United States General Accounting Office

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Report to Congressional Requesters

March 2003

HIGHWAY SAFETY

Research Continues on a Variety of Factors That Contribute to Motor Vehicle Crashes

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GAO-03-436

March 2003

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Highlights

Highlights of GAO-03-436, a report to congressional requesters

HIGHWAY SAFETY

Research Continues on a Variety of Factors That Contribute to Motor Vehicle Crashes

Why GAO Did This Study

Nearly 6.3 million motor vehicle crashes occurred in the United States in 2001, or one crash every 5 seconds. On average, a person was injured in these crashes every 10 seconds, and someone was killed every 12 minutes. Since the 1970s, progress has been made in reducing the number of fatalities and injuries on our nation's roads. From 1975 through 2001, fatalities decreased from 44,525 to 42,116, while the rate of fatalities per 100 million vehicle miles traveled decreased from 3.35 to 1.51. However, the decline in fatalities has leveled off in recent years. In the 1970s, Indiana University conducted one of the most significant studies to date on the factors that contribute to motor vehicle crashes. This study examined human, environmental, and vehicle factors that contribute to crashes. As requested, this report provides more recent information from data, experts, and studies about the factors that contribute to motor vehicle crashes and information about major ongoing and planned Department of Transportation research into factors that contribute to crashes.

www.gao.gov/cgi-bin/getrpt?GAO-03-436

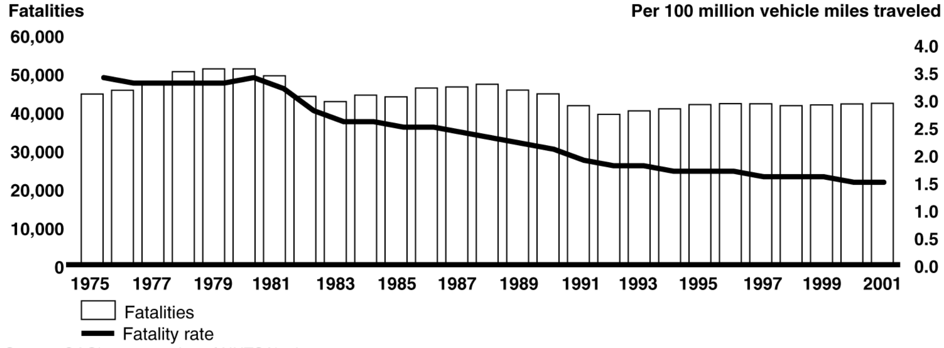
To view the full report, including the scope and methodology, click on the link above. For more information, contact Peter Guerrero, (202) 512-2834, guerrerog@gao.gov.

What GAO Found

Many factors combine to produce circumstances that may lead to a motor vehicle crash—there is rarely a single cause of such an event. Three categories of factors contribute to crashes: human factors, roadway environment factors, and vehicle factors. Human factors involve the actions taken by or the condition of the driver of the automobile, including speeding and violating traffic laws, as well as being affected by alcohol or drugs, inattention, decision errors, and age. Roadway environment factors include the design of the roadway, roadside hazards, and roadway conditions. Vehicle factors include any failures that may exist in the automobile or design of the vehicle. Human factors are seen as the most prevalent, according to data, experts, and studies, in contributing to crashes, followed by roadway environment and vehicle factors.

Agencies within the Department of Transportation have research projects underway or planned that address the factors that contribute to crashes. For example, the Federal Motor Carrier Safety Administration and the National Highway Traffic Safety Administration are conducting a study on the causes and contributing factors to large truck crashes. In addition, the National Highway Traffic Safety Administration is conducting a 100-Car Naturalistic Driving Study and the Drive Atlanta Study. The 100-Car Naturalistic Driving Study involves collecting data from vehicles equipped with sensors and cameras to obtain better information on crashes and near misses. The Drive Atlanta Study involves collecting data from 1,100 vehicles equipped with data recorders to develop information about how excessive speed contributes to crashes. In addition, the Transportation Research Board has proposed a broad, 6-year, $180 million research program focused on making significant improvements in highway safety. This study, among other things, would involve installing sensors and other data collection devices on over 5,000 vehicles.

Fatality Statistics, 1975–2001



Source: GAO's presentation of NHTSA's data.

Contents

Abbreviations

AAA	former American Automobile Association
AASHTO	American Association of State Highway and Transportation Officials
BAC	blood alcohol content
CDS	Crashworthiness Data System
DOT	Department of Transportation
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
F-SHRP	Future Strategic Highway Research Program
GES	General Estimates System
NHTSA	National Highway Traffic Safety Administration
SUV	sport utility vehicle
VMT	vehicle miles traveled

GAO

Accountability * Integrity * Reliability

United States General Accounting Office
Washington, DC 20548

March 31, 2003

The Honorable Carl Levin
United States Senate

The Honorable George V. Voinovich
United States Senate

Nearly 6.3 million motor vehicle crashes occurred in the United States in 2001, or one crash every 5 seconds. On average, a person was injured in these crashes every 10 seconds, and someone was killed every 12 minutes. While there have been significant improvements in motor vehicle safety over the past several decades, decreases in injuries and fatalities have leveled off since the early 1990s.

In the 1970s, Indiana University conducted a major study that examined the human, environmental, and vehicle factors that contribute to traffic crashes.[1] You asked us to (1) provide more recent information on the factors that contribute to motor vehicle crashes, and (2) identify major ongoing and planned Department of Transportation research into factors that contribute to crashes.

To provide information on factors that contribute to motor vehicle crashes, we obtained and analyzed crash data from three Department of Transportation databases. In addition, we interviewed experts from academia, insurance organizations, and advocacy groups. To identify recent studies on factors that contribute to motor vehicle crashes, we conducted a literature search, explored the Transportation Research Information System, and reviewed periodicals. This effort resulted in numerous studies being identified on various aspects of motor vehicle crashes. We then, with input from a number of experts and agency officials, judgmentally selected studies that would provide additional information on the particular factors being discussed. For each of the selected studies that are used in this report, we determined whether the studies' findings were generally reliable. We evaluated the methodological soundness of the studies using common social science and statistical practices. To identify the major ongoing and planned research into factors

[1]J.R. Treat et al., *Tri-Level Study of the Causes of Traffic Accidents* (Washington, D.C.: Institute for Research in Public Safety, May 30, 1979), for the U.S. Department of Transportation.

that contribute to crashes, we interviewed officials from the National Highway Traffic Safety Administration, the Federal Highway Administration, and the Transportation Research Board. Appendix I provides more details on our scope and methodology.

Results in Brief

Many factors can combine to produce circumstances that lead to a motor vehicle crash—there is rarely a single cause of such an event. Three categories of factors contribute to crashes: human factors, roadway environment factors, and vehicle factors. Human factors involve the actions taken by or the condition of the driver of the motor vehicle, including speeding and violating traffic laws, as well as being affected by alcohol or drugs, inattention, decision errors, and age. Roadway environment factors that contribute to, or are associated with, crashes include the roadway design (for example, medians, narrow lanes, the lack of shoulders, curves, access points, or intersections); roadside hazards (for example, poles, trees, or embankments adjacent to the road); and roadway conditions (for example, rain, ice, snow, or fog). Vehicle factors include any vehicle-related failures that may exist in the automobile or design of the vehicle. In general, human factors are considered to be the most prevalent factors contributing to crashes, followed by roadway environment and vehicle factors.

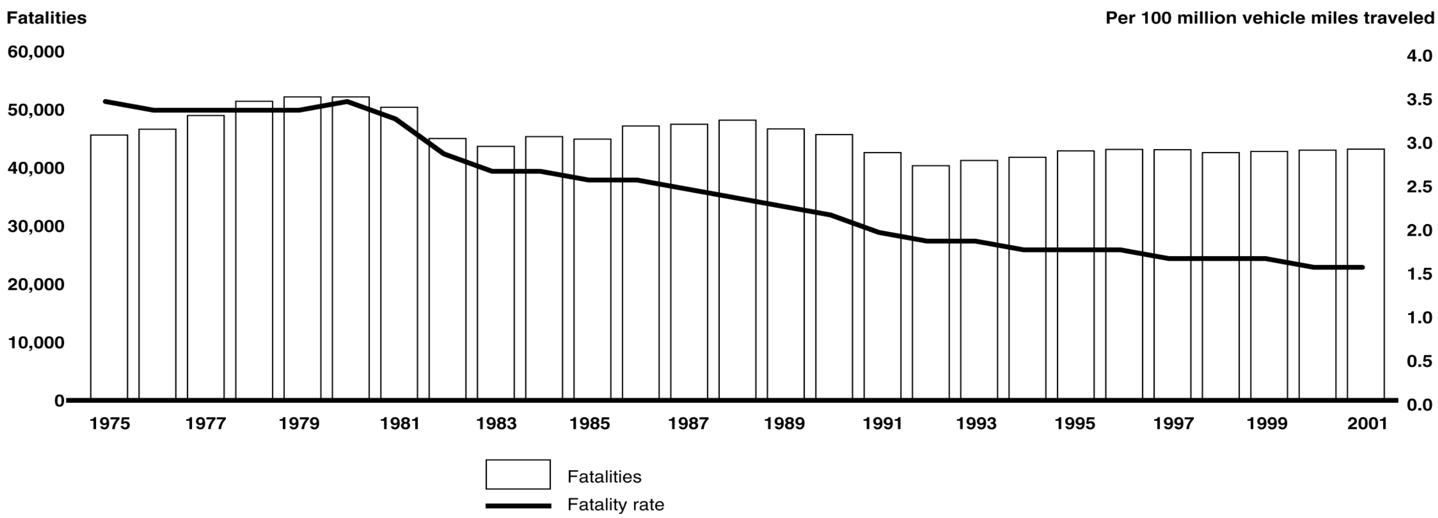
Various agencies within the Department of Transportation have research projects underway or planned that address the factors that contribute to crashes. For example, the Federal Motor Carrier Safety Administration and the National Highway Traffic Safety Administration are studying the causes of, and factors contributing to, large truck crashes. In addition, the National Highway Traffic Safety Administration's 100-Car Naturalistic Driving Study involves collecting data from vehicles equipped with sensors and cameras to obtain better information on crashes and near misses. Another project, the Drive Atlanta Study, involves collecting data from 1,100 vehicles equipped with data recorders to develop information about how speeding contributes to crashes. A number of follow-on studies to these efforts are also being considered. In addition, the Transportation Research Board has proposed a broad, 6-year, $180 million research program focused on making significant improvements in highway safety. This program, among other things, could involve installing sensors and other data collection devices on over 5,000 vehicles. The final phase of the research program would use the results of the instrumented vehicle study to identify countermeasure improvements.

We provided copies of a draft of this report to the Department of Transportation for its review and comment. In discussing this report, agency officials provided technical clarification and information, which we incorporated in the report as appropriate. In addition, National Highway Traffic Safety Administration officials provided information comparing light truck and passenger car crash rates, which we also incorporated in the report.

Background

Since the 1970s, progress has been made in reducing the number of fatalities and injuries on our nation's roads, but the numbers are still significant. From 1975 through 2001, annual fatalities decreased from 44,525 to 42,116, or about 5 percent. During the same period, the fatality rate per 100 million vehicle miles traveled, a common method of measurement, dropped from 3.35 to 1.51, or about 55 percent. This reduction in fatalities was considerable, given the growth in the number of drivers and vehicles on the road. For example, from 1975 through 2001, licensed drivers increased from about 130 million to about 191 million, and the number of registered vehicles increased from about 126 million to about 221 million. Figure 1 shows the yearly number of fatalities and the rate of fatalities per 100 million vehicle miles traveled. Injury and property-damage-only crashes also fell, going from about 6.8 million in 1988, the earliest year of available data, to about 6.3 million in 2001.

Figure 1: Fatality Statistics, 1975–2001

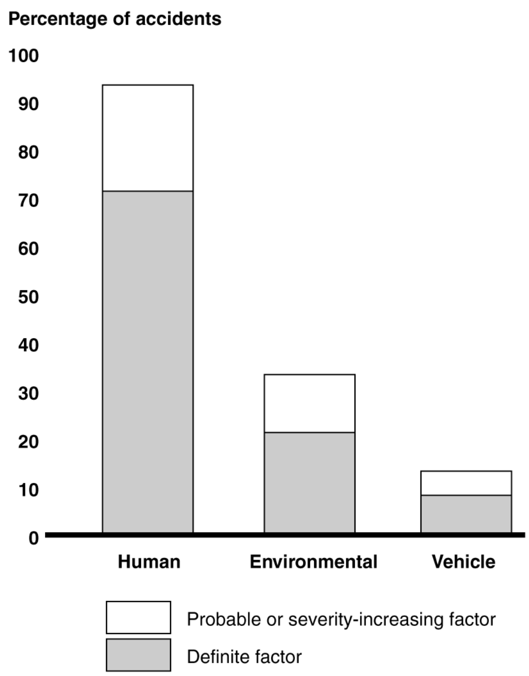


Source: GAO's presentation of NHTSA's data.

The fatal, injury, and property-damage-only crashes have significant economic cost. The National Highway Traffic Safety Administration (NHTSA) recently calculated the economic costs for motor vehicle crashes in 2000 at more than $230 billion, or the equivalent of over $800 for every person living in the United States. NHTSA's estimate of economic costs includes productivity losses, property damage, medical costs, rehabilitation costs, travel delay, legal and court costs, emergency services, insurance administration costs, and costs to employers.

