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Mass Transit Crashworthiness Statistical Data Analysis

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Executive Summary

Mass transportation systems and specifically bus systems are a key element of the national transportation network. Buses are one of the safest forms of transportation. Nonetheless, bus crashes resulting in occupant injuries and fatalities do occur. Therefore, crashworthiness research is a continuing effort. Using funding from the Federal Transit Administration (FTA), the National Institute for Aviation Research (NIAR) is performing research to improve the crashworthiness of mass transit buses.

In order to maximize the utility of the research, NIAR reviewed statistical data describing the injuries and fatalities associated with transit bus accidents. Transit bus usage, in terms of passenger-miles, averages 20.6 billion miles per year. From 1992-2002, transit motor bus ridership has increased 11% in terms of unlinked trips. From 1990-2002, the number of transit motor buses in the U.S. has increased 30%. Clearly, transit buses are an integral part of the national transportation system.

According to the Traffic Safety Facts reports from 1999-2003, an average of 40 fatalities and 18,430 injuries of bus occupants occurred per year. The majority of fatal crashes involving buses result from frontal crashes. Bus occupant injuries are evenly distributed to crashes on all sides of the bus.

The majority of transit bus fatalities occur during the work week, in urban environments, on dry roadway surfaces under normal weather conditions. According to the ‘Buses Involved in Fatal Accidents’ reports from 1999-2001, over half of fatal transit bus involvements occur on roadways with posted speed limits of 25-35 mph. Shorter, heavy-duty, low-floor transit buses account for the majority of fatal transit bus involvements.

The primary research objectives of this project are to: (1) characterize the structural response of mass transit buses; (2) characterize the occupant kinematics and injury mechanisms in mass transit bus interiors; (3) develop interior design guidelines and crashworthiness design procedures; for mass transit buses in order to reduce occupant injuries and fatalities during side, frontal and rear impact collisions with various vehicle types. Based on the typical crash scenarios identified in this report, a detailed FE Bus Model will be generated to extract typical crash pulses and vehicle intrusions at various occupant locations to support the research objectives.

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Nomenclature

Acronym	Definition
FMVSS	Federal Motor Vehicle Standards
FTA	Federal Transit Administration
NIAR	National Institute for Aviation Research
SBPG	Standard Bus Procurement Guidelines
NHTSA	National Highway Traffic Safety Administration
FARS	Fatality Analysis Reporting System
GES	National Automotive Sampling System General Estimates System
BIFA	Buses Involved in Fatal Accidents
UMTRI	University of Michigan Transportation Research Institute
TIFA	Trucks Involved in Fatal Accidents
NCTR	National Center for Transit Research
FDOT	Florida Department of Transportation
CUTR	Center for Urban Transportation Research
HART	Hillsborough Area Regional Transit Authority
RTS	Gainesville Regional Transit System
SCAT	Sarasota Count Transportation Authority
LeeTran	Lee County Regional Transit System

1 Introduction

Crashworthiness research is a continuing effort. With funding from the Federal Transit Administration (FTA), the National Institute for Aviation Research (NIAR) is performing research to improve the crashworthiness of mass transit buses. NIAR is evaluating typical bus interiors, Figure 1.1, and floor arrangements, Figure 1.2, in the context of the Federal Motor Vehicle Standards (FMVSS) and the Standard Bus Procurement Guidelines (SBPG).

In order to maximize the utility of the research, NIAR reviewed statistical data describing the injuries and fatalities associated with transit bus accidents. General statistics for the United States lumped bus types: school, intercity and transit, into a single category. Transit bus specific data was found for the state of Kansas and four regions in Florida. Attempts to obtain data for more regions were not successful. As documented in Reference [10], there is not a standard for collecting crash data for mass transit buses. Furthermore, not all agencies collect crash data. Based on inquiries to transit agencies by NIAR, the experiences of the authors in Reference [10] and the scope of this project, NIAR made the decision to proceed with the available crash data. All data presented in this report was compiled from data reported by other agencies, listed in the References section.

Figure 1.1 Typical mass transit bus interior.

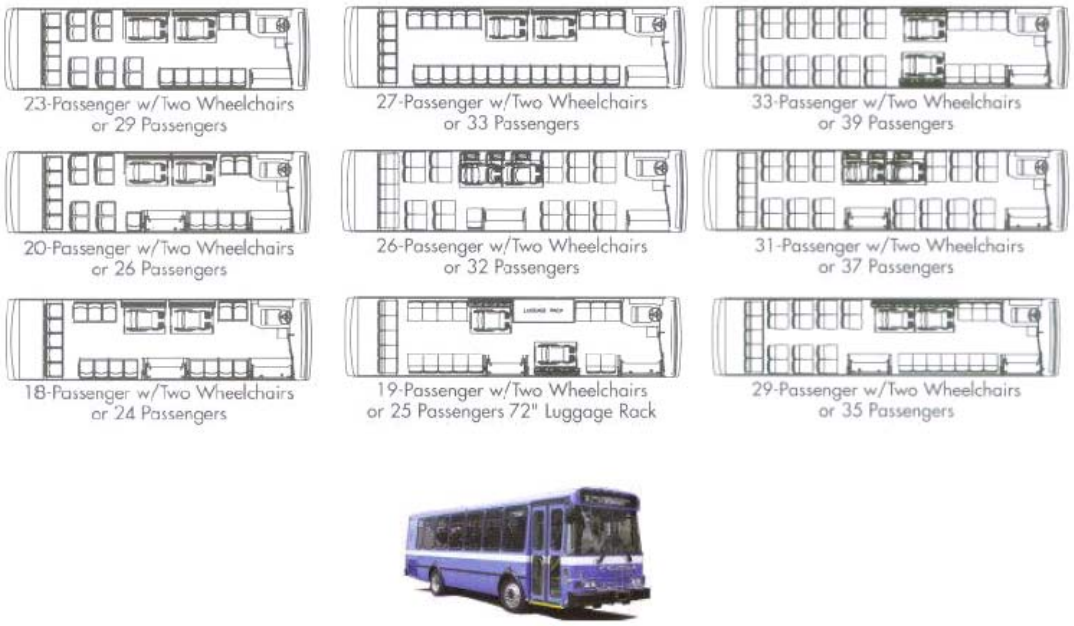


Figure 1.2 Typical mass transit bus layouts.

2 General Statistics

This section presents a summary of statistics on bus utilization and crashes. Bus utilization data was obtained from the National Transportation Statistics 2005 report [1]. Bus crash data was obtained from the Traffic Safety Facts report [2]-[6], years 1999-2003, and the Buses Involved in Fatal Accidents report [7]-[9], years 1999-2001.This statistical review was performed to gain insight into the types of bus crash mechanisms that result in occupant injuries and fatalities.

2.1 Bus Utilization

Transit motor bus data from the National Transportation Statistics 2005 report, Ref. [1], that infers the utilization of buses is presented in Figure 2.1 through Figure 2.6. The report documents data from as far back as 1960 through 2003. Generally, data are presented in five year increments through 1995 and annually thereafter. A transit motor bus is defined as “a rubber-tired, self-propelled, manually steered bus with fuel supply onboard the vehicle. Motor bus types include: intercity, school, and transit.”

Transit authorities reporting to the FTA provide data on the number of passengers who board public transportation vehicles rather than the number of passengers they serve. Passenger boardings are called unlinked and linked passenger trips. Unlinked trips are total boardings on an individual vehicle. Linked trips refers to the total number of riders and measures the actual number of complete trips from origin to destination, including transfers. Unlinked trips are viewed as a measure of transit utilization (at the system, route, or subroute level), while linked trips are used to measure revenue passengers. The ratio of unlinked to linked trips indicates the relative usage of transfers in the transit system. Determining the actual number of passengers using a transit system can be a difficult task because of the tracking requirements for the number of transfers from one vehicle or mode to the next, from one agency to another, and from the use of day passes and cash.

- Transit motor bus vehicle-miles increased 40% from 1975-1990, was constant from 1990-1998 and increased 11% from 1998-2002.
- From 1980-2003, transit motor bus passenger-miles have remained constant at an average of 20.6 billion miles per year.
- From 1992-2002, transit motor bus ridership has increased 11% in terms of unlinked trips.
- From 1998-2003, the average age of full-size transit motor buses has decreased 14% to 7.3 years while the average age of mid-size transit motor buses has remained steady at an average of 5.7 years old.
- From 1990-2002, the number of transit motor buses in the U.S. has increased 30%.
- From 1990-2000, new sales or deliveries of transit motor buses increased 61%.

- 11,018 new sales or deliveries of transit motor buses occurred in 2001, nearly twice the average new sales or deliveries per year over the previous 10 years. New sales or deliveries decreased in 2002 and 2003, with 2003 11% below 2000 new sales or deliveries.

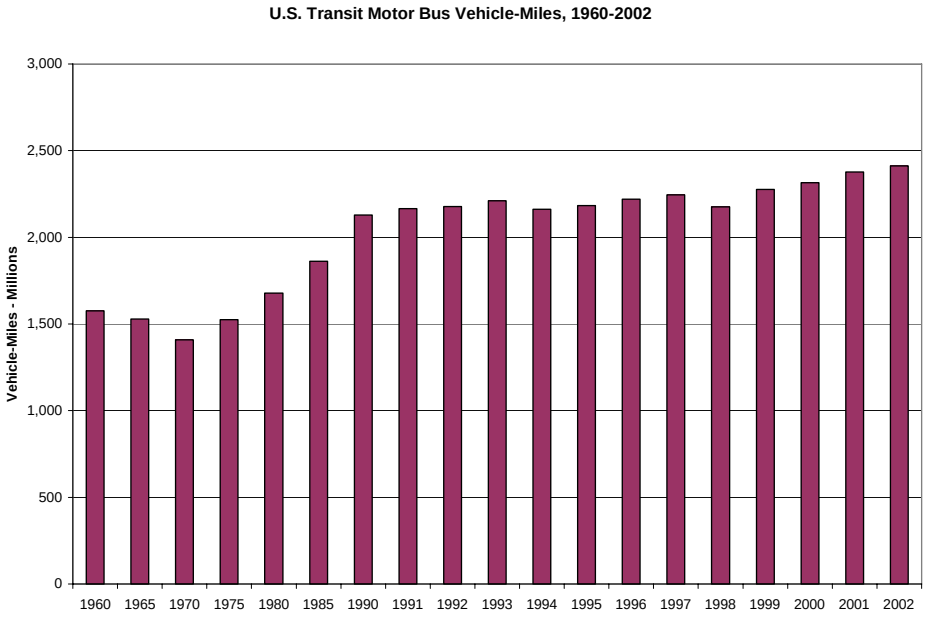


Figure 2.1 U.S. Transit Motor Bus Vehicle-Miles, 1960-2002.

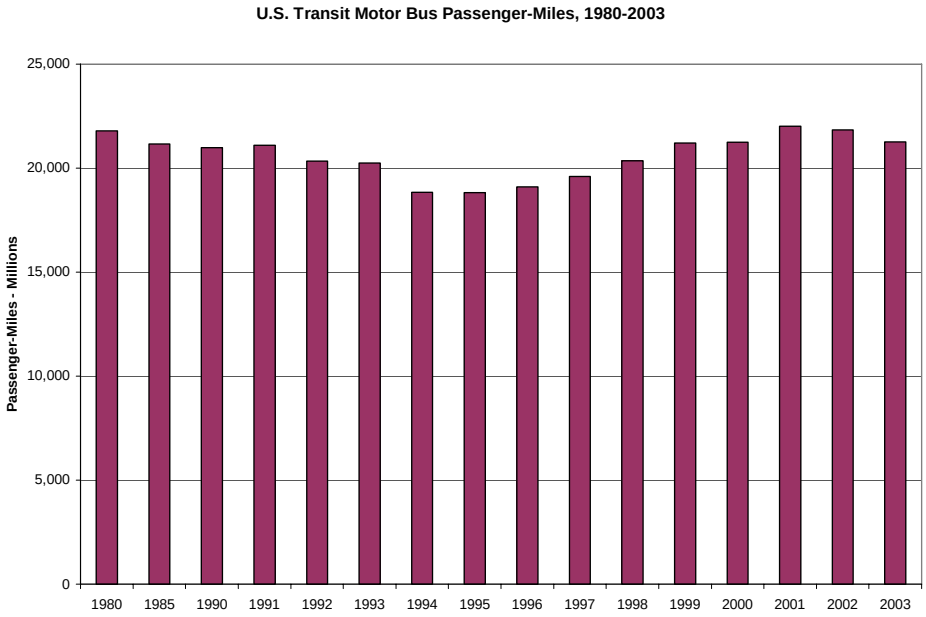
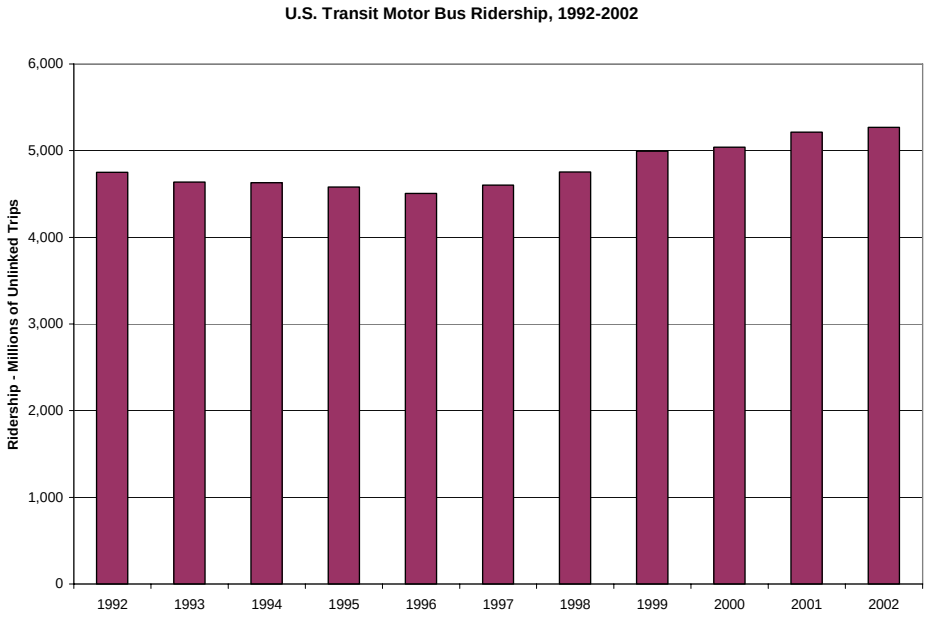


Figure 2.2 U.S. Transit Motor Bus Passenger-Miles, 1980-2003.



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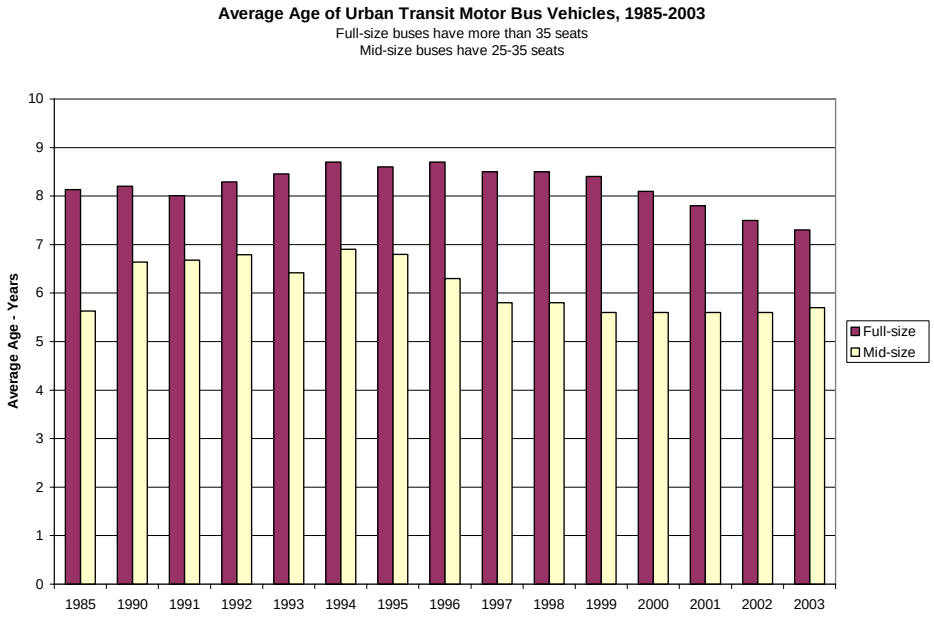

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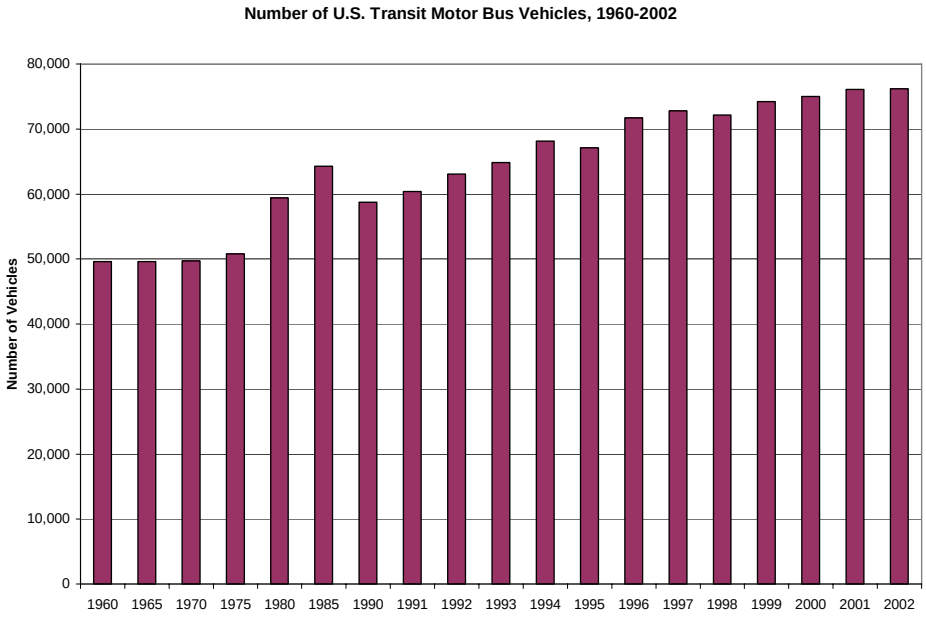

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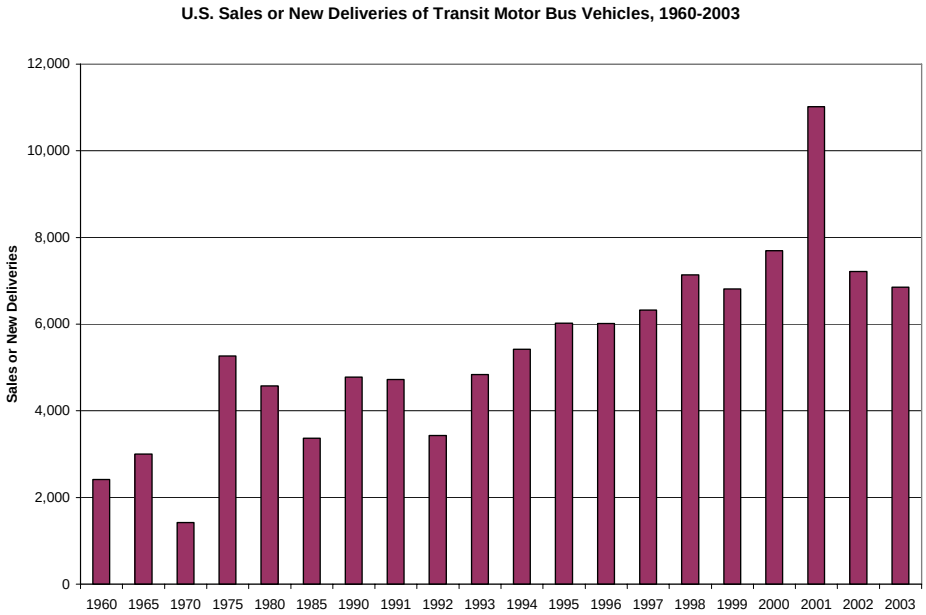


Figure 2.6 U.S. Sales or New Deliveries of Transit Motor Bus Vehicles, 1960-2003.

2.2 Summary of Traffic Safety Facts (1999-2003)

The Traffic Safety Facts report is an annual compilation of motor vehicle crash data presented by the National Highway Traffic Safety Administration (NHTSA). Data from the Fatality Analysis Reporting System (FARS) and the National Automotive Sampling System General Estimates System (GES) is combined to create Traffic Safety Facts. The FARS database, established in 1975, records data from traffic crashes involving a fatality. The GES database, established in 1988, records data from a nationally representative sample of police reported crashes of all severities, including those that result in death, injury or property damage.

Selected bus data from the Traffic Safety Reports from 1999 through 2003 is presented in Figure 2.7 through Figure 2.48. In the Traffic Safety Reports, a buses are defined as “Large motor vehicles used to carry more than ten passengers, including school buses, inter-city buses, and transit buses”. Data presented in the Traffic Safety Report is often grouped by crash severity, with the following categories: (1) Fatal Crash. A police-reported crash involving a motor vehicle in transport on a trafficway in which at least one person dies within 30 days of the crash. (2) Injury Crash. A police-reported crash that involves a motor vehicle in transport on a trafficway in which no one died but at least one person was reported to have: (i) an incapacitating injury; (ii) a visible but not incapacitating injury; (iii) a possible, not visible injury; or (iv) an injury of unknown severity.

Vehicle

- 64% of bus crashes involving fatalities result from a frontal initial point of impact. Rear impacts account for 16% and side impacts account for 14%.
- The initial point of impact in bus crashes involving injuries is evenly distributed, with frontal accounting for 37%, side for 36% and rear for 25%.
- Rollover occurs in less than 3.1% of buses involved in crashes with fatalities, and 0.1% of buses involved in crashes with injuries.
- Fire occurs in less than 0.3% of buses involved in crashes with fatalities, and less than 0.05% of buses involved in crashes with injuries.
- 38% of buses involved in fatal accidents are School Buses, 36% Transit Buses, 11% Other, 9% Intercity, and 6% is Unknown.

Occupant

- An average of 40 bus occupants per year were killed and 18,430 injured from 1999-2003.
- 47% male and 53% female were killed. 51% male and 49% female were injured.
- School age occupants, ages 5-20, account for 24% of bus occupants killed.

- Occupants over the age of 55 years account for 43% of bus occupants killed.
- 68% of bus occupant injuries occur during two vehicle crashes.
- 61% of bus occupant fatalities result from frontal crashes, 17% from side crashes and 9% from rear crashes.
- 36% of bus occupant injuries result from side crashes, 33% from frontal crashes and 30% from rear crashes.
- 28% of bus occupant fatalities result from occupant ejection, 53% from non-ejected fatal impacts and 19% were unknown.
- An average of 49 pedestrians and 9 pedalcyclists per year are killed in crashes with buses.
- 40% of bus occupant injuries result from school bus crashes, 24% from intercity bus crashes and 23% from transit bus crashes.
- 30% of bus occupant fatalities result from intercity bus crashes, 24% from school bus crashes and 14% from transit bus crashes.
- An average of 11 bus occupants per year are killed in two vehicle crashes while 162 occupants per year of other vehicles are killed.(102 occupants in passenger cars, 49 in light trucks 9 in motorcycles, 2 in large trucks).
- An average of 12,000 bus occupants per year is injured in two vehicle crashes while 8,800 occupants per year of other vehicles are injured.(6,000 in passenger cars and 2,800 in light trucks).

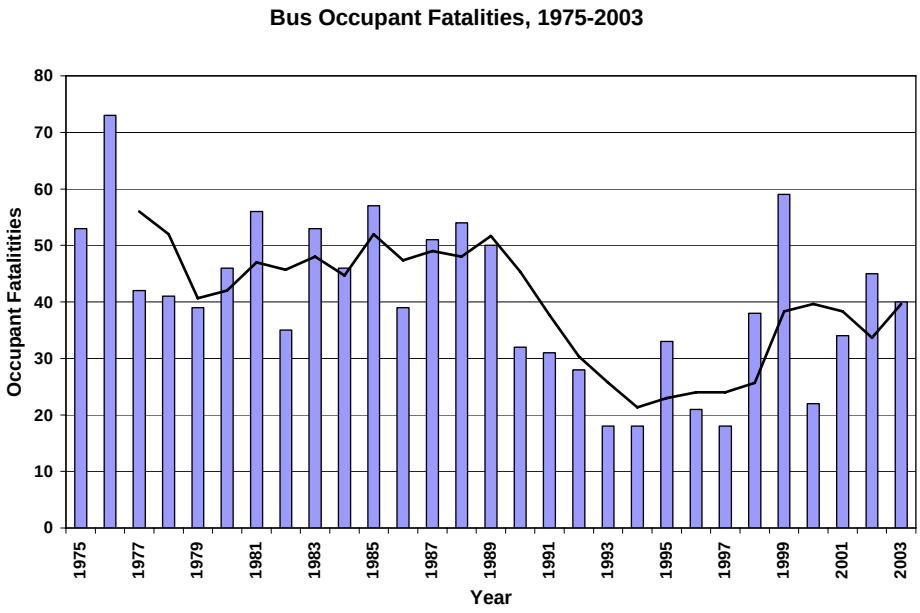


Figure 2.7 Bus Occupant Fatalities, 1975-2003.

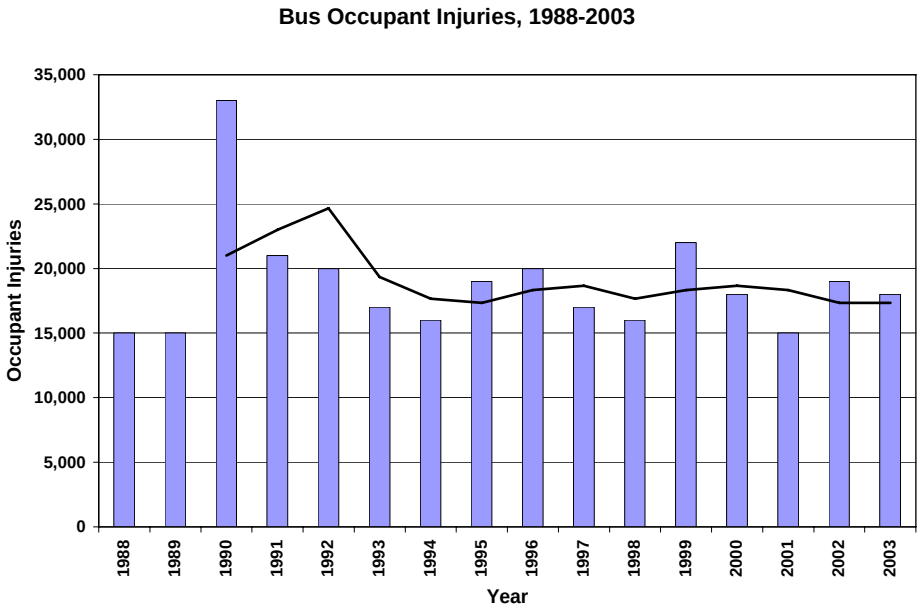
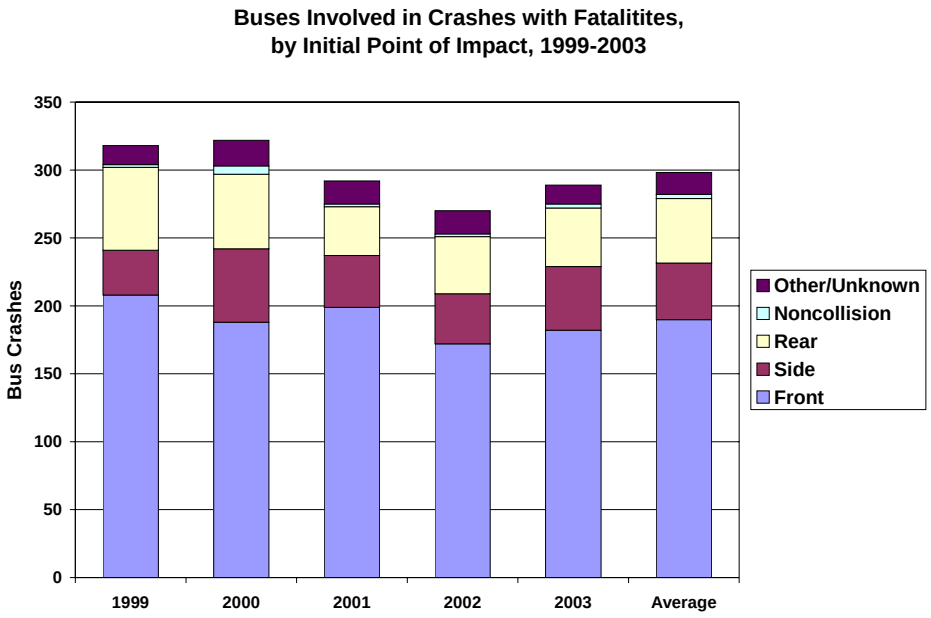


Figure 2.8 Bus Occupant Injuries, 1988-2003.



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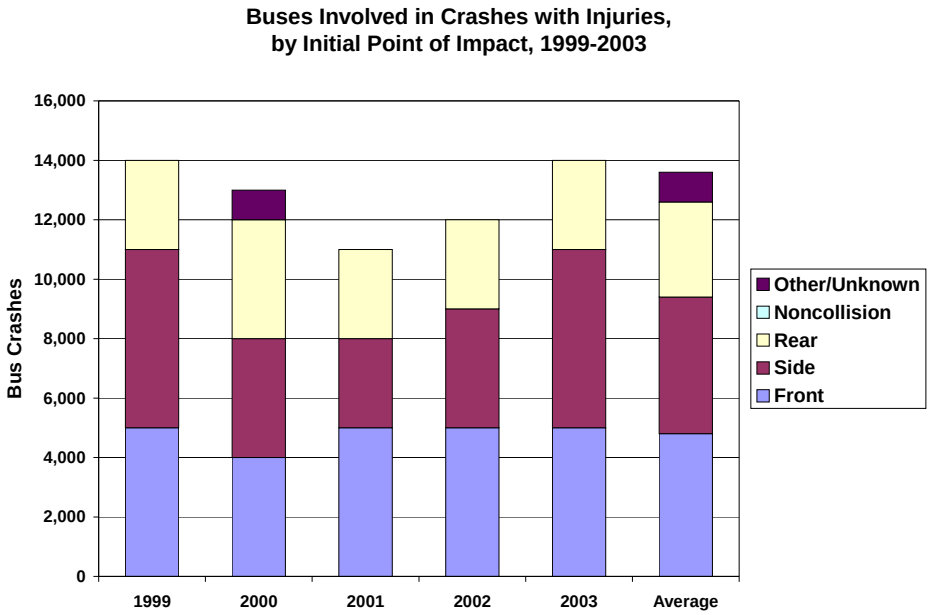

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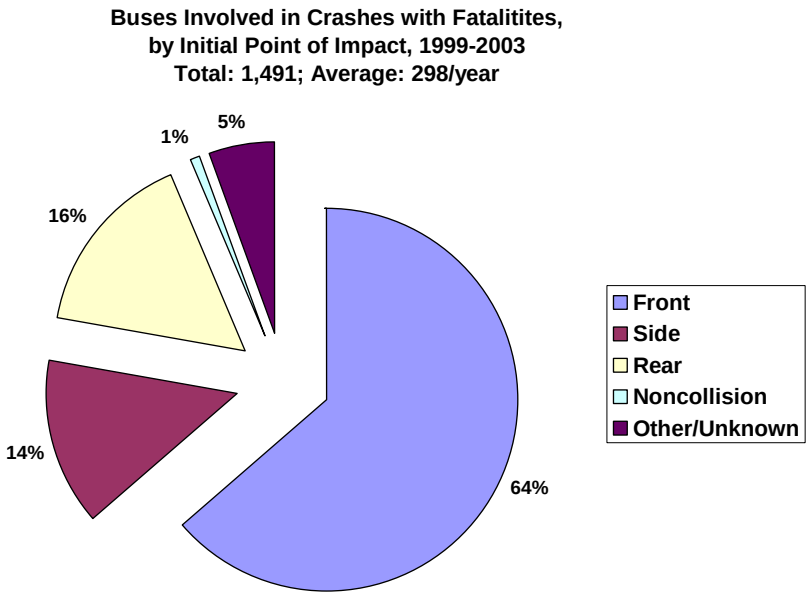

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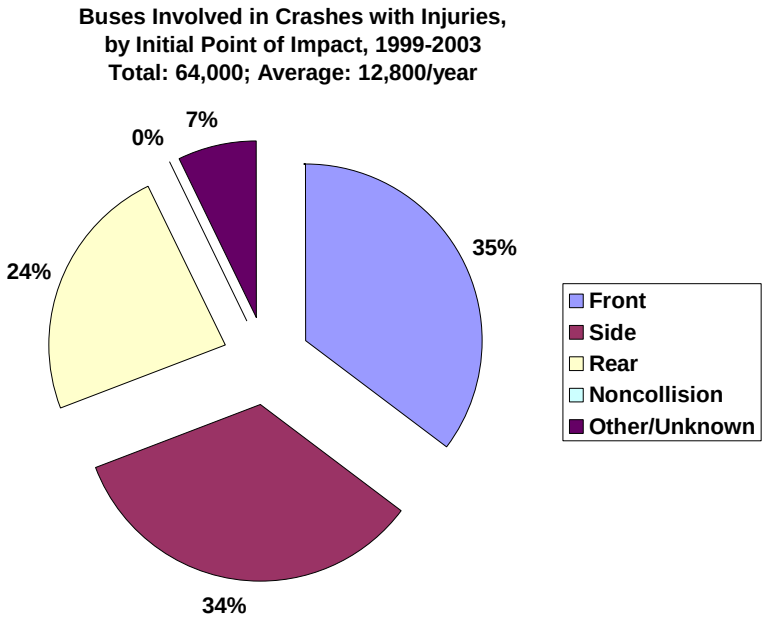

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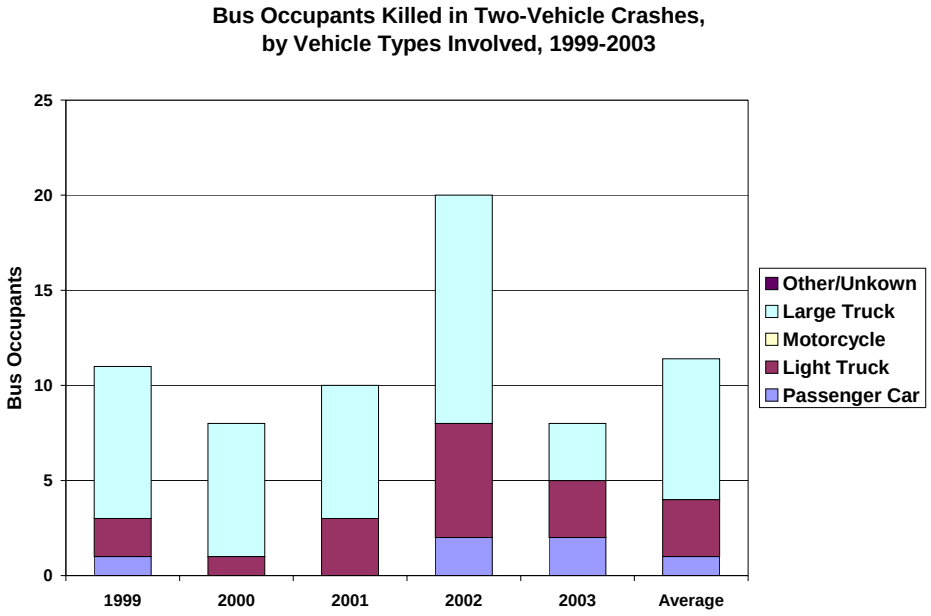

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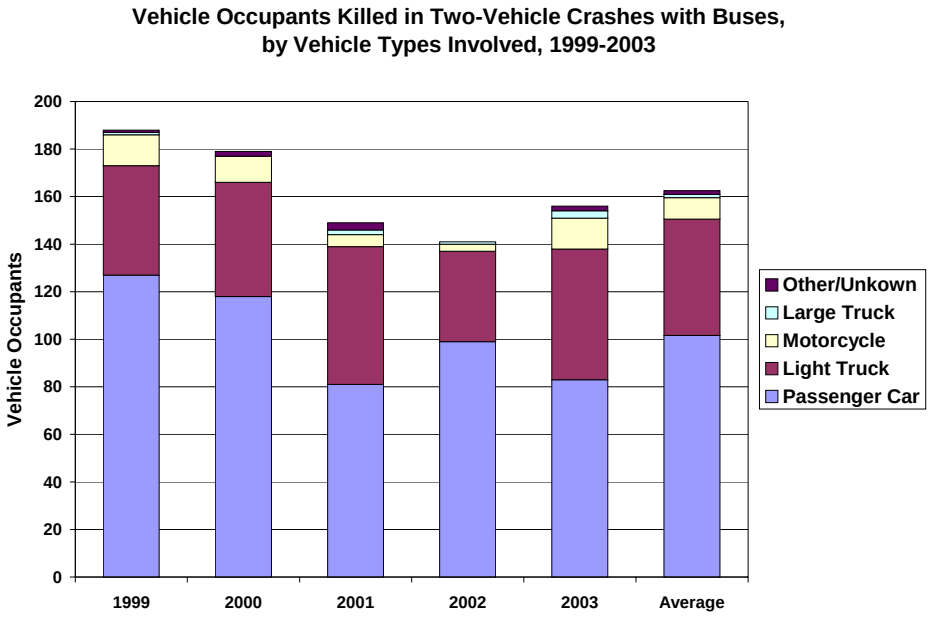

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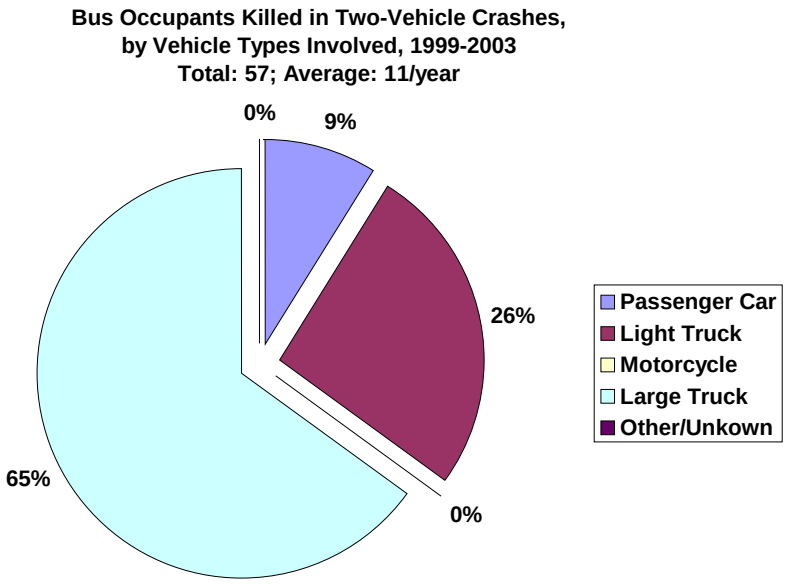
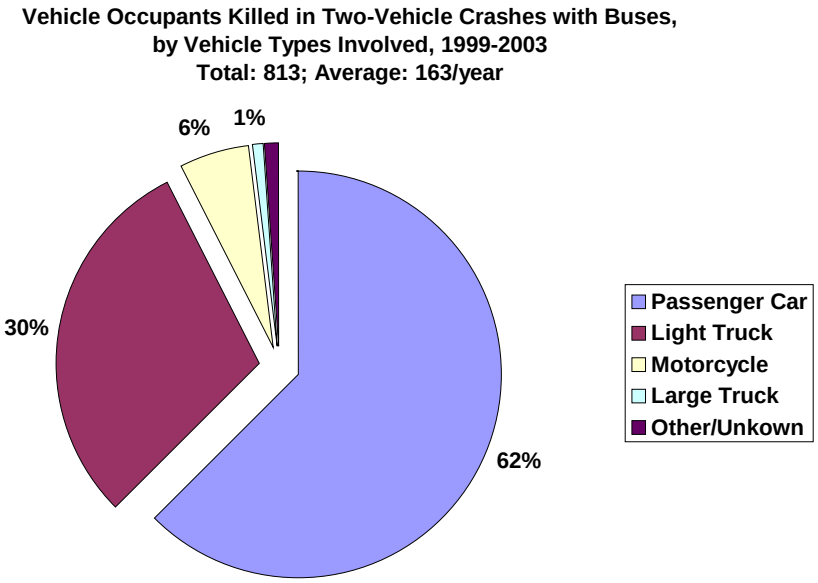


Figure 2.15 Bus Occupants Killed in Two-Vehicle Crashes, by Vehicle Types Involved, 1999-2003 summary.



