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16. Abstract

Accidents involving buses are a serious highway safety problem, resulting in about 15,000 injuries in the U.S. each year. The objective of this study was to examine the characteristics of bus accidents and recommend countermeasures. Analyses were carried out on a primary study file of 8,897 commercial bus crashes in five states and other accident data. The most important results of these analyses are related to temporal factors, vehicle factors, driver factors, and accident types. For example, the overall number of crashes was highest in winter months, older buses were overrepresented in injury and fatal crashes compared to newer buses, neither bus driver age nor gender was related to accident involvement, and the most common bus accident types were rear-end with one vehicle stopped, sideswipe same-direction, and turning. Bus passenger injury data were also analyzed and revealed that one-third of all non-collision passenger injuries occurred during boarding and alighting and another one-fourth occurred during stopping.

A number of measures may be used to improve bus safety. Improvements to the roadway design and operation are suggested, such as wider lanes and shoulders, separate turn lanes, traffic signal improvements, bus pull-off lanes, and safer roadside designs. Passenger safety outside the bus can be improved by having bus stops on the far side of intersections and adequate passenger loading areas. Bus-related safety measures include improved interior and seat design and consistent riser heights and tread widths in stepwells. Also important are appropriate transit agency policies and practices and organized safety and security reporting to allow for better identification of problem sites.

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ABSTRACT

Accidents involving buses are a serious highway safety problem, resulting in about 15,000 injuries in the U.S. each year. The objective of the study documented in this report was to describe the bus accident picture and recommend countermeasures. Analyses were carried out on a primary study file of 8,897 commercial bus crashes in five states -- Illinois, Maine, Michigan, Minnesota, and Utah -- for 1985 through 1989. A subset file with urban crashes in four states and the entire Illinois motor vehicle accident file with all vehicle types were also analyzed. The overall number of crashes was highest in winter months, perhaps due partly to snow and ice conditions. Older buses were overrepresented in injury and fatal crashes compared to newer buses. Bus drivers were much less prone to injury in crashes than bus passengers. Neither bus driver age nor gender was related to accident involvement. Bus crashes at traffic lights were more likely to cause injuries and fatalities than those at stop signs. In Illinois, the most common bus accident types were rear-end with one vehicle stopped, sideswipe same-direction, and turning. Rear-end and angle accidents were most likely to cause injuries and fatalities. Bus passenger injury data from the Washington Metropolitan Area Transit Authority were also analyzed, and revealed that one-third of all non-collision passenger injuries occurred during boarding and alighting and another one-fourth occurred during stopping.

A number of measures may be used to improve bus safety. Roadway improvements on bus routes include wider travel lanes, paved shoulders or bus pull-off lanes, wider intersection turning radii, separate turn lanes, adequate nighttime lighting, restriction of on-street parking, proper use and placement of signs and lane markings, separate left-turn phasing, flatter roadside slopes, and improved design of guardrail and horizontal curves. Bus-related safety measures include interior and seat design that minimize the effects of passenger impact against interior surfaces, and consistent riser heights and tread widths in stepwells. Passenger safety outside the bus can be improved by having bus stops on the far side of intersections and adequate passenger loading areas. Also important are appropriate transit agency policies and practices and organized safety and security reporting to allow for better identification of problem sites.

EXECUTIVE SUMMARY

In 1990, an estimated 64,000 buses of all types were involved in motor vehicle crashes in the United States. Thirty-two bus occupants were killed in these crashes (less than 0.1 percent of all motor vehicle accident fatalities) and approximately 35,000 people were injured (1.1 percent of all injuries). Bus crashes are associated with roughly 100 deaths to non-occupants (i.e., largely pedestrians and bicyclists) and 200 deaths to occupants of other vehicles each year.[1]

The objectives of the study documented in this report were to quantify and characterize the bus accident problem. In addition, the study was to recommend countermeasures for the predominant accident types and causes. School bus accidents were excluded for the purposes of this study.

The primary study file was from the Highway Safety Information System (HSIS) data base. The file contained information on a total of 8,897 crashes involving one or more commercial buses for the years 1985 through 1989 (the primary study file). These crashes were distributed among five states, exhibiting a variety of geographic, environmental, climate and roadway features: 43.0 percent were from Illinois, 24.3 percent were from Michigan, 22.6 percent were from Minnesota, 5.9 percent were from Utah, and 4.2 percent were from Maine. A subset of 5,283 crashes identified as having occurred on urban roadways in Illinois, Michigan, Minnesota, and Utah was also analyzed. Nearly two-thirds (63.6%) of the urban crashes occurred in Illinois. The study also examined the entire Illinois accident file for the years 1988 and 1989, containing more than 620,000 vehicle crash involvements (including 1,500 commercial buses).

The data were examined for characteristics related to bus crashes that could be used in identifying important problems and appropriate countermeasures. Most bus crashes (70.8%) in the primary study file involved property damage only, while 28.5 percent resulted in non-fatal injuries and 0.7 percent caused fatalities. The pattern for urban crashes was similar, with 0.5 percent fatal and 28.3 percent non-fatal injuries. From the Illinois data, crashes involving buses were about equally as likely as those involving cars/pickups to result in a fatality. However, crashes involving buses were slightly less likely to result in other non-fatal injury. Truck crashes were twice as likely as crashes involving other vehicles to result in a fatality.

Approximately equal numbers of bus crashes were reported in each of the five years, 1985 to 1989. Both overall and injury crashes were lowest during July and August, likely reflecting fewer bus trips and reduced ridership. The overall number of crashes was greatest in January and February, but winter crashes were less likely to result in injury compared to other reasons. The highest percentages of crashes involving injury occurred in April and May. Bus crashes were least likely to occur on weekends, perhaps due to reduced exposure. Although the highest overall number of crashes occurred on Fridays, bus injury crashes were most likely to occur on Tuesdays (as was also the case for other vehicle types on the Illinois file). The frequency of urban bus crashes by time of day generally followed travel patterns, with the peak accident rate during the afternoon rush hours. Nighttime bus crashes tended to be more severe - nearly 40 percent of crashes occurring between 9 p.m. and 3 a.m. resulted in injury.

Four-fifths of urban bus crashes occurred during daylight hours, due to the significant travel during that time. One-third of the nighttime bus crashes on lighted streets resulted in injuries or fatalities, compared with one-fourth of the nighttime bus crashes on streets without lights. This difference may be due to the greater use of lighting on arterial routes (where higher travel speeds result in more severe crashes), compared to lower-speed collector or local streets. Almost two-thirds of all bus crashes occurred on dry pavement. Injury and fatal crashes were more common on wet roads than on dry roads or on snow and ice. The presence of efficient snow removal procedures, or added driver caution, could account for the lower accident percentages for snowy/icy roads.

An analysis of bus crashes in urban areas in four states showed that older buses had higher percentages of injury and fatal crashes than newer buses. Another analysis, with Illinois and Michigan data, accounted for relative exposure to accident risk and demonstrated that buses built before 1975 were more likely to be involved in repeated crashes than buses built after 1984.

Fewer bus drivers than passengers are injured in crashes. No cases were reported in which the driver was injured while the passengers were not. Reasons for the discrepancies between the number of driver and passenger injuries include the facts that buses usually have multiple passengers but only one driver on board. Also, compared to the bus driver, the passengers

are not as well protected with safety belts and seat padding, many passengers are more frail, and passengers may have a greater incentive in possible legal action to claiming injuries. While bus driver age was not related to accident involvement, drivers between 36 and 45 years of age were overrepresented in injury and fatal crashes. These drivers may drive more demanding routes and carry more passengers.

The results of innocent victim analysis performed on urban crash data from Illinois and Michigan revealed that bus driver gender was not related to crash involvement or crash severity. In Utah, the only state to record data on the driving experience of bus drivers, no relationship was found between driving experience and involvement in injury and fatal accidents. The bus driver's physical condition proved to be a very minor factor in explaining accidents, as 97 percent of the drivers were reported by the investigating police officer to be in "normal" condition. The bus driver was reported to have been drinking (alcoholic beverages) in only 14 of 5,861 accidents (less than one-fourth of one percent). By comparison, the two-year Illinois file indicated that about three percent of car and pickup drivers involved in crashes were reported to have been drinking.

There was no traffic control (such as a traffic signal or a sign) in about 46 percent of the cases listed in the primary study file. Bus crashes at traffic signals were more likely to cause injuries and fatalities than those at stop signs or at locations without any traffic control. Nearly 45 percent of urban bus crashes took place on straight roads. In the small sample of cases that enabled distinction between straight and curved road crashes, injuries and fatalities were more likely on straight roads. From the Illinois data, roughly 45 percent of commercial bus, car/pickup, and school bus accidents happened at intersections, but only one-third of truck accidents occurred at intersections.

Accident type variables revealed patterns of accidents and helped lead to suggested countermeasures. In Illinois, the most common bus accident types were rear-end with one vehicle stopped (probably the bus in most cases), sideswipe same-direction, and turning. Commercial bus accidents are more often sideswipe/same direction accidents and less often rear-end both moving accidents as compared to accidents involving other vehicles. Rear-end and angle accidents were most likely to cause injuries and fatalities compared to other accident types. Single-vehicle, fixed-object, or overturn accidents

involving buses rarely occurred and resulted in a relatively low percentage of injuries. Single-vehicle accidents on urban streets tend to occur at night, in the snow and ice, and during right turns more often than multiple-vehicle accidents.

Pedestrians were involved in 189 of the 8,897 commercial bus crashes in the HSIS data base. Some of these bus-pedestrian crashes may occur when individuals waiting at a bus stop are struck by an approaching bus or when alighting individuals are struck by a departing bus. Although bus-pedestrian crashes were infrequent, they almost always (98.4%) resulted in injuries or fatalities, with 13 crashes (6.9%) being fatal. In multi-vehicle collisions, buses were more likely to be struck than to strike another vehicle. On urban streets in Illinois, angle accidents and rear-end accidents were overrepresented on snowy/icy roads. Angle accidents were overrepresented at nighttime, and rear-end accidents with one vehicle stopped were overrepresented during morning peak hours.

Many bus-related injuries do not involve crashes with other vehicles, pedestrians, or fixed objects. Common examples of these "non-collision accidents" are passenger falls occurring during boarding and alighting (i.e., exiting) and falls due to sudden acceleration and deceleration while standing on board a moving bus. Bus stop location and walking surface conditions at the stop are among the factors likely contributing to passenger accidents at bus stops.

Detailed passenger injury data were collected for more than 5,000 passenger injuries from the Washington, D.C. Metropolitan Area Transit Authority (WMATA) between July 1984 through January 1991. For that city, the passenger injury rate fell by one-third between 1976 and 1990. Roughly one-third of all passenger injuries occurred during boarding and alighting, and another one-fourth occurred during stopping. Forty-five percent of the injuries on stopping buses took place as passengers were getting up, sitting down, or while seated. One-third of the alighting injuries happened when passengers tripped or slipped.

Based on the identified characteristics of bus crashes and passenger injuries, a number of potential roadway improvements and other measures may be implemented to reduce the probability and/or severity of bus crashes. Possible roadway design changes such as wider travel lanes along bus routes, bus pull-off lanes, wider intersection turning radii, separate turning lanes

and the elimination of on-street parking along routes can help reduce the frequency of sideswipe and rear-end collisions. Other improvements such as the proper use and placement of signs and lane markings, larger traffic signal lenses, longer signal clearance intervals, and separate left-turn phasing can reduce the number of intersection crashes. Run-off-road collision frequency and severity can be mitigated through safe guardrail (and other roadside hardware) design, prompt snow and ice removal, adequate nighttime lighting, flatter slopes, adequate clear zones, and improved horizontal curve design.

To improve passenger safety outside the bus, bus stops should be at the far side of an intersection, provide good walking surfaces, be free from tripping hazards, and offer adequate loading areas. Far-side bus stops allow alighting passengers to cross behind the bus where they can be seen more easily by approaching drivers. The far-sided stops also reduce bus conflicts with right-turning vehicles. The loading area should accommodate passenger queues and wheelchair loading and unloading as well as normal pedestrian traffic. Bus shelters should not infringe upon the space for passenger waiting, boarding and unloading, and other nearby pedestrian activities.

For both collisions and on-board falls, good interior design will prevent injuries in some cases and reduce their severity in other cases. The adverse effects of passenger impacts against interior surfaces can be minimized by manufacturers' avoidance of the use of equipment with sharp edges or protrusions that passengers may bump into and materials that shatter upon impact. Seats, partitions, and railings should be securely mounted so that they do not become dislodged in a collision. Good seat design is especially important. Through structural design and the use of energy-absorbing padding, seats should be capable of distributing local impact forces to prevent serious passenger injury. The use of non-slip flooring materials, installation of level walking surfaces and routine maintenance of bus floors will also reduce the number and severity of slipping and tripping falls in buses.

Drivers should be trained to be aware of passenger motion hazards. On-board falls may be prevented by drivers' encouraging passengers to sit whenever possible and by their instructing standing passengers to use hand-holds. To reduce the occurrence of boarding and alighting falls in stepwells, riser heights and tread widths must be consistent within any stepwell. Riser heights should be between 6 and 8 inches and effective tread width, between 11 and 12 inches. Treads should be well-lighted and have slip-resistant

surfaces. Handrails should be reachable and graspable. Both the "Kneeling Bus" and the "Low Floor Bus" were developed to lower bus floor heights above the ground, thus facilitating safe boarding and alighting.

Some collisions may be avoided by properly screening and training bus drivers. In addition, the performance of drivers should be continually monitored and evaluated, with remedial training or disciplinary action as warranted.

A number of transit agency policies and practices can help minimize the likelihood of collisions and/or passenger injuries. These included well-planned bus routing to lower accident exposure, equipment and facility inspections, safety instruction, and accident reporting and investigation. Ideally, specific departments or individuals within transit agencies should be assigned the responsibility and authority for implementing, performing, and monitoring these activities.

An organized safety and security reporting program is important for bus transit carriers to monitor the number and types of incidents occurring on the system. Such information can provide insight into the potential causes of these incidents and appropriate countermeasures. Moreover, transit agencies and highway safety engineers need to identify intersections and roadway segments where there are clusters of bus crashes and then undertake appropriate remedial action.

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CHAPTER 1. INTRODUCTION

Crashes and injuries related to buses represent a safety problem on U.S. highways deserving of further study. For example, in 1990, an estimated 64,000 of the 627,000 registered buses nationwide were involved in crashes for a rate of 10.2%. By comparison, only 5.8% of other types of vehicles were involved in crashes.[1] The higher involvement rate of buses results from greater exposure to potential accident situations - stop-and-start operation and more encounters with other vehicles.

Bus crashes also take a substantial toll of injuries and deaths. In 1990, an estimated 35,000 bus occupants sustained minor or moderate injuries in highway crashes. Another 3,000 sustained serious injury,[1] including 32 deaths to bus occupants. In addition, bus crashes are associated with approximately 100 deaths to non-occupants (i.e., largely pedestrians and bicyclists) and 200 deaths to occupants of other vehicles per year, according to the Fatal Accident Reporting System (FARS).[2]

The purpose of this study is first, to quantify the characteristics and causes of traffic crashes involving buses. It will focus on crashes involving non-school buses (i.e., crashes involving local transit and intercity/cross country buses), and their resulting injuries. It considers both bus crashes with other motor vehicles and bus run-off-road crashes (e.g., rollovers, striking poles, trees, and other fixed objects). A detailed analysis was conducted using computer accident files of police-reported bus crashes. These files contained information on 8,897 bus-related highway crashes in five states - Illinois, Maine, Michigan, Minnesota, and Utah for five years (i.e., from January 1, 1985 through December 31, 1989).

The second objective of the study is to review information related to non-collision passenger injuries. This aspect of the study involved a review of literature on the nature of injuries sustained by passengers as they ride, board, or exit (alight) the bus. Detailed passenger injury data from the Washington, D.C. Metropolitan Area Transit Authority (WMATA), covering more than 5,000 passenger injuries for July 1984 through January 1991, were analyzed.

The third objective of the study is to make recommendations for reducing bus-related highway crashes in addition to reducing on-board injuries to bus passengers. Such recommendations relate to highway improvements, modifications to bus design features, and bus driver training. The recommendations, based on the results of the analyses, are directed primarily to highway designers, engineers, and bus transit officials.

The information in this report should prove useful to a wide range of professionals. Transit managers should improve driver training programs as necessary and implement other practices to enhance safety. Designers can improve the crashworthiness of buses and create bus interiors that are less likely to injure passengers and exteriors that are less hostile to other vehicles as well as pedestrians. Transportation planners and engineers can implement roadway improvements to reduce the probability and severity of crashes and can locate and design bus stops for safer boarding and exiting.

CHAPTER 2. LITERATURE REVIEW - BUS CRASHES

Accident Types

For the purposes of this study, bus accidents are divided into collision accidents (also referred to as "crashes") and non-collision (on-board passenger injury) accidents. Collisions include crashes with other motor vehicles, bicycles, pedestrians, and fixed objects. Examples of non-collisions are passenger falls while boarding, alighting, or riding buses. This chapter and Appendix A discuss previous literature on collision accidents. Chapter 6 covers non-collision accidents.

As a general background, Dixon, Williams and Joubert discuss the injury-producing mechanisms for five types of collision accidents: head-on, rear-end, sideswipe, side impact, and rollover.[3] Head-on collisions encompass those that involve impact at the front of the vehicle causing the bus to decelerate (and where the direction of deceleration is toward the rear of the bus). Rear-end collisions usually involve another vehicle running into the back of the bus, causing the bus to accelerate. Contact with the bus described as a "glancing blow to the side" is a sideswipe collision. A side impact is characterized by lateral acceleration.

Of the five accident types, rollover accidents are the most likely to result in severe, life threatening passenger injury or death. A lack of occupant restraints (e.g., seat belts) results in uncontrolled body movement, and during rollover, passengers impact internal bus fittings and other passengers. Partial or complete passenger ejection through windows, doors, or other openings in the passenger compartment created by the collision may result in severe injuries. For all motor vehicle accidents, occupants who are ejected are four times more likely to suffer a serious or fatal injury than occupants who are not ejected.[1] Injuries may also occur through the collapse of a roof or wall into the passenger compartment.

Large-Scale Studies

A few studies have analyzed data bases related to bus crashes. These studies include information about the types of bus accidents, when and where they occurred, and injuries. The National Public Service Vehicles (PSV)

Accident Survey conducted in Great Britain found that 57 percent of passenger injuries were the result of falls and other incidents under normal conditions.[4] The remaining 43 percent of passenger injuries occurred as the result of collisions.

Accident report data from PACE, a suburban bus transit agency in metropolitan Chicago, for 1982 through 1984 were analyzed by Jovanis, et al.[5] Eighty-nine percent of the 1,800 accidents involved collisions with another vehicle or object; 11 percent involved non-collision passenger injuries while boarding, alighting, or moving about the bus. In metropolitan Chicago, most accidents resulted in property damage only, though 10 percent involved auto driver injuries and two percent involved bus driver injuries. For buses in motion, 40 percent of auto and bus driver injuries occurred due to an auto rear-ending a bus. For stationary buses, 80 percent of the auto occupant injuries occurred when the auto rear-ended the bus. Based upon these findings, the authors suggest that buses pose the greatest risk to auto occupants when the buses are stationary, such as when stopped behind other vehicles or when processing passengers.[5]

The number of collision accidents in the Chicago study was fairly evenly distributed throughout the year. Weather was a contributing factor but not a major factor, as 75 percent of the accidents occurred during clear weather on dry pavement. Bus accidents did not appear to be more prevalent relative to exposure during times of darkness. The number of accidents dropped during night hours, reflecting lower service frequency and lower levels of automobile traffic.[5]

The gender and age of bus drivers did not contribute to accident occurrence. However, the number of years of experience was found to be a contributing factor. Drivers with three to six years of experience at PACE were significantly overrepresented. While accident frequency by time of day generally followed congestion patterns, there were also smaller peaks at around 10 a.m. to 11 a.m. and at 2 p.m. These times correspond to driver shift changes. The number of accidents along a route was virtually linear with its mileage, and negatively correlated with vehicle headway and speed. The negative correlation between number of accidents and speed is most likely due to the higher number of stop signals on urbanized roadways leading to frequent stopping by buses and rear-ending by other vehicles.[5]

Details on large-scale studies in Great Britain, India, and Australia are given in Appendix A.

Accident Attributes

It is traditional to view the occurrence of a highway traffic accident as the result of the interaction of the driver, vehicle, roadway, and environment.[6] Driver factors may include: 1) nonadjustment to the driving conditions; 2) inattention; 3) following too closely; 4) fatigue; 5) driving under the influence of alcohol; 6) driving too fast for the range of vision and reaction time; and 7) faulty meeting and passing.[6]

Present vehicle configurations and rear vision devices create a blind area to the rear of vehicles. This problem is particularly severe with large vehicles such as vans, trucks, buses, and motor homes. In these vehicles, rear windows may be blocked or even non-existent, and conventional mirror systems cannot provide a clear rear field of view.[7]

Interior design affects the severity of collision accidents. In a collision, passengers and drivers may be thrown against a seat, a window, the entrance well, or the windshield. In more severe accidents, especially rollovers, occupants may be ejected, quite often resulting in serious or fatal injuries. The sides of the bus or the roof may be forced into the passengers' survival space, possibly leading to crushing injuries or entrapment.[5] Insufficient roadway and lane width, poor geometric design, high automobile volume, and parking can all increase accident risk by presenting opportunities for collisions and reducing opportunities for avoidance.[5]

Accidents Involving Fires

Thirteen passenger carrier (bus) accidents involving fire were reported to the Bureau of Motor Carrier Safety, Federal Highway Administration, in 1968.[8] Although the information contained in that report is now 25 years old, it was the only available report found on bus accidents with fire. The 13 cases in this report represented 0.58 percent of the 2,225 accidents reported by passenger carriers, but resulted in 17.36 percent of deaths, 2.23 percent of non-fatal injuries, and 4.13 percent of property damage for all passenger carrier accidents. It should be noted, however, that one accident with fire in 1968 resulted in 20 fatalities, 12 injuries, and $46,000 property damage. Even with this accident excluded, accidents with fire still represented 4.03 percent of fatalities, 1.95 percent of injuries, and 2.45 percent of property damage. This increased likelihood of injury in bus crashes involving fires likely reflects the more severe nature of these crashes and not just the effect of the fires *per se*.

Gaps in the Literature

This section has reviewed past research on the types, causes, and characteristics of commercial bus collisions. In addition, case studies summarized in Appendix A analyze selected crashes in detail to determine their causes and contributing factors and to develop recommendations.

Additional research is needed to fill a number of gaps that exist in the literature. For example, the available studies do not contain sufficient information on commercial bus-pedestrian accidents. The characteristics of bus accidents have not been adequately compared to the characteristics of accidents involving other vehicle types. Little information is available on the role of roadway, driver, or environmental features in bus accidents. Furthermore, except for boarding and alighting accidents, bus stop safety is not addressed. This study was intended to address some of the gaps.

CHAPTER 3. DATA SOURCES

The primary objective of this study was to quantify the causes and characteristics of commercial bus crashes for use in developing appropriate countermeasures. Commercial buses included all types of full-sized buses except school buses. Thus, the desired type of data was a large sample of motor-vehicle highway crashes involving one or more buses. Statewide computerized bus crash data from several states was considered adequate to provide for a wide variety of geographic, environmental climate, and roadway features.

The data base chosen for analysis in this study was the Highway Safety Information System (HSIS). This data base consists of computerized information related to motor vehicle crashes, traffic volume data, and roadway characteristics from five states: Michigan, Minnesota, Maine, Illinois, and Utah. The HSIS data were obtained from the respective states by the UNC Highway Safety Research Center through funding from the Federal Highway Administration. The HSIS states were chosen based on many factors, such as the availability of good quality data, the capabilities for merging various data files, and other factors. Although these states may not be representative of the entire United States, they have data on accidents occurring in both urban and rural areas, on different types of roads, under a variety of weather and lighting conditions, etc. Thus, the information obtained from these states was useful in achieving the primary study objective.

For this study, the statewide computer data bases on motor vehicle crashes were used. These data bases basically included information for each of the police-reported crashes in the state, and these were subsequently coded onto computer files for the five-year period of 1985 to 1989. For a majority of the analyses, the accident records of interest were all crashes involving any type of full-size bus, excluding school buses. A total of 8,897 of these bus accidents were found from the five states and used for further analyses. These bus crashes included 3,825 (43.0%) from Illinois (mostly from Chicago), 2,160 from Michigan (24.3%), 2,014 from Minnesota (22.6%), 526 from Utah (5.9%), and 372 from Maine (4.2%). The sample distribution of bus crashes by state is illustrated in figure 1.

The distribution of bus crashes by state from 1985 to 1989 is shown in figure 2. In general, bus accidents were greatest in Illinois, where they ranged from 819 in 1985 to 726 in 1989. Bus crashes also held relatively

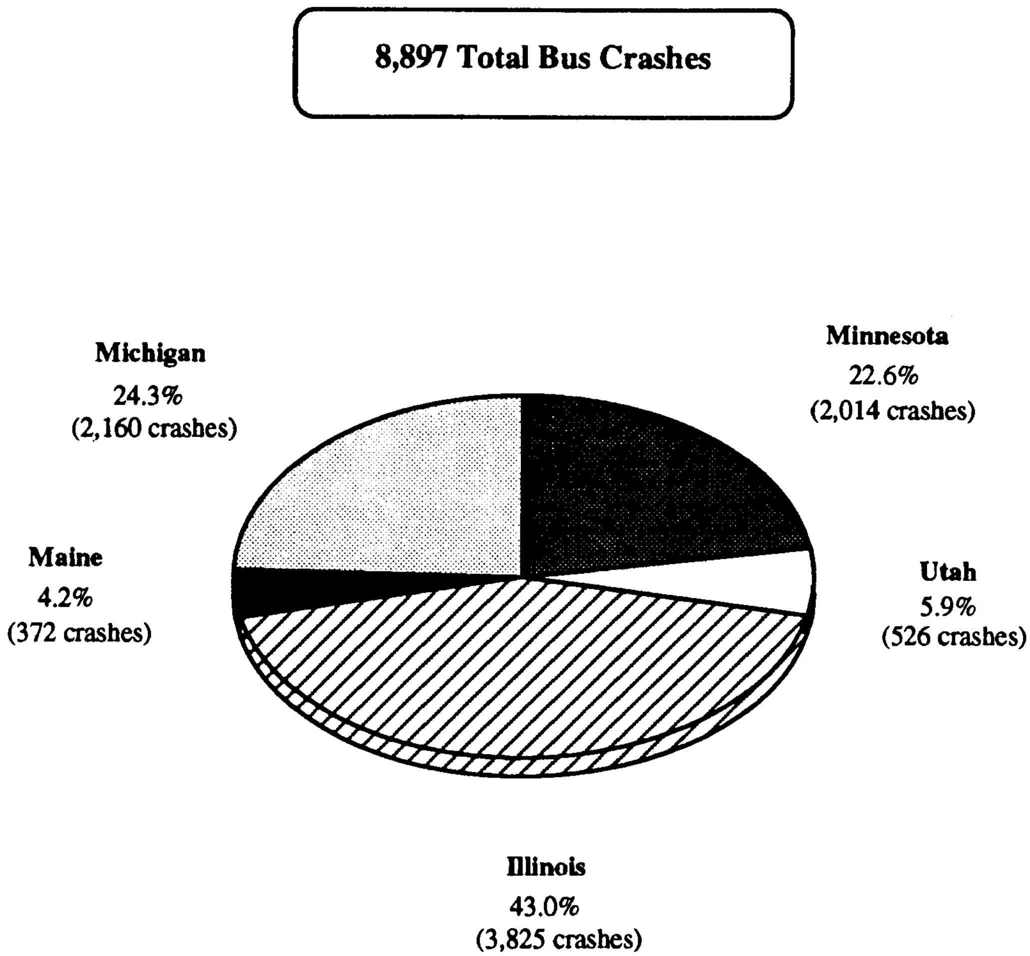


Figure 1. Distribution of bus crashes on the HSIS data file.