One of the most significant studies to date on the factors that contribute to motor vehicle crashes was the *Tri-Level Study of the Causes of Traffic Accidents*, conducted in the 1970s by the Indiana University at Bloomington Institute for Research in Public Safety. Referred to as the Tri-Level study, it investigated how frequently various factors contributed to traffic crashes. According to NHTSA officials, the Tri-Level study has been the only study in the past 30 years to collect large amounts of on-scene crash causation data. To provide researchers with insight into the factors that contribute to traffic crashes, collision data were collected on three levels, each providing an increasing level of detail, including 13,568 police-reported crashes; 2,258 crashes investigated by on-scene technicians; and 420 crashes investigated in depth by a multidisciplinary team. The study assessed causal factors as either definite, probable, or possible. The study found that crashes were caused by human (or driver-based) factors, environmental (roadway or weather-related) factors, or vehicle-related factors. As shown in figure 2, the study concluded that the human factors were definite or probable causes in about 93 percent of crashes, while environmental and vehicle factors contributed to about 33 and 13 percent, respectively. See appendix II for a more detailed discussion of the Tri-Level study.

Figure 2: Crash Causes Found by the Tri-Level Study



Source: Tri-Level study.

NHTSA's mission is to reduce deaths, injuries, and economic losses resulting from motor vehicle crashes. As part of this responsibility, NHTSA conducts or sponsors research into the causes of motor vehicle crashes. NHTSA also conducts research on driver behavior and traffic safety to develop more efficient and effective means to improve safety. Three principal databases provide information about traffic crashes: the Fatality Analysis Reporting System (FARS), the Crashworthiness Data System (CDS), and the General Estimates System (GES). The FARS database contains information provided by the states on all vehicle crashes that result in the death of an occupant or nonmotorist within 30 days of the incident. The CDS database contains information from a detailed sample of about 4,000 minor, serious, or fatal tow-away crashes, annually. To obtain this information, teams of trained crash investigators visit the crash site and collect data on such elements as the damage to the vehicle and interior locations struck by the occupants. The GES database contains information from a nationally representative sample of police accident reports. This is NHTSA's largest crash database, with information collected on over 50,000 crashes each year.

The Federal Highway Administration's (FHWA) safety mission is to reduce highway fatalities and injuries through development and implementation of a program of nationally coordinated research and technology innovations. Research is conducted in areas that address FHWA's highway safety goals related to roadway departure, intersections, and pedestrians. FHWA is also conducting research in a number of areas that will partially focus on crash causation, including rollovers, speed management, intersection safety, and pedestrian and bicyclist safety. FHWA annually produces a highway statistics report, which consists of data on motor fuel, motor vehicles, driver licensing, highway-user taxing, state and local government highway finance, highway mileage, and federal aid for highways. FHWA also maintains a database, called the Highway Safety Information System. The system uses data on crash, roadway, and traffic variables collected by eight states to analyze a number of highway safety problems. These analyses range from identifying basic problems, to identifying the size and extent of a safety issue, to modeling efforts that attempt to predict future crashes from roadway characteristics and traffic factors.

Human, Roadway Environment, and Vehicle Factors Contribute to Motor Vehicle Crashes

Motor vehicle crashes are complex events that rarely have a single cause. For example, it would be challenging to identify a single cause of a crash that occurred on a narrow, curvy, icy road when an inexperienced driver, who had been drinking, adjusted the radio or talked on a cell phone. It would likely be the combined effect of a number of these factors that contributed to the crash.

In examining the causes of motor vehicle crashes, a number of experts and studies identified three categories of factors that contribute to crashes—human, roadway environment, and vehicle factors. Human factors involve the actions taken by or the condition of the driver of the automobile, including speeding and other traffic violations, as well as the effects of alcohol or drugs, inattention, decision errors, and age. Roadway environment factors that contribute to or are associated with crashes include the design of the roadway (for example, medians, lane width, shoulders, curves, access points, or intersections); roadside hazards (for example, poles, trees, or embankments adjacent to the road); and the roadway conditions (for example, rain, ice, snow, or fog). Vehicle factors include vehicle-related failures and vehicle design issues that contribute to a crash. In general, human factors are considered to be the most prevalent factor contributing to crashes, followed by roadway environment and vehicle factors. Although this report discusses these categories separately, they should be viewed in terms of how they can concurrently contribute to an unstable situation that results in a crash.

Human Factors Contribute to Motor Vehicle Crashes

Human factors involve actions taken by or the condition of the driver of the vehicle. They are considered the most prevalent factors by data, experts, and studies in traffic crashes. Human factors that can contribute to crashes include speeding and other traffic violations, as well as the effects of alcohol or other drugs, inattention, driver decision errors, and age.

Speeding

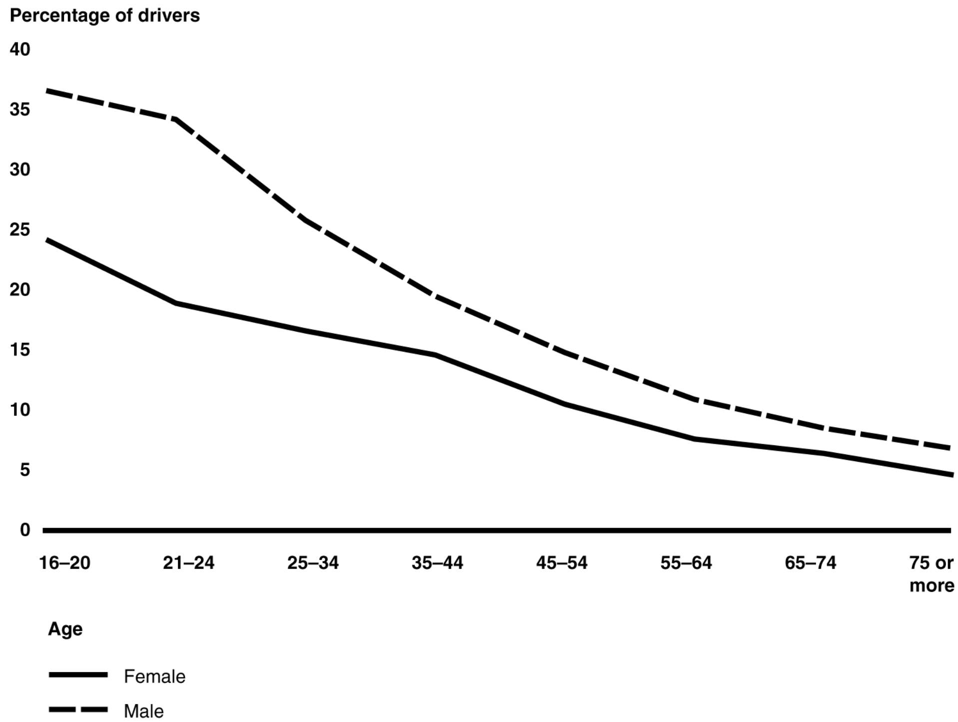
Driving either faster than the posted speed limit or faster than conditions would safely dictate can contribute to traffic crashes. Speeding reduces a driver's ability to steer safely around curves or objects in the roadway, extends the distance necessary to stop a vehicle, and increases the distance a vehicle travels while the driver reacts to a dangerous situation.

According to our analysis of NHTSA's databases, from 1997 through 2001, speeding was identified as a contributing factor in about 15 percent of all crashes and about 30 percent of all fatal crashes. In addition, almost 64,000 lives were lost in speeding-related crashes.[2] As shown in figure 3, we found that for every age category of drivers involved in fatal crashes, males were more likely than females to be involved in a fatal speed-related crash. In addition, younger drivers, regardless of sex, are the most likely to be involved in a speed-related fatality. From 1997 through 2001, 36 percent of male drivers and 24 percent of female drivers 16 to 20 years old who were involved in fatal crashes were speeding at the time of the crash. The

[2]NHTSA defines a crash as speed-related if the driver was charged with a speed-related offense or if an officer indicated that the driver was racing, driving too fast for conditions, or exceeding the posted speed limit.

percentage of speeding-related fatal crashes decreases with increasing driver age.[3]

Figure 3: Speeding Drivers in Fatal Crashes, by Age and Gender, 1997–2001



Source: GAO's analysis of NHTSA's data.

A 1998 study by NHTSA and FHWA indicates that fatal crashes increased in states that raised speed limits.[4] When Congress enacted the National Highway System Designation Act of 1995 (P.L. 104-59), which repealed the national maximum speed limit, the Secretary of Transportation was required to study the impact of states' actions to raise speed limits above

[3]Some analyses in this report discuss fatality data associated with specific factors. It should be noted that other elements, in addition to the factor discussed, might have also contributed to the fatalities. These would include circumstances such as the use of safety belts or other occupant protection measures.

[4]NHTSA/FHWA, *Report to Congress: The Effect of Increased Speed Limits in the Post-NMSL Era* (Washington, D.C.: February 1998).

55 and 65 miles per hour. The study found that states with increased speed limits in 1996 experienced approximately 350 more Interstate fatalities than would have been expected based on historical trends—about 9 percent above expectations. Concurrently, the Interstate fatalities experienced in states that did not increase speed limits in 1996 were consistent with pre-1996 trends. The Insurance Institute for Highway Safety also assessed the effects of speed limit increases.[5] Its researchers found an increase in fatalities for a 9-month period in 1996 on Interstate highways and freeways, as compared with the previous 6 years—about 16 percent in 12 of the states that had raised maximum speed limits to at least 70 miles per hour by March 1996. In contrast, occupant fatalities increased only 4 percent on Interstate highways and freeways in the comparison group of states that did not raise speed limits. However, both of these studies are limited because they cover short time periods.

According to a Transportation Research Board official, studies have confirmed a direct relationship between speed and crash severity.[6] Once a crash has occurred—that is, a vehicle has hit another vehicle or a stationary object—the vehicle undergoes a rapid change in speed. While the vehicle decelerates rapidly, its occupants continue to move at the vehicle's speed prior to impact until they are stopped by striking the interior of the vehicle, by impact with objects external to the vehicle if ejected, or by being restrained by a safety belt or an airbag that deploys.

According to the FHWA Director of the Office of Safety Programs, while absolute speed clearly relates to injury and fatality outcomes, speeding is the real issue. The Director pointed out that despite their lower volumes, almost half of all speeding-related fatalities occur on local or collector roads—low-speed roads found in residential and business areas. In addition, the Director said that speed variance is also a factor. When vehicles driving down a particular roadway are traveling at very different speeds, the probability of a crash increases. The relative crash-involvement rate increases for vehicles that are traveling above or below the average speed of traffic.

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[5]Charles M. Farmer, Richard A. Retting, and Adrian K. Lund, *Effect of 1996 Speed Limit Changes on Motor Vehicle Occupant Fatalities* (Washington, D.C.: Insurance Institute for Highway Safety, October 1997). This study focused on 12 states that raised maximum speed limits to at least 70 miles per hour between December 8, 1995, and April 1, 1996.

[6]The Transportation Research Board is a unit of the National Research Council, a private, nonprofit institution that is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering.

Traffic Control Violations

Drivers who fail to follow prescribed traffic control laws also contribute to crashes. This includes running red lights or failing to stop at stop signs. Our analysis of NHTSA's data found that from 1997 through 2001, about 36 percent of motor vehicle crashes occurred at traffic control devices. Of those crashes, 59 percent occurred at traffic lights while an additional 28 percent occurred at stop signs.

A study performed by the Insurance Institute for Highway Safety and the Preusser Research Group identified characteristics of red light–running crashes and the drivers involved.[7] It found that drivers' noncompliance with traffic control devices, such as traffic signals and stop signs, is a major cause of motor vehicle crashes. The study examined the prevalence of red light–running crashes on a national basis to identify the characteristics of such crashes and the drivers involved.[8] The study estimated that almost 260,000 red light-running crashes occurred in 1996, of which 809 resulted in fatalities. It also found that, as a group, red light runners involved in crashes were more likely than other drivers to be younger than age 30, to be male, to have prior moving violations and convictions for driving while intoxicated, to have invalid driver's licenses, and to be reported by police as having consumed alcohol prior to the crash.

According to an official from Northwestern University, red light–running might also partly reflect driver frustration with poor traffic operations. For example, a driver might feel the need to speed through a red light because of previous experience of being held at that light too long, or of being subjected to a series of unsynchronized stop lights. A 1999 study funded by DaimlerChrysler Corporation surveyed over 5,000 people regarding their behavior at red lights.[9] The study found that those respondents who reported speeding up to beat a red light would most often do so because they were in a rush and wanted to save time.

[7]Richard A. Retting and Allan F. Williams for the Insurance Institute for Highway Safety, and Robert G. Ulmer for the Preusser Research Group, "Prevalence and Characteristics of Red Light Running Crashes in the United States," *Accident Analysis and Prevention*, vol. 31 (1999), pp. 687–94.

[8]The study reviewed intersection crashes in both the Fatality Analysis Reporting System and the General Estimates System during the 5-year period from 1992 through 1996.

[9]Bryan E. Porter, Thomas D. Berry, Jeff Harlow, and Tancy Vandecar, *A Nationwide Survey of Red Light Running: Measuring Driver Behaviors for the "Stop Red Light Running" Program*, June–August 1999.

