off-Roadway Pre-Crash Scenarios on Freeways for All Vehicles (Based on 1998 GES)**

First Harmful Event		Pre-Crash Scenario						Average	Cumulative Total
		1	2	3	4	5	6		
Non-collision	Rollover	12.9%	11.5%	9.7%	8.6%	6.0%	10.2%	11.3%	16,000
	Immersion	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Jackknife	0.0%	0.7%	0.3%	0.0%	0.0%	0.1%	0.3%	*
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
Object Not Fixed	Pedestrian	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Cyclist	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Animal	0.0%	0.2%	0.4%	0.0%	0.0%	0.0%	0.1%	*
	Veh in Transport	0.0%	0.6%	0.2%	0.1%	0.0%	0.0%	0.3%	*
	Parked Vehicle	11.7%	2.5%	0.9%	2.8%	18.7%	5.6%	5.5%	8,000
	Other/Non Mot.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Other Object	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	*
Crash With Fixed Object	Ground	0.3%	0.3%	0.0%	0.5%	0.0%	0.0%	0.2%	*
	Building	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	*
	Impact Attenuation	1.0%	0.2%	0.0%	1.2%	7.0%	0.0%	0.6%	1,000
	Bridge Structure	2.0%	5.4%	1.3%	1.2%	0.0%	1.8%	3.2%	4,000
	Guardrail	22.7%	21.5%	26.8%	25.3%	12.0%	18.1%	22.5%	31,000
	Concr Traffic Barrier	9.9%	22.1%	24.1%	10.7%	20.2%	31.7%	18.7%	26,000
	Sign Post	10.2%	3.5%	8.1%	17.4%	24.5%	0.1%	7.1%	10,000
	Culvert or Ditch	7.2%	8.5%	7.0%	3.5%	5.6%	3.5%	7.3%	10,000
	Curb	2.1%	3.7%	5.9%	2.3%	2.0%	6.0%	3.6%	5,000
	Embankment	3.8%	4.9%	4.4%	7.8%	0.0%	7.2%	4.7%	7,000
	Fence	2.9%	2.6%	2.4%	1.1%	0.0%	1.1%	2.4%	3,000
	Wall	1.5%	1.7%	3.4%	5.9%	0.0%	8.2%	2.5%	3,000
	Fire Hydrant	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Shrubbery/Bush	0.5%	0.4%	1.4%	0.0%	0.0%	0.0%	0.5%	1,000
	Tree	7.3%	7.4%	3.5%	8.8%	0.7%	6.4%	6.6%	9,000
	Boulder	0.5%	0.5%	0.4%	0.0%	0.0%	0.0%	0.4%	1,000
	Pavement Irregularity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Other Fixed Object	2.1%	1.8%	0.0%	2.9%	3.4%	0.0%	1.6%	2,000
Fix Object-No Detail	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	*	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Cumulative Total		41,000	59,000	21,000	8,000	3,000	8,000		139,000

**Key to Scenarios**

1	Going straight and departed road edge
2	Going straight and lost control
3	Negotiating a curve and lost control
4	Negotiating a curve and departed road edge
5	Initiating a maneuver and departed road edge
6	Initiating a maneuver and lost control

\* refers to a crash count below 500

### 2.5.3 MAXIMUM INJURY SEVERITY

The maximum injury severity was determined using the GES *Imputed Maximum Injury Severity in Crash* variable. This variable indicates the most severe injury sustained by all persons involved in the crash, excluding unknown values. Table 21 provides the distribution of maximum injury severity sustained in target off-roadway crashes on non-freeways based on 1998 GES. Property damage only or no injury was reported in 63.4% of these crashes. The “negotiating a curve and departed road edge” pre-crash scenario had the most injury crashes among all scenarios. About 49% of crashes in this scenario resulted in some form of injury. The “initiating a maneuver and departed road edge” pre-crash scenario had the lowest injury rate. Generally, “initiating a maneuver” pre-crash scenarios had the least harmful crashes due to the low speed nature of these crashes.

**Table 21. Distribution of Maximum Injury Severity by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Maximum Injury Severity						Total	Cumulative Total
	None	Possible	Non-incapacitating	Incapacitating	Fatal	Unknown		
Going straight and departed road edge	65.3%	12.6%	14.2%	6.2%	0.8%	1.0%	100.0%	307,000
Going straight and lost control	59.8%	14.0%	17.0%	7.4%	1.2%	0.7%	100.0%	159,000
Negotiating a curve and lost control	61.1%	11.8%	15.8%	9.1%	1.7%	0.5%	100.0%	141,000
Negotiating a curve and departed road edge	50.8%	17.7%	18.6%	9.9%	1.9%	1.1%	100.0%	104,000
Initiating a maneuver and departed road edge	83.0%	7.5%	6.4%	2.4%	0.0%	0.8%	100.0%	63,000
Initiating a maneuver and lost control	72.3%	9.9%	10.2%	6.2%	0.6%	0.9%	100.0%	42,000
Average	63.4%	12.9%	14.7%	7.1%	1.1%	0.8%	100.0%	
Cumulative Total	517,000	105,000	120,000	58,000	9,000	7,000		816,000

Similar to non-freeway crash statistics, the “negotiating a curve and departed road edge” pre-crash scenario resulted in most injury crashes on freeways as seen in Table 22. Overall, road edge departure scenarios resulted in more injury crashes than control loss scenarios on freeways. The “going straight and departed road edge” pre-crash scenario accounted for 52% of all fatal off-roadway crashes on freeways. Target off-roadway crashes on freeways resulted in more severe injury crashes than on non-freeways due to the higher speeds of freeway travel.

**Table 22. Distribution of Maximum Injury Severity by Target Off-Roadway Pre-Crash Scenarios on Freeways for All Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Maximum Injury Severity						Total	Cumulative Total
	None	Possible	Non-incapacitating	Incapacitating	Fatal	Unknown		
Going straight and departed road edge	53.5%	14.9%	18.4%	9.7%	3.0%	0.5%	100.0%	41,000
Going straight and lost control	61.4%	15.2%	12.4%	9.7%	0.5%	0.9%	100.0%	59,000
Negotiating a curve and lost control	61.6%	14.7%	12.5%	9.3%	1.9%	0.0%	100.0%	21,000
Negotiating a curve and departed road edge	46.3%	18.4%	23.0%	8.8%	3.6%	0.0%	100.0%	8,000
Initiating a maneuver and departed road edge	71.6%	12.0%	10.8%	4.2%	1.5%	0.0%	100.0%	3,000
Initiating a maneuver and lost control	62.0%	10.4%	17.8%	8.6%	1.2%	0.0%	100.0%	8,000
Average	58.5%	14.8%	15.0%	9.4%	1.7%	0.5%	100.0%	
Cumulative Total	81,000	21,000	21,000	13,000	2,000	1,000		139,000





### 3. CRASH-IMMINENT TEST SCENARIOS

This section proposes a set of crash-imminent scenarios based on crash statistics to test off-roadway crash countermeasure systems for intelligent light vehicle applications. Crash imminent scenarios refer to driving situations that require certain action (e.g., warning signal) by the countermeasure system. Moreover, this set of crash-imminent scenarios is devised to objectively test countermeasure systems at the vehicle-system level (i.e., driver condition not included). The physical setting, vehicle speed, and environmental conditions constitute the fundamental pieces of information required for the development of these test scenarios.

Appendix A contains 1998 GES statistics on light vehicles involved in off-roadway crashes. The target crash population for light vehicles was restricted by the same methods used for all vehicles as discussed in Section 2.1. Figure A-1 illustrates the breakdown of light vehicle off-roadway crashes. It should be noted that light vehicle results are nearly identical to all vehicle results due to the high percentage of light vehicle crashes in the all vehicle crash category (92.7%). The six most common pre-crash scenarios listed in Table A-1 form the basis for the development of the crash-imminent test scenarios.

#### 3.1 PHYSICAL SETTING OF TEST SCENARIOS

The following list defines basic test scenarios that correlate specific vehicle movements with critical events from light vehicle crash statistics presented in Tables A-1 and A-3:

- Going straight and departed road edge (327,000)
- Going straight and lost control (210,000)
- Negotiating a curve and lost control (153,000)
- Negotiating a curve and departed road edge (104,000)
- Turning and departed road edge (31,000)
- Turning and lost control (31,000)

The list of basic test scenarios is expanded to describe the physical setting of each scenario by including information on road type, relation to junction, and number of lanes. As a result, the following list of scenarios is generated by selecting physical characteristics where most light vehicle target off-roadway crashes occurred in 1998 based on data from Tables A-4–A-9:

1. Going straight and departed road edge on undivided non-freeway with two lanes at non-junction.
2. Going straight and lost control on undivided non-freeway with two lanes at non-junction.
3. Negotiating a curve and lost control on undivided non-freeway with two lanes at non-junction.
4. Negotiating a curve and departed road edge on undivided non-freeway with two lanes at non-junction.
5. Going straight and lost control on freeway with two lanes at non-junction.
6. Going straight and departed road edge on freeway with two lanes at non-junction.
7. Turning and departed road edge on undivided non-freeway with two lanes at intersection.

8. Turning and lost control on undivided non-freeway with two lanes at intersection.

The above list of test scenarios can be separated into two categories based on whether the vehicle departed the road edge or lost control. Consequently, each category consists of 4 scenarios as delineated in Table 23. The differentiation between these two categories is helpful for the development of test scenarios since they require distinct crash countermeasure functions. The side of the roadway that the vehicle departs at is only relevant in the “road edge departure” category. Based on crash statistics presented in Tables A-17 and A-18, it is recommended that test scenarios at a non-junction should include a vehicle leaving the road on both the right and left edges while the test scenario at intersection should only consider the right edge. One of the three scenarios at a non-junction requires freeway type roadway. The distinction between freeway and non-freeway type roadway in these scenarios is necessary to evaluate and compare the capability of potential countermeasures since some systems might be designed to operate exclusively on freeways. It should be noted that freeways are generally better constructed than non-freeways in terms of roadway geometry (lane width and curve), roadway shoulder, and lane markings. Table 23 recommends that all scenarios be conducted on two lanes of travel to assess the field of view and the capability of the countermeasure system to warn of road departure on either side of the road. Rural and urban locations might have influence on the operation of the countermeasures but were not considered here due to the large number of GES cases coded as “unknown” for this type of crash location. Roadways in urban areas might be better built and more illuminated than roadways in rural areas.

**Table 23. Breakdown of Test Scenarios by Critical Event**

Test Scenario	Road Edge Departure	Control Loss
Going straight on undivided non-freeway with two lanes at non-junction.	1	2
Negotiating a curve on undivided non-freeway with two lanes at non-junction.	4	3
Going straight on freeway with two lanes at non-junction.	6	5
Turning on undivided non-freeway with two lanes at intersection.	7	8

**3.1.1 SELECTION OF CURVE FOR TEST SCENARIOS**

The results of a detailed analysis of 201 crash cases drawn from the 1993 CDS crash data base were reviewed to collect information on radius of curvature and road shoulder. The analysis of these crash cases was conducted previously by a project to develop performance guidelines for single vehicle roadway departure crash countermeasure systems (Reference 3, 4). It should be noted that this 1993 CDS sample did not represent the national profile of off-roadway crashes. The intent of our analysis was simply to select values of roadway curve and shoulder for the test scenarios and not to statistically describe the national profile of the geometrical locations where off-roadway crashes occurred. Table 24 provides the radius of curvature for 2-lane roadways at 25, 35, and 55 mph posted speed limits as derived from the 201 CDS crash cases. The radius of curvature in Table 24 was measured to the outside edge of the curve (i.e., travel lanes included). Table 25 shows the average radius of curvature for each of the posted speed limits and compares the average values to the minimum radius of curvature that is recommended by highway design guidelines (Reference 13). As seen in Table 25, the average value of the radius of curvature

encountered in off-roadway crashes falls below the recommended minimum value for non-freeways with 35 mph and 55 mph posted speed limits. The average values of the radius of curvature in Table 25 are suggested for test scenarios with curved roadways. Moreover, test scenarios should account for curves to the left or to the right since a recent query of the 1998 CDS showed that 60% and 40% of single vehicle off-roadway crashes happened on left curves and right curves, respectively.

**Table 24. Radius of Curvature by Posted Speed Limit (Based on 1993 CDS Sample)**

Radius of Curvature (ft) (2-Lane Roadways)			
Non-Freeway			Freeway
25 mph	35 mph	55 mph	55 mph
47	75	231	547
94	139	236	657
139	166	329	821
139	236	821	821
184	329	821	1823
206	329	1094	1846
206	337		
236	362		
446	547		
463	3281		
3691	3281		
5468			

**Table 25. Comparison between Average (Based on 1993 CDS Sample) and Recommended Minimum Values for Radius of Curvature**

Radius of Curvature (ft) (2-Lane Roadways)				
	Non-Freeway			Freeway
Posted Speed Limit	25 mph	35 mph	55 mph	55 mph
Average Value	216*	280^	589	1086
<b>Recommended Minimum Value**</b>	158–202	304–390	854–1137	854–1137

\* Numbers in last two cells of 25 mph column in Table 24 were excluded from “average” computation.

^:Numbers in last two cells of 35 mph column in Table 24 were excluded from “average” computation.

\*\* A range of recommended minimum values is provided to account for different “coefficient of side friction” and “superelevation” values.