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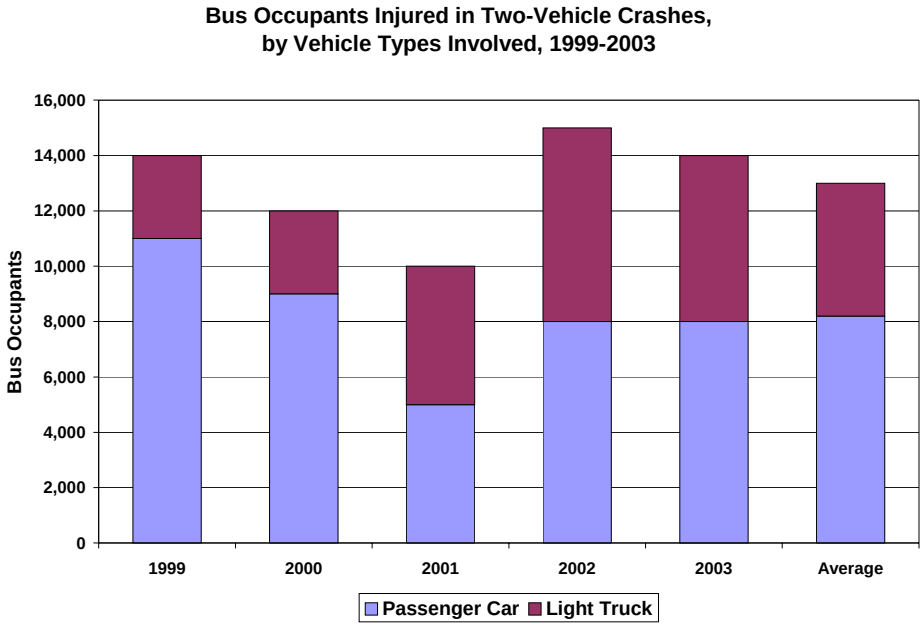

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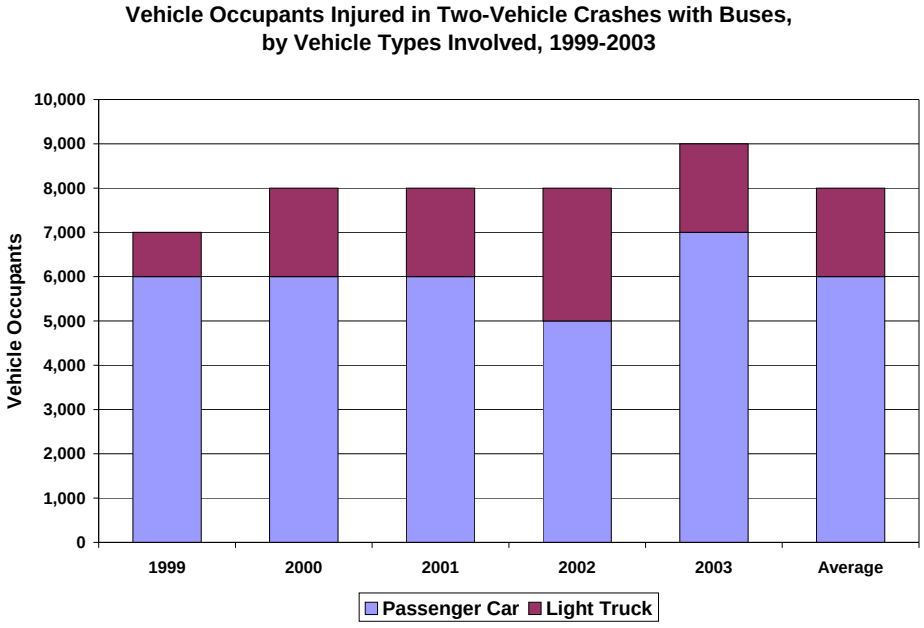

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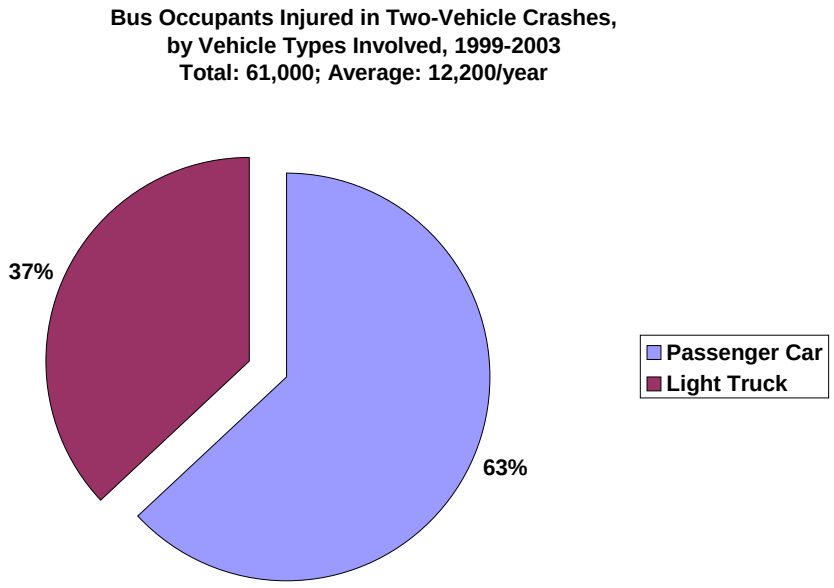

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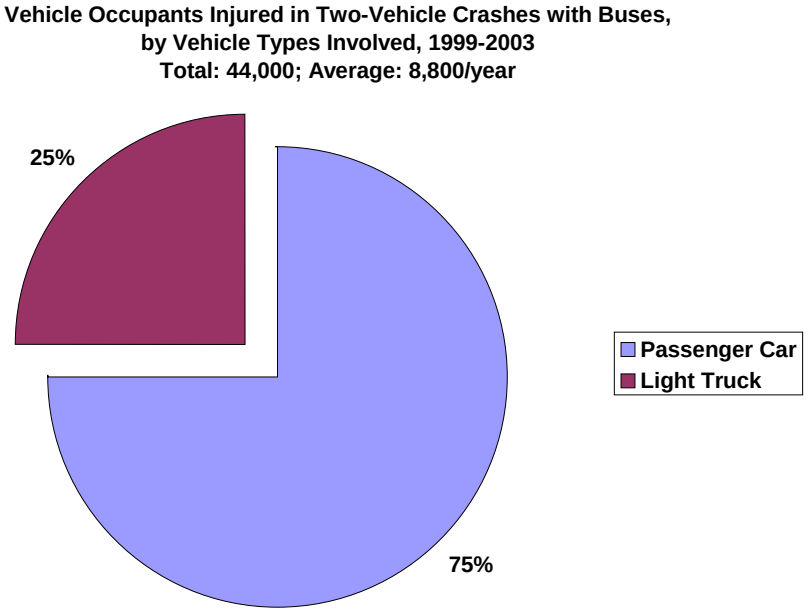

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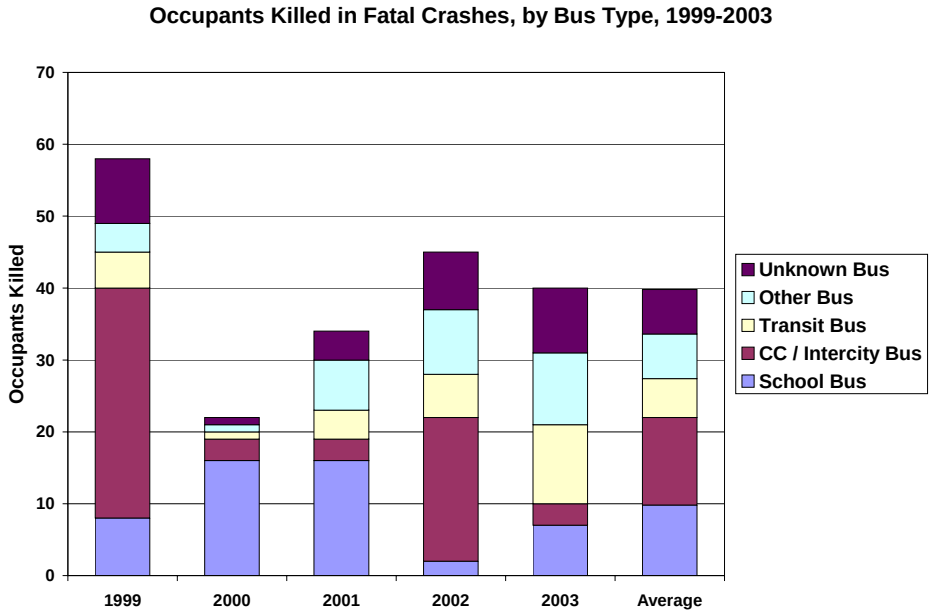

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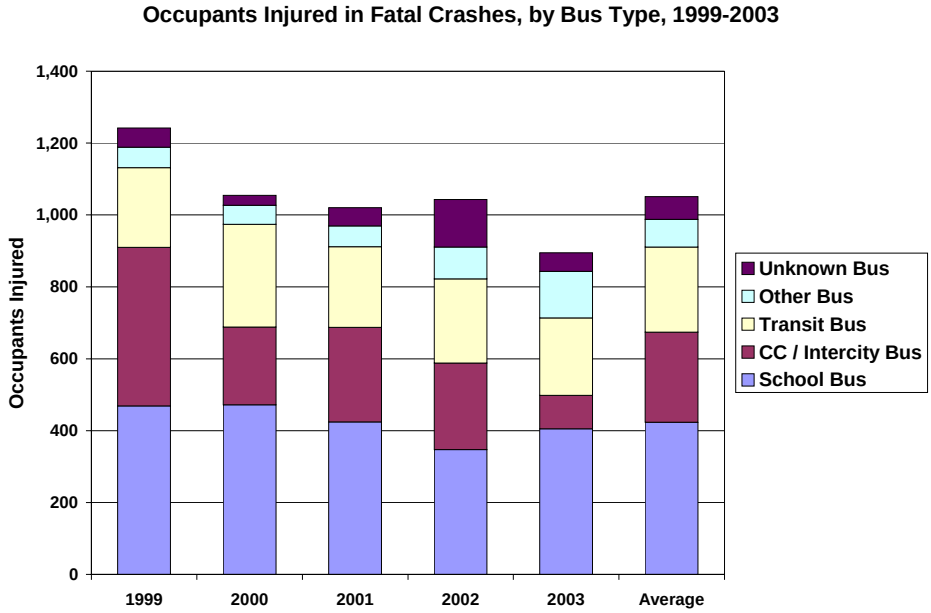


Figure 2.22 Occupants Injured in Fatal Crashes, by Bus Type, 1999-2003.

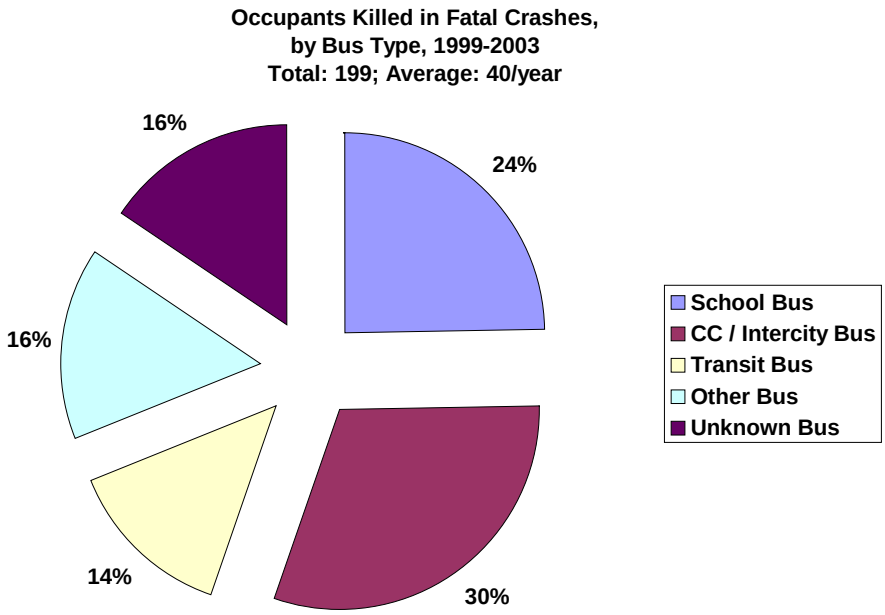
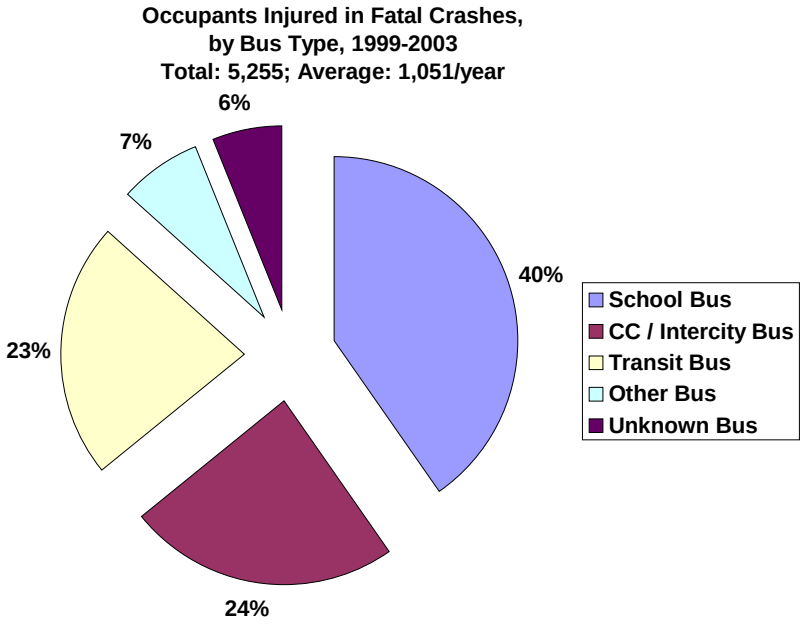


Figure 2.23 Occupants Killed in Fatal Crashes, by Bus Type, 1999-2003 summary.



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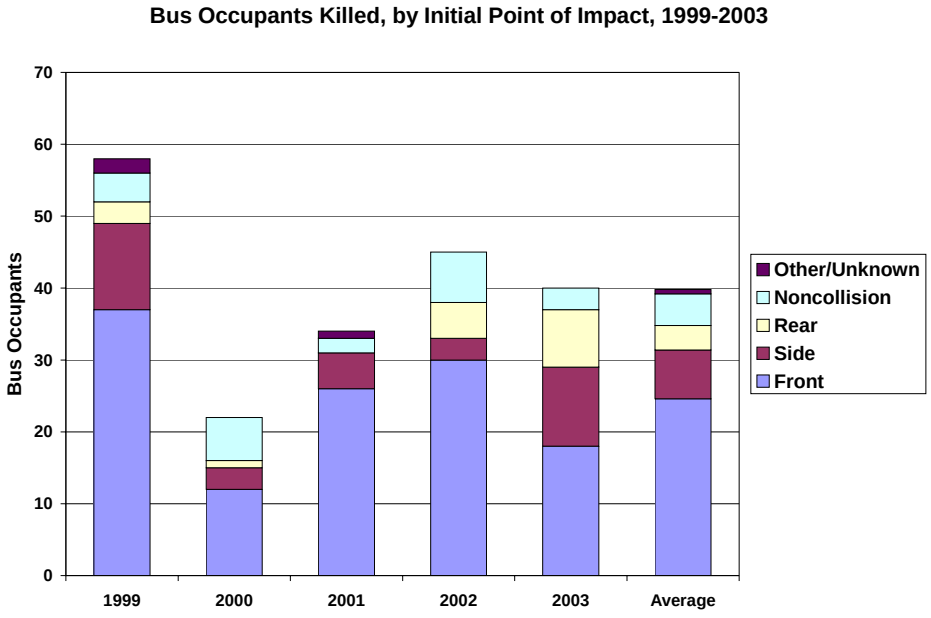


Figure 2.25 Bus Occupants Killed, by Initial Point of Impact, 1999-2003.

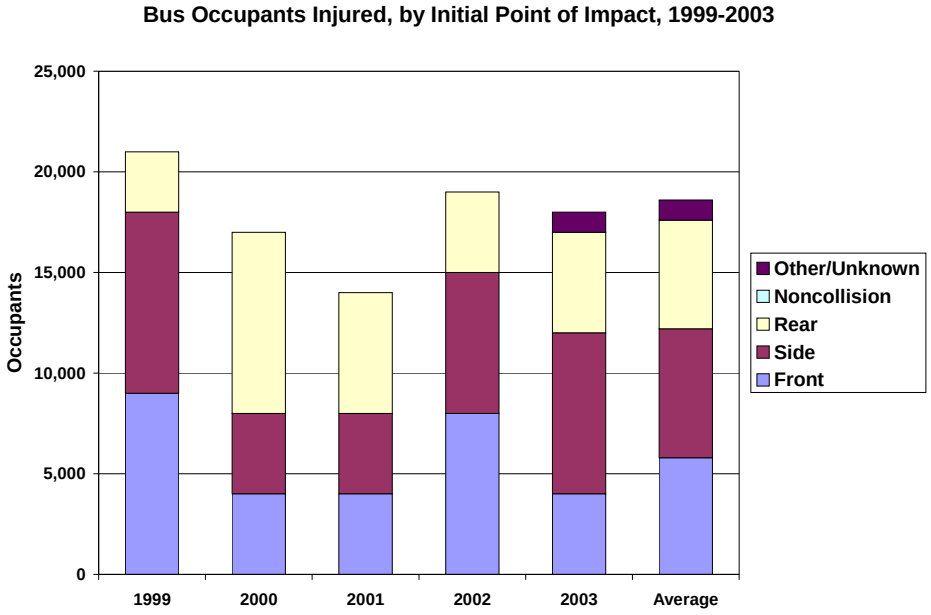
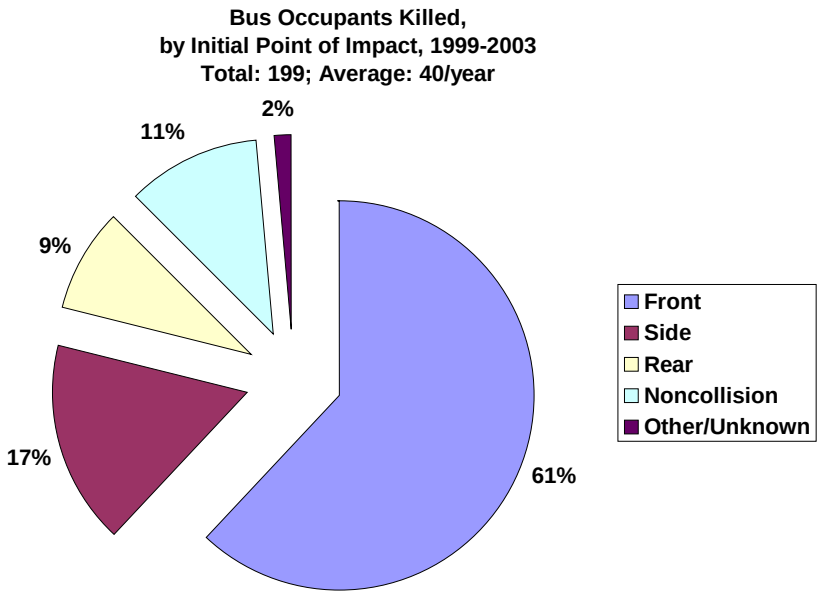


Figure 2.26 Bus Occupants Injured, by Initial Point of Impact, 1999-2003.



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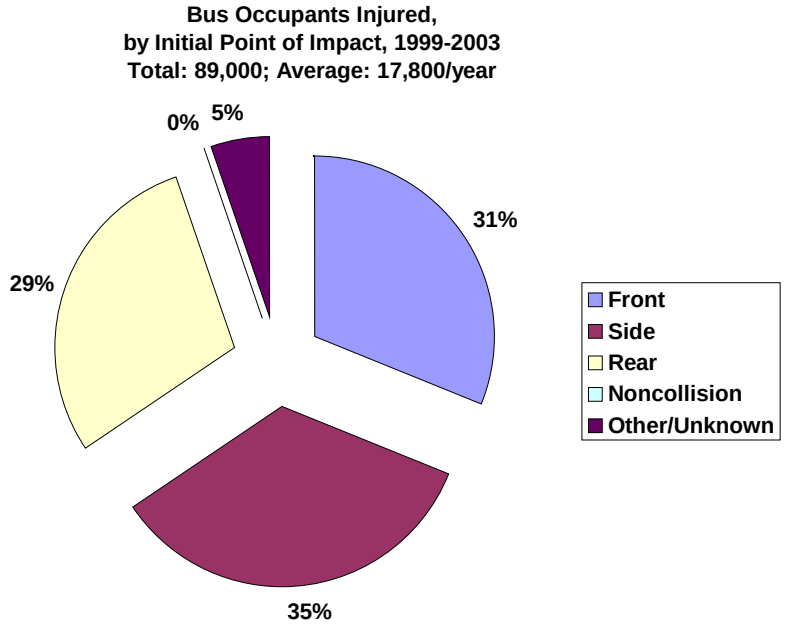

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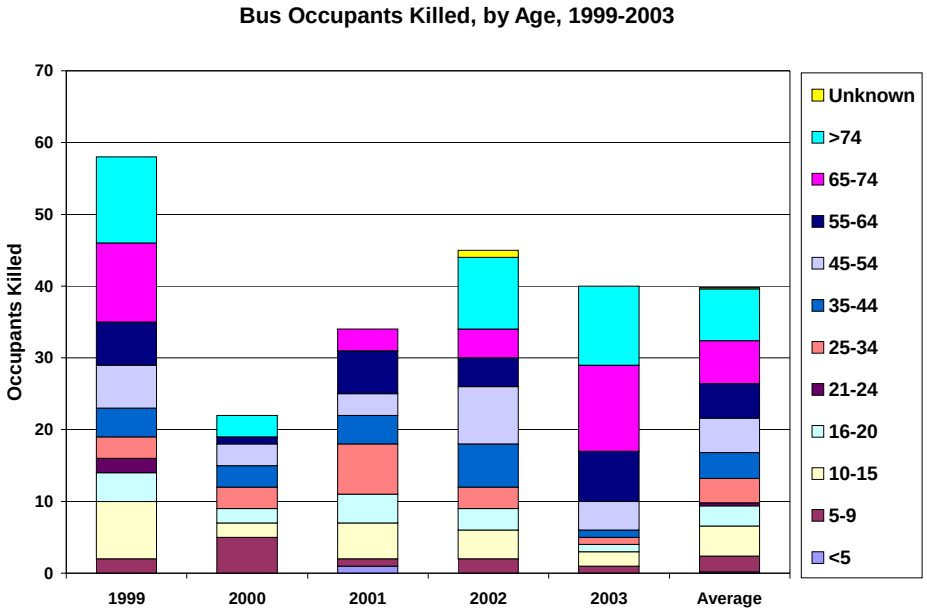


Figure 2.29 Bus Occupants Killed, by Age, 1999-2003.

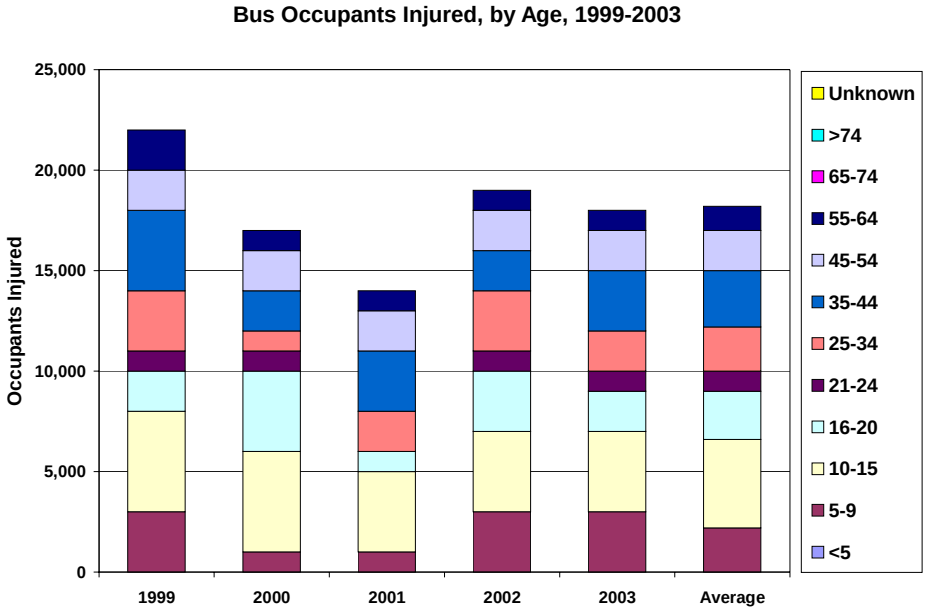


Figure 2.30 Bus Occupants Injured, by Age, 1999-2003.

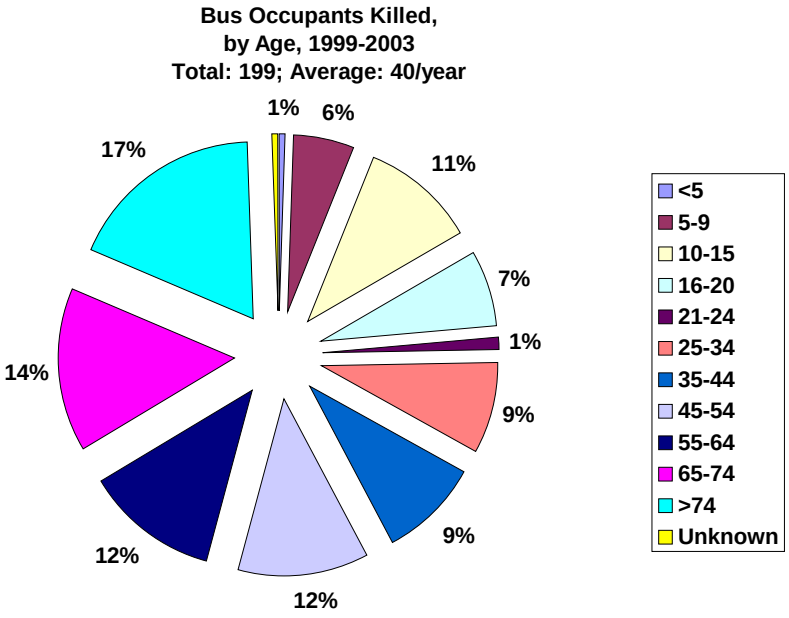


Figure 2.31 Bus Occupants Killed, by Age, 1999-2003 summary.

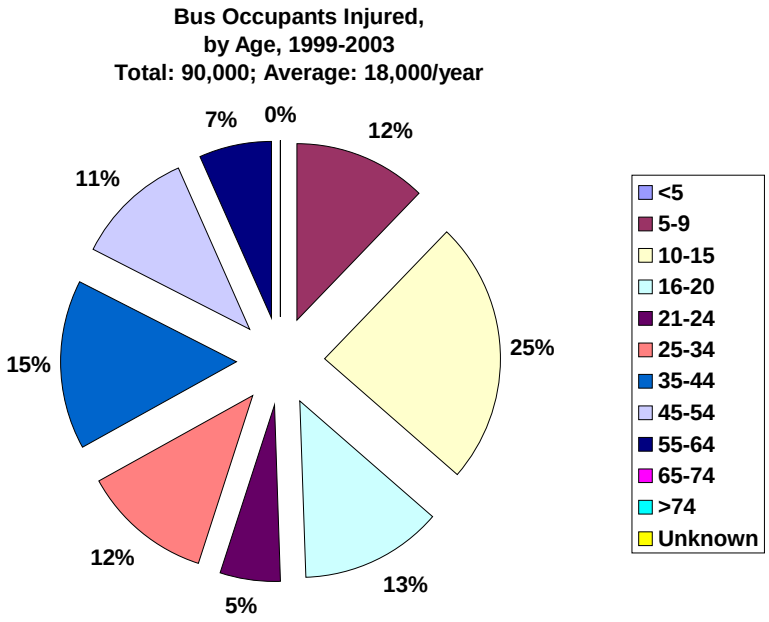
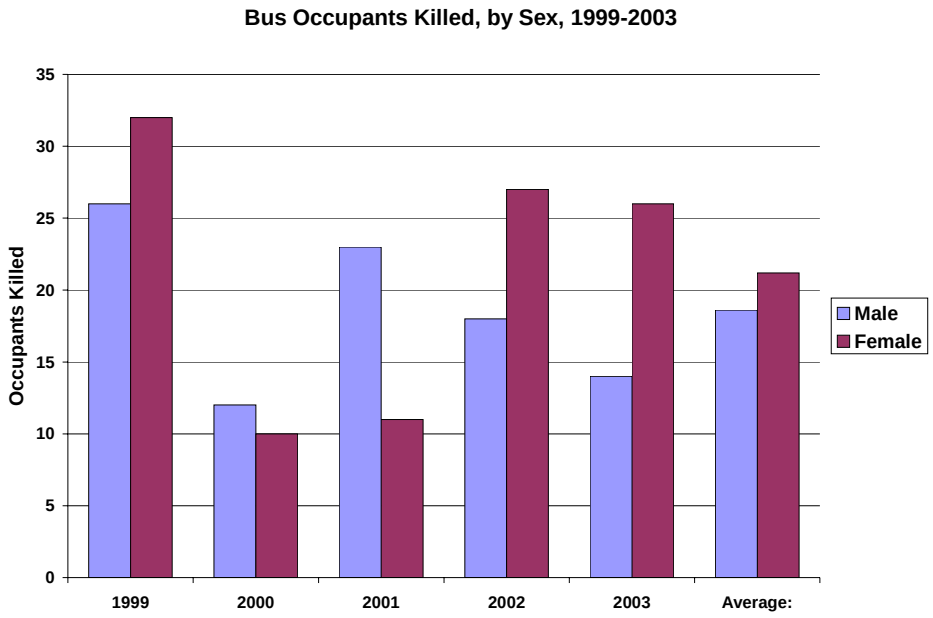


Figure 2.32 Bus Occupants Injured, by Age, 1999-2003 summary.



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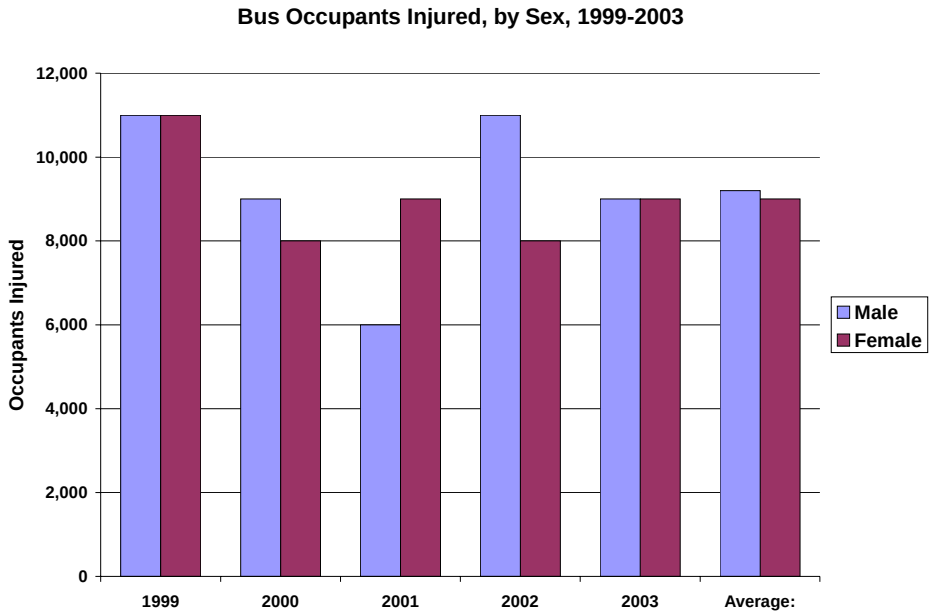


Figure 2.34 Bus Occupants Injured, by Sex, 1999-2003.

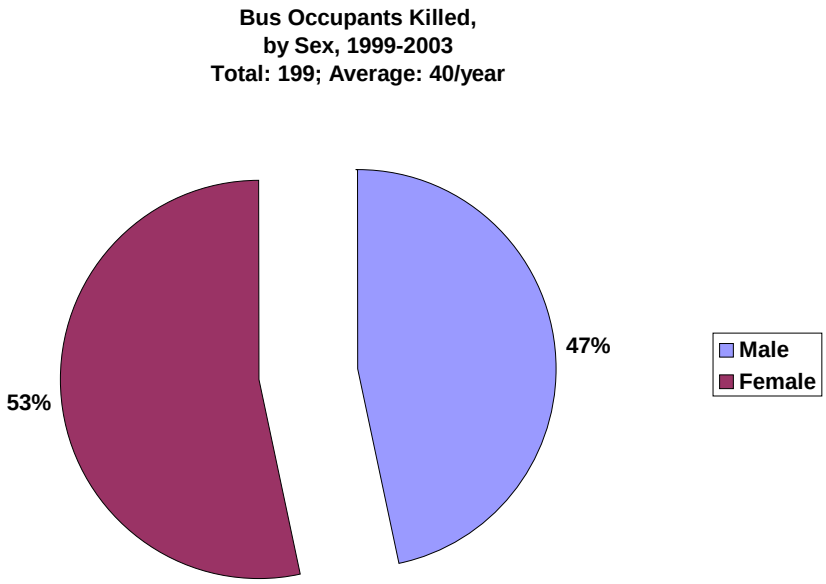


Figure 2.35 Bus Occupants Killed, by Sex, 1999-2003 summary.

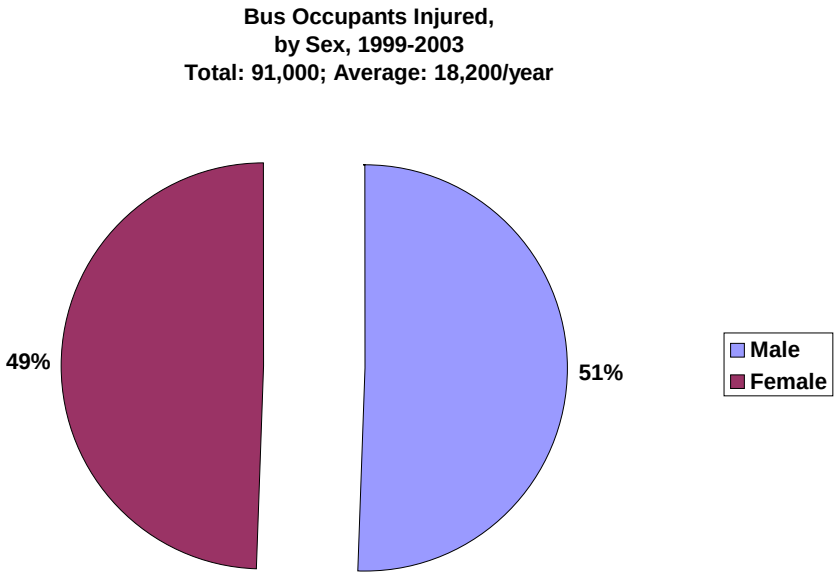


Figure 2.36 Bus Occupants Injured by Sex, 1999-2003 summary.

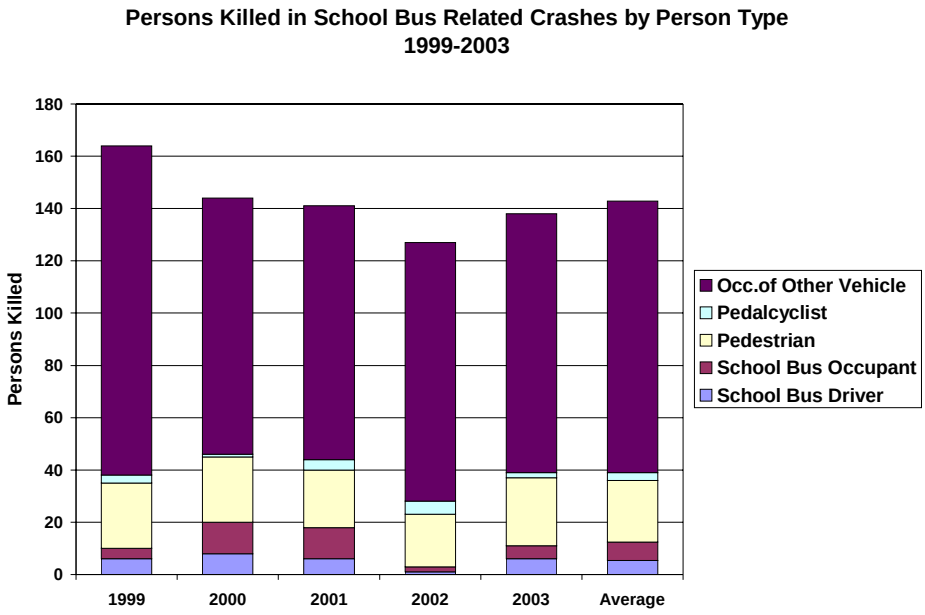


Figure 2.37 Persons Killed in School Bus Related Crashes by Person Type, 1999-2003.