Alcohol and Other Drugs

Alcohol and other drugs are contributing factors in many motor vehicle crashes. It is illegal in every state and the District of Columbia to drive a motor vehicle while under the influence of, impaired by, or with a specific blood content of alcohol or drugs. In addition, all states but Massachusetts have blood alcohol laws that make it illegal to drive with a specified level of alcohol in their blood.[10] As of January 2003, 17 states had set the standard at .10 percent blood alcohol content (BAC)—the level at which a person's blood contains 1/10 of 1 percent alcohol.[11] The remaining states have more stringent laws, setting the limit at .08 percent BAC. According to NHTSA, on average, a 170-pound man reaches .08 percent BAC after consuming five 12-ounce beers (4.5 percent alcohol by volume) over a 2-hour period. A 120-pound woman reaches the same level after consuming three beers over the same period.

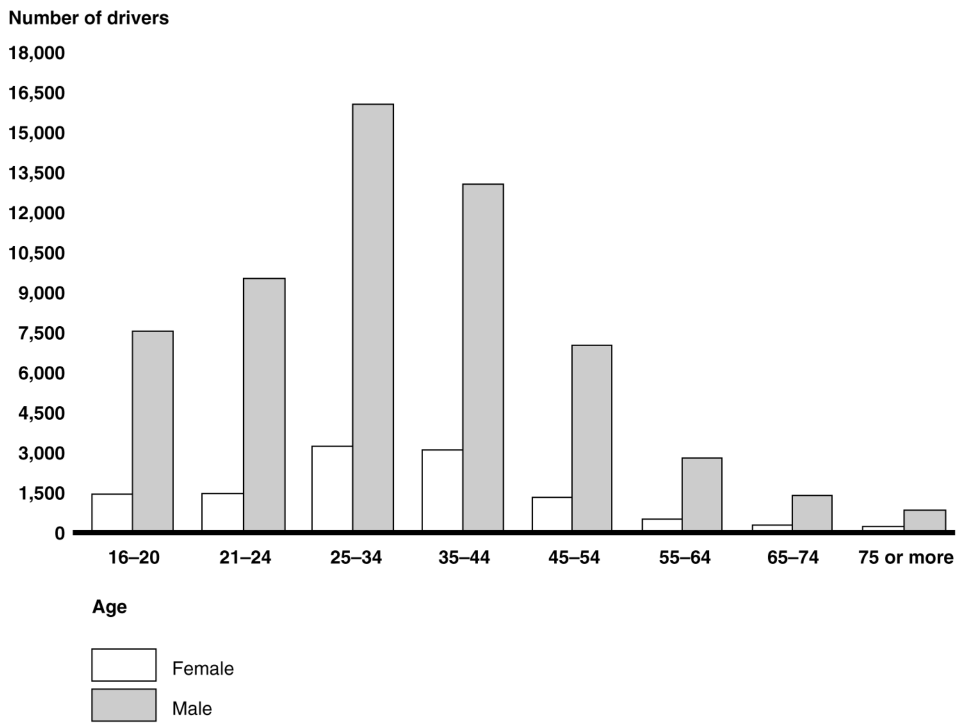
In analyzing NHTSA's databases, we found that from 1997 through 2001, there were about 76,000 alcohol-related fatal crashes (41 percent of all fatal crashes), 980,000 alcohol-related injury crashes (10 percent of all injury crashes), and 2.3 million alcohol-related crashes (7 percent of all crashes).[12] During this 5-year period, nearly 85,000 people died in alcohol-related crashes. Eighty-six percent of these fatalities occurred in crashes where the highest recorded BAC was .08 percent or above, while 14 percent occurred in crashes where the highest recorded BAC was between .01 percent and .07 percent. In addition, we found that male drivers were more likely to be involved in alcohol-related fatal crashes than female drivers. Figure 4 shows that, for each age category, there were a greater number of male than female drivers in fatal crashes that involved alcohol.

[10] Blood alcohol content of .08 percent in Massachusetts is evidence of alcohol impairment, but it is not illegal per se.

[11] Of these states, Louisiana, New York, and Tennessee have .08 percent BAC laws that will be effective during the latter half of 2003.

[12] NHTSA indicates that a fatality is alcohol-related if it occurred in a crash where any one of the actively involved persons in the crash had a BAC of .01 percent or greater.

Figure 4: Drivers in Alcohol-Related Fatal Crashes, by Age and Gender, 1997–2001



Source: GAO's analysis of NHTSA's data.

While research has shown that everyone's driving is impaired at blood alcohol levels of .10 percent and higher, recent research has shown that lower levels of alcohol also affect performance. In a study by the Southern California Research Institute, 168 test subjects were tested at zero BAC; then at the highest BAC for their drinking classification of either light, moderate, or heavy drinker; and then at .02 percent BAC intervals, as their alcohol levels decreased.[13] For this study, the researchers defined impairment by comparing the subjects' performance on a given test while under the influence of alcohol versus their performance on the same test after being given a placebo. According to the resulting report, alcohol impaired the driving-related skills for these volunteers at .02 percent BAC,

[13]H. Moskowitz, M. Burns, D. Fiorentino, A. Smiley, and P. Zador, *Driver Characteristics and Impairment at Various BACs* (Los Angeles, CA: Southern California Research Institute, August 2000).

the lowest tested alcohol level. The magnitude of impairment increased consistently at BACs through .10 percent, the highest level tested.[14] According to a Southern California Research Institute official, this study is significant because it provided important, previously unknown findings that certain driving-related skills are impaired at any departure from zero BAC.

A recent study by Westat examined the relative risk of fatal crash involvement as a function of the BAC of fatally injured or surviving drivers.[15] By combining crash data from FARS with exposure data from the 1996 National Roadside Survey, the researchers determined that, in general, the relative risk of involvement in a fatal passenger vehicle crash increased steadily with increased driver's BAC.[16] For example, the study found that a .02 percent BAC increase among 16-through-20-year-old male drivers was estimated to more than double the relative risk of a fatal single-vehicle crash injury. The study also found that among drivers aged 21 through 34, those with a BAC of .03 percent have twice the risk of fatalities as compared with drivers with zero BAC. Furthermore, among drivers aged 21 through 34, those with a BAC of .10 percent have over 10 times the risk of a fatality compared with drivers with zero BAC.

All states restrict driving while under the influence of, being impaired by, or being incapable of safely driving because of illegal drugs or prohibited substances in the driver's body. As of January 2003, eight states have statutes that make it unlawful for a driver to have any amount of an illegal drug or prohibited substance in his or her body while operating a motor vehicle, regardless of how the drug affects the driver's driving ability.[17]

[14]The study subjects were examined only as their BAC was declining and, according to the study, the results would underestimate the magnitude of impairment expected during alcohol consumption when BAC was rising.

[15]P.L. Zador, S.A. Krawchuk, and R.B. Voas, *Relative Risk of Fatal Crash Involvement by BAC, Age and Gender* (Rockville, MD: Westat, April 2000).

[16]The 1996 National Roadside Survey was a national survey of weekend, nighttime drivers in the 48 contiguous states. The survey consisted of interviewing and breath-testing over 6,000 noncommercial four-wheel vehicle operators between September and November 1996.

[17]These eight states include Arizona, Georgia, Indiana, Illinois, Iowa, Minnesota, Rhode Island, and Utah. The Georgia Supreme Court has determined that the Georgia statute, Ga. Code Ann. 40-6-391(a)(6) (2002), is an unconstitutional denial of equal protection. See Love v. State, 271 Ga. 398 (1999). Accordingly, the enforceability of the Georgia statute is questionable.

Additional states have varying legislation that also allows zero tolerance to driving under the influence of drugs.[18]

Studies have shown that drugs can affect driving-related skills. For example, a study by Maastricht University, the Netherlands, indicated that the combined use of marijuana and alcohol impairs driving performance.[19] For a small number of subjects who were somewhat frequent users of marijuana, the study found that either marijuana doses alone or alcohol alone impaired the subjects' test-driving performances. However, subjects who used marijuana in combination with alcohol demonstrated impairment in several aspects of driving performance. Another study by Maastricht University also found the combined use of marijuana and alcohol to produce similar effects on a small, limited group of subjects. The study showed that under the influence of low doses of either marijuana or alcohol, the drivers were less able to detect peripheral traffic and instead focused on the central driving task.[20]

Driver Inattention

Driver inattention occurs when there is a delay in recognition of information needed to safely accomplish the driving task. Two categories of driver inattention are distraction and drowsiness. Drivers may become distracted when they direct their attention elsewhere because of some occurrence inside or outside of the vehicle. NHTSA defines four categories of distraction: visual distraction (for example, looking away from the roadway), auditory distraction (for example, responding to a noise, such as a ringing cell phone), biomechanical distraction (for example, manually adjusting the radio volume), and cognitive distraction (for example, being lost in thought). Many distracting activities that drivers engage in can involve more than one of these components. Driver drowsiness is also a type of driver inattention, in that a tired or fatigued driver may exhibit behaviors typically associated with inattentive drivers.

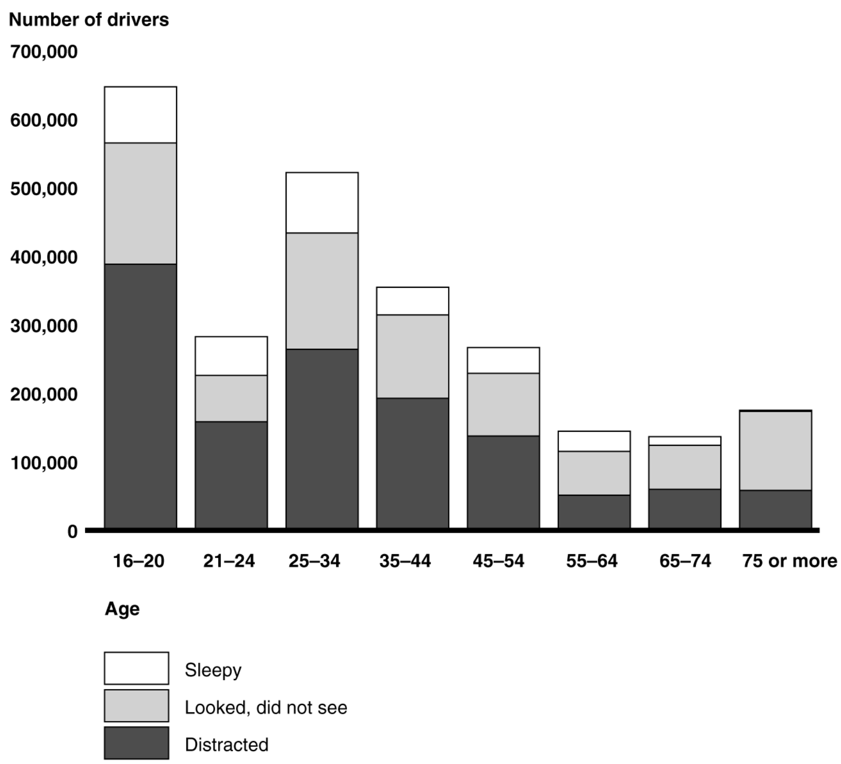
[18] Examples of zero tolerance to driving under the influence of drugs include laws that prohibit drug addicts or habitual users of drugs from driving vehicles (found in California, Colorado, Idaho, Kansas, and West Virginia) or statutes that make it illegal for minors to drive with any amount of a prohibited drug in their bodies (found in North Carolina and South Dakota).

[19] Hindrik W. J. Robbe and James F. O'Hanlon, *Marijuana, Alcohol, and Driving Performance* (The Netherlands: Institute for Human Psychopharmacology, July 1999).

[20] C.T.J. Lamers and J.G. Ramaekers, *Visual Search and Urban City Driving under the Influence of Marijuana and Alcohol* (The Netherlands: Maastricht University, June 2001). Specifically, both studies examined the effects of delta-9-tetrahydrocannabinol (THC), the primary active ingredient of cannabis (marijuana).

Our analysis of 1997 through 2001 data from NHTSA found that, overall, about 2.5 million drivers of passenger vehicles that were towed away from crashes were identified as inattentive. Of these, about 1.3 million were distracted, about 871,000 "looked but did not see" (an aspect of being inattentive), and about 348,000 were sleepy or asleep. In addition, about 7.6 million drivers were identified as "attentive" at the time of the crash.[21] We also conducted a more detailed analysis of inattentive drivers. As figure 5 shows, overall, more drivers between ages 16 and 44 were involved in inattentive-type crashes than drivers aged 45 and above. More drivers aged 16 to 20 were inattentive than any other age group.

Figure 5: Inattentive Drivers Involved in Crashes by Age, 1997–2001



Source: GAO's analysis of NHTSA's data.

Note: This includes only those drivers involved in crashes where at least one passenger vehicle had to be towed away.

[21] About 6 million were identified as "unknown" or "no driver present."

We also analyzed NHTSA's databases to determine specific sources of distraction. We found that some outside person, object, or event was identified as contributing to 27 percent of the distractions. Other common sources of distractions included another occupant in the vehicle, followed by adjusting a radio, cassette, or CD.

A recent study by the AAA Foundation for Traffic Safety analyzed 1995 through 1999 NHTSA crash data on driver attention status and sources of distraction and found that 8 percent of drivers were identified as distracted, 5 percent as "looked but did not see," and 2 percent as sleepy or asleep, while 49 percent of the drivers were identified as attentive at the time of the crash.[22] The remaining 36 percent were either unknown or had no driver present. Without the unknowns, the percentage of drivers identified as distracted increases to 13 percent. The study also identified specific sources of distraction. Some external person, object, or event caused almost 30 percent of such distractions.