### 3.1.2 SELECTION OF SHOULDER FOR TEST SCENARIOS

The 1993 CDS sample also provided information on road shoulders, which included the presence and width of a shoulder, material of graded shoulder, and material of usable shoulder. Table 26 shows that a road shoulder was not available in about 31% of the crash cases. The road shoulder was available in 92% and 64% of crash cases on freeways and non-freeways, respectively. Freeway shoulders were graded by asphalt or concrete. Asphalt, stone, gravel, grass, or dirt covered non-freeway shoulders. Table 27 provides data from the CDS sample about the distribution of shoulder width on vehicle departure side by roadway type. This CDS sample had only 79 crash cases with known shoulder width. As seen in Table 27, the shoulder width was less than 6 feet in about 67% of the crash cases on non-freeways. On the other hand, the shoulder width was greater than or equal to 6 feet in about 50% of the crash cases on freeways. The average shoulder width is recommended for the test scenarios and was 5.5 and 7.5 feet respectively on non-freeways and freeways in the CDS sample.

**Table 26. Road Shoulder Data (Based on 1993 CDS Sample)**

Road Type	Alignment	All Cases	No Shoulder Cases	% No Shoulder
Freeways	Curve	16	2	12.5
	Straight	22	1	4.5
	Total	38	3	7.9
Non-Freeways	Curve	74	24	32.4
	Straight	89	35	39.3
	Total	163	59	36.2
All Roads	Curve	90	26	28.9
	Straight	111	36	32.4
	Total	201	62	30.8

**Table 27. Road Shoulder Width by Roadway Type (Based on 1993 CDS Sample)**

Roadway Type	Shoulder Width (ft)							Total	Number of Cases
	< 2	2-4	4-6	6-8	8-10	10-12	> 12		
Non-Freeway	21.1%	24.6%	21.1%	10.5%	14.0%	3.5%	5.3%	100.0%	57
Freeway	4.5%	9.1%	36.4%	9.1%	13.6%	13.6%	13.6%	100.0%	22
Average	16.5%	20.3%	25.3%	10.1%	13.9%	6.3%	7.6%	100.0%	
Number of Cases	13	16	20	8	11	5	6		79

### 3.2 SELECTION OF VEHICLE TRAVEL SPEED IN TEST SCENARIOS

The *Speed Limit* and *Speed-Related* variables in the 1998 GES were examined to select the travel speed for light vehicles in crash-imminent test scenarios. Unfortunately, the GES *Travel Speed* variable cannot be utilized for this analysis since it was coded as “unknown” between 60% and 70% of the 1998 GES cases. Thus, an assumption might be made that vehicles would be traveling at the posted speed limit if they were not speeding. If coded as speeding, vehicles would be traveling at 10 or 15 mph over the posted speed limit. It should be noted that vehicles might be coded as speeding under severe environmental conditions even though they were traveling around the posted speed limit. Table A-10 provides statistics on posted speed limit in target off-roadway pre-crash scenarios on non-freeways. As defined in this report, freeways had posted speed limit of 55 mph or higher. Table 28 shows dominant posted speed limits in each of the six pre-crash scenarios on non-freeways. Table 29 provides the relative frequency of crashes cited with speeding for each of the six target off-roadway crashes on both freeways and non-freeways.

**Table 28. Dominant Posted Speed Limits in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Posted Speed Limit (mph)			
	25	35	45	55
Going straight and departed road edge	•	•		•
Going straight and lost control	•	•		•
Negotiating a curve and lost control		•		•
Negotiating a curve and departed road edge		•	•	•
Initiating a maneuver and departed road edge	•			
Initiating a maneuver and lost control	•			

Based on Table 29, speeding was a significant factor in all “control loss” pre-crash scenarios as well as in “negotiating a curve and departed road edge” pre-crash scenario on both freeways and non-freeways. In non-speeding cases, travel speeds of 25, 35, 45, and 55 mph will be considered for the test scenarios according to the breakdown of posted speed limit by pre-crash scenario in Table 28. In pre-crash scenarios with considerable speeding cases, this analysis suggests the addition of 10 mph to the dominant posted speed limits. As a result, Table 30 recommends a range of travel speeds to select from for each of the eight test scenarios described in the previous section.

**Table 29. Relative Frequency of Target Off-Roadway Pre-Crash Scenarios Cited with Speeding for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Non-Freeway	Freeway
Going straight and departed road edge	18%	27%
Going straight and lost control	40%	47%
Negotiating a curve and lost control	53%	54%
Negotiating a curve and departed road edge	38%	32%
Initiating a maneuver and departed road edge	17%	28%
Initiating a maneuver and lost control	47%	45%

**Table 30. Range of Travel Speeds (mph) for each Category of Test Scenario**

Test Scenario	Road Edge Departure	Control Loss
Going straight on undivided non-freeway with two lanes at non-junction.	25, 35, 55	25, 35, 45, 55, 65
Negotiating a curve on undivided non-freeway with two lanes at non-junction.	35, 45, 55, 65	35, 45, 55, 65
Going straight on freeway with two lanes at non-junction.	55	55, 65
Turning on undivided non-freeway with two lanes at intersection.	25	25, 35

### 3.3 ENVIRONMENTAL CONDITIONS OF TEST SCENARIOS

The roadway surface, lighting, and weather conditions constitute the environmental conditions that were examined in light vehicle off-roadway crashes. The incorporation of environmental conditions in test scenarios is important to assess the operating range of off-roadway crash countermeasure systems. Tables 31 and 32 present statistics on environmental conditions that surrounded light vehicle off-roadway crashes on non-freeways and freeways, respectively. Moreover, these statistics were described for speeding and non-speeding crash cases. Table 33 recommends the inclusion of some environmental conditions in each category of test scenarios based on the high frequency of occurrence of these conditions in crash statistics listed in Tables 31 and 32.

### 3.4 SYSTEM ROBUSTNESS TESTING

The robustness of off-roadway crash countermeasure systems should also be considered as part of the test scenarios. System robustness refers to the capability of a system to perform its safety-critical functions without any degradation under a wide variety of driving conditions. Recommended conditions include, but are not limited to the following:

- Transmittance of the atmosphere (illumination and precipitation):
  - Rain, fog, or snow
  - Dark or bright sunlight
  - Twilight conditions
  - Dark rainy conditions
- Dynamic motion of the host vehicle:
  - Vehicle roll on curves either to the right or left (side looking sensor)
  - Vehicle pitch (forward/down-looking sensor)
- Road maintenance:
  - No lane edge markers
  - Spacing of lane edge markers (dashed lines)
  - Worn out lane edge markers (low marker-pavement contrast ratio)
  - Wet, ice, or snow-covered markers
- Traffic situation:
  - Following a vehicle at close headway (forward/down-looking sensor)
  - Following a larger vehicle (masking of message broadcast)
  - Two vehicles side-by-side in adjacent lanes (side looking sensor)

A set of crash-imminent test scenarios was proposed to evaluate off-roadway crash countermeasure systems that address “road edge departure” and “control loss” pre-crash scenarios. These scenarios would require a countermeasure system to provide a signal to the vehicle or driver. It is noteworthy that a countermeasure system should perform in crash-imminent scenarios as well as in operational scenarios. The latter scenarios are essential in objective testing of countermeasure systems by assessing the capability of the system to deal with driving situations that don’t require any system response. For instance, “road edge departure” test scenarios that don’t require a signal may include:

- Driver’s intent to pull to the side of the road
- Changing lanes
- Avoiding an obstacle in the road ahead
- Turning onto a cross street
- Taking an exit ramp (Y-shaped roadways)

A vehicle moving away from a hazardous roadway location may form an operational scenario for “control loss” crash countermeasure systems. The development of operational scenarios for objective testing is beyond the scope of this current study and will be done in future research. Such effort requires further research into the operational capabilities of enabling sensors and warning algorithms that might be utilized to build off-roadway crash countermeasure systems.

**Table 31. Distribution of Environmental Conditions by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Speeding/Non-Speeding	Day						Dark						Total	Cumulative Total
		Clear, Dry		Adverse, Dry		Adverse, Slippery		Clear, Dry		Adverse, Dry		Adverse, Slippery			
		Clear, Dry	Clear, Slippery	Adverse, Dry	Adverse, Slippery	Adverse, Slippery	Clear, Dry	Clear, Slippery	Adverse, Dry	Adverse, Slippery	Adverse, Slippery				
Going straight and departed road edge	Non-Speeding	41.2%	2.3%	0.7%	3.0%	3.9%	42.7%	3.9%	0.7%	5.6%	100.0%	237,000			
	Speeding	29.5%	4.2%	0.2%	7.2%	5.2%	42.9%	5.2%	0.7%	10.1%	100.0%	52,000			
Going straight and lost control	Non-Speeding	20.0%	10.4%	0.5%	19.1%	8.3%	23.1%	8.3%	0.5%	18.1%	100.0%	93,000			
	Speeding	17.7%	12.7%	0.2%	13.4%	11.5%	30.3%	11.5%	0.2%	14.1%	100.0%	61,000			
Negotiating a curve and lost control	Non-Speeding	13.3%	14.2%	0.0%	24.5%	11.8%	17.9%	17.9%	0.4%	17.9%	100.0%	63,000			
	Speeding	21.2%	12.3%	0.0%	17.3%	8.0%	27.7%	8.0%	0.4%	13.1%	100.0%	71,000			
Negotiating a curve and departed road edge	Non-Speeding	37.5%	3.6%	0.0%	8.7%	3.6%	38.2%	3.6%	1.0%	7.6%	100.0%	60,000			
	Speeding	32.2%	4.7%	0.0%	7.5%	5.1%	38.6%	5.1%	0.5%	11.3%	100.0%	37,000			
Initiating a maneuver and departed road edge	Non-Speeding	51.0%	3.5%	0.6%	4.6%	3.1%	32.1%	3.1%	0.3%	4.7%	100.0%	40,000			
	Speeding	31.1%	6.2%	0.0%	2.2%	5.7%	45.8%	5.7%	0.0%	9.0%	100.0%	8,000			
Initiating a maneuver and lost control	Non-Speeding	24.6%	13.0%	0.4%	12.9%	5.7%	21.2%	5.7%	2.5%	19.7%	100.0%	21,000			
	Speeding	22.9%	12.2%	0.0%	17.3%	4.3%	33.0%	4.3%	0.0%	10.2%	100.0%	19,000			
Average		30.5%	7.0%	0.4%	10.5%	6.2%	34.0%	6.2%	0.6%	10.8%	100.0%	761,000			
Cumulative Total		232,000	54,000	3,000	80,000	47,000	258,000	47,000	5,000	82,000	100.0%	761,000			

**Table 32. Distribution of Environmental Conditions by Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Speeding/Non-Speeding	Day						Dark						Total	Cumulative Total	
		Clear, Dry		Adverse, Dry		Adverse, Slippery		Clear, Dry		Adverse, Dry		Adverse, Slippery				
		%	Count	%	Count	%	Count	%	Count	%	Count	%	Count			
Going straight and departed road edge	Non-Speeding	40.0%	1,000	0.3%	100	6.2%	1,500	44.7%	1,000	3.5%	1,000	0.2%	100	4.6%	1,000	28,000
	Speeding	36.1%	900	0.0%	0	16.8%	400	31.7%	900	1.9%	500	0.0%	0	11.0%	900	10,000
Going straight and lost control	Non-Speeding	20.4%	500	0.3%	100	19.5%	475	21.6%	500	7.2%	1,750	0.3%	250	23.4%	500	30,000
	Speeding	12.3%	300	0.0%	0	33.3%	800	9.9%	2,400	10.7%	2,600	0.0%	0	23.7%	300	26,000
Negotiating a curve and lost control	Non-Speeding	14.5%	350	0.0%	0	26.5%	650	22.6%	550	8.0%	2,000	0.0%	0	21.3%	350	9,000
	Speeding	10.5%	250	0.0%	0	30.8%	750	16.6%	400	10.2%	2,500	0.0%	0	17.8%	250	10,000
Negotiating a curve and departed road edge	Non-Speeding	42.5%	1,000	0.0%	0	9.2%	220	32.0%	750	9.2%	220	0.0%	0	5.6%	1,000	5,000
	Speeding	35.4%	850	0.0%	0	3.2%	750	28.2%	680	3.7%	900	0.0%	0	29.5%	850	2,000
Initiating a maneuver and departed road edge	Non-Speeding	41.8%	1,000	0.0%	0	12.4%	300	24.3%	600	0.0%	0	0.0%	0	21.6%	1,000	2,000
	Speeding	43.7%	1,000	0.0%	0	10.7%	250	45.7%	1,000	0.0%	0	0.0%	0	0.0%	1,000	1,000
Initiating a maneuver and lost control	Non-Speeding	40.3%	1,000	0.0%	0	12.8%	300	10.7%	250	6.0%	1,500	0.0%	0	15.4%	1,000	4,000
	Speeding	23.2%	550	0.0%	0	30.3%	720	12.7%	300	2.1%	500	0.0%	0	21.1%	550	4,000
Average		25.1%	6,000	6.5%	1,500	19.9%	4,750	24.6%	6,000	6.7%	1,500	0.1%	250	16.9%	6,000	132,000
Cumulative Total		33,000	9,000	*	*	26,000	32,000	9,000	*	22,000	*	*	22,000	*	132,000	

\* refers to a crash count below 500



**Table 33. Recommended Environmental Conditions for each Category of Test Scenarios**

Test Scenario	Road Edge Departure	Control Loss
Going straight on undivided non-freeway with two lanes at non-junction.	Clear day on dry surface Clear night on dry surface	Clear day on dry surface Clear night on dry surface Adverse day on slippery surface Adverse night on slippery surface
Negotiating a curve on undivided non-freeway with two lanes at non-junction.		
Going straight on freeway with two lanes at non-junction.		
Turning on undivided non-freeway with two lanes at intersection.	Clear day on dry surface	Clear day on dry surface Adverse night on slippery surface



## 4. CONCLUDING REMARKS

This report defined the problem of off-roadway crashes and developed a set of crash imminent test scenarios to objectively test potential IVI countermeasures for light vehicles. Off-roadway crashes were defined as all vehicular crashes in which the first harmful event happened off the roadway. The problem definition included a detailed analysis of off-roadway crashes involving all vehicles using the 1998 GES crash data base. The results of such an analysis provide background information to devise concepts, derive functional requirements, develop performance guidelines, set up objective test procedures, and assess the safety effectiveness of potential IVI countermeasure systems. This report also presented data on off-roadway crashes that involved light vehicles based on 1998 GES and commercial vehicles based on 1996-1998 GES. The development of test scenarios for light vehicle countermeasures relied on GES statistics as well as crash data from a sample of CDS crashes.