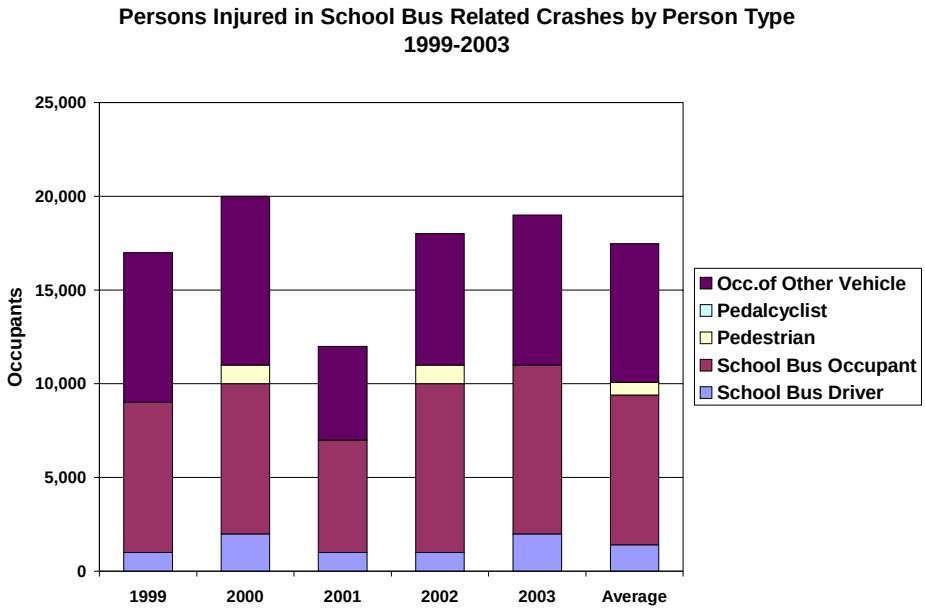


Figure 2.38 Persons Injured in School Bus Related Crashes by Person Type, 1999-2003.

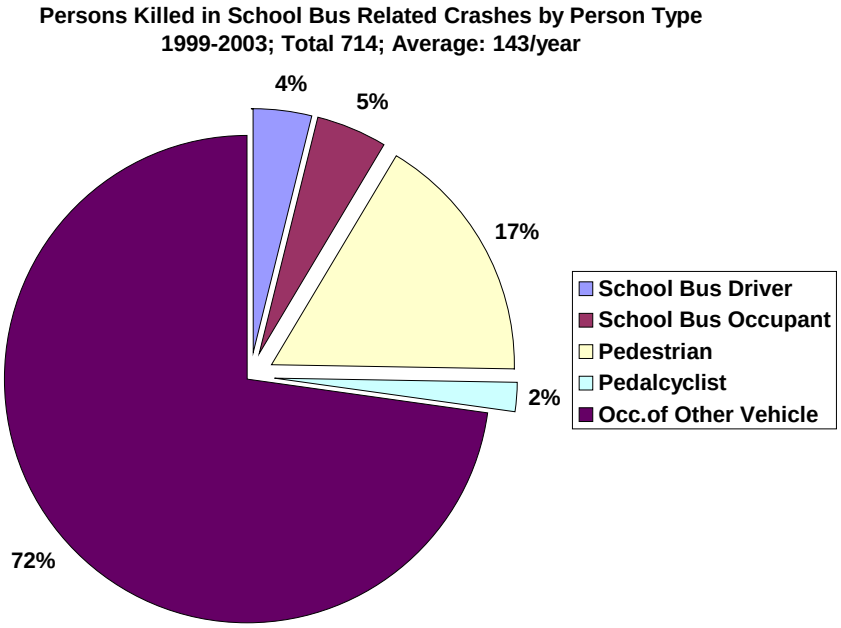


Figure 2.39 Persons Killed in School Bus Related Crashes by Person Type, 1999-2003 summary.

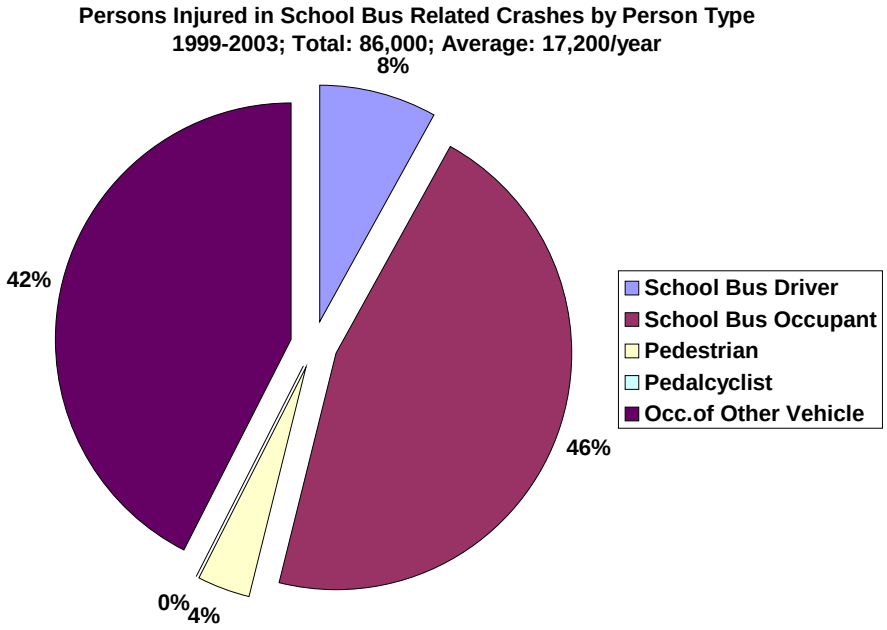


Figure 2.40 Persons Injured in School Bus Related Crashes by Person Type, 1999-2003 summary.

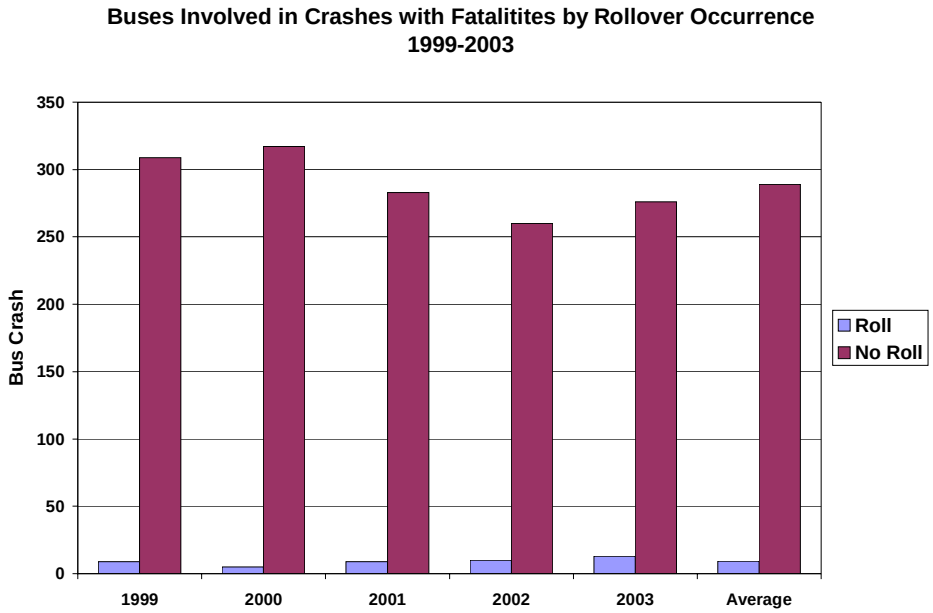


Figure 2.41 Buses Involved in Crashes with Fatalities by Rollover Occurrence, 1999-2003.

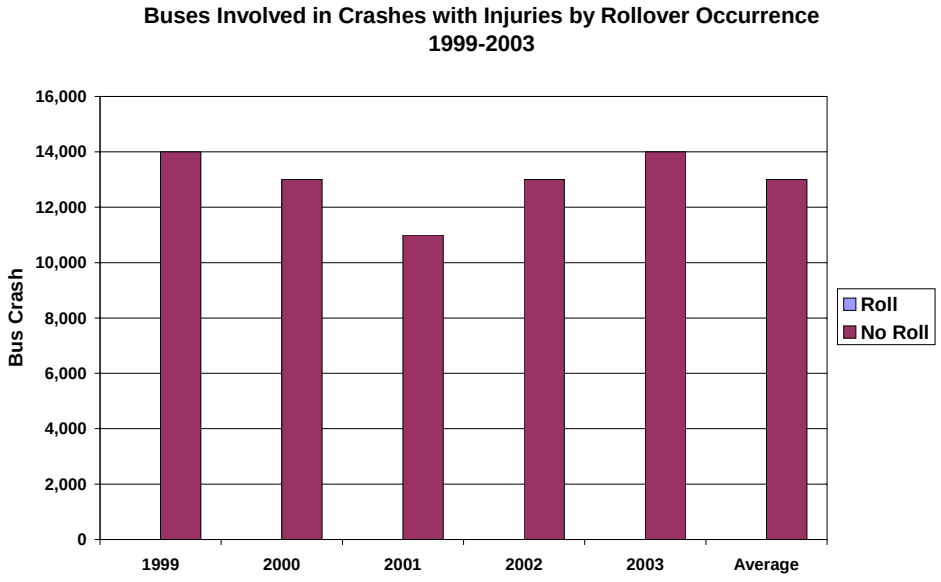


Figure 2.42 Buses Involved in Crashes with Injuries by Rollover Occurrence, 1999-2003.

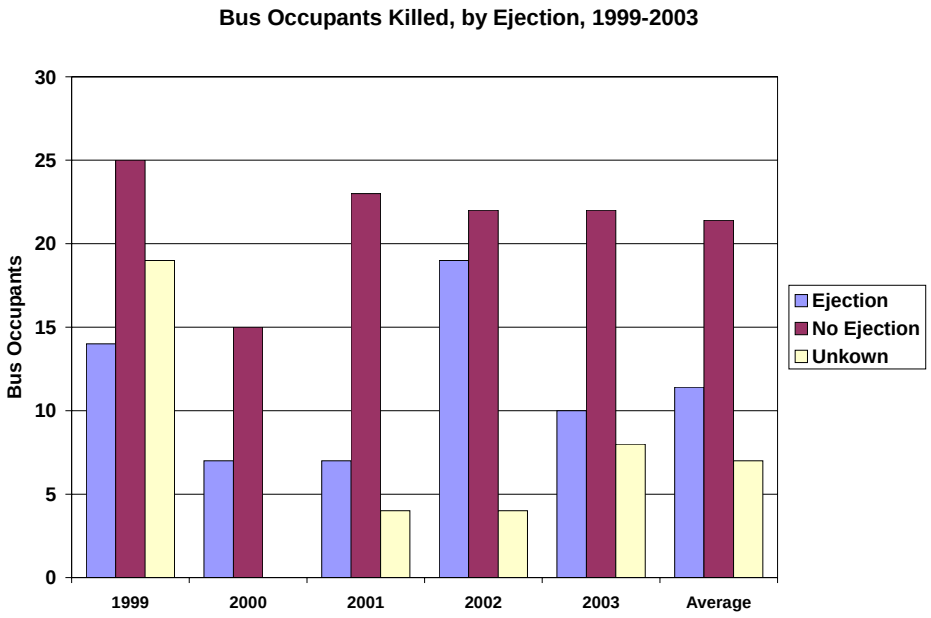


Figure 2.43 Bus Occupants Killed, by Ejection, 1999-2003.

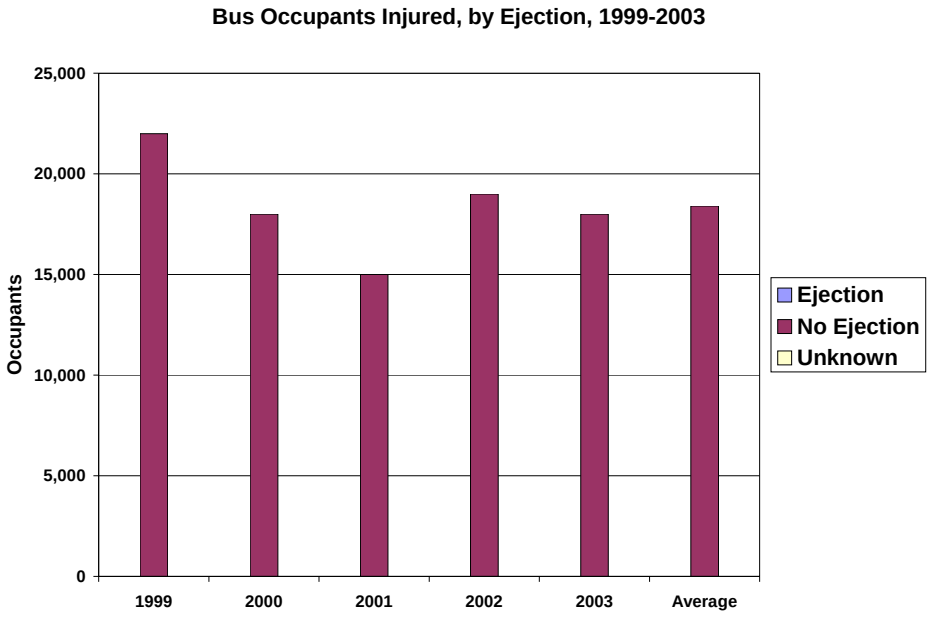


Figure 2.44 Bus Occupants Injured, by Ejection, 1999-2003.

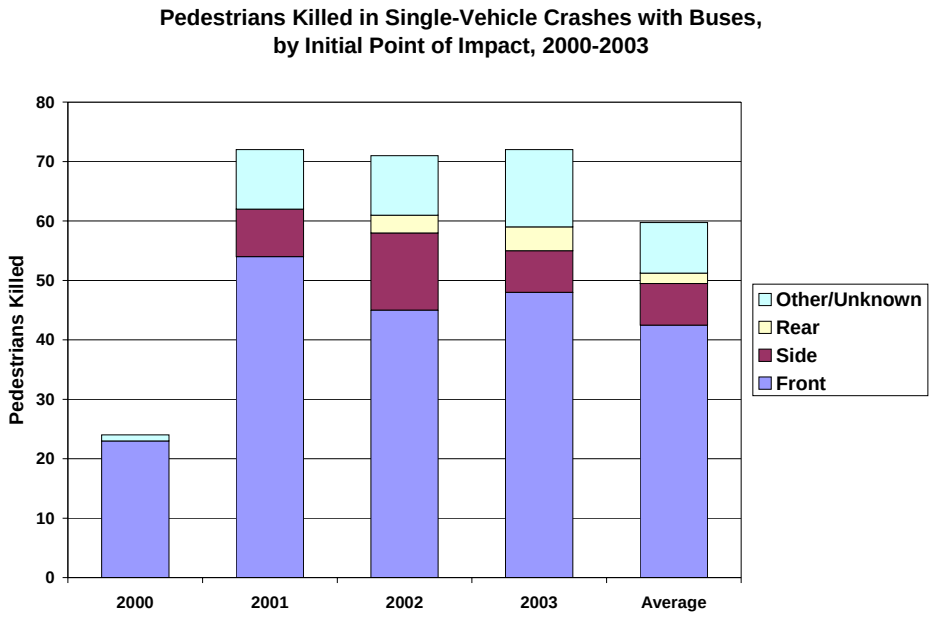


Figure 2.45 Pedestrians Killed in Single-Vehicle Crashes with Buses, by Initial Point of Impact, 2000-2003.

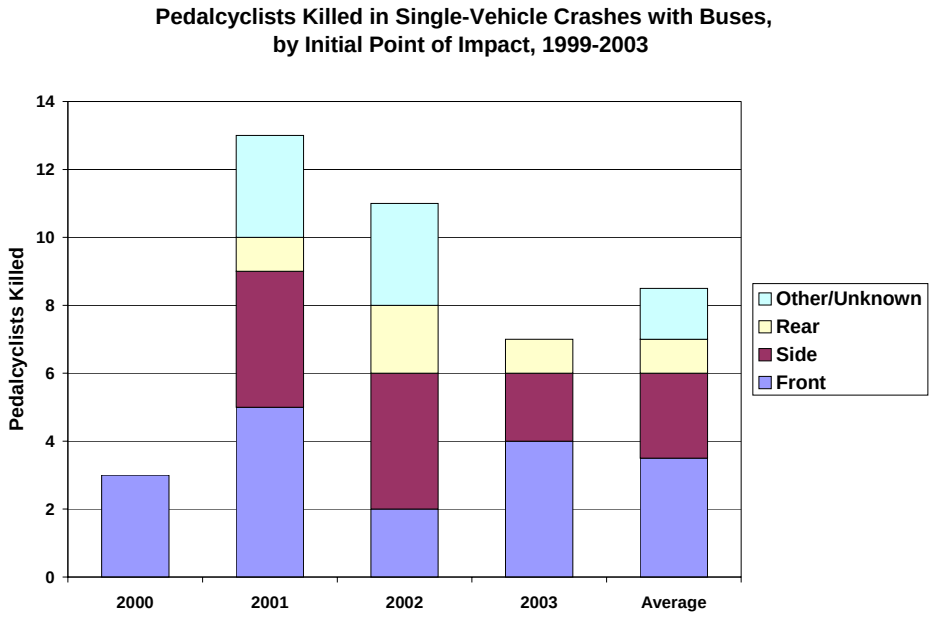


Figure 2.46 Pedalcyclists Killed in Single-Vehicle Crashes with Buses, by Initial Point of Impact, 1999-2003.

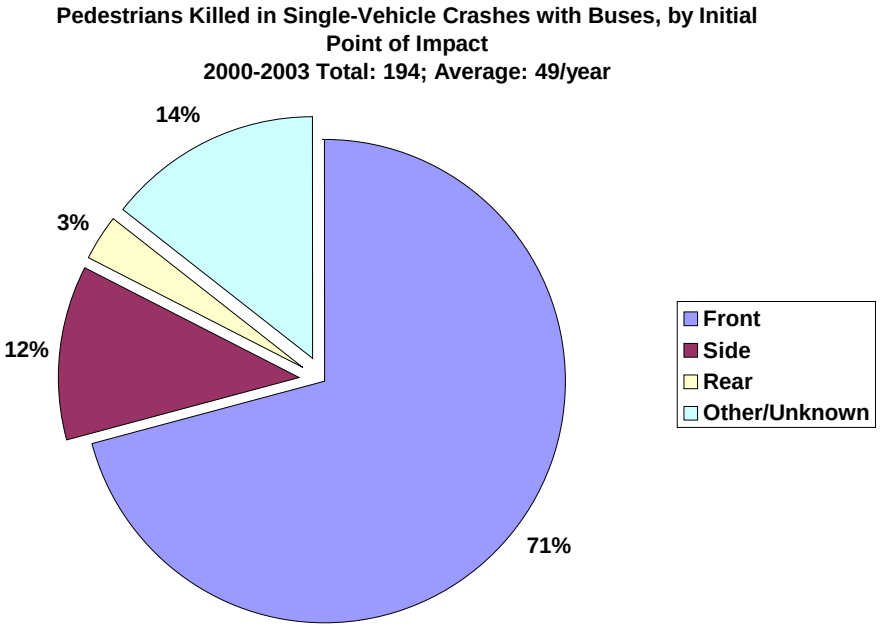


Figure 2.47 Pedestrians Killed in Single-Vehicle Crashes with Buses, by Initial Point of Impact, 2000-2003 summary.

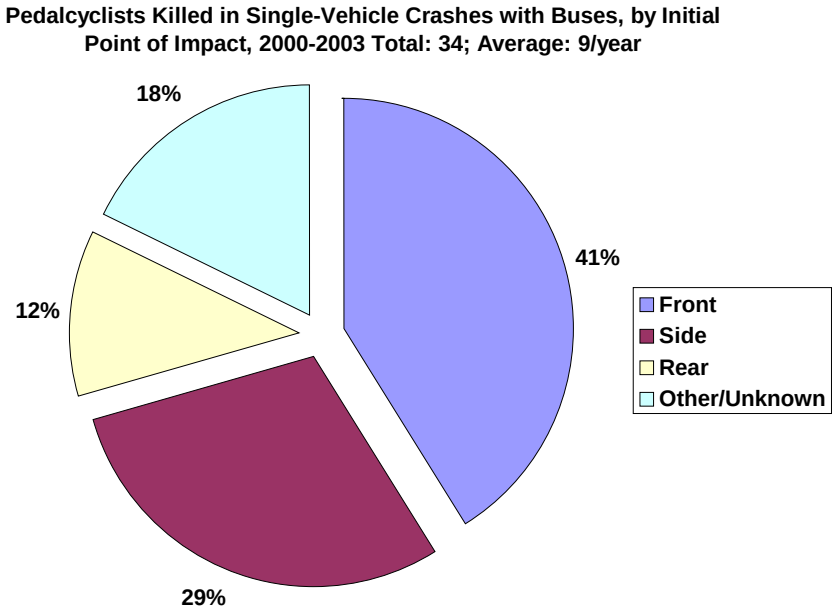


Figure 2.48 Pedalcyclists Killed in Single-Vehicle Crashes with Buses, by Initial Point of Impact, 2000-2003 summary.

2.3 Summary of Buses Involved in Fatal Accidents (1999-2001)

The Buses Involved in Fatal Accidents (BIFA) report presents aggregate statistics for buses involved in traffic accidents, compiled by the University of Michigan Transportation Research Institute (UMTRI). The BIFA database is a census of all buses involved in a fatal accident in the United States, and provides coverage of buses recorded in the Fatality Analysis Reporting System (FARS) file. BIFA combines vehicle, accident, and occupant records from FARS with information about the physical configuration and operating authority of the bus from the BIFA survey.

Modeled after UMTRI's Trucks Involved in Fatal Accidents (TIFA) program, the BIFA survey collects detailed information on all buses involved in all fatal traffic accidents. Buses are defined as motor vehicles with seating for nine or more, including the driver, that are not operated as personal transportation, and all motor vehicles with seating for 16 or more. The BIFA file is produced annually, beginning with the 1999 data year, from a survey of bus records extracted from the FARS file, compiled by the National Center for Statistics and Analysis at the National Highway Traffic Safety Administration.

Accident, vehicle, and driver records that appear to involve a bus are selected from the FARS file. Police reports for each accident represented are requested from the appropriate states. The BIFA file is a census file, meaning there is one record for each bus involved in a fatal accident. The data presented in BIFA reports includes all bus type involvements. The data summarized in this report is focused on transit bus involvements only.

Involvements: counts of the buses involved in a fatal accident.

Fatalities: counts of fatalities of occupants of bus and/or other vehicle involved.

Transit – an entity providing passenger transportation over fixed, scheduled routes, within primarily urban geographical areas.

Trends 1999-2001

- An average of 111 transit buses is involved in a fatal traffic accident each year.
- A total of 246 fatalities resulted from transit bus involvements from 1999-2000. 43% of the fatalities were drivers of other vehicles, 37% were pedestrians, 13% percent were passengers of other vehicles.

Temporal

- About 50% of fatal transit bus involvements occur during rush hour, from 6:00 to 9:59 a.m. and from 3:00 to 6:59 p.m.

- 80% of transit bus fatal involvements occur during the work week. The lowest percentage of involvements, 7.8%, occur on Sunday.

Environment

- 88% of fatal transit bus involvements occurred in urban environments.
- 62% of fatal transit bus involvements occur in daylight, 29% in dark but lighted conditions.
- 82% of fatal transit bus involvements occur on dry roadway surface conditions.
- 89% of fatal involvements occur under “normal” weather conditions (i.e. no rain, snow, fog, or other adverse condition).

Roadway

- 58% of fatal transit bus involvements occur on local streets (township or municipality), 15% on state highways, and 8% on county roads.
- 55% of fatal transit bus involvements occur on 2 travel lanes.
- 63% of fatal transit bus involvements occurred between 25-35 mph.

Accident

- 99% of single vehicle fatal transit bus involvements hit an object in the road.
- 82% of two vehicle fatal transit bus involvements on the same trafficway, same direction resulted from a rearend, bus struck.
- 88% of two vehicle fatal transit bus involvements on the same trafficway, different direction resulted from a head-on collision in the buses lane.
- 77% of two vehicle fatal transit bus involvements on intersecting paths, both going straight resulted from the bus crashing into the side of the other vehicle.
- 52% of fatal transit bus by first harmful event, collision with non-fixed object, occurred with a motor vehicle in transport, 41% with other type non-motorist.
- 68% of the fatal transit bus involvements by vehicle role in accident occurred from the vehicle striking the bus.

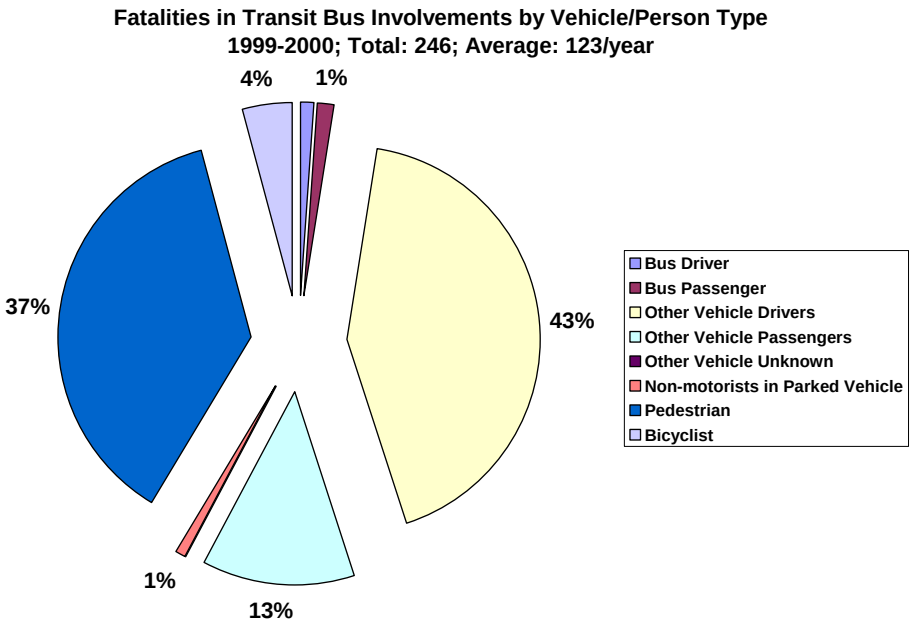
Vehicle

- Shorter, heavy-duty, transit buses accounted for 73% of fatal transit bus involvements.

- Buses accounted for 99% of fatal transit bus involvements.
- Low platform buses accounted for 65% of fatal transit bus involvements.
- Flat from buses accounted for 96% of fatal transit bus involvements.
- 36-40 foot buses accounted for 61% of fatal transit bus involvements.
- Buses with 25,001-30,000 lb. empty weights accounted for 70% of fatal transit bus involvements.
- Buses with gross weight greater than 33,001 lb accounted for 62% of fatal transit bus involvements.
- 89% of fatal transit bus involvements were from buses with 2 axles.
- 55% of fatal transit bus involvements occurred in buses with a passenger seating capacity of 36-45, excluding the driver.
- 88% of fatal transit bus involvements occurred in buses with no passenger restraints available, excluding the driver.
- 84% of fatal transit bus involvements occurred on local trips.
- For the most harmful event, collision with non-fixed object, of fatal transit bus involvements, 53% were with a vehicle in transport and 41% with a pedestrian.

Driver

- 73% of drivers in fatal transit bus involvements experienced no injury.



Fatalities in Transit Bus Involvements by Vehicle/Person type, 1999-2000 summary.

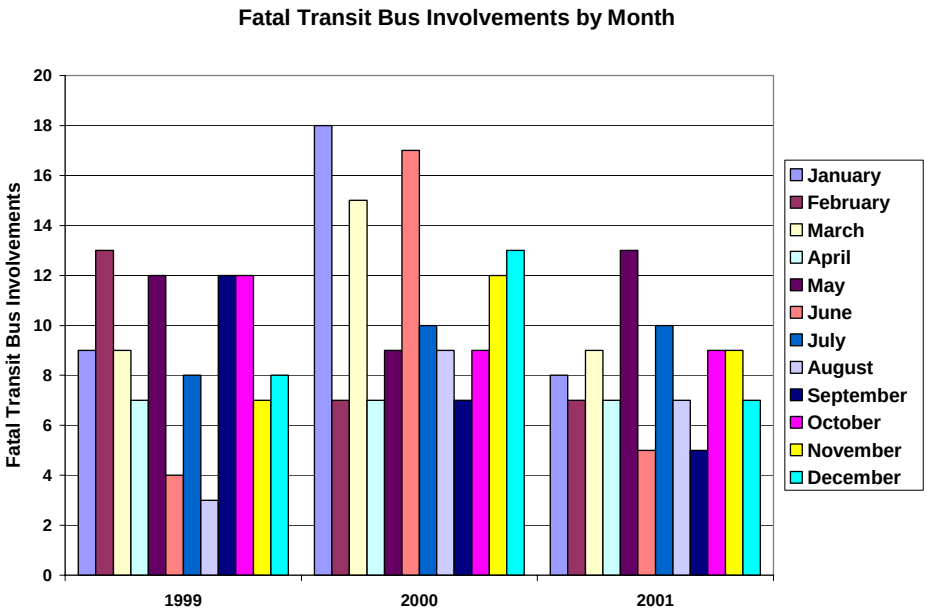


Figure 2.49 Fatal Transit Bus Involvements by Month.

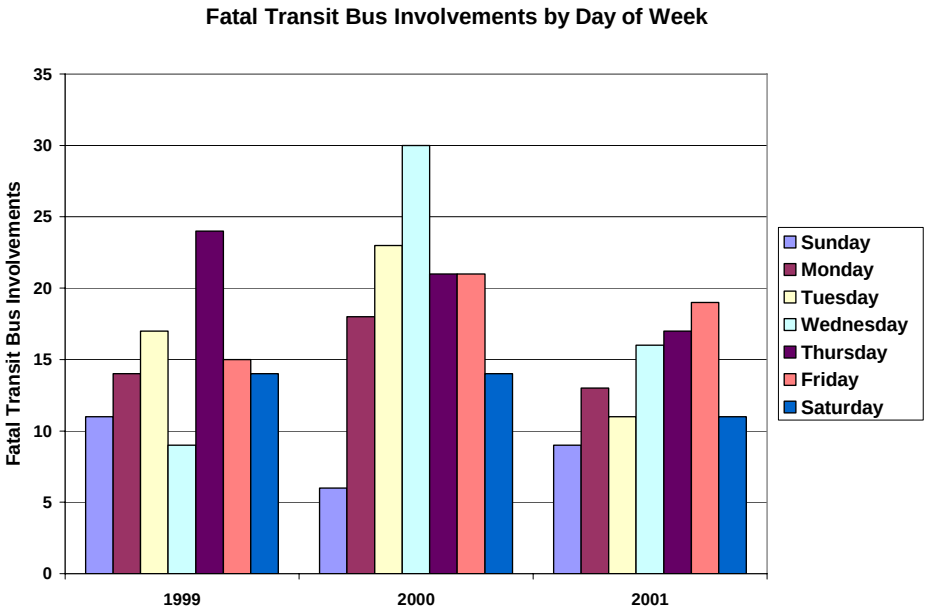


Figure 2.50 Fatal Transit Bus Involvements by Day of Week.

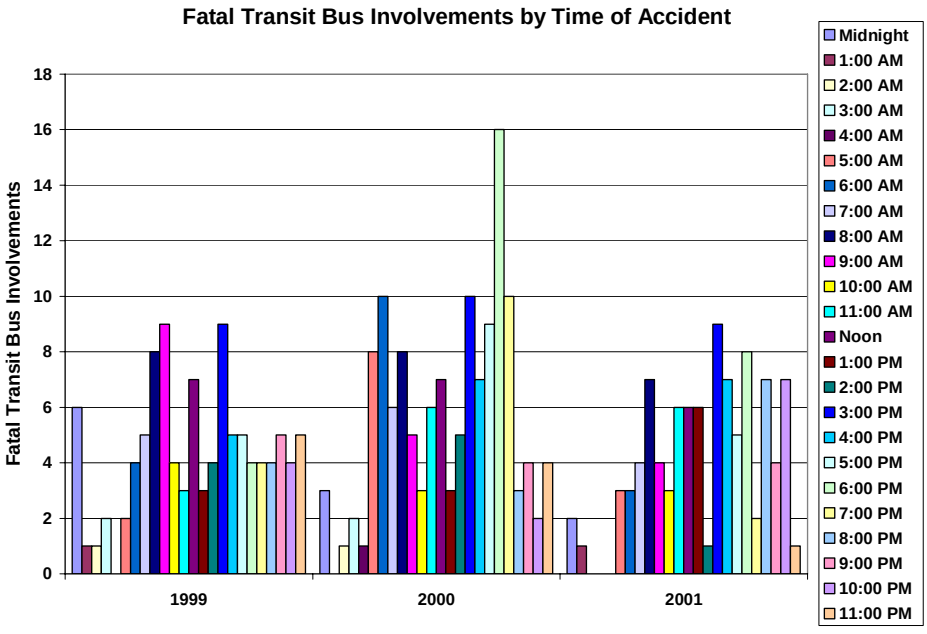


Figure 2.51 Fatal Transit Bus Involvements by Time of Accident.

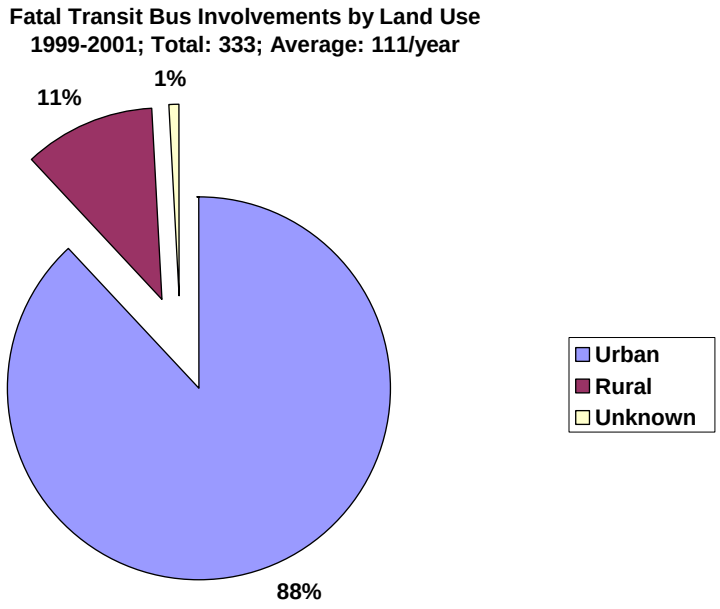


Figure 2.52 Fatal Transit Bus Involvements by Land Use, 1999-2001 summary.

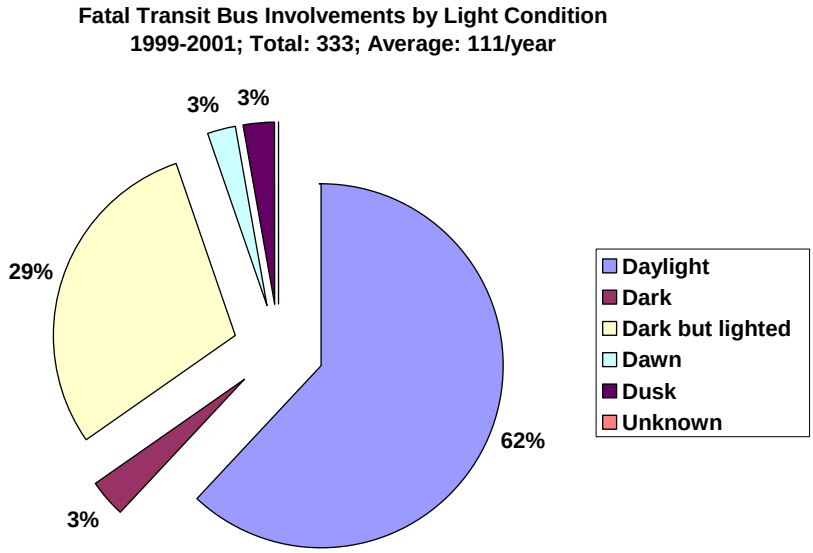
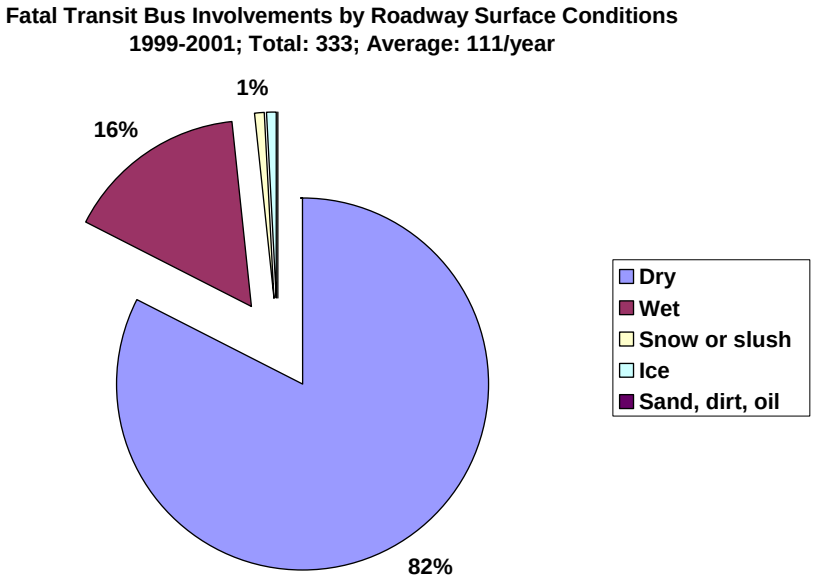
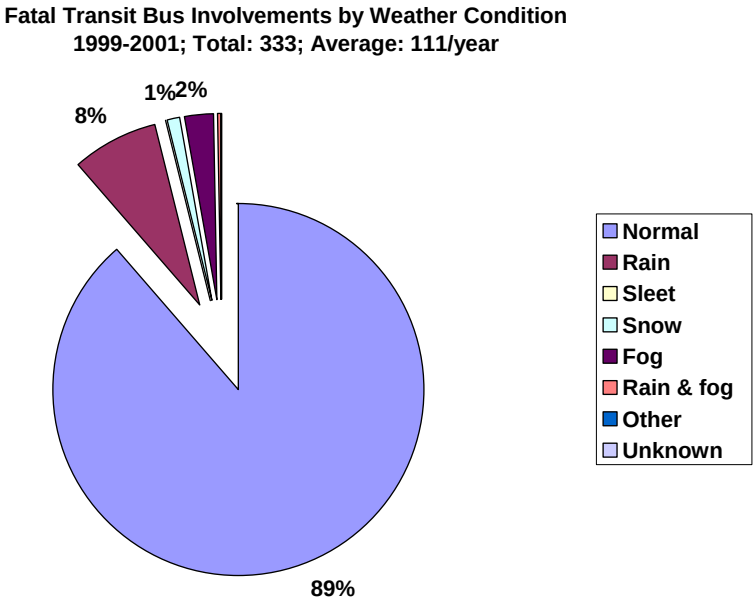


Figure 2.53 Fatal Transit Bus Involvements by Light Condition, 1999-2001 summary.