Drowsiness and fatigue are also aspects of inattention and can contribute to crashes. Drowsiness is a basic physiological state, brought about by the restriction or interruption of sleep. It also results from natural changes in the body's level of alertness during each 24-hour sleep-wake cycle. According to the National Sleep Foundation, our internal body clocks program us to be sleepy twice a day: first during the early morning hours between midnight and dawn, and again between 1:00 p.m. and 4:00 p.m. For the driver, the main effect of drowsiness or fatigue is a progressive withdrawal of attention from the road and traffic demands, leading to impaired performance behind the wheel. Drivers can become so fatigued that they are slow to perceive risky situations and are unable to respond quickly enough to avoid a crash. Fatigue can also arise because of medication or illness.

According to an official from the National Sleep Foundation, studies have shown that sleep-deprived individuals are less likely to be able to concentrate on the task at hand. In addition, as people get tired they engage in behaviors that lead to other distractions, such as smoking, drinking or eating, turning up the radio, or employing other "tricks" to try to stay awake. The official also told us that the foundation's national polls

[22]Jane C. Stutts, Donald W. Reinfurt, Loren Staplin, and Eric A. Rodgman, *The Role of Driver Distraction in Traffic Crashes* (Washington, D.C.: University of North Carolina for the AAA Foundation for Traffic Safety, May 2001). This study examined drivers involved in crashes where at least one vehicle had to be towed away.

and international studies support the perspective that driver fatigue is a much larger problem than what the federal statistics show. Recently, the National Sleep Foundation conducted a telephone survey and found that about 51 percent of the respondents reported that they had driven a car or another vehicle while feeling drowsy, and about 17 percent had dozed off while driving within the past year.[23] The study found that male respondents were more likely than female respondents to say they had driven while feeling drowsy. In addition, respondents with children and respondents aged 18 to 29 were at the highest risk for driving while feeling drowsy. The study also found that older respondents, 65 and over, are less likely to drive drowsy or to fall asleep at the wheel.

Driver Decision Errors

Driver decision errors involve misjudgments made while driving. These include improperly judging stopping distances, improperly judging distances of cars traveling behind the vehicle, and other misjudgments of distance between cars that result in a crash. Decision errors also include crashes that result from traveling the wrong way on a one-way street. A driver decision error differs from an error that may have resulted from inattention or distraction because the driver sees a hazard, such as an oncoming car making a left-hand turn, but makes the wrong decision concerning the proper action to take.

A recent study by Veridian Engineering examined unsafe driving acts in severe crashes in four sites across the United States to determine the specific driver behaviors and unsafe driving acts that lead to crashes, along with the situational, driver, and vehicle characteristics associated with these behaviors.[24] According to the study, in 717 of the 723 crashes analyzed (99 percent), a driver behavioral error caused or contributed to the crash. Of the 1,284 drivers involved in these crashes, 732 drivers (57 percent) contributed in some way to the cause of their crashes.

Age

There is a strong relationship between a driver's age and the likelihood of being involved in a crash. While age, in itself, would not be the cause of

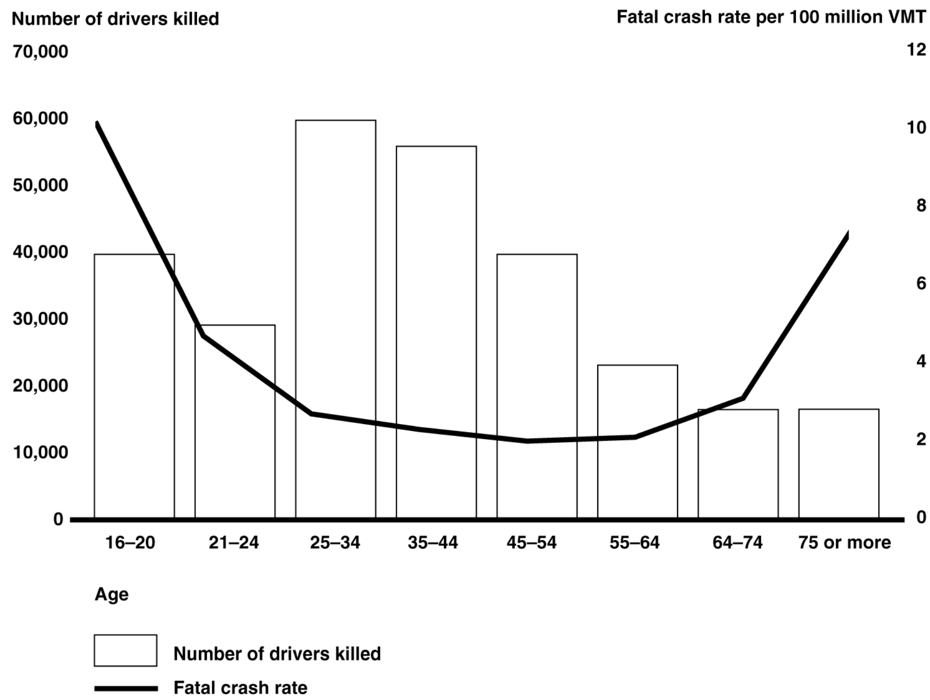
[23]The National Sleep Foundation commissioned WB&A Market Research to conduct the 2002 "Sleep in America" telephone poll of 1,010 adults at least 18 years old between October 1 and December 10, 2001. The margin of error is plus or minus 3.1 percent.

[24]D. L. Hendricks, M. Freedman, P.L. Zador, and J.C. Fell, *The Relative Frequency of Unsafe Driving Acts in Serious Traffic Crashes* (Washington, D.C.: Veridian Engineering, Westat, Inc., and Star Mountain, Inc., January 2001). A sample of 723 crashes involving 1,284 drivers was investigated at four different sites in the country between April 1, 1996, and April 30, 1997.

the crash, some of the characteristics displayed at various ages can lead to a higher probability of being involved in traffic crashes.

Our analysis of NHTSA's databases found that younger and older drivers become involved in a greater number of crashes, especially fatal crashes, than do other age groups. Figure 6 shows that drivers aged 16 through 20 and those aged 75 or more have a greater chance of being involved in fatal crashes per vehicle mile traveled (VMT) than do other age groups.[25]

Figure 6: Number and Rate of Driver Involvement in Fatal Crashes by Age, 1997–2001



Source: GAO's analysis of NHTSA's data.

[25]For this VMT analysis, we used data from 2001 National Household Travel Survey. The National Household Travel Survey consists of household-based travel surveys conducted every 5 years by DOT. Survey data are collected from a sample of U.S. households and expanded to provide national estimates of trips and miles by travel mode, purpose, and a host of other characteristics. The survey collects information on daily, local trips and on long-distance travel in the United States.

According to the Insurance Institute for Highway Safety, teenagers' crash rates are disproportionately high mainly because of the drivers' youth combined with driving inexperience. A recent study by the Insurance Institute for Highway Safety showed that the age factor plays out in a more risky driving style among adolescents.[26] The study, which reviewed and summarized other research on the risks associated with younger drivers, found that increased crash risk comes immediately on licensure and drops very rapidly in the first few months. Compared with older drivers, this study concluded that young people are more likely to drive at excessive speeds, follow too closely, violate traffic signs and signals, overtake other vehicles in a risky manner, allow too little time to merge, and fail to yield to pedestrians. Risky driving leads young people into hazardous situations, and inexperience makes it more difficult to cope with such situations. The researchers also found that driving at night is associated with an increased risk of serious crashes for young drivers. The driving task is more difficult for young drivers when it's dark, and the risky driving that involves younger drivers, generally associated with recreational activities, is more likely to occur at night. Fatigue and alcohol are also more likely to contribute to younger drivers' crashes during nighttime hours. The study also found that there is a heightened crash risk when teenage drivers have passengers in their vehicles. The study found that this increased risk is present only for teenage drivers, and it increases incrementally with each additional passenger.

Older drivers are also at increased risk, because the elderly have higher rates of fatal crashes per vehicle mile traveled than all but the youngest drivers. According to a recent study by the Insurance Institute for Highway Safety, this is largely attributable to their increased fragility.[27] In the study, fragility started at age 60 to 64 and continued to rise with advancing age. In addition, a recent study by Dr. Leonard Evans found that given similar crash severity, older drivers are more likely to sustain fatal injuries than younger drivers.[28] The author suggested that if populations of 70-year-old

[26]A.F. Williams and S.A. Ferguson for the Insurance Institute for Highway Safety, "Rationale for Graduated Licensing and the Risks It Should Address," *Injury Prevention*, vol. 8 (2002), pp. 9–16.

[27]Guohua Li, Elisa R. Braver, and Li-Hui Chen, *Exploring the High Driver Death Rates per Vehicle-Mile of Travel in Older Drivers: Fragility versus Excessive Crash Involvement* (Arlington, VA: Insurance Institute for Highway Safety, August 2001).

[28]Leonard Evans, "Age and Fatality Risk from Similar Severity Impacts," *Journal of Traffic Medicine*, vol. 29, 2001, pp. 10–19.

males and 20-year-old males were subjected to the identical mixes of blunt trauma, the population of older males would sustain over two times more fatalities. A similar comparison of female populations would yield almost two times more fatalities for older females. In addition, a literature review conducted by the University of Michigan Transportation Research Institute found that older drivers are more likely to suffer from medical disabilities that could impair their driving, and they may use medications that could affect their driving performance.[29] The study also found that with increasing age, most drivers experience some loss of visual perception and decreased cognitive and psychomotor functions. For example, a 1988 AAA Traffic Safety Foundation study tested a small group of volunteers and found that older adults with less joint flexibility exhibited poorer driving ability than those with wider ranges of motion.[30] In addition, according to the FHWA Director of the Office of Safety Programs, frailty is not the sole factor in older driver fatality rates, noting that drivers 85 and older have more than twice the overall crash rate of middle-aged drivers aged 40 through 44.

Roadway Environment Contributes to Motor Vehicle Crashes

The roadway environment is generally cited as the second most prevalent factor contributing to crashes by data, experts, and studies. It can be defined as those factors external to the driver and the vehicle that increase the risk of a crash. Roadway environment factors that contribute to, or are associated with, crashes include the design of the roadway (for example, medians, narrow lanes, the lack of shoulders, curves, access points, or intersections); roadside hazards (for example, poles, trees, or embankments adjacent to the road); and the roadway conditions (for example, rain, ice, snow, or fog).

Roadway Design

The principal guidance on roadway design is the American Association of State Highway and Transportation Officials' (AASHTO) Policy on Geometric Design of Highways and Streets. This guidance provides recommendations on constructing the nation's roadways, including such features as the sharpness of curves, the slope of roadways, the width of

[29]David W. Eby, Deborah A. Trombley, Lisa J. Molnar, and Jean T. Shope, *The Assessment of Older Drivers' Capabilities: A Review of the Literature* (Ann Arbor, MI: University of Michigan Transportation Research Institute, August 1998).

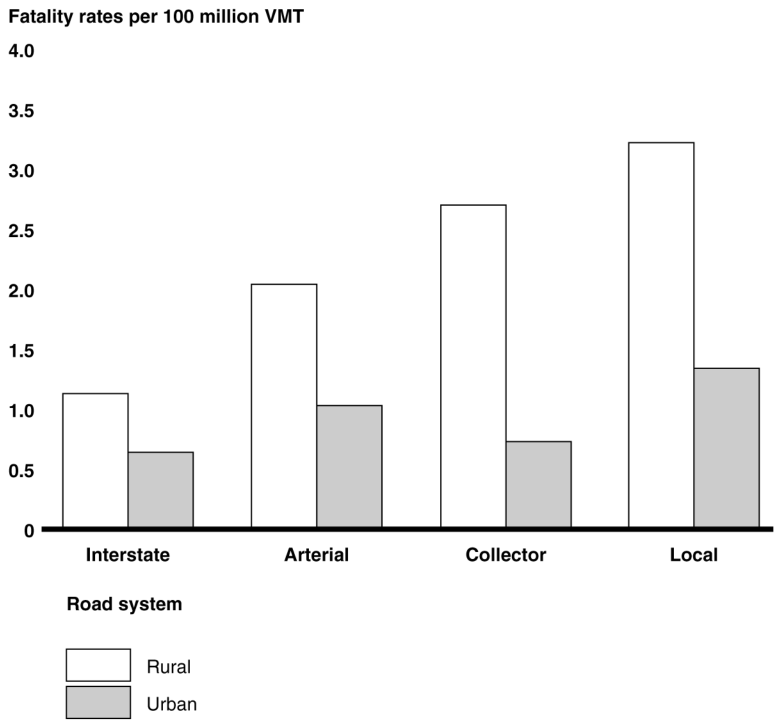
[30]Kenard McPherson, Jeffrey Michael, Andrew Ostrow, and Peter Shaffron, *Physical Fitness and the Aging Driver*, *Phase I* (Washington, D.C.: AAA Foundation for Traffic Safety, 1988).

lanes, and the design of medians and barriers. In general, different functional road systems are constructed for specific purposes. For example, Interstate highways are intended for high mobility and therefore have limited access points, while local roads are designed for increased access, which can limit mobility. Design principles generally suggest that as average daily traffic increases, additional design elements should be adopted that increase safety, including wider lanes, paved shoulders, and clear zones (areas free of roadside hazards next to the roadway).

Based on FHWA's data, we found that fatal crashes were more frequent on rural roads than on urban roads.[31] In 2001, rural roads handled only about 40 percent of all vehicle miles traveled, yet more than 60 percent of all fatalities occurred on these roads. Figure 7 shows that fatality rates are higher on rural roads in comparison with urban roads, regardless of the road type.