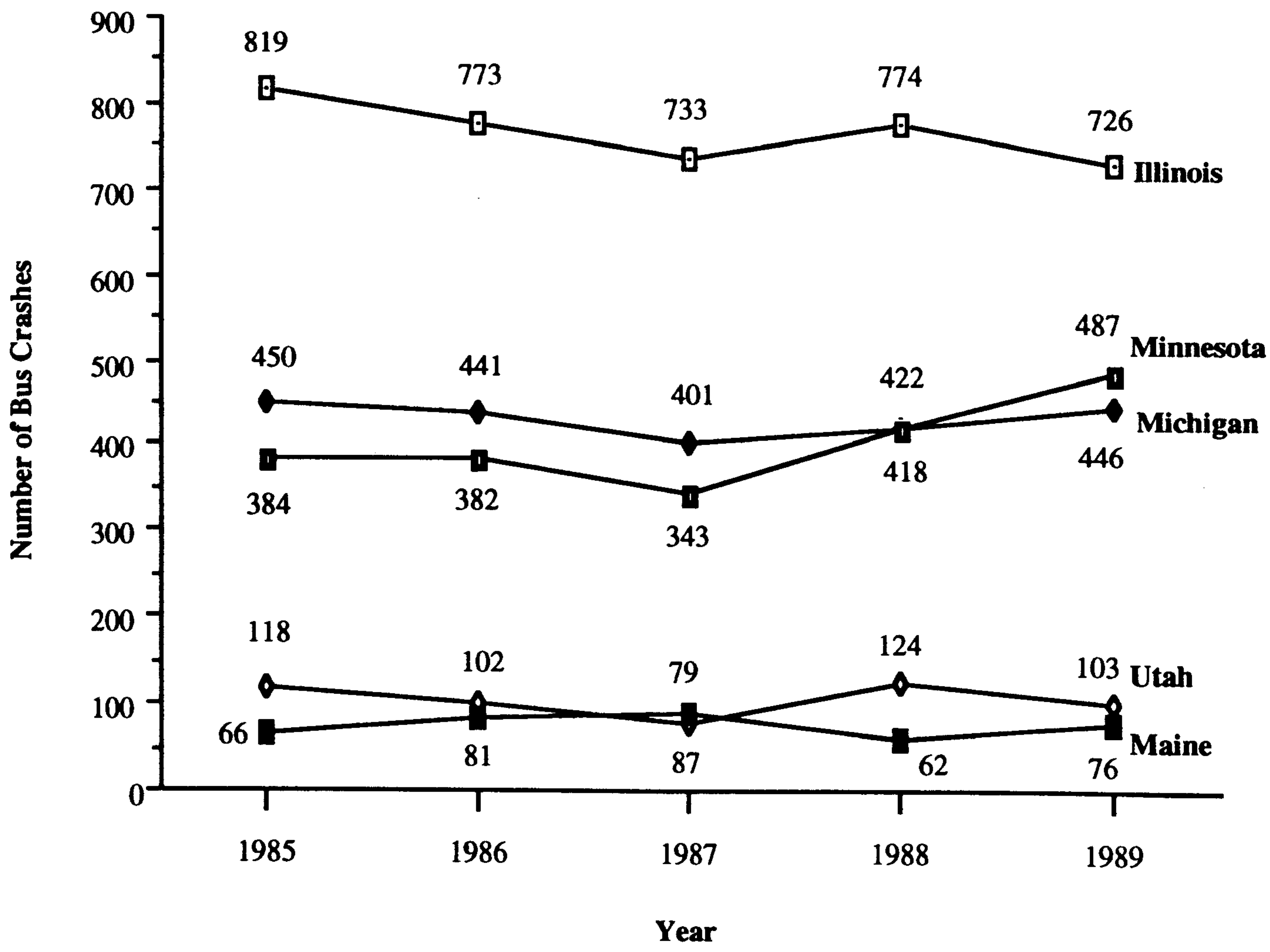


Figure 2. Number of bus crashes on HSIS data files by state and year.

steady in the other states as well, except for Minnesota, which experienced an increase from 343 in 1987 to 487 in 1989. A greater number of accidents in a state does not mean that buses are less safe in that state, since no measure of exposure, like buses registered or bus-miles driven, is available to normalize these data.

For each of the 8,897 bus accidents, pertinent information was available on the computer files related to when the crash occurred (i.e., time, day of week, month), environmental conditions (light and weather condition), vehicle information (e.g., age of bus), driver information (age, gender, injury), accident type (i.e., single-vehicle, sideswipe, turning accident, etc.), crash severity, and other information. Such variables were analyzed to gain a better understanding of factors related to bus crashes. Some of the analyses included all of these bus crashes, while only urban non-freeway bus accidents were used in other analyses.

For some types of analyses, there was a need to compare crash factors for buses with those of other vehicle types. For example, to determine the types of crashes in which buses were overrepresented (e.g., sideswipe crashes), it was necessary to compare the distribution of crash types for buses with that for cars and pickups, trucks, and school buses. Thus, all 620,000 vehicle crash involvements (bus as well as non-bus) from the Illinois accident file for the years 1988 and 1989 were analyzed. Comparisons were then made for bus crashes vs. other vehicle types by accident types and crash severity.

The second objective of this study was to quantify the types of non-collision events resulting in passenger injuries, such as passengers falling while boarding or when the bus stops abruptly. The HSIS data do not contain any information on non-collision accidents. A limited amount of passenger injury data was obtained from the Washington (DC) Metropolitan Area Transit Authority (WMATA), which supplied summary data for passenger injuries by year (1976-1990) and accident type (boarding, alighting, starting, stopping, running, other accidents, and miscellaneous). Since 1984, the number of passenger injuries has fluctuated around 2,000 per year. That agency also supplied more detailed passenger injury data, covering more than 5,000 on-board passenger injuries for July, 1984, through January, 1991, by fiscal year.

CHAPTER 4. ANALYSIS METHODS

Several methods were used to analyze the HSIS bus accident data. The most common analysis technique was a simple comparison among the levels of a particular variable. For example, the numbers of bus-involved accidents reported by day of the week were computed and compared. These simple comparisons were useful when the variable was not highly related to exposure. Many comparisons between the levels of a variable based on the percentage of severe accidents (i.e., accidents involving one or more fatalities or injuries) were also made. These comparisons did not depend on exposure and show the levels of the variable that deserve particular attention.

For a two-year sample of HSIS accident reports from Illinois, commercial bus-involved accidents were compared to truck-involved accidents, to school bus-involved accidents, to accidents involving only passenger cars, and to other accidents. These comparisons were made for several variables of interest. This sample included 1,500 bus-involved accidents and greater numbers of the other categories, so it was large enough to place confidence in the findings. Readers need to remember when considering these analyses that the categories were not strictly defined. For example, accidents involving a commercial bus and an auto were placed in the "commercial bus-involved" category along with accidents between two commercial buses. These definitions affect the analyses only slightly because the great majority of commercial bus-involved, school bus-involved, truck-involved, and other accidents also involved a passenger car.

While the computer accident files contained a large sample of bus crashes and dozens of variables of interest for each accident, one limitation of the analysis was that no bus "exposure" data were available. In particular, statewide bus mileage data were not available for computing overall bus accident rates (e.g., in terms of bus accidents per million vehicle miles of travel), or for computing accident rates by driver characteristic, age of bus, etc.

Thus, the driver age, driver sex, and bus model year variables were analyzed with the innocent victim technique. The innocent victim technique adjusts for the exposure of driver or vehicle-related groups using only accident data. The technique relies on the assumption that a group's (e.g., bus group's) exposure is related to the number of times the group's members are involved in crashes in which they are not the "at-fault" or striking vehicle and, thus are "innocent victims."

The best way to understand the innocent victim technique is to think through an example application. Suppose an analyst wants to know whether younger drivers are overrepresented in intersection-related crashes. The analyst computes that 20 percent of drivers involved in intersection-related crashes were under 25 years old. The analyst then computes that 15 percent of the innocent victims of crashes at intersections were under 25 years old. The ratio of the two percentages provides an indication of overrepresentation. Since the percentage of younger drivers involved in all intersection-related accidents is higher than the percentage of younger innocent victims, the analyst concludes that younger drivers are overrepresented. The innocent victim technique has been used by researchers in accident studies for more than 20 years. Readers interested in a review of the theory and applications of the technique should refer to Bowman and Hummer.[9]

The innocent victim technique was used with data from Michigan and Illinois. The technique requires relatively large samples to be effective, and these states provided the largest samples of bus-related accidents among the five states. Innocent victims were defined using the best available variables and accident types in the two states. In Michigan, bus innocent victims were identified when the bus driver had "no hazardous action" coded and the other driver had some type of hazardous action coded. This is a very strong definition of an innocent victim. In Illinois, bus innocent victims were identified when a bus was struck in a rear-end collision.

Some analyses were performed for all bus-involved accidents in the five-state sample. However, these analyses include accidents involving <u>intercity</u> buses on rural highways, which probably have different characteristics than accidents involving <u>intracity</u> transit buses. Therefore, most detailed analyses were performed for bus-involved accidents on urban surface streets, using the best available definition in each state for those factors. When knowledge of the confidence in a finding was required, statistical tests such as the Chi-square test and the Z-test for proportions were performed.

The reader should remember that in accident analysis, many data elements may vary at the same time. For example, a difference in frequency or severity on lighted and unlighted streets may not be attributable to the lighting itself but to factors that affect the decision to which streets to install lighting. Such factors may include traffic volume, prevailing speed, geometry, number of lanes, or others. It may be concluded that some unspecified factor (or combination of factors) associated with lighting affects the number or severity of accidents. Much more effort may be needed in an analysis to separate the variables having the greatest effects on crash frequency or severity.

CHAPTER 5. RESULTS OF COLLISION ACCIDENT ANALYSIS

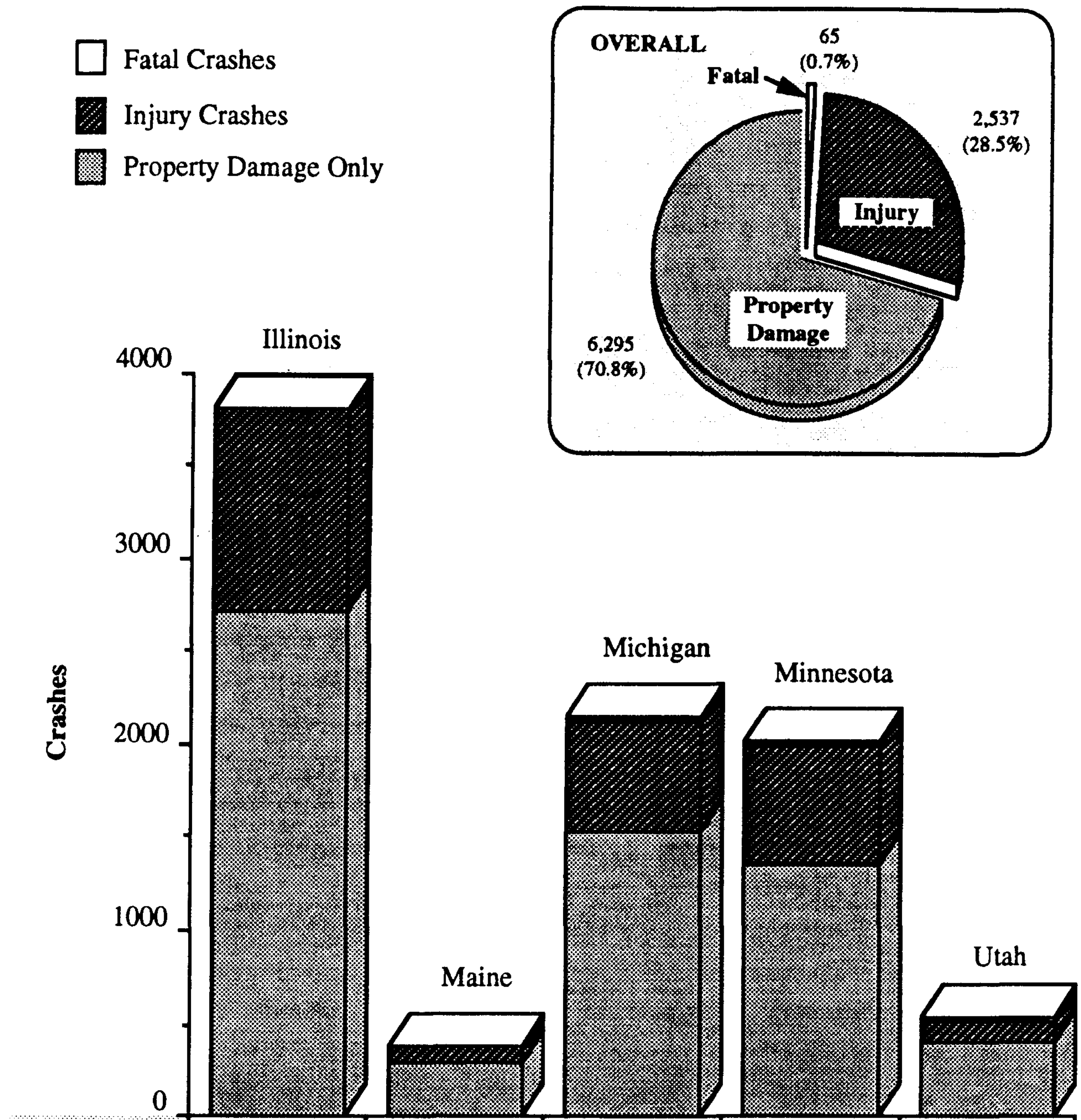
This section presents the results of the analysis of the HSIS bus crash data. As previously noted, analyses were carried out on both the full file of all reported bus crashes and the subset of crashes occurring on urban (non-freeway) roadways. Where differences resulted, they are noted in the text. Most results mentioned in the text are presented graphically. Tables corresponding to the graphs are included in Appendix B. Results of significance tests appear as footnotes to the tables.

General

A total of 8,897 crashes involving commercial buses was identified from the HSIS files. Figure 3 shows the distribution of bus crashes by severity of the crash for each of the five states included in the files. Overall, 0.7 percent (65) of the crashes resulted in fatal injury, 28.5 percent (2,537) in non-fatal injury, and 70.8 percent (6,295) in property damage alone. For fatal and injury crashes combined, Minnesota was highest with 32.7 percent, and Maine lowest with 22.6 percent. For this study, a "serious" bus crash was defined as one which resulted in at least one injury or fatality.

Of the total 8,897 crashes, 5,283, or 59.4 percent, were identified as urban crashes (i.e., occurring on urban surface streets). These urban bus crashes had a severity pattern very similar to the overall sample, with 0.5 percent resulting in fatal and 28.3 percent in non-fatal injuries. As shown in figure 4, the majority of the urban bus crashes on the HSIS file occurred in Illinois (63.6%), with smaller percentages in Minnesota (16.1%), Michigan (15.7%), and Utah (4.6%). The available HSIS data for Maine did not permit the identification of urban crashes in that state.

Given the large percentage of urban commercial bus crashes contributed by Illinois to the HSIS file, a separate analysis was carried out on the Illinois data comparing bus crashes with other crash types. Commercial bus crashes represented less than one-fourth of one percent of all crashes occurring in Illinois in 1988 to 1989 (see figure 5). In comparison, cars and pickup trucks were involved in 87.2 percent of crashes, and large trucks in 6.2 percent. Commercial bus fatalities also represented only one-fourth of one percent of the total 2,878 crash fatalities occurring during this two-year



	Illinois	Maine	Michigan	Minnesota	Utah
Fatal Crashes	**23 (0.6%)**	**1 (0.3%)**	**18 (0.8%)**	**17 (0.8%)**	**6 (1.1%)**
Injury Crashes	**1,081 (28.3%)**	**83 (22.3%)**	**601 (27.8%)**	**642 (31.9%)**	**130 (24.7%)**
Prop. Damage Only Crashes	**2,721 (71.1%)**	**288 (77.4%)**	**1,541 (71.3%)**	**1,355 (67.3%)**	**390 (74.1%)**
Total	**3,825**	**372**	**2,160**	**2,014**	**526**

Figure 3. Distribution of bus crashes on HSIS file by state.

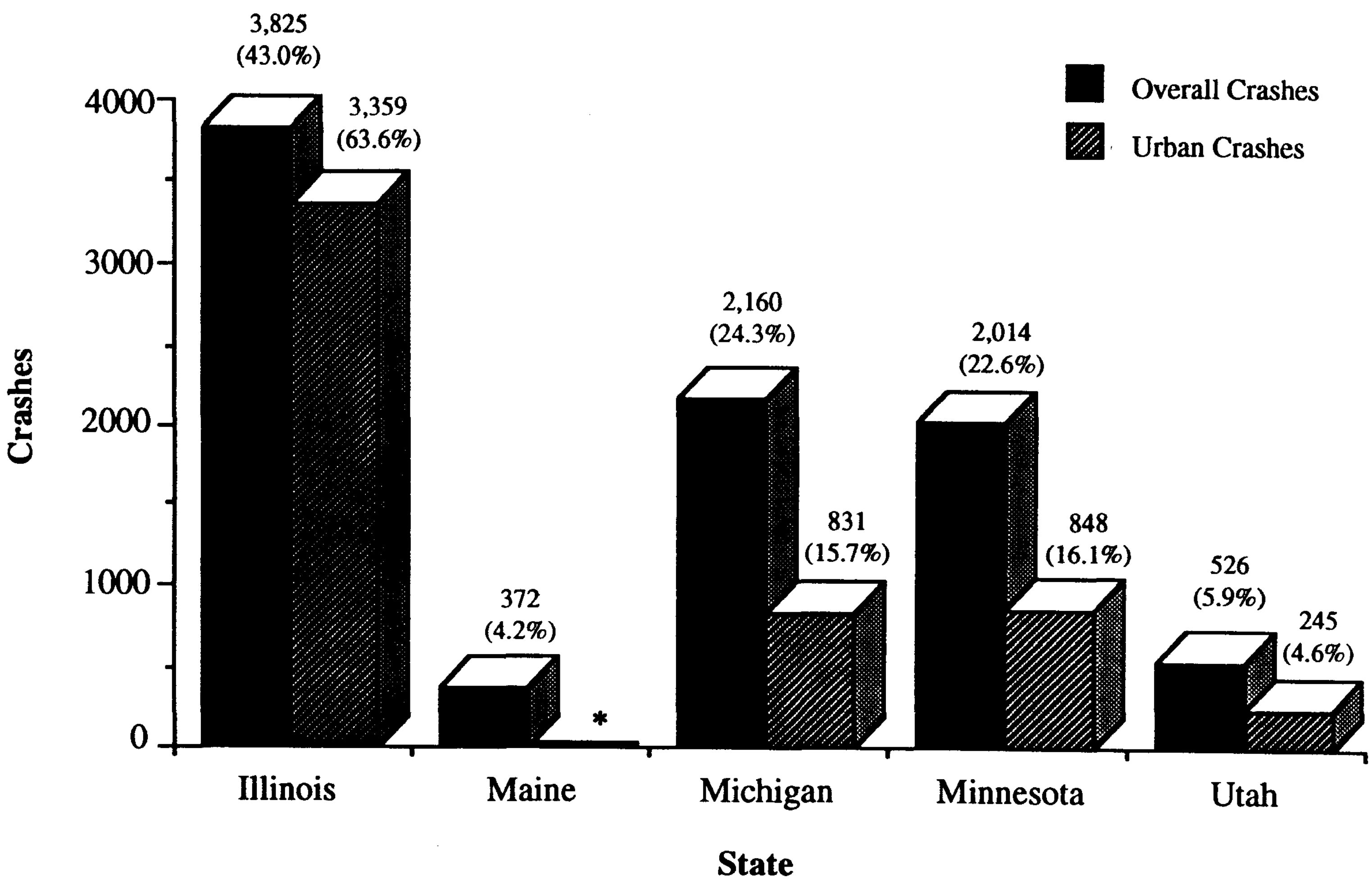


Figure 4. Number of bus crashes on HSIS file by state, both overall and urban.

* Note: The available HSIS data for Maine did not permit the identification of urban crashes in that state.

Illinois Motor Vehicle Crashes
1988-1989

	Number	Percent
Car, Pickup	541,660	87.2%
Commercial Bus	1,500	0.2%
Truck	38,599	6.2%
School Bus	1,253	0.2%
Other	39,438	6.2%

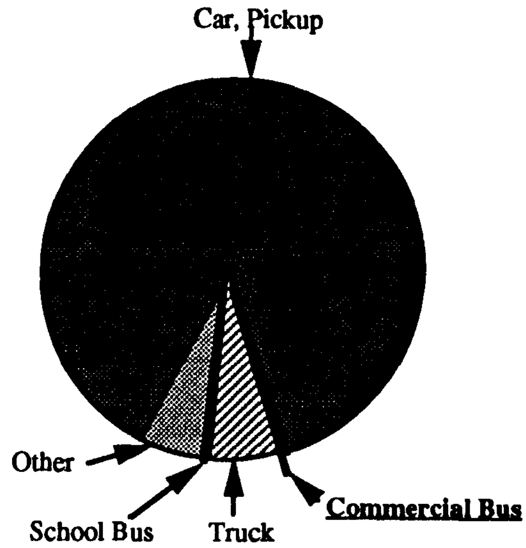


Figure 5. Distribution of 1988-1989 Illinois crashes by vehicle type.

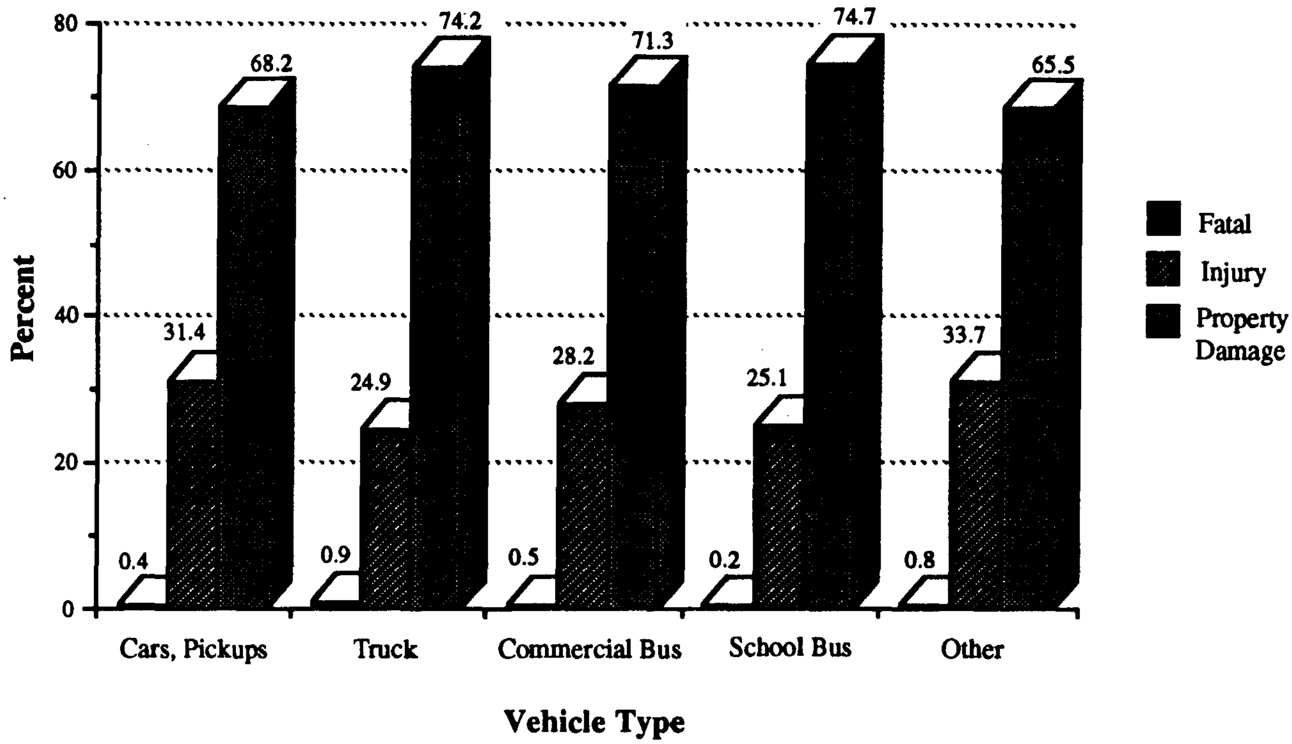


Figure 6. Distribution of 1988-1989 Illinois crashes by vehicle type and crash severity.

Note: "Other" includes vans, farm equipment, motorcycles and vehicles coded as "other".

period. Compared to car and pickup truck crashes, bus accidents are about equally likely to result in a fatality, or injury (figure 6). Truck crashes and events involving pedestrians, motorcycles, and other vehicle types were found to have the highest fatality rates.

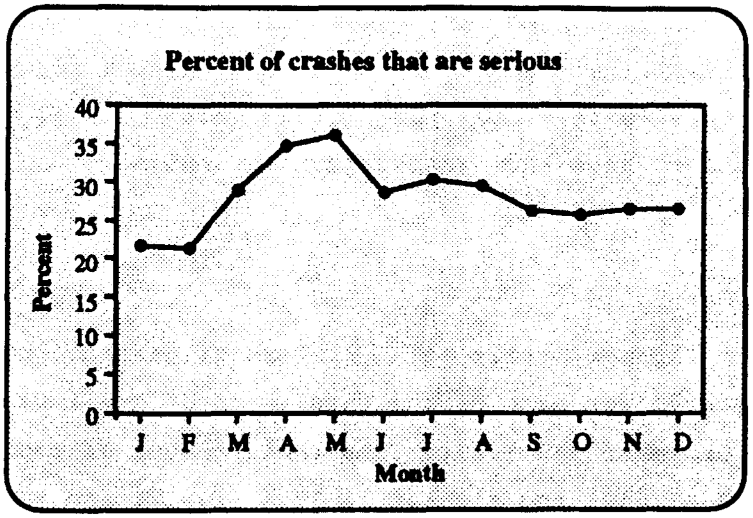
Temporal

Approximately equal numbers of crashes involving commercial buses were reported for each of the five years of available HSIS data (January 1, 1985, to December 31, 1989). The total number of reported crashes was lowest in 1987 (1,643) and highest in 1985 (1,837) and 1989 (1,838). The number of injury crashes ranged from a low of 499 in 1987 to a high of 568 in 1985. Overall, 29.2 percent of the crashes resulted in injury, with some evidence of a decline in this percentage over the five-year period.

The month of the year when bus crashes occurred is shown in figure 7. Both overall and injury crashes were lowest in the months of July and August, likely reflecting the reduced number of bus trips and reduced ridership typical during this time. While the overall number of crashes is greatest in January and February, these winter month crashes are less likely to involve injury compared to some other months. April and May have the highest percentages of crashes involving injury.