Fatal Transit Bus Involvements by Roadway Surface Conditions, 1999-2001 summary.



Fatal Transit Bus Involvements by Weather Condition, 1999-2001 summary.

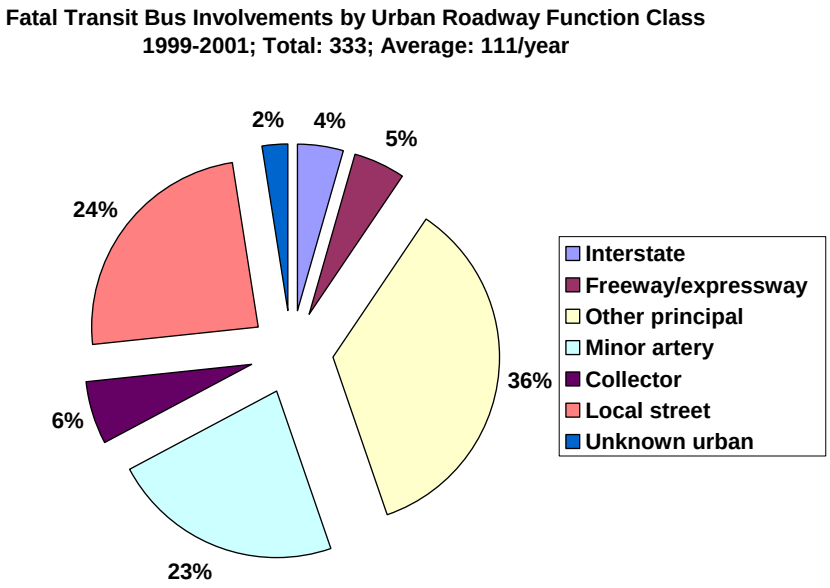


Figure 2.54 Fatal Transit Bus Involvements by Urban Roadway Function Class, 1999-2001 summary.

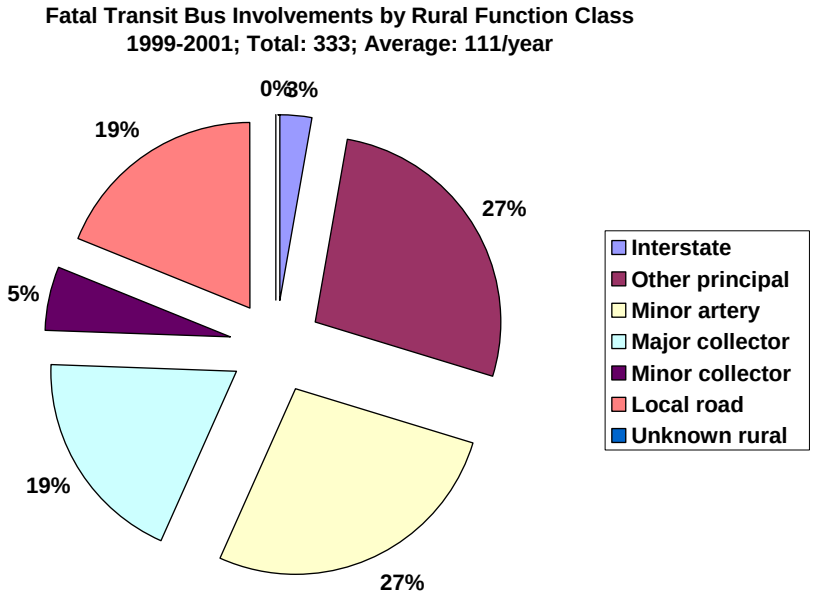


Figure 2.55 Fatal Transit Bus Involvements by Rural Function Class, 1999-2001 summary.

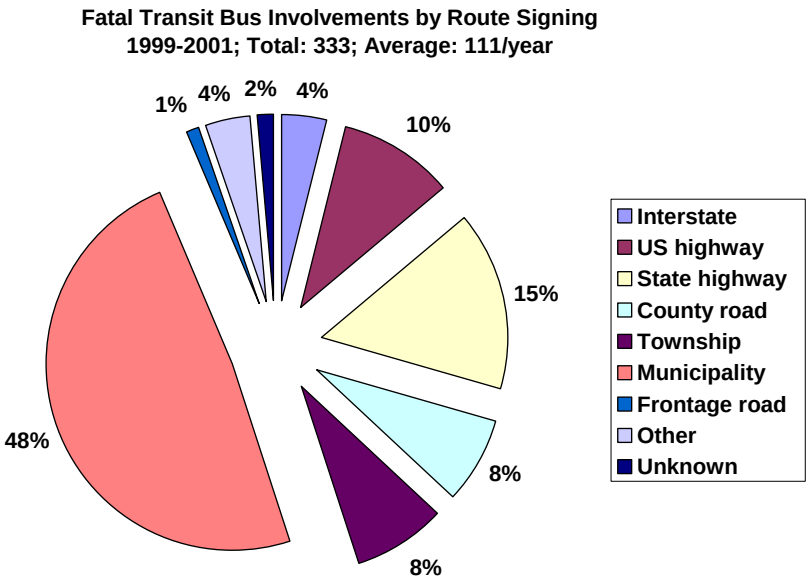


Figure 2.56 Fatal Transit Bus Involvements by Route Signing, 1999-2001 summary.

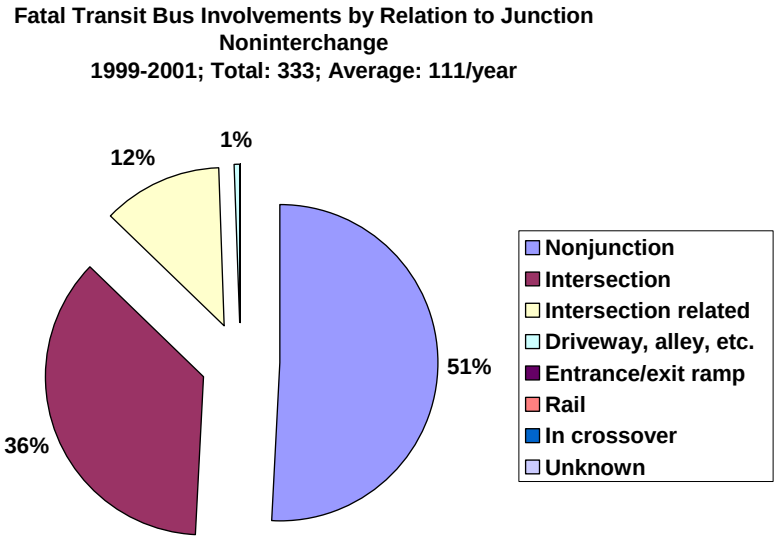


Figure 2.57 Fatal Transit Bus Involvements by Relation to Junction – Noninterchange – 1999-2001 summary.

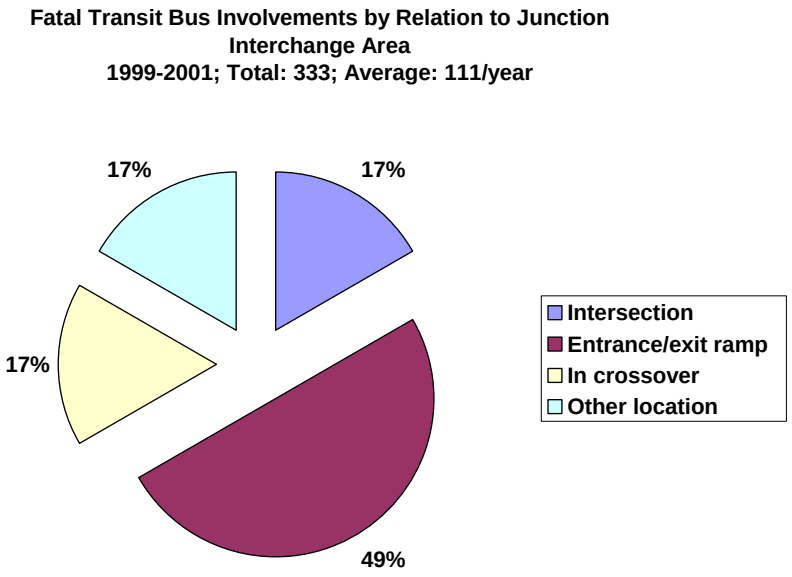


Figure 2.58 Fatal Transit Bus Involvements by Relation to Junction – Interchange Area – 1999-2001 summary.

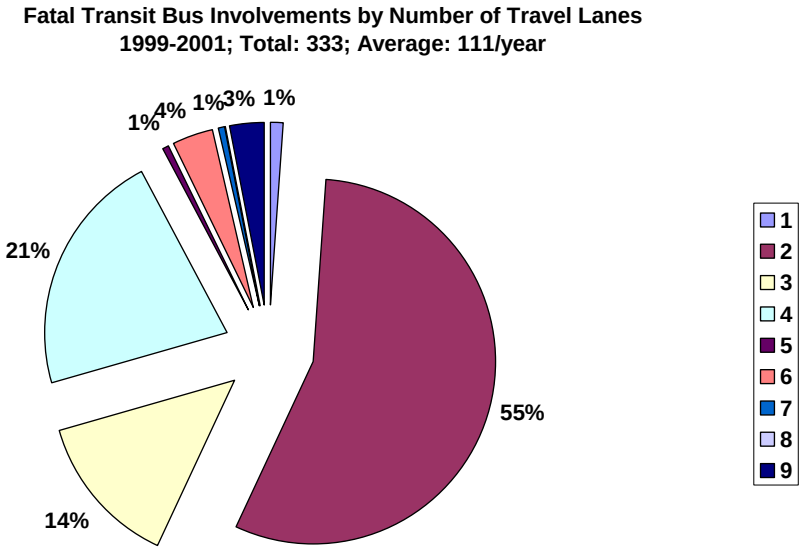


Figure 2.59 Fatal Transit Bus Involvements by Number of Travel Lanes, 1999-2001 summary.

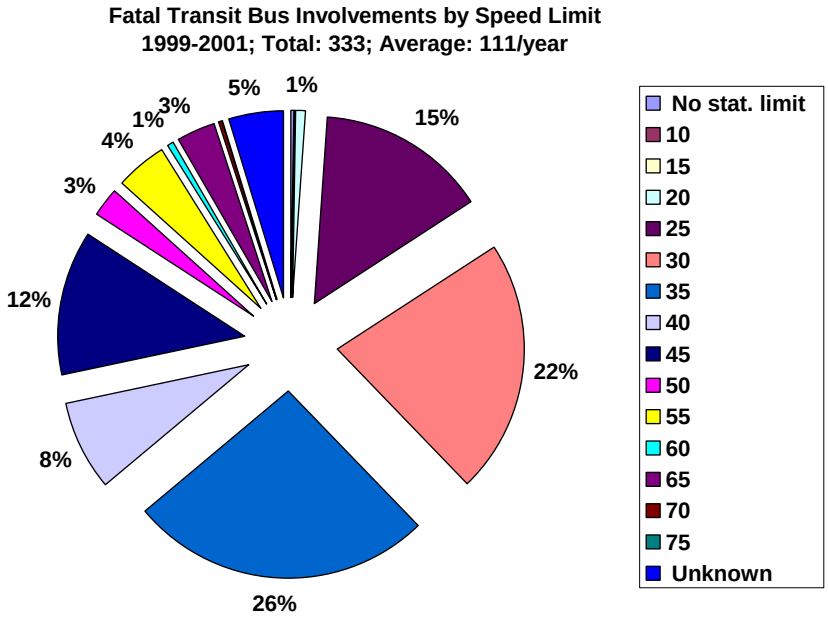


Figure 2.60 Fatal Transit Bus Involvements by Speed Limit, 1999-2001 summary.

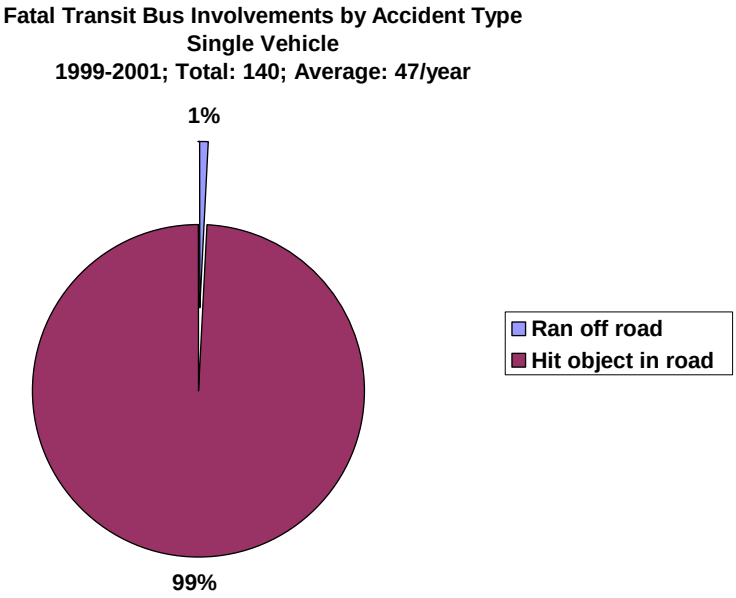


Figure 2.61 Fatal Transit Bus Involvements by Accident Type – Single Vehicle, 1999-2001 summary.

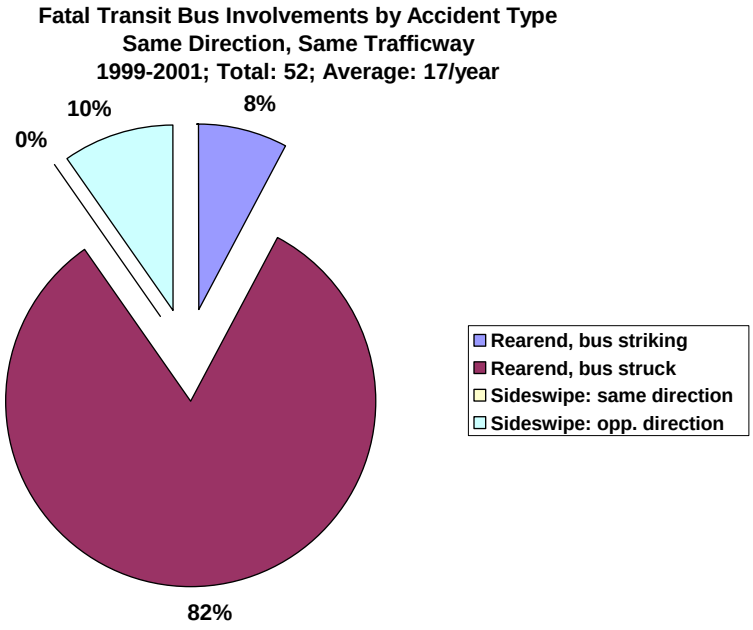


Figure 2.62 Fatal Transit Bus Involvements by Accident Type – Same Direction, Same Trafficway, 1999-2001 summary.

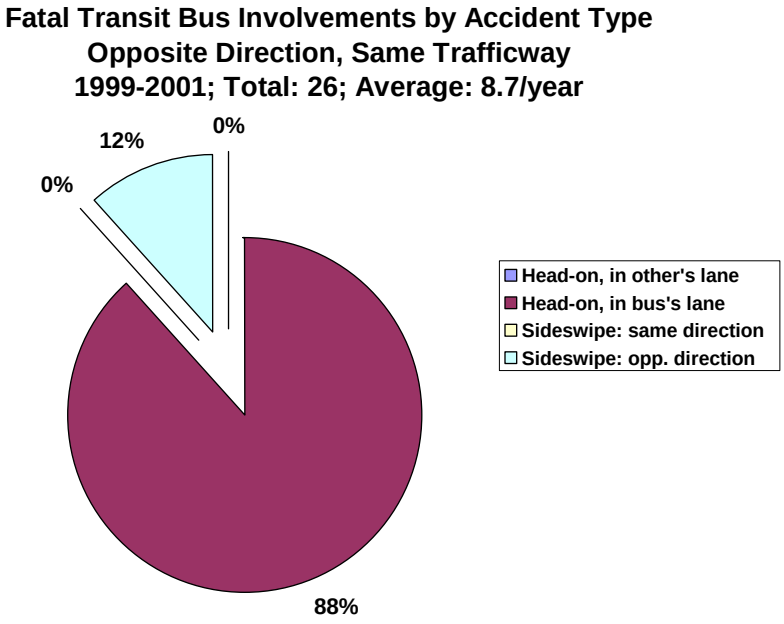


Figure 2.63 Fatal Transit Bus Involvements by Accident Type – Opposite Direction, Same Trafficway, 1999-2001 summary.

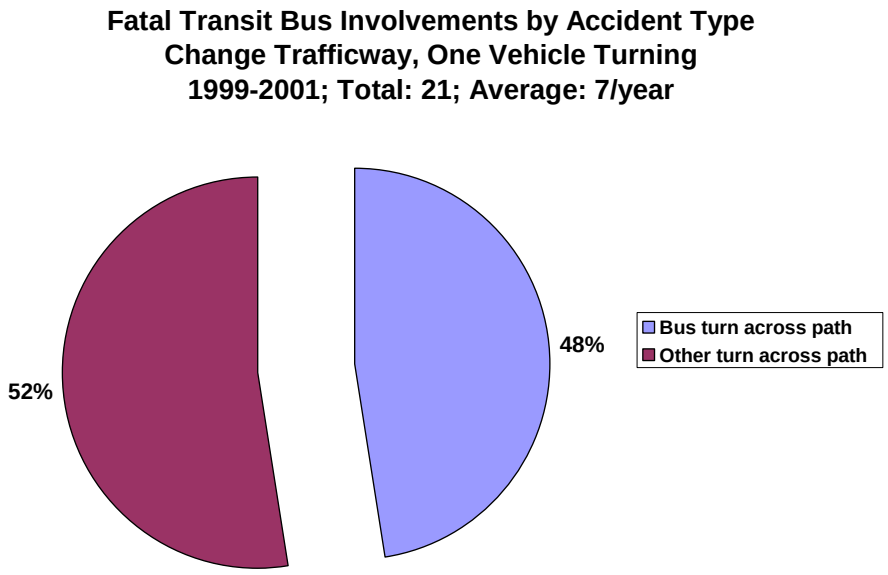


Figure 2.64 Fatal Transit Bus Involvements by Accident Type – Change Trafficway, One Vehicle Turning, 1999-2001. summary.

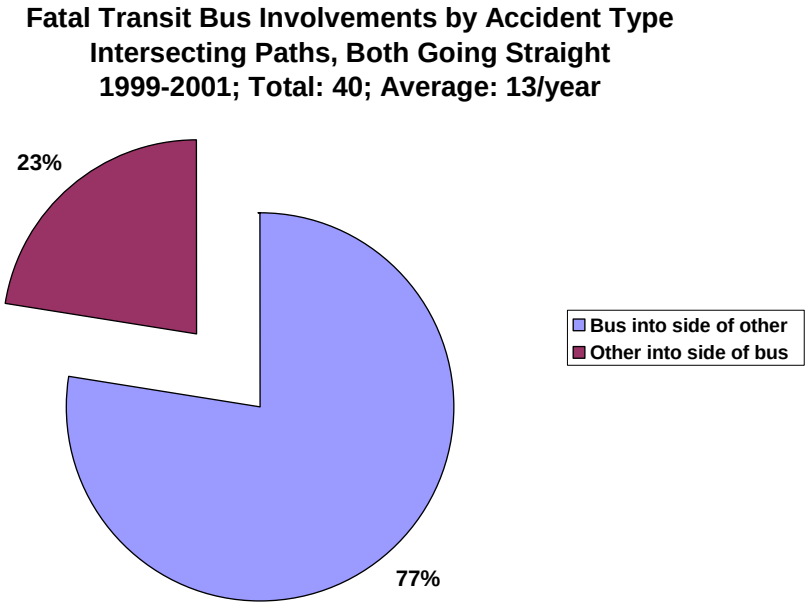


Figure 2.65 Fatal Transit Bus Involvements by Accident Type – Intersecting Paths, Both Going Straight, 1999-2001 summary.

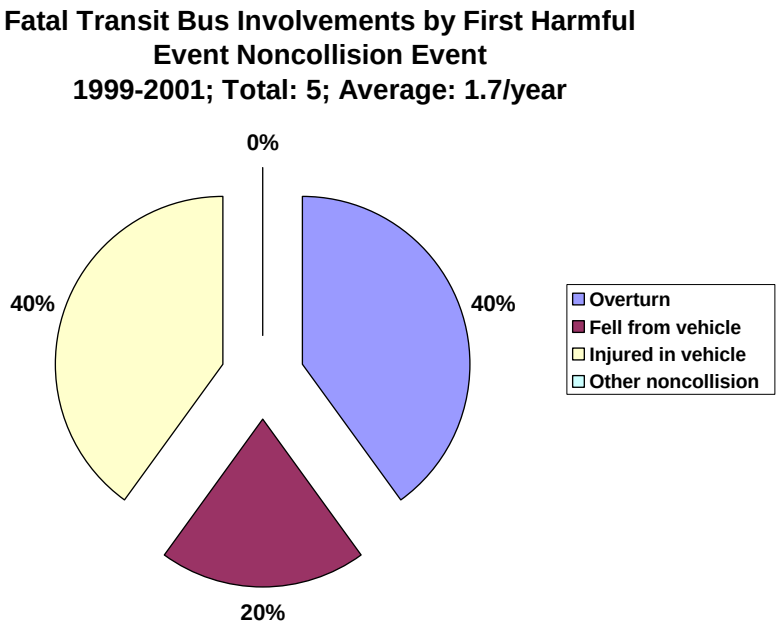


Figure 2.66 Fatal Transit Bus Involvements by First Harmful Event, Noncollision Event, 1999-2001 summary.

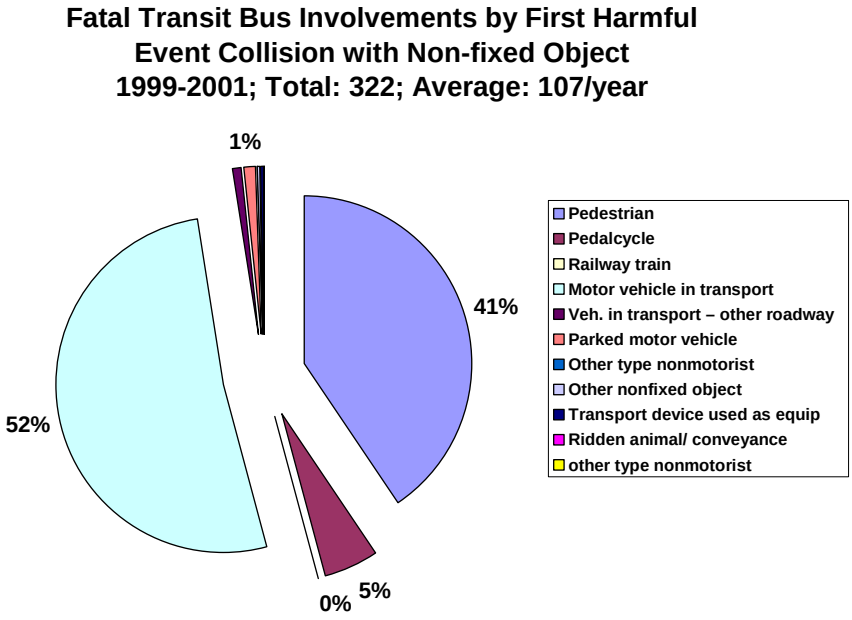


Figure 2.67 Fatal Transit Bus Involvements by First Harmful Event, Collision with Non-Fixed Object, 1999-2001 summary.

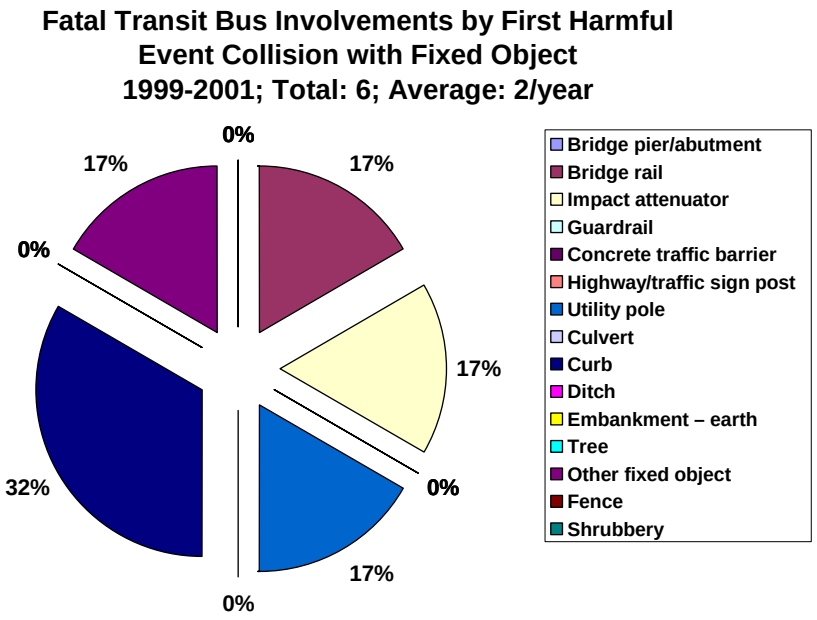


Figure 2.68 Fata Transit Bus Involvements by First Harmful Event, Collision with Fixed Object, 1999-2001 summary.

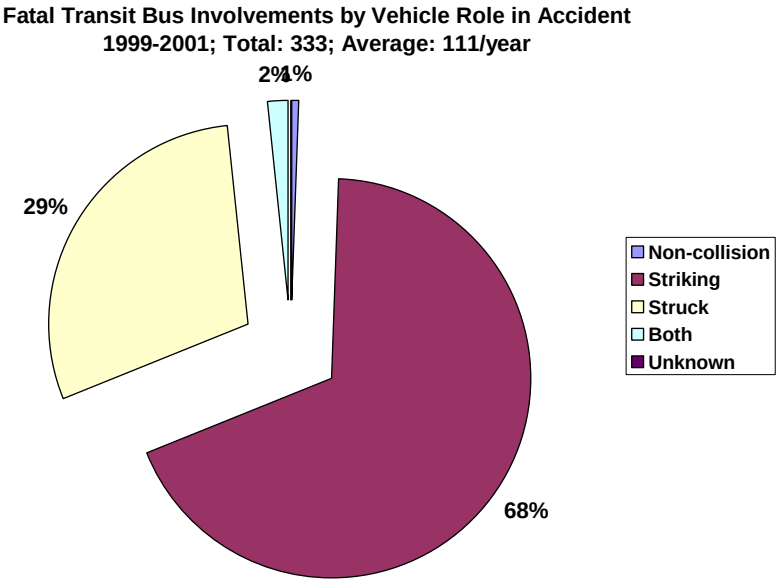


Figure 2.69 Fatal Transit Bus Involvements by Vehicle Role in Accident, 1999-2001 summary.

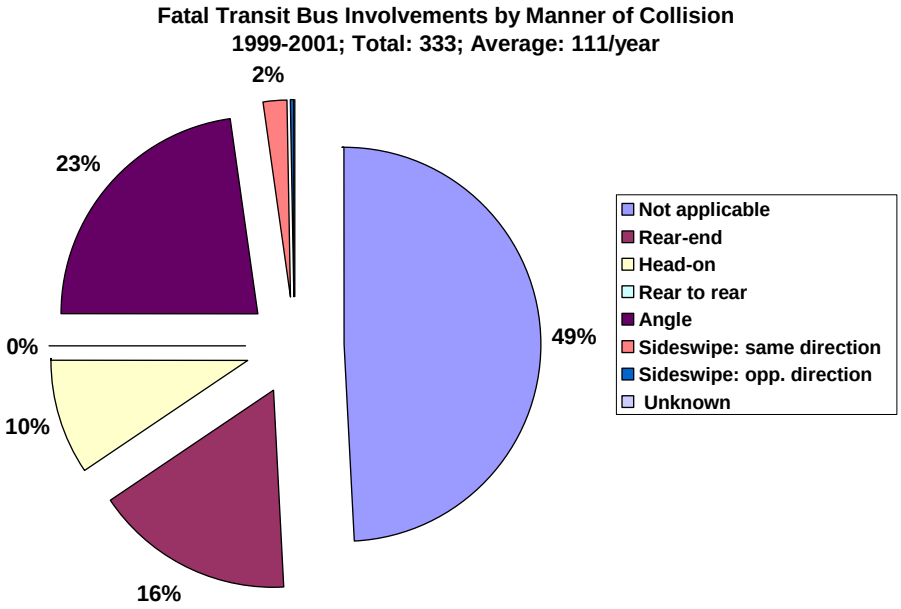


Figure 2.70 Fatal Transit Bus Involvements by Manner of Collision, 1999-2001 summary.

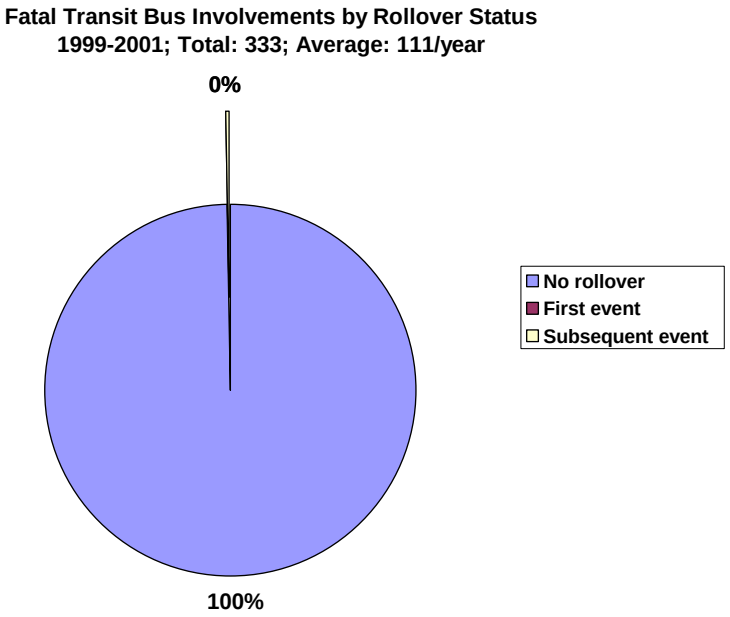


Figure 2.71 Fatal Transit Bus Involvements by Rollover Status, 1999-2001 summary.

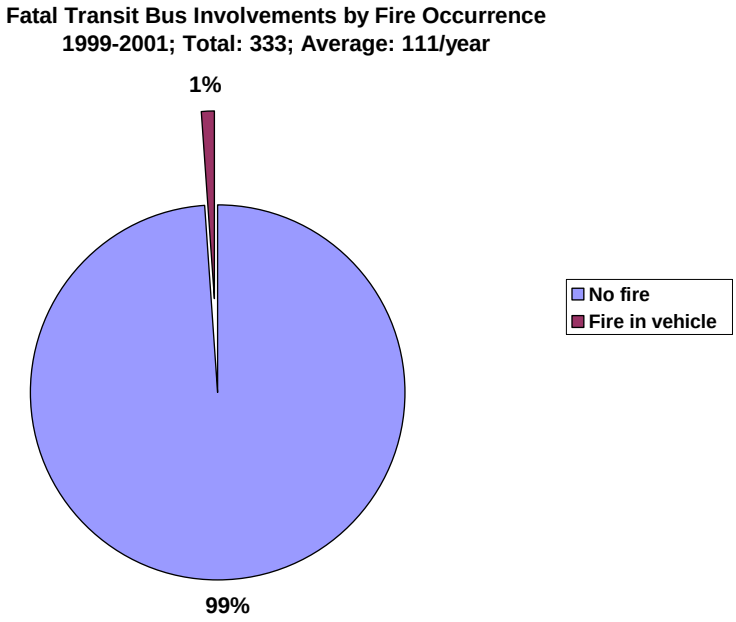


Figure 2.72 Fatal Transit Bus Involvements by Fire Occurrence, 1999-2001 summary.

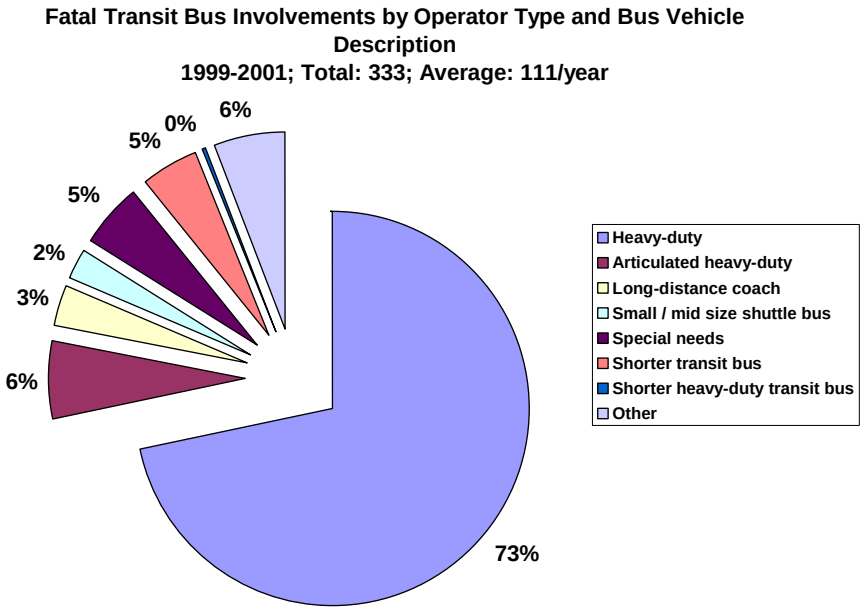


Figure 2.73 Fatal Transit Bus Involvements by Operator Type and Bus Vehicle Description, 1999-2001 summary.

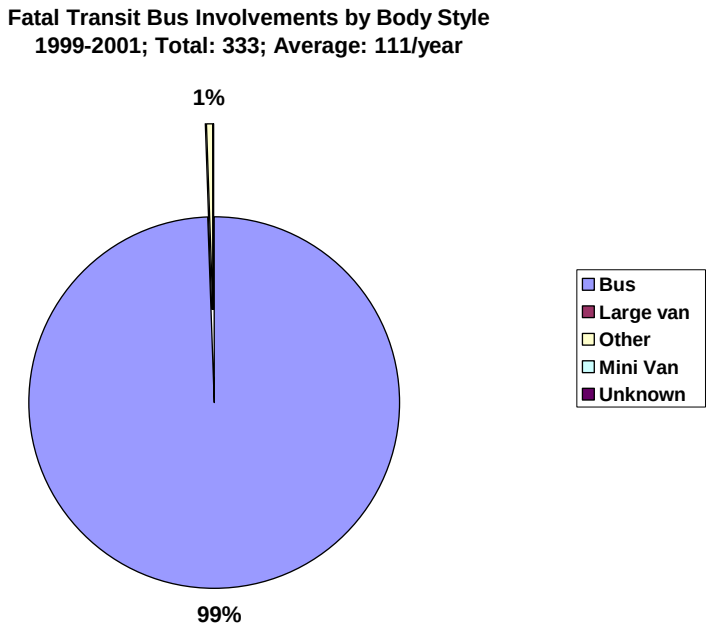


Figure 2.74 Fatal Transit Bus Involvements by Body Style, 1999-2001 summary.

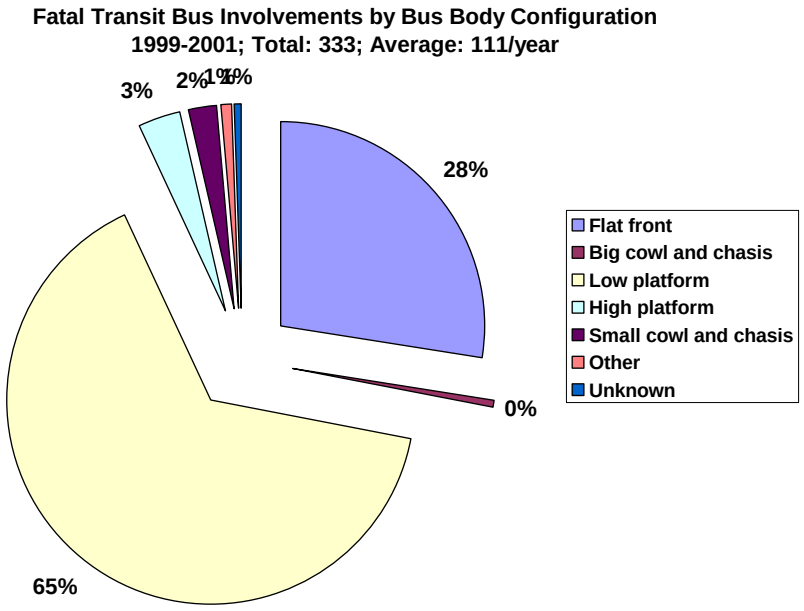


Figure 2.75 Fatal Transit Bus Involvements by Bus Body Configuration, 1999-2001 summary.