The universe of police-reported off-roadway crashes involved about 1,350,000 crashes, composed of 1,251,000 or 92.6% light vehicle crashes and 70,000 or 5.2% commercial vehicle crashes in 1998. This analysis selected a target population of off-roadway crashes in which the involved vehicle was moving in the forward direction and the critical event was characterized by roadway edge departure or control loss, excluding crashes resulting from evasive maneuvers and vehicle control loss due to vehicle failure. As a result, the target crash population was estimated at 992,000 vehicles or 73.5% of all vehicles involved in off-roadway crashes. About 956,000 vehicles or 96.3% of the target crash population were involved in six off-roadway crash scenarios that depicted vehicle dynamics immediately prior to leaving the roadway. Three pre-critical event vehicle movements (going straight, negotiating a curve, and initiating a maneuver) and two critical events (departed road edge and lost control) were combined to form these six scenarios (3×2 matrix). This analysis designated target off-roadway crashes as those resulting from the six scenarios.

The physical setting of target off-roadway crashes was described in terms of the roadway type, land use, relation to junction, number of travel lanes, and posted speed limit. The following notable results were obtained and presented in terms of the relative frequency of occurrence of all target off-roadway crashes:

- Non-freeways: 85%
- Away from junctions: 82%
- Rural areas: 66%
- < 55 mph Speed Limit: 61%
- Two lanes of travel: 59%

The identification of factors that might have contributed to the cause of target off-roadway crashes was also attempted by relying on relevant 1998 GES variables. This analysis revealed the following percentages of all target off-roadway crashes:

- Speeding: 24%
- Alcohol or drugs: 19%

- Hit and run: 7%
- Impairment: 6%
- Distraction: 6%
- Other (none of the above): 38%

Environmental factors were later investigated to infer circumstances that might lead to the 38% of target off-roadway crashes noted above as “other.” This investigation identified the following percentages of all target off-roadway crashes (total adds up to 38%):

- Daylight, clear weather, and dry road: 14%
- Dark, clear weather, and dry road: 8%
- Daylight, adverse weather, and slippery road: 6%
- Dark, adverse weather, and slippery road: 5%
- Daylight, clear weather, and slippery road: 3%
- Dark, clear weather, and slippery road: 2%

Based on the list above, one may speculate that driving inexperience or some sort of inattention or distraction might have contributed to the cause of “other” target off-roadway crashes in daylight, clear weather, and dry roadway surface. Moreover, reduced visibility and or slippery surfaces might have caused the remaining “other” target off-roadway crashes.

Post roadway departure events were examined in terms of the road departure side, first harmful event, and maximum injury severity sustained in target off-roadway crashes involving all vehicles. The vehicle departed the edge of the road or lost control and departed the road on the following percentages of all target off-roadway crashes:

- Right edge: 59%
- Left edge: 32%
- End departure: 2%
- Unknown 6%

The top 5 objects that the vehicle struck after departing the road and resulted in first harmful events were:

- Parked vehicle: 21%
- Sign post: 14%
- Culvert or ditch: 11%
- Tree: 10%
- Guardrail: 8%

The distribution of maximum injury severity as a consequence of target off-roadway crashes was as follows:

- No injury: 63%
- Non-incapacitating injury: 15%

- Possible injury: 13%
- Incapacitating injury: 7%
- Fatal injury: 1%
- Unknown injury: 1%

The 1998 GES statistics and a sample of crashes from the 1993 CDS were utilized to develop a set of crash imminent scenarios to objectively test potential off-roadway crash countermeasure systems for intelligent light vehicle applications. Pre-crash scenarios formed the basis for these test scenarios that were then distinguished by roadway type (freeway/non-freeway), number of lanes (two), and relation to junction (non-junction/intersection). This report also recommended test values for the radius of roadway curvature and the width of shoulder. In addition, a range of vehicle travel speeds and environmental conditions were proposed to better describe these scenarios. Objective test procedures normally include crash imminent test scenarios and operational scenarios. The former scenarios are used to assess the capability of countermeasures to take action in driving situations that require a system response. The latter scenarios are devised to evaluate the capability of countermeasures to not react in driving situations that do not lead to imminent crashes. This report did not address operational scenarios that remain to be investigated in future research.



## 5. REFERENCES

1. U.S. Department of Transportation ITS Joint Program Office, *ITS National Intelligent Transportation Systems Program Plan Five-Year Horizon*. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., FHWA-OP-00-008, August 2000.
2. W.G. Najm, M. Mironer, J. Koziol, Jr., J.S. Wang, and R.R. Knipling, *Synthesis Report: Examination of Target Vehicular Crashes and Potential ITS Countermeasures*. DOT HS 808 263, June 1995.
3. J.A. Pierowicz, D.A. Pomerleau, D.L. Hendricks, E.S. Bollman, and N.J. Schmitt, *Run-Off-Road Collision Avoidance Countermeasures Using IVHS Countermeasures*. Task 2: Draft Interim Report, Vol. 1: Technical Findings, U.S. Department of Transportation, National Highway Traffic Safety Administration, Contract No. DTNH22-93-C-07023, June 1995.
4. D. Pomerleau, T. Jochem, C. Thorpe, P. Batavia, D. Pape, J. Hadden, N. McMillan, N. Brown, and J. Everson, *Run-Off-Road Collision Avoidance Using IVHS Countermeasures*. Final Report, Contract No. DTNH22-93-C-07023, U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C., December 1999.
5. R. Kiefer, D. LeBlanc, M. Palmer, J. Salinger, R. Deering, and M. Shulman, *Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning/Avoidance Systems*. Crash Avoidance Metrics Partnership, DOT HS 808 964, August 1999.
6. W.G. Najm and M.P. daSilva, *Benefits Estimation Methodology for Intelligent Vehicle Safety Systems Based on Encounters with Critical Driving Conflicts*. ITS America's Tenth Annual Meeting & Exposition, Boston, Massachusetts, May 2000.
7. W.G. Najm, M.P. daSilva, and C.J. Wiacek, *Estimation of Crash Injury Severity Reduction for Intelligent Vehicle Safety Systems*. SAE 2000 World Congress, Paper No. 2000-01-1354, Detroit, Michigan, March 2000.
8. J.S. Wang and R.R. Knipling, *Single Vehicle Roadway Departure Crashes: Problem Size Assessment and Statistical Description*. DOT HS 808 113, March 1994.
9. D. Hendricks, D. Pomerleau, and J. Pierowicz, *Run-Off-Road Collision Avoidance Countermeasures Using IVHS Countermeasures*. Task 1, Vol. 1: Technical Findings, DOT HS 808 497, October 1994.
10. M. Mironer and D. Hendricks, *Examination of Single Vehicle Roadway Departure Crashes and Potential IVHS Countermeasures*. DOT-VNTSC-NHTSA-94-3, DOT HS 808 144, August 1994.

11. National Center for Statistics and Analysis, *National Automotive Sampling System General Estimates System Analytical User's Manual 1988-1998*. U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C., 20590, June 1999.
12. National Center for Statistics and Analysis, *General Estimates System Coding Manual 1998*. U.S. Department of Transportation, National Highway Traffic Safety Administration, DOT HS 808 928, June 1999.
13. F.L. Mannering and W.P. Kilareski, *Principles of Highway Engineering and Traffic Analysis*. John Wiley & Sons, 1990.



## A. LIGHT VEHICLE OFF-ROADWAY CRASH STATISTICS

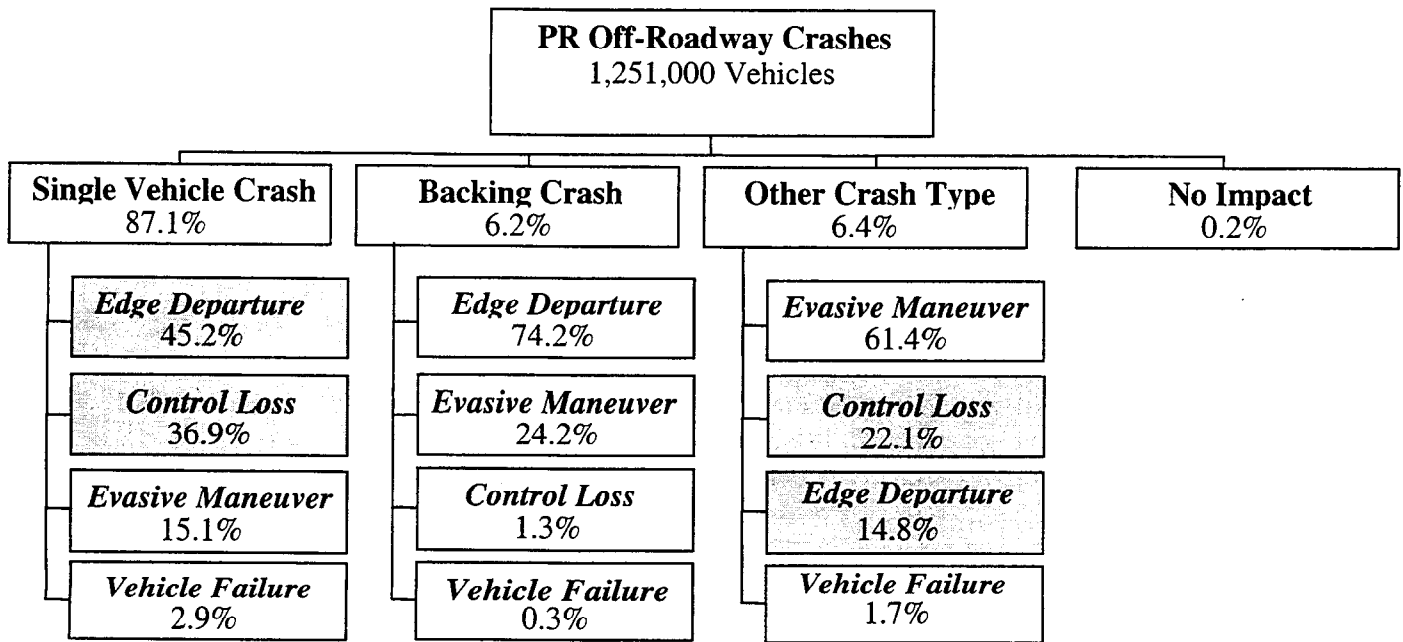
This appendix provides data on off-roadway crashes that involved light vehicles (passenger cars, sport utility vehicles, vans, and pickup trucks) based on 1998 GES. The *Hotdeck Imputed Body Type* and *Special Use* variables in the GES "Vehicle/Driver File" were utilized to identify light vehicles. The *Hotdeck Imputed Body Type* variable contains the following categories:

- Codes 01-09: Automobiles
- Codes 10-13: Automobile derivatives
- Codes 14-19: Utility vehicles
- Codes 20-29: Van-based light large trucks
- Codes 30-39: Light conventional large trucks less than or equal to 4,500 Kg in Gross Vehicle Weight Ratio (GVWR)
- Codes 40-48: Other light large trucks less than 4,500 Kg GVWR
- Codes 50-59: Buses excluding van-based
- Codes 60-78: Medium/heavy large trucks greater than 4,500 Kg GVWR
- Codes 80-89: Motored cycles excluding all terrain vehicles/cycles
- Codes 90-97: Other vehicles

The relevant codes of the *Special Use* variable are:

- Code 00: No special use
- Code 03: Vehicle used as "other" bus
- Code 05: Police
- Code 06: Ambulance
- Code 07: Fire truck and car

The codes 01–22, 28–41, or 45–48 from the *Hotdeck Imputed Body Type* variable and code 00 from the *Special Use* variable identify crashes that involved at least one light vehicle. Figure A-1 illustrates the distribution of off-roadway crashes that involved at least one light vehicle. Tables A-1–A-22 present detailed statistics of off-roadway crashes involving this vehicle platform.