Information on the day of the week when bus crashes occur is depicted in figure 8, based on urban crashes only. As expected, the percentage of crashes occurring on weekends (Saturday and Sunday) is lower than on weekdays. The distribution of injury crashes is similar to that of total crashes. A higher percentage of crashes occurs on Friday than on other weekdays ($p < 0.05$, signifying that the probability of more crashes occurring on Friday due to chance alone, and not because of actual differences in the distribution of crash frequencies by day of week, is less than five percent). However, these crashes are generally less likely to result in injury than some other days. The greatest number of injury crashes actually occurs on Tuesday.

The higher percentage of overall crashes occurring on Friday also held for other vehicle types examined in the two-year Illinois data file: 18.5 percent of crashes involving cars and pickup trucks occurred on a Friday, compared to 14.9 percent on Thursday, the next highest day of the week. For trucks, 18.9 percent occurred on Friday.



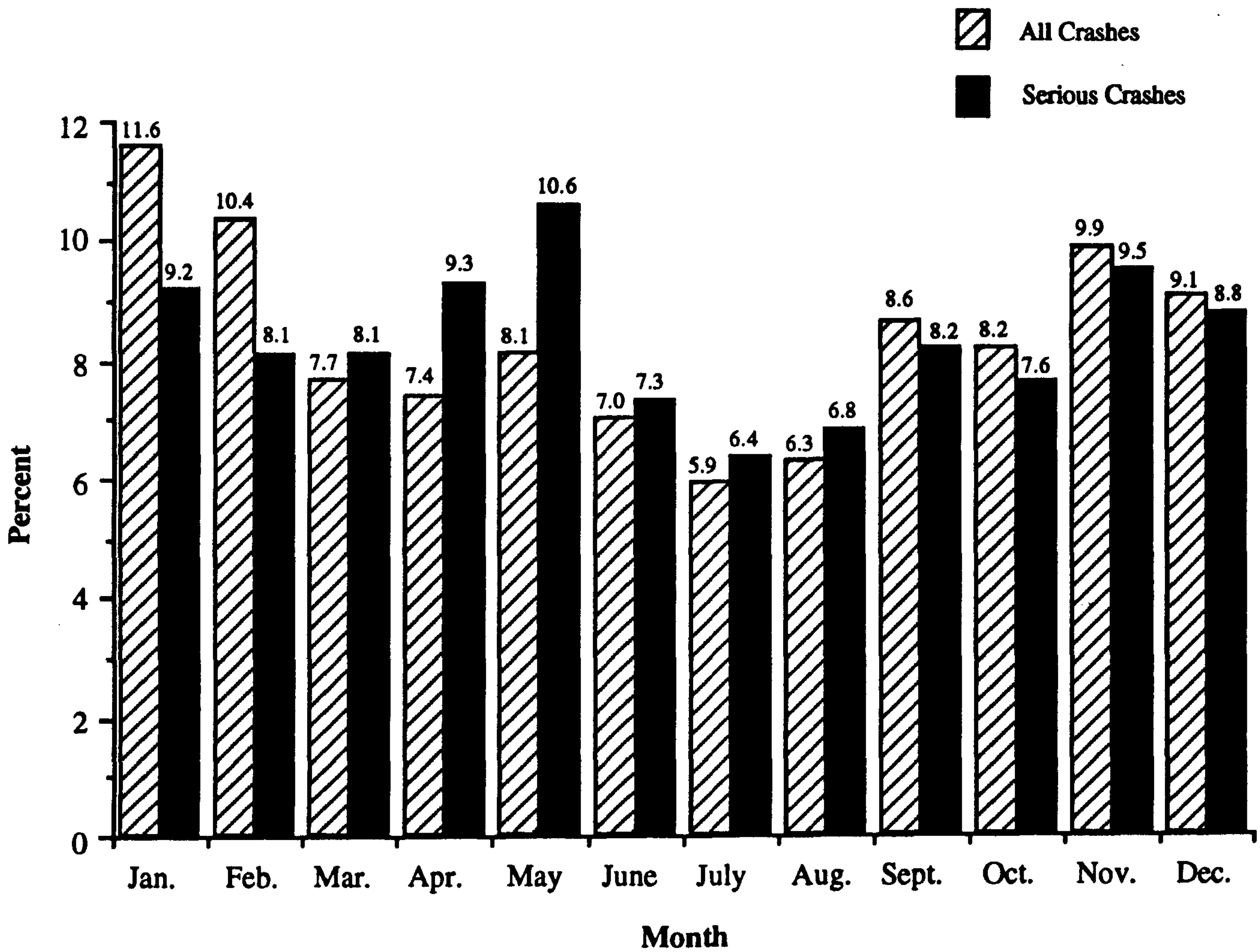


Figure 7. Distribution of bus crashes by month of the year.

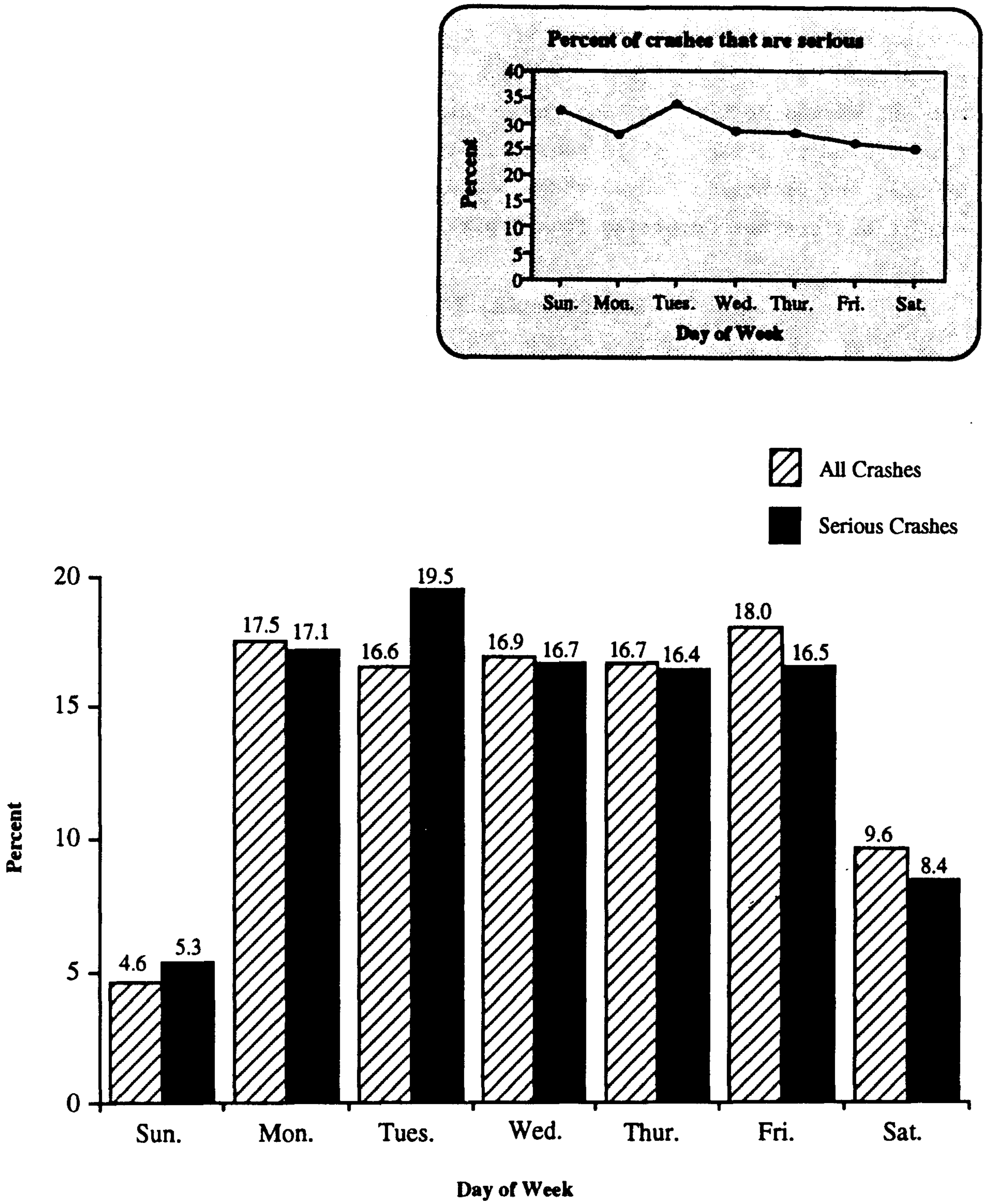


Figure 8. Distribution of urban bus crashes by day of the week.

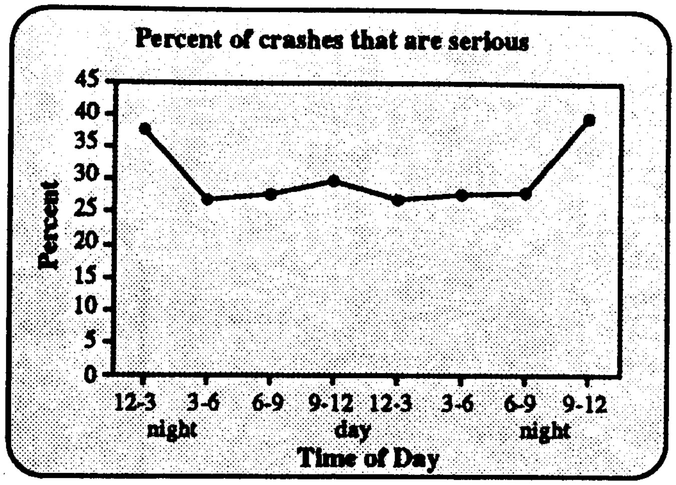
Frequency of urban bus crashes by <u>time of day</u> generally followed expected bus travel patterns (figure 9). Crashes were most common during the afternoon rush hours, from 3 p.m. to 6 p.m. (28.3% of the total). Another 56 percent of crashes occurred during the morning commute and midday hours, that is, from 6 a.m. to 3 p.m. While considerably fewer crashes occurred during the evening and nighttime hours, these tended to be more severe. Nearly 40 percent of bus crashes occurring from 9 p.m. to 3 a.m. resulted in injury.

Environmental Factors

Light Condition

An analysis of bus crashes by light condition on urban streets was conducted based on available data from Illinois, Minnesota, and Utah, as shown in figure 10. Accidents are most common during daylight hours (80.3%), due to the significant amount of bus travel during this time. Lower percentages of crashes occur after dark on lighted streets (12.3%), during dawn or dusk (4.9%), or in darkness with no street lights (2.5%). These percentages for urban crashes agreed closely with the total sample (rural as well as urban areas) of bus crashes. The two-year sample of Illinois data revealed that 78.7 percent of commercial bus accidents occurred during daylight hours, compared to 68.8 percent of car/pickup accidents and 92.9 percent of school bus accidents occurring in daylight.

Urban bus accidents occurring at night on lighted streets had a higher percentage of injury plus fatal accidents (33.8%) compared to those during daylight (28.3%), dawn/dusk (26.1%), or dark without lights (25.2%). These differences were significant at the 0.05 level. The higher severity of crashes at night on lighted roadways could be the result of the greater use of lighting on high-speed arterial routes, compared to lower-speed collector or local streets. Also, a different distribution of accident types may occur on lighted streets, compared to unlighted streets. For example, a greater percentage of run-off-road crashes and a smaller percentage of rear-end crashes may occur on lighted arterial streets than on unlighted collector streets.



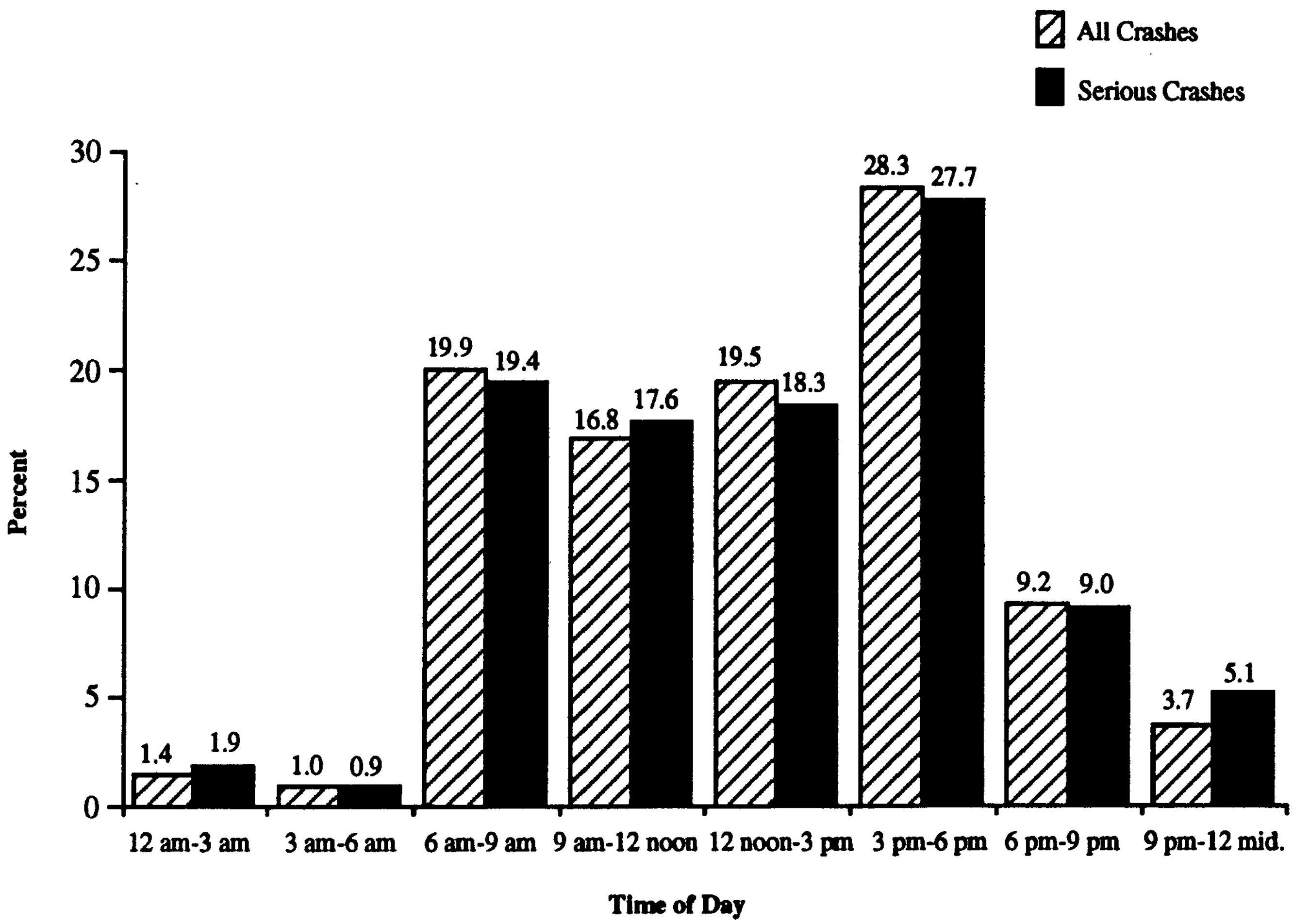
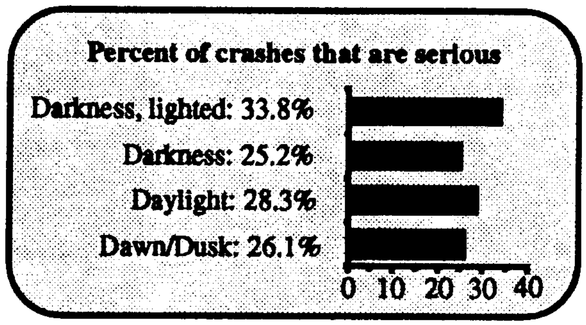


Figure 9. Distribution of urban bus crashes by time of day.



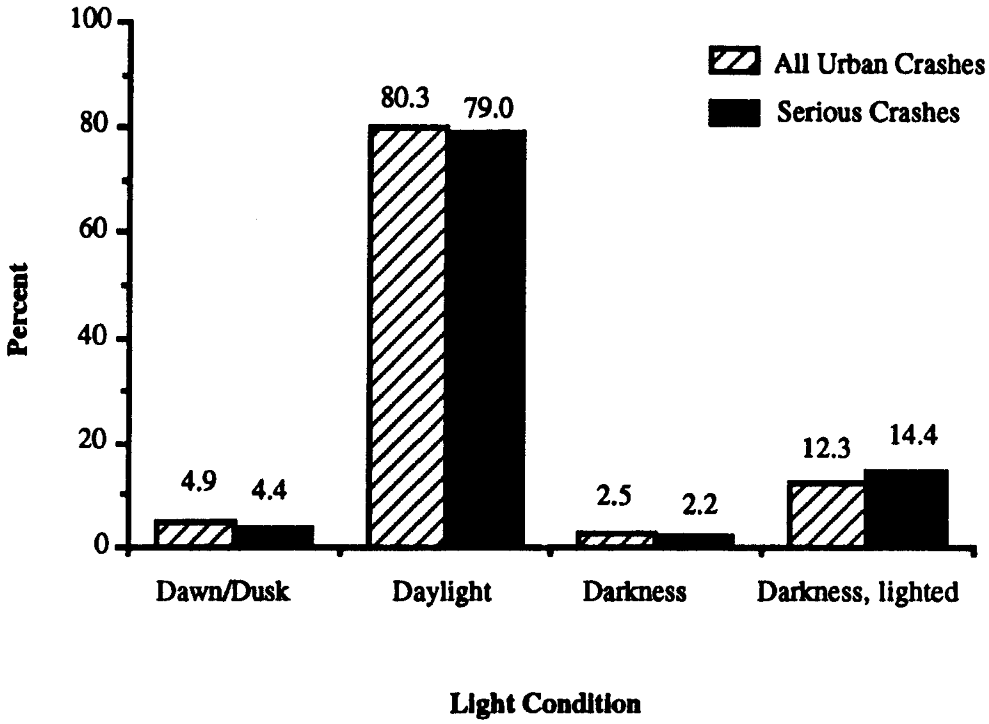


Figure 10. Distribution of urban bus crashes by light condition.

Weather/Road Conditions

Snow and ice occur in all five HSIS states. There are differences in the quantities and the length of time - northern Michigan has a larger total annual snowfall and has a longer snow season than southern Illinois. The efficiency of snow removal varies from one city to another. Arterial streets are often cleared before collector streets. Drivers in northern areas are likely to have more winter driving experience than those in other areas. Any combination of these factors could explain state and local differences in accident distribution by road condition.

Of the total bus accidents (urban plus rural areas), 64.8 percent occurred on dry pavement compared to 20.7 percent on wet pavement and 13.9 percent on snow and ice (see figure 11). On urban streets, accident percentages were slightly higher on dry pavement (66.2%) and wet pavement (22.9%), but were lower on ice and snow (10.6%). This lower percentage of urban crashes on ice and snow could be related to better snow removal and/or lower speeds in urban areas than in rural areas.

The injuries tended to be more severe on wet roads compared to other pavement conditions, with 32.2 percent of wet-road crashes resulting in injury or fatality. This compared to 28.9 percent injury or fatal crashes on dry roads and 26.4 percent on snowy/icy roads. Wet roads are associated with increased braking distances than dry roads, which can result in higher-speed impacts (all else being equal). The lower severity on snowy/icy roads could be the result of added driver caution, including reduced travel speeds.

Vehicle Factors

The primary vehicle factor available for analysis from the HSIS crash file was the model year. Model year was analyzed with simple comparisons and with the innocent victim technique. Figure 12 shows that buses built in 1975 through 1979 were involved in a higher percentage of reported accidents in the four states with available data than any other range of model year. This finding is most likely due to a larger number of these vehicles in service (greater exposure) than other categories. Figure 12 also shows that older buses were overrepresented in injury and fatal crashes. The injury and fatality rate was almost six percentage points lower for buses built after

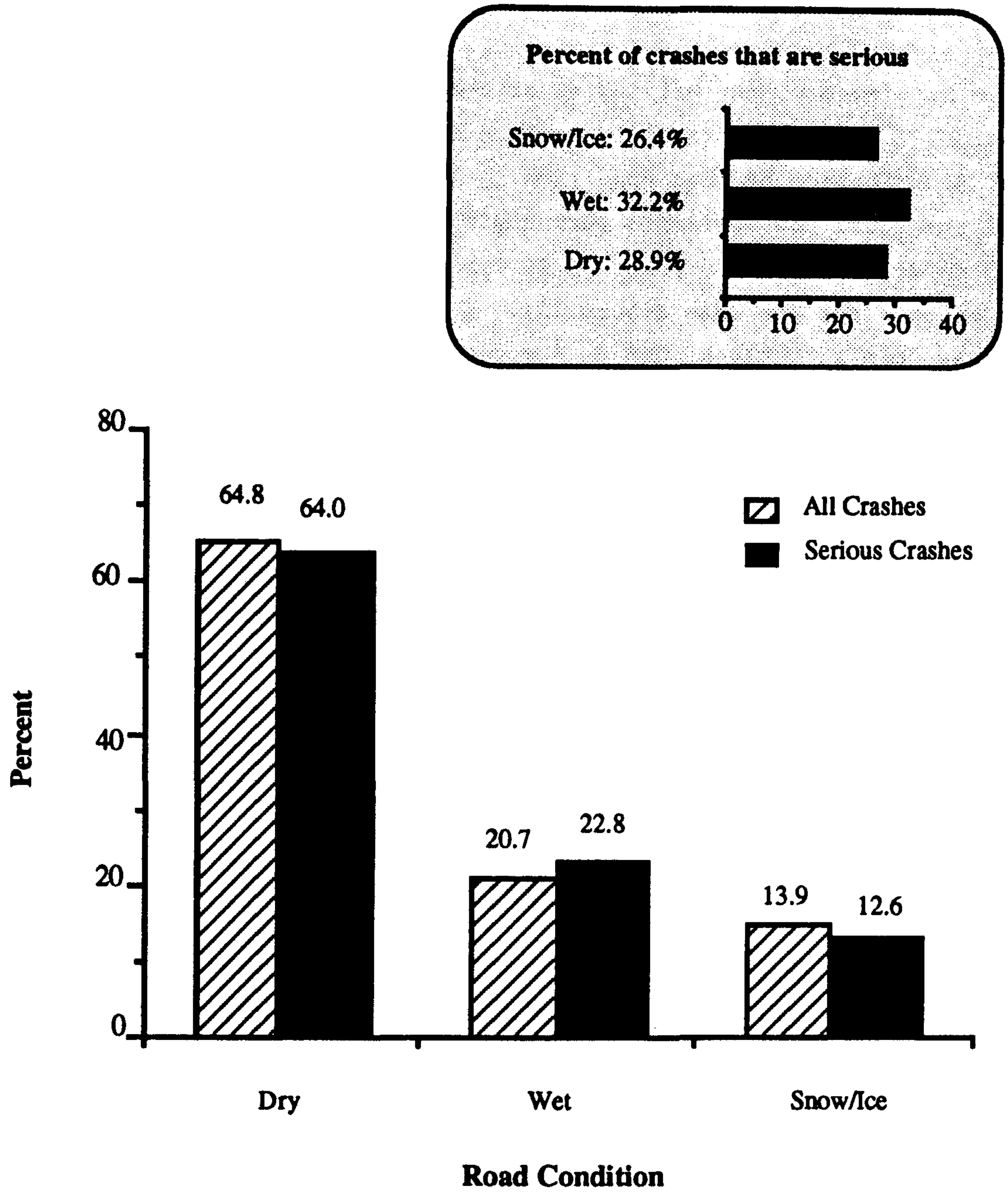
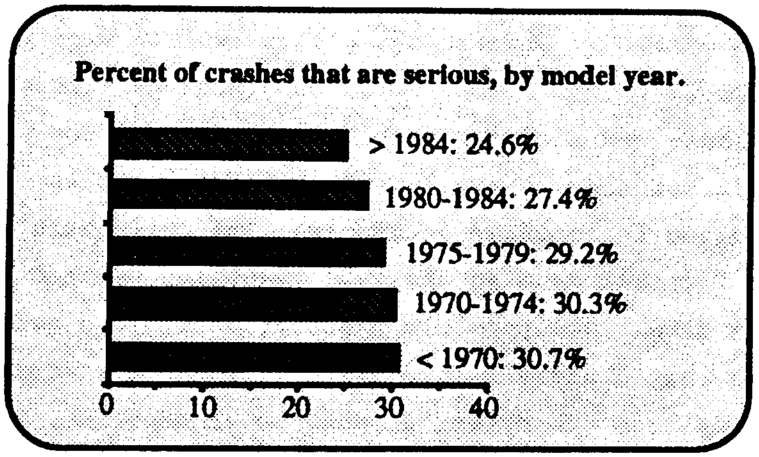


Figure 11. Distribution of urban and rural bus crashes by road condition.



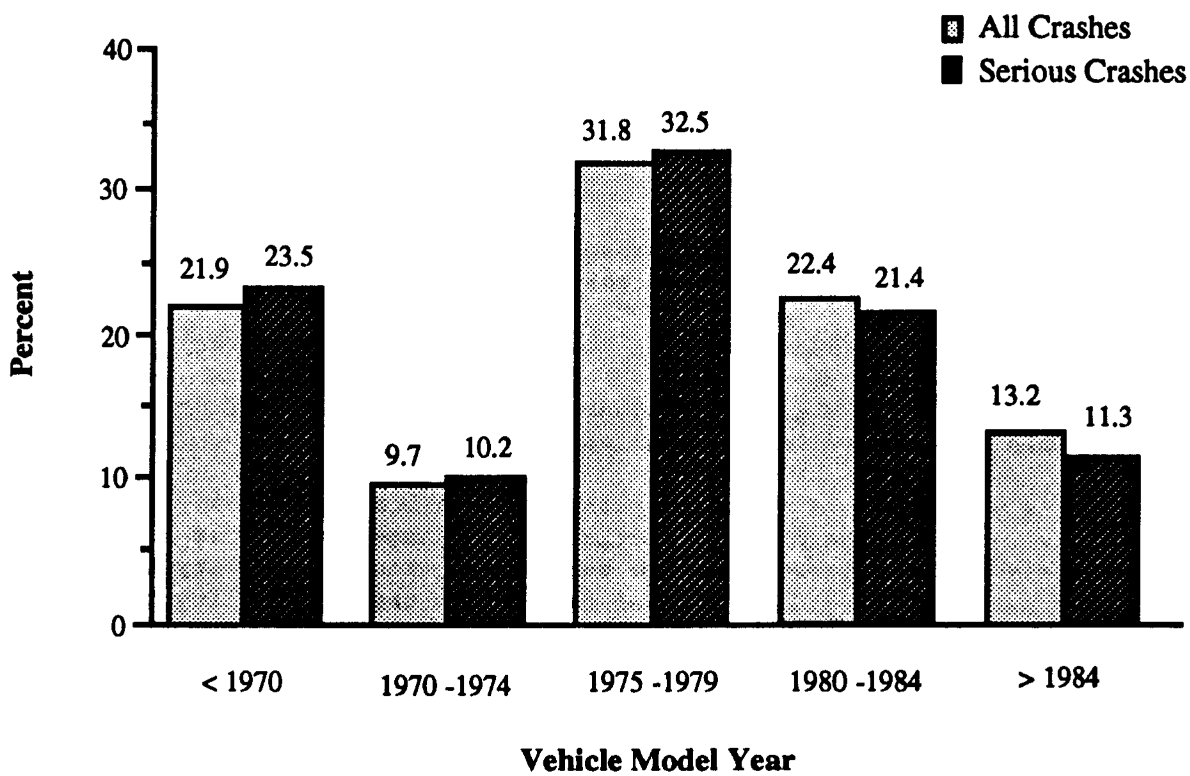


Figure 12. Distribution of urban crashes by vehicle model year.