[31]The term "urban" is used to denote the federal-aid legislation definition of an area. Such areas include, at a minimum, a census place with an urban population of 5,000 to 49,999, or a designated urbanized area with a population of 50,000 or more. Rural areas are those areas outside urban areas.

Figure 7: Fatality Rates by Type of Road System, 2001



Source: GAO's presentation of FHWA's Highway Statistical Series data.

Note: The urban Interstate fatality rate also includes fatalities from other urban freeways and expressways.

A recent FHWA study developed relationships between roadway features and crash rates on two-lane rural highways.[32] For this study, FHWA developed predictive models to estimate the safety impacts of roadway design features. Studies have found that the following roadway design features can affect crash rates. Appendix III contains additional information on roadway design features.

- *Medians* — Medians (that is, the physical separations between opposite lanes of traffic) provide a recovery area for out-of-control vehicles and reduce head-on crashes by separating traffic driving in opposite directions.

[32]D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways*, FHWA-RD-99-207 (December 2000).

- *Lane width* — Wider lanes may reduce crashes by allowing for greater separation between vehicles traveling in adjacent lanes as well as providing additional space to recover from near-crash situations.

- *Shoulders* — Wide roadway shoulders that are paved provide an opportunity for drivers to recover from errors that cause a vehicle to stray out of a lane.

- *Curves* — Curves have been shown to contribute to crashes, whether horizontal curves (left or right) or vertical curves (up and down). Crash rates on curves are associated with their design features (including degree, length, and angle) and cross-sectional curve elements (lane width, shoulder size and type, and median characteristics).

- *Access points* — As the number of access points, or locations where vehicles can gain entry to the roadway, increases, the more likely it is that a traffic crash will occur.

- *Intersections* — Intersections, or at-grade locations where vehicles may transfer between roads, are among the most complex roadway designs a driver encounters. This is the result of increased points of conflict between vehicles, and between vehicles and pedestrians.

FHWA's Chief Highway Safety Engineer told us that it is important that a roadway be designed to allow a driver the time and space to make and recover from various errors without crashing. For example, two-lane rural roads are often characterized by sharp horizontal and vertical curves, narrow lanes, no shoulders or narrow ones, and roadside hazards such as utility poles or trees adjacent to the road. These design elements can be associated with higher fatality rates. This contrasts with the multilane highways, which generally have gradual horizontal and vertical curves, wider lanes and shoulders, and wide, clear zones adjacent to the road.

FHWA's Director of Office of Safety Research and Development pointed out that there are some data limitations associated with crashes and roadway design. For example, the Director noted that NHTSA's crash databases contain very limited data on roadway design features at the crash location or immediately preceding the crash location. Accordingly, detailed analysis comparable to what is possible for the driver is not possible for the roadway. The Director also stated that efforts are underway to provide the means to more precisely locate the point of a crash and to relate that location to detailed roadway and roadside information databases.

Roadside Hazards

Roadside hazards are physical features that a vehicle can crash into if it leaves the roadway. Each year, about 14,000 persons are killed and almost 1 million persons are injured when vehicles run off the road and crash. Many of these deaths and injuries result from crashes into poles and trees, which are often located close to the edge of the roadway.

Our analysis of NHTSA's data found that 16 percent of all crashes from 1997 through 2001 involved striking a roadway object as the first property-damaging or injury-producing event in the crash. In addition, we found that that in these crashes, posts or poles were the most common fixed objects for a vehicle to hit after leaving the roadway (about 20 percent), followed by ditches (14 percent), trees (14 percent), and guardrails (11 percent).

The Washington State Transportation Center conducted a study examining roadside crashes on a single section of roadway.[33] Models were created to predict the frequency and severity of run-off-the-road crashes related to a variety of roadway environmental factors. The study found, for example, that both a decreased distance from the outside shoulder edge to roadside objects and an increased number of trees near the roadway increased the likelihood of a crash. Overall, the study supported the enlargement of roadside recovery space to decrease the occurrence and severity of run-off-the-road crashes.

The chairperson of AASHTO's Task Force on Roadside Safety addressed the importance of roadside hazards. The AASHTO official said that, in order of preference, the four methods for addressing roadside hazards are to (1) remove it, (2) relocate it, (3) redesign it, and (4) shield the roadside hazards (for example, a guardrail or impact barrier).

Roadway Conditions

Roadway conditions can contribute to crashes through both road surface conditions and reduced visibility. Surface conditions that can impair a driver's ability to control the vehicle include standing water, snow, ice, and oil, in addition to such road surface features as holes, ruts, paved edge drop-offs, and worn surfaces. Crashes can also result when visibility is somehow reduced, preventing a driver from receiving the proper visual

[33] Jinsun Lee and Fred Mannering, *Analysis of Roadside Crash Frequency and Severity and Roadside Safety Management*, Washington State Transportation Center (December 1999).

driving cues. Reduced visibility can occur because of weather-related events or the presence or absence of natural or artificial lighting.

Surface conditions. Common road surface conditions that can create slippery roads are rain, snow, and ice. Slippery road conditions lead to a loss of friction between a vehicle's tires and the roadway. This loss of friction may lead to the reduced controllability of the vehicle, ultimately resulting in a crash.

Our analysis of NHTSA's data from 1997 through 2001 found that about 23 percent of crashes occurred when road surface conditions were either wet, snowy, slushy, or icy. In addition, a recent study by Iowa State's Center for Transportation Research and Education examined the weather's impacts on safety.[34] The researchers examined the impact of more severe winter storms on volume, safety, and speed characteristics on seven segments of Interstate highways in Iowa. Their analysis of 54 storm events concluded that crash rates increased by over 1,000 percent during winter storm events with high snowfall rates.

Reduced visibility. Reduced visibility can occur during nighttime hours (including dawn and dusk) and during weather-related events, such as fog, rain, or snow. Reduced visibility can decrease a driver's ability to receive the proper visual cues to successfully navigate the road.

Our analysis of NHTSA's data found that overall, while 15 percent of all crashes took place under limited light conditions, about 34 percent of all traffic fatalities occurred at that time. Although other factors are involved during nighttime crashes, such as alcohol or fatigue, the reduction of visual cues for the driver also appears to play a role.

The primary purpose of roadway lighting is to provide increased visibility of the roadway and its immediate environment, to allow a person to drive more efficiently and safely. An FHWA study examined the impact of lighting options on urban freeways in Minnesota.[35] The study used data on crashes, roadways, and traffic volume to compare the safety of

[34]Keith K. Knapp, Dennis Kroeger, and Karen Giese, *The Mobility and Safety Impacts of Winter Storm Events in a Freeway Environment Final Report*, Iowa State Center for Transportation Research and Education (February 2000).

[35]Federal Highway Administration, *Comparison of the Safety of Lighting Options on Urban Freeways*, FHWA Public Roads On-Line (Autumn 1994).

continuously lighted urban freeways with that of urban freeways having interchange lighting only. Using data from between 1985 and 1990, the study determined that 12 percent more crashes occur on sections with interchange-only lighting than on road sections with continuous lighting, assuming all other factors remain the same. The study concluded that there was a positive relationship between urban freeway lighting and highway safety.

Weather-related phenomena can also inhibit driver visibility. While fog crashes are proportionally small compared with all other crashes, they can involve numerous vehicles in a chain-reaction pileup. A recent example of this occurred in Wisconsin in October 2002, where a fog-related crash involving 51 vehicles resulted in 10 deaths. The National Transportation Safety Board has concluded that major fog-related incidents generally occur because drivers have not maintained uniform reduced speeds during times of limited visibility.

According to NHTSA's Director of the Office of Human-Centered Research, the significance of adverse weather, including both slippery roads and reductions in driver visibility, is not fully understood because there are no measurements (for example, vehicle miles traveled under adverse weather conditions) available to make comparisons between crash rates under various conditions. A researcher at the University of Michigan's Transportation Research Institute said that pedestrian-related crashes are particularly sensitive to light conditions. The researcher pointed out that, unlike vehicles and roads that may have lighting or reflective markings, pedestrians are generally not highly visible and are more likely to be involved in crashes during nighttime hours.

Vehicle Factors Contribute to Motor Vehicle Crashes

Vehicle factors can contribute to crashes through vehicle-related failures and vehicle design characteristics (attributes that may increase the likelihood of being involved in certain types of crashes). While such recent events as the number of crashes involving tire separations have highlighted the importance of vehicle factors, it is generally shown by data and studies and believed by experts that vehicle factors contribute less often to crashes than do human or roadway environment factors.

Vehicle-Related Failures

Two types of vehicle-related failures can contribute to traffic crashes: equipment-related and maintenance-related. Equipment-related failures include both original manufacturer and aftermarket-installed vehicle equipment that function improperly. If not corrected, some equipment-related failures might lead to the loss of a vehicle's handling capabilities, resulting in traffic crashes. The widely publicized tire separations are a recent example of an equipment-related failure. Equipment-related failures can be identified by the manufacturer or by NHTSA, and may result in a recall. In 2002, NHTSA reported 413 recalls involving over 18 million vehicles, over 1 million pieces of equipment, about 675,000 tires, and over 1 million child safety seats. NHTSA's Director of the Office of Defects Investigations told us that its investigations have identified 143 fatalities associated with recalls from 1990 through 2000. Maintenance-related failures result from an operator's improper maintenance of vehicle components, which may impair the function of the vehicle's equipment. Examples of maintenance-related failures include inadequate tire tread depth, worn brakes, unchecked or unchanged vehicle fluids, and underinflated tires.

Our analysis of NHTSA's data found that from 1997 through 2001, there were about 778,000 crashes in which police identified that a specific vehicle-related failure might have contributed to the crash. Where these failures were identified, brake systems and tires were identified most frequently, at 29 percent and 27 percent, respectively. Data is not collected by NHTSA in a manner that provides information on whether these crashes were caused by equipment or maintenance-related failures.

One vehicle factor that NHTSA believes may contribute to crashes is underinflated tires. In 2001, NHTSA conducted a study that found that 27 percent of passenger cars and 33 percent of light trucks were being driven with one or more underinflated tires. To reduce this problem, Congress passed the Transportation Recall Enhancement, Accountability, and Documentation Act of 2000 (P.L. 106-414), which will require motor vehicles to be equipped with a tire-pressure monitoring system to warn the driver if a tire is significantly underinflated. In May 2002, NHTSA issued part one of a two-part final rule requiring this system. It requires that between November 1, 2003, and October 31, 2006, auto manufacturers phase in one of two different tire-monitoring systems. The second rule, which has yet to be finalized, is scheduled to be issued March 1, 2005.

Several officials told us that vehicle-related failures and their effect on crashes are difficult to quantify. For example, NHTSA's Chief of Information Services stated that the central problem with identifying vehicle factors is that police officers are not necessarily qualified to identify vehicle defects.

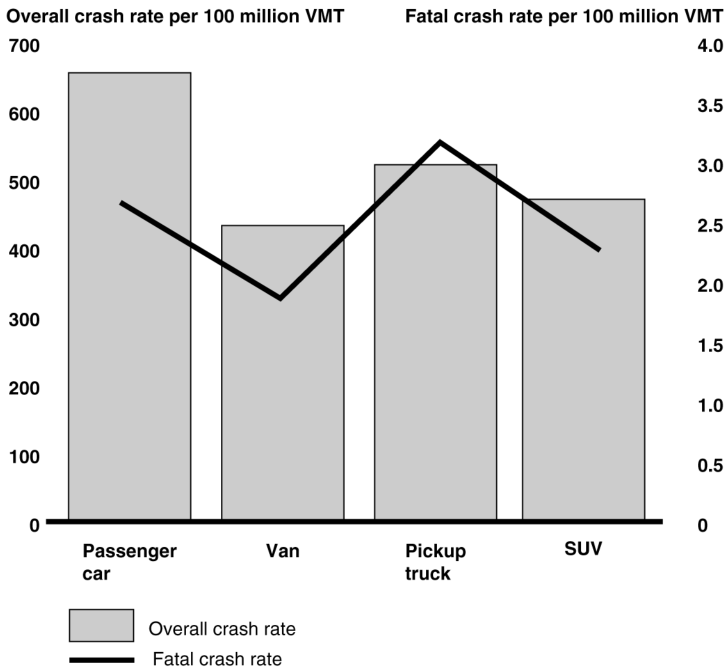
Vehicle Design

The design of a vehicle has been shown to affect handling in particular types of maneuvers. For example, high-performance sports cars have very different handling characteristics from those of sport utility vehicles (SUV). Recent changes in the composition of the nation's vehicle fleet, in part attributable to the purchase of many SUVs, have resulted in an overall shift toward vehicles with a higher center of gravity (more top-heavy), which can roll over more easily than some other vehicles. Rollover crashes are particularly serious because they are more likely to result in fatalities. NHTSA has developed rollover ratings for vehicles by calculating their static stability. This factor is a static metric that is determined by dividing a vehicle's track width, or distance between wheels from side to side, by twice the height of its center of gravity.

As shown in figure 8, our analysis of NHTSA's 2001 data showed that vans were the least likely to be involved in a crash, with about 432 crashes per 100 million vehicle miles traveled (VMT).[36] Passenger cars were the most likely to be involved in a crash, with a rate of 655 crashes per 100 million VMT. The figure also shows that both vans and SUVs had the lowest fatal crash rate, at 1.9 and 2.3 fatal crashes per 100 million VMT, respectively.

[36]For this VMT analysis we used data from the 2001 National Household Travel Survey.