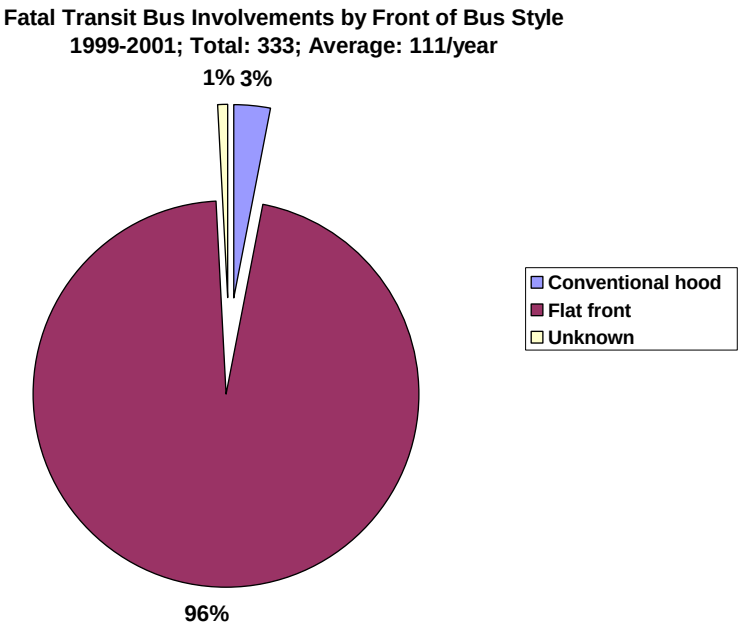


Figure 2.76 Fatal Transit Bus Involvements by Front of Bus Style, 1999-2001 summary.

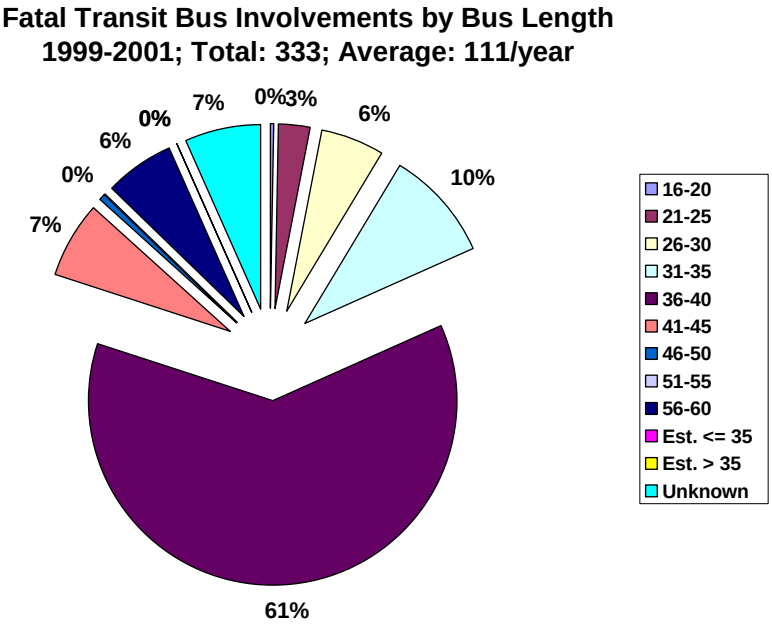


Figure 2.77 Fatal Transit Bus Involvements by Bus Length, 1999-2001 summary.

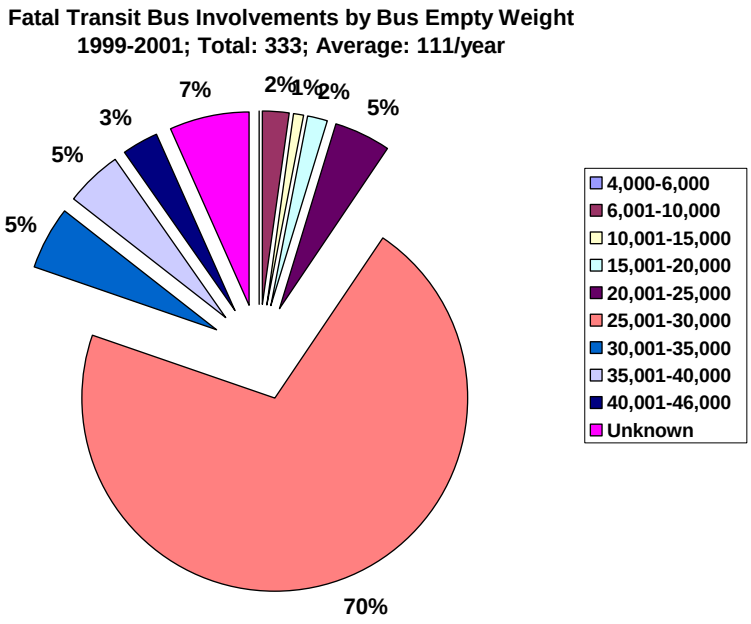


Figure 2.78 Fatal Transit Bus Involvements by Bus Empty Weight, 1999-2001 summary.

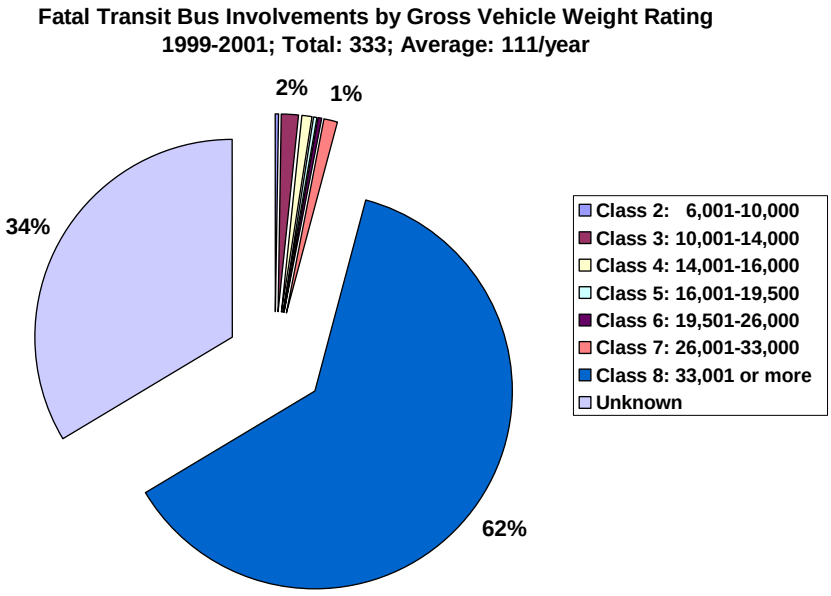


Figure 2.79 Fatal Transit Bus Involvements by Gross Vehicle Weight Rating, 1999-2001 summary.

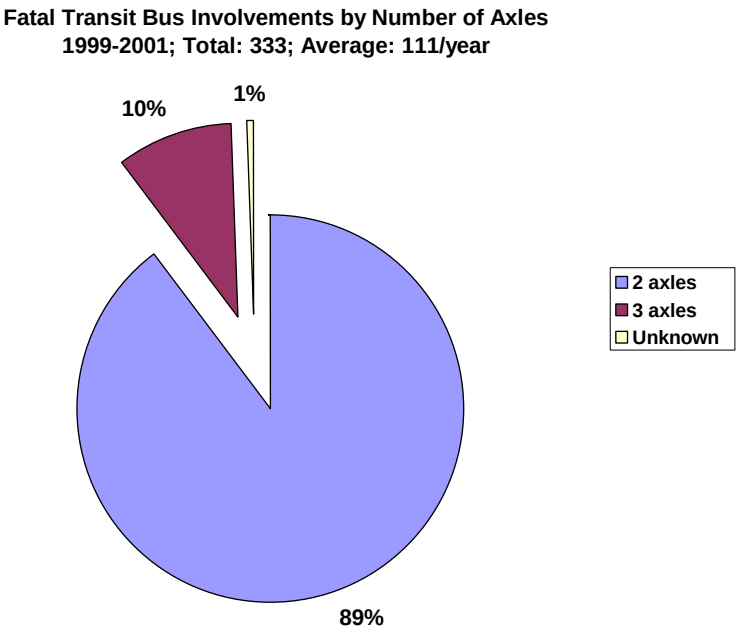


Figure 2.80 Fatal Transit Bus Involvements by Number of Axles, 1999-2001 summary.

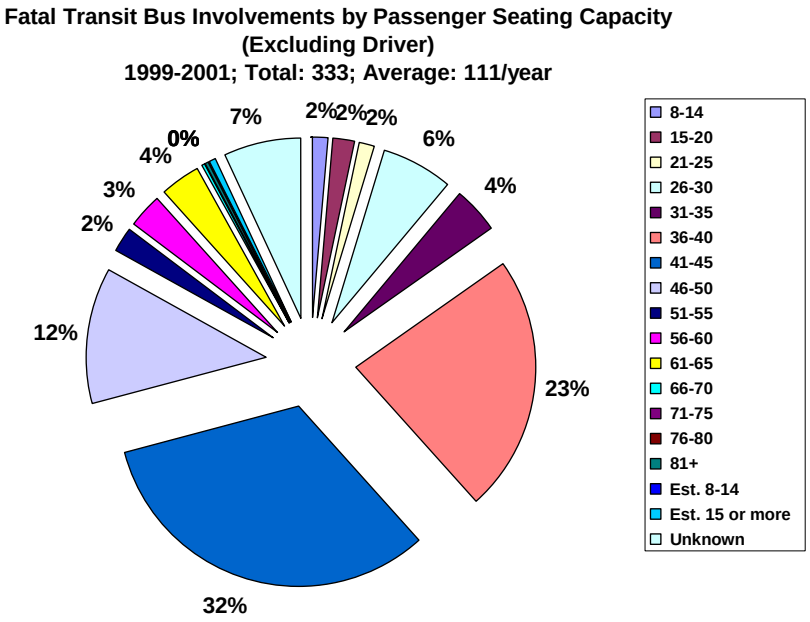


Figure 2.81 Fatal Transit Bus Involvements by Passenger Seating Capacity (Excluding Driver), 1999-2001 summary.

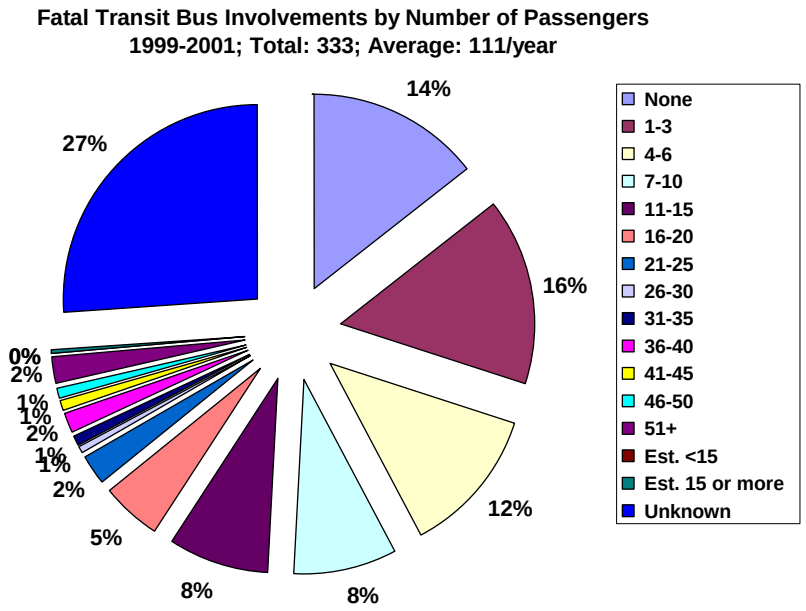


Figure 2.82 Fatal Transit Bus Involvements by Number of Passengers, 1999-2001 summary.

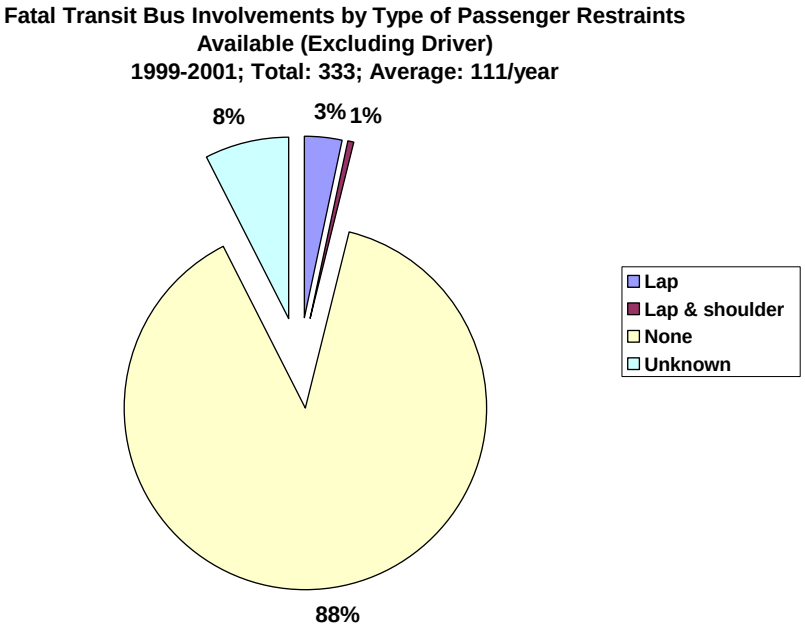


Figure 2.83 Fatal Transit Bus Involvements by Type of Passenger Restraints, 1999-2001 summary.

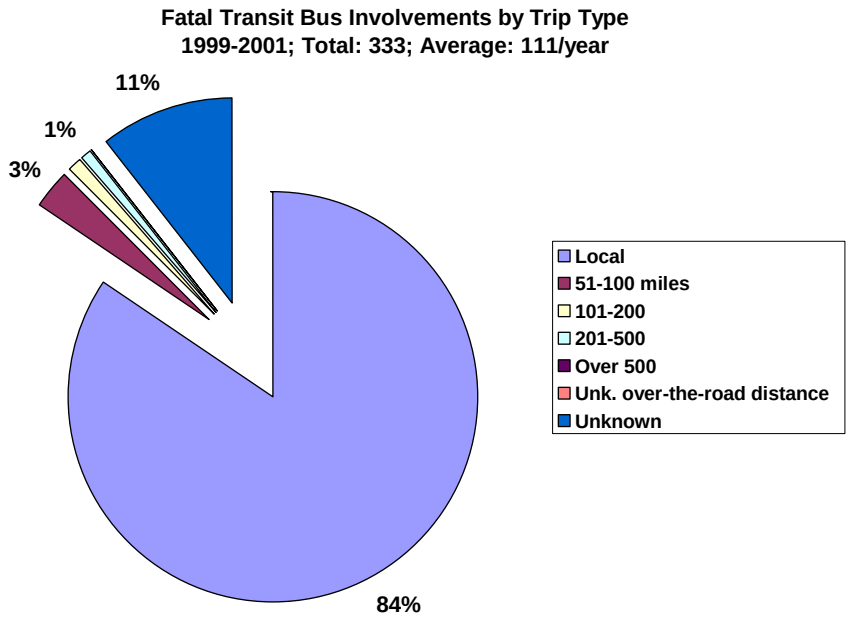


Figure 2.84 Fatal Transit Bus Involvements by Trip Type, 1999-2001 summary.

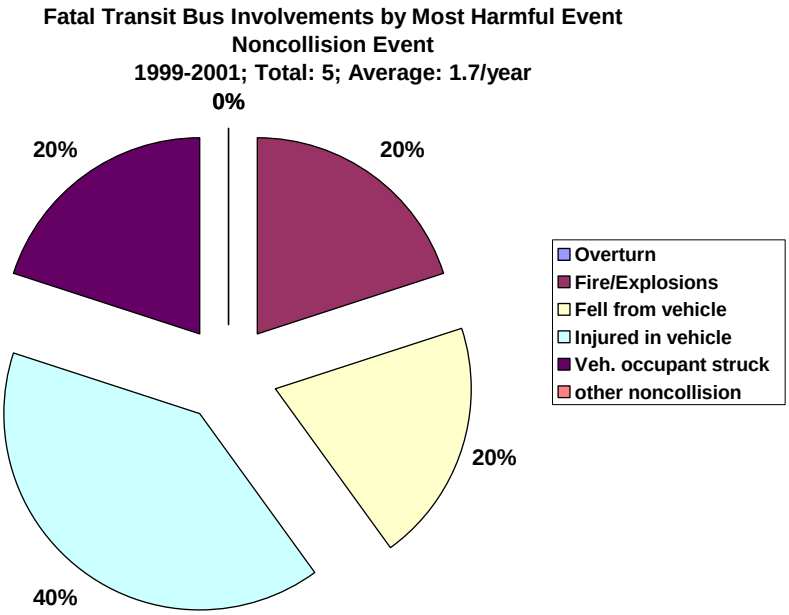


Figure 2.85 Fatal Transit Bus Involvements by Most Harmful Event, Noncollision Event, 1999-2001 summary.

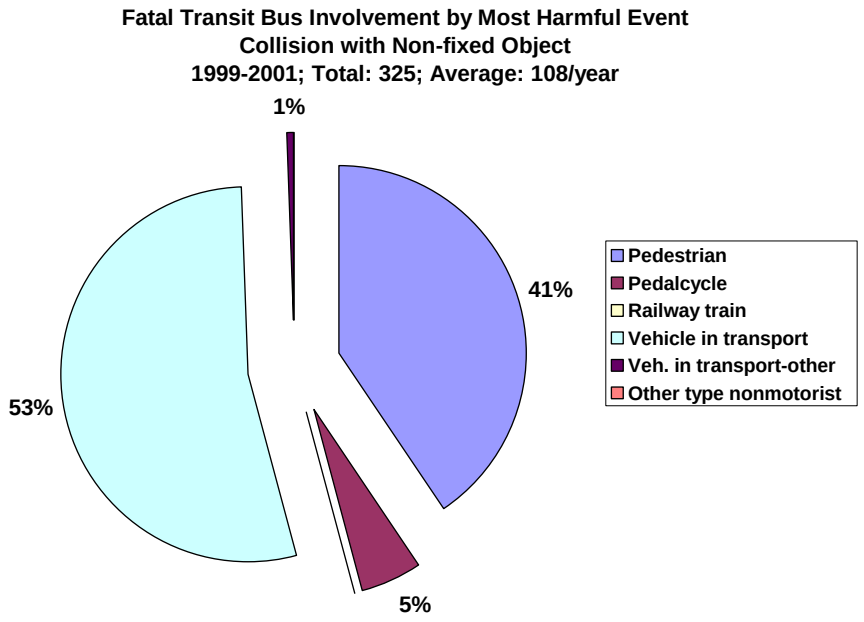


Figure 2.86 Fatal Transit Bus Involvements by Most Harmful Event, Collision with Non-fixed Object, 1999-2001 summary.

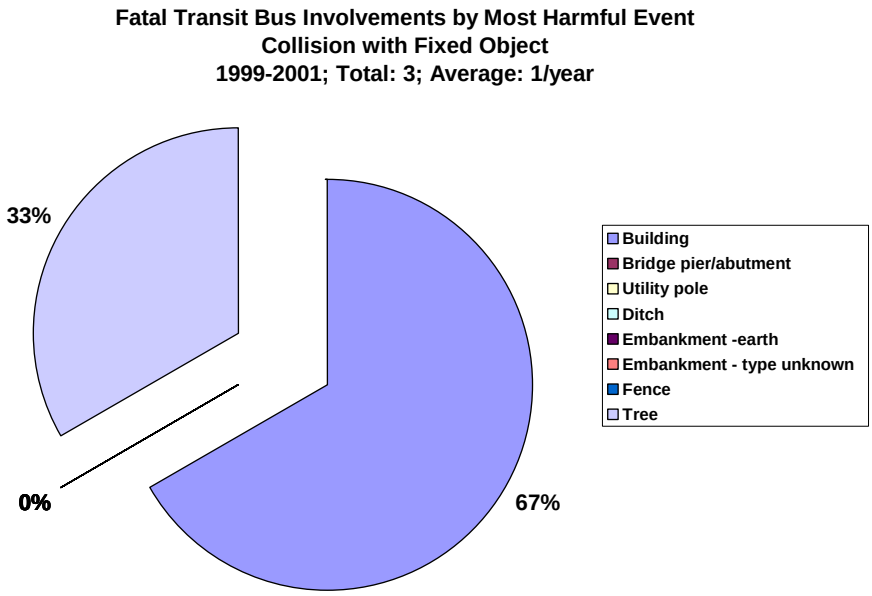


Figure 2.87 Fatal Transit Bus Involvements by Most Harmful Event, Collision with Fixed Object, 1999-2001 summary.

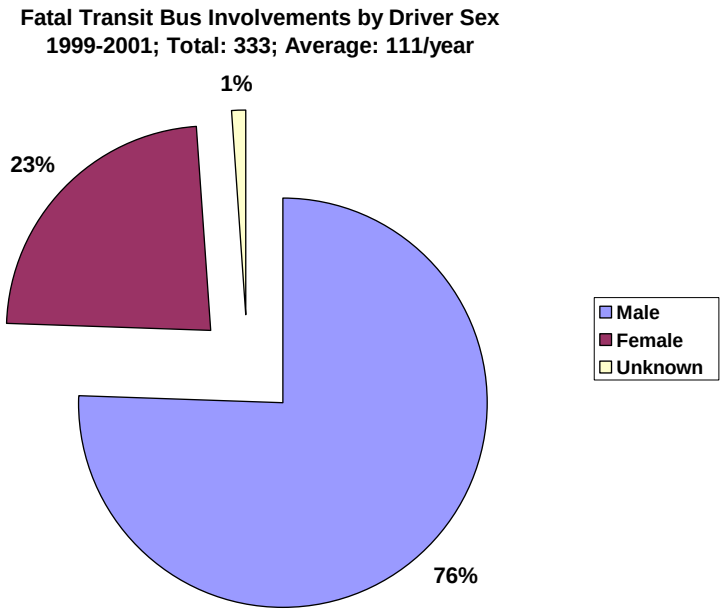


Figure 2.88 Fatal Transit Bus Involvements by Driver Sex, 1999-2001 summary.

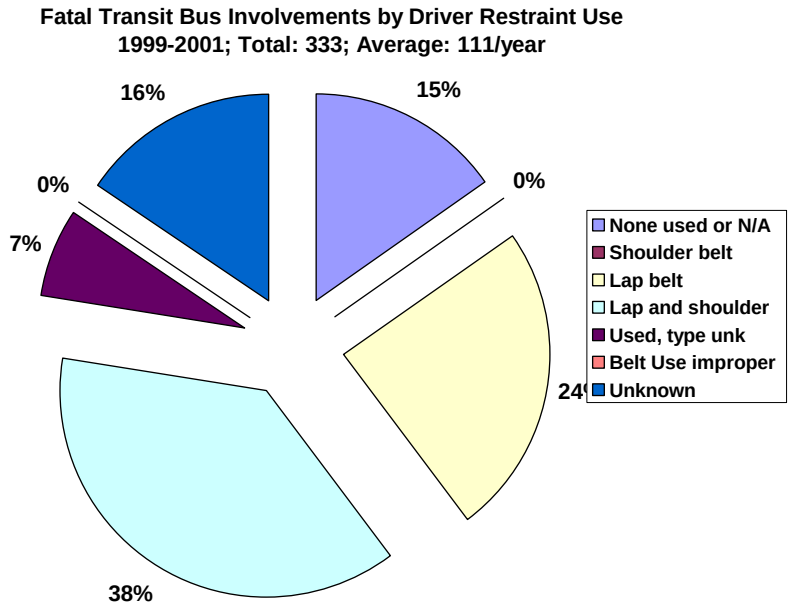


Figure 2.89 Fatal Transit Bus Involvements by Driver Restraint Use, 1999-2001 summary.

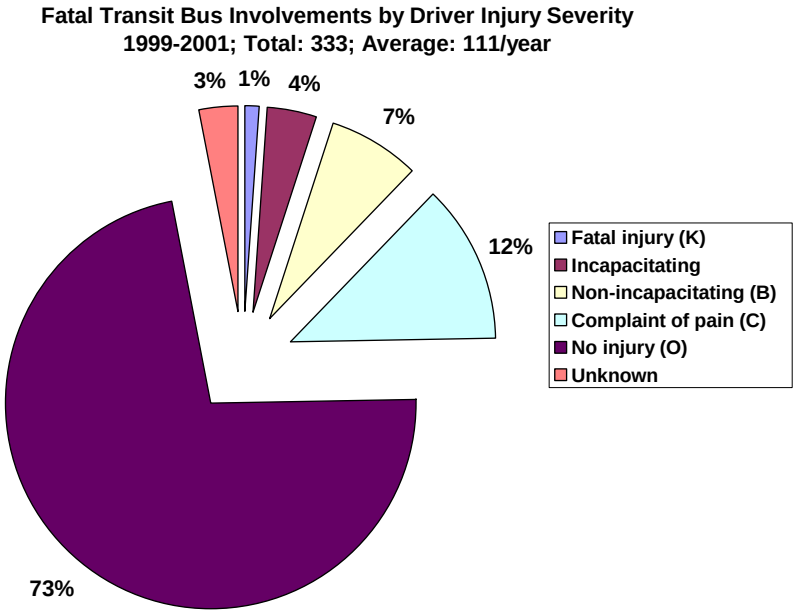


Figure 2.90 Fatal Transit Bus Involvements by Driver Injury Severity, 1999-2001 summary.

3 Mass Transit Bus Statistics

Mass transit bus data for specific communities was reviewed to provide greater insight into the predominant crash conditions resulting in injuries and fatalities. Data specific to the state of Kansas was found in the 'National Transit Bus Accident Data Collection and Analysis" report [10]. Data for two large communities in Florida was obtained from the "Analysis of Florida Transit Bus Crashes" report [11]. Finally, data for four medium size communities in Florida was obtained from the "Analysis of Florida Transit Bus Accidents" report [12]. A summary of these datasets is presented in this section.

Attempts to obtain data for more regions were not successful. As documented in Reference [10], there is not a standard for collecting crash data for mass transit buses. Furthermore, not all agencies collect crash data. Based on inquiries to transit agencies by NIAR, the experiences of the authors in Reference [10] and the scope of this project, NIAR made the decision to proceed with the available crash data.

3.1 State Specific Statistical Data (Kansas) [10]

Those accidents that involve either a fatality, injury, or property damage of at least $500 are reported to the State. Accidents resulting only in property damage of less than $500 are "non-reportable" and, therefore, are not entered into the State's automated database system and are not included in statewide accident data summaries 1991 through 2000.

A total of 768 transit buses were involved in accidents from 1991 through 2000 in Kansas. Transit bus accidents averaged 77 accidents per year. A "typical" accident involving a transit bus from 1991 through 2000, according to the database, occurred:

- on a Tuesday;
- between the hours of 3:00-4:59 p.m.;
- under clear weather conditions;
- on dry roadways;
- in connection with another moving motor vehicle; and
- involving a rear-end or angle impact.

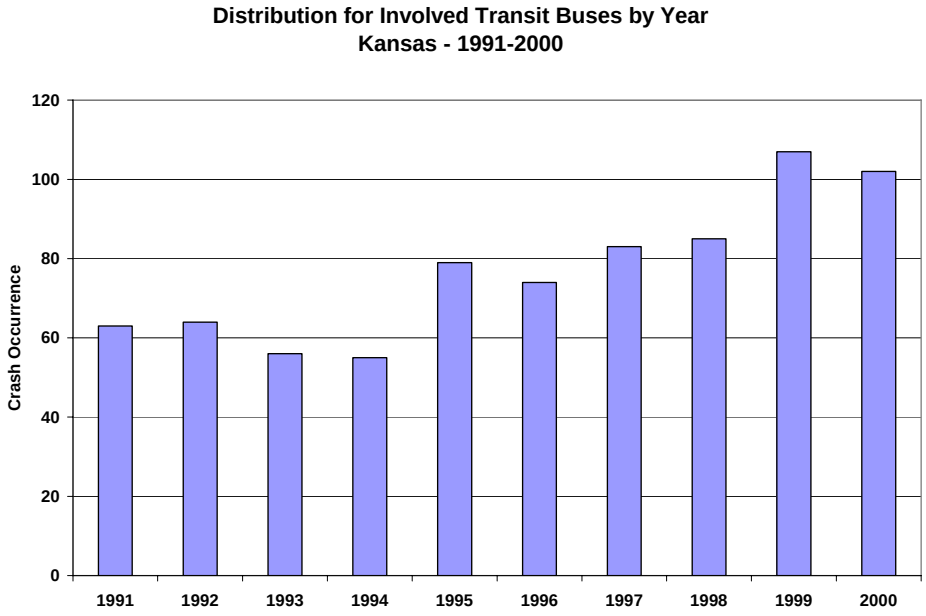


Figure 3.1 Distribution for Involved Transit Buses by Year – Kansas – 1991-2000.

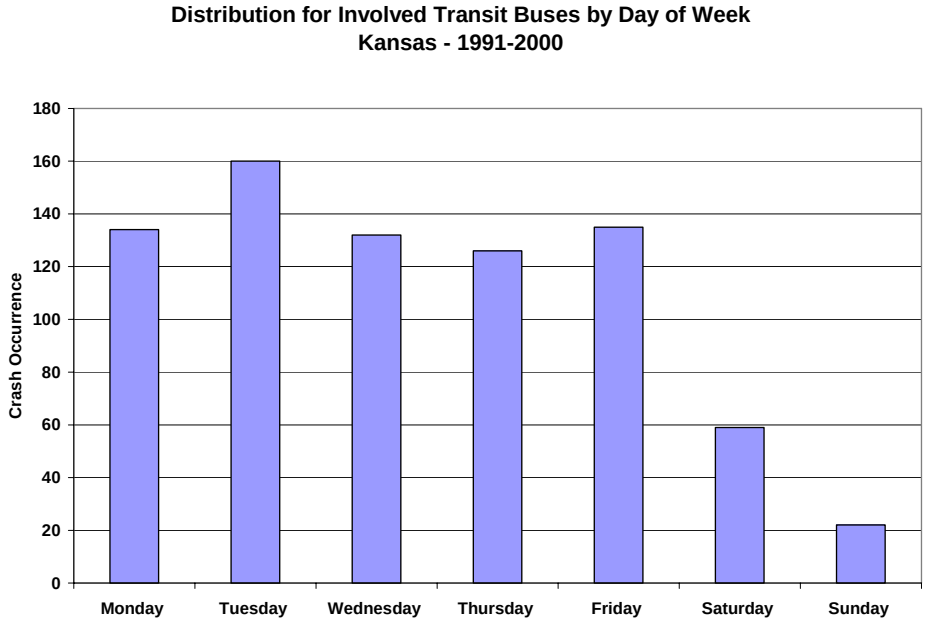


Figure 3.2 Distribution for Involved Transit Buses by Day of Week – Kansas – 1991-2000.

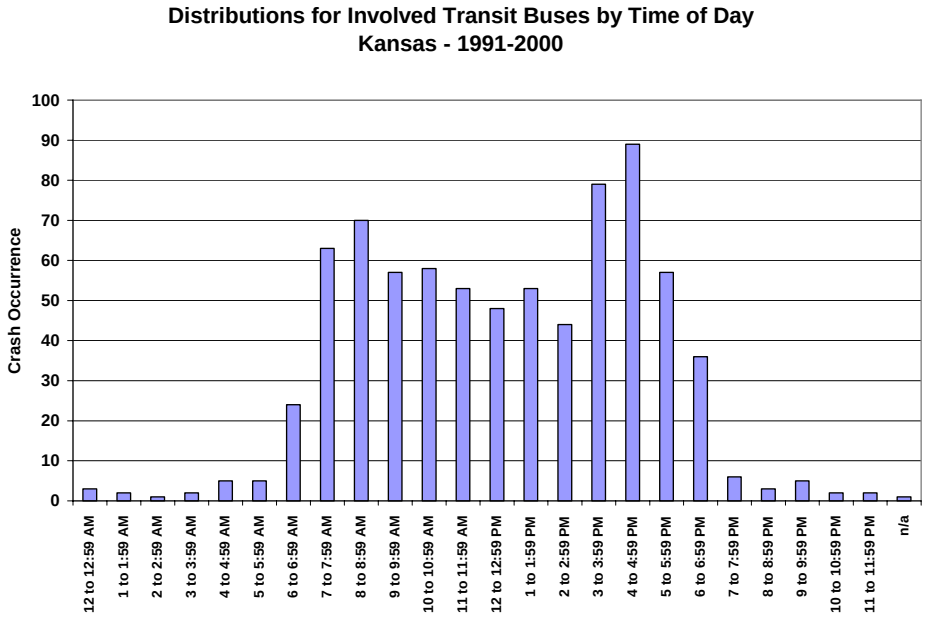


Figure 3.3 Distributions for Involved Transit Buses by Time of Day.

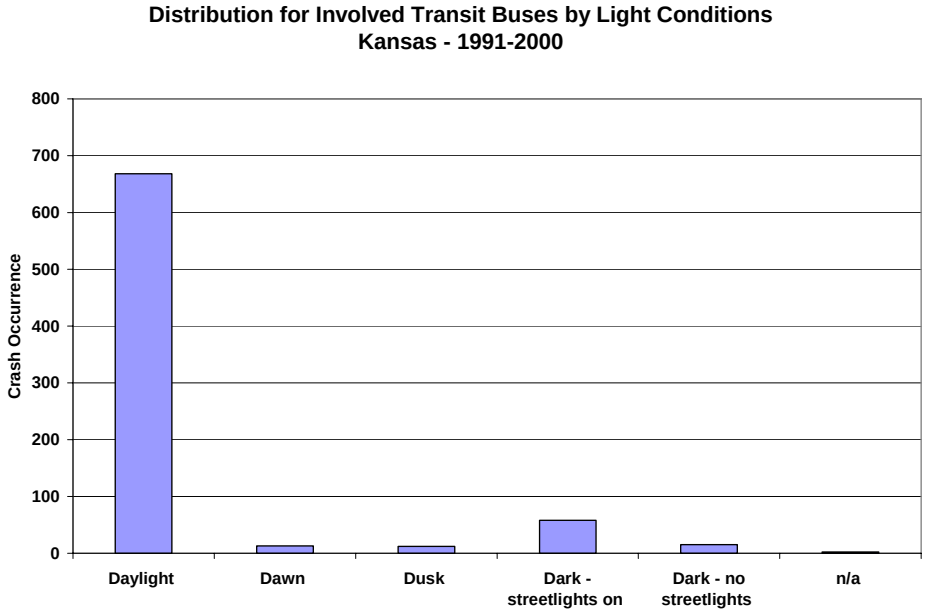


Figure 3.4 Distribution for Involved Transit Buses by Light Conditions – Kansas – 1991-2000.

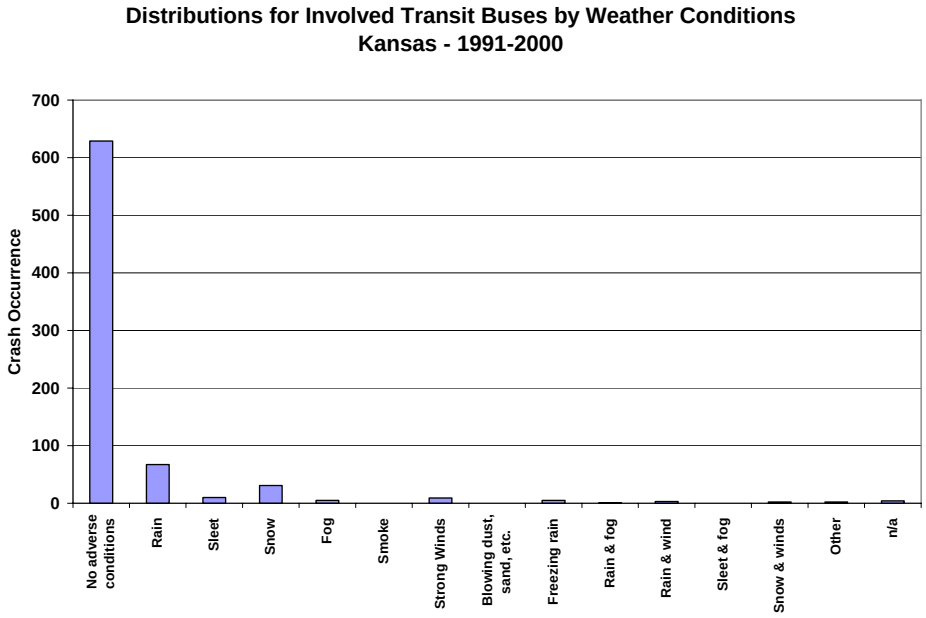


Figure 3.5 Distributions for Involved Transit Buses by Weather Conditions – Kansas – 1991-2000.

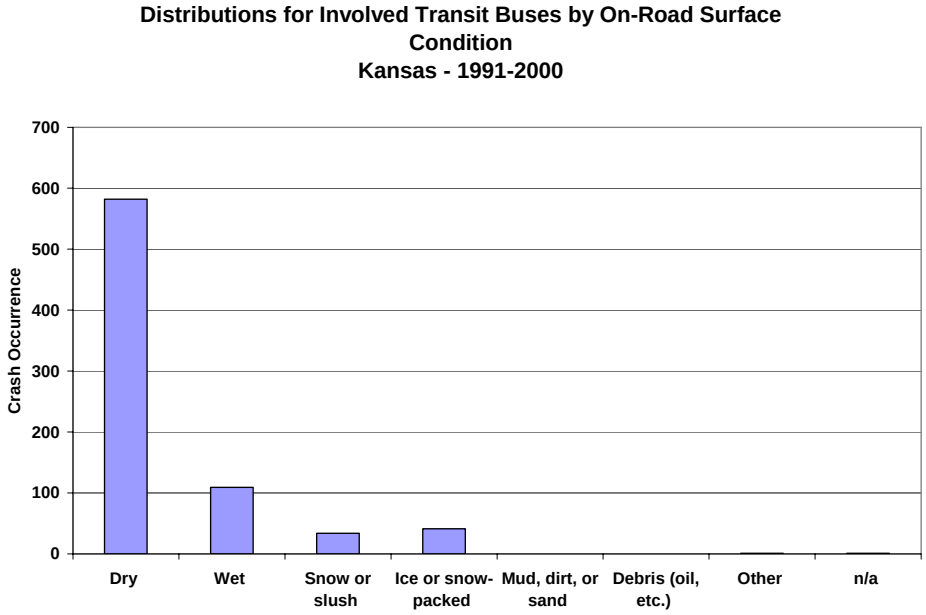


Figure 3.6 Distributions for Involved Transit Buses by On-Road Surface Condition – Kansas – 1991-2000.