Notes:
1. Data were not available for Maine.
2. Total percentages do not add to 100.0 because the figure does not show "unknown" model year.

1984 than for buses built before 1975, and the Chi-square statistic for this table was significant at the 0.05 level.

As mentioned previously, direct vehicle exposure data were not available to the project team. Therefore, the innocent victim data presented in table 1 for Illinois and Michigan were used to account for the relative exposure of the different model years. From these data, it is clear that older buses are overinvolved in reported accidents. The Chi-square statistic was significant for the Illinois data at the 0.01 level and reached the 0.10 level for the Michigan data. One possible explanation for the better performance of newer buses is that changes in bus design through the years, such as better visibility from the driver's seat, power steering, and improved brakes, have had a positive impact.

According to the accident data for Illinois, the bus driver appears much less prone to injury than the passengers. There were no reported cases where the driver was injured while passengers were not injured, but there were 245 cases where the driver was not injured and at least one passenger was injured. Data from Maine show a similar but less dramatic pattern. There are several possible explanations for this pattern, including:

- passengers are not as well protected with safety belts, padding, etc., as the bus driver,
- in general, passengers may be more frail than the driver,
- passengers have a greater incentive, in possible legal action, to claim injuries than bus drivers, and
- buses usually have multiple passengers on board (and only one driver). Thus, even if a particular passenger were less likely to be injured than the bus driver, the probability that any passenger would be injured may exceed the probability that the bus driver would be injured.

The relative safety of bus drivers is also demonstrated by the sample of two years of Illinois data comparing commercial buses to other vehicles. Crashes involving commercial buses resulted in driver injury six percent of the time, as compared to six percent for crashes involving school buses, seven percent for crashes involving trucks, and 17 percent for crashes that involved automobiles. Thus, the likelihood of driver injury is the least for drivers of buses, slightly higher for truck drivers, and considerably higher for drivers of automobiles.

Table 1. Bus crashes in Illinois and Michigan analyzed for model year using the innocent victim technique.

		Number of Accidents Where Bus Was Innocent Victim		Number of Other Accidents	
State	Vehicle Model Year	Observed	Expected	Observed	Expected
Illinois[1]	Prior to 1970	23	30	668	661
	1970-1974	13	18	398	393
	1975-1979	63	60	1292	1295
	1980-1984	31	37	806	800
	After 1984	38	23	493	508
Michigan[2]	Prior to 1970	25	31	33	27
	1970-1974	27	36	41	32
	1975-1979	303	298	256	261
	1980-1984	348	345	300	303
	After 1984	222	215	182	189

[1] $p = 0.01$

[2] $p = 0.10$

Driver Factors

Several driver-related factors were analyzed. Driver age was investigated through simple comparisons and through innocent victim techniques. In the full five-state sample, drivers near the age of 40 years were involved in many more reported crashes than other age groups. More than 30 percent of all reported bus crashes involved a bus driver aged 36 to 45. Of course, this finding may be due to greater number of bus drivers aged 36 to 45 years old group, and/or the high number of miles driven by this age group. When innocent victim techniques were used to account for exposure, a different pattern emerged. Table 2, with innocent victim results from Illinois and Michigan, shows that driver age was not related to accident involvement.

As figure 13 illustrates, drivers near the age of 40 were overrepresented in injury and fatal accidents, while drivers under 35 and over 65 were underrepresented. This finding, which was statistically significant at the 0.005 level, may be due to the route and schedule tendencies of the different driver groups. Younger and older drivers may drive less-demanding routes and/or schedules with fewer passengers.

Another driver age-related variable analyzed was "driver experience," which was recorded only in Utah. No statistically significant differences were found among groups with different amounts of driving experience in terms of involvement in injury and fatal accidents. Note that this variable was driving experience, and not bus driving experience: none of the five states recorded that factor.

The gender of the bus driver was investigated and proved to be unrelated to accident involvement. Male bus drivers were involved in almost 80 percent of the crashes in the four states where data were available (Maine did not report driver gender). To account for exposure, an innocent victim analysis was performed. Table 3 shows innocent victim results from Illinois and Michigan and reveals that gender was not significantly related to accident involvement at the 0.10 level in either state. In addition, figure 14 demonstrates that there was no statistically significant relationship between driver gender and accident severity at the 0.10 level.

The bus driver condition reported on the accident form proved to be a very minor factor in explaining accidents. Ninety-seven percent of all bus-involved accidents in the sample from Illinois, Maine, and Minnesota (where

Table 2. Bus crashes in Illinois and Michigan analyzed for bus driver age using the innocent victim technique.

State	Bus Driver Age (Years)	Number of Accidents where Bus Was Innocent Victim		Number of Other Accidents	
		Observed	Expected	Observed	Expected
Illinois[1]	Under 26	6	11	227	222
	26-35	44	41	855	858
	36-45	59	56	1178	1181
	46-55	37	36	756	757
	56-65	17	19	409	407
Michigan[2]	Under 26	65	78	82	69
	26-35	336	324	272	284
	36-45	322	317	272	277
	46-55	201	196	167	172
	56-65	80	86	82	76
	Over 65	16	19	19	16

[1] $p > 0.10$

[2] $p > 0.10$

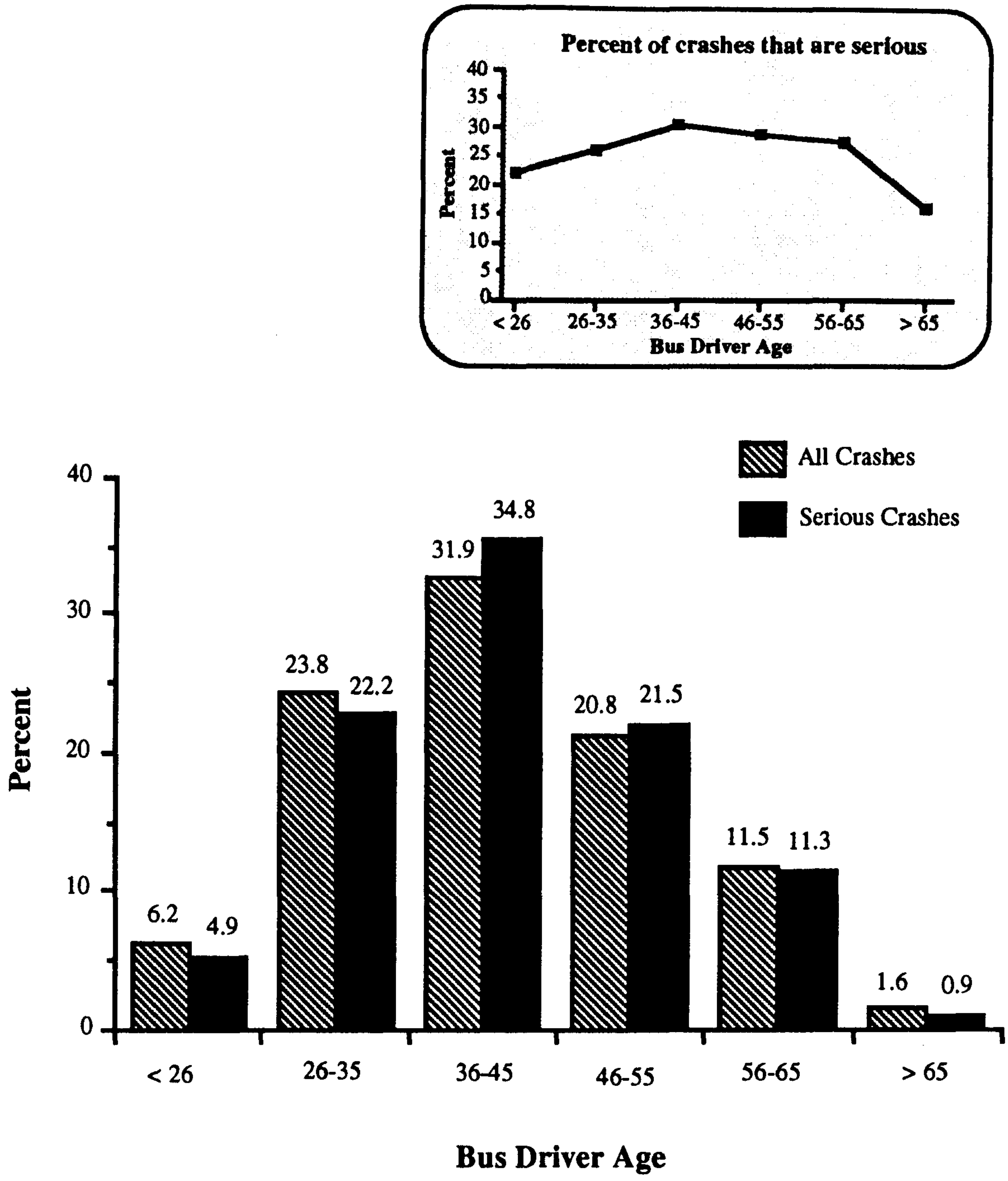


Figure 13. Distribution of urban bus crashes by bus driver age.

Note: Total percentages do not add to 100.0 because the figure does not show "unknown" bus driver age.

Table 3. Bus crashes in Illinois and Michigan analyzed for bus driver gender using the innocent victim technique.

State	Bus Driver Gender	Number of Accidents Where Bus Was Innocent Victim		Number of Other Accidents	
		Observed	Expected	Observed	Expected
Illinois[1]	Male Female	135 30	134 31	2863 657	2864 656
Michigan[2]	Male Female	806 269	820 255	841 244	827 258

[1] $p > 0.10$

[2] $p > 0.10$

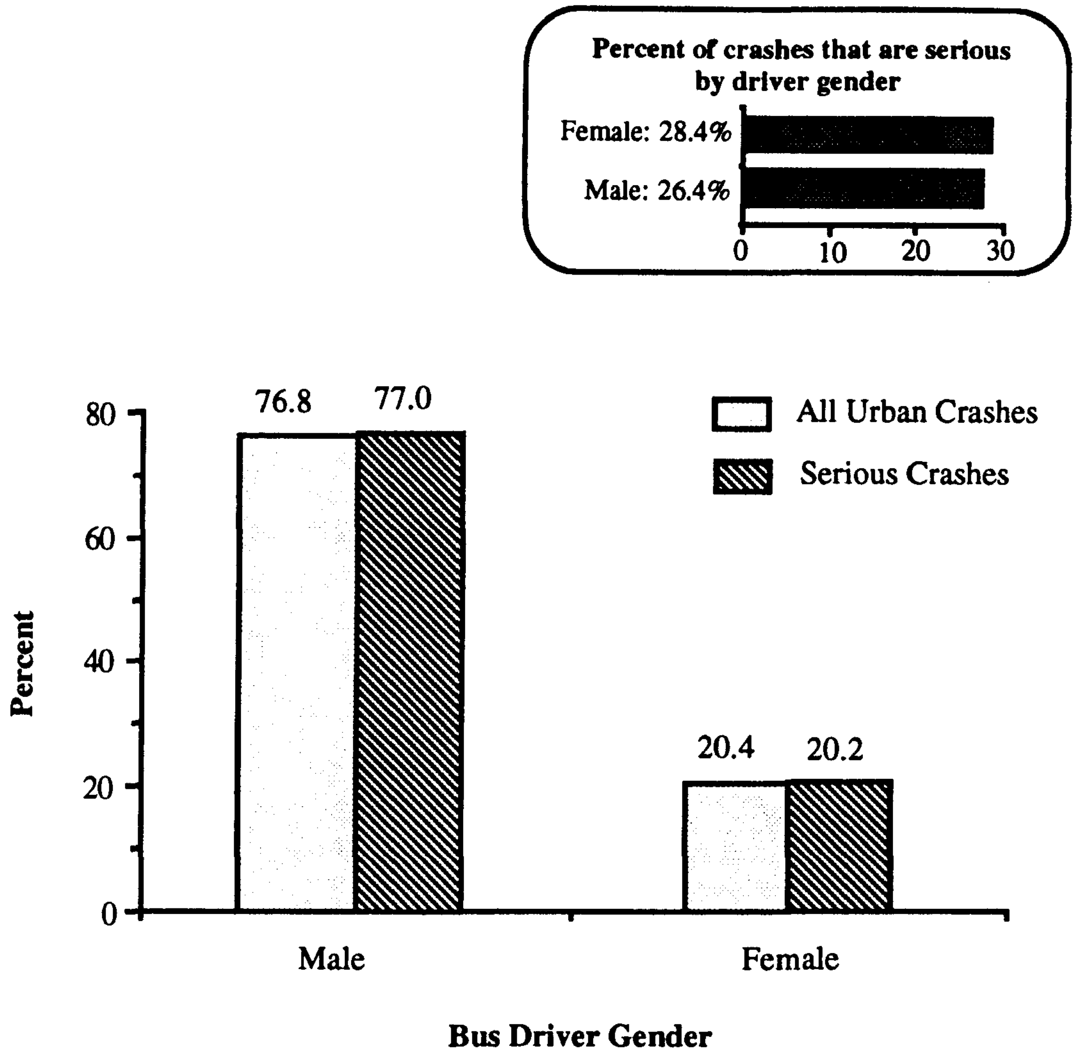


Figure 14. Distribution of urban crashes by bus driver gender.

Note: Total percentages do not add to 100.0 because the figure does not show "unknown" bus driver gender.

driver condition was reported) had a "normal" bus driver condition recorded. The driver condition recorded for most of the remaining cases was "other" or "unknown". The bus driver was reported to have been drinking (alcoholic beverages) in only 14 of 5,861 accidents (less than one fourth of one percent). The two-year Illinois sample of accidents comparing commercial buses to other vehicles showed that the level of reported bus driver drinking was also relatively low. A driver was reported to have been drinking in about three percent of car and pickup truck accidents as compared to less than one percent of bus drivers in commercial bus-involved accidents.

Roadway Factors

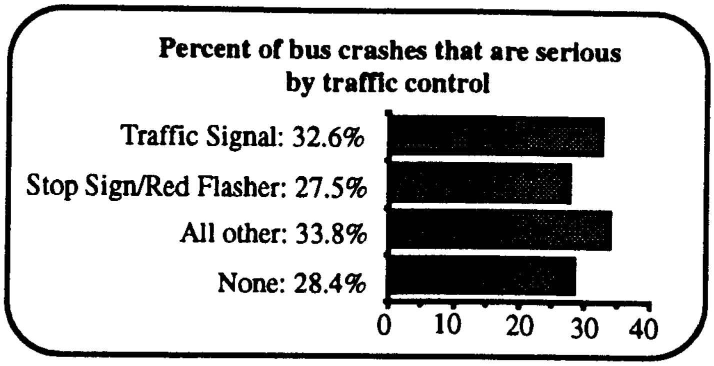
The full data base of bus crashes for the five states was used to analyze bus crashes by traffic control, while only urban street bus crashes were analyzed by road alignment. The data showed that there was no traffic control in about 46 percent of the cases (figure 15). In other cases, a traffic signal or a stop sign was present. Bus crashes at traffic signals were more likely to cause injuries and fatalities than bus crashes at stop signs. This difference was significant the 0.01 level.

Road alignment data for urban streets were collected in Michigan, Minnesota, and Utah. The vast majority of collisions took place on straight roads (figure 16). Injuries and fatalities appear to be more likely in accidents on straight roads than on curved roads (29.9% versus 20.2%), but this finding is based on a small sample of curved roads and should be interpreted with caution.

The two-year sample of Illinois accidents (comparing buses to other vehicles) revealed that about 55 percent of commercial bus accidents occurred at non-intersections (figure 17), while the remaining 45 percent occurred at various types of intersections. Relatively similar percentages of car/pickup crashes and school bus accidents happened at intersections. However, only one-third of truck accidents occurred at intersections. Situations that may result in bus accidents at intersections include:

1) buses stopping to pick up passengers from stops located at intersections (while the general traffic stream is moving on a normal green phase), and

2) buses entering or leaving curb loading areas (which may not be anticipated by some drivers).



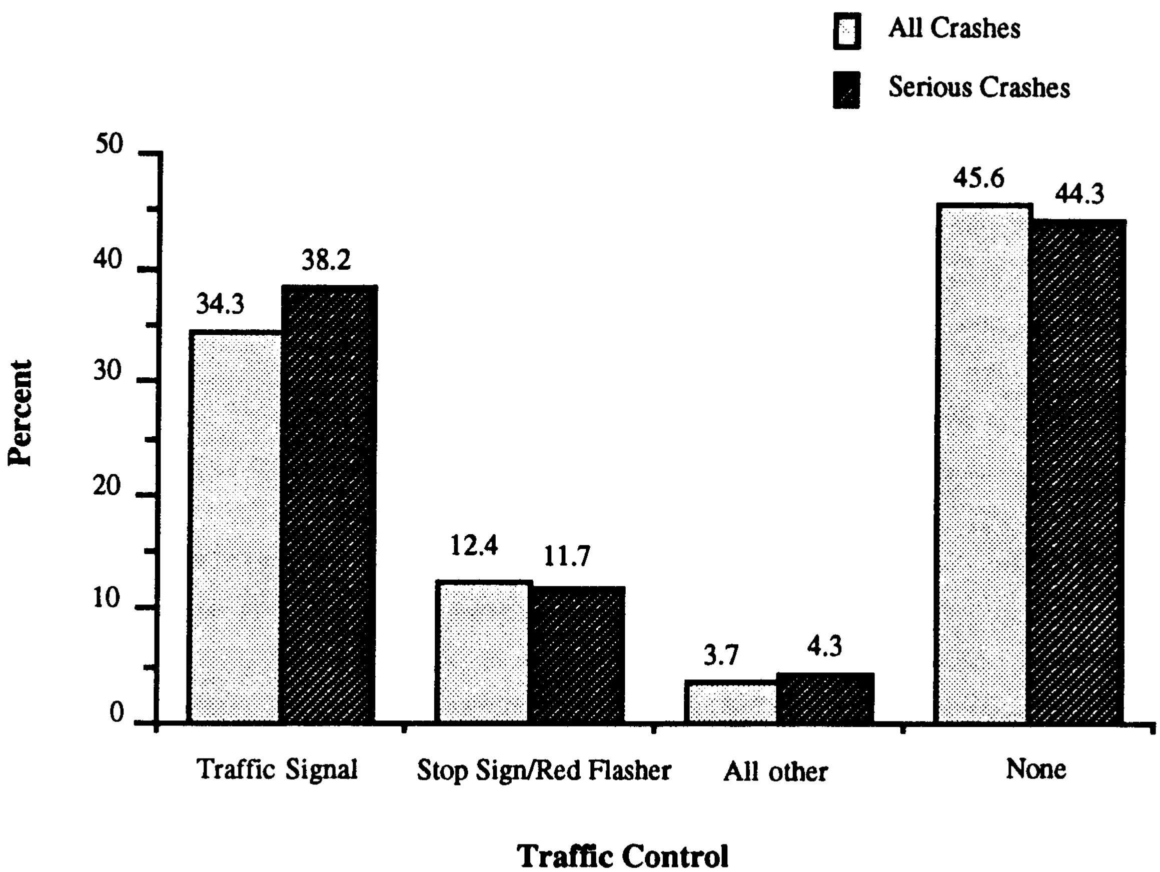


Figure 15. Distribution of bus crashes by traffic control.

Note: Total percentages do not add to 100.0 because the figure does not show "not stated/unknown" traffic control.

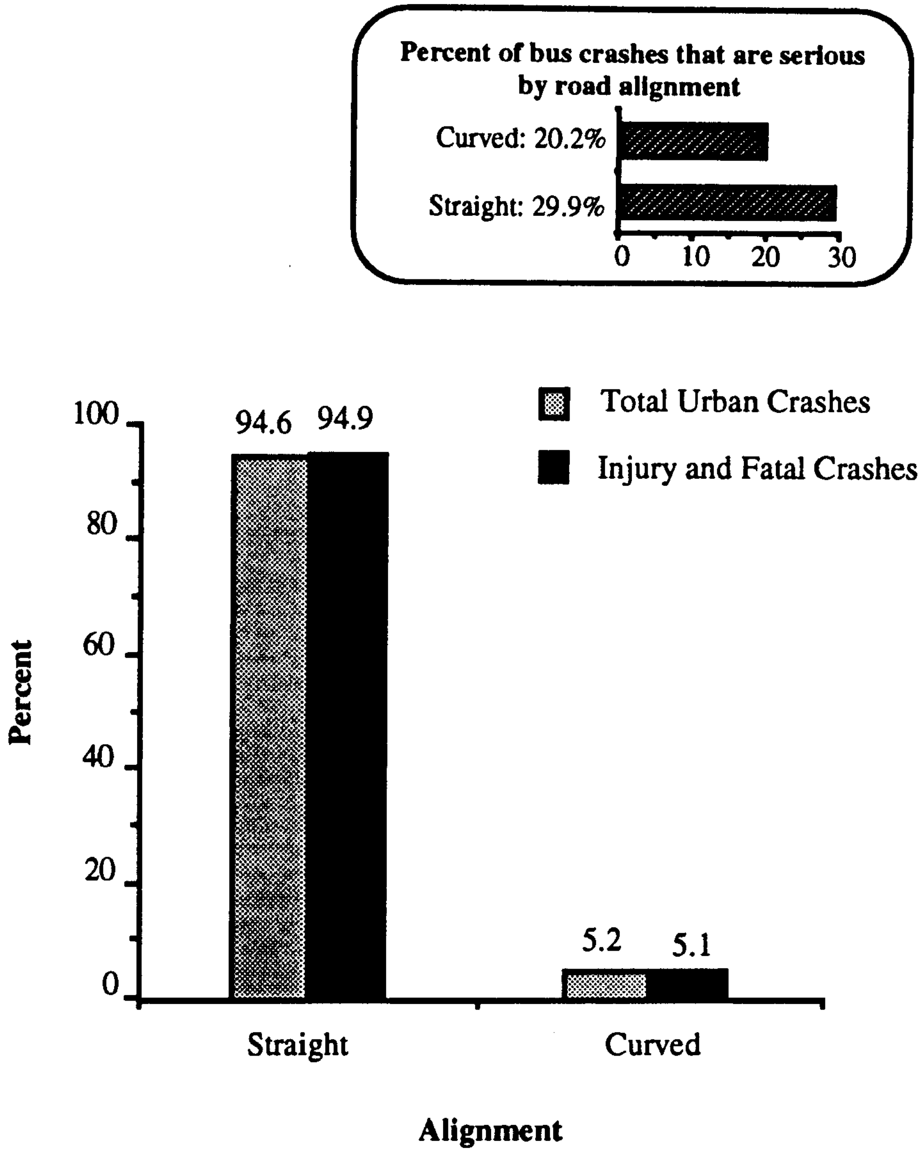


Figure 16. Percent of urban crashes by road alignment.

Note: Total percentages do not add to 100.0 because the figure does not show "other/unknown" road alignment.

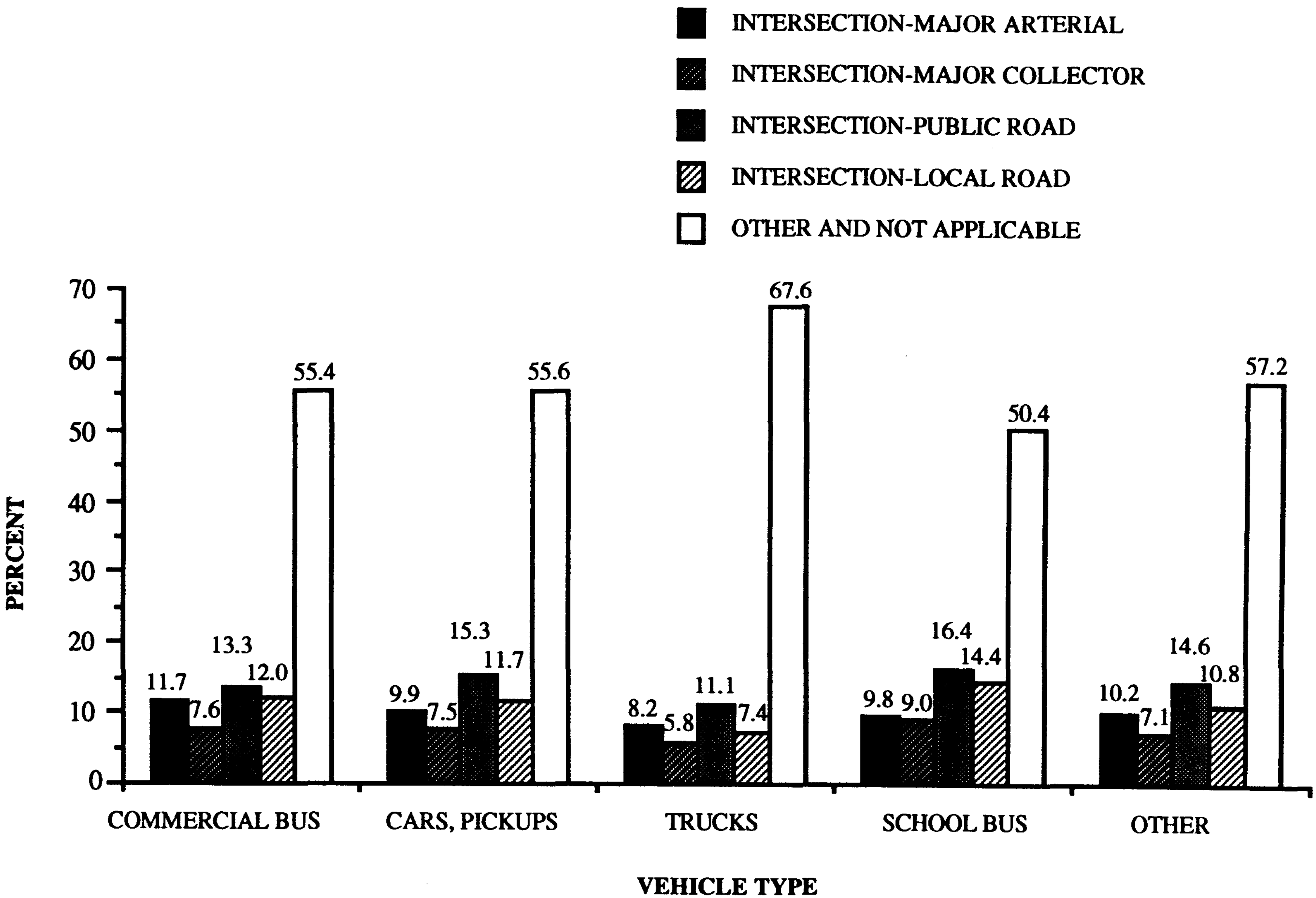


Figure 17. Percent distribution of crashes by roadway feature and vehicle type for 1988 to 1989 Illinois sample.

Accident Type

Each of the five HSIS states coded accident type differently. Extra attention was paid to analyzing accident type because this variable reveals patterns of accidents and helps suggest possible countermeasures related particularly to roadway design and bus driver operation.