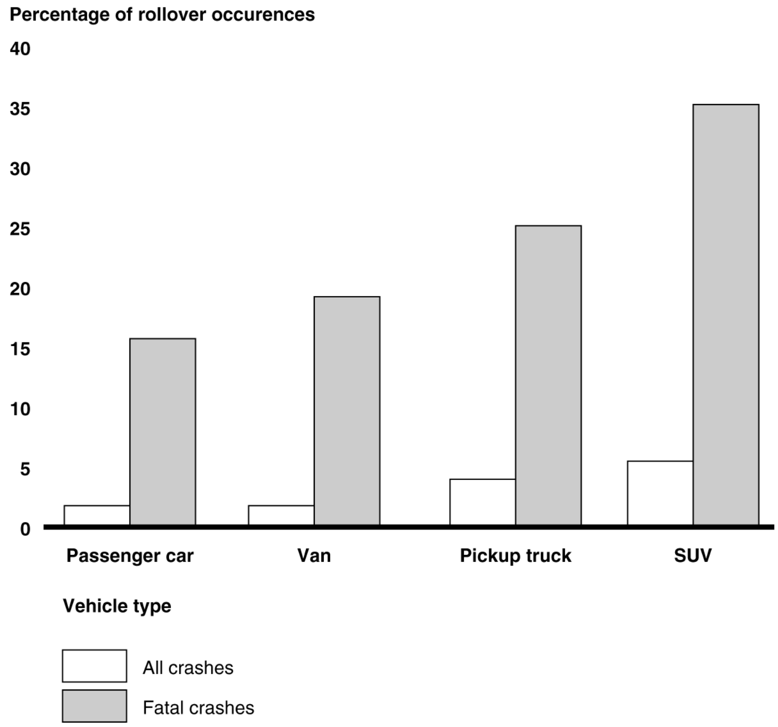
Figure 8: Vehicle Crash Rates, 2001



Source: GAO's analysis of NHTSA's data.

In 2001, rollover crashes killed 10,118 occupants in passenger cars, pickup trucks, SUVs, and vans. This represents almost one-third of the year's 31,875 occupant deaths in these types of vehicles. Figure 9 shows the percentage of rollover occurrence by vehicle type in 2001. Passenger cars were the vehicle type least likely to roll over in a crash; passenger cars rolled over in about 2 percent of all crashes, and rolled over nearly 16 percent of the time in fatal crashes. In comparison, our analysis shows that SUVs were over three times more likely to roll over in a crash than were passenger cars; that is, occurring in almost 6 percent of all crashes. The proportion of SUVs that rolled over in fatal crashes was over twice as high when compared with passenger cars. In 2001, SUVs rolled over in fatal crashes over 35 percent of the time.

Figure 9: Passenger Vehicle Rollovers, 2001



Source: GAO's analysis of NHTSA's data.

The National Transportation Safety Board (NTSB) recently examined rollovers in 15-passenger vans from 1991 through 2000.[37] The NTSB found that 15-passenger vans with 10 to 15 passengers had a rollover rate about three times greater than that of vans seating 5 or fewer passengers. In addition, NTSB found that the 15-passenger vans carrying 10 to 15 passengers rolled over in 96 of the 113 single-vehicle crashes (85 percent). However, they also found that the vans rolled over only 28 percent of the time, or 69 times out of the 244 single-vehicle crashes, when there were fewer than 5 occupants in the van. Additional analysis showed that higher speeds were also strongly correlated with a greater chance of rollovers. NTSB recommended that 15-passenger vans be rated by NHTSA for rollover propensity. Although NHTSA has established a rollover resistance

[37]National Transportation Safety Board, *Evaluation of the Rollover Propensity of 15-Passenger Vans*, NTSB SR-02/03 (October 2002).

rating system and is currently developing dynamic rollover tests, 15-passenger vans will not be evaluated for rollover propensity because they exceed the weight criteria for the testing program.

A study by the Insurance Institute for Highway Safety examined single-vehicle rollover crashes.[38] The study concluded that the combined rollover crash rate for pickup trucks and SUVs was more than twice the rate for passenger cars. The higher rollover rate for pickup trucks and SUVs was present even when taking into consideration a variety of crash circumstances, including location, roadway alignment, and the driver's age. The study concluded that both pickup trucks and SUVs are more prone to rollover crashes than are passenger cars.

A recent NHTSA study addressed rollovers from 1991 through 2000.[39] One of its findings was that of all vehicle types considered in the study, SUVs are the only type in which the number of occupant fatalities in rollover crashes exceeds the number of occupant fatalities in nonrollover crashes; in 2000, nearly two-thirds of SUVs' occupant fatalities occurred in rollover crashes. One of the report's conclusions was that, despite declines in passenger car occupant fatalities, the increasing influence of light truck fatal crashes in general, and rollover crashes in particular, is instrumental in maintaining the level of traffic crash fatalities. NHTSA's Division Chief of Math Analysis stated that reducing rollovers is one of the NHTSA Administrator's top five priorities.

In commenting on a draft of this report, NHTSA provided an analysis comparing the crash rates for both passenger cars and light trucks using VMT based on FHWA's Highway Statistics Series.[40] The analysis indicates that passenger cars had a lower fatal crash rate at 1.73 per 100 million VMT, as compared with a rate of 2.13 for light trucks. With regard to the

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[38]Charles Farmer and Adrian Lund, "Rollover Risk of Cars and Light Trucks after Accounting for Driver and Environmental Factors," *Accident Analysis and Prevention*, vol. 34 (2002), pp. 163–73. The study examined all single-vehicle fatal crashes for 4 years, along with single-vehicle injury crashes involving rollovers from three states by vehicle type for 4 years. The study used vehicle registration as a means to make comparisons among vehicle types.

[39]William Deutermann, *Characteristics of Fatal Rollover Crashes*, DOT HS 809 438 (April 2002).

[40]This VMT analysis used the FHWA's Highway Statistics Series. FHWA obtains its data on vehicle miles traveled by counting the number and types of vehicles passing particular points around the country.

vehicle involvement rate in all crashes, NHTSA's analysis shows that passenger cars had a rate of 423 crashes per 100 million VMT, which is slightly higher than that for the light trucks (401 crashes per 100 million VMT).

In February 2003, the Alliance of Automobile Manufacturers, a trade group that represents the three major U.S. automobile manufacturers and a number of foreign manufacturers, published analyses examining occupant fatality rates by vehicle type. One analysis used registered vehicles as a method to compare fatality rates between vehicle types. Its results indicate that in 2001, SUVs had a slightly higher occupant fatality rate than had passenger cars—16.25 and 15.70 per 100,000 registered vehicles, respectively. The alliance points out, however, that 72 percent of people killed in SUV rollover crashes were not wearing safety belts, which can reduce a driver's risk of fatal injury in a rollover by 80 percent. They further stated that in 2000, 35 percent of SUV single-vehicle rollover fatalities were alcohol-related.

Federal Research Directed at Better Understanding of Factors That Contribute to Crashes

Various modal agencies within the Department of Transportation have research projects underway and planned that address aspects of crash causes. For example, the Federal Motor Carrier Safety Administration and NHTSA are conducting a study on the causes and contributing factors to large truck crashes. NHTSA is also funding the 100-Car Naturalistic Driving Study, which involves collecting data about crashes and near misses from 100 vehicles equipped with sensors. Further, NHTSA is funding a project called the Drive Atlanta Study that involves collecting data from 1,100 vehicles equipped with data recorders. In addition to possible follow-on research on the above projects, planned research includes a Transportation Research Board proposal for a 6-year program that would, among other things, involve installing sensors and other data collection devices on over 5,000 vehicles.

Large Truck Crash Causation Study

In 1999, Congress established the Federal Motor Carrier Safety Administration (FMCSA) within DOT and mandated that it study the causes of and contributing factors in large truck crashes. In 2001, large truck crashes resulted in about 5,000 fatalities and 131,000 injuries. FMCSA partnered with NHTSA to implement the 4-year, $18 million Large Truck Crash Causation Study. The study's goal is to develop a greater understanding of the factors leading to large truck crashes, so that cost-effective countermeasures can be developed to decrease the number and severity of these crashes.

To conduct this study, FMCSA and NHTSA built on the existing crash investigation system that NHTSA had established to collect data for the Crashworthiness Data System database. For this effort, researchers at 24 locations collect information on a sample of large truck crashes by visiting the crash sites shortly after they occur and completing a response protocol that was developed for this project. NHTSA's Director of the National Center on Statistics and Analysis told us that the most informative crash causation data is often collected at the site of the crash while the vehicles and participants are still present.

Cooperative agreements were established between the police, FMCSA, and NHTSA to use an established, on-scene investigative approach. These cooperative agreements were based on previous agreements set up between NHTSA and police for data collection for the CDS database, but they were modified to accommodate the other parties involved and a faster time frame for the crash investigations. A NHTSA official stated that this multiagency partnering is important for the success of the study, and that establishing rapid notification procedures requires the cooperation of state and local police along with their police dispatch personnel.

The researchers expect to investigate at least 1,000 crashes by the end of 2003. FMCSA and NHTSA officials said that the results will yield findings about critical pre-crash events, the reasons for these events, and relative risks in truck crashes. They also said that this information should significantly help to create proven countermeasures to decrease the number and limit the severity of truck crashes.

As a follow-on to this study, NHTSA requested $10 million in its fiscal year 2004 budget to begin a National Motor Vehicle Crash Causation Survey. This study would develop and conduct a nationally representative effort to collect on-scene crash causation data. The Large Truck Crash Causation Study would be used as the model for the proposed study. The on-scene methodologies and procedures developed for the Large Truck Crash Causation Study would also be applicable to this proposed effort. NHTSA officials said that start-up costs and implementation timing would be reduced by making use of the infrastructure in place for the truck study, which is scheduled to complete data collection by the end of 2003.

One Hundred-Car Naturalistic Driving Study

NHTSA is currently conducting the 100-Car Naturalistic Driving Study, whose purpose is to help develop better crash-avoidance warning systems. This 1-year, $3 million driving research study involves collecting data from 100 vehicles equipped with various sensors and cameras. NHTSA has partnered with FHWA, Virginia, and the Virginia Polytechnic Institute and State University (Virginia Tech) to fund the study. Virginia Tech is responsible for conducting the study.

NHTSA has equipped 100 cars (80 individually owned and 20 leased) with five video cameras and a variety of sensors to track proximity and relationships to other vehicles and objects. In addition, the vehicles have sensors that detect glare and whether the driver is using a cell phone in the car. Volunteers will use the vehicles for their everyday driving in the metropolitan Washington, D.C., area for the duration of the study, which began in early 2003. The cameras and sensors are to provide data for studying crashes as well as near misses. In the event of a crash, NHTSA will send a team of researchers to the site to investigate.

NHTSA officials told us that they are considering a follow-on to this study, if it is successful. An expanded version of the study could include a representative sample of up to 10,000 equipped cars around the country. The official said that after completion of the initial study, researchers should have greater knowledge about which sensors and equipment provided the most relevant information on contributing factors to motor vehicle crashes, and would install only that equipment in the larger fleet of vehicles. NHTSA told us that they might seek funding from auto manufacturers and other entities to supplement their funding.

Drive Atlanta Study

Later this year, NHTSA will begin a 2-year, $3.1 million Drive Atlanta Study, which involves installing data recorders in 1,100 vehicles to develop information on situations and circumstances where excessive speed contributes to crashes. Drive Atlanta is primarily funded by a $1.9 million contract with NHTSA and $1.2 million from Safety Intelligence Systems, Inc. FHWA is also contributing money to the study. The private company is providing the development costs and is prototyping and testing the MACBOX, the data recorder that will be used by the Georgia Institute of Technology to conduct the study.

In this study, the data recorder information will be combined with three other types of data. Data will be contributed by the Atlanta Traffic Management Center on prevailing traffic conditions, the National Oceanic and Atmospheric Administration on weather, and the Georgia Department of Transportation on roadway characteristics. According to a program official, this combination of data will enable the researchers to know when and where the driving occurred, what were the posted speed limits along the drivers' routes, what were the roads' characteristics, and numerous other data. The researchers plan to create speed profiles for all of the study's participants at the conclusion of the study, to examine exactly how speed is involved in crashes. NHTSA estimates that at least 100 crashes will occur over the next 2 years involving these vehicles.

Future Strategic Highway Research Program

In the Transportation Equity Act for the 21st Century (P.L. 105-178), Congress requested that the Transportation Research Board conduct a study to determine the goals, purposes, research agenda and projects, administrative structure, and fiscal needs for a new strategic highway research program. In response to this request, a committee of highway industry leaders was formed to develop recommendations. The committee engaged in an outreach process to gather input from the highway community regarding strategic priorities and promising research approaches. The committee's report was published in October 2001 and recommended a 6-year, $450 million to $500 million Future Strategic Highway Research Program (F-SHRP) focused on the following areas: (1) accelerating the renewal of America's highways; (2) making a significant improvement in highway safety; (3) providing a highway system with reliable travel times; and (4) providing highway capacity in support of the nation's economic, environmental, and social goals. FHWA contributed $1.5 million over fiscal years 2002 and 2003 toward the F-SHRP planning activities.

The F-SHRP objective of "making a significant improvement in highway safety" includes three major areas: (1) methodology development using existing data, (2) large-scale research studies of multiple factors related to the risk of collisions and casualties for high priority roadway safety issues, and (3) analysis of the field data for countermeasure implications. A key aspect of this project is the use of in-vehicle and roadside technologies to gather data to examine crash rates and pre-crash conditions on a large scale to perform risk analyses. The study recommended that $180 million to $200 million be committed to this safety objective.