**Figure A-1. Distribution of Off-Roadway Crashes Involving Light Vehicles  
(Based on 1998 GES)**

**Table A-1. Target Off-Roadway Pre-Crash Scenarios for Light Vehicles  
(Based on 1998 GES)**

Pre-Crash Scenario	Frequency	Relative Frequency*	Cumulative Frequency	Cumulative Relative Frequency*
Going straight and departed road edge	327,000	35.3%	327,000	35.3%
Going straight and lost control	210,000	22.7%	537,000	58.1%
Negotiating a curve and lost control	153,000	16.5%	690,000	74.6%
Negotiating a curve and departed road edge	104,000	11.2%	794,000	85.8%
Initiating a maneuver and departed road edge	51,000	5.5%	845,000	91.3%
Initiating a maneuver and lost control	48,000	5.2%	893,000	96.5%

\* Scenario crash frequency relative to the frequency of target crash population (925,000)

Note: Frequency values are rounded to the nearest 1,000.

**Table A-2. 95% Confidence Bounds of Target Off-Roadway Pre-Crash Scenario Counts for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Frequency	Lower 95 % Confidence Bound	Upper 95 % Confidence Bound
Going straight and departed road edge	327,000	283,000	371,000
Going straight and lost control	210,000	180,000	240,000
Negotiating a curve and lost control	153,000	130,000	176,000
Negotiating a curve and departed road edge	104,000	87,000	121,000
Initiating a maneuver and departed road edge	51,000	41,000	61,000
Initiating a maneuver and lost control	48,000	39,000	57,000
Total	893,000	782,000	1,004,000

**Table A-3. Distribution of Vehicles Movements in "Initiating a Maneuver" Scenarios (Based on 1998 GES)**

Pre-Crash Scenario	Maneuver						Total	Cumulative Total
	Turning	Passing or Changing	Parking	Slowing or Stopping	Merging	Starting		
Initiating a maneuver and departed road edge	60.5%	10.4%	23.1%	4.0%	0.9%	1.0%	100.0%	51,000
Initiating a maneuver and lost control	64.0%	21.3%	1.1%	10.6%	2.1%	0.9%	100.0%	48,000
Average	62.2%	15.7%	12.4%	7.2%	1.5%	0.9%	100.0%	
Cumulative Total	61,000	15,000	12,000	7,000	1,000	1,000		99,000

**Table A-4. Distribution of Target Off-Roadway Crash Scenarios by Roadway Type for Light Vehicles (Based on 1998 GES)**

Crash Scenario	Non-Freeway		Freeway	
	Frequency	Relative Frequency	Frequency	Relative Frequency
Going straight and departed road edge	289,000	38.0%	38,000	29.0%
Going straight and lost control	153,000	20.2%	57,000	43.1%
Negotiating a curve and lost control	133,000	17.5%	19,000	14.8%
Negotiating a curve and departed road edge	97,000	12.7%	7,000	5.4%
Initiating a maneuver and departed road edge	49,000	6.4%	2,000	1.6%
Initiating a maneuver and lost control	40,000	5.2%	8,000	6.0%
Total	761,000	100.0%	132,000	100.0%

\* 55.1% of freeway crashes occurred on interstate highways

**Table A-5. Distribution of Target Off-Roadway Pre-Crash Scenarios on *Non-Freeways* by Land Use and Relation to Junction for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Land Use	Relationship to Junction					Total
		Non-Junction	Intersection	Driveway	Ent/Exit Ramp	Other	
Going Straight and Departed Road Edge (289,000)	Rural (55.8%)	89.3%	8.1%	0.4%	0.6%	1.7%	100.0%
	Urban (38.2%)	91.3%	7.9%	0.0%	0.4%	0.3%	100.0%
	Unknown (6.0%)	90.5%	7.8%	0.0%	0.0%	1.7%	100.0%
Going Straight and Lost Control (153,000)	Rural (72.8%)	88.8%	7.1%	0.3%	0.6%	3.2%	100.0%
	Urban (17.8%)	79.9%	13.7%	0.0%	1.4%	5.1%	100.0%
	Unknown (9.4%)	91.0%	6.3%	0.7%	0.0%	2.1%	100.0%
Negotiating a Curve and Lost Control (133,000)	Rural (75.0%)	92.4%	3.6%	0.0%	2.1%	1.9%	100.0%
	Urban (9.9%)	76.5%	9.1%	0.0%	13.1%	1.4%	100.0%
	Unknown (15.1%)	92.7%	0.8%	0.5%	6.0%	0.0%	100.0%
Negotiating a Curve and Departed Road Edge (97,000)	Rural (77.9%)	95.9%	2.4%	0.2%	0.5%	1.0%	100.0%
	Urban (12.9%)	86.1%	6.8%	0.7%	4.2%	2.3%	100.0%
	Unknown (9.2%)	96.9%	0.0%	0.0%	3.1%	0.0%	100.0%
Initiating a Manuever and Departed Road Edge (49,000)	Rural (52.2%)	35.5%	53.7%	10.8%	0.0%	0.0%	100.0%
	Urban (43.7%)	42.1%	51.5%	5.6%	0.0%	0.8%	100.0%
	Unknown (4.1%)	3.9%	94.2%	1.9%	0.0%	0.0%	100.0%
Initiating a Manuever and Lost Control (40,000)	Rural (65.6%)	23.7%	68.1%	5.0%	1.6%	1.6%	100.0%
	Urban (27.4%)	10.1%	79.2%	6.0%	1.4%	3.4%	100.0%
	Unknown (7.0%)	18.6%	74.3%	3.9%	0.0%	3.2%	100.0%
Average		83.2%	12.9%	0.9%	1.2%	1.7%	99.9%
Cumulative Total		633,000	98,000	7,000	9,000	13,000	761,000

**Table A-6. Distribution of Target Off-Roadway Pre-Crash Scenarios on Freeways by Land Use and Relation to Junction for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Land Use	Relationship to Junction					Total
		Non-Junction	Intersection	Driveway	Ent/Exit Ramp	Other	
Going Straight and Departed Road Edge (38,000)	Rural (53.1%)	93.8%	0.3%	0.0%	3.5%	2.4%	100.0%
	Urban (30.9%)	92.3%	0.0%	0.0%	5.6%	2.1%	100.0%
	Unknown (16.0%)	94.2%	1.7%	0.0%	2.5%	1.5%	100.0%
Going Straight and Lost Control (57,000)	Rural (58.2%)	81.9%	2.0%	0.0%	6.6%	9.5%	100.0%
	Urban (26.1%)	84.7%	1.1%	0.0%	9.2%	5.1%	100.0%
	Unknown (15.7%)	95.6%	0.0%	0.0%	0.0%	4.5%	100.0%
Negotiating a Curve and Lost Control (19,000)	Rural (47.6%)	49.9%	1.0%	0.0%	47.7%	1.4%	100.0%
	Urban (33.9%)	62.3%	3.7%	0.0%	26.7%	7.4%	100.0%
	Unknown (18.5%)	66.4%	7.2%	0.0%	26.4%	0.0%	100.0%
Negotiating a Curve and Departed Road Edge (7,000)	Rural (52.7%)	70.6%	6.5%	0.0%	18.1%	4.8%	100.0%
	Urban (38.0%)	48.2%	3.4%	0.0%	45.7%	2.7%	100.0%
	Unknown (9.3%)	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Initiating a Manuever and Departed Road Edge (2,000)	Rural (38.0%)	83.8%	8.5%	0.0%	7.7%	0.0%	100.0%
	Urban (57.0%)	74.4%	16.9%	0.0%	8.7%	0.0%	100.0%
	Unknown (5.0%)	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Initiating a Manuever and Lost Control (8,000)	Rural (49.0%)	60.8%	12.5%	6.7%	17.7%	2.3%	100.0%
	Urban (42.6%)	65.1%	16.1%	0.0%	16.3%	2.5%	100.0%
	Unknown (8.4%)	71.5%	16.7%	0.0%	11.9%	0.0%	100.0%
Average		80.3%	2.3%	0.0%	12.1%	4.5%	99.2%
Cumulative Total		106,000	3,000	*	16,000	6,000	132,000

\* refers to a crash count below 500

**Table A-7. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Undivided Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	>7	unk		
Going straight and departed road edge	0.8%	55.3%	2.1%	4.6%	1.7%	0.2%	0.0%	35.3%	100.0%	260,000
Going straight and lost control	0.9%	70.2%	2.2%	3.6%	1.5%	0.2%	0.2%	21.3%	100.0%	139,000
Negotiating a curve and lost control	0.3%	76.9%	1.5%	1.5%	0.1%	0.0%	0.1%	19.6%	100.0%	120,000
Negotiating a curve and departed road edge	0.0%	79.2%	0.9%	1.7%	0.1%	0.1%	0.0%	18.0%	100.0%	91,000
Initiating a maneuver and departed road edge	1.0%	42.9%	2.9%	7.4%	3.3%	1.2%	0.7%	40.7%	100.0%	41,000
Initiating a maneuver and lost control	0.0%	54.5%	5.6%	4.9%	5.5%	1.0%	1.4%	27.0%	100.0%	34,000
Average	0.6%	64.5%	2.1%	3.6%	1.4%	0.3%	0.2%	27.3%	100.0%	
Cumulative Total	4,000	442,000	14,000	25,000	10,000	2,000	1,000	187,000		686,000

**Table A-8. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Divided Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	>7	unk		
Going straight and departed road edge	13.0%	35.0%	19.7%	6.3%	0.3%	1.3%	0.0%	24.5%	100.0%	28,000
Going straight and lost control	6.8%	45.8%	20.1%	4.9%	0.4%	0.0%	0.0%	22.1%	100.0%	14,000
Negotiating a curve and lost control	30.1%	30.1%	13.2%	2.1%	0.7%	0.0%	0.0%	23.9%	100.0%	6,000
Negotiating a curve and departed road edge	21.4%	42.3%	9.8%	1.7%	0.0%	0.0%	0.0%	24.9%	100.0%	13,000
Initiating a maneuver and departed road edge	5.6%	29.9%	20.9%	3.2%	1.2%	0.0%	0.0%	39.3%	100.0%	8,000
Initiating a maneuver and lost control	17.2%	33.9%	17.5%	5.9%	0.0%	0.0%	0.0%	25.7%	100.0%	6,000
Average	14.9%	36.2%	17.8%	4.6%	0.4%	0.5%	0.0%	25.6%	100.0%	
Cumulative Total	11,000	27,000	13,000	3,000	*	*	*	19,000		75,000

\* refers to a crash count below 500

**Table A-9. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	>7	unk		
Going straight and departed road edge	4.6%	56.9%	19.7%	8.7%	6.3%	0.4%	0.0%	3.4%	100.0%	38,000
Going straight and lost control	4.4%	48.0%	23.2%	13.8%	3.9%	1.4%	0.8%	4.4%	100.0%	57,000
Negotiating a curve and lost control	25.4%	37.6%	19.7%	7.5%	1.7%	0.0%	0.0%	8.2%	100.0%	7,000
Negotiating a curve and departed road edge	28.5%	40.7%	18.6%	7.5%	0.1%	0.0%	0.0%	4.5%	100.0%	19,000
Initiating a maneuver and departed road edge	5.0%	44.4%	14.8%	20.7%	8.1%	4.0%	0.0%	3.1%	100.0%	2,000
Initiating a maneuver and lost control	9.0%	33.7%	28.3%	17.1%	4.4%	0.0%	0.0%	7.6%	100.0%	8,000
Average	9.2%	47.7%	21.6%	11.4%	4.2%	0.8%	0.4%	4.8%	100.0%	
Cumulative Total	12,000	63,000	28,000	15,000	6,000	1,000	*	6,000		132,000

\* refers to a crash count below 500

**Table A-10. Distribution of Posted Speed Limits in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Posted Speed Limit (mph)											Total	Cumulative Total
	<20	25	30	35	40	45	50	55	60	65	>65		
Going straight and departed road edge	3.2%	27.3%	13.0%	15.9%	5.3%	11.0%	2.8%	18.1%	0.8%	1.7%	1.0%	100.0%	289,000
Going straight and lost control	1.2%	14.9%	7.3%	14.8%	4.6%	13.0%	6.7%	34.3%	0.4%	1.9%	1.0%	100.0%	153,000
Negotiating a curve and lost control	2.7%	11.6%	9.9%	17.3%	6.5%	14.3%	3.2%	33.1%	0.4%	0.9%	0.1%	100.0%	133,000
Negotiating a curve and departed road edge	3.4%	12.1%	8.6%	15.9%	5.8%	15.8%	1.7%	34.2%	1.0%	0.8%	0.7%	100.0%	97,000
Initiating a maneuver and departed road edge	4.8%	38.6%	12.5%	20.3%	4.6%	10.0%	2.6%	5.3%	0.7%	0.4%	0.2%	100.0%	49,000
Initiating a maneuver and lost control	6.0%	24.3%	9.3%	16.5%	8.6%	14.1%	2.9%	16.8%	0.2%	0.7%	0.6%	100.0%	40,000
Average	3.0%	20.7%	10.5%	16.2%	5.6%	12.7%	3.5%	25.1%	0.6%	1.3%	0.7%	100.0%	
Cumulative Total	23,000	157,000	80,000	123,000	42,000	96,000	27,000	191,000	5,000	10,000	5,000		761,000