Figure 18 provides a general accident type breakdown for all bus-involved accidents in Illinois. Rear-end accidents with one vehicle stopped (probably most often the bus), sideswipe same-direction accidents, and turning accidents were the most common in the sample. Pedestrian and pedalcycle (bicycles, tricycles, etc.) accidents were uncommon, but when they occurred they usually resulted in an injury or fatality. Both kinds of rear-end accidents, angle accidents, and other accidents (mostly single-vehicle fixed-object accidents) also had high percentages of injuries and fatalities. Other states showed basically similar patterns.

Figure 19, with results from the two-year Illinois sample comparing commercial buses to other vehicles, clarifies the general pattern. Commercial bus-involved accidents are more often sideswipe same-direction accidents, and are less often rear-end, both moving accidents as compared to accidents involving other vehicles.

Single-vehicle bus accidents on urban streets (including fixed-object, overturn, and animal accidents, but not including pedalcycle and pedestrian accidents) were not common and resulted in injuries or fatalities less often than other accident types. Only 139 such accidents were reported on urban streets in four states (Illinois, Michigan, Minnesota, and Utah) during the sampled years. Only 27 of those accidents involved an injury, and there were no fatalities. This finding does not contradict the data in figure 18 above, which includes accidents on freeways and in rural areas where higher speeds result in more severe accidents. Single-vehicle accidents on urban streets tend to occur at night, in the snow and ice, and during right turns more often than multiple-vehicle accidents, as shown in figure 20, figure 21, and figure 22, respectively.

In multi-vehicle accidents, buses were more likely to be struck rather than to strike another vehicle. The two-year Illinois sample comparing commercial buses to other vehicles showed that:

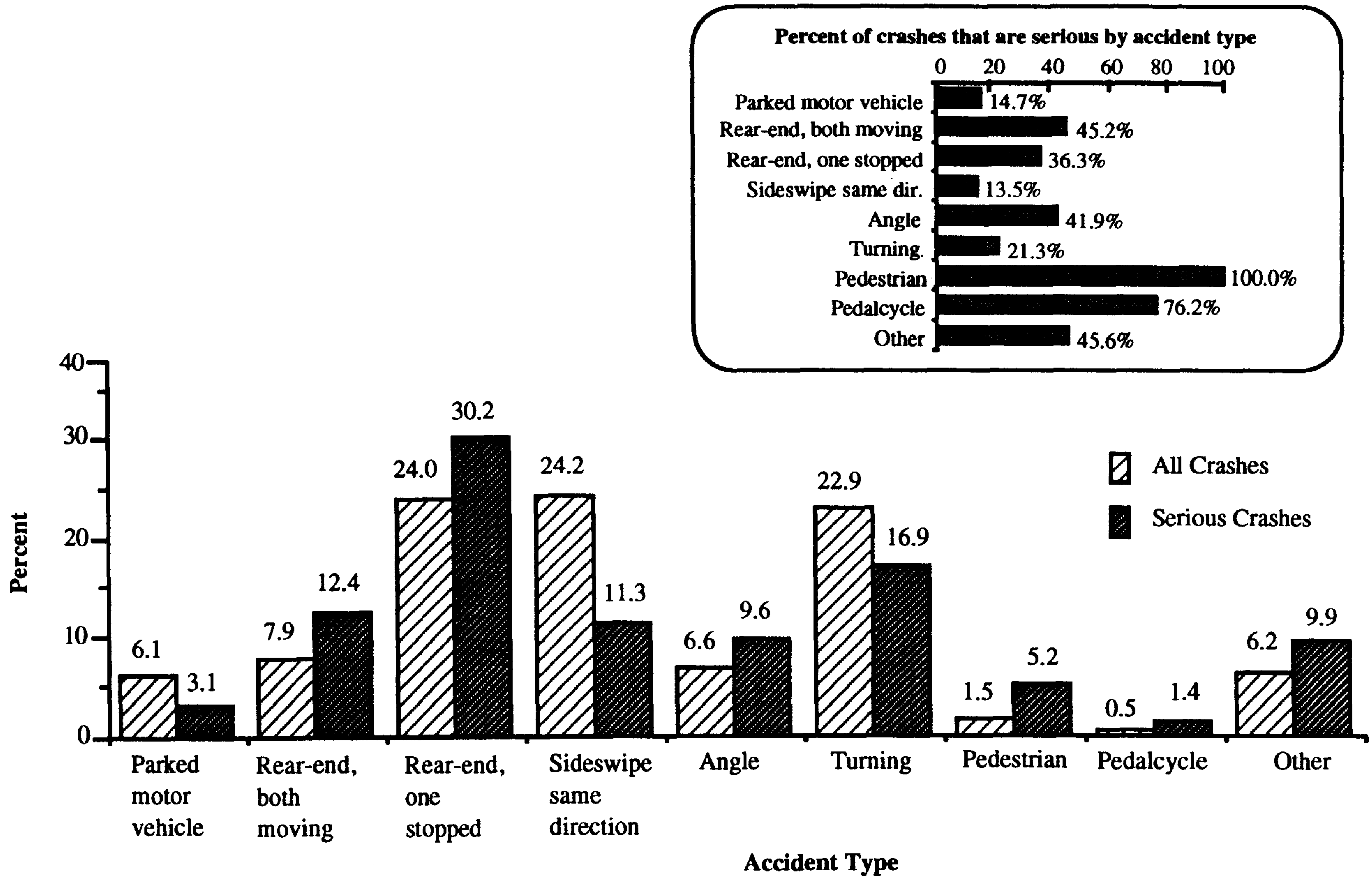


Figure 18. Distribution of bus crashes in Illinois by accident type.

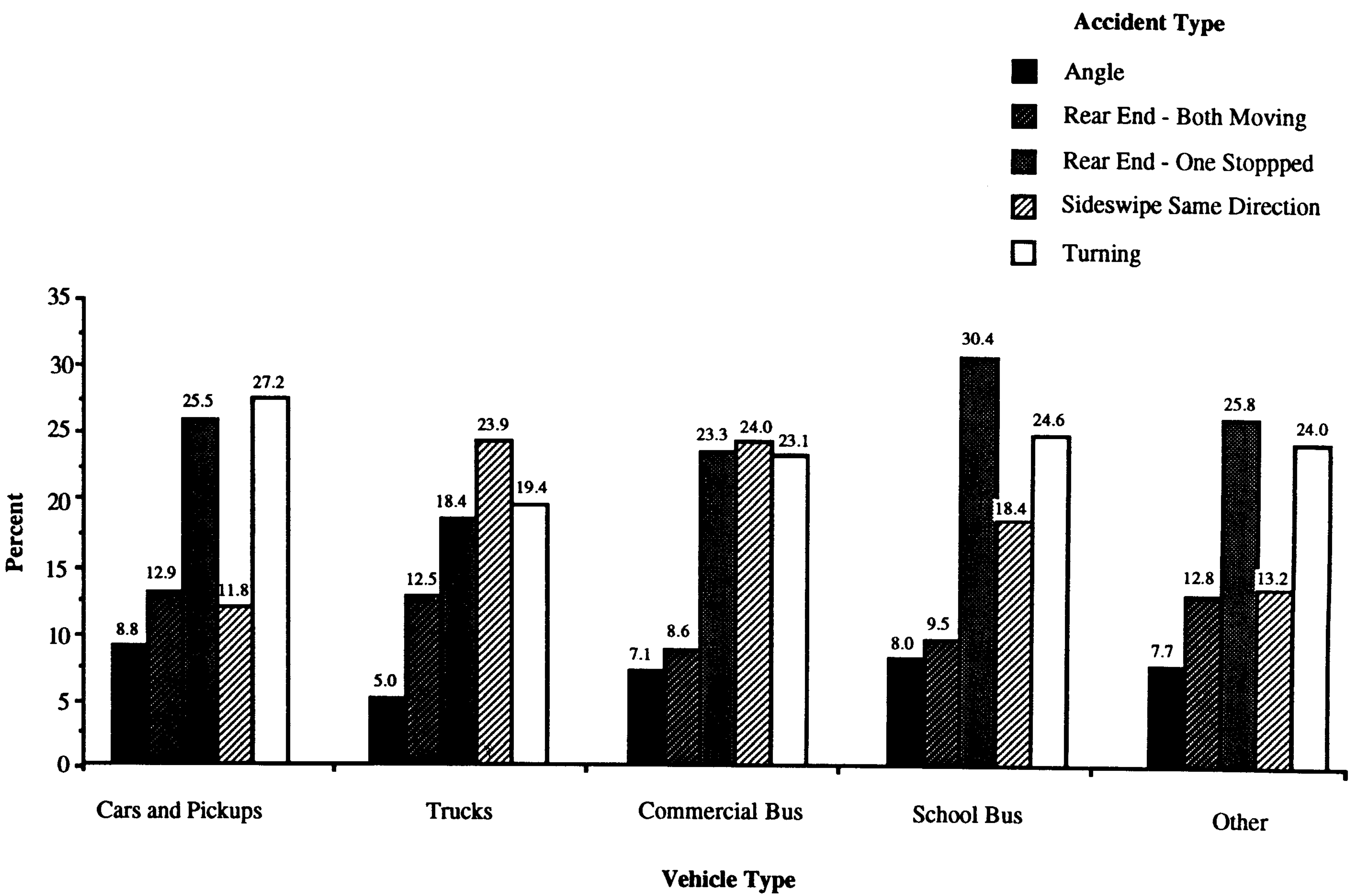


Figure 19. Distribution of motor vehicle crashes by accident type, Illinois, 1988 and 1989.

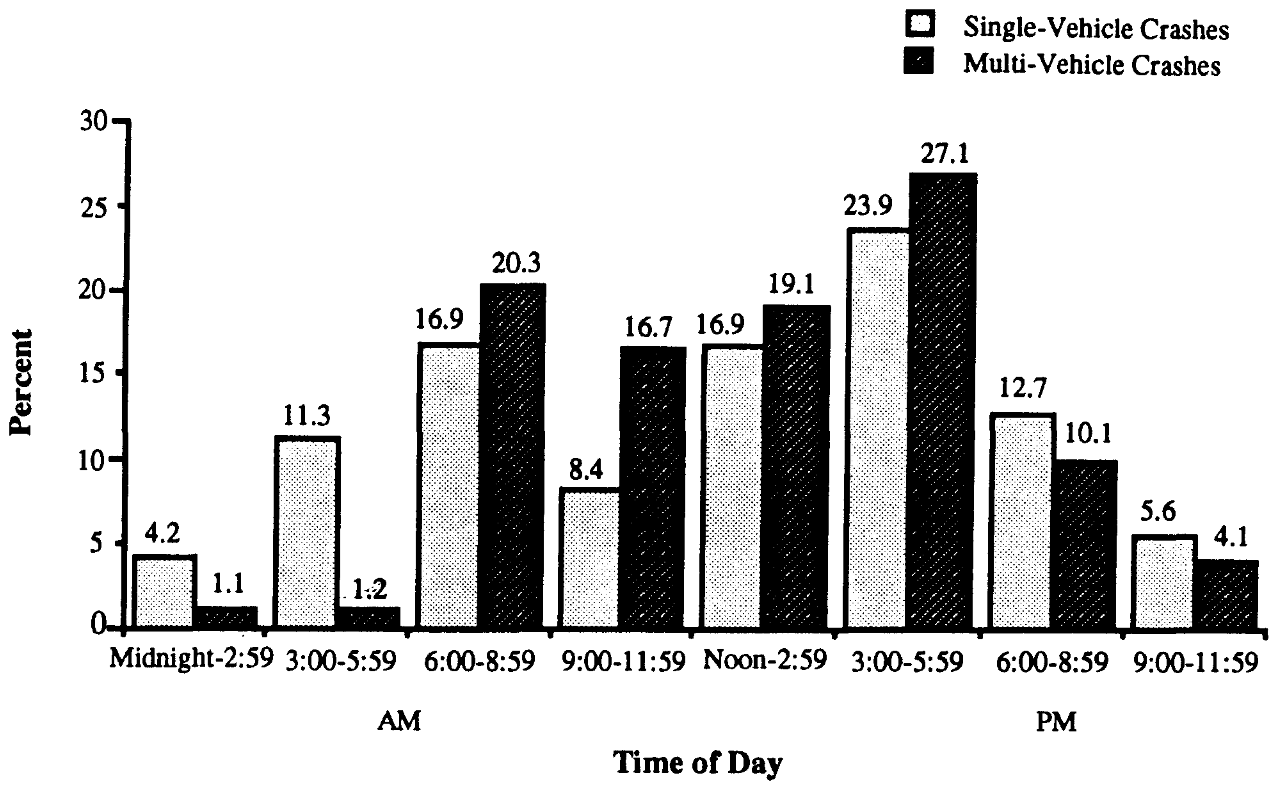


Figure 20. Single- and multi-vehicle bus crashes on urban streets by time of day, Illinois.

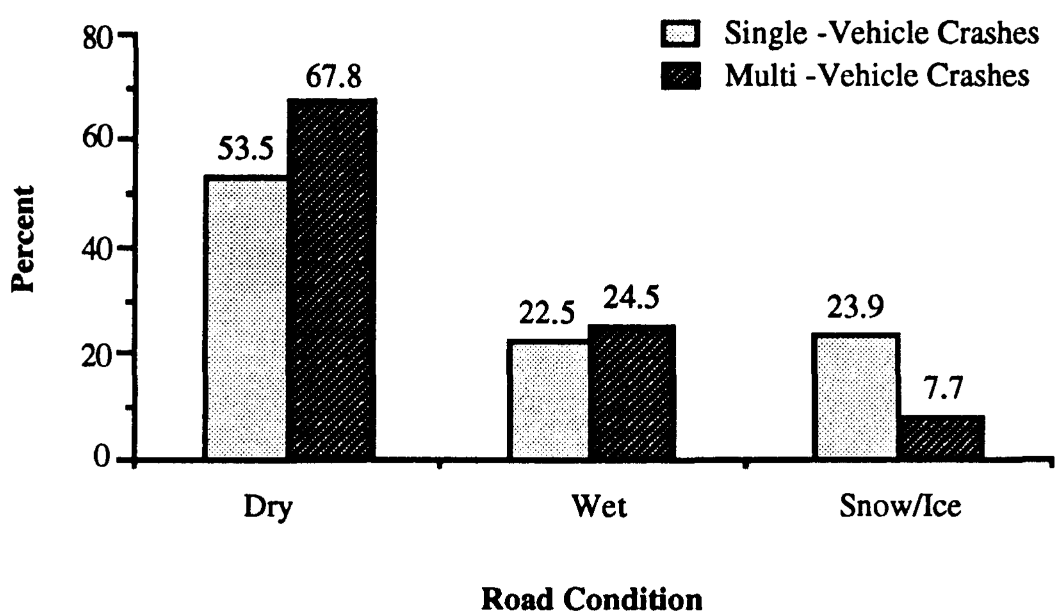


Figure 21. Single- and multi-vehicle crashes on urban streets by road condition, Illinois.

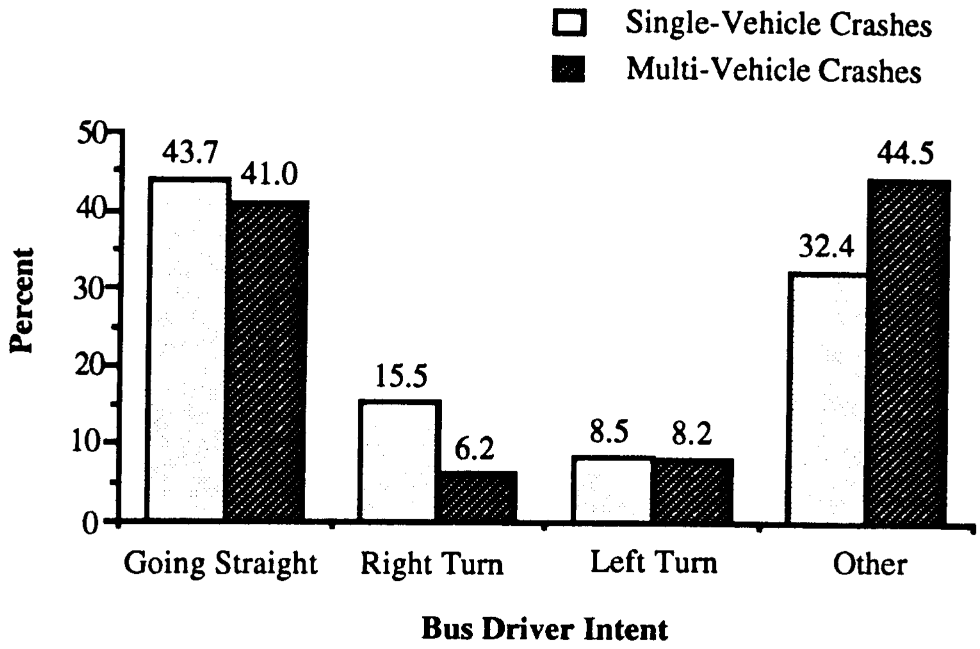


Figure 22. Single- and multi-vehicle crashes on urban streets by driver intent, Illinois.

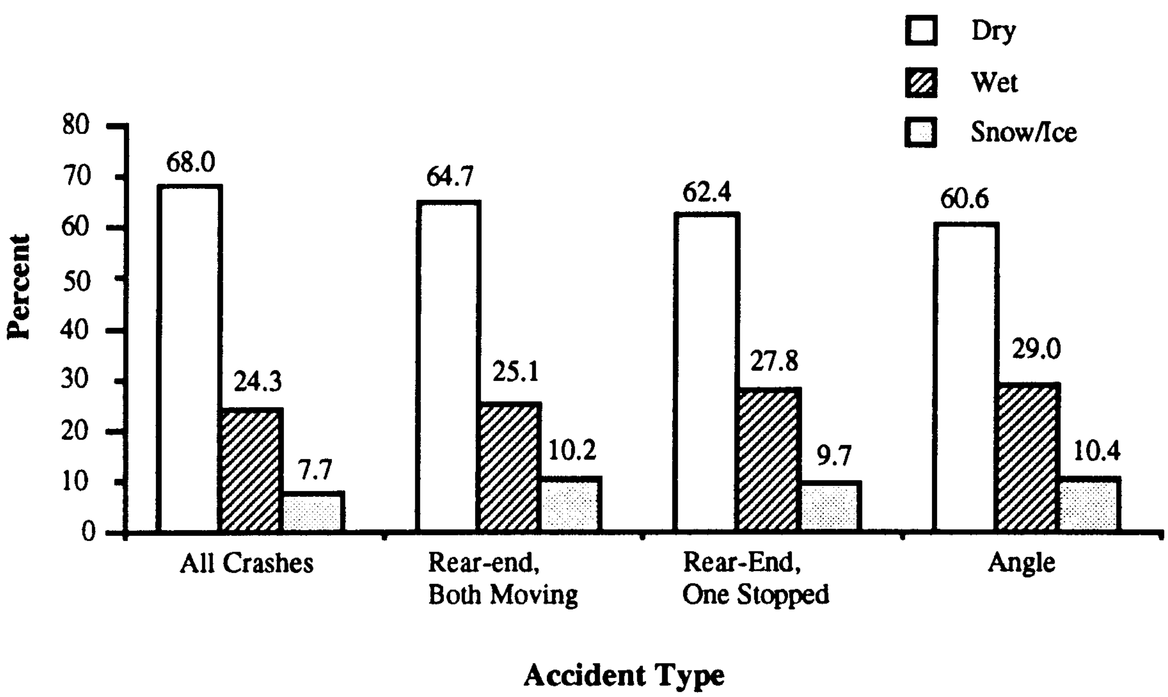


Figure 23. Distribution of multi-vehicle bus crashes on urban streets in Illinois by road condition and accident type.

- Commercial buses were struck by autos 1,474 times but struck autos 1,051 times;

- Commercial buses were struck by trucks 180 times but struck trucks 77 times; and

- Commercial buses were struck by other vehicles (not trucks or autos) 100 times but struck other vehicles 61 times.

School buses had a similar accident pattern to commercial buses. The comparison between buses and trucks, both large vehicles, is revealing. Overall, commercial buses did the striking 1,204 times and were struck 1,769 times, while trucks did the striking 40,826 times and were struck 28,885 times. Thus, buses were less likely to be the "offending" vehicle in bus crashes, while trucks were more likely to be the "offending" vehicle in truck crashes.

A breakdown of multi-vehicle bus-involved accidents on urban streets in Illinois revealed some interesting trends. Table 4 crosses accident type by the bus maneuver at the time of the accident. More than 10 percent of all 3,075 multi-vehicle accidents in this sample were reported as sideswipe same-direction accidents when the bus was going straight. (These may have been due to buses pulling into and out of curb loading areas.) For rear-end accidents where one vehicle was stopped, the bus was coded more often as stopped in traffic rather than picking up passengers, going straight, or stopped for traffic control. The relative scarcity of accidents involving a right-turning bus (6% of the total) is also worth noting from table 4.

Accident type and road condition were significantly related at the 0.005 level. Figure 23 demonstrates that angle accidents and rear-end accidents (including those with either one vehicle stopped or both vehicles moving) are overrepresented on snowy/icy roads (i.e., 10.4%, 9.7%, and 10.2%), compared to snow/ice accidents for all crashes combined (7.7%).

Accident type and time of day were also significantly related at the 0.005 level. Figure 24 reveals that angle accidents were overrepresented at nighttime; rear-end accidents with one vehicle stopped were overrepresented during the morning peak hours; parked vehicle accidents were overrepresented during the early afternoon; and sideswipe same-direction accidents were somewhat overrepresented during the afternoon peak hours.

Of the 8,897 commercial bus crashes in the HSIS files, pedestrians were involved in 189 (2.1%). Nearly all (98.4%) of these pedestrian accidents

Table 4. Multi-vehicle bus crashes on urban streets in Illinois by bus driver intent and accident type.

	Number of Accidents						
Bus Driver Intent / Accident Type[1]	Parked Motor Vehicle	Rear-end, Both Moving	Rear-end, One Stopped	Sideswipe Same-Direction	Angle	Turning	Total[3]
Going Straight	120 (53.1)[2]	126 (64.6)	168 (19.5)	359 (51.7)	206 (84.1)	255 (29.9)	1234 (40.1)
Making left turn	3 (1.3)	0 (0.0)	0 (0.0)	2 (0.3)	0 (0.0)	254 (29.8)	259 (8.4)
Making right turn	14 (6.2)	0 (0.0)	0 (0.0)	3 (0.4)	1 (0.4)	179 (21.0)	197 (6.4)
Stopped for traffic control	0 (0.0)	0 (0.0)	113 (13.1)	18 (2.6)	8 (3.3)	24 (2.8)	163 (5.3)
Picking up passengers	4 (1.8)	13 (6.7)	200 (23.2)	52 (7.5)	2 (0.8)	31 (3.6)	302 (9.8)
Stopped in traffic	2 (0.9)	5 (2.6)	282 (32.7)	87 (12.5)	9 (3.7)	51 (6.0)	436 (14.2)
Other	83 (36.7)	51 (26.2)	99 (11.5)	173 (24.9)	19 (7.8)	59 (6.9)	484 (15.7)
Total[3]	226	195	862	694	245	853	3075

[1]All accident types are on roadway only.
[2]Column percent.
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

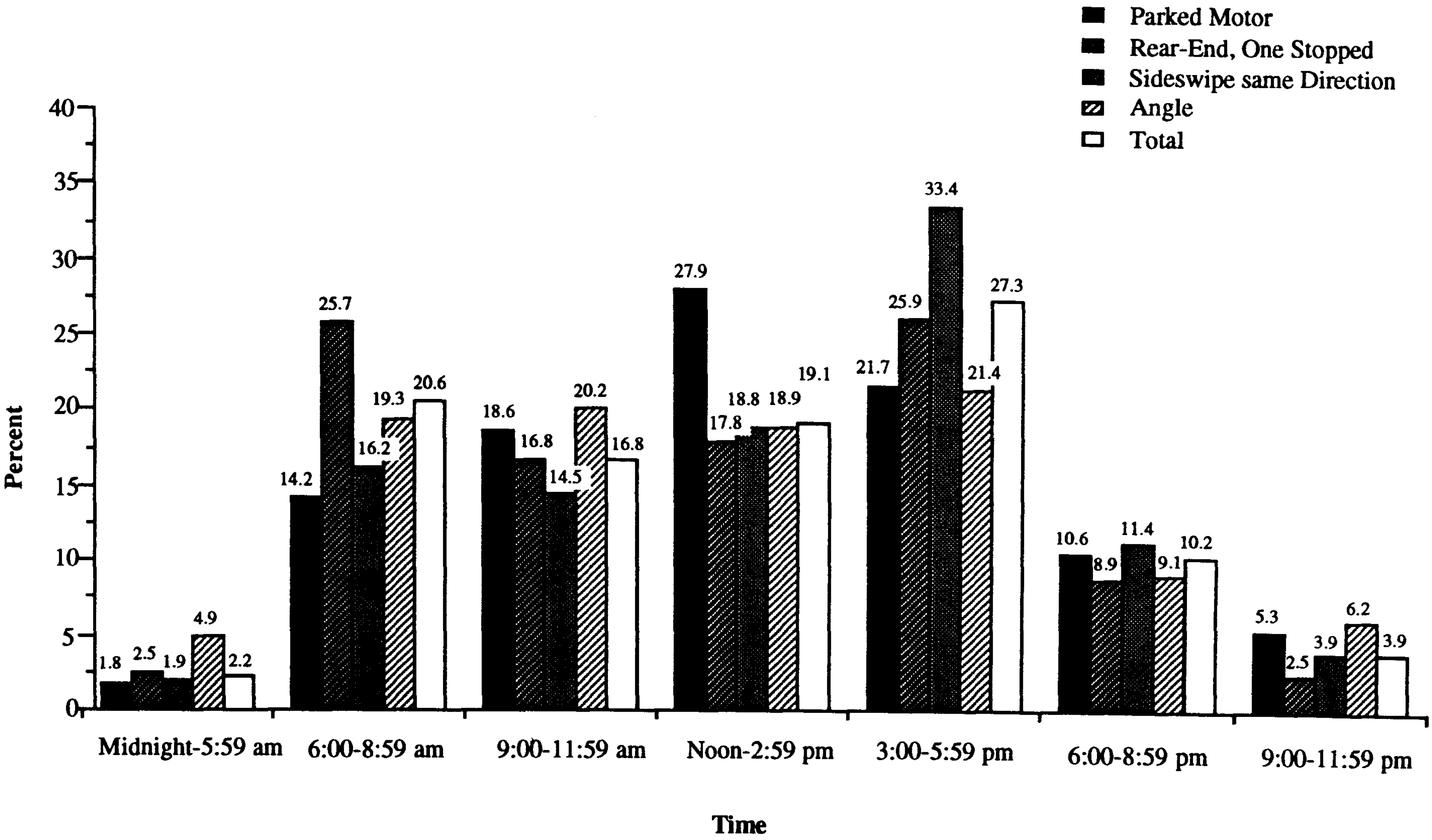


Figure 24. Distribution of multi-vehicle bus crashes on urban streets in Illinois by time of day and accident type.

resulted in injuries or fatalities, presumably to the pedestrian. In fact, 13 accidents (6.9%) were fatal. The two-year Illinois data file showed that 1.2 percent of all commercial bus crashes involved pedestrians, compared with 0.3 to 0.5 percent of other vehicle types. Many of these bus-pedestrian crashes may occur when individuals waiting at a bus stop are struck by an approaching bus or when alighting (exiting) individuals are struck by a departing bus.