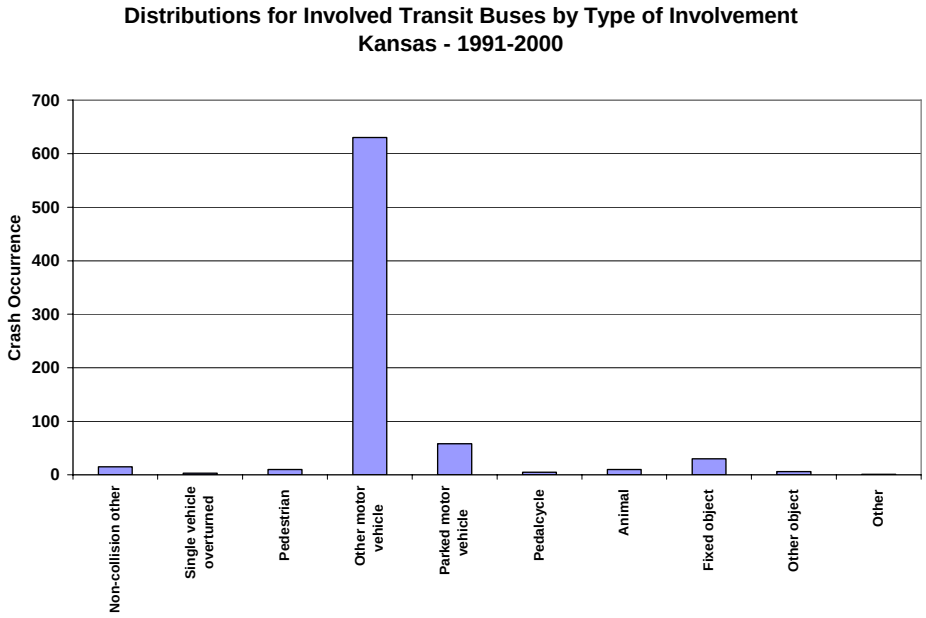


Figure 3.7 Distributions for Involved Transit Buses by Type of Involvement – Kansas – 1991-2000.

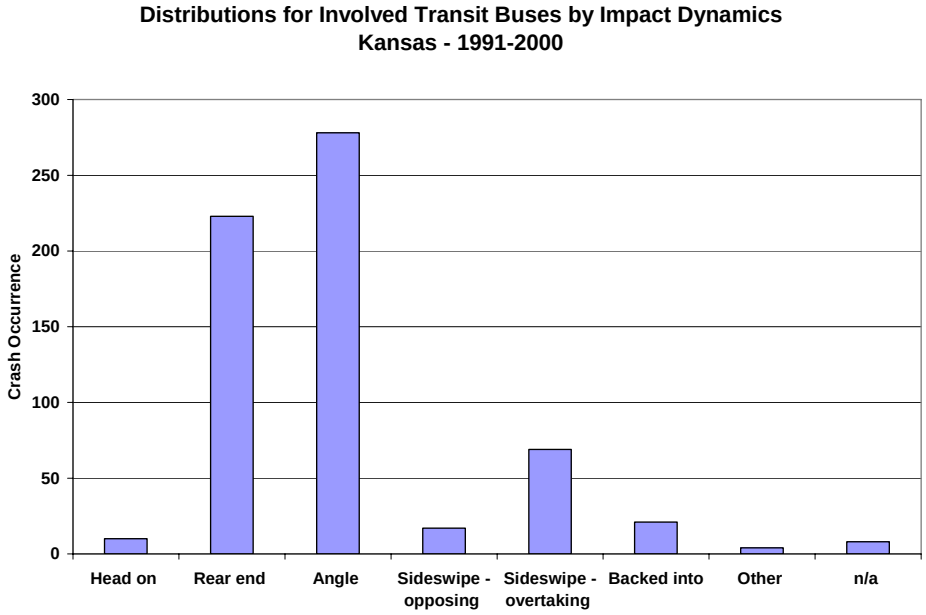


Figure 3.8 Distributions for Involved Transit Buses by Impact Dynamics – Kansas – 1991-2000.

3.2 Analysis of Florida Transit Bus Crashes [11]

Through its National Center for Transit Research (NCTR), and under contract with the Florida Department of Transportation (FDOT), the Center for Urban Transportation Research (CUTR) was tasked with reviewing a sample of transit bus crash occurrence data from selected Florida transit systems. The purpose of that review was to analyze changes in crash occurrence over time in relation to the effectiveness of training programs and capital safety improvements in reducing bus crashes. After an initial evaluation of Florida's larger transit systems, and with guidance from FDOT, two systems were ultimately selected for the CUTR investigation: Hillsborough Area Regional Transit Authority (HART) in Tampa and LYNX Transit in Orlando. The data collected for the study is applicable to the current research effort being conducted by NIAR.

3.2.1 Hillsborough Area Regional Transit Authority

The Hillsborough Area Regional Transit Authority is an independent authority that provides fixed route motorbus and demand response services to all of Hillsborough County (excluding Plant City). Data was collected from October 1996 through November 1999.

A "typical" accident involving a transit bus, according to the database, occurred:

- on a Tuesday;
- between the hours of 5:00-5:59 p.m.;
- under clear weather conditions;
- in commercial areas of the suburbs;
- in connection with another moving motor vehicle; and
- involving a rear-end or broadside impact.

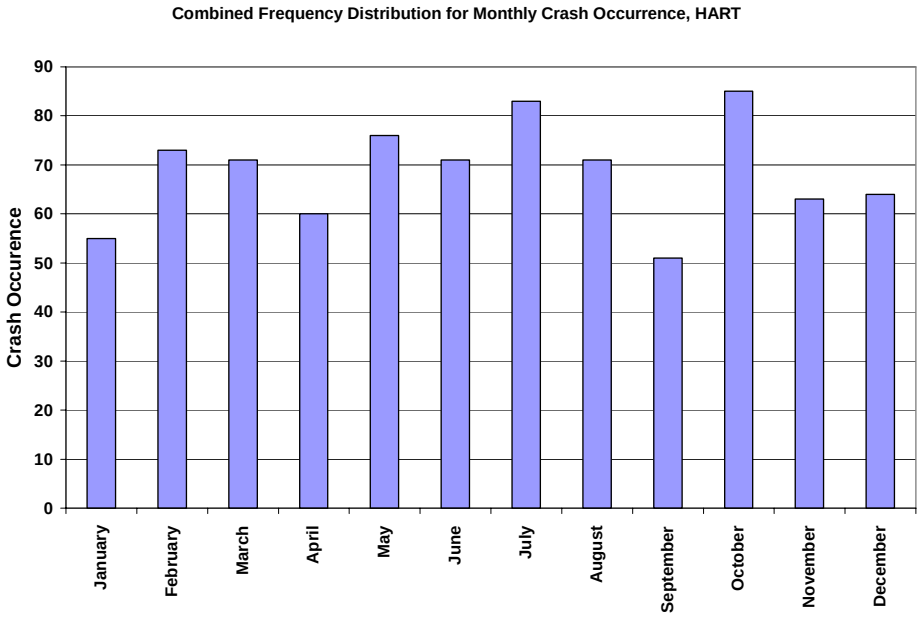


Figure 3.9 Combined Frequency Distribution for Monthly Crash Occurrence, HART.

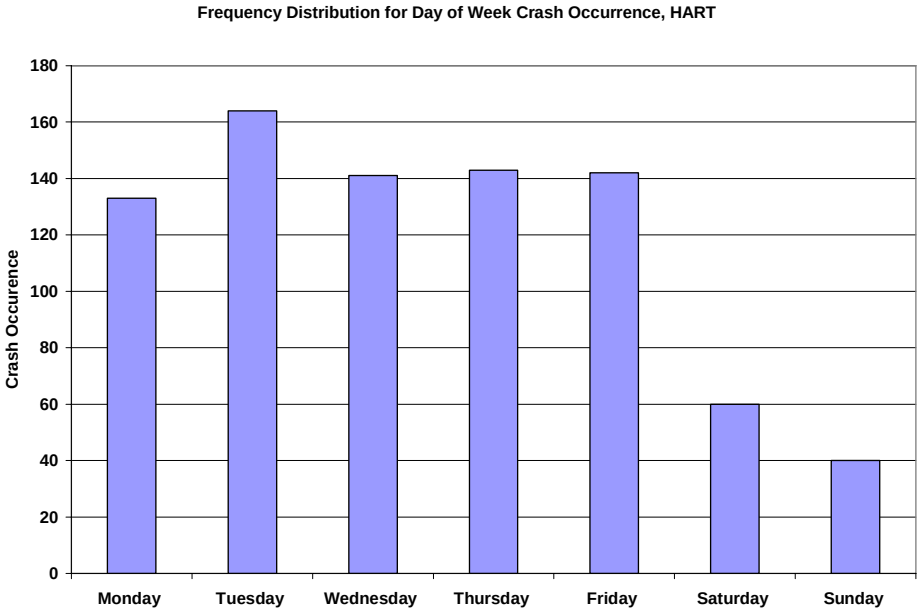


Figure 3.10 Frequency Distribution for Day of Week Crash Occurrence – HART.

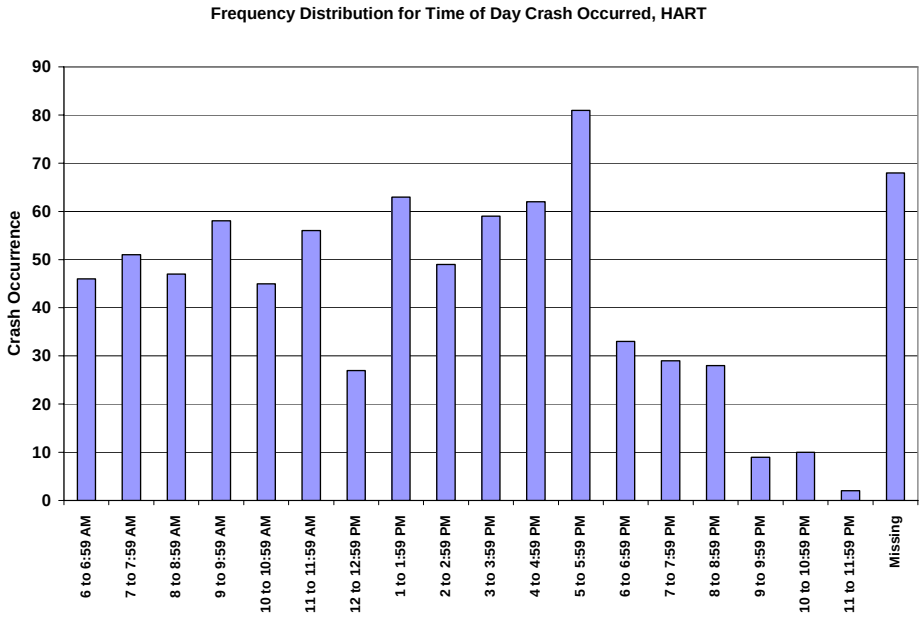


Figure 3.11 Frequency Distribution for Time of Day Crash Occurred – HART.

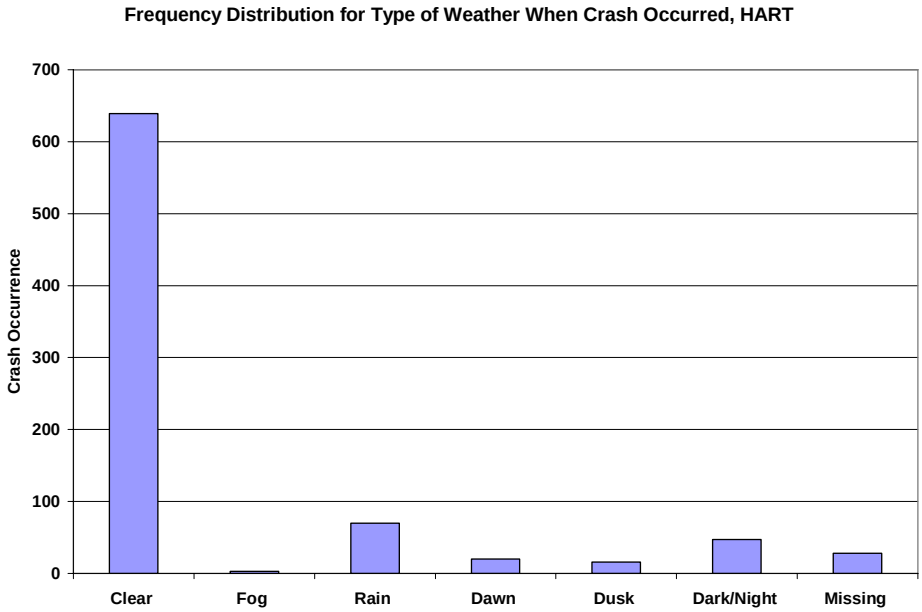


Figure 3.12 Frequency Distribution for Type of Weather When Crash Occurred – HART.

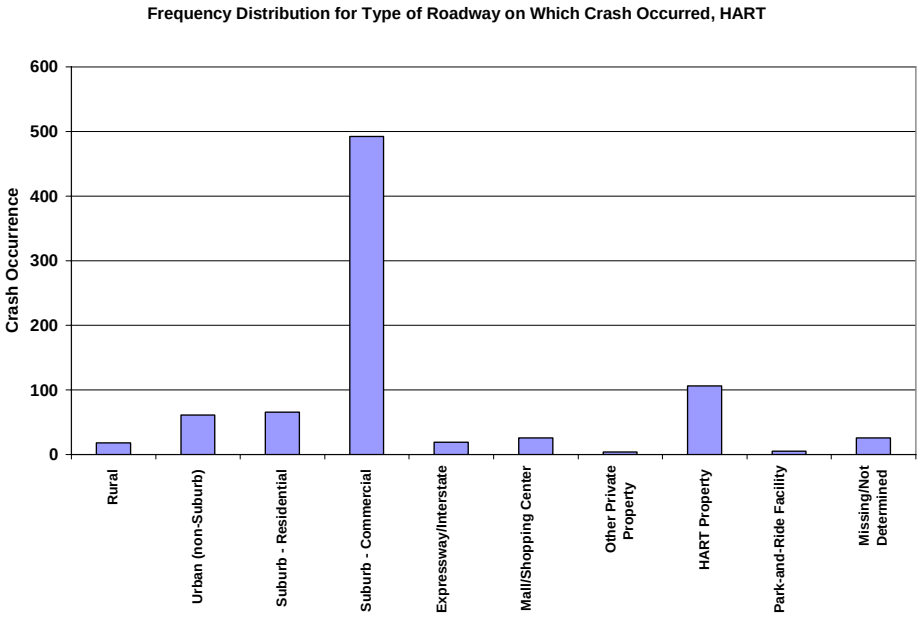


Figure 3.13 Frequency Distribution for Type of Roadway on Which Crash Occurred – HART.

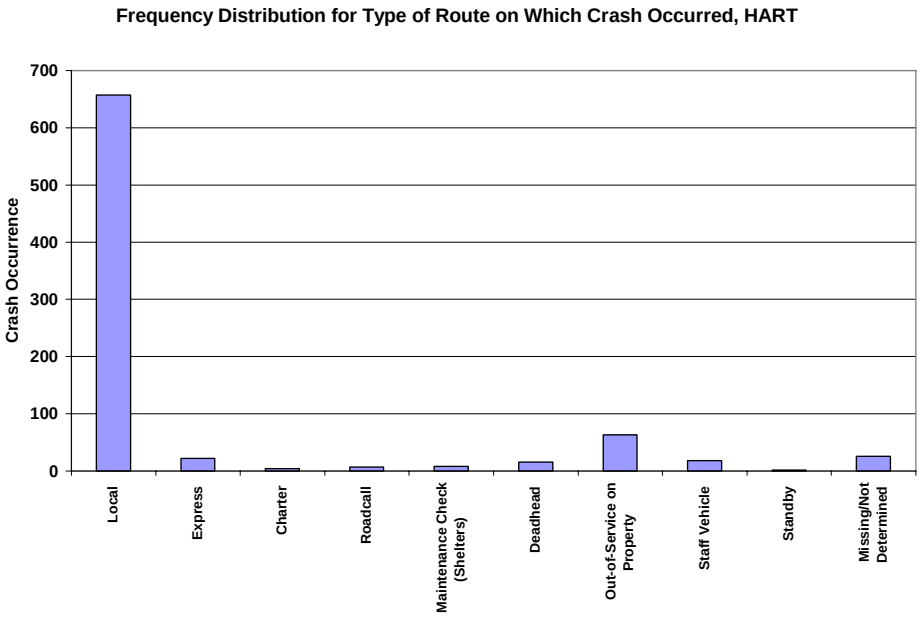


Figure 3.14 Frequency Distribution for Type of Route on Which Crash Occurred – HART.

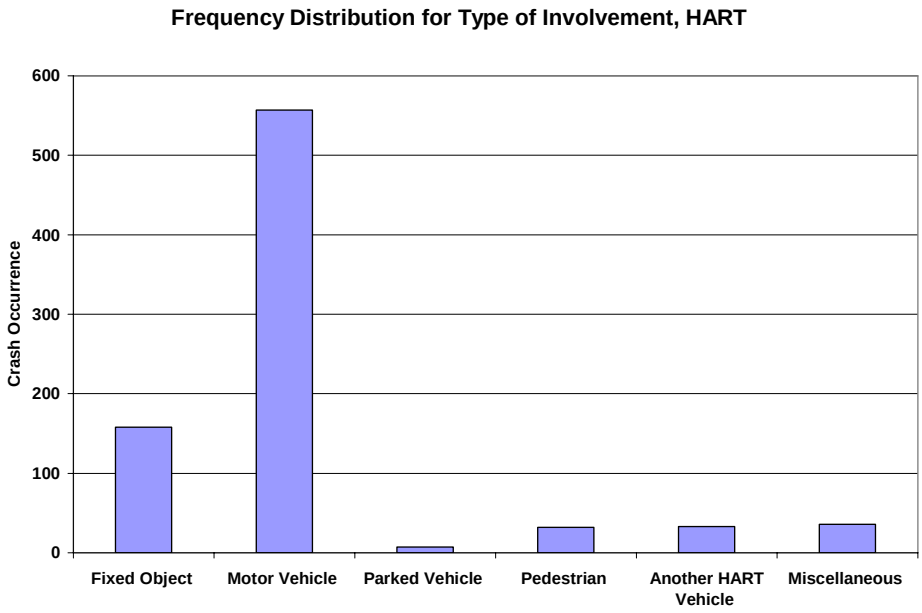


Figure 3.15 Frequency Distribution for Type of Involvement – HART.

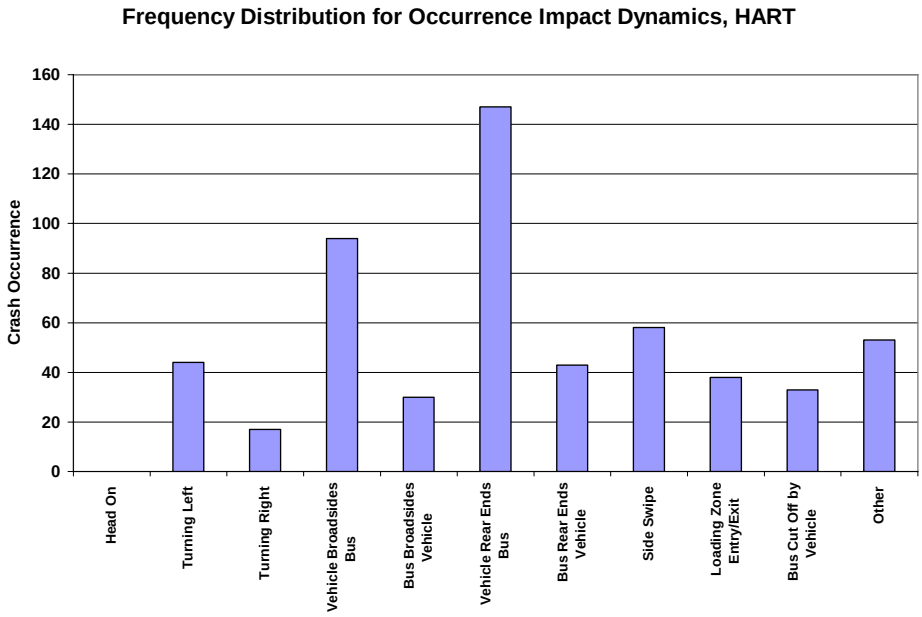


Figure 3.16 Frequency Distribution for Occurrence Impact Dynamics – HART.

3.2.2 LYNX

LYNX is an independent authority that provides fixed-route motorbus, demand response, and vanpool services to a three-county region that includes Orange, Seminole, and Osceola Counties. The system also coordinates a five-county regional ridesharing assistance program and transportation disadvantaged services for the region. Data was reviewed over two time periods, March 1997 to February 1998 and January 1999 to December 1999.

A “typical” accident involving a transit bus, according to the database, occurred:

- between the hours of 5:00-5:59 p.m.;
- as a rear end collision with the bus being hit from behind;
- while the bus was either stopped or operating at a slow speed

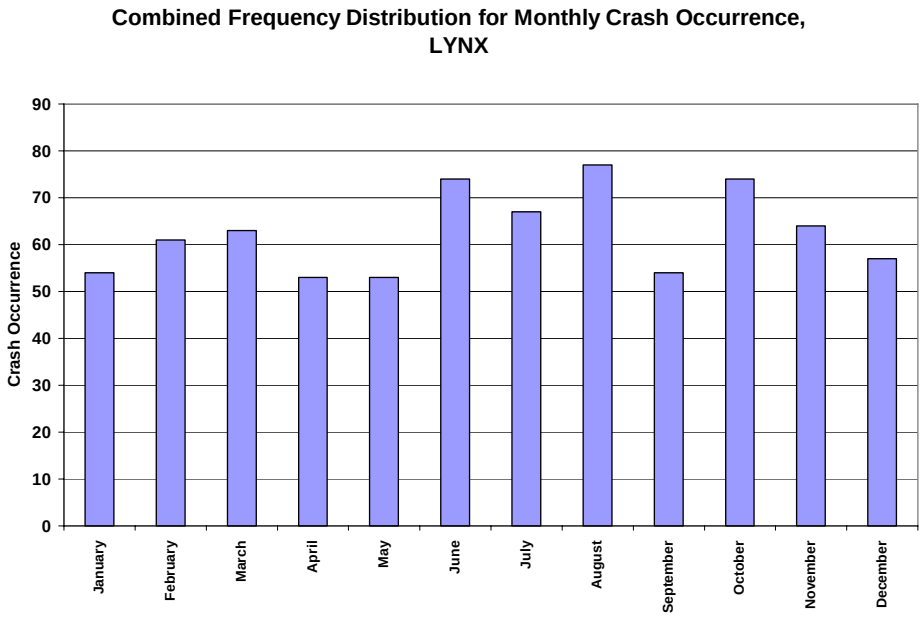


Figure 3.17 Combined Frequency Distribution for Monthly Crash Occurrence – LYNX.

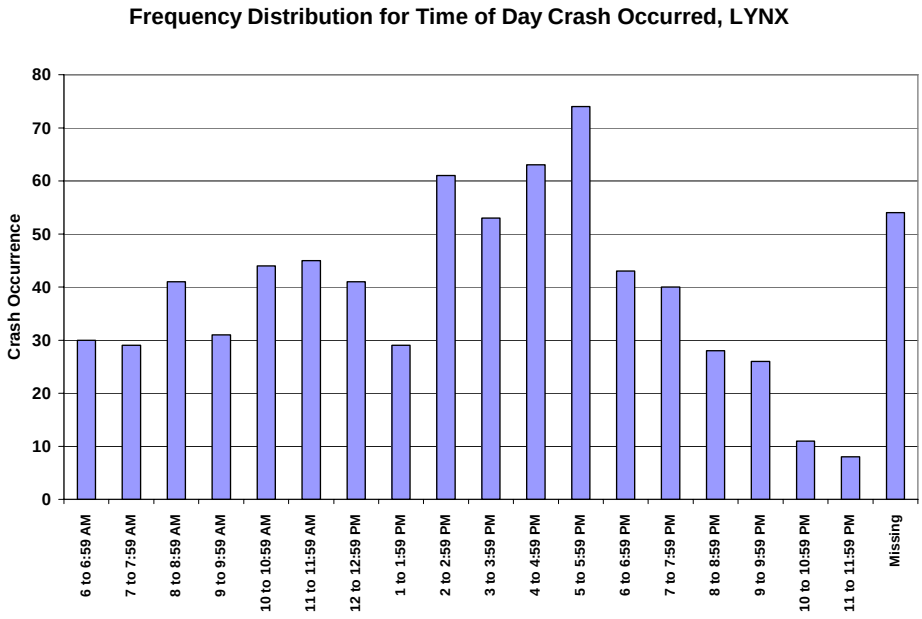


Figure 3.18 Frequency Distribution for Time of Day Crash Occurred – LYNX.

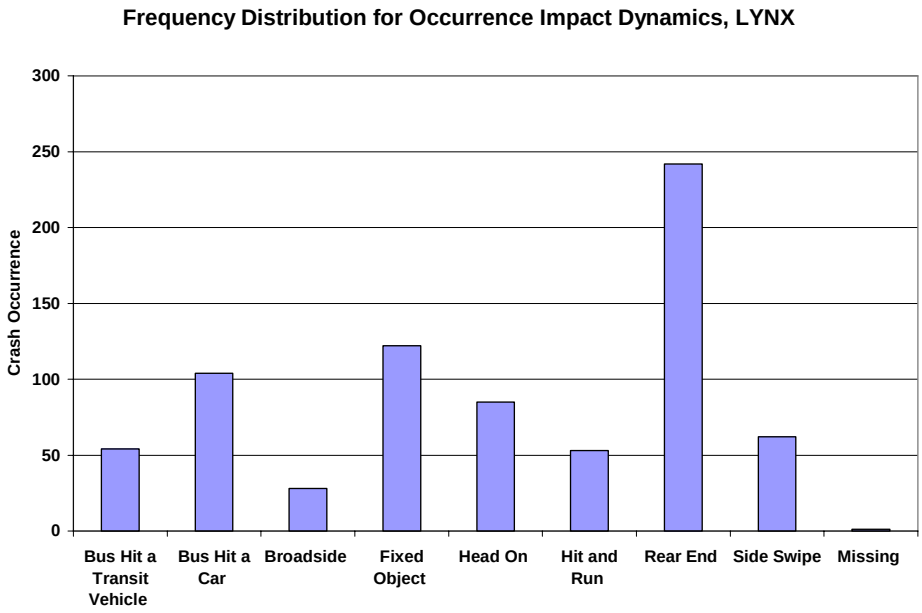


Figure 3.19 Frequency Distribution for Occurrence Impact Dynamics – LYNX.

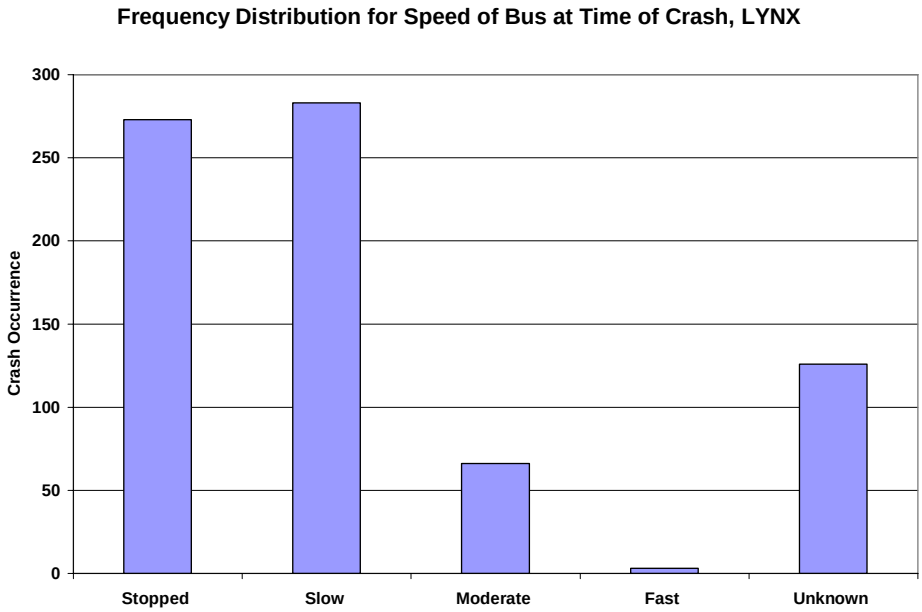


Figure 3.20 Frequency Distribution for Speed of Bus at Time of Crash – LYNX.

3.3 Analysis of Florida Bus Accidents [12]

Through its National Center for Transit Research (NCTR), and under contract with the Florida Department of Transportation (FDOT), the Center for Urban Transportation (CUTR) was tasked to undertake a continued sampled review of bus transit accidents at selected Florida public transit systems. The purpose of the review was to analyze the change in accident data over time. The goal of the project was to show transit systems, through demonstration, the simplicity by which accident data can be analyzed, how to use the data to identify the success of safety campaigns, and how a small investment in analyses might have a great impact on reducing transit accidents, thereby lowering operating costs and insurance premiums.

After an initial evaluation of Florida's medium transit systems, and with guidance from FDOT, four systems were ultimately selected for this investigation: Gainesville Regional Transit System (RTS) in Gainesville; Sarasota County Transportation Authority (SCAT) in Sarasota; County of Volusia, dba VOTRAN in Daytona Beach and Lee County Regional Transit System (LeeTran) in Fort Myers.

3.3.1 Gainesville Regional Transit System

The City of Gainesville located in Alachua County, Florida ranked 21st out of 67 counties in Florida with an estimated population of 223,578 people according to the 2003 United States Census population estimates. The 2003 population of Gainesville was approximately 117,182 people (52 percent of the county population). In addition to being the largest municipality in the county, Gainesville is also home to the oldest and largest university in the State of Florida, the University of Florida (UF) in 2004, Fall Semester enrollment at UF was approximately 48,000 students.

The Gainesville Regional Transit System (RTS) was established in 1975, and operated as a small urban transit system. The current RTS system operates as a pulsed network, focused on the downtown city plaza and the UF transportation hub. Data from June 2001 to July 2003 was analyzed for the study.

A "typical" accident involving a transit bus, according to the database, occurred:

• on a Tuesday

• between the hours of 4:00 p.m. - 5:00 p.m.

• in clear weather

• involving another motor vehicle

• either a rear end or angle type of accident

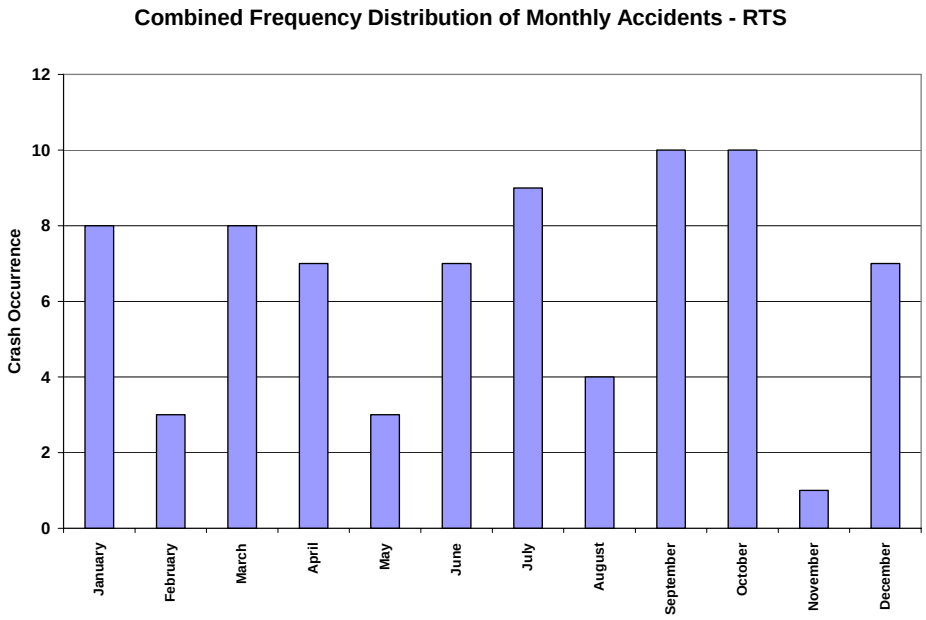


Figure 3.21 Combined Frequency Distribution of Monthly Accidents – RTS.

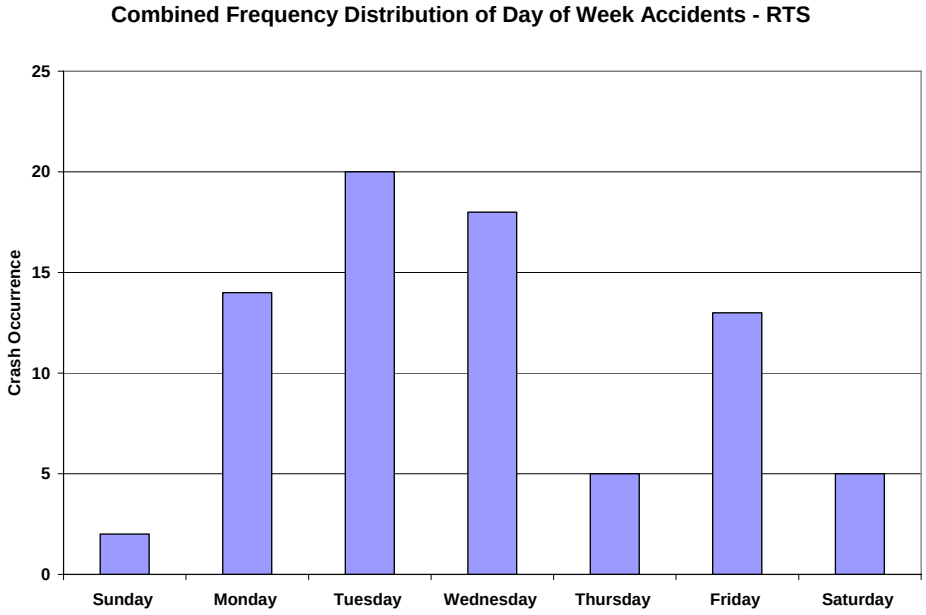


Figure 3.22 Combined Frequency Distribution of Day of Week Accidents – RTS.

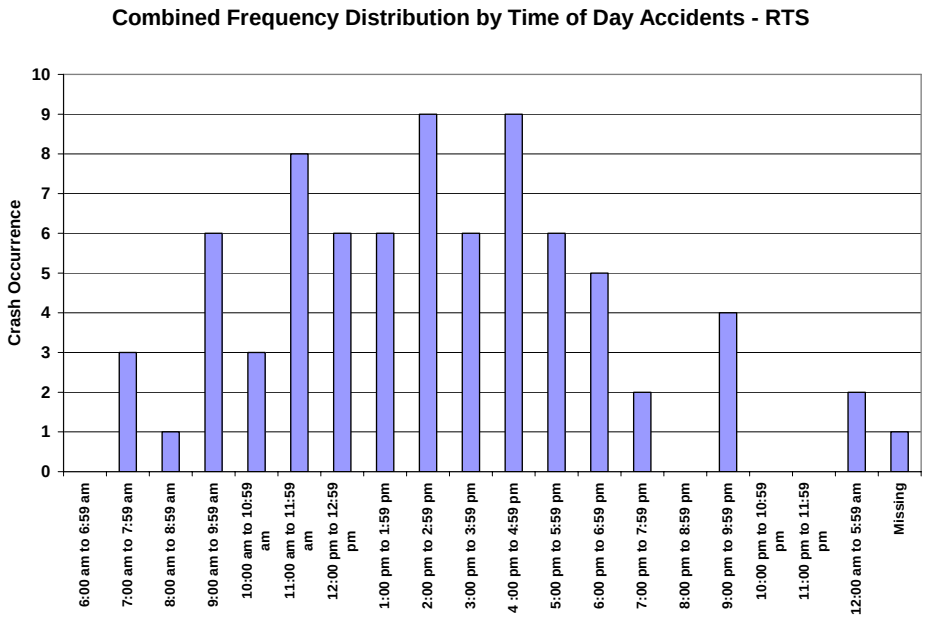


Figure 3.23 Combined Frequency Distribution of Time of Day Accidents – RTS.

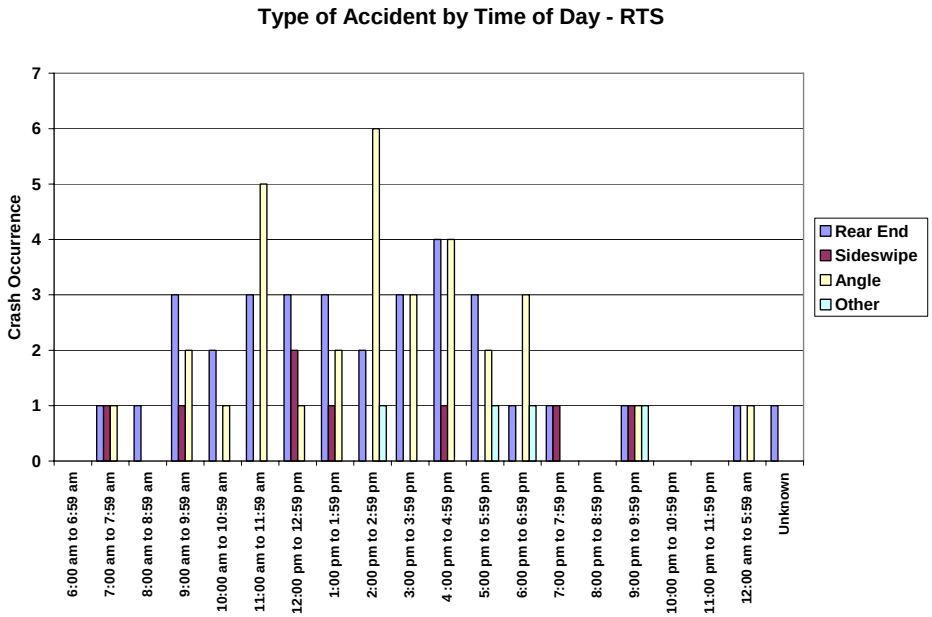


Figure 3.24 Type of Accident by Time of Day – RTS.

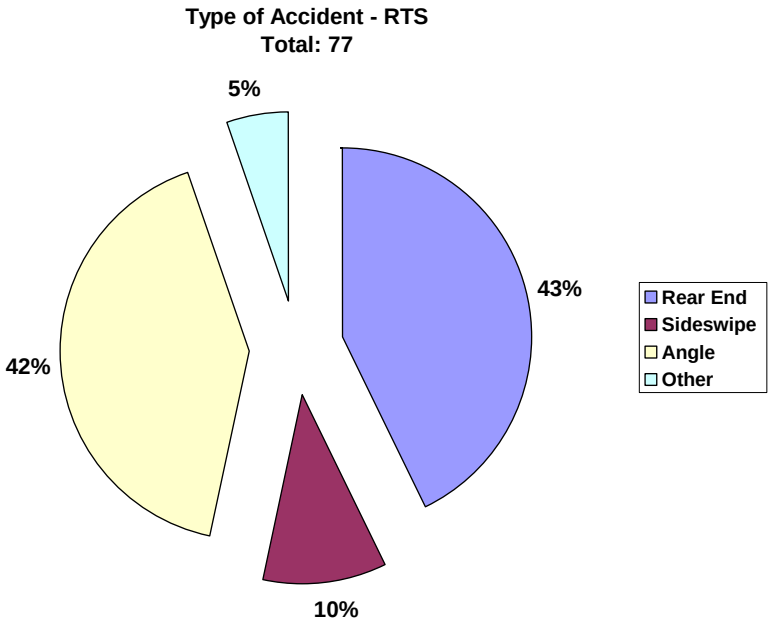


Figure 3.25 Type of Accident – RTS.