**Table A-11. Distribution of Contributing Factors in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Contributing Factors/Driver Circumstance						Total	Cumulative Total
	Alcohol or Drugs	Driver Impaired	Driver Distracted	Speeding	Hit/Run	Other		
Going straight and departed road edge	24.7%	9.5%	9.4%	10.5%	14.5%	31.5%	100.0%	289,000
Going straight and lost control	18.2%	2.5%	3.2%	29.3%	3.1%	43.8%	100.0%	153,000
Negotiating a curve and lost control	14.8%	1.8%	4.1%	41.4%	1.0%	37.0%	100.0%	133,000
Negotiating a curve and departed road edge	24.6%	7.0%	7.1%	25.9%	3.3%	32.2%	100.0%	97,000
Initiating a maneuver and departed road edge	17.5%	1.7%	3.7%	11.5%	14.7%	51.0%	100.0%	49,000
Initiating a maneuver and lost control	17.7%	1.3%	2.8%	35.1%	3.3%	39.9%	100.0%	40,000
Average	20.8%	5.5%	6.2%	23.0%	7.8%	36.7%	100.0%	
Cumulative Total	158,000	42,000	47,000	175,000	60,000	279,000		761,000

**Table A-12. Distribution of Environmental Conditions in "Other" Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Night				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	49.0%	3.2%	0.9%	4.4%	31.8%	3.3%	0.8%	6.7%	100.0%	91,000
Going straight and lost control	18.4%	13.8%	0.8%	24.7%	15.3%	7.4%	0.6%	19.2%	100.0%	67,000
Negotiating a curve and lost control	12.4%	15.7%	0.0%	28.6%	10.8%	11.7%	0.3%	20.5%	100.0%	49,000
Negotiating a curve and departed road edge	43.9%	4.1%	0.0%	11.5%	29.3%	3.7%	0.5%	7.1%	100.0%	31,000
Initiating a maneuver and departed road edge	56.7%	4.5%	0.0%	5.9%	24.0%	4.3%	0.0%	4.6%	100.0%	25,000
Initiating a maneuver and lost control	28.2%	15.6%	0.6%	15.1%	11.2%	4.2%	1.3%	23.9%	100.0%	16,000
Average	34.1%	8.9%	0.5%	15.1%	22.0%	5.9%	0.6%	13.0%	100.0%	
Cumulative Total	95,000	25,000	1,000	42,000	61,000	17,000	2,000	36,000		279,000

**Table A-13. Distribution of Environmental Conditions in Target Off-Roadway Pre-Crash Scenarios Cited with Speeding on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slipper	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	31.9%	5.3%	0.0%	11.8%	33.7%	4.9%	1.2%	11.1%	100.0%	30,000
Going straight and lost control	19.0%	15.8%	0.3%	17.6%	20.0%	11.3%	0.1%	16.0%	100.0%	45,000
Negotiating a curve and lost control	21.7%	15.0%	0.0%	20.9%	20.6%	8.1%	0.5%	13.2%	100.0%	55,000
Negotiating a curve and departed road edge	38.4%	6.2%	0.0%	9.6%	30.1%	3.4%	0.4%	11.9%	100.0%	25,000
Initiating a maneuver and departed road edge	36.4%	3.5%	0.0%	3.3%	36.0%	8.6%	0.0%	12.4%	100.0%	6,000
Initiating a maneuver and lost control	26.3%	16.4%	0.0%	23.2%	19.8%	3.2%	0.0%	11.2%	100.0%	14,000
Average	26.0%	12.0%	0.1%	16.5%	24.5%	7.3%	0.5%	13.2%	100.0%	
Cumulative Total	45,000	21,000	*	29,000	43,000	13,000	1,000	23,000		175,000

\* refers to a crash count below 500

**Table A-14. Distribution of Contributing Factors in Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Contributing Factors/Driver Circumstance						Total	Cumulative Total
	Alcohol or Drugs	Driver Impaired	Driver Distracted	Speeding	Hit/Run	Other		
Going straight and departed road edge	20.1%	21.8%	6.2%	17.5%	1.2%	33.3%	100.0%	38,000
Going straight and lost control	9.2%	1.9%	2.1%	41.9%	1.2%	43.7%	100.0%	57,000
Negotiating a curve and lost control	12.1%	1.4%	2.3%	46.3%	0.4%	37.4%	100.0%	19,000
Negotiating a curve and departed road edge	19.2%	16.7%	9.8%	21.4%	0.0%	32.8%	100.0%	7,000
Initiating a maneuver and departed road edge	5.5%	1.2%	20.1%	23.5%	4.5%	45.3%	100.0%	2,000
Initiating a maneuver and lost control	9.7%	0.0%	1.0%	36.9%	1.0%	51.5%	100.0%	8,000
Average	13.3%	8.3%	4.0%	33.8%	1.1%	39.7%	100.0%	
Cumulative Total	17,000	11,000	5,000	44,000	1,000	52,000		132,000



**Table A-15. Distribution of Environmental Conditions in “Other” Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	46.3%	0.0%	0.6%	10.9%	32.0%	4.1%	0.5%	5.7%	100.0%	13,000
Going straight and lost control	19.3%	8.6%	0.3%	22.8%	15.6%	6.9%	0.3%	26.2%	100.0%	25,000
Negotiating a curve and lost control	10.2%	8.7%	0.0%	31.9%	15.3%	9.8%	0.0%	24.1%	100.0%	7,000
Negotiating a curve and departed road edge	51.5%	3.0%	0.0%	8.3%	27.1%	6.8%	0.0%	3.4%	100.0%	2,000
Initiating a maneuver and departed road edge	30.1%	0.0%	0.0%	19.8%	24.8%	0.0%	0.0%	25.4%	100.0%	1,000
Initiating a maneuver and lost control	38.7%	15.8%	0.0%	13.5%	11.3%	4.3%	0.0%	16.3%	100.0%	4,000
Average	27.7%	6.7%	0.3%	19.8%	19.9%	6.3%	0.3%	19.1%	100.0%	
Cumulative Total	14,000	3,000	*	10,000	10,000	3,000	*	10,000		52,000

\* refers to a crash count below 500

**Table A-16. Distribution of Environmental Conditions in Target Off-Roadway Pre-Crash Scenarios Cited with Speeding on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	37.3%	2.6%	0.0%	22.2%	23.8%	0.0%	0.0%	14.1%	100.0%	7,000
Going straight and lost control	11.6%	11.0%	0.0%	36.2%	6.9%	10.1%	0.0%	24.3%	100.0%	24,000
Negotiating a curve and lost control	10.0%	14.4%	0.0%	35.8%	9.4%	10.6%	0.0%	19.9%	100.0%	9,000
Negotiating a curve and departed road edge	45.8%	0.0%	0.0%	4.8%	16.7%	0.0%	0.0%	32.7%	100.0%	2,000
Initiating a maneuver and departed road edge	33.8%	0.0%	0.0%	12.5%	53.7%	0.0%	0.0%	0.0%	100.0%	*
Initiating a maneuver and lost control	14.7%	9.9%	0.0%	37.3%	12.1%	2.6%	0.0%	23.3%	100.0%	3,000
Average	16.7%	9.9%	0.0%	32.7%	11.1%	7.8%	0.0%	21.8%	100.0%	
Cumulative Total	7,000	4,000	*	15,000	5,000	3,000	*	10,000		44,000

\* refers to a crash count below 500

**Table A-17. Distribution of Departure Side in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Departure Side				Total	Cumulative Total
	Left Edge	Right Edge	End Departure	Unknown		
Going straight and departed road edge	23.2%	67.2%	4.4%	5.2%	100.0%	289,000
Going straight and lost control	36.4%	50.1%	1.7%	11.8%	100.0%	153,000
Negotiating a curve and lost control	38.4%	55.6%	0.4%	5.6%	100.0%	133,000
Negotiating a curve and departed road edge	27.3%	68.8%	0.8%	3.1%	100.0%	97,000
Initiating a maneuver and departed road edge	27.7%	65.1%	2.1%	5.1%	100.0%	49,000
Initiating a maneuver and lost control	34.7%	53.0%	1.0%	11.3%	100.0%	40,000
Average	29.9%	61.0%	2.4%	6.6%	100.0%	
Cumulative Total	228,000	464,000	18,000	51,000		761,000

**Table A-18. Distribution of Departure Side in Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Departure Side				Total	Cumulative Total
	Left Edge	Right Edge	End Departure	Unknown		
Going straight and departed road edge	48.0%	51.3%	0.3%	0.5%	100.0%	38,000
Going straight and lost control	50.4%	45.6%	0.0%	4.0%	100.0%	57,000
Negotiating a curve and lost control	48.9%	48.9%	0.0%	2.1%	100.0%	19,000
Negotiating a curve and departed road edge	50.5%	46.9%	0.0%	2.5%	100.0%	7,000
Initiating a maneuver and departed road edge	59.4%	40.6%	0.0%	0.0%	100.0%	2,000
Initiating a maneuver and lost control	52.7%	40.2%	0.0%	7.1%	100.0%	8,000
Average	49.8%	47.4%	0.1%	2.7%	100.0%	
Cumulative Total	65,000	62,000	*	4,000		132,000

\* refers to a crash count below 500

**Table A-19. Distribution of First Harmful Events by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

First Harmful Event		Pre-Crash Scenario						Average	Cumulative Total
		1	2	3	4	5	6		
Non-collision	Rollover	2.6%	10.1%	8.3%	6.8%	1.8%	6.4%	6.0%	44,000
	Immersion	0.0%	0.1%	0.2%	0.1%	0.0%	0.5%	0.1%	1,000
	Other	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	*
Object Not Fixed	Pedestrian	0.4%	0.0%	0.0%	0.1%	0.9%	0.0%	0.2%	2,000
	Cyclist	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	*
	Animal	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.1%	1,000
	Veh in Transport	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	*
	Parked Vehicle	41.1%	8.1%	2.9%	8.3%	43.6%	8.0%	18.6%	167,000
	Other/Non Mot.	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Other Object	0.2%	0.5%	0.0%	0.4%	0.0%	0.3%	0.2%	2,000
Crash With Fixed Object	Ground	0.1%	0.2%	0.2%	0.1%	0.0%	0.2%	0.1%	1,000
	Building	0.7%	0.7%	0.4%	0.6%	1.0%	1.4%	0.8%	5,000
	Impact Attenuation	0.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.1%	1,000
	Bridge Structure	0.9%	1.9%	0.6%	0.8%	0.2%	1.3%	0.9%	8,000
	Guardrail	3.1%	6.2%	11.5%	5.9%	2.2%	8.9%	6.3%	44,000
	Concr Traffic Barrier	0.9%	1.4%	2.1%	0.8%	1.9%	4.1%	1.9%	11,000
	Sign Post	14.9%	15.2%	12.8%	17.1%	19.5%	19.5%	16.5%	117,000
	Culvert or Ditch	8.7%	15.1%	14.4%	16.1%	7.7%	5.5%	11.2%	89,000
	Curb	4.1%	4.3%	4.8%	2.9%	8.3%	14.5%	6.5%	38,000
	Embankment	2.5%	5.5%	13.4%	8.4%	0.7%	4.3%	5.8%	44,000
	Fence	3.5%	6.8%	4.2%	5.1%	2.3%	7.8%	4.9%	35,000
	Wall	1.0%	1.5%	0.8%	1.1%	1.3%	1.3%	1.1%	8,000
	Fire Hydrant	0.8%	1.3%	0.5%	0.8%	1.7%	1.0%	1.0%	7,000
	Shrubbery/Bush	0.7%	0.3%	0.3%	0.4%	0.4%	0.9%	0.5%	4,000
	Tree	7.9%	13.5%	15.8%	17.0%	5.1%	10.2%	11.6%	88,000
	Boulder	0.3%	0.5%	1.1%	1.5%	0.2%	0.5%	0.7%	5,000
	Pavement Irregularity	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	*
Other Fixed Object	5.1%	5.1%	4.2%	5.4%	1.3%	2.9%	4.0%	35,000	
Fix Object-No Detail	0.6%	1.3%	0.7%	0.5%	0.0%	0.6%	0.6%	5,000	
Average		38.0%	20.2%	12.7%	17.5%	6.4%	5.2%	100.0%	
Cumulative Total		289,000	153,000	133,000	97,000	49,000	40,000		761,000

**Key to Scenarios**

1	Going straight and departed road edge
2	Going straight and lost control
3	Negotiating a curve and lost control
4	Negotiating a curve and departed road edge
5	Initiating a maneuver and departed road edge
6	Initiating a maneuver and lost control