CHAPTER 6. RESULTS OF NON-COLLISION ACCIDENT ANALYSIS

The General Estimates System (GES) and the Highway Safety Information System (HSIS) data bases contain information on bus crashes and resulting injuries. Many bus accidents, however, do not involve crashes with other vehicles, pedestrians, or fixed objects. These "non-collision accidents" take their toll on passenger safety, yet they are commonly overlooked in transit agency and police accident records.

Bus passengers can be exposed to non-collision accident hazards while riding buses, boarding and alighting the bus, and while standing or walking at or near bus stops. Studies of non-collision related accidents on buses show that the majority of bus passenger injuries are due to falls.[5]

Analyses of interim data from the National PSV Accident Survey showed that about 57 percent of passenger injuries were the result of falls and other incidents that occurred under normal conditions. Another 29 percent of passenger casualties resulted when the bus driver took emergency action to prevent an accident. Only 14 percent of passenger casualties resulted from collisions. In non-collision accidents, 36 percent of the casualties were persons age 60 or older, but in collision accidents, only 17 percent were 60 or older. For passengers aged 60 and over, boarding, door entrapment, and gangway accidents comprised 19, 5, and 27 percent of all non-collision casualties, respectively. The corresponding numbers for passengers under 60 were 11, 2, and 21 percent.[4] These differences were significant at the 0.01 level.

Cuts, grazes, and bruises to various parts of the body were the most common injuries in non-collision accidents. Cut, grazes, and bruises to the head or neck were more frequently reported from accidents in the gangway (i.e., aisle) and when entering and leaving seats. Leg and foot cuts, bruises, and grazes were more common in doorway and platform accidents. Fractures of all kinds were most often reported for doorway and gangway accidents.[10]

Passenger falls during the movement of the bus occur due to the forces of sudden acceleration or deceleration, lateral motion on curves, and slip or trip-related falls. Hirshfield found in his famous experiments to develop the PCC (President's Conference Committee) Streetcar design criteria that a 0.15 g (4.83 ft/sec^2) deceleration or acceleration was the threshold at which people would begin to lose their footing.[11] Many slips occur on flooring materials that do not have good slip resistance under wet conditions. The presence of foreign materials on the floor, such as spilled beverages or food, also lowers slip resistance.

Boarding and alighting falls occur as a result of slipping or tripping within the stepwell, overstepping the step trend, or falling on the ground surface outside the bus. Design features such as high steps, inadequate grab handles, and poor illumination of the stepwell contribute to these accidents. Older pedestrians are likely to be overrepresented in boarding and alighting falls, due in large part to their limited mobility and age-related changes in vision, balance,and coordination. Because of the characteristics of stair falls, alighting stepwell falls are typically more serious than boarding falls. In one study of stair falls in transit terminals, 94.1 percent of the ambulance-aided cases occurred in the downward direction[12] The reason for this difference in severity is the greater fall height and impact energy of the downward direction stair fall.

Bus stop location, walking surface conditions at the stop, sidewalk width, and illegal parking in bus stop zones are factors that contribute to passenger accidents prior to boarding or after alighting. Alighting passengers who step onto a rough or icy walking surface may slip and fall. Along a narrow sidewalk, a passenger may be bumped or jostled off the sidewalk into the street or down an abutting slope.

The incidence of non-collision injuries can be reduced by appropriate countermeasures, such as interior vehicle design modifications and by stop locations that passengers can safely use. More information about these countermeasures is provided in Chapter 8, "Recommendations."

Washington, DC Metrobus Data Analysis

The Washington, DC Metropolitan Area Transit Authority (WMATA) operates one of the largest transit bus fleets in the United States. As mentioned in Chapter 3, WMATA supplied this study summary passenger injury data for 1976 to 1990 and more detailed data for July 1984 to January 1991. The agency also provided summary traffic accident data for 1976 to 1990.

Figure 25 shows that the collision rate (traffic accidents per million miles operated) fell from 73.8 in 1976 to 38.5 in 1986, before rising somewhat

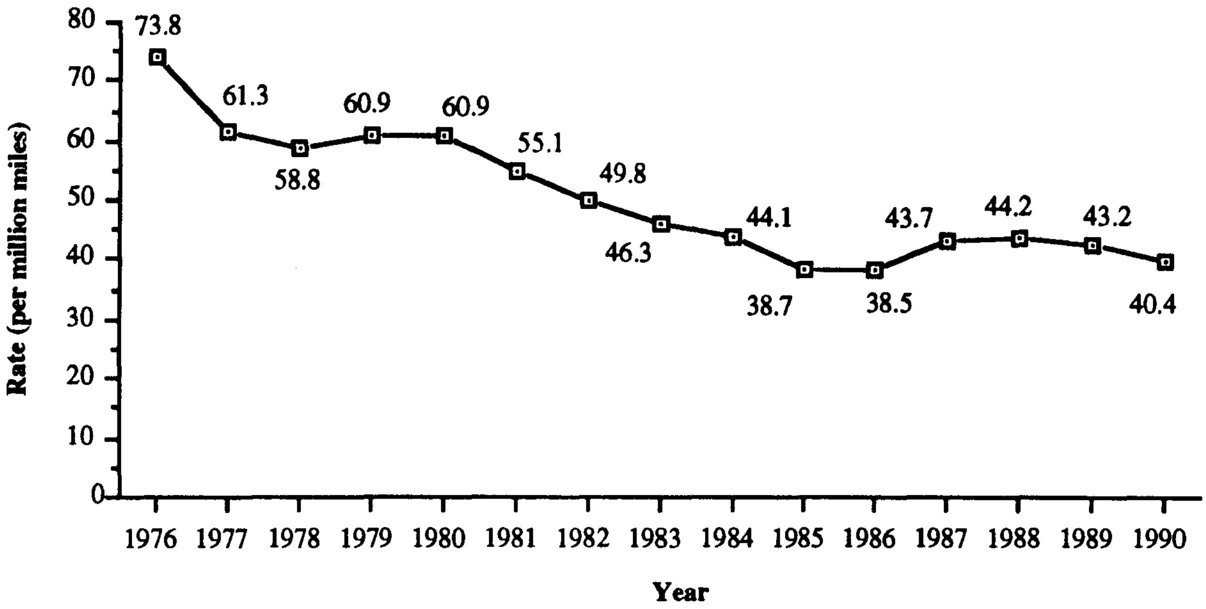


Figure 25. Washington, D.C., Metrobus traffic accident rate by year.

Source: Adapted from Reference 13.

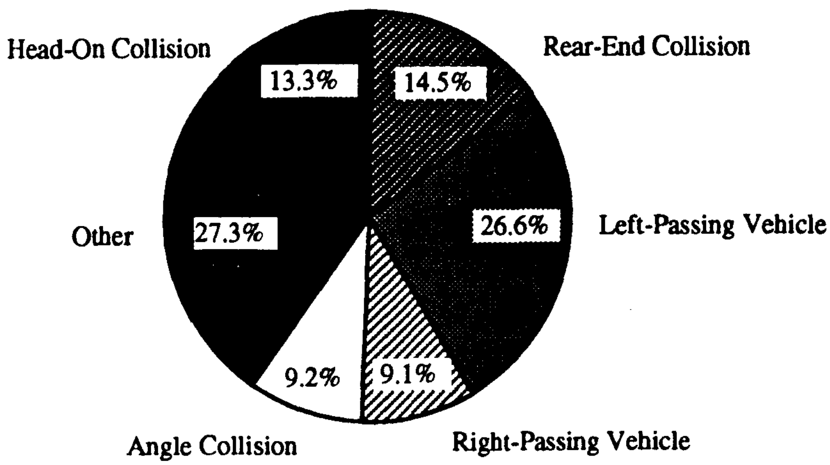


Figure 26. Washington, D.C., Metrobus traffic accidents by type, 1976 - 1990.

Source: Adapted from Reference 13.

in subsequent years.[13] Reasons for this drop are not known with any certainty. The accident types reported involving WMATA buses include vehicles passing on left (26.6%), rear-end collisions (14.5%), and head-on collisions (13.3%), angle collisions (9.2%) and right-passing vehicles (9.1%) (figure 26). These results show that sideswipe and rear-end collisions prevailed, as was the case with the five-state HSIS data discussed earlier in this report. For most accident types, the crash percentages by type remained relatively constant between 1976 to 1980 and 1986 to 1990, although accidents involving vehicles following (i.e., vehicles striking the bus from behind) increased from 12.4 percent to 17.9 percent.

During 1976 to 1990, slightly more than 1,000 accidents occurred involving pedestrians, which was about 2.6 percent of the total number of accidents by WMATA buses. Of the 346 bus-person collisions between January 1984 and January 1991, 72 occurred as the bus was traveling between stops. Fifty-eight pedestrians were struck as buses were leaving stops, 56 were hit in crosswalks, and 160 were struck under other circumstances.

The passenger injury rate (per million passengers) has shown a general downward trend, from 7.3 in 1976 to 4.9 in 1990 (figure 27).[13] Roughly one-third of all passenger injuries occurred during boarding or alighting, and another one-fourth occurred during stopping (figure 28). "Other" and "miscellaneous" accidents combined accounted for another one-third of the injuries. The percentage share of each passenger injury accident type remained relatively constant between 1976 through 1980 and 1986 through 1990.

A more detailed breakdown of 5,507 non-collision accidents that occurred in metropolitan Washington between July 1984 and January 1991 appears in table 5. Passengers were most likely to be injured while aboard a stopping bus or while boarding and alighting. Forty-five percent of the injuries on stopping buses occurred while passengers were getting up, sitting down, or while seated. One-third of the alighting vehicle injuries occurred when passengers tripped, slipped, or stumbled.

The WMATA data do not report injury severity for the traffic accidents and the non-collision passenger injury accidents. Information was not available on potential bus stop safety problems such as far-side versus near-side stop location or adequacy of loading areas.

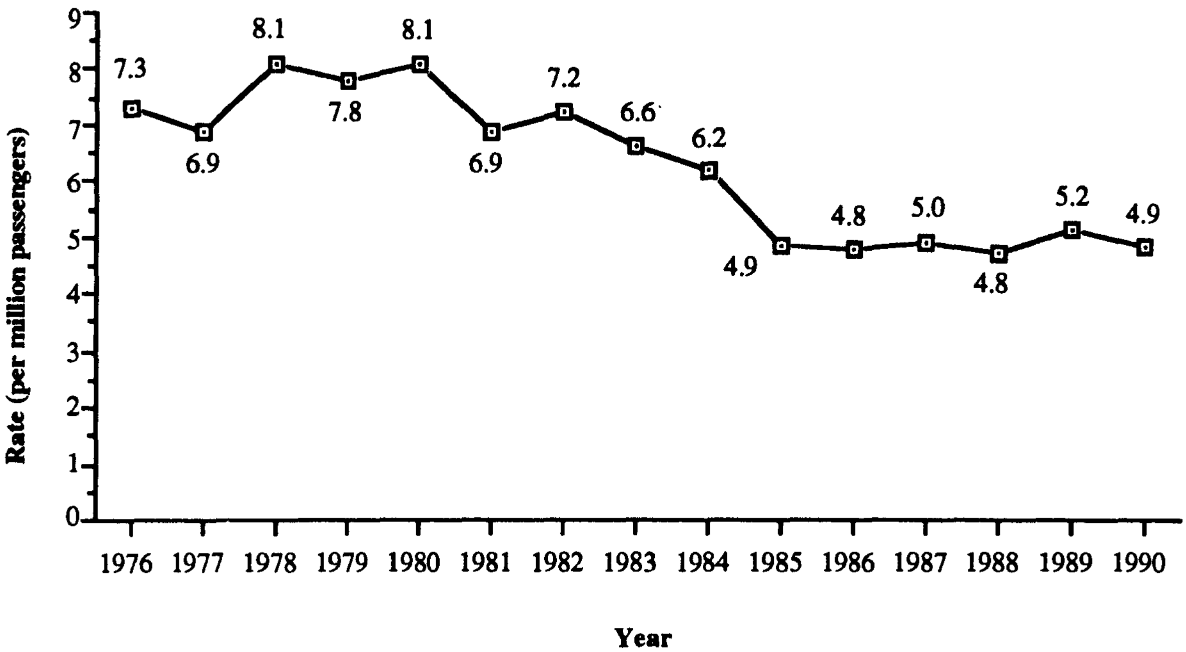


Figure 27. Washington, D.C., Metrobus passenger injury rate by year.

Source: Adapted from Reference 13.

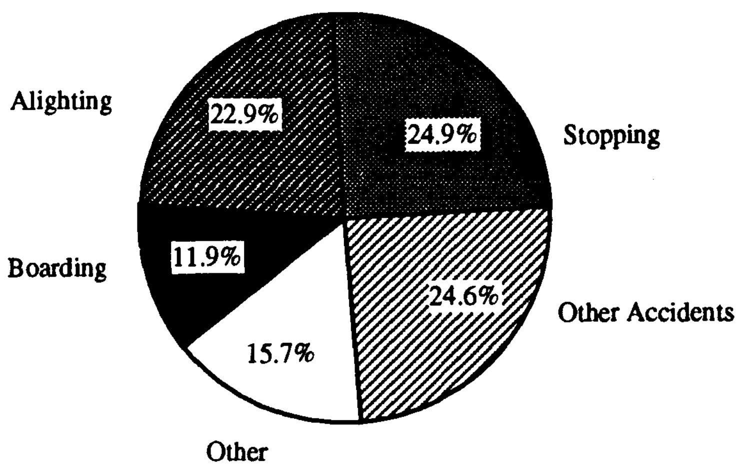


Figure 28. Washington, D.C., Metrobus passenger injuries by type.

Source: Adapted from Reference 13.

Table 5. Washington, D.C., Metrobus non-collision accident types, July 1984 - January 1991.

Passenger injury boarding vehicle	681 (100%)
- Struck by front doors closing	34.9%
- Tripped, slipped, stumbled	32.9%
- General	9.0%
- Between street and step at front door	7.8%
- Other	15.4%
Passenger injury alighting vehicle	1215 (100%)
- Tripped, slipped, stumbled	33.2%
- General	15.7%
- Struck by center/rear doors closing	13.7%
- Between street and step at front door	9.9%
- Struck by front doors closing	7.5%
- Other	20.0%
Passenger injury on board starting bus	142 (100%)
- Walking front seat area	23.2%
- Standing front door area	19.7%
- Other	57.0%
Passenger injury on board stopping bus	1508 (100%)
- Getting up/down/seated	45.4%
- General	16.6%
- Standing front door area	10.3%
- Standing front seat area	7.2%
- Walking front seat area	7.1%
- Standing rear seat area	5.6%
- Walking rear seat area	4.3%
- Other	3.4%
Passenger injury on board moving bus	382 (100%)
- Getting up/down/seated	54.7%
- General	10.2%
- Standing front door area	9.9%
- Other	25.1%
Other passenger injury	1200 (100%)
- Injured by defective equipment while on board	24.0%
- Injured by missile while on board	19.4%
- General	17.1%
- Bus standing: trip, slip, or stumble	13.4%
- Injured by others on board	11.0%
- Bus moving: tripped, slipped, stumbled	7.8%
- Other	7.3%

Source: Adapted from Reference 14.

CHAPTER 7. SUMMARY

This study was carried out to examine the characteristics of crashes involving transit buses, and to make recommendations for reducing the incidence of bus crashes and related personal injuries. Components of the study included a detailed review of the available literature and an analysis of bus accidents identified on the Highway Safety Information Systems (HSIS) data base. The latter included records of police-reported crashes occurring in five states: Illinois, Maine, Michigan, Minnesota, and Utah. The study also examined the characteristics of non-collision bus-related injuries, such as falls while boarding or alighting.

Literature Review

Literature from the United States, Australia, Great Britain, and India was examined with respect to both collision and non-collision (on-board) accidents. Of particular interest are the following findings:

- Accidents in which a bus rolls over are particularly likely to result in severe or fatal injury, since unrestrained passengers may be thrown against the interior of the bus or ejected through windows, doors, or other openings. The collapse of a roof or wall into the passenger compartment can also result in injury.[3]

- Nearly nine out of every ten bus crashes in a Chicago area study involved collision with another vehicle.[1] However, the results of a British accident survey showed only 14 percent of bus passenger injuries to result from collisions; 57 percent resulted from falls and other incidents under normal conditions, and 29 percent from emergency action taken by the bus driver.[4]

- Older bus passengers are particularly likely to be involved in non-collision accidents, such as those that occur while boarding or alighting. [4]

- Stopped buses appear to pose a particular threat to car occupants. In the Chicago study, for example, 80 percent of the auto occupant injuries occurred when the auto rear-ended the bus.[5]

The present study has examined a particularly large accident data base to investigate the characteristics and causes of bus accidents, and to facilitate the identification and implementation of countermeasures to reduce their frequency and severity. A total of 8,897 crashes involving commercial buses was identified on the HSIS file: 43.0 percent from Illinois, 24.3 percent from Michigan, 22.6 percent from Minnesota, 5.9 percent from Utah, and 4.2 percent from Maine. These crashes became the primary study file. In addition, separate analyses were carried out on a smaller sample of 5,283 crashes (59 percent of the original study sample) identified as occurring on surface streets.

The analysis was primarily descriptive, involving cross tabulations of selected variables of interest and testing of differences in the resulting distributions. In addition, application of the "innocent victim" technique allowed for some control over exposure differences that might otherwise confound results. Using the Illinois data only, a comparative analysis was conducted comparing bus crashes with other motor vehicle (passenger car, truck, etc.) crashes. Key findings include:

Overall

- Less than one percent (0.7%) of bus crashes on the overall five-state file resulted in fatal injury; 28.5 percent resulted in non-fatal injury, and the remaining 70.8 percent involved property damage only. The pattern for only urban crashes was similar, with 0.5 percent fatal and 28.3 percent non-fatal injury.

- Commercial bus accidents represented less than one-fourth of one percent of all motor vehicle crashes occurring in Illinois during 1988 to 1989.

- Also from the Illinois data, bus accidents and car and pickup accidents were all about equally likely to result in a fatality; however, truck accidents were twice as likely to result in a fatality compared to other vehicle types.

Temporal Factors

- Numbers of bus crashes are lowest during the summer months (July and August) and highest during the winter months (January and February). However, winter month crashes tend to be less severe, so that the greatest percentage of injury crashes actually occurs in May.

- Similarly, bus accidents are least likely to occur on weekends, perhaps a reflection of reduced exposure. Although the greatest overall number of crashes occurs on Fridays, followed by Mondays, injury crashes are most likely to occur on Tuesdays.

- The percentage of injury accidents is significantly higher in nighttime crashes. Almost 40 percent of crashes occurring between 9 p.m. and 3 a.m. resulted in injury. This compares to 27 to 29 percent of crashes resulting in injury at other times during the day.

Environment Factors

- A great majority (80%) of bus crashes occur under daylight conditions, when transit buses in particular are most likely to be on the road. Crashes occurring at night and at night on lighted streets, however, are more severe than at other times. This may be due to the higher speeds at night (i.e., under congested conditions) and greater use of lighting on high-speed arterial routes, compared to lower-speed collector or local streets.

- While bus crashes are most prevalent on dry pavements, crashes occurring on wet pavements are significantly more likely to result in injury. Those occurring on snowy or icy roadways, on the other hand, are less likely to result in injury.

Vehicle Factors

- Older buses are overinvolved in accidents when considering their population in the traffic stream. The accidents in which they are involved tend to be severe more often than accidents with newer buses.

- More bus passengers are injured in accidents than bus drivers. This finding was expected because a bus has one driver but often carries multiple passengers.

Driver Factors

- Bus driver age is not related to accident involvement, but a greater percentage of accidents involving bus drivers near the age of 40 are severe. This could be related to the complexity or operating speeds of routes assigned to drivers in various age groups.

- Bus driver gender is neither related to overall accident involvement or to crash severity.

- Reports of bus drivers who had been drinking are much less frequent, on a percentage basis, than reports involving automobile drivers.

Road Factors

- Bus crashes at traffic signals were more likely to cause injuries and fatalities than bus crashes at stop signs or at locations where no traffic control was present. This may be due to higher traffic volumes and/or speed at signalized intersections (which are typically on arterial streets) compared to intersections with stop signs or no control (typically local or collector streets).

- From the Illinois data, roughly 45 percent of commercial bus, car/pickup, and school bus accidents happened at intersections, but only one-third of truck accidents occurred at intersections.

Accident Type

- The most common accident types involving buses are rear-end with one vehicle stopped, sideswipe same-direction, and turning. Left-turning buses were involved in accidents more often than those making right turns.

- Bus accidents involving pedestrians or pedalcycles are very infrequent, but when they occurred, they usually resulted in an injury or fatality.

- Single-vehicle fixed-object or overturn accidents involving buses are infrequent on urban streets and result in a relatively low percentage of injuries.

- Buses are more likely to be struck than to be the striking vehicle in a multi-vehicle collision.

CHAPTER 8. RECOMMENDATIONS

It is often impossible to identify the precise cause of a bus crash or passenger injury and, in fact, motor vehicle crashes and resulting severity often involve a multitude of factors. Consider, for example, one of the most tragic bus accidents in U.S. history which occurred on May 31, 1975. A chartered bus carrying 51 passengers went out of control on a sharply curved exit ramp of Interstate Highway 680 near Martinez, California. The bus rolled over the railing, turned upside down, and fell 22 feet, landing on its roof. The roof collapsed, crushing three passengers who remained in their seats. Twenty-nine passengers were killed. The ultimate cause of the accident was determined to be the breakage of a compressor drive belt in the air pressure braking system. Additional factors were poor ramp design, ineffective curb and railing design, poor warning signs, and driver inexperience with the bus. Also, no access was available to the interior for the extrication of the victims, which may have contributed to the deaths of several victims.[15]

The example above is indicative of the role of multiple bus, roadway, and other factors in a bus crash, based on an in-depth accident investigation of that one accident. Also, specific countermeasures were recommended based on this detailed investigation.

While the analyses of the 8,897 bus crashes in this study were not based on such an in-depth investigation of each crash, the analyses of many crash factors allow for making some educated judgements of probable causes and then developing potential countermeasures corresponding to each probable cause.

Based on the results of the analyses of bus crash factors, the bus safety literature, and decades of highway safety literature and experiences on causes and treatments for various crash types, a number of general measures are recommended to reduce the likelihood of bus crashes and/or resulting passenger injuries. Not all of these recommendations apply to all bus accidents, but one or more of these recommendations or safety measures are likely to apply to a given bus crash, based on the particular factors involved. Such measures may be classified into the following areas:

- Roadway design and improvements
- Bus-stop location
- Bus design and operations to reduce passenger injuries
- Bus driver screening and education

- Transit agency policies
- Safety and security reporting system

Details of specific accident countermeasures are discussed below within each of these topics.

Roadway Design and Improvements

Based on the specific types of bus-related highway crashes as quantified in the five-state accident analysis, a number of potential roadway improvements may be used to reduce the probability and/or severity of bus-related crashes. These include:

1. Wider intersection turning radii - One of the common types of accidents involving buses is that they are often rear-ended, particularly at intersections. One potential measure for reducing rear-end crashes to the bus at intersections involves providing wider turning radii. Because of the length of transit buses, problems may occur when buses turn right at intersections or driveways with a very tight turning radius. This will require the bus to swing wide and often encroach the oncoming lane of the side street to the bus's right, which can increase the risk of an accident with an oncoming vehicle from the side street. In addition, with a tight turning radius, the bus must slow down considerably when making such a right turn and a rear-end crash to the back of the bus can result. By designing or reconstructing the curb radius to be wider, the bus can then make an easier turn without slowing to a near stop and without swinging across the center line as it makes its right turn. This can reduce rear-end and other crashes involving the bus. (At the same time, however, it may result in increased risk to pedestrians being struck by faster turning cars.)

2. Wider lanes on bus routes - Another primary transit bus accident type involves sideswipe collisions between buses and other motor vehicles. Because of the wider vehicle dimensions on buses, it is important that lane widths be adequate to minimize the chance for sideswipe accidents involving other vehicles in adjacent lanes. With narrower lane widths, the potential for sideswipe accidents is increased, particularly when a bus passes or is being passed by a large truck or other bus. Along major arterials where buses and large trucks are likely to travel, consideration should be made for providing lane widths of 12 feet when possible, or at least 11 feet. This will increase the lateral spacing between buses and other motor vehicles.

3. Turn lanes at intersections along bus routes - When adequate separate turning lanes are not available at intersections

where buses make right and left turns, several types of accidents may occur. First of all, for making right turns, the bus must slow down and may be rear-ended. When making left turns with no left-turn lane, the bus will often be forced to stop in the left-most thru lane and wait for oncoming traffic to clear before turning left into an adequate gap and through traffic. By stopping in this left-most through lane, the bus is exposed to the potential for rear-end collisions. Also, other vehicles behind the bus may change into the right lane to get around the bus, thereby being struck by vehicles from behind. One desirable alternative to these types of bus accidents involves adding separate left-turn and right-turn lanes when feasible.

4. Eliminate on-street parking along bus routes - Parked vehicles along bus routes can be associated with several types of motor vehicle crashes related to the bus. These include (1) parked vehicles being struck by the bus, (2) pedestrian accidents due to pedestrians stepping or running into the path of the bus from between parked cars, or (3) sideswipe accidents between the bus and other motor vehicles in adjacent lanes (due to the bus swerving over the lane line to provide adequate clearance between the bus and parked vehicles.) To reduce the probability of such accidents, the elimination of on-street parking along the bus route is sometimes an effective solution. While the elimination of parking spaces is often politically unpopular and difficult to achieve, the results of such actions can not only reduce accidents involving buses, but also reduce accident rates for motor vehicles in general.

5. Provide adequate paved shoulders or a bus pull-off lane - For bus travel in suburban and rural areas, some crashes occur when buses stop in the lane to pick up or drop off passengers, thereby resulting in a rear-end collision to the back of the bus. One potential countermeasure to reduce such accidents involves providing paved shoulders of preferably 8 to 12 feet along such bus routes to allow buses to pull out of the thru lane and onto the shoulder to pick up and unload passengers. Where the provision of continuous paved shoulders is unfeasible, a paved pull-off lane at the bus stop should be considered to allow buses to pull out of the travel lane. Such pull-off lanes are particularly important at bus stop locations where sight distance is severely limited for approaching motorists due to horizontal or vertical alignment. For example, if a bus is stopped in the through lane around a sharp curve, an oncoming vehicle has a limited amount of time to see the bus and stop before striking the bus in the rear. Also, in such situations, the vehicle approaching from behind the bus may try to pass to the left of the bus and may be struck by an oncoming vehicle.

6. Adequate signs and markings - The proper use and placement of signs and lane markings may reduce the incidence of some bus crashes. For example, overhead lane designation signs near intersections can help bus drivers and other motorists to understand the appropriate lane for thru and turning movements. This can help reduce the number of sudden lane changes at intersection approaches. Similarly, well-marked turn lanes can provide adequate warning for motorists concerning the proper lanes for maneuvers ahead. Well marked lane lines, direction arrows (left turn, right turn, or through), and pavement delineation (raised pavement markers) can be particularly beneficial at night and/or in rainy weather.