The F-SHRP safety plan includes using the data from NHTSA's national crash databases as well as other studies that have used instrumented vehicles and roadside technologies. The F-SHRP study would involve collecting data from 5,000 to 6,000 instrumented vehicles and roadside technologies for over 2 to 3 years. According to the contractor who developed the implementing plan for the F-SHRP safety goal, analysis of the previous study data will enable the F-SHRP researchers to first test risk measures and analysis methods before implementation of the F-SHRP field study. The contractor said that NHTSA's 100-Car Naturalistic Driving

Study and Drive Atlanta Study and FHWA's Road Departure Study would be good sources of the type of instrumented vehicle data the early methodology projects need.[41] The proposed F-SHRP instrumented vehicle study would involve data collection for two high-priority highway safety problems: run-off-the-road and intersection crashes. The fleet of instrumented vehicles would be split between at least two geographic areas, with volunteer drivers using the vehicles for their everyday driving. The final phase of the research would be to use the results of the large-scale instrumented vehicle study to identify appropriate countermeasure improvements.

Agency Comments and Our Evaluation

We provided copies of a draft of this report to the Department of Transportation for its review and comment. In discussing this report, NHTSA and FHWA officials provided technical clarification and information, which we incorporated in the report as appropriate. In addition, NHTSA provided information comparing light truck and passenger car crash rates, which we also incorporated in the report.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies of this report to cognizant congressional committees and to the Honorable Norman Y. Mineta, Secretary of Transportation; the Honorable Dr. Jeffrey W. Runge, Administrator of the National Highway Traffic Safety Administration; and the Honorable Mary E. Peters, Administrator of the Federal Highway Administration. We will also make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

[41]In the Road Departure Study, the University of Michigan Transportation Research Institute will develop and test a new crash avoidance warning system in 11 passenger cars. The system, designed to prevent road departure and run-off-the-road crashes, will alert the driver when the vehicle begins to wander off the road or when the vehicle is traveling too fast for an upcoming curve.

If you have questions about the report, please contact me at (202) 512-2834. Key contributors to this report were Michele Fejfar, Glenn C. Fischer, Bonnie Pignatiello Leer, Sara Ann Moessbauer, Elsie Picyk, Beverly Ross, and Glen Trochelman.

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Appendix I: Objectives, Scope, and Methodology

To provide information on the factors that contribute to motor vehicle crashes, we obtained and analyzed crash data from National Highway Traffic Safety Administration (NHTSA) databases, obtained and reviewed research studies on the topic, and interviewed a variety of experts and federal officials. To identify major ongoing and planned Department of Transportation (DOT) research into factors that cause crashes, we obtained documents from and interviewed officials of NHTSA and the Federal Highway Administration (FHWA).

Analyzing NHTSA Data

For each factor contributing to traffic crashes, we obtained and analyzed data for calendar years 1997 through 2001 from NHTSA's crash reporting systems—the most recent 5-year period for which these data are available. Our analysis involved the use of three of NHTSA's databases: the Fatality Analysis Reporting System, the General Estimates System, and the Crashworthiness Data System. Each database contained different levels of crash data.

- **Fatality Analysis Reporting System (FARS)** – This database provides information on all traffic-related fatalities. A crash must result in the death of an occupant or nonmotorist within 30 days of the incident to be included in this database. Each of the states provides the data to NHTSA in a standardized format. The states generally obtain this information through data from reports that police officials prepare at the scene of the crash as well as state vehicle registration files, state driver licensing files, state highway department data, death certificates, coroner or medical examiner reports, hospital medical records, and emergency medical service reports. NHTSA created the database to identify traffic safety problems, develop and implement countermeasures, and evaluate vehicle safety standards and highway safety programs. We used this database to present overall information on traffic deaths as well as to provide an understanding of crashes involving speed, alcohol, age, and vehicle design. It should be noted that while fatality data is useful in understanding crashes, other factors, in addition to those involved in causing the crash, might have contributed to the fatality. This would include such factors as whether safety belts or other occupant protection measures were used and operated properly.

- **General Estimates System (GES)** – This database is created from a nationally representative sample of police accident reports completed for crashes. Other criteria necessary for inclusion in the database are that the crash must involve at least one motor vehicle traveling on a traffic way, and that the crash must result in property damage, injury, or death. This database was created to identify traffic safety problem areas, provide a basis for regulatory and consumer initiatives, and form the basis for cost and benefit analyses of traffic safety initiatives. This is NHTSA's largest crash database, with information collected on over 50,000 randomly sampled police accident reports each year. We analyzed the GES data to provide information on speed, traffic control violations, roadside hazards, roadway conditions, and vehicle defects. In addition, for the analysis in which we compared fatalities with other types of crashes (reduced visibility, vehicle design, age), we combined FARS and GES data.

- **Crashworthiness Data System (CDS)** – This database contains information from a detailed sample of about 4,000 minor, serious, and fatal crashes annually. The criterion necessary for inclusion in the database is that at least one passenger vehicle must be damaged severely enough to require towing from the crash site. Teams of trained crash investigators visit the crash site and collect data elements such as vehicle crash damage and interior vehicle locations that the occupants struck. The investigators also generally locate and interview crash victims and review medical records to determine the types of crash-related injuries. A goal of this database includes having the ability to examine the crashworthiness of vehicles; that is, how vehicles perform in crashes with respect to protecting their occupants. We used the CDS database to provide information on crashes involving driver inattention.

In commenting on a draft of our report, NHTSA officials said that the FARS, GES, and CDS databases, although providing useful information, rely on data from police accident reports or on data collected days or weeks after the crash, making it difficult to obtain causation data. Therefore, NHTSA relies on the Indiana Tri-Level study data, which is almost a quarter of a century old. They noted that since the Tri-Level study was completed, cars, drivers, highways, technology, and lifestyles in the United States have changed dramatically. As previously discussed, NHTSA has proposed to develop and conduct a nationally representative survey to collect on-scene crash causation data—the National Motor Vehicle Crash Causation Survey. NHTSA officials indicated that these on-scene, real-time data are needed to best understand crash causation.

In addition to using these three databases, for some analyses we also calculated frequency rates using vehicle miles traveled. We used vehicle miles traveled data from two different sources—the 2001 FHWA Highway Statistics Series data and the 2001 National Household Travel Survey. For example, we used FHWA's vehicle miles traveled data in examining crash rates by road type. FHWA obtains its data on vehicle miles traveled by counting the number and types of vehicles passing particular points around the country. Because FHWA's statistics do not include data on age or gender, we used vehicle miles traveled from the 2001 National Household Travel Survey for some analyses.[42] This survey of about 26,000 households in the United States was conducted from March 2001 through May 2002. It provides data on personal travel behavior at the national level to use as a benchmark for a variety of applications. Although the overall response rate for sampled households was low (41 percent), there are few other sources for information on U.S. travel patterns. We used the most recent available data, preliminary release (version 1), to get estimates of annual vehicle miles traveled for our tables on rates of driver involvement and types of vehicles involved in crashes.

We assessed the reliability of FARS, CDS, and GES by reviewing existing information about the data and performing electronic tests of the data. There are certain limitations associated with using these databases for our analysis. For example, the source of the GES data is police accident reports that are prepared at the scene of the crash. Although the GES has procedures to ensure that data reflect information in the accident reports, we did not verify the accuracy of the accident reports themselves. In addition, since GES, CDS, and the National Household Travel Survey are based on samples, any estimates derived from these databases are subject to sampling errors. A sampling error indicates how closely the results of a particular sample would be reproduced if a complete count of the population were taken with the same measurement methods. The estimated sampling errors (at the 95 percent confidence level) do not exceed plus or minus 11 percentage points.

Identifying Studies

To identify recent studies on factors that contribute to motor vehicle crashes, we conducted a literature search, explored the Transportation Research Information System, and reviewed periodicals. This effort resulted in numerous studies being identified on various aspects of the motor vehicle crashes. We then, with input from a number of experts and officials from NHTSA and FHWA, judgmentally selected studies that would provide additional information on the particular factors being discussed. For each of the selected studies that are used in this report, we determined whether the study's findings were generally reliable. To do so, we evaluated the methodological soundness of the studies using common

[42] *2001 National Household Travel Survey User's Guide*, Version 1(Preliminary Release) January 2003.

social science and statistical practices. For example, we examined each study's methodology, including its limitations, data sources, analyses, and conclusions.

Interviewing Federal Officials and Experts

In conducting this review we interviewed a wide variety of federal officials and other experts. Within DOT, we interviewed officials from the Volpe Center, the National Highway Traffic Safety Administration, and the Federal Highway Administration. We also spoke with individuals affiliated with academic institutions, including the University of North Carolina's Highway Safety Research Center, the University of Michigan's Transportation Research Institute, Northwestern University's Center for Public Safety, Texas A&M University's Texas Transportation Institute, and the Johns Hopkins School of Public Health. In addition, we interviewed officials from the Insurance Institute for Highway Safety. We also spoke with automobile industry representatives at the Alliance of Automobile Manufacturers, a trade group that represents the three major U.S. automobile manufacturers and a number of foreign manufacturers. We spoke with officials from the Transportation Research Board, Advocates for Highway and Auto Safety, AAA (formerly the American Automobile Association), American Association of State Highway and Transportation Officials (AASHTO), the National Sleep Foundation, the Midwest Research Institute, and the Southern California Research Institute. In general, the officials and experts provided information about major factors that contribute to motor vehicle crashes and research on these factors.

Ongoing and Planned Transportation Research

To identify major ongoing and planned DOT research into factors that contribute to motor vehicle crashes, we interviewed officials from NHTSA, FHWA, and the Transportation Research Board. These agencies have a great deal of ongoing and planned research on a wide variety of motor vehicle safety issues, such as research to mitigate accident severity and safety system issues. However, to respond to this objective, we selected ongoing and planned studies that (1) represented major research studies, (2) examined multiple factors contributing to crashes, (3) examined causal factors rather than countermeasures, and (4) collected original data, rather than analyzed existing data. We also obtained documents describing the research projects and reviewed federal budgetary documents on the projects.

We performed our review from July 2002 through February 2003 in accordance with generally accepted government auditing standards.

Appendix II: *Tri-Level Study of the Causes of Traffic Accidents*

Researchers at the Indiana University Bloomington's Institute for Research in Public Safety conducted the *Tri-Level Study of the Causes of Traffic Accidents* from 1972 through 1977. The study investigated how frequently various human, environmental, and vehicle factors were involved in traffic crashes. According to NHTSA officials, the Tri-Level study has been the only study in the past 30 years to collect on-scene crash causation data. The study, conducted for NHTSA, incorporated 13,568 police-reported crashes, including on-scene investigation of 2,258 crashes, and an in-depth investigation of 420 crashes. The investigation teams assessed causal factors as definite, probable, or possible. The in-depth team identified human errors as definite or probable causes in 93 percent of the crashes, environmental factors in 34 percent, and vehicle factors in 13 percent. In 20 percent of the crashes studied in depth, no definite cause could be identified.

Objectives, Scope, and Methodology for the Tri-Level Study

Indiana University conducted the study to satisfy a broad range of NHTSA's needs for data on traffic crash causation. Two of the main objectives for the research were to:

- Identify those factors that are present and serve to initiate or influence the sequence of events resulting in a motor vehicle crash.
- Determine the relative frequency of these factors and their causal contribution within a defined crash and within the driving population.

Researchers collected collision data on three levels (A, B, and C), each providing an increasing amount of detail. Data collection for level A involved examining police reports for 13,568 crashes and collecting other baseline data, such as vehicle registration files, driver license files, roadway inventories, and local surveys. For level B, teams of technicians conducted on-site investigations of 2,258 crashes immediately following their occurrence. For level C, a multidisciplinary team conducted independent, in-depth investigations of 420 of the crashes. The crashes investigated on-scene and in-depth were generally representative of all police-reported crashes occurring in Monroe County, Indiana, during the study period.

In the clinical assessments of crash causation in Monroe County, a traffic crash was viewed as the last event in a chain of events and conditions that preceded it. A crash cause was defined as an event or condition but for which the crash would not have occurred. Emphasis was placed on events and conditions that immediately preceded the crash because they may be viewed as the final links of a casual chain that culminates in the crash.