\* refers to a crash count below 500

**Table A-20. Distribution of First Harmful Events by Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

First Harmful Event		Pre-Crash Scenario						Average	Cumulative Total
		1	2	3	4	5	6		
Non-collision	Rollover	12.0%	11.0%	9.3%	8.2%	4.3%	8.9%	9.0%	14,000
	Immersion	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
Object Not Fixed	Pedestrian	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Cyclist	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Animal	0.0%	0.2%	0.4%	0.0%	0.0%	0.0%	0.1%	*
	Veh in Transport	0.0%	0.7%	0.2%	0.0%	0.0%	0.0%	0.2%	*
	Parked Vehicle	10.4%	2.5%	1.0%	2.6%	24.1%	5.9%	7.7%	7,000
	Other/Non Mot.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Other Object	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	*
Crash With Fixed Object	Ground	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.1%	*
	Building	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Impact Attenuation	1.0%	0.2%	0.0%	1.3%	9.0%	0.0%	1.9%	1,000
	Bridge Structure	2.1%	5.6%	1.3%	1.3%	0.0%	1.9%	2.0%	4,000
	Guardrail	23.6%	21.4%	26.9%	26.0%	7.3%	17.5%	20.4%	30,000
	Concr Traffic Barrier	10.2%	22.5%	25.3%	11.3%	24.9%	33.2%	21.2%	25,000
	Sign Post	10.0%	3.6%	8.6%	18.1%	17.6%	0.0%	9.7%	9,000
	Culvert or Ditch	7.0%	8.6%	5.8%	3.5%	7.3%	3.7%	6.0%	9,000
	Curb	2.3%	3.8%	4.6%	1.3%	1.2%	6.2%	3.2%	5,000
	Embankment	4.0%	5.0%	4.7%	8.2%	0.0%	7.6%	4.9%	6,000
	Fence	3.0%	2.6%	2.5%	1.2%	0.0%	1.2%	1.8%	3,000
	Wall	1.6%	1.7%	3.7%	6.2%	0.0%	7.5%	3.5%	3,000
	Fire Hydrant	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
	Shrubbery/Bush	0.6%	0.4%	1.5%	0.0%	0.0%	0.0%	0.4%	1,000
	Tree	7.7%	7.5%	3.7%	8.3%	0.0%	6.5%	5.6%	9,000
	Boulder	0.6%	0.5%	0.4%	0.0%	0.0%	0.0%	0.2%	1,000
	Pavement Irregularity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*
Other Fixed Object	2.2%	1.8%	0.0%	2.7%	4.3%	0.0%	1.8%	2,000	
Fix Object-No Detail	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	*	
Average		29.0%	43.1%	5.4%	14.8%	1.6%	6.0%	100.0%	
Cumulative Total		38,000	57,000	19,000	7,000	2,000	8,000		132,000

**Key to Scenarios**

1	Going straight and departed road edge
2	Going straight and lost control
3	Negotiating a curve and lost control
4	Negotiating a curve and departed road edge
5	Initiating a maneuver and departed road edge
6	Initiating a maneuver and lost control

\* refers to a crash count below 500

**Table A-21. Distribution of Maximum Injury Severity by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Maximum Injury Severity						Total	Cumulative Total
	None	Possible	Non-Incapacitating	Incapacitating	Fatal	Unknown		
Going straight and departed road edge	64.4%	13.0%	14.5%	6.2%	0.8%	0.9%	100.0%	289,000
Going straight and lost control	60.1%	14.3%	16.5%	7.2%	1.2%	0.7%	100.0%	153,000
Negotiating a curve and lost control	62.9%	11.7%	15.2%	8.4%	1.3%	0.5%	100.0%	133,000
Negotiating a curve and departed road edge	51.6%	17.6%	18.6%	9.3%	1.7%	1.2%	100.0%	97,000
Initiating a maneuver and departed road edge	79.3%	8.9%	7.7%	3.1%	0.0%	1.0%	100.0%	49,000
Initiating a maneuver and lost control	72.2%	10.1%	10.3%	5.9%	0.6%	0.9%	100.0%	40,000
Average	63.0%	13.2%	14.9%	7.0%	1.0%	0.8%	100.0%	
Cumulative Total	480,000	101,000	113,000	53,000	8,000	6,000		761,000

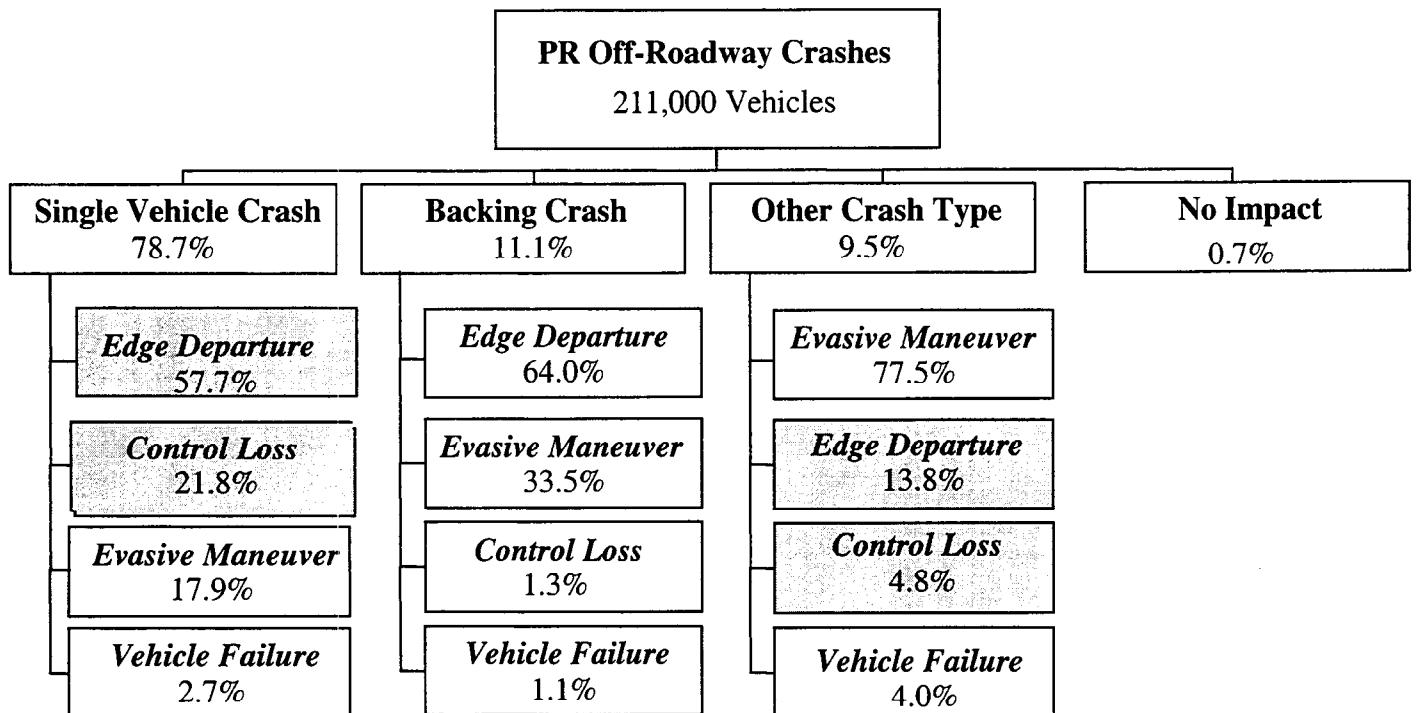
**Table A-22. Distribution of Maximum Injury Severity by Target Off-Roadway Pre-Crash Scenarios on Freeways for Light Vehicles (Based on 1998 GES)**

Pre-Crash Scenario	Maximum Injury Severity						Total	Cumulative Total
	None	Possible	Non-Incapacitating	Incapacitating	Fatal	Unknown		
Going straight and departed road edge	52.6%	14.9%	18.8%	10.1%	3.1%	0.5%	100.0%	38,000
Going straight and lost control	61.4%	15.4%	12.2%	9.7%	0.5%	0.9%	100.0%	57,000
Negotiating a curve and lost control	62.9%	15.4%	11.8%	8.0%	1.9%	0.0%	100.0%	19,000
Negotiating a curve and departed road edge	47.0%	18.9%	22.7%	7.9%	3.4%	0.0%	100.0%	7,000
Initiating a maneuver and departed road edge	72.2%	13.0%	12.6%	1.4%	0.8%	0.0%	100.0%	2,000
Initiating a maneuver and lost control	64.9%	9.3%	17.7%	7.9%	0.2%	0.0%	100.0%	8,000
Average	58.7%	15.0%	14.9%	9.2%	1.6%	0.5%	100.0%	
Cumulative Total	77,000	20,000	20,000	12,000	2,000	1,000		132,000



## B. COMMERCIAL VEHICLE OFF-ROADWAY CRASH STATISTICS

This appendix provides data on off-roadway crashes that involved commercial vehicles (large trucks - medium and heavy trucks) based on 1996-1998 GES. The codes 60, 64, 66, or 78 from the *Hotdeck Imputed Body Type* variable and not codes 05-07 from the *Special Use* variable identify this vehicle platform in the GES. Figure B-1 illustrates the distribution of off-roadway crashes that involved at least one commercial vehicle. Tables B-1–B-22 present detailed statistics of off-roadway crashes involving commercial vehicles.



**Figure B-1. Distribution of Off-Roadway Crashes Involving Commercial Vehicles  
(Based on 1996–1998 GES)**

**Table B-1. Target Off-Roadway Pre-Crash Scenarios for Commercial Vehicles  
(Based on 1996–1998 GES)**

Pre-Crash Scenario	Frequency	Relative Frequency*	Cumulative Frequency	Cumulative/Relative Frequency*
Going straight and departed road edge	44,000	32.5%	44,000	32.5%
Initiating a maneuver and departed road edge	37,000	27.4%	81,000	59.9%
Going straight and lost control	18,000	13.4%	99,000	73.4%
Negotiating a curve and lost control	12,000	8.9%	111,000	82.2%
Negotiating a curve and departed road edge	10,000	7.2%	121,000	89.4%
Initiating a maneuver and lost control	6,000	4.1%	127,000	93.5%

\*Scenario crash frequency relative to the frequency of target crash population (136,000)

Note: Frequency values are rounded to the nearest 1,000.

**Table B-2. 95% Confidence Bounds of Target Off-Roadway Pre-Crash Scenario Counts for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Frequency	Lower 95 % Confidence Bound	Upper 95 % Confidence Bound
Going straight and departed road edge	44,000	35,000	53,000
Initiating a maneuver and departed road edge	37,000	29,000	45,000
Going straight and lost control	18,000	13,000	23,000
Negotiating a curve and lost control	12,000	9,000	15,000
Negotiating a curve and departed road edge	10,000	7,000	13,000
Initiating a maneuver and lost control	6,000	4,000	8,000
Total	127,000	16,000	238,000

**Table B-3. Distribution of Vehicles Movements in “Initiating a Maneuver” Scenarios (Based on 1996–1998 GES)**

Pre-Crash Scenario	Maneuver						Total	Cumulative Total
	Turning	Passing or Changing	Parking	Slowing or Stopping	Merging	Starting		
Initiating a maneuver and departed road edge	86.5%	4.0%	5.7%	2.3%	0.8%	0.7%	100.0%	37,000
Initiating a maneuver and lost control	75.6%	7.5%	0.0%	10.0%	6.9%	0.0%	100.0%	6,000
Average	85.1%	4.5%	5.0%	3.3%	1.6%	0.6%	100.0%	
Cumulative Total	36,000	2,000	2,000	1,000	1,000	*		43,000

\* refers to a crash count below 500



**Table B-4. Distribution of Off-Roadway Pre-Crash Scenarios by Roadway Type for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Non-Freeway		Freeway	
	Frequency	Relative Frequency	Frequency	Relative Frequency
Going straight and departed road edge	36,000	34.7%	8,000	35.3%
Initiating a maneuver and departed road edge	36,000	34.1%	1,000	6.2%
Going straight and lost control	10,000	9.6%	8,000	37.2%
Negotiating a curve and lost control	10,000	9.2%	2,000	11.0%
Negotiating a curve and departed road edge	8,000	7.8%	2,000	7.0%
Initiating a maneuver and lost control	5,000	4.6%	1,000	3.2%
Total	105,000	100.0%	22,000	100.0%

Note: 75.1% of freeway crashes occurred on interstate highways

**Table B-5. Distribution of Target Off-Roadway Pre-Crash Scenarios on *Non-Freeways* by Land Use and Relation to Junction for Commercial Vehicles  
(Based on 1996 – 1998 GES)**

Pre-Crash Scenarios	Land Use	Relationship to Junction					Total
		Non-Junction	Intersection	Driveway	Ent/Exit Ramp	Other	
Going Straight and Departed Road Edge (36,000)	Rural (56.4%)	89.4%	7.2%	1.2%	0.3%	2.0%	100.0%
	Urban (41.8%)	84.6%	15.2%	0.0%	0.2%	0.1%	100.0%
	Unknown (1.8%)	99.3%	0.7%	0.0%	0.0%	0.0%	100.0%
Initiating a Manuever and Departed Road Edge (36,000)	Rural (58.0%)	12.0%	76.3%	10.2%	0.0%	1.5%	100.0%
	Urban (38.2%)	15.4%	75.5%	8.8%	0.2%	0.1%	100.0%
	Unknown (3.8%)	0.0%	77.6%	20.9%	0.0%	1.5%	100.0%
Going Straight and Lost Control (10,000)	Rural (61.3%)	82.9%	15.1%	0.2%	1.4%	0.5%	100.0%
	Urban (30.3%)	71.2%	25.2%	0.0%	1.5%	2.0%	100.0%
	Unknown (8.5%)	81.8%	13.4%	0.0%	0.0%	4.8%	100.0%
Negotiating a Curve and Lost Control (10,000)	Rural (80.7%)	93.9%	0.0%	0.0%	5.9%	0.2%	100.0%
	Urban (6.5%)	73.6%	3.1%	0.0%	22.0%	1.3%	100.0%
	Unknown (12.8%)	97.8%	0.0%	0.0%	2.2%	0.0%	100.0%
Negotiating a Curve and Departed Road Edge (8,000)	Rural (80.8%)	99.3%	0.5%	0.0%	0.2%	0.0%	100.0%
	Urban (9.1%)	95.0%	1.5%	0.0%	3.4%	0.0%	100.0%
	Unknown (10.1%)	97.8%	1.2%	0.0%	1.0%	0.0%	100.0%
Initiating a Manuever and Lost Control (5,000)	Rural (63.3%)	2.1%	72.1%	14.9%	7.4%	3.5%	100.0%
	Urban (30.5%)	37.2%	62.4%	0.0%	0.4%	0.0%	100.0%
	Unknown (6.2%)	1.4%	98.6%	0.0%	0.0%	0.0%	100.0%
Average		59.2%	34.6%	4.1%	1.1%	1.0%	100.0%
Cumulative Total		62,000	36,000	4,000	1,000	1,000	105,000