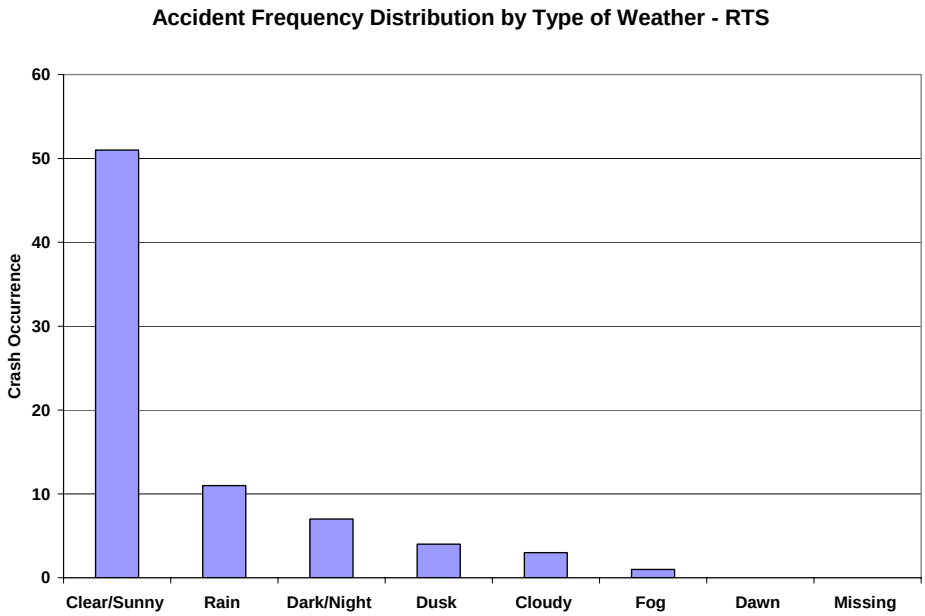


Figure 3.26 Accident Frequency Distribution by Type of Weather – RTS.

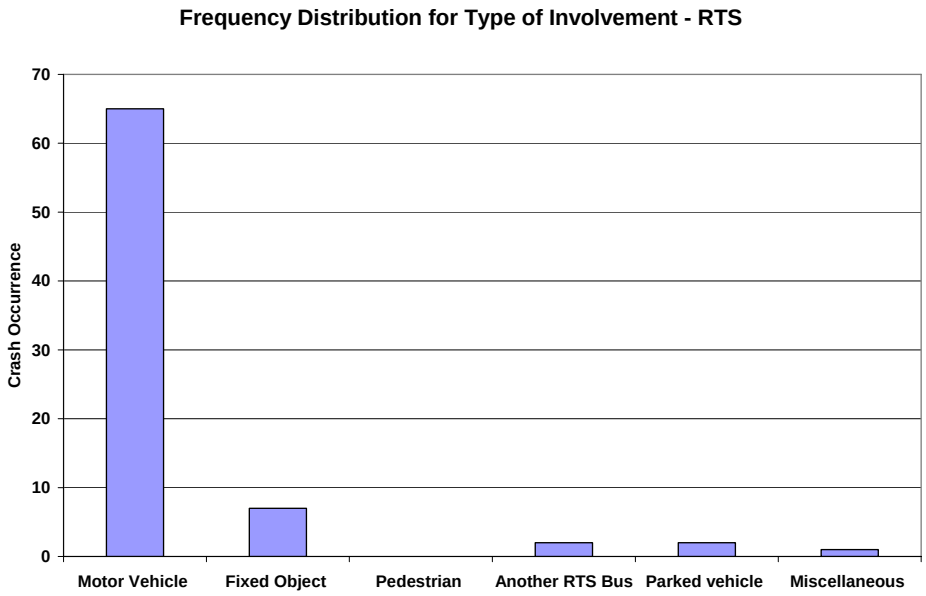


Figure 3.27 Frequency Distribution for Type of Involvement – RTS.

3.3.2 Sarasota County Transportation Authority

On April 9, 1979, Sarasota County entered the public transit business by taking over a county operated bus system from Cities Transit, a private transit operator. This acquisition led to the formation of the Sarasota County Transportation Authority, informally known at Sarasota County Area Transit (SCAT). SCAT is an organizational member of the Sarasota County Government and is also governed by a five-member Board of County Commissioners. SCAT serves the urbanized portion of Sarasota County (including the cities of Longboat Key, Sarasota, Venice, Englewood and North Port) via fixed-route and demand-response service. Since the County entered the public transit arena, bus patronage levels have dramatically increased from approximately 700,000 riders in the early 1980's to more than 1.8 million in the late 1990's. In SCAT's 20 years of service, more than 20 million passengers have taken advantage of SCAT's transit services.

SCAT records all accidents which involve buses even when a third party may have been involved. Data from SCAT spanned from September 2001 to August 2003.

A "typical" accident involving a transit bus, according to the database, occurred:

- on a Monday or Thursday
- between 2:00 p.m. to 3:00 p.m.
- in clear weather
- involving another motor vehicle
- was a rear end or angle type of accident

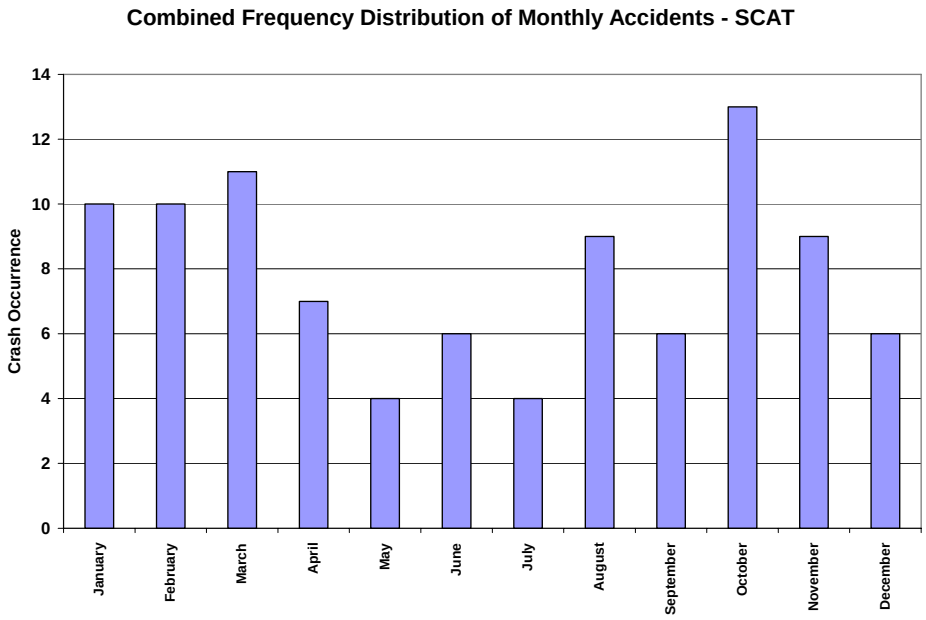


Figure 3.28 Combined Frequency Distribution of Monthly Accidents – SCAT.

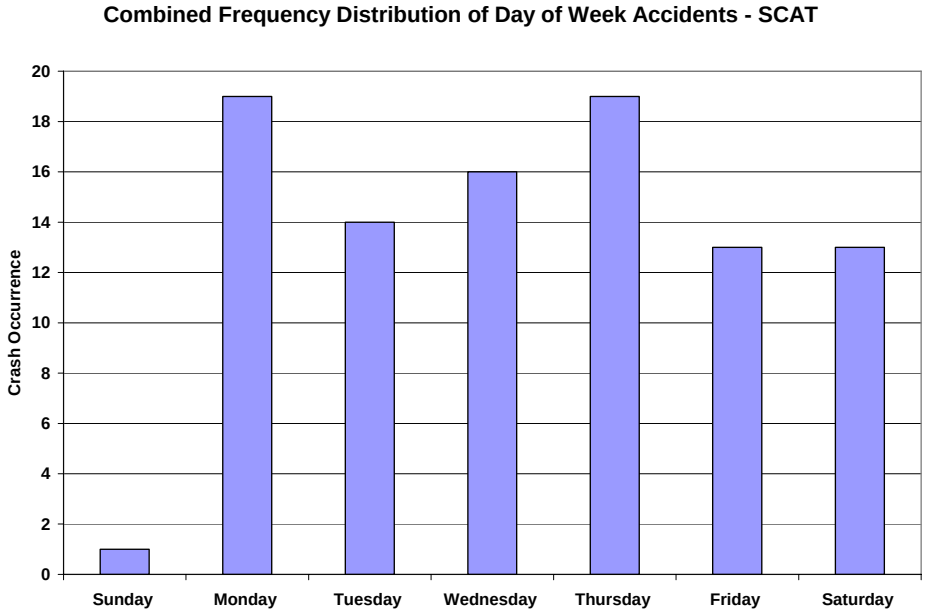


Figure 3.29 Combined Frequency Distribution of Day of Week Accidents – SCAT.

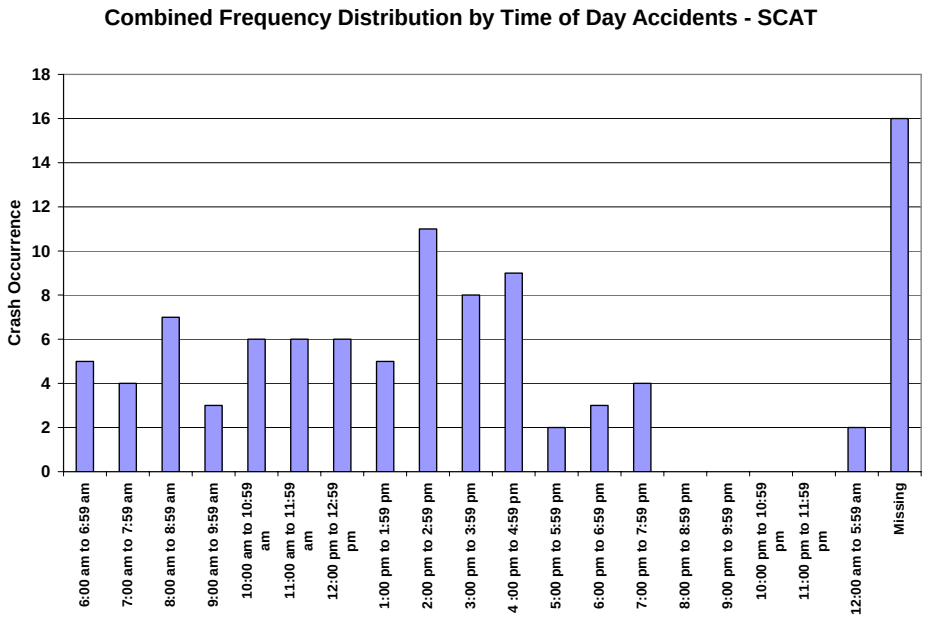


Figure 3.30 Combined Frequency Distribution by Time of Day Accidents – SCAT.

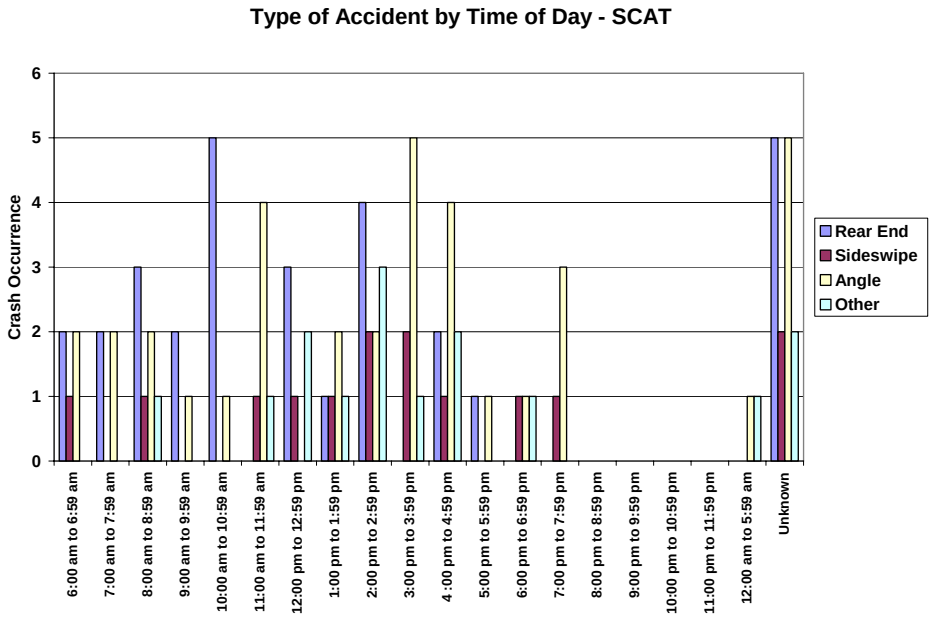


Figure 3.31 Type of Accident by Time of Day – SCAT.

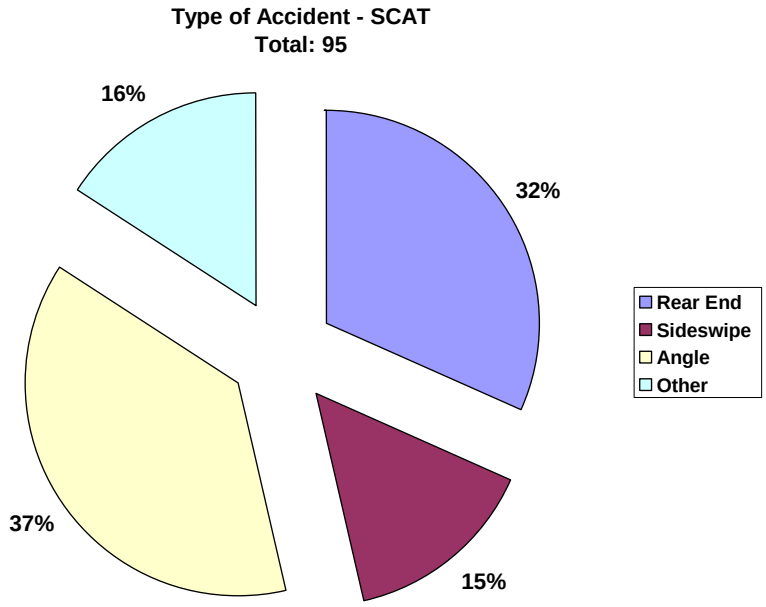


Figure 3.32 Type of Accident – SCAT.

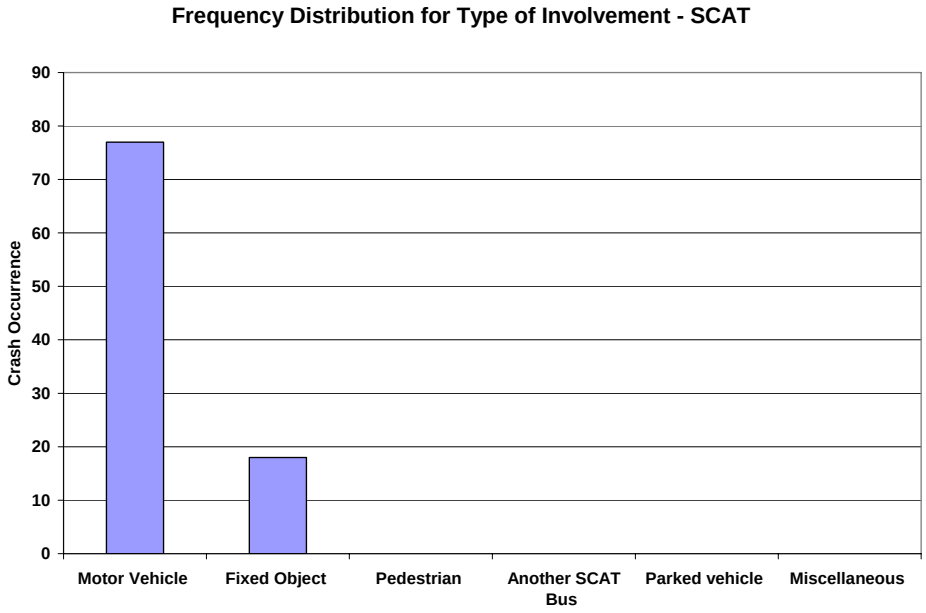


Figure 3.33 Frequency Distribution for Type of Involvement – SCAT.

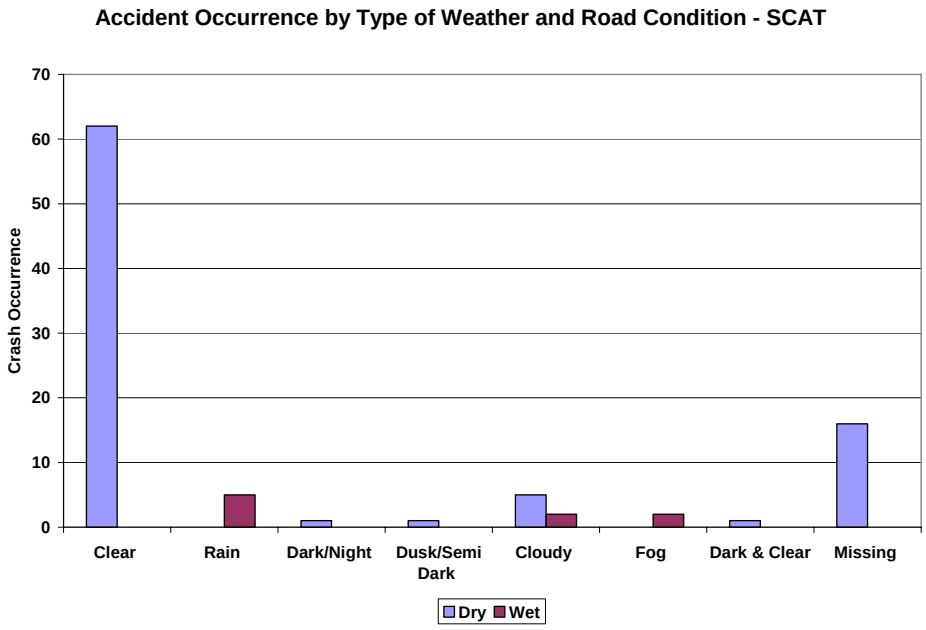


Figure 3.34 Accident Occurrence by Type of Weather and Road Condition – SCAT.

3.3.3 Volusia County Public Transit System

VOTRAN is a county-wide tax-supported public transit system. According to the 2002 National Transit Database, VOTRAN had a fleet of 60 revenue-producing fixed route buses operating over a route network of 645 miles, with additional vehicles leased or contracted to satisfy transportation demand.

All accidents involving any VOTRAN bus is recorded by VOTRAN, even when a third party may have been involved. Through such data collection, basic accident statistics are captured on a regular basis, which are subsequently used as management information. VOTRAN data was analyzed for the period July 2001 to June 2003.

A “typical” accident involving a transit bus, according to the database, occurred:

- Occurred on Wednesday or Friday
- Occurred between 1:00 p.m. - 2 p.m.
- Occurred in clear weather
- Involved another motor vehicle
- Was a sideswipe type of accident

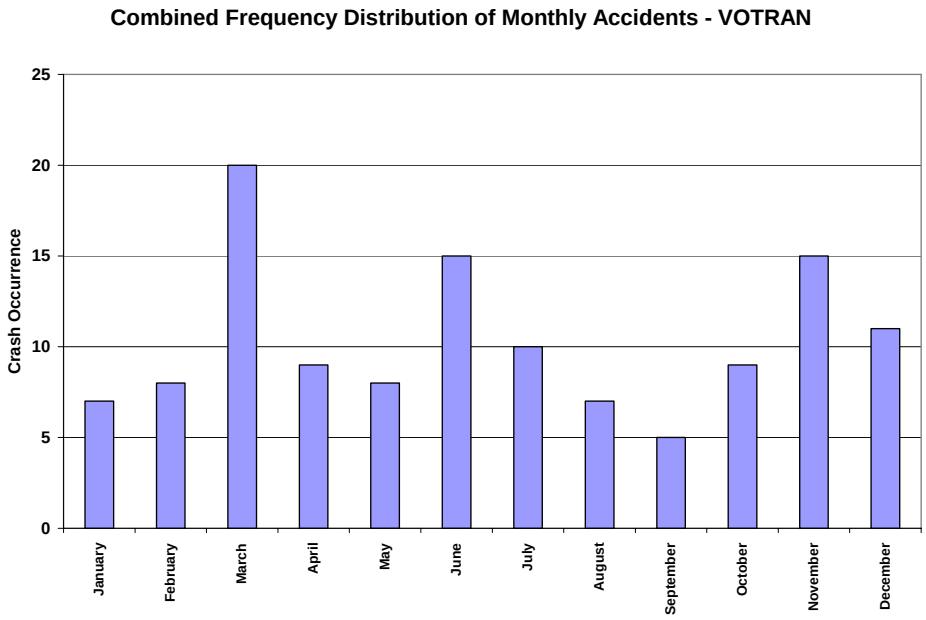


Figure 3.35 Combined Frequency Distribution of Monthly Accidents – VOTRAN.

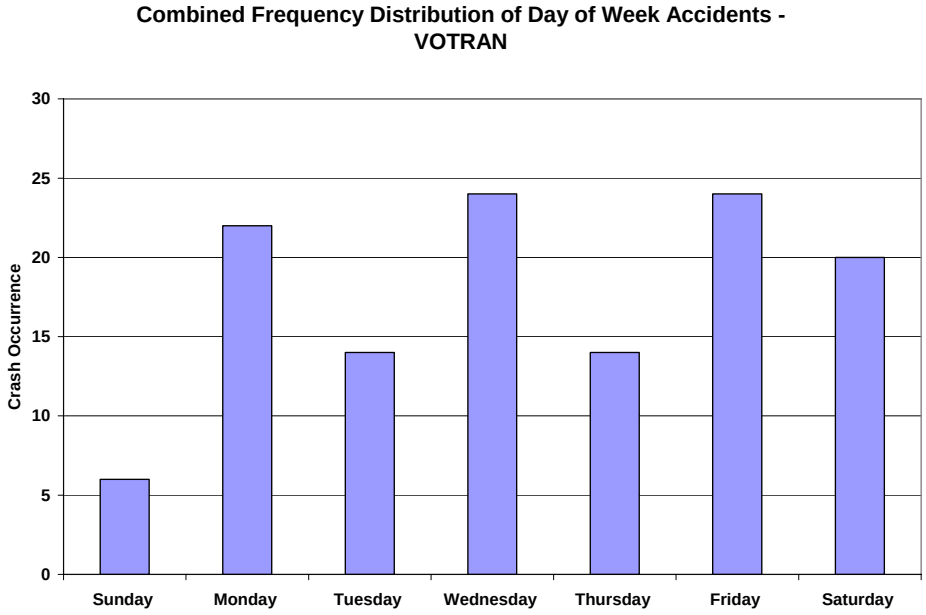


Figure 3.36 Combined Frequency Distribution of Day of Week Accidents – VOTRAN.

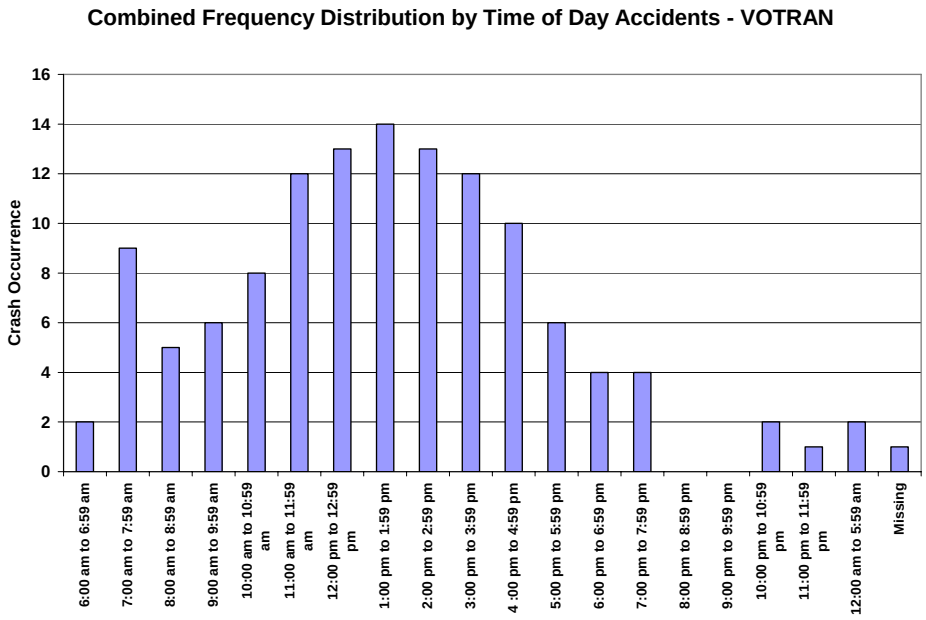


Figure 3.37 Combined Frequency Distribution by Time of Day Accidents – VOTRAN.

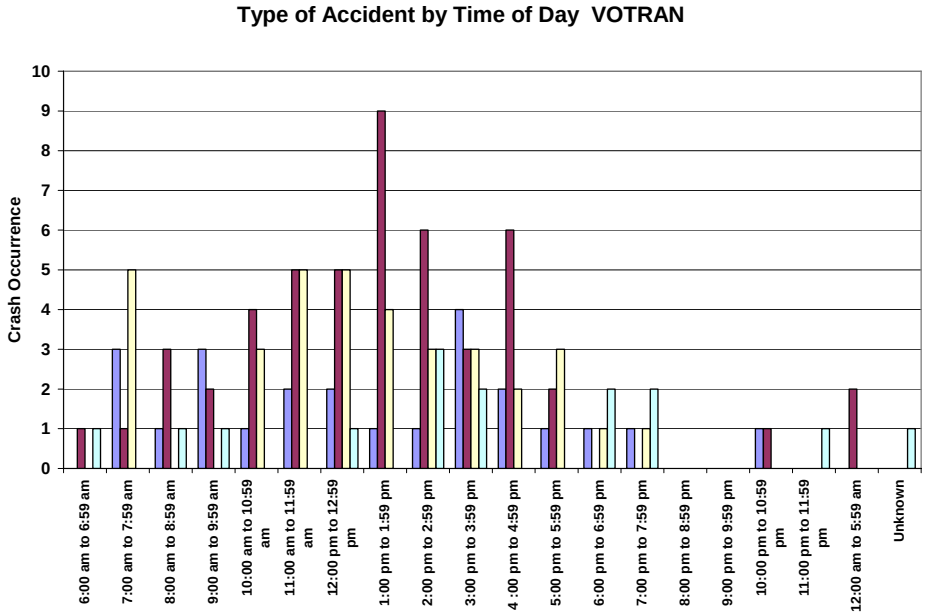


Figure 3.38 Type of Accidents by Time of Day – VOTRAN.

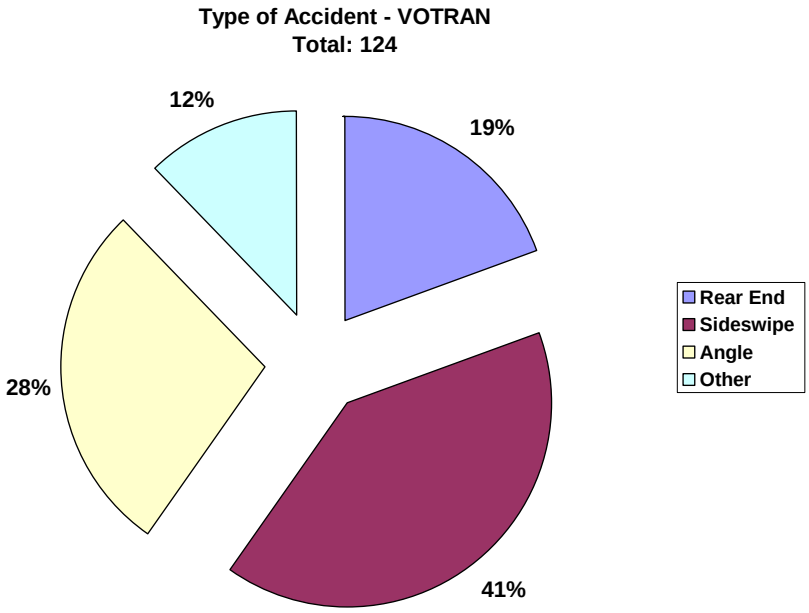


Figure 3.39 Type of Accident – VOTRAN.

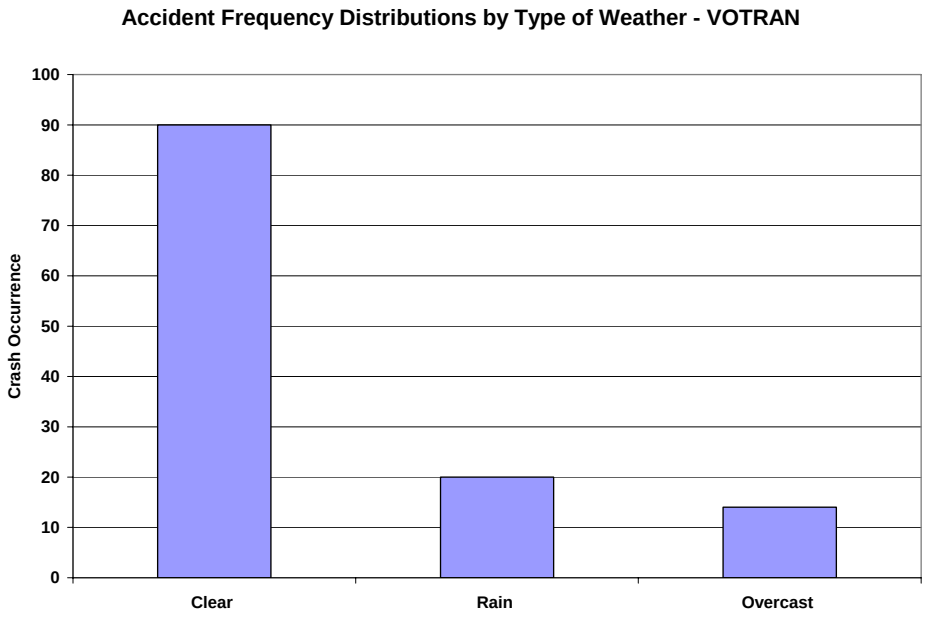


Figure 3.40 Accident Frequency Distributions by Type of Weather – VOTRAN.

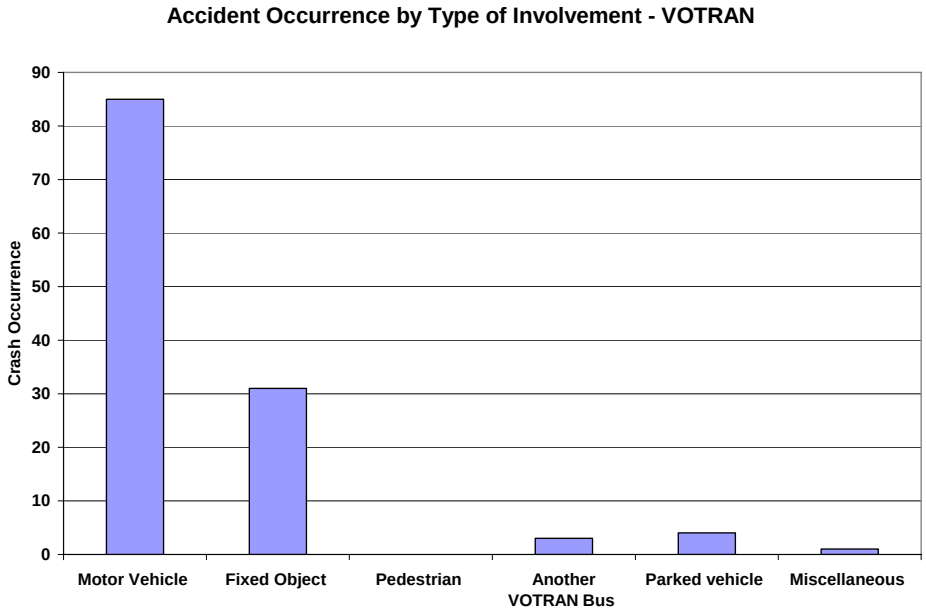


Figure 3.41 Accident Occurrence by Type of Involvement – VOTRAN.

3.3.4 Lee County Regional Transit System

Lee County Transit, known locally (and referred to in this report) as "LeeTran" is operated under the authority of the Lee County Government and the Lee County Board of Commissioners. LeeTran primarily operates a fixed-route, fixed-schedule type bus service.

LeeTran records all accidents which involve their buses, even when a third party may have been involved. All accident and incident reports are scanned into LeeTran's computer system after the report is completed. Other divisions in Lee County perform accident data analysis which includes bus accidents. Currently, LeeTran does not perform in-house data analysis in relation to accidents involving its buses. The analysis reported here covers a period of 24 months from October 2001 to September 2003. It should be noted that the fiscal year for LeeTran starts in October and ends in September the following year.

A "typical" accident involving a transit bus, according to the database, occurred:

- Occurred on a Wednesday
- Occurred between the hour of 2:00 p.m. - 3:00p.m.
- Occurred in clear/sunny weather
- Involved another motor vehicle
- Sideswipe, angle or rear end type of accident

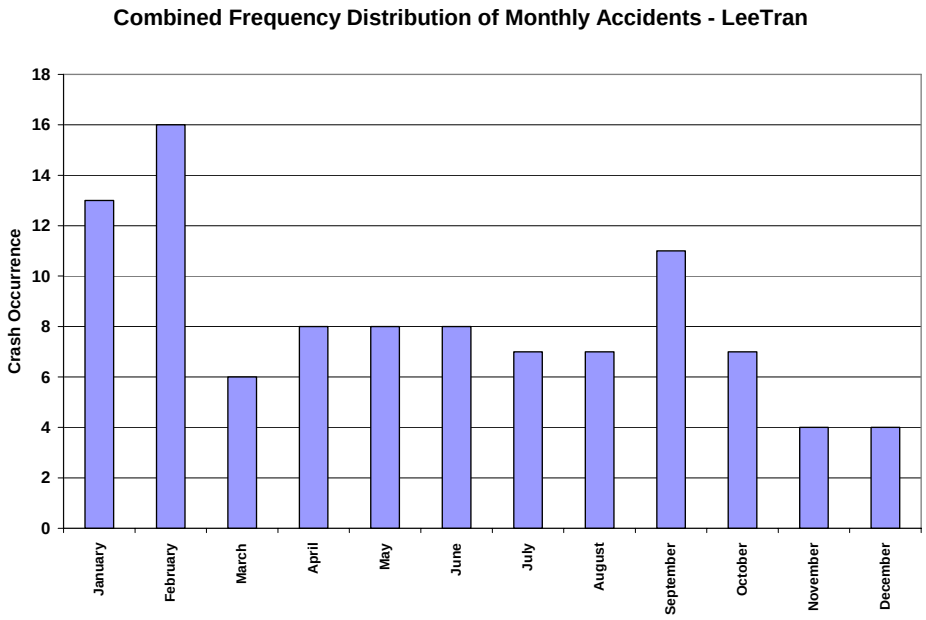


Figure 3.42 Combined Frequency Distribution of Monthly Accidents – LeeTran.

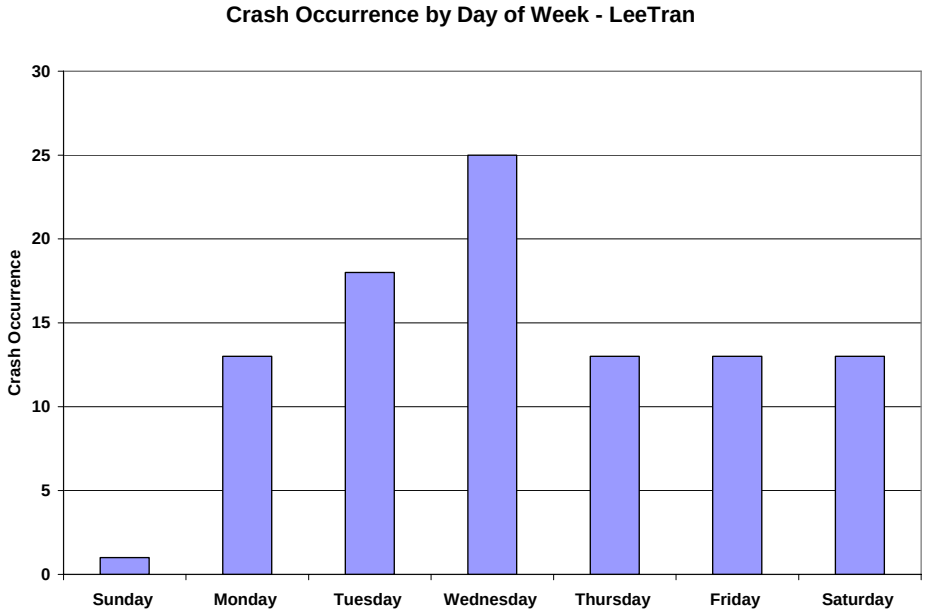


Figure 3.43 Crash Occurrence by Day of Week – LeeTran.

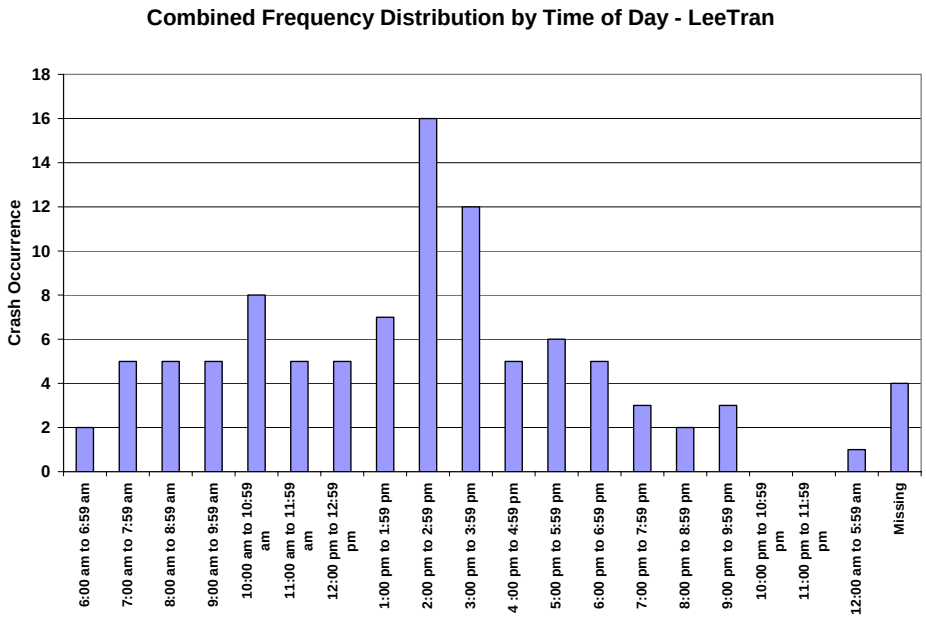


Figure 3.44 Combined Frequency Distribution by Time of Day – LeeTran.