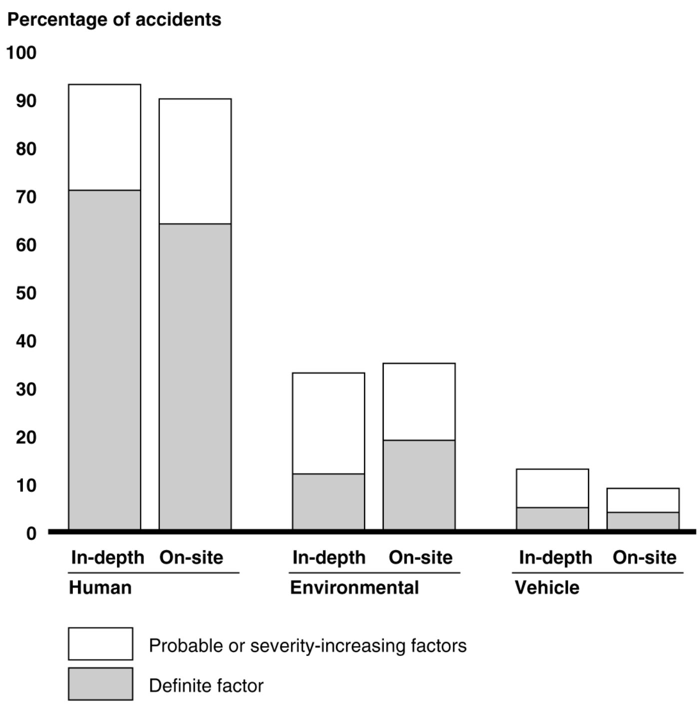
According to the study, during in-depth investigations, the researchers attempted to acquire as much relevant information as possible, and then made clinical case-by-case determinations of the causal factors involved, based on all of the information obtained. An assessment system permitted each identified factor to be evaluated as definitely, probably, or possibly involved as either a causal or severity-increasing factor. A causal factor was defined as a factor necessary or sufficient for the occurrence of the crash; had the factor not been present in the crash sequence, the crash would not have occurred. A severity-increasing factor was defined as a factor that was neither necessary nor sufficient for the occurrence of the crash, but its removal from the crash sequence would have lessened the speed of the initial impact. The causal assessment process for each crash involved two major steps: first, identifying relevant deficiencies of drivers, vehicles, and the driving environment that were present in the crash sequence; and second, assessing the investigation team's certainty that the crash would not have occurred had each deficiency been corrected to its minimally acceptable state.

In addition, data on Monroe County drivers, vehicles, roads, and crashes were compared with available national data. It was found that for Monroe County the severity distribution of reported crashes; the proportion of crashes occurring on dry, wet, or snow- or ice-covered roads; the proportion occurring in urban or rural areas; and the age distribution of the vehicles were nearly the same as for the United States as a whole. The most notable difference was that young drivers were overrepresented. However, the effects of this overrepresentation on the overall causal results were found to be minimal. Thus, it was found that while the results from Monroe County, Indiana, do not represent the United States as a whole in a statistical sense, they indicate factors that are likely to be important on a national level and their relative involvement.

Results of the Tri-Level Study

Human factors were the most frequently implicated of the three categories, and vehicle factors the least frequently implicated. As figure 10 shows, the in-depth team concluded that human factors were definite causal factors in 71 percent of the crashes; environmental factors in 13 percent; and vehicle factors in 4 percent. Similarly, the in-depth team concluded that these same three categories were definite or probable causal or severity-increasing factors in 93 percent, 34 percent, and 13 percent, respectively.

Figure 10: Factors Contributing to Crashes Identified by the Tri-Level Study



Source: Tri-Level study.

The on-site team concluded that human factors were definite causal factors in 64 percent of the crashes; environmental factors in 19 percent; and vehicle factors in 4 percent. The on-site team concluded that these same three categories were definite or probable causal or severity-increasing factors in 90 percent, 35 percent, and 9 percent, respectively. The in-depth team could not establish a definite cause for 20 percent of the crashes they investigated, while the on-site technicians could not establish a cause for 26 percent of the crashes. However, the on-site team identified one or more probable causes in nearly all the crashes. Also, more than one factor was implicated as a cause in many of the crashes.

Human Factors

The study categorizes human direct causes based on an information-processing model of the driver as vehicle controller. This model assumes that drivers are continuously engaged in perceiving and comprehending information, making decisions, and taking actions to achieve necessary control responses. The “perception” and “comprehension” categories were combined as “recognition errors” because of the difficulty in distinguishing errors in these functions through crash investigation. A “critical nonperformance” category was added to reflect instances where a driver ceases to perform as an information processor. A “noncrash” category was included to accommodate any intentional crash involvements. Recognition errors were cited as the most prevalent human causal factor, followed by decision errors, performance errors, and critical nonperformance errors.

More specific human-direct-cause categories were grouped in the causal hierarchy, under these major headings. With regard to specific human errors, improper lookout was cited as the most prevalent error. Other specific human errors cited included excessive speed, inattention, improper evasive action, and internal distraction.

The researchers separately recorded human conditions and states that impeded the ability of the driver to function as an information processor. These factors, which included fatigue, driver experience, and alcohol impairment, were viewed as potential “reasons behind the reasons.” Alcohol impairment was cited as the most prevalent human condition, followed by other drug impairment and fatigue.

Environmental Factors

The study categorized environmental factors as involving highway-related factors, slick roads, or other ambience-related factors. Among these, highway-related factors predominated; the in-depth team identified them as definite causes in 7 percent of crashes. Slick roads were definite causes in 4 percent of crashes, and other ambience-related factors in 2 percent. More specific environmental causes were defined under these three broad headings. The most commonly cited specific environmental factors were view obstructions and slick roads.

Vehicle Factors

The study categorized vehicle factors according to major vehicle systems, and then according to more specific categories. The most commonly cited deficiency in these systems was with the brake system, followed by the tires and wheels. The most commonly cited vehicle deficiency causal factor was gross brake failure, followed by inadequate tread depth.

Appendix III: Roadway Design Features

A number of roadway design studies and experts we spoke with addressed how various aspects of roadway design might contribute to traffic crashes. These included medians, lane widths, shoulders, curves, access points, and intersections.

Medians

Medians are physical separations between opposite lanes of traffic that provide a recovery area for out-of-control vehicles. They also serve to separate traffic driving in opposite directions, thereby minimizing their interactions and likelihood of being involved in catastrophic head-on crashes. Some considerations regarding medians include their presence or absence (that is, divided vs. undivided roads), the width of the median, and whether a barrier is placed in the median.

Presence or Absence of Medians

An analysis of NHTSA's databases showed that from 1997 through 2001, 44 percent of all traffic fatalities occurred on undivided, rural, two-lane roads. This represents 73 percent of all traffic fatalities in rural areas. In urban areas, 35 percent of traffic fatalities occurred on two-lane undivided roadways. In addition, a study conducted by the Kentucky Transportation Center examined the impact of converting two-lane undivided rural roads to four-lane divided roads at 25 locations.[43] They found that, on average, there was a reduction in crash rate after the road's conversion from a two-lane undivided rural road to a four-lane divided road.

Width of Medians

According to experts with whom we spoke, medians provide safety benefits by allowing vehicles enough room to recover from various vehicle or human factors that could contribute to a crash. A study published in the Transportation Research Record used Highway Safety Information System data from Illinois and Utah to assess the relationship between median width and crash rates.[44] The study was based on a total of 3,055.1 miles of roadway, with speed limits of at least 35 miles per hour. The study attempted to isolate only the median's width as the predictive factor for crash rates, but it acknowledged that there could be other elements influencing the crash rates as well. Overall, the study concluded that crash rates decrease with increasing median widths greater than 25 to 30 feet,

[43]Kenneth Agent and Jerry Pigman, *Safety Impacts of Rural Road Construction*, Kentucky Transportation Center KTC-01-01(February 2001).

[44]M.W. Knuiman, F.M. Council, and D.W. Reinfurt, *The Effect of Median Width on Highway Accident Rates*, Transportation Research Record 1401, 1993.

and increasing widths continue to provide additional benefits up to widths of approximately 65 to 80 feet.

Existence of Barriers

Some experts told us that although the installation of median barriers can reduce head-on crashes, their presence may increase the number of total crashes. This might occur because the median barrier reduces the amount of space a vehicle has to recover within the median. The Washington State Department of Transportation recently conducted a study of cross-median crashes on multilane and divided state highways with full-access control.[45] One goal of the study was to revise the guidelines for the installation of median barriers. The study examined cross-median crashes from 1996 through 2000 from a sample of 677 miles of road. Using a benefit-cost analysis, the study recommended installing median barriers on all full-access control, multilane highways with posted speed limits of 45 miles per hour or greater where the median width was 50 feet or less.

Lane Widths

Wider lanes increase the separation between vehicles traveling in adjacent lanes as well as provide additional space to recover from near-crash situations. In a recent study, FHWA addressed the relationship between lane width and crashes on two-lane rural highways based on expert assessments and previous studies.[46] The study included an analysis of the combined effects of lane width and average daily traffic on crash rates, and it predicted that lane width has only a slight impact on crash rates at low volumes of traffic.[47] However, the study also predicted that at high-average daily traffic volumes, the two-lane rural roads with 9-foot lanes have a 50 percent greater chance of having crashes than have similar roads with 12-foot lanes. In discussing lane width with experts, we were told by one academic researcher that while wider lanes provide additional space between vehicles, wider lanes may give drivers an increased perception of safety resulting in higher rates of speed, possibly leading to other safety problems.

[45] Washington State Department of Transportation, *Median Treatment Study on Washington State Highways* (March 2002).

[46] D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways*, FHWA-RD-99-207 (December 2000).

[47] This factor applies to single-vehicle run-off-the-road, multiple-vehicle same-direction sideswipe crashes, and multiple-vehicle opposite-direction crashes.

Roadway Shoulders

Roadway shoulders provide a clear space for drivers to recover from errors. A recent FHWA study examined the relationship between shoulder width, average daily traffic, and crash rates for two-lane rural highways and predicted that, in general, at low-average daily traffic rates, shoulder width only slightly affects the crash rate but as the average daily traffic rate increases, so does the influence of shoulder width on crash rates.[48] For example, at high-average daily traffic volumes, the study predicted that a 50 percent greater number of crashes occur on two-lane rural highways with no shoulders than on similar roads with 6-foot shoulders. Experts told us that while wider shoulders are generally better than narrow ones, the benefits that shoulders provide are also influenced by the material from which they are constructed. A researcher at the University of North Carolina's Highway Research Safety Center told us that paved shoulders are associated with fewer crashes at lower rates than those with gravel or grass shoulders. Another expert pointed out that soft shoulders can lead to a loss of vehicle control both through the uneven edges between the driving lane and the shoulder or through a differential of friction between the driving lane and the shoulder.

Curves

Curves have been shown to contribute to crashes, whether horizontal curves (left or right) or vertical curves (up and down). Various elements of curves may affect the likelihood of a crash, including features of the curve (for example, degree, length, and angle of the curve) and cross-sectional curve elements (for example, lane width, shoulder size and type.) A 1991 FHWA study identified factors more strongly associated with curves than adjacent straightaways in Washington State.[49] These factors included a higher percentage of fatal crashes, head-on and opposite sideswipe crashes, fixed-object and rollover crashes, crashes at night, and crashes involving drinking drivers. Vertical curves have also been associated with higher crash rates, though, according to an American Association of State Highway and Transportation Officials chairperson, not as much as compared with horizontal curves. An important design element regarding

[48]D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways*, FHWA-RD-99-207 (December 2000).

[49]C. Zegeer, J. Stewart, F. Council, and D. Reinfurt, *Cost Effective Geometric Improvements for Safety Upgrading of Horizontal Curves*, Federal Highway Administration Report FHWA-RD-90-021 (October 1991).

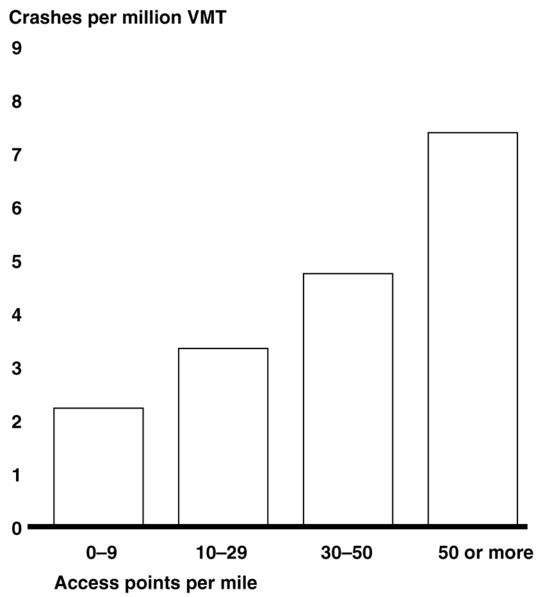
vertical curve safety is the need to provide drivers with adequate stopping sight distance.

Access Points

Access points are locations where vehicles enter a roadway, such as residential and business driveways and exit and entrance ramps on highways. A 1998 study completed for the Minnesota Department of Transportation found that as access points to roads increase, so do the number of crashes.[50] For example, on four-lane urban conventional roadways, with no left turns, the researchers found that in Minnesota there were an average of 2.22 crashes per million vehicle miles traveled when there were from zero to ten access points per mile. (See fig. 11.) However, the rate of crashes increased to 7.38 when the number of access points was greater than 50 per mile. Additionally, traffic safety experts supported the conclusion that more access points generally lead to higher crash rates.

[50]Minnesota Department of Transportation, *Statistical Relationship Between Vehicle Crashes and Highway Access* (August 1998).

Figure 11: Impact of Access Points on Traffic Crashes



Source: GAO's presentation of Minnesota DOT's data.

Intersections

According to FHWA, intersections are among the most complex roadway designs a driver encounters. A recent report for NHTSA found that in 2001, intersection and intersection-related crashes represented 22.5 percent of total fatal crashes and 43 percent of overall crashes.[51] There are four major crash types at intersections: crossing, rear-end, improper lane changing, and pedestrian and bike. Multiple factors contribute to intersection crashes, including: poor physical design, inadequate traffic engineering, failure of driver licensing and education to train drivers in negotiating intersections, and driver disregard for traffic control devices. For example, a poorly designed intersection might provide inadequate sight distance, which could limit a driver's response time to react to vehicles or pedestrians at that intersection. Additionally, incorrectly timed or inconspicuous traffic control devices can also contribute to a crash.

[51]National Highway Traffic Safety Administration, *Traffic Safety Facts, 2001*.

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