**Table B-6. Distribution of Target Off-Roadway Pre-Crash Scenarios on Freeways by Land Use and Relation to Junction for Commercial Vehicles (Based on 1996– 1998 GES)**

Pre-Crash Scenarios	Land Use	Relationship to Junction					Total
		Non-Junction	Intersection	Driveway	Ent/Exit Ramp	Other	
Going Straight and Departed Road Edge (8,000)	Rural (71.0%)	97.4%	1.0%	0.0%	0.4%	1.2%	100.0%
	Urban (15.1%)	89.5%	0.0%	0.0%	9.6%	0.8%	100.0%
	Unknown (13.9%)	95.1%	0.0%	0.0%	0.0%	4.9%	100.0%
Initiating a Manuever and Departed Road Edge (1,000)	Rural (64.5%)	13.6%	52.4%	0.0%	34.1%	0.0%	100.0%
	Urban (29.6%)	82.8%	0.0%	0.0%	17.2%	0.0%	100.0%
	Unknown (5.9%)	75.5%	0.0%	0.0%	24.6%	0.0%	100.0%
Going Straight and Lost Control (8,000)	Rural (71.2%)	85.1%	0.8%	0.0%	1.9%	12.3%	100.0%
	Urban (18.5%)	96.3%	0.0%	0.0%	3.7%	0.0%	100.0%
	Unknown (10.3%)	90.5%	0.0%	0.0%	0.2%	9.3%	100.0%
Negotiating a Curve and Lost Control (2,000)	Rural (39.4%)	53.9%	0.0%	0.0%	46.1%	0.0%	100.0%
	Urban (41.4%)	68.0%	0.0%	0.0%	29.6%	2.4%	100.0%
	Unknown (19.2%)	49.6%	0.9%	0.0%	49.5%	0.0%	100.0%
Negotiating a Curve and Departed Road Edge (2,000)	Rural (58.3%)	24.8%	0.0%	0.0%	75.2%	0.0%	100.0%
	Urban (35.0%)	32.8%	0.0%	0.0%	67.2%	0.0%	100.0%
	Unknown (6.7%)	63.3%	0.0%	0.0%	36.7%	0.0%	100.0%
Initiating a Manuever and Lost Control (1,000)	Rural (71.1%)	56.6%	6.2%	0.7%	5.7%	30.9%	100.0%
	Urban (13.2%)	48.3%	25.3%	0.0%	20.7%	5.8%	100.0%
	Unknown (15.7%)	80.0%	12.7%	0.0%	7.3%	0.0%	100.0%
Average		79.3%	2.9%	0.0%	12.7%	5.0%	100.0%
Cumulative Total		17,000	1,000	*	3,000	1,000	22,000

\* refers to a crash count below 500

**Table B-7. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Undivided Non-Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	≥7	unknown		
Going straight and departed road edge	0.8%	46.9%	3.8%	3.0%	0.9%	0.0%	0.0%	44.7%	100.0%	33,000
Initiating a maneuver and departed road edge	0.9%	33.5%	4.6%	12.3%	6.0%	0.0%	0.0%	42.8%	100.0%	31,000
Going straight and lost control	0.0%	78.3%	0.2%	4.0%	0.1%	0.3%	0.3%	16.9%	100.0%	9,000
Negotiating a curve and lost control	0.0%	88.5%	1.9%	0.5%	0.0%	0.0%	0.0%	9.0%	100.0%	9,000
Negotiating a curve and departed road edge	0.0%	65.9%	1.7%	0.1%	0.0%	0.0%	0.0%	32.3%	100.0%	7,000
Initiating a maneuver and lost control	5.5%	56.3%	0.3%	2.3%	4.7%	0.1%	0.7%	30.2%	100.0%	4,000
Average	0.8%	51.3%	3.2%	5.7%	2.5%	0.0%	0.1%	36.4%	100.0%	
Cumulative Total	1,000	48,000	3,000	5,000	2,000	*	*	34,000		94,000

\* refers to a crash count below 500

**Table B-8. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Divided Non-Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Number of Lanes								Total	Cumulative Total
	1	2	3	4	5	6	≥7	unknown		
Going straight and departed road edge	12.6%	38.1%	9.9%	2.8%	0.0%	0.0%	0.0%	36.7%	100.0%	3,000
Initiating a maneuver and departed road edge	1.1%	41.7%	27.7%	5.8%	0.0%	0.0%	0.0%	23.8%	100.0%	5,000
Going straight and lost control	31.0%	48.3%	11.9%	2.3%	0.0%	0.0%	0.0%	6.4%	100.0%	1,000
Negotiating a curve and lost control	51.9%	26.7%	2.8%	0.0%	0.0%	5.9%	0.0%	12.7%	100.0%	1,000
Negotiating a curve and departed road edge	3.1%	17.6%	1.1%	0.0%	0.0%	0.0%	0.0%	78.2%	100.0%	1,000
Initiating a maneuver and lost control	0.8%	6.9%	10.9%	0.0%	0.0%	0.0%	0.0%	81.4%	100.0%	1,000
Average	11.4%	36.5%	16.3%	3.4%	0.0%	0.5%	0.0%	31.8%	100.0%	
Cumulative Total	1,000	4,000	2,000	*	*	*	*	4,000		12,000

\* refers to a crash count below 500

**Table B-9. Distribution of Number of Lanes in Target Off-Roadway Pre-Crash Scenarios on Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Number of Lanes							Total	Cumulative Total
	1	2	3	4	5	6	unknown		
Going straight and departed road edge	5.7%	67.8%	17.3%	2.4%	0.4%	0.0%	6.4%	100.0%	8,000
Initiating a maneuver and departed road edge	32.7%	19.3%	0.6%	0.6%	0.0%	0.0%	46.9%	100.0%	1,000
Going straight and lost control	1.1%	68.1%	20.5%	7.2%	0.7%	0.0%	2.4%	100.0%	8,000
Negotiating a curve and lost control	32.0%	51.6%	8.0%	2.6%	0.5%	2.2%	3.1%	100.0%	2,000
Negotiating a curve and departed road edge	48.7%	43.1%	1.5%	0.5%	0.0%	0.0%	6.3%	100.0%	2,000
Initiating a maneuver and lost control	5.3%	58.0%	29.6%	5.1%	0.7%	0.0%	1.4%	100.0%	1,000
Average	11.6%	61.1%	15.7%	4.1%	0.5%	0.3%	6.9%	100.0%	
Cumulative Total	3,000	13,000	3,000	1,000	*	*	1,000		22,000

\* refers to a crash count below 500

**Table B-10. Distribution of Posted Speed Limits in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Posted Speed Limit (mph)											Total	Cumulative Total
	<20	25	30	35	40	45	50	55	60	65	>65		
Going straight and departed road edge	3.0%	47.2%	9.4%	11.2%	0.5%	10.7%	2.1%	13.8%	0.3%	1.8%	0.0%	100.0%	36,000
Initiating a maneuver and departed road edge	4.9%	31.8%	12.6%	26.2%	10.1%	5.1%	1.6%	6.8%	0.2%	0.0%	0.8%	100.0%	36,000
Going straight and lost control	1.5%	8.3%	7.8%	14.0%	3.1%	15.9%	2.6%	43.1%	3.7%	0.0%	0.0%	100.0%	10,000
Negotiating a curve and lost control	1.5%	11.2%	2.3%	19.0%	5.0%	12.9%	3.1%	41.6%	1.7%	1.7%	0.0%	100.0%	10,000
Negotiating a curve and departed road edge	9.0%	22.5%	4.7%	18.8%	3.8%	9.6%	0.7%	30.8%	0.0%	0.1%	0.0%	100.0%	8,000
Initiating a maneuver and lost control	6.6%	37.4%	6.6%	7.7%	4.6%	14.4%	3.5%	17.5%	0.1%	0.1%	1.6%	100.0%	5,000
Average	4.0%	32.5%	9.2%	17.7%	4.8%	9.6%	2.0%	18.3%	0.7%	0.8%	0.3%	100.0%	
Cumulative Total	4,000	34,000	10,000	19,000	5,000	10,000	2,000	19,000	1,000	1,000	*		105,000

\* refers to a crash count below 500

**Table B-11. Distribution of Contributing Factors in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Commercial Vehicles (Based on 1997–1998 GES)**

Pre-Crash Scenario	Contributing Factors/Driver Circumstance						Total	Cumulative Total
	Alcohol or Drugs	Driver Impaired	Driver Distracted	Speeding	Hit/Run	Other		
Going straight and departed road edge	0.4%	0.9%	7.0%	5.9%	48.1%	37.7%	100.0%	29,000
Initiating a maneuver and departed road edge	0.0%	0.0%	2.2%	3.9%	16.6%	77.2%	100.0%	24,000
Going straight and lost control	1.1%	1.6%	1.6%	31.7%	10.5%	53.6%	100.0%	7,000
Negotiating a curve and lost control	0.4%	0.6%	5.7%	50.9%	10.1%	32.3%	100.0%	6,000
Negotiating a curve and departed road edge	1.0%	1.8%	5.6%	13.4%	29.7%	48.5%	100.0%	6,000
Initiating a maneuver and lost control	0.2%	0.0%	14.9%	27.3%	8.8%	48.9%	100.0%	3,000
Average	0.4%	0.7%	5.1%	12.7%	28.5%	52.8%	100.0%	
Cumulative Total	*	1,000	4,000	10,000	22,000	40,000		76,000

\* refers to a crash count below 500

**Table B-12. Distribution of Environmental Conditions in “Other” Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Commercial Vehicles (Based on 1997–1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	68.7%	3.7%	0.0%	9.2%	8.7%	6.0%	0.0%	3.7%	100.0%	11,000
Initiating a maneuver and departed road edge	65.0%	5.7%	0.0%	6.5%	17.3%	3.6%	0.0%	1.9%	100.0%	19,000
Going straight and lost control	28.0%	31.8%	0.0%	14.9%	1.5%	1.0%	7.9%	14.9%	100.0%	4,000
Negotiating a curve and lost control	52.6%	1.7%	0.0%	24.3%	17.7%	0.3%	0.0%	3.5%	100.0%	2,000
Negotiating a curve and departed road edge	60.8%	0.3%	0.8%	2.4%	12.5%	0.5%	0.0%	22.8%	100.0%	3,000
Initiating a maneuver and lost control	39.4%	31.4%	0.0%	24.6%	2.5%	0.0%	0.0%	2.2%	100.0%	2,000
Average	60.6%	8.1%	0.1%	9.3%	12.5%	3.5%	0.8%	5.2%	100.0%	
Cumulative Total	24,000	3,000	*	4,000	5,000	1,000	*	2,000		40,000

\* refers to a crash count below 500

**Table B-13. Distribution of Environmental Conditions in Target Off-Roadway Pre-Crash Scenarios Cited with Speeding on Non-Freeways for Commercial Vehicles (Based on 1997 - 1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	50.4%	0.0%	0.0%	39.8%	4.6%	0.0%	5.2%	0.0%	100.0%	2,000
Initiating a maneuver and departed road edge	64.4%	4.2%	0.0%	1.3%	29.5%	0.0%	0.6%	0.0%	100.0%	1,000
Going straight and lost control	22.2%	28.0%	0.0%	22.5%	12.0%	2.7%	12.7%	0.0%	100.0%	2,000
Negotiating a curve and lost control	64.6%	0.3%	0.0%	7.0%	17.1%	3.2%	7.9%	0.0%	100.0%	3,000
Negotiating a curve and departed road edge	67.0%	0.0%	0.0%	10.5%	22.5%	0.0%	0.0%	0.0%	100.0%	1,000
Initiating a maneuver and lost control	26.7%	0.3%	0.0%	5.6%	28.3%	0.0%	39.2%	0.0%	100.0%	1,000
Average	48.6%	7.3%	0.0%	16.3%	16.2%	1.6%	10.0%	0.0%	100.0%	
Cumulative Total	5,000	1,000	*	2,000	2,000	*	1,000	*		10,000

\* refers to a crash count below 500

**Table B-14. Distribution of Contributing Factors in Target Off-Roadway Pre-Crash Scenarios on Freeways for Commercial Vehicles (Based on 1997 - 1998 GES)**