7. Larger traffic signal lenses - The intersection of two roadways is often associated with large frequencies (i.e., clusters) of accidents related to rear-end and turning collisions as a result of conflicting traffic movements. To reduce such intersection collisions involving buses (and other motor vehicle crashes as well), a number of traffic signal-related improvements may be helpful. For example, the use of 12-inch signal lenses instead of the customary 8-inch lenses allows approaching motorists to see the signal more clearly. Vehicles following a transit bus are, therefore, more likely to see a red light and stop behind a bus at the intersection. This is important, because vehicles behind a bus have a limited field of vision of the traffic signal due to the height of the bus and may see the signal of a larger red signal head sooner.

8. Longer clearance intervals - In addition to having larger traffic signal heads, the use of adequate traffic signal intervals can reduce the chance of angle accidents between buses and vehicles at side street intersections. This is because some intersections are currently programmed with a minimal amount of yellow time that results in more vehicles running red lights and colliding with vehicles on the cross street. Angle accidents may be a particular problem for transit buses because of their greater length and, therefore, greater target area for vehicles coming from cross streets. In addition, at intersections where pedestrians are present, the use of extended clearance intervals and/or adequately timed pedestrian crossing intervals can help to reduce pedestrian accidents, because pedestrians are less likely to be caught out in the middle of the street when the signal changes to green for oncoming traffic.

9. Separate left-turn phasing - Another common transit bus collision type involves buses making left turns at intersections. Without left-turn phasing, a left-turning bus must wait in traffic for an adequate gap in oncoming traffic before making the left-turn. Under congested traffic conditions, bus drivers may be tempted or forced

into making a left-turn with an inadequate gap and may be struck by an oncoming thru vehicle. This, of course, is a particular problem for buses since they are much longer than cars and require a larger gap in traffic to safely complete a left-turn. Separate left-turn phasing stops the oncoming movement of traffic, allowing a protected interval for the bus to turn left. Left-turn phasing has been shown to have a significant effect on such left-turn accidents for motor vehicles in general and should be particularly beneficial in reducing such accidents involving transit buses along routes where they are required to make left turns.

10. Adequate nighttime lighting - One of the accident problems found involved nighttime bus crashes along streets with lighting. This is probably the result of very low mileage of bus travel on local unlighted streets at night, with most of the interstate nighttime bus travel occurring on major streets where lighting is often present. To safely provide for nighttime travel for buses, trucks, and other vehicles, adequate levels of overhead lighting are needed, particularly at interchanges and on interstates and freeways, and along urban and suburban and arterial streets. In providing nighttime lighting, the luminaire poles should be of the breakaway design to reduce the injury resulting from buses or other vehicles running off the road and striking the poles.

11. Safe design of guardrail and other roadside hardware - In developing design criteria for guardrail, bridgerail, and other roadside hardware, designers may not have considered large buses as a possible striking vehicle. Some types of more stable guardrail, such as thriebeam, allow a bus, truck, or other striking vehicle to be supported and redirected back into the lane of traffic, as opposed to running through the guardrail and rolling over or striking a rigid object. On rural high-speed roads in particular, it is important to consider the possibility of buses and other large vehicles striking guardrail and to design to the extent possible with these vehicles in mind.

12. Design flatter slopes and better clear zones - Past studies indicate that one of the more severe types of bus crashes results from bus rollovers, particularly on steep roadside slopes. One important roadway improvement is to provide flatter slopes (e.g., slopes of 4:1 or flatter) such that a bus or other vehicle that runs off the road will have a much greater chance to safely recover without rolling over. In addition, the roadside should be cleared to the extent possible to reduce the presence of trees, utility poles, concrete culverts, and other rigid objects that could result in serious injury or death if struck by a bus or other run-off-road vehicle.

13. Design and improvement of horizontal curves - With respect to roadway sections that contain curves to the right or left, several kinds of basic design features or improvements are important to reduce the chance of a bus or other vehicle running off the road. For example, such curves should be designed with adequate lane and shoulder width, should be designed with adequate superelevation (i.e., banking), warning signs and chevron signs as needed (particularly on sharp curves where vehicles must slow down to safely negotiate around them), adequate delineation, and roadside designs with mild slopes relatively clear of roadside objects.

14. Exclusive bus lanes - In urbanized areas, exclusive bus lanes may be needed to facilitate traffic flow during peak periods. These lanes improve the operations and safety of buses and bus passengers, particularly during the morning and afternoon rush hours. Such exclusive bus lanes also encourage bus ridership, thereby reducing overall traffic congestion as well as reducing fuel usage.

15. Improved snow and ice removal - Based on the analysis discussed earlier, bus crashes tended to be greater in frequency during the winter months than the summer months. This may be partly due to the increased snow and ice on the roadways that could contribute to rear-end and other crashes. While snow removal is a problem in many northern states, special efforts should be made to promptly clear streets of snow and ice along bus routes.

The roadway design and other improvements discussed above are examples of some roadway and engineering enhancements that can be helpful in the reduction of bus crashes on various types of roadways. These and other types of normal traffic and safety engineering practices can reduce accidents involving buses as well as other vehicle types.

Bus Stop Location

The safety responsibility of bus transit carriers has been extended to bus stop loading and unloading areas under some circumstances. For example, boarding and alighting passengers may slip and fall on icy surfaces. They may be bumped off narrow sidewalk loading areas, perhaps into the street or down an embankment. In rural or suburban areas, passengers may be unloaded at unpaved areas where there is greater bus/road step height, poor footing, or tripping hazards.

Transit agencies should provide adequate loading areas for passengers, reasonably free from safety hazards. This responsibility will increase as Americans with Disabilities Act (ADA) accessibility and facility design requirements become the common standard of practice. Bus stops should be located in paved areas, with slip-resistant walking surfaces, and should be free from tripping hazards. The criteria for slip resistance and tripping hazard height are outlined in the American National Standard ANSI-A117.1.[16] The stop area should be wide enough to allow for queuing passengers and to accommodate wheelchair loading and unloading, without disrupting normal on-street pedestrian movement in the vicinity of the stop. Passengers in a single file queue typically line up with an inter-personal spacing of 20 inches, and require a lateral space of 30 inches.[17]

Near-side versus far-side bus stop location has an impact on passenger and pedestrian safety.[18,19] Factors that influence the selection of bus stop locations include: availability of curb and sidewalk space; bus routing patterns (turns); location of other stops or bus services; passenger and street pedestrian volumes; passenger accessibility; street width; one-way or two-way streets; traffic volumes and turning volumes; traffic controls; and signal cycles. From the bus passenger and pedestrian safety viewpoint, the far-side location is the safest because pedestrians cross in the crosswalk behind the bus where they can be seen, and because the bus does not block the view of traffic controls and other intersection traffic. Other advantages of the far-side bus stop include:

- reduced bus conflicts with right-turn vehicles;
- increased intersection capacity by freeing the curb lane for thru movement;
- improved sight distances at intersections;
- shorter curb length requirements for bus-stop approaches;
- easier reentry into traffic after passenger loading.

Bus shelters provide passengers with protection from wind, rain, and snow. Shelter location is an important consideration, because the shelter can occupy sidewalk area needed for passenger waiting, boarding and unloading, and other nearby pedestrian activities. If the shelter is located too close to the curb, the restricted space between the fixed shelter and the moving bus can become hazardous to passengers.

Bus Design and Operations to Reduce Passenger Injuries

Bus passengers can be exposed to non-collision accident hazards while riding buses, boarding and alighting the bus, and at or near bus stops. Studies of non-collision related accidents on buses show that the majority are due to falls.[5] Passenger falls during the movement of the bus occur due to the forces of sudden acceleration or deceleration, lateral motion on curves, and slip or trip-related falls. Boarding and alighting accidents are generally related to slips or trips within the stepwell, or overstepping of the step trend. Bus stop location, walking surface conditions at the stop, sidewalk width, and illegal parking in bus stop zones are factors that contribute to passenger accidents prior to boarding or after alighting.

As mentioned in Chapter 5, commercial buses are more likely to be struck rather than to strike another vehicle. Many of these accidents occur when a vehicle rear-ends a bus that has stopped to pick-up or discharge passengers. During daylight hours, a stop arm (as is commonly installed on school buses) could be raised to warn drivers who are following the bus that the bus has stopped. Bus conspicuity at night and during inclement weather could be improved through the installation of brighter warning lights on the rear of the bus or perhaps through a special illuminated "STOP" sign on the rear of the bus.

Some rear-end and sideslope accidents may be prevented by improving the visibility of turn signals on buses. Audible warning devices could be attached to buses to warn other motorists of the bus's presence. Even closed circuit television cameras could be installed to give the bus driver a better view of the sides and rear. To reduce injury severity to the driver and occupants of the other vehicle, energy-absorbing material may be placed at the front and the back of the bus.

Motion-Related Falls

Sudden deceleration of buses is unavoidable when the driver must stop to avoid a vehicular accident, or obey a changing traffic signal. Ideally, buses should not operate with standees in the aisles, but this objective is difficult to attain. Where seats are available, every effort should be made to encourage passengers to sit while the bus is in motion, and to remain seated until the bus stops. The strategic location of handholds, within easy reach of passengers in aisles, is another means of preventing motion falls. Excessive forces due to acceleration and lateral movement on curves can largely be avoided by training drivers to be aware of passenger motion hazards.

In both motion-related and collision-related falls, the effects of "second impacts" should be minimized.[4] These impacts occur when passengers are thrown about the interior of the vehicle. All interior surfaces, edges, trim, etc., should be designed so that clothing will not be caught, or the victim cut by sharp edges. Interior seats, partitions, railings, and other elements should be securely mounted so that they will not loosen during normal use or under the force of a collision. Protrusions that passengers can bump into under normal use or during falls should be avoided wherever possible. The use of materials that shatter or break upon impact should also be avoided. Padded surfaces provide passengers added impact protection in a collision, but are also known to encourage vandalism.

Falls Due to Trips and Slips

The selection of non-slip flooring material, careful application of these materials, and continued maintenance of a safe walking surface is necessary to reduce slipping and tripping falls in buses. The standard for a slip-resistant walking surface is set by the United States Architectural and Transportation Barriers Compliance Board (USATBC).[20] Many flooring materials that are normally considered slip-resistant will not meet that standard. Flooring materials selected for bus transit use should be tested for slip-resistance using procedures specified by the American Society for Testing Materials (ASTM), or their recognized equivalent.[21] Slips on bus floors can also result from newspapers, spilled foods or liquids, mud, or other foreign materials on the floor. Slip accidents can occur in northern climates due to icing of stepwell treads.

Tripping hazards occur where the walking surface is not level. In the normal walking pattern toe clearances vary between 0.375 in. and 1.5 in., with an average of about 0.6 in.[22] However, passengers in buses, particularly those standing in aisles, potentially could trip on surface differentials lower than 0.375 in. in lateral or sideways movement of their feet as they adjust standing positions. The USATBC has set a standard of a surface height differential of 0.25 in. as the threshold at which trip hazard mitigation should occur.[23] Tripping hazards do not generally occur with bus floor surfaces unless the surface is worn and/or the surface materials become loose or dislodged in some manner. This requires periodic inspection of bus floors and replacement of floors with tripping hazard defects. To avoid slipping hazards caused by spills or refuse, the consumption of food and drink should be prohibited on buses.

Boarding and Alighting Falls

Boarding and alighting falls occur within the stepwell or on the ground surface outside the bus. Because of the characteristics of stair falls, alighting stepwell falls are typically more serious than boarding falls. In one study of stair falls in transit terminals, 94.1 percent of the ambulance-aided cases occurred in the downward direction.[12] The reason for this difference in severity is the greater fall height and impact energy of the downward direction stair fall. The elements of safe stair design are well established.[24,25,26] Riser heights should be between 6 to 8 inches and effective tread width between 11 and 12 inches. A well-established safety requirement is that riser heights and tread widths be consistent and equal within small tolerances in any stair flight. Handrails should be reachable and graspable and should extend beyond the top and bottom treads. Treads should be well lighted, and step edges visually well defined. Tread surfaces should be slip-resistant.

The "Kneeling Bus" was developed to reduce the height of ground to first step on the bus, for the convenience and safety of users. Many drivers dislike using the kneeling mechanism, and it can lock in the kneeling position, or otherwise malfunction, sometimes taking the bus out of service.

The "Low Floor Bus" has recently been developed to overcome stepwell safety problems and to provide a simpler means of accommodating wheelchair users.[27] The bus floor in one manufacturer's version is 14.38 inches above ground, and the ground clearance under the rear axle only 6 inches. This manufacturer also offers a kneeling mechanism option to lower the bus floor an additional three to four inches. Wheelchair access is via a ramp. The bus is being tested at a major regional airport. It is claimed that the low floor is speeding up the loading and unloading of passengers with baggage, significantly reducing bus stop dwell times and bus turnaround time.

The ADA (Subpart D, section 37.71 titled, "Purchase or lease of new non-rail vehicles by public entities operating fixed route systems" paragraph (a)) states that, "Except as provided elsewhere in this section, each public entity operating a fixed route system making a solicitation after August 25, 1990, to purchase or lease a new bus or other new vehicle for use on the system, shall ensure the vehicle is readily accessible and usable by individuals with disabilities, including individuals who use wheelchairs."[28] There are few waivers to this requirement, assuring that with normal replacement of existing bus fleets, eventually all public buses will be wheelchair accessible.

Seat Design and Performance

Good seat design is an important countermeasure to reduce passenger injury either as a result of collisions or of sudden stops by the bus. Past accident studies have shown that many passenger injuries result from a lack of seat retention or from the impact of unrestrained seats with otherwise uninjured occupants.

Among designers, legislators and researchers, it is generally agreed that seat performance should achieve two major objectives:

- In the event of a passenger impacting the seat in front, the seat should be capable of local deformation in the knee/chest area to enable "pocketing" of the passenger, thus absorbing some of the initial kinetic energy. It should also provide for controlled deformation of the seat back (without fracture) to absorb the remaining kinetic energy and prevent the passenger from ramping over the top of the seat.

- Through careful design and placement of structural members and the use of adequate energy-absorbing padding, the seat should be capable of distributing local impact forces to the head, thorax, chest, and knee areas in such a way as to prevent serious injury.[3]

A seat should be designed with:

- Strong seat anchorages to ensure seat retention.

- Provision for knee penetration to minimize femur forces and to prevent the pivoting of the upper body and consequent high head impact loads.

- Adequate seat back height to prevent ramping and unacceptable head impact.

- Suitable seat/back stiffness to allow passenger retention without either a) premature seat collapse or b) excessive body forces.
- Adequate energy-absorbing padding in the knee and head protection zones to prevent unduly high localized forces.
- Suitable seat/back angle to enhance the retention capabilities of the seat.[3]

Bus Driver Screening and Education

Recommendations for improved bus safety as affected by the bus driver have been developed by the Wisconsin Department of Transportation and other sources.[29,30] They include the following:

1. Thoroughly screen potential bus drivers. The screening process should consider the applicant's past driving record and include a physical examination, an illicit drug test, and a background check. Evidence from the trucking industry indicates that individuals with poor driving records in their private car are more likely to have a poor professional driving record.[5]
2. Properly train newly hired drivers, covering both standard and emergency operating procedures. The Wisconsin Department of Transportation recommends that driver training consist of four stages:

   A. Classroom training.
   This covers company policies, general vehicle orientation, route system orientation, defensive driving skills, and passenger relations.

   B. Off-the-road vehicle training.
   This covers detailed vehicle orientation and basic vehicle maneuvers such as turning, stopping, and checking clearance.

   C. Road work and route familiarization.
   Once trainees learn the basic maneuvers, they should receive extensive practice in driving a bus, particularly on their assigned routes.

   D. Revenue service under observation.
   The trainee should first ride with an experienced operator and observe that operator's activities while in revenue service. Then the trainee should operate the bus and handle fares while the experienced operator monitors. In training, particular attention should be devoted to driving at a speed appropriate

for the existing road and light conditions, the importance of getting sufficient rest, and how to safely drive under adverse weather conditions.

3. Develop a structured recurrent training program. Such a program should include classroom instruction as well as simulator and/or behind-the-wheel instruction. The program should be geared toward maintaining and reinforcing good driving habits. Additionally, remedial training should be developed for and given to "problem drivers."
4. Continually monitor and evaluate the performance of drivers. This assessment should be done by someone who is familiar with the driver's record, qualified to interpret it, and authorized to impose appropriate measures such as remedial training or disciplinary action. New drivers should be observed by senior drivers and supervisors. Senior drivers should be monitored by supervisors, other transit agency representatives, or firms hired to independently evaluate agency operations.

Transit Agency Policies

A number of policies and practices by transit agencies can help to minimize risk of collisions and/or passenger injuries related to transit bus operations. These include:[29,30]

1. Routing should lower accident exposure by minimizing turns, allowing for intersection controls, avoiding dangerous intersections, and not crossing several lanes of traffic. Schedules should incorporate adequate running time so that drivers do not feel compelled to speed. Transit bus schedules should also include layover time to give drivers a short break and to allow for traffic delays.
2. Establish a safety committee. Possible tasks for the committee include monitoring safety policies and procedures, setting annual safety goals, and recommending changes in procedures when warranted. The committee could organize meetings for all employees. These meetings provide the opportunity to discuss safety policies and procedures and to resolve safety concerns. This committee could

also offer awards and other recognition for accident-free driving as incentives for increased safety awareness.

3. Inspect and maintain the bus regularly. Effective preventive maintenance not only makes buses safer, but also adds to their useful life and reliability. Daily inspections are needed to check fuel tank and other fluid levels, to replace burned out lights, etc. Inspections can help ensure reporting of torn seats, worn or broken steps, cracked or broken glass, and other potentially dangerous situations in passenger areas. Pre-trip inspections should include vehicle systems, access doors, and the bus interior. Periodic inspections should be made to detect damage before major repairs are necessary. Interval maintenance should be set up on a time and mileage schedule to anticipate wear, alignment, and deterioration problems. Breakdown maintenance is needed when a vehicle failure (e.g., a flat tire or loss of brake function) makes it unsafe to continue operation.

Bus inspection and maintenance for safety is especially important for older buses, since the analysis showed that older buses are overrepresented in crashes.

Ideally, specific departments or individuals within transit agencies should be assigned responsibility and authority for implementing, performing, and monitoring various safety activities. These activities should include equipment and facility inspections, safety instruction, monitoring of employee work habits, incentives, accident reporting and investigation, meetings, and program documentation. A safe driver award program, based on the number of days without a collision or on-board accident, can offer a strong incentive for drivers to operate their buses more safely.

Safety and Security Incident Reporting

An organized safety and security reporting program is important for bus transit carriers to monitor the number and types of incidents occurring on the system.[31] Buses should be equipped with two-way radios so that the dispatcher can be notified when an accident has occurred. To facilitate accident investigation, a report needs to be completed for each accident and a supervisor should be dispatched to the scene. These data can provide useful insights on the potential causes of these incidents, and help to identify appropriate preventative measures. A thorough record of an incident can prove to be invaluable if there is a subsequent litigation related to it. At times, litigations can be filed as much as two years after an incident, and facts altered where there is no record, or the record is incomplete.

In addition to providing more complete reporting of bus crashes and other incidents, transit agencies need to identify intersections and highway segments where there are clusters of bus crashes. A good example of this is the New York City Transit Authority, which in 1990 identified the 10 locations having the greatest number of bus crashes in the previous two years.[32] Areas around these locations were mapped to establish other adjacent accident problems. An analysis of bus accidents provided information on accident characteristics which was supplemented by field surveys. Recommendations were made for remedial action as considered appropriate. Such a procedure is highly recommended for bus transit accidents by other transit agencies in cooperation with local traffic and safety engineers.

Future Research Needs

During the course of the study, several ideas for future research in the area of bus transit safety emerged. The primary future need is for a study that integrates accident data with high-quality, widespread exposure data. Exposure data can help answer more subtle questions about routes, drivers, and vehicles that could not be answered with the methods of this study, such as:

* What are the levels of bus exposure (i.e., mileage) by bus age, bus type (e.g., interstate buses vs. local transit buses), type of roadway, and by driver factors (e.g., driver age, driving experience)?
* What types of streets and highways have the highest bus accident rates?
* Are bus accident rates higher at certain times of day and for various types of buses, driver factors, etc.?
* What are the specific causes of bus passenger injuries from a wide range of bus transit agencies in the U.S.?
* What are the specific safety effects of various training programs for bus drivers?

* What are the effects of specific improvements (e.g., related to routing, bus stop location, geometric and traffic control improvements, etc.) on bus crash rates?

The HSIS data do not separate local transit and intercity buses. Yet these types of buses are likely to have different levels of exposure and are operated under different conditions. Bus exposure data can be obtained from local transit agency and interstate bus company records. In order to merge the exposure data with accident data, the researchers would have to establish a common locational reference system and would have to recode some of the data.

The study team also identified several other areas for promising future bus safety research. First, accident data should be obtained from states not included in the HSIS data base. A larger number of states will incorporate a wider range of roadway and weather conditions and increase the sample of injury data. Thus, more definite conclusions relating accident characteristics to bus crashes and associated injuries can be drawn.

Another area of needed research would involve a more extensive data base, to be obtained from local transit agencies, of non-collision accidents would allow better comparisons of different bus designs and operating practices. Also, research is needed on accidents where the bus contributed to an accident but did not collide with other vehicles or persons. For example, pedestrians may step out in front of buses and be struck by passing automobiles. However, such accidents would not have appeared in the data base in this study. It would probably be very labor intensive to collect adequate data samples in these two areas, but the results would likely be very useful for transit agencies.

Buses should be subjected to crashworthiness tests to determine the level of driver and passenger safety offered by various bus designs. Computer simulation of bus crashes could also be attempted. Accident reconstruction studies of bus crashes could help to identify specific crash causes.

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APPENDIX A

ADDITIONAL LITERATURE - BUS CRASHES

Injury Mechanisms for Collision Accidents

Dixon, Williams, and Joubert discuss the injury-producing mechanisms for five types of collision accidents: head-on, rear-end, sideswipe, side impact, and rollover. For head-on collisions, passenger impacts with seats are the principal cause of both facial and head injuries. Injuries result from frontal collision involvement or from contact between passengers and seat backs. Intrusion of bus walls and roofs into the passenger compartment is usually not a significant cause of injury.[3]

Rear-end collisions usually involve slower impact velocities and milder acceleration levels. The load applied to the passenger is distributed over his back and does not involve any point loads. There is a high possibility of whiplash with low back seats, especially padded ones, which produce a distinct neck bending location. Side-facing seats cause the same problems in rear-end accidents as they do in head-on collisions, though the injuries sustained tend to be less severe. As with head-on crashes, intrusion into the passenger compartment is usually not a problem.[3]

Sideswipe collisions are generally the least severe of all bus collision types in terms of deceleration levels. The major concern in such collisions is the intrusion of the bus side wall into the passenger compartment.[3] A side impact accident involves relatively high levels of deceleration as compared to a sideswipe collision. In such an accident, there is a much greater chance of passenger compartment deformation. Lateral accelerations tend to force passengers out of their seats. Window passengers are likely to either contact the window or side wall or to slide across the seat, forcing aisle passengers against the armrest. If there is no armrest, passengers may be thrown out of their seats into the aisle or across the aisle onto the adjacent seat and its occupants. Seats that face the aisle offer no means of passenger restraint and allow passengers to be catapulted across the vehicle.[3]

Of the five accident types, rollover accidents are the most likely to cause injury. The lack of passenger restraints results in uncontrolled body movement and passengers impact internal bus fittings and other passengers.

Partial or complete passenger ejection through windows, doors, and openings in the passenger compartment created by the collision may result in severe injuries.[3] For all motor vehicle accidents, occupants who are ejected are four times more likely to have suffered a serious or fatal injury than occupants who were not ejected.[1] Injuries may also occur through the collapse of a roof or wall into the passenger compartment.[3]

Preventable and Non-Preventable Accidents

The National Safety Council has established standards for classifying accidents as either preventable or non-preventable. Based on its criteria, a preventable accident is any accident in which the driver failed to do everything he/she could reasonably have done to avoid it. By contrast, a non-preventable accident is any accident in which the driver has done everything he/she could have done to avoid it.[29]

The Council defines 13 types of potentially preventable accidents:

1. Intersection - Drivers should approach, enter, and cross intersections prepared to avoid accidents that might occur through the action of other drivers.

2. Vehicle Ahead - Drivers can reduce rear-end collisions by maintaining a safe following distance at all times.

3. Vehicle Behind - Drivers can reduce the risk of being struck from behind by maintaining a margin of safety in their own following distance.

4. Passing - Failure to pass safely indicates faulty judgment and the possible failure to consider one or more of the important factors a driver must observe before attempting a maneuver.

5. Being Passed - Sideswipes and cut-offs while the bus is being passed are preventable when the driver fails to yield to the passing vehicle by not slowing down or not moving to the right where possible.

6. Oncoming - Even when an oncoming vehicle enters a driver's lane, it may be possible in some cases for the driver to avoid an impact.

7. Fixed Objects - Collisions with fixed objects usually involve failure to check or properly judge lane placement of the bus.

8. Pedestrians - Drivers should travel through school zones, shopping areas, residential streets, and other areas of pedestrian traffic at reduced speeds.

9. Private Property - When a driver is expected to make pick-ups or drop-offs at unusual locations, or on driveways not built to support heavy commercial vehicles, it is his/her responsibility to discuss the operation with the transit management and to obtain permission prior to entering the area.

10. Passenger Accidents - These are preventable when they are caused by faulty operation of the bus by the driver.

11. Non-collision - Many accidents, such as overturning, or running off the road, may result from emergency action by the driver to avoid a collision. The driver's actions should be examined for possible errors or lack of defensive driving practices.

12. Failure to Adjust for Conditions - Adverse weather conditions increase the hazards of driving. Drivers must use caution in adverse conditions.

13. Miscellaneous - This includes the improper use of doors or interlock systems and passengers hanging out of windows.

Large-Scale Studies

In addition to studying Chicago data, various researchers have also analyzed large accident data bases in the United Kingdom, Delhi (India), and Australia.

United Kingdom

During 1976-1978, the Department of Industry in the United Kingdom collected data on approximately 5,000 Public Service Vehicle (PSV) accidents.[33] These were accidents in which either injury occurred or the PSV was severely damaged (requiring at least 180 hours of craft repair labor). The study found that

- Concerning hours of the day, the maximum number of accidents (10%) occurred between 4 and 5 p.m.

- Concerning days of the week, the maximum number (18%) occurred on Fridays; the minimum number (4%) occurred on Sundays.

- In some 9 percent of the cases, there was a bus lane.

- The road surface was reported as being wet in 25 percent of the accidents; in 15 percent of the cases it was raining. The number of accidents in which snow or ice was contributory was very small (3%).

- Street lighting was on in 17 percent; 14 percent were described as "dark" and 6 percent as "halflight."

- In 35 percent, the bus was cruising, in 33 percent it was stationary or moving off from a bus stop.

- In 8 percent, the bus was turning at a junction, and in 9 percent it was proceeding across a junction.

- Some emergency action was reported in 36 percent.

- Skidding was mentioned in 6 percent.

- 99 percent of the drivers were male, and drivers were about equally distributed among the 20 to 29, 30 to 39, and 40+ age groups.

- 20 percent of the drivers had fewer than two years of experience while 30 percent had two to four years of experience.

- No other vehicle was involved in 90 percent of the accidents, a car was involved in 5 percent and some other vehicle in 5 percent.

- In only 20 percent of cases was bus repair needed; damage occurred predominantly to the front or front corners (70%).

- Of the casualties, 20 percent were pedestrians and 70 percent were bus passengers -- on the ground, on the platform, in the gangway, on the staircase, and seated.