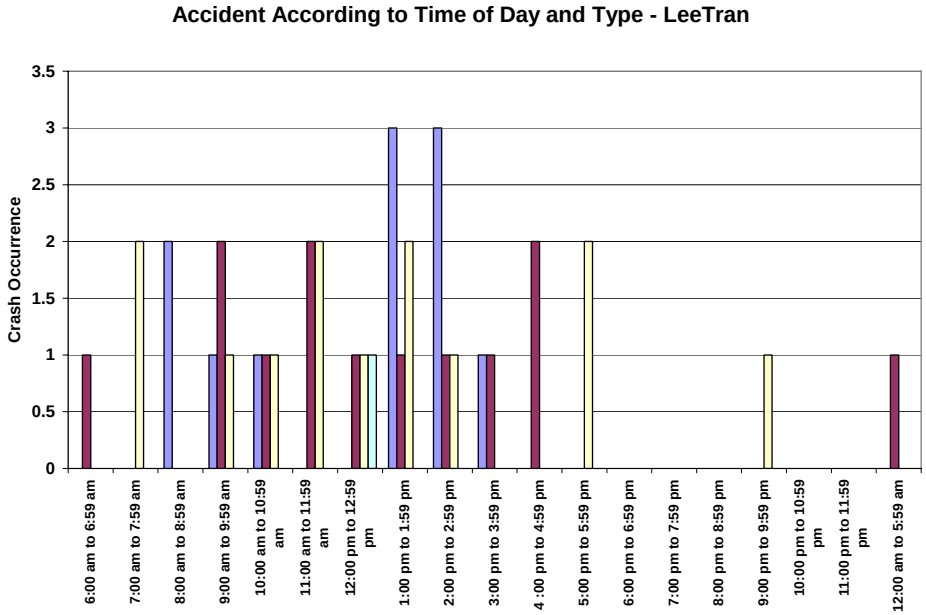


Figure 3.45 Accident According to Time of Day and Type – LeeTran.

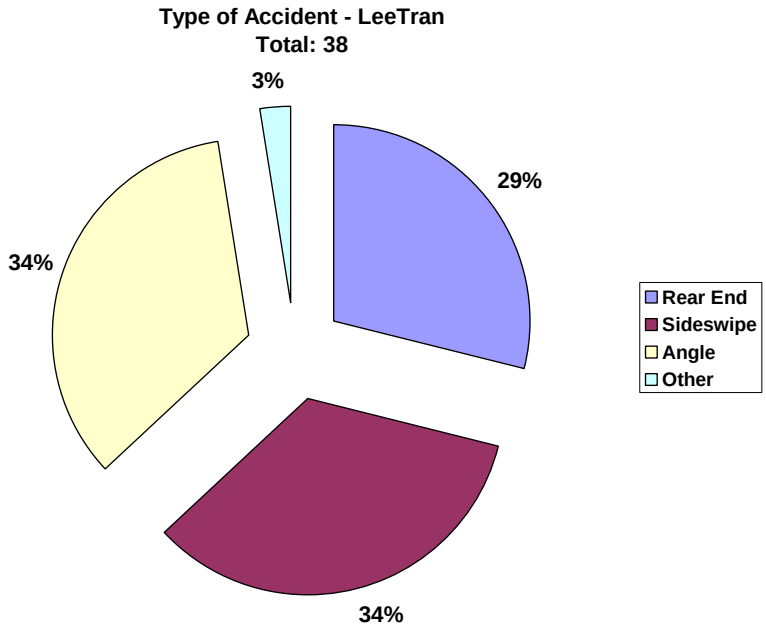


Figure 3.46 Type of Accident – LeeTran.

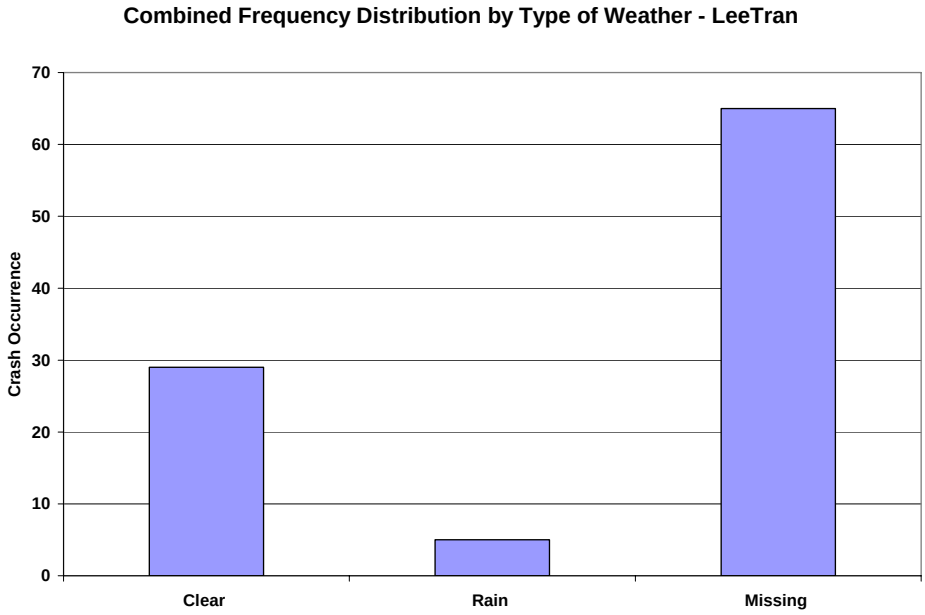


Figure 3.47 Combined Frequency Distribution by Type of Weather – LeeTran.

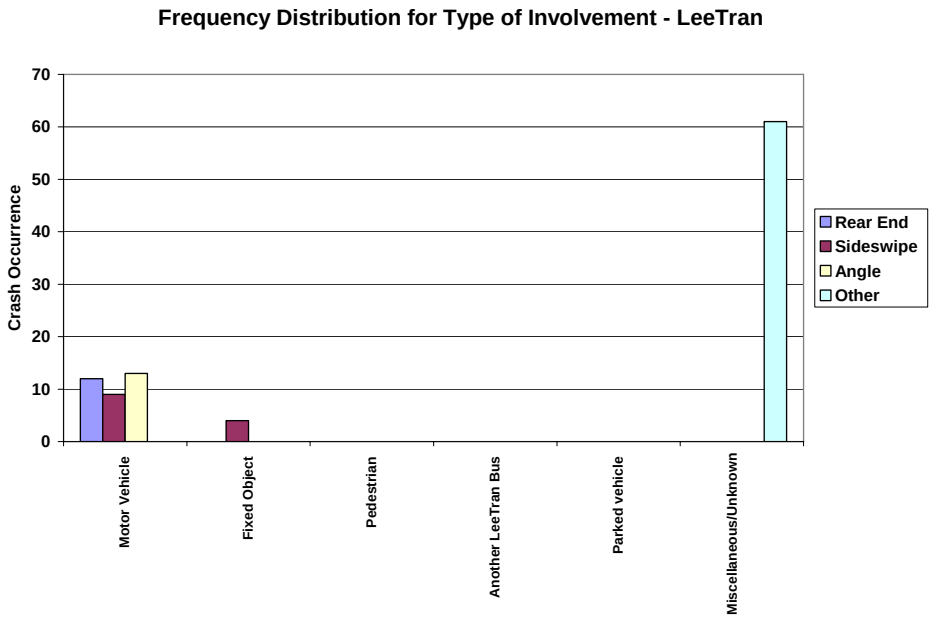


Figure 3.48 Frequency Distribution for Type of Involvement – LeeTran.

4 Conclusions

Nearly two-thirds of bus occupant injuries occur during two vehicle crashes. The crash types are evenly distributed between side, frontal and rear. An average of 12,000 bus occupants per year are injured in two vehicle crashes while 8,800 occupants per year of other vehicles are injured.(6,000 in passenger cars and 2,800 in light trucks).

The majority of fatal crashes involving buses result from frontal crashes. Half of bus fatalities occur during either morning or evening rush hour. An average of 11 bus occupants per year is killed in two vehicle crashes while 162 occupants per year of other vehicles are killed. Transit bus crashes account for 14% of all bus occupant fatalities. The majority of transit bus fatalities occur during the work week, in urban environments, on dry roadway surfaces under normal weather conditions. Over half of fatal transit bus involvements occur on roadways with posted speed limits of 25-35 mph. Shorter, heavy-duty, low-floor transit buses account for the majority of fatal transit bus involvements. Most fatal transit bus involvements occurred on buses with 2 axles. Half of fatal transit bus involvements occurred on buses with a passenger seating capacity of 36-45 seats, excluding the driver. The majority of fatal transit bus involvements occurred in buses with no passenger restraints available, excluding the driver seat. An average of 49 pedestrians and 9 pedalcyclists per year are killed in crashes with buses.

Based on the data reviewed, a typical transit bus accident occurred:

- In the afternoon, primarily during evening rush hour.
- under clear weather conditions
- on dry roadways
- in connection with another moving motor vehicle
- involving a rear-end or angle impact
- while the bus was either stopped or operating at a slow speed

The primary research objectives of this project are to: (1) characterize the structural response of mass transit buses; (2) characterize the occupant kinematics and injury mechanisms in mass transit bus interiors; (3) develop interior design guidelines and crashworthiness design procedures; for mass transit buses in order to reduce occupant injuries and fatalities during side, frontal and rear impact collisions with various vehicle types. Based on the typical crash scenarios identified in this report, a detailed FE Bus Model will be generated to extract typical crash pulses and vehicle intrusions at various occupant locations to support the research objectives.

5 References

[1] Editor C. Moore, *National Transportation Statistics*, Bureau of Transportation Statistic, U.S. Department of Transportation, Washington DC 20590, June 2005.

[2] Anon., *Traffic Safety Facts 1999: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington DC 20590. December 2000.

[3] Anon., *Traffic Safety Facts 2000: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington DC 20590. December 2001.

[4] Anon., *Traffic Safety Facts 2001: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington DC 20590. December 2002.

[5] Anon., *Traffic Safety Facts 2002: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington DC 20590. January 2004.

[6] Anon., *Traffic Safety Facts 2003: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington DC 20590. May 2005.

[7] A. Matteson and D. Blower, *Buses Involved in Fatal Accidents Factbook 1999*, Center for National Truck and Bus Statistics, University of Michigan Transportation Research Institute, Ann Arbor, Michigan, 48109-2150, June 2003.

[8] A. Matteson, D. Blower and D. Hershberger, *Buses Involved in Fatal Accidents Factbook 2000*, Center for National Truck and Bus Statistics, University of Michigan Transportation Research Institute, Ann Arbor, Michigan, 48109-2150, April 2004.

[9] A. Matteson, D. Blower, D. Hershberger and J. Woodrooffe, *Buses Involved in Fatal Accidents Factbook 2001*, Center for National Truck and Bus Statistics, University of Michigan Transportation Research Institute, Ann Arbor, Michigan, 48109-2150, February 2005.

[10] C. Foreman, J. R. Rey and C. DeAnnuntis, *National Transit Bus Accident Data Collection and Analysis*, National Center for Transit Research,University of South Florida, Tampa, Florida, 33620-5375, February 2002.

[11] J. R. Rey, D. Hinebaugh and J. Fernandez, *Analysis of Florida Transit Bus Crashes*, National Center for Transit Research,University of South Florida, Tampa, Florida, 33620-5375, June 2001.

[12] D. B. Sapper and O. Page, *Analysis of Florida Transit Bus Accidents*, National Center for Transit Research, Center for Urban Transportation Research, University of South Florida, Tampa, Florida, 33620-5375, December 2004.

Appendix A Detailed Data

A.1 Buses Involved in Fatal Accidents

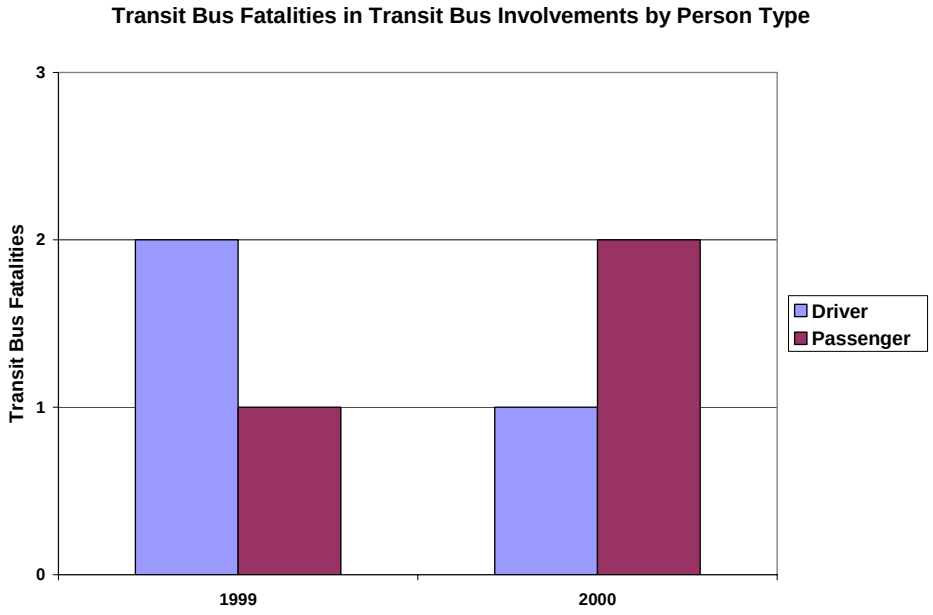


Figure A.1 Transit Bus Fatalities in Transit Bus Involvements by Person Type.

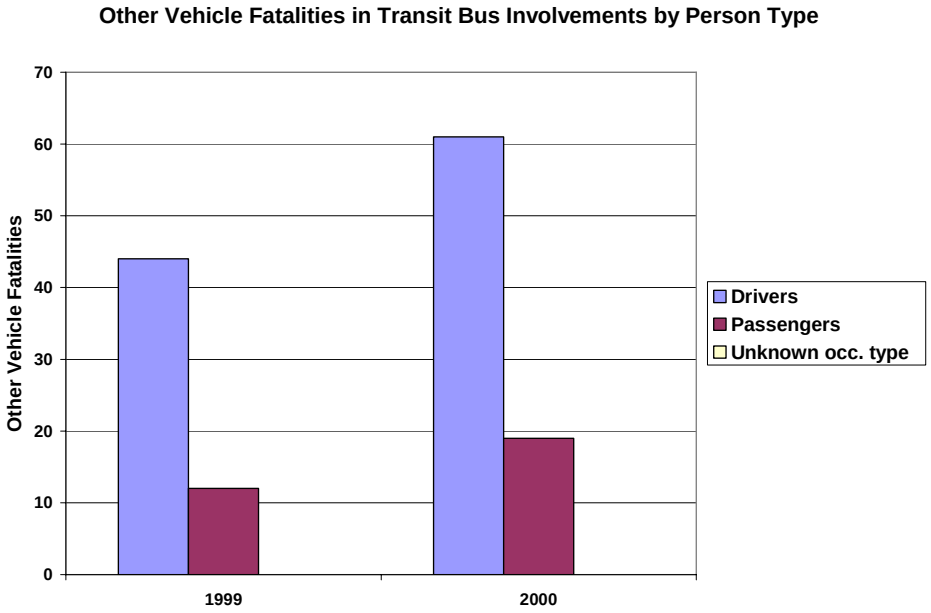


Figure A.2 Other Vehicle Fatalities in Transit Bus Involvements by Person Type.

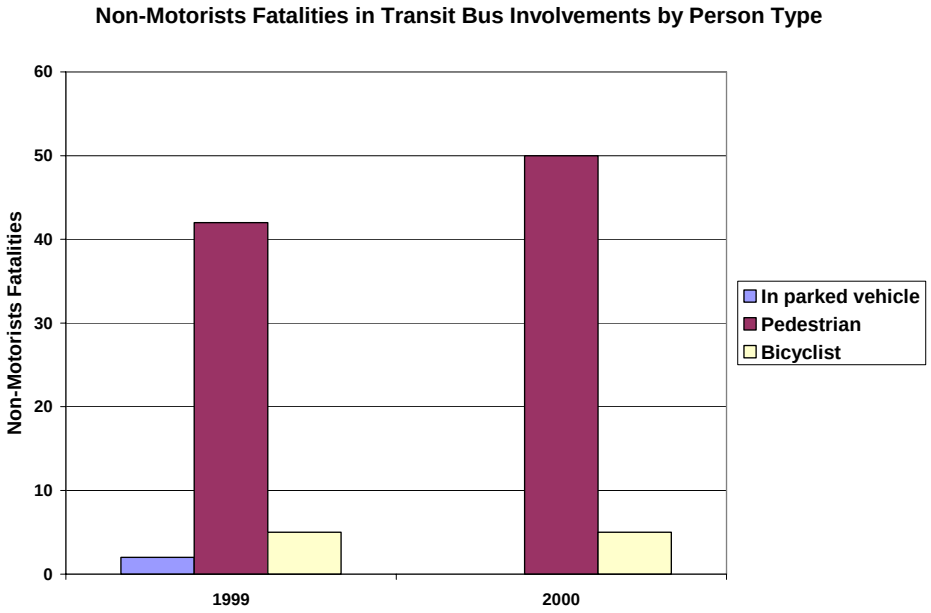


Figure A.3 Non-Motorists Fatalities in Transit Bus Involvements by Person Type.

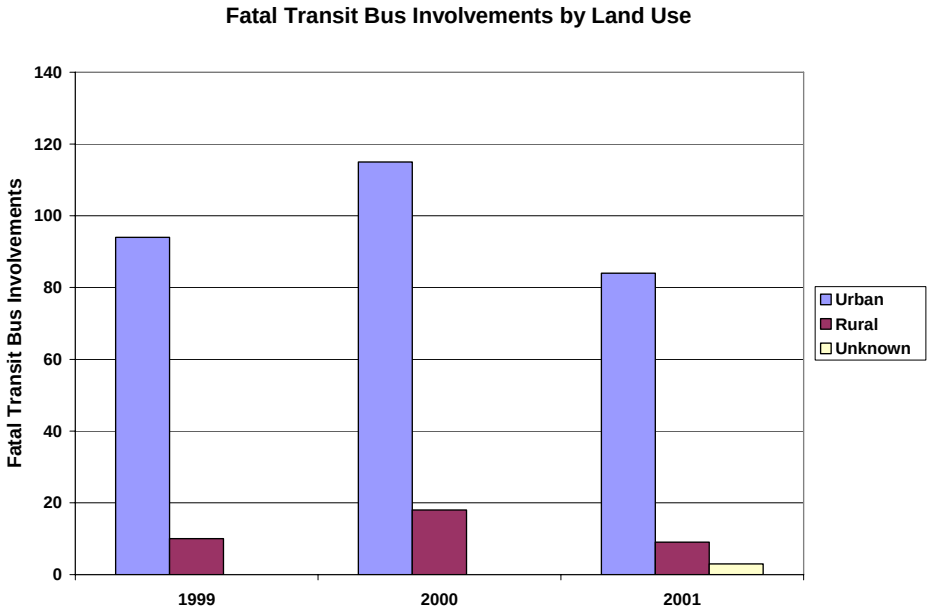


Figure A.4 Fatal Transit Bus Involvements by Land Use.

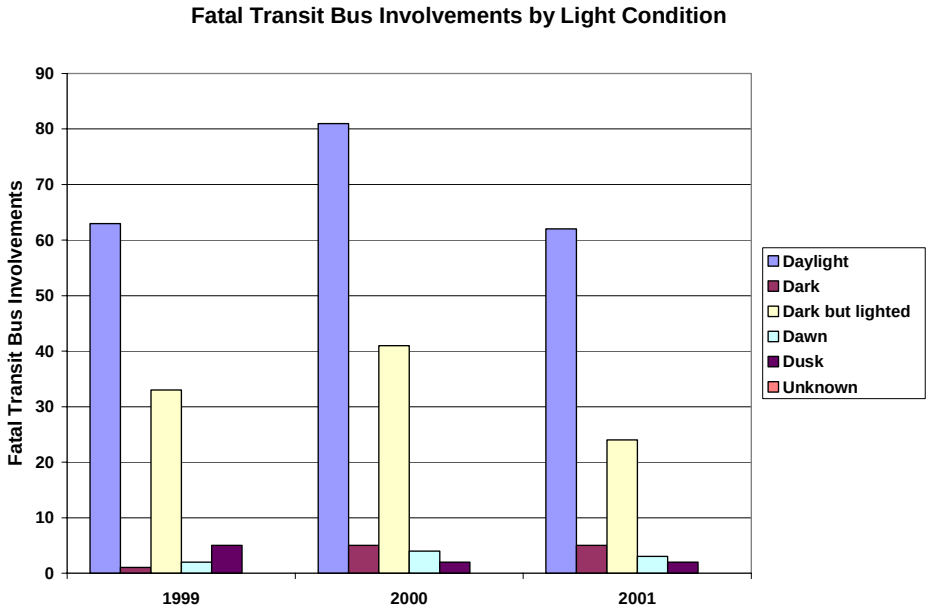


Figure A.5 Fatal Transit Bus Involvements by Light Condition.

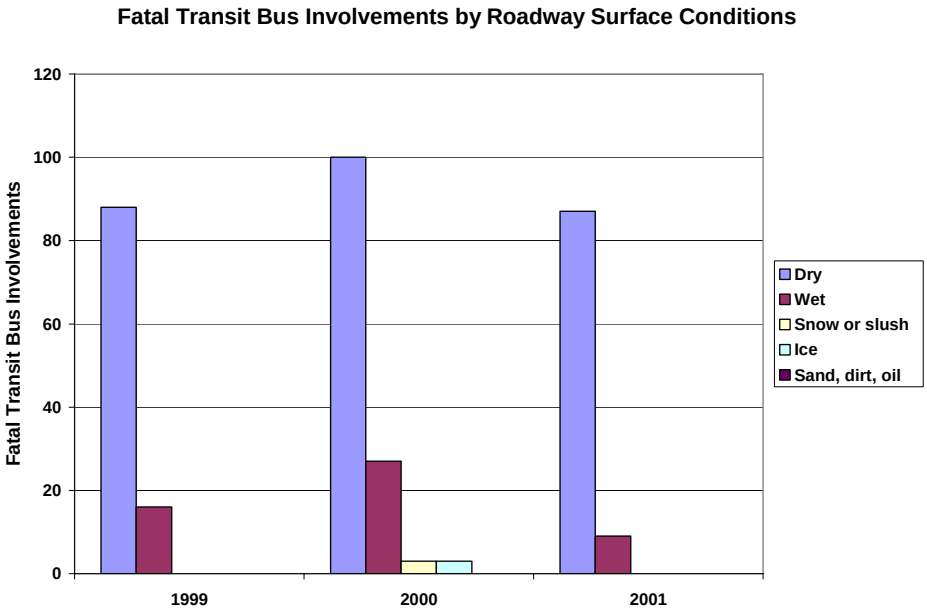


Figure A.6 Fatal Transit Bus Involvements by Roadway Surface Conditions.

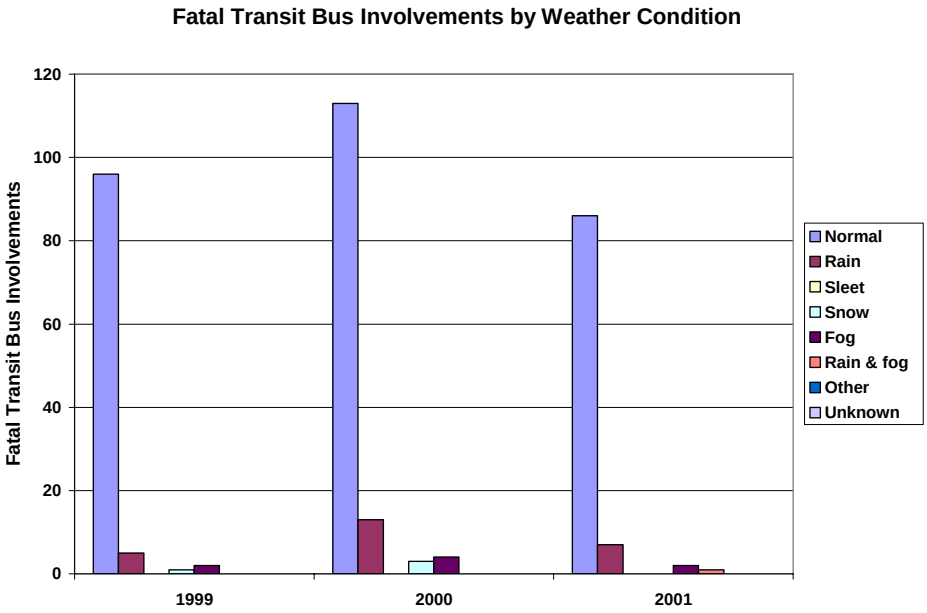


Figure A.7 Fatal Transit Bus Involvements by Weather Condition.

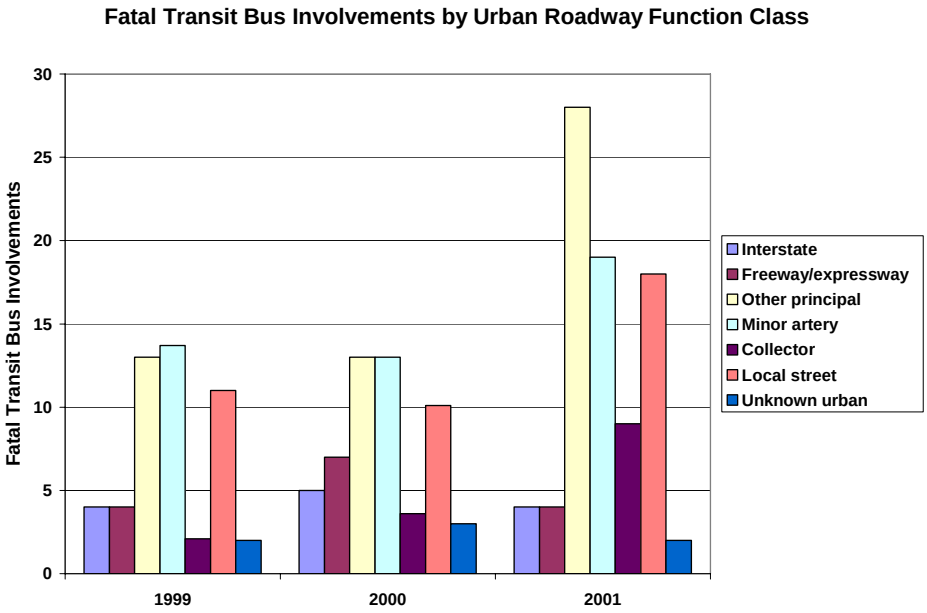


Figure A.8 Fatal Transit Bus Involvements by Urban Roadway Function Class.

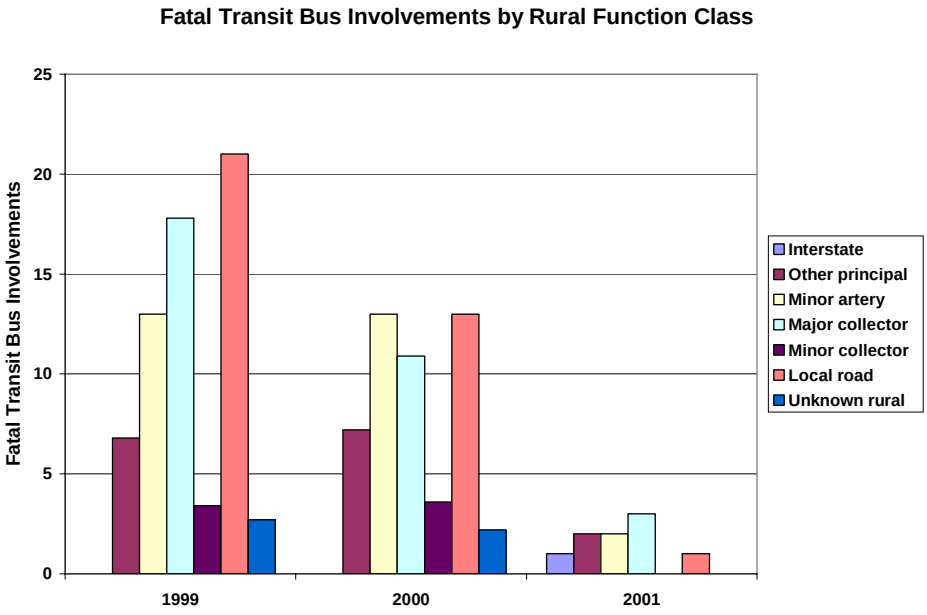


Figure A.9 Fatal Transit Bus Involvements by Rural Function Class.

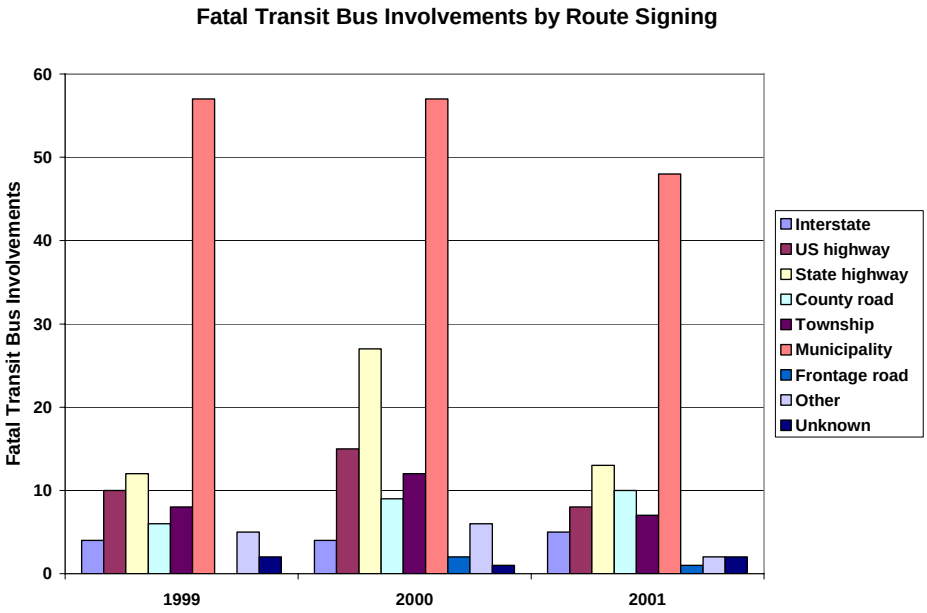


Figure A.10 Fatal Transit Bus Involvements by Route Signing.

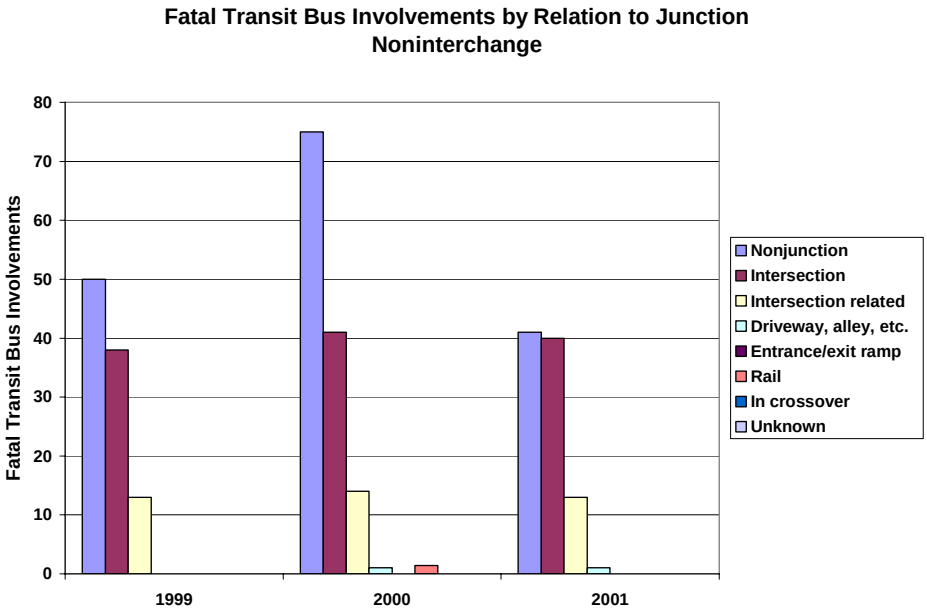


Figure A.11 Fatal Transit Bus Involvements by Relation to Junction – Noninterchange.

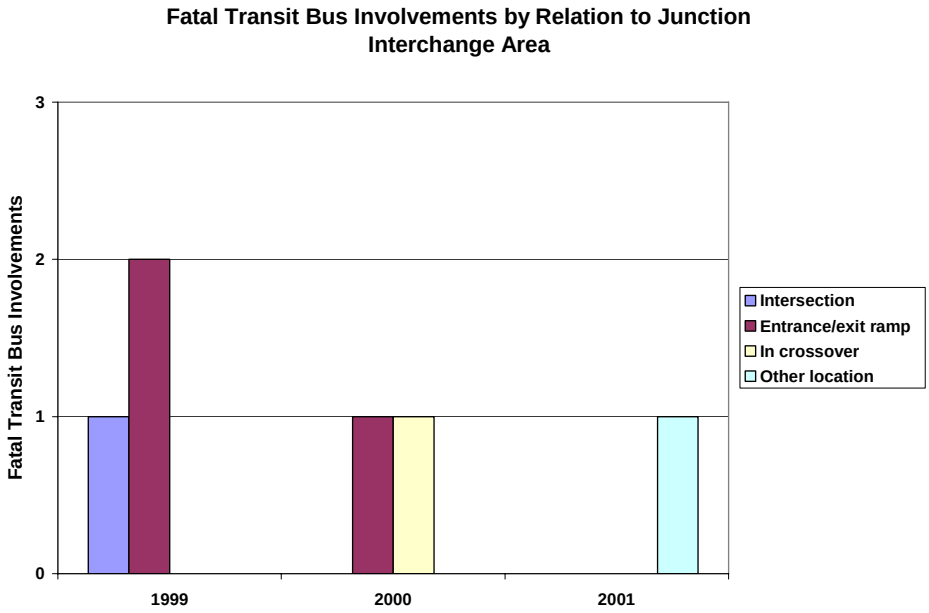


Figure A.12 Fatal Transit Bus Involvements by Relation to Junction – Interchange Area.

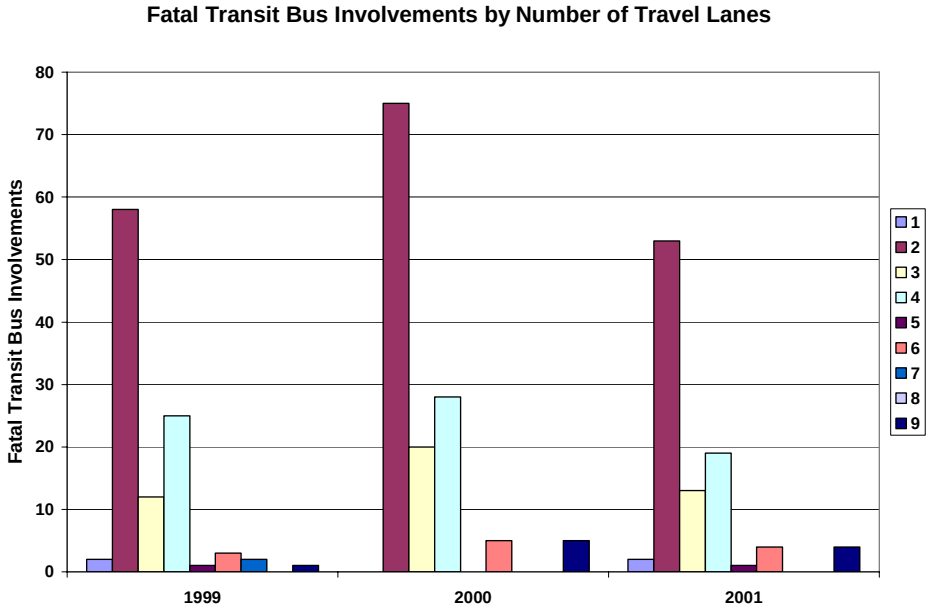


Figure A.13 Fatal Transit Bus Involvements by Number of Travel Lanes.

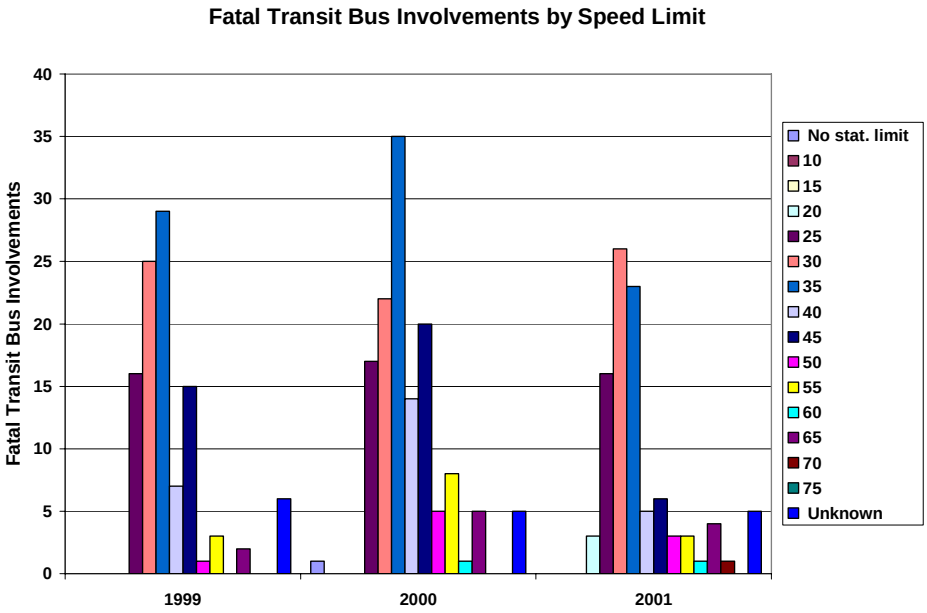


Figure A.14 Fatal Transit Bus Involvements by Speed Limit.