Pre-Crash Scenario	Contributing Factors/Driver Circumstance						Total	Cumulative Total
	Alcohol or drugs	Driver impaired	Driver Distracted	Speeding	Hit/Run	Other		
Going straight and departed road edge	2.5%	14.8%	9.5%	9.8%	2.8%	60.6%	100.0%	6,000
Initiating a maneuver and departed road edge	0.0%	0.0%	0.5%	0.0%	0.0%	99.5%	100.0%	1,000
Going straight and lost control	1.8%	2.9%	1.9%	43.9%	0.0%	49.6%	100.0%	4,000
Negotiating a curve and lost control	1.1%	0.0%	1.1%	48.9%	0.0%	49.0%	100.0%	2,000
Negotiating a curve and departed road edge	0.7%	8.5%	2.5%	30.3%	0.0%	58.1%	100.0%	1,000
Initiating a maneuver and lost control	0.0%	0.0%	0.8%	43.3%	0.0%	55.9%	100.0%	*
Average	1.7%	7.3%	4.7%	26.4%	1.1%	58.9%	100.0%	
Cumulative Total	*	1,000	1,000	4,000	*	9,000		15,000

\* refers to a crash count below 500

**Table B-15. Distribution of Environmental Conditions in "Other" Target Off-Roadway Pre-Crash Scenarios on Freeways for Commercial Vehicles (Based on 1997-1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	50.5%	1.5%	0.0%	14.7%	29.5%	1.6%	0.0%	2.3%	100.0%	3,000
Initiating a maneuver and departed road edge	33.0%	0.2%	4.9%	4.4%	55.5%	0.0%	0.0%	1.9%	100.0%	1,000
Going straight and lost control	25.9%	12.6%	2.5%	22.6%	21.3%	0.7%	0.4%	14.0%	100.0%	2,000
Negotiating a curve and lost control	36.5%	0.7%	0.0%	11.1%	39.9%	0.3%	0.0%	11.4%	100.0%	1,000
Negotiating a curve and departed road edge	76.4%	0.0%	0.0%	0.0%	15.0%	0.0%	0.0%	8.6%	100.0%	1,000
Initiating a maneuver and lost control	21.5%	0.0%	0.0%	1.0%	69.0%	0.0%	0.0%	8.6%	100.0%	*
Average	41.7%	3.8%	1.3%	13.4%	32.2%	0.9%	0.1%	6.7%	100.0%	
Cumulative Total	4,000	*	*	1,000	3,000	*	*	1,000		9,000

\* refers to a crash count below 500

**Table B-16. Distribution of Environmental Conditions in Target Off-Roadway Pre-Crash Scenarios Cited with Speeding on Freeways for Commercial Vehicles (Based on 1997–1998 GES)**

Pre-Crash Scenario	Day				Dark				Total	Cumulative Total
	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery	Clear & Dry	Clear & Slippery	Adverse & Dry	Adverse & Slippery		
Going straight and departed road edge	71.5%	1.1%	8.0%	2.7%	11.3%	2.0%	3.4%	0.0%	100.0%	1,000
Initiating a maneuver and departed road edge	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	*
Going straight and lost control	6.0%	7.4%	0.0%	41.5%	7.0%	1.9%	36.3%	0.0%	100.0%	2,000
Negotiating a curve and lost control	26.2%	1.3%	0.0%	24.4%	7.6%	0.8%	39.9%	0.0%	100.0%	1,000
Negotiating a curve and departed road edge	7.4%	0.8%	0.0%	1.4%	15.8%	0.0%	74.7%	0.0%	100.0%	*
Initiating a maneuver and lost control	47.7%	0.0%	0.0%	12.7%	25.8%	0.0%	13.9%	0.0%	100.0%	*
Average	22.1%	4.2%	1.2%	27.1%	9.4%	1.4%	34.8%	0.0%	100.0%	
Cumulative Total	1,000	*	*	1,000	*	*	1,000	*		4,000

\* refers to a crash count below 500

**Table B-17. Distribution of Departure Side in Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Departure Side				Total	Cumulative Total
	Left Edge	Right Edge	End Departure	Unknown		
Going straight and departed road edge	18.5%	70.7%	0.1%	10.7%	100.0%	36,000
Initiating a maneuver and departed road edge	20.2%	75.7%	0.7%	3.4%	100.0%	36,000
Going straight and lost control	29.0%	52.1%	7.2%	11.7%	100.0%	10,000
Negotiating a curve and lost control	32.9%	60.7%	0.0%	6.4%	100.0%	10,000
Negotiating a curve and departed road edge	22.6%	72.5%	0.0%	5.0%	100.0%	8,000
Initiating a maneuver and lost control	18.3%	66.2%	0.1%	15.5%	100.0%	5,000
Average	21.7%	69.6%	1.0%	7.7%	100.0%	
Cumulative Total	23,000	73,000	1,000	8,000		105,000



**Table B-18. Distribution of Departure Side in Target Off-Roadway Pre-Crash Scenarios on Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Departure Side				Total	Cumulative Total
	Left Edge	Right Edge	End Departure	Unknown		
Going straight and departed road edge	27.5%	69.0%	0.0%	3.6%	100.0%	8,000
Initiating a maneuver and departed road edge	58.4%	41.6%	0.0%	0.0%	100.0%	1,000
Going straight and lost control	56.0%	36.3%	0.0%	7.7%	100.0%	8,000
Negotiating a curve and lost control	39.6%	57.8%	0.0%	2.6%	100.0%	2,000
Negotiating a curve and departed road edge	40.0%	60.0%	0.0%	0.0%	100.0%	2,000
Initiating a maneuver and lost control	53.1%	45.7%	0.0%	1.1%	100.0%	1,000
Average	43.1%	52.5%	0.0%	4.5%	100.0%	
Cumulative Total	9,000	11,000	*	1,000		22,000

\* refers to a crash count below 500

**Table B-19. Distribution of First Harmful Events by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Commercial Vehicles  
(Based on 1996–1998 GES)**

First Harmful Event		Pre-Crash Scenario						Average	Cumulative Total
		1	2	3	4	5	6		
Non-collision	Rollover	6.5%	4.1%	17.9%	30.7%	15.6%	20.4%	10.3%	11,000
	Jackknife	0.1%	0.1%	4.3%	2.8%	0.6%	1.3%	0.9%	1,000
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	*
Object Not Fixed	Pedestrian	0.8%	0.0%	0.0%	0.0%	0.1%	0.0%	0.3%	*
	Veh in Transport	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	*
	Parked Vehicle	66.9%	30.7%	16.1%	4.1%	22.2%	18.5%	38.2%	40,000
	Other Object	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.6%	1,000
Crash With Fixed Object	Ground	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.1%	*
	Building	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.5%	1,000
	Impact Attenuation	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	*
	Bridge Structure	0.8%	1.0%	0.3%	0.2%	0.0%	2.2%	0.8%	1,000
	Guardrail	1.8%	3.9%	3.7%	18.6%	24.4%	4.8%	6.1%	6,000
	Concr Traffic Barrier	0.2%	0.1%	1.9%	1.2%	0.1%	0.1%	0.4%	*
	Sign Post	12.6%	41.0%	14.6%	4.4%	9.8%	17.8%	21.7%	23,000
	Culvert or Ditch	3.3%	2.3%	15.4%	15.7%	13.8%	2.5%	6.1%	6,000
	Curb	0.9%	0.9%	2.1%	0.4%	0.7%	0.9%	1.0%	1,000
	Embankment	1.6%	0.0%	7.9%	11.7%	5.4%	0.1%	2.8%	3,000
	Fence	0.4%	1.7%	6.4%	6.7%	0.0%	6.6%	2.2%	2,000
	Wall	0.0%	0.8%	0.1%	0.3%	0.1%	0.0%	0.3%	*
	Fire Hydrant	0.0%	6.2%	0.0%	0.0%	0.0%	6.3%	2.4%	3,000
	Shrubbery/Bush	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.3%	*
	Tree	0.7%	0.9%	3.3%	2.6%	6.8%	16.6%	2.4%	3,000
Boulder	0.3%	0.0%	0.3%	0.1%	0.0%	0.0%	0.2%	*	
Other Fixed Object	2.1%	3.2%	5.3%	0.6%	0.2%	0.0%	2.4%	3,000	
Fix Object-No Detail	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Cumulative Total		36,000	36,000	10,000	10,000	8,000	5,000		105,000

**Key to Scenarios**

1	Going straight and departed road edge
2	Initiating a maneuver and departed road edge
3	Going straight and lost control
4	Negotiating a curve and lost control
5	Negotiating a curve and departed road edge
6	Initiating a maneuver and lost control

\* refers to a crash count below 500

**Table B-20. Distribution of First Harmful Events by Target Off-Roadway Pre-Crash Scenarios on Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Freeway									
First Harmful Event		Pre-Crash Scenario						Average	Cumulative Total
		1	2	3	4	5	6		
Non-collision	Rollover	24.7%	12.9%	17.3%	24.8%	12.0%	35.0%	20.7%	4,000
	Jackknife	0.3%	0.0%	9.6%	5.0%	0.0%	4.9%	4.4%	1,000
	Other	0.7%	0.0%	0.8%	0.1%	0.0%	0.0%	0.5%	0
Object Not Fixed	Pedestrian	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
	Veh in Transport	0.0%	0.0%	0.1%	0.0%	0.4%	0.0%	0.1%	0
	Parked Vehicle	24.9%	24.1%	4.8%	0.3%	24.8%	0.3%	13.8%	3,000
	Other Object	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
Crash With Fixed Object	Ground	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
	Building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
	Impact Attenuation	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%	0
	Bridge Structure	0.7%	0.1%	4.2%	0.5%	0.7%	3.7%	2.1%	0
	Guardrail	13.1%	36.7%	18.0%	28.7%	4.5%	17.8%	17.7%	4,000
	Concr Traffic Barrier	3.0%	0.2%	12.2%	7.9%	5.1%	25.3%	7.6%	2,000
	Sign Post	14.7%	24.0%	5.2%	5.2%	39.6%	2.8%	12.1%	3,000
	Culvert or Ditch	8.2%	0.4%	17.6%	14.6%	5.5%	3.9%	11.6%	3,000
	Curb	0.2%	0.2%	0.4%	2.8%	1.1%	2.0%	0.7%	0
	Embankment	0.2%	0.0%	3.0%	3.1%	0.2%	2.0%	1.6%	0
	Fence	4.9%	0.0%	0.9%	0.0%	0.4%	0.0%	2.1%	0
	Wall	0.1%	0.0%	0.4%	1.5%	0.8%	2.2%	0.5%	0
	Fire Hydrant	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
	Shrubbery/Bush	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.1%	0
	Tree	3.1%	1.4%	5.2%	5.1%	5.0%	0.0%	4.0%	1,000
	Boulder	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
	Other Fixed Object	0.3%	0.0%	0.0%	0.3%	0.0%	0.0%	0.2%	0
Fix Object-No Detail	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Cumulative Total		8,000	1,000	8,000	2,000	2,000	1,000		22,000

**Key to Scenarios**

1	Going straight and departed road edge
2	Initiating a maneuver and departed road edge
3	Going straight and lost control
4	Negotiating a curve and lost control
5	Negotiating a curve and departed road edge
6	Initiating a maneuver and lost control

\* refers to a crash count below 500

**Table B-21. Distribution of Maximum Injury Severity by Target Off-Roadway Pre-Crash Scenarios on Non-Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Maximum Injury Severity						Total	Cumulative Total
	None	Possible	Non-Incapacitating	Incapacitating	Fatal	Unknown		
Going straight and departed road edge	86.1%	5.8%	5.1%	1.8%	0.5%	0.9%	100.0%	36,000
Initiating a maneuver and departed road edge	97.2%	2.2%	0.6%	0.0%	0.0%	0.0%	100.0%	36,000
Going straight and lost control	71.1%	14.1%	10.9%	3.6%	0.0%	0.3%	100.0%	10,000
Negotiating a curve and lost control	52.2%	16.9%	17.1%	7.8%	5.9%	0.2%	100.0%	10,000
Negotiating a curve and departed road edge	70.6%	5.0%	14.6%	9.2%	0.6%	0.0%	100.0%	8,000
Initiating a maneuver and lost control	85.3%	6.2%	3.8%	4.7%	0.0%	0.1%	100.0%	5,000
Average	84.1%	6.3%	5.9%	2.6%	0.7%	0.4%	100.0%	
Cumulative Total	88,000	7,000	6,000	3,000	1,000	*		105,000

\* refers to a crash count below 500

**Table B-22. Distribution of Maximum Injury Severity by Target Off-Roadway Pre-Crash Scenarios on Freeways for Commercial Vehicles (Based on 1996–1998 GES)**

Pre-Crash Scenario	Maximum Injury Severity						Total	Cumulative Total
	None	Possible	Non-Incapacitating	Incapacitating	Fatal	Unknown		
Going straight and departed road edge	63.8%	9.2%	13.0%	12.5%	0.8%	0.7%	100.0%	8,000
Initiating a maneuver and departed road edge	90.1%	3.8%	1.2%	4.8%	0.0%	0.0%	100.0%	1,000
Going straight and lost control	68.1%	15.6%	9.2%	6.7%	0.5%	0.0%	100.0%	8,000
Negotiating a curve and lost control	47.3%	11.4%	15.9%	24.8%	0.7%	0.0%	100.0%	2,000
Negotiating a curve and departed road edge	60.0%	26.8%	3.5%	9.0%	0.0%	0.7%	100.0%	2,000
Initiating a maneuver and lost control	34.0%	43.8%	12.2%	10.0%	0.0%	0.0%	100.0%	1,000
Average	64.0%	13.8%	10.4%	10.9%	0.6%	0.3%	100.0%	
Cumulative Total	14,000	3,000	2,000	2,000	*	*		22,000

\* refers to a crash count below 500



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