- Injured passengers were mostly female (75%) and a disproportionate number were 60 and over (ranging from 31% in seat to 51% on ground).

- Other casualties (pedestrians, cyclists, motorcyclists, conductors, and drivers) were mostly male (67%) and young (88 percent of injured motorcyclists were under 30, while 69% of injured cyclists and 44% of pedestrians were also under 30).

- In 6 percent of passenger casualty cases, some apparent disability such as intoxication was reported.

- In 12 percent of passenger casualty cases, the person was temporarily impeded, usually by a shopping bag.

Delhi, India

In India, buses are involved in about five times more accidents than might be expected from their numbers on the road. Fatality rates per million bus kilometers traveled are about six times greater than that for public transport in London. An analysis of the Delhi Transport Commission's (DTC) accident records for 1980-81 showed that

- The majority of accidents involved either another bus or truck.
- The majority of fatal accidents involved pedestrians and cyclists.
- More than 50% of injury accidents involved pedestrians, cyclists, and motorcyclists.
- Proportionately more injury accidents took place during darkness and when passengers were travelling on the footboard of the bus.

As part of the same study, 580 DTC bus drivers were interviewed to understand how driver factors (such as training, experience, and working conditions) could affect accident rates. More than 200 DTC buses were inspected to assess the condition of items (such as tire condition, mirrors, steering play, lights, handholds, and seats) that may have an effect on bus safety. However, no accident data were used or collected to assess how driver and mechanical factors actually affect accident rates.[34]

Australia

Within Australia, the Australian Bureau of Statistics has computer printouts of bus accident summary data for the State of Victoria. The data do not specify whether school buses are included. In 1969 there were three fatal accidents and 109 injury accidents involving buses. The injury accidents were as follows: 41 angle collisions, 20 rear-end, six head-on, five sideswipe, 16 pedestrians, 15 falls from moving vehicle, three off-road and struck fixed object, two off-road with no fixed object, and one object on roadway.[35] In 1971 to 1972, nearly three-fifths of all injury-producing accidents were angle and rear-end collisions and falls from the bus.[36]

Case Studies

The National Transportation Safety Board (NTSB; formerly the Bureau of Motor Carrier Safety, BMCS) investigates selected bus accidents to determine their causes and to recommend countermeasures. Short descriptions of seven case studies are presented below.

On July 31, 1967, on the Sunshine State Parkway near Stuart, Florida, a tour bus skidded out of control on wet pavement, left the roadway, and overturned. The driver and all 20 passengers aboard were injured, and property damage amounted to $35,000. Examination of the bus after the accident showed that three of the four rear tires were seriously worn. The bus was being driven too fast for the conditions -- wet pavement and worn tires. The BMCS called for a "more meaningful management commitment to safe operations and to compliance with safety regulations..." and emphasized that "both management and drivers must recognize and fulfill their responsibilities to passengers and the public to operate vehicles safely under all conditions."[37]

On September 10, 1967, on the New Jersey Turnpike, an intercity bus collided with the rear of a disabled tractor-semitrailer combination being towed by a wrecker. Although 2,440 gallons of gasoline were spilled from the truck, there was no fire or explosion. The bus driver was killed and all eight passengers were injured, one seriously. Property damages amounted to $44,000. The BMCS identified several contributing factors: 1) the bus was travelling over the posted limit, 2) the driver was apparently inattentive, perhaps due to fatigue, 3) the disabled vehicle may have been inadequately lighted, and 4) the disabled vehicle was not taken off at the nearest exit to reduce exposure. The BMCS recommended that "motor carriers should take steps to reduce the period of exposure to possible collision by making certain that disabled vehicles are towed properly and removed from the highway as quickly as possible."[38]

On October 9, 1968, an intercity bus entered a railroad crossing in spite of warning signals and was struck by a freight train in Calvin, Oklahoma. The bus was shoved off the tracks and overturned. The driver and 21 passengers were injured. Property damage totalled $25,000. The driver asserted that the brakes had failed but extensive testing found no defects. The BMCS attributed the accident to the driver, who entered the crossing in disregard of warning signals. It recommended that "motor passenger carriers must insist that their drivers come to a full stop at grade crossings, and additionally must require that drivers pause long enough to look both ways, and assure themselves that the way is safe for crossing."[39]

On October 11, 1975, a chartered bus travelling along Interstate 495 in Bethesda, Maryland, lost traction while negotiating a curve during heavy rain. The bus rolled over and landed on its left side in a roadside ravine. Of the 29 bus occupants, 26 were injured. The NTSB determined that the inadequate frictional coefficient between the tires and the pavement caused this accident. For urgent follow-up, the NTSB recommended that the state of Maryland "install flashing lights, which are activated by wet pavement conditions, to complement the recently installed 'Slippery when Wet' sign, and reduce the speed limit until construction and resurfacing can be accomplished."[40]

On November 30, 1983, an intercity bus travelling on US 59 near Livingston, Texas, struck the rear of an unloaded tractor-flatbed semitrailer. The bus then veered across the adjacent lane, crashed through a bridge guardrail, and landed on a creek bank 26 feet below the bridge. Six of the 11 bus passengers were killed, including three of four who were ejected through the windows. Several factors contributed to the accident and its severity: 1) the bus driver was operating his bus above the posted speed limit; 2) the bus driver was not alert, perhaps because of fatigue, and 3) the 40-year-old bridge guardrail was not designed to contain and safely contain a large vehicle travelling at high speed. The NTSB urged that the bus company monitor its drivers' compliance with posted speed limits and that it determine means to prevent drivers from dozing at the wheel.[41]

On November 19, 1988, an intercity bus on Interstate 65 in Nashville, Tennessee, suddenly went out of control while travelling in a construction zone. The bus overturned and came to rest on an embankment. Of the 38 passengers, 12 sustained serious injuries and 26 received minor injuries. The driver was ejected out the front but received minor injuries. The NTSB determined that this accident resulted from bus operation above the posted speed limit, compounded by different coefficients of friction of the travel lanes in the construction zone. In fact, the driver had a driving record that indicated a tendency to speed. The NTSB recommended that the bus company review and modify its policies concerning unsafe drivers, driver training, medical histories, and supervisor evaluations.[42]

APPENDIX B

SUPPLEMENTAL TABLES OF BUS CRASHES IN FIVE STATES

Table B-1. Number of bus crashes by crash severity and state - full file.

Crash Severity	Illinois	Maine	Michigan	Minnesota	Utah	Total[2]
Fatal	23 (0.6)[1]	1 (0.3)	18 (0.8)	17 (0.8)	6 (1.1)	65 (0.7)
Injury	1081 (28.3)	83 (22.3)	601 (27.8)	642 (31.9)	130 (24.7)	2537 (28.5)
Property Damage Only	2721 (71.1)	288 (77.4)	1541 (71.3)	1355 (67.3)	390 (74.1)	6295 (70.8)
Total	3825	372	2160	2014	526	8897

[1]Column percent
[2]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-2. Number of bus crashes by crash severity and state - urban crashes only.

Crash Severity	Illinois	Michigan	Minnesota	Utah	Total[2]
Fatal	15 (0.4)[1]	4 (0.5)	5 (0.6)	1 (0.4)	25 (0.5)
Injury	931 (27.7)	224 (27.0)	273 (32.2)	65 (26.5)	1493 (28.3)
Property Damage Only	2413 (71.8)	603 (72.6)	570 (67.2)	179 (73.1)	3765 (71.3)
Total	3359	831	848	245	5283

[1]Column percent
[2]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-3. Number of crashes by crash severity and vehicle type - 1988-1989 Illinois data.

Crash Severity	Commercial Bus	Cars, Pickups	Trucks	School Bus	Other	Total
Fatal	7 (0.5)[1]	2,205 (0.4)	343 (0.9)	3 (0.2)	320 (0.8)	2,878 (0.5)
Injury	423 (28.2)	170,193 (31.4)	9,619 (24.9)	314 (25.1)	12,946 (33.7)	193,495 (31.1)
Property Damage Only	1,070 (71.3)	369,262 (68.2)	28,637 (74.2)	936 (74.7)	25,172 (65.5)	425,077 (68.4)
Total	1,500	541,660	38,599	1,253	38,438	621,450

[1]Column percent

Table B-4. Number and percent distribution of bus crashes by year.

Year	Total Crashes[2]	Injury and Fatal Crashes[2]	% Injury and Fatal
1985	1837 (20.7)[1]	568 (21.8)	30.9
1986	1779 (20.0)	510 (19.6)	28.7
1987	1643 (18.5)	499 (19.2)	30.4
1988	1800 (20.2)	522 (20.1)	29.0
1989	1838 (20.7)	503 (19.3)	27.4
Total	8897	2602	29.2

[1]Column percent
[2]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-5. Number and percent distribution of bus crashes by month.[1]

Month	Total Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
January	354 (11.6)[2]	77 (9.2)	21.8
February	317 (10.4)	68 (8.1)	21.5
March	236 (7.7)	68 (8.1)	28.8
April	225 (7.4)	78 (9.3)	34.7
May	248 (8.1)	89 (10.6)	35.9
June	214 (7.0)	61 (7.3)	28.5
July	179 (5.9)	54 (6.4)	30.2
August	193 (6.3)	57 (6.8)	29.5
September	262 (8.6)	69 (8.2)	26.3
October	250 (8.2)	64 (7.6)	25.6
November	302 (9.9)	80 (9.5)	26.5
December	278 (9.1)	74 (8.8)	26.6
Total	3058	839	27.4

[1]Data were not available for Illinois and Minnesota.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-6. Number and percent distribution of urban bus crashes by day of the week.[1]

Day of Week	Total Urban Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
Sunday	249 (4.6)[2]	81 (5.3)	32.5
Monday	942 (17.5)	262 (17.1)	27.8
Tuesday	893 (16.6)	300 (19.5)	33.6
Wednesday	909 (16.9)	257 (16.7)	28.3
Thursday	897 (16.7)	252 (16.4)	28.1
Friday	968 (18.0)	254 (16.5)	26.2
Saturday	513 (9.6)	129 (8.4)	25.1
Total	5371	1535	28.6

[1]Data were not available for Maine.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off-error.

$p = 0.05$

Table B-7. Number and percent distribution of urban bus crashes by time of the day.[1]

Time	Total Urban Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
12:00 a.m. - 2:59 a.m.	77 (1.4)[2]	29 (1.9)	37.7
3:00 a.m. - 5:59 a.m.	52 (1.0)	14 (0.9)	26.9
6:00 a.m. - 8:59 a.m.	1070 (19.9)	296 (19.3)	27.7
9:00 a.m. - 11:59 a.m.	899 (16.7)	269 (17.5)	29.9
12:00 noon - 2:59 p.m.	1041 (19.4)	279 (18.2)	26.8
3:00 p.m. - 5:59 p.m.	1510 (28.1)	422 (27.5)	27.9
6:00 p.m. - 8:59 p.m.	491 (9.1)	138 (9.0)	28.1
9:00 p.m. - 11:59 p.m.	197 (3.7)	78 (5.1)	39.6
Not stated/ Unknown	35 (0.7)	11 (0.7)	31.4
Total	5372	1536	28.6

[1]Data were not available for Maine.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

$p = 0.01$

Table B-8. Number and percent distribution of urban bus crashes by light condition.[1]

Light Condition	Total Urban Crashes	Injury and Fatal Crashes	% Injury and Fatal
Dawn/Dusk	222 (4.9)[2]	58 (4.4)	26.1
Daylight	3643 (80.3)	1032 (79.0)	28.3
Darkness	115 (2.5)	29 (2.2)	25.2
Darkness, lighted	556 (12.3)	188 (14.4)	33.8
Unknown	2 (0.0)	0 (0.0)	0.0
Total	4538	1307	28.8

[1]Data were not available for Maine and Michigan.
[2]Column percent

p = 0.05

Table B-9. Number and percent distribution of bus crashes by road condition - full file.

Road Condition	Total Crashes[2]	Injury and Fatal Crashes[2]	% Injury and Fatal
Dry	5732 (64.8)[1]	1655 (64.0)	28.9
Wet	1833 (20.7)	590 (22.8)	32.2
Snow/Ice	1233 (13.9)	325 (12.6)	26.4
Other/Unknown	41 (0.5)	17 (0.7)	41.5
Total	8839	2587	29.3

[1]Column percent
[2]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-10. Number and percent distribution of urban bus crashes by vehicle model year.[1]

Vehicle Model Year	Total Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
Prior to 1970	1177 (21.9)[2]	361 (23.5)	30.7
1970-1974	519 (9.7)	157 (10.2)	30.3
1975-1979	1706 (31.8)	498 (32.5)	29.2
1980-1984	1202 (22.4)	329 (21.4)	27.4
After 1984	707 (13.2)	174 (11.3)	24.6
Unknown	55 (1.0)	15 (1.0)	27.3
Total	5366	1534	28.6

[1]Data were not available for Maine.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

$p = 0.05$

Table B-11. Injuries to bus drivers and bus passengers in Illinois.[1]

Bus Driver Injury Severity \ Bus Passenger Injury Severity	Number of Occupants				
	Incapacitating	Non-capacitating	Possible	None	Total
Incapacitating	9	0	6	0	15
Non-Incapacitating	0	6	14	0	20
Possible	5	3	59	0	67
None	15	30	200	55	300
Total	29	39	279	55	402

[1]The values in each cell represent the number of passengers for that combination of passenger and driver injury severity. For example, nine passengers received incapacitating injuries in crashes in which the bus drivers also received incapacitating injuries. Two hundred passengers received possible injuries in crashes in which the bus drivers received no injuries.

Table B-12. Number of urban bus crashes by bus driver age.[1]

Bus Driver Age (Years)	Total Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
Under 26	327 (6.2)[2]	75 (4.9)	22.9
26-35	1258 (23.8)	337 (22.2)	26.8
36-45	1687 (31.9)	528 (34.8)	31.3
46-55	1100 (20.8)	327 (21.5)	29.7
56-65	607 (11.5)	172 (11.3)	28.3
Over 65	83 (1.6)	14 (0.9)	16.9
Unknown	221 (4.2)	65 (4.3)	29.4
Total	5283	1518	28.7

[1]Data were not available for Maine.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

$p = 0.005$

Table B-13. Number of urban bus crashes by bus driver gender.[1]

Bus Driver Gender	Total Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
Male	4056 (76.8)[2]	1169 (77.0)	26.4
Female	1076 (20.4)	306 (20.2)	28.4
Unknown	151 (2.9)	43 (2.8)	28.5
Total	5283	1518	26.8

[1]Data were not available for Maine.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-14. Number and severity of bus crashes by traffic control - full file.

Control	Total Crashes[2]	Injury and Fatal Crashes[2]	% Injury and Fatal
Stop-and-go light	3046 (34.3)[1]	993 (38.2)	32.6
Stop sign/ Red flasher	1104 (12.2)	304 (11.7)	27.5
All other	328 (3.7)	111 (4.3)	33.8
None	4053 (45.6)	1153 (44.3)	28.4
Not Stated/ Unknown	359 (4.0)	40 (1.5)	11.1
Total	8890	2601	29.3

[1]Column percent
[2]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-15. Number and severity of urban bus crashes by road alignment.[1]

Alignment	Total Urban Crashes	Injury and Fatal Crashes	% Injury and Fatal
Straight	1902 (94.6)[2]	569 (94.9)	29.9
Curved	104 (5.2)	21 (5.1)	20.2
Other/ Unknown	4 (0.2)	0 (0.0)	0.0
Total	2010	590	29.4

[1]Data were not available for Maine.
[2]Column percent

Table B-16. Percent distribution of crashes by roadway feature and vehicle type for two-year Illinois sample.

Roadway Feature	Percent of All Accidents for this Involved Vehicle[1]				
	Commercial Bus (N=1,500)	Cars, Pickups (N=541,660)	Trucks (N=38,599)	School Bus (N=1,253)	Other (N=38,438)
Intersection - major arterial	11.7	9.9	8.2	9.8	10.2
Intersection - major collector	7.6	7.5	5.8	9.0	7.1
Intersection - public road	13.3	15.3	11.1	16.4	14.6
Intersection - local road	12.0	11.7	7.4	14.4	10.8
All other	40.8	35.1	44.2	31.0	36.6
Not applicable	14.6	20.5	23.4	19.4	20.6

[1]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-17. Distribution of crashes in Illinois by accident type.

Accident Type[1]	Total Crashes[3]	Injury and Fatal Crashes[3]	% Injury and Fatal
Parked motor vehicle	232 (6.1)[2]	34 (3.1)	14.7
Rear-end, both moving	303 (7.9)	137 (12.4)	45.2
Rear-end, one stopped	918 (24.0)	333 (30.2)	36.3
Sideswipe same dir.	925 (24.2)	125 (11.3)	13.5
Angle	253 (6.6)	106 (9.6)	41.9
Turning	877 (22.9)	187 (16.9)	21.3
Pedestrian	57 (1.5)	57 (5.2)	100.0
Pedalcycle	21 (0.5)	16 (1.4)	76.2
Other	239 (6.2)	109 (9.9)	45.6
Total[3]	3825	1104	28.9

[1]All accident types except "other" are on roadway only.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-18. Accident type by involved vehicle for two-year Illinois sample.

Accident Type[1] / Involved Vehicle	Percent of Accidents for Involved Vehicle[2]				
	Commercial Bus (N= 1500)	Cars, Pickups (N = 541,660)	Truck (N = 38,599)	School Bus (N = 1,253)	Other (N = 38,438)
Parked motor vehicle	6.7	1.8	2.2	3.0	2.3
Rear-end, both moving	8.6	12.9	12.5	9.5	12.8
Rear-end, one stopped	23.3	25.5	18.4	30.4	25.8
Sideswipe same dir.	24.0	11.8	23.9	18.4	13.2
Angle	7.1	8.8	5.0	8.0	7.7
Turning	23.1	27.2	19.4	24.6	24.0
Pedestrian	1.2	0.5	0.3	0.4	0.0
Other one-vehicle	3.9	8.9	12.8	2.9	11.4
Other	2.1	2.5	5.5	2.9	2.9

[1]All accident types except "other one-vehicle" and "other" are on roadway only.

[2]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-19. Number of single-vehicle bus crashes on urban streets by time of day.

Time of Day	Single-Vehicle Accidents[1]		Multi-Vehicle Accidents on Urban Streets
	IL, MI, MN & UT[3]	Illinois Only[3]	Illinois Only[3]
Midnight - 2:59 am	6 (4.3)[2]	3 (4.2)	36 (1.1)
3:00 am - 5:59 am	8 (5.8)	8 (11.3)	37 (1.2)
6:00 am - 8:59 am	28 (20.1)	12 (16.9)	641 (20.3)
9:00 am - 11:59 am	18 (12.9)	6 (8.4)	527 (16.7)
Noon - 2:59 pm	22 (15.8)	12 (16.9)	602 (19.1)
3:00 pm - 5:59 pm	35 (25.2)	17 (23.9)	855 (27.1)
6:00 pm - 8:59 pm	14 (10.1)	9 (12.7)	319 (10.1)
9:00 pm - 11:59 pm	8 (5.8)	4 (5.6)	129 (4.1)
Total	139	71	3159

[1]Does not include pedestrian or pedalcycle accidents.
[2]Column percent
[3]Total column percentages may not add to 100.0 exactly due to round-off error.

Table B-20. Number of single-vehicle bus crashes on urban streets by road condition.

Road Condition	Single-Vehicle Accidents[1]		Multi-Vehicle Accidents on Urban Streets
	IL, MI & MN[3]	Illinois Only[3]	Illinois Only[3]
Dry	71 (55.9)[2]	38 (53.5)	2106 (67.8)
Wet	23 (18.1)	16 (22.5)	761 (24.5)
Snow/Ice	33 (26.0)	17 (23.9)	240 (7.7)
Total	127	71	3107

[1]Does not include pedestrian or pedalcycle accidents.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-21. Number of single-vehicle bus crashes on urban streets by driver intent.

Bus Driver Intent	Single-Vehicle Accidents[1]		Multi-Vehicle Accidents on Urban Streets
	IL, MI, MN & UT[3]	Illinois only[3]	Illinois only[3]
Going Straight	63 (44.7)[2]	31 (43.7)	1295 (41.0)
Right Turn	28 (19.9)	11 (15.5)	197 (6.2)
Left Turn	13 (9.2)	6 (8.5)	260 (8.2)
Other	37 (26.2)	23 (32.4)	1407 (44.5)
Total	141	71	3159

[1]Does not include pedestrian or pedalcycle accidents.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-22. Multi-vehicle bus crashes on urban streets in Illinois by road condition and accident type.

Road Condition / Accident Type[1]	Number of Accidents[3]						
	Parked Motor Vehicle	Rear-end, Both Moving	Rear-end, One Stopped	Sideswipe Same-Direction	Angle	Turning	Total
Dry	162 (72.9)[2]	121 (64.7)	532 (62.4)	501 (73.4)	146 (60.6)	596 (70.9)	2058 (68.0)
Wet	41 (18.5)	47 (25.1)	237 (27.8)	142 (20.8)	70 (29.0)	198 (23.6)	735 (24.3)
Snow/Ice	19 (8.6)	19 (10.2)	83 (9.7)	40 (5.9)	25 (10.4)	46 (5.5)	232 (7.7)
Total	222	187	852	683	241	840	3025

[1]All accident types are on roadway only.
[2]Column percent
[3]Total column percentages may not add to exactly 100.0 due to round-off error.

Table B-23. Multi-vehicle bus crashes on urban streets in Illinois by time of day and accident type.

	Number of Accidents[4]						
Time of Day / Accident Type[1]	Parked Motor Vehicle	Rear-end, Both Moving	Rear-end, One Stopped	Sideswipe Same-Direction	Angle	Turning	Total
Midnight - 5:59 a.m.[2]	4 (1.8)[3]	3 (1.5)	21 (2.5)	13 (1.9)	12 (4.9)	13 (1.5)	66 (2.2)
6:00 a.m. - 8:59 a.m.	32 (14.2)	43 (22.1)	220 (25.7)	112 (16.2)	47 (19.3)	176 (20.7)	630 (20.6)
9:00 a.m. - 11:59 a.m.	42 (18.6)	30 (15.4)	144 (16.8)	100 (14.5)	49 (20.2)	149 (17.5)	514 (16.8)
Noon - 2:59 p.m.	63 (27.9)	36 (18.5)	152 (17.8)	130 (18.8)	46 (18.9)	159 (18.7)	586 (19.1)
3:00 p.m. - 5:59 p.m.	49 (21.7)	54 (27.7)	222 (25.9)	231 (33.4)	52 (21.4)	227 (26.7)	835 (27.3)
6:00 p.m. - 8:59 p.m.	24 (10.6)	19 (9.7)	76 (8.9)	79 (11.4)	22 (9.1)	91 (10.7)	311 (10.2)
9:00 p.m. - 11:59 p.m.	12 (5.3)	10 (5.1)	21 (2.5)	27 (3.9)	15 (6.2)	36 (4.2)	121 (3.9)
Total	226	195	856	692	243	851	3063

[1]All accident types are on roadway only.
[2]Two time periods
[3]Column percent
[4]Total column percentages may not add to exactly 100.0 due to round-off error.

$p < 0.005$

Table B-24. Washington, D.C. Metrobus traffic accident rate.

Year	Number of Accidents	Miles Operated (000)	Collision Rate (per million miles)
1976	4308	58,370	73.80
1977	3474	56,660	61.32
1978	3126	53,180	58.78
1979	3164	51,930	60.93
1980	3379	55,480	60.91
1981	3017	54,790	55.06
1982	2652	53,250	49.80
1983	2424	52,540	46.25
1984	2227	50,520	44.08
1985	1920	49,570	38.73
1986	1876	48,730	38.50
1987	2139	48,920	43.72
1988	2206	49,970	44.15
1989	2172	50,260	43.21
1990	2037	51,350	40.37

Source: Adapted from Reference 13.

Table B-25. Washington, D.C. Metrobus traffic accidents by type and year.

Collision with ...	1976-1980 Number	1976-1980 Pct.[1]	1981-1985 Number	1981-1985 Pct.[1]	1986-1990 Number	1986-1990 Pct.[1]	TOTAL 1976-1990 Number	TOTAL 1976-1990 Pct.[1]
another WMATA vehicle	802	4.6	441	3.6	352	3.4	1595	4.0
vehicles ahead	2404	13.8	1679	13.7	1261	12.0	5344	13.3
vehicles following	2162	12.4	1796	14.7	1878	17.9	5836	14.5
vehicles passing on left	4765	27.3	3325	27.2	2608	24.9	10698	26.6
vehicles passing on right	852	4.9	587	4.8	597	5.7	2036	5.1
vehicle being passed on left	885	5.1	475	3.9	348	3.3	1708	4.3
vehicle being passed on right	1670	9.6	1083	8.8	905	8.6	3658	9.1
vehicle from an angle	1473	8.4	1142	9.3	1090	10.4	3705	9.2
vehicle met and passed	704	4.0	505	4.1	442	4.2	1651	4.1
motorcycles or bicycle	167	1.0	81	0.7	81	0.8	329	0.8
other objects	61	0.3	28	0.2	11	0.1	100	0.2
fixed objects	1038	5.9	802	6.6	601	5.7	2441	6.1
persons	468	2.7	296	2.4	292	2.8	1056	2.6
Total	17451	100.0	12240	100.0	10466	100.0	40157	99.9
Miles operated (x 1,000,000)	275.620		260.670		249.23		785.52	
Collision rate (accidents per million miles)	63.32		46.96		41.99		51.12	

[1]Sum of column percentages may not be exactly 100.0 due to round-off error.

Source: Adapted from Reference 13.

Table B-26. Washington, D.C. Metrobus passenger injury rate summary.

Year	Number of Accidents	Total Passengers (x 1,000)	Injury Rate (per million passengers)
1976	1233	169,570	7.27
1977	1164	169,640	6.86
1978	1196	148,700	8.06
1979	1218	158,000	7.77
1980	1590	196,980	8.07
1981	1280	186,660	6.86
1982	1293	179,150	7.22
1983	1138	172,130	6.61
1984	1083	173,970	6.23
1985	851	173,950	4.89
1986	866	180,610	4.79
1987	891	180,170	4.95
1988	873	183,000	4.77
1989	954	184,080	5.18
1990	901	185,190	4.87

Source: Adapted from Reference 13.

Table B-27. Washington, D.C. Metrobus passenger injuries by type and year.

Injury Occurred While ...	1976-1980		1981-1985		1986-1990		1976-1990	
	Number	Pct.[1]	Number	Pct.[1]	Number	Pct.[1]	Number	Pct.[1]
Boarding	737	11.5	632	11.2	597	13.3	1966	11.9
Alighting	1323	20.6	1360	24.1	1099	24.5	3782	22.9
Starting	172	2.7	85	1.5	132	2.9	389	2.4
Stopping	1668	26.0	1278	22.6	1176	26.2	4122	24.9
Running	380	5.9	345	6.1	313	7.0	1038	6.3
Other Accidents	1654	25.8	1358	24.1	1055	23.5	4067	24.6
Miscellaneous	478	7.5	587	10.4	113	2.5	1178	7.1
Total	6412	100.0	5645	100.0	4485	100.0	16542	100.0
Total passengers (x 1,000,000)	842.59		885.86		913.05		2641.50	
Collision rate (injuries per million miles)	7.61		6.37		4.91		6.26	

[1]Sum of column percentages may not be exactly 100.0 due to round-off error.

Source: Adapted from Reference 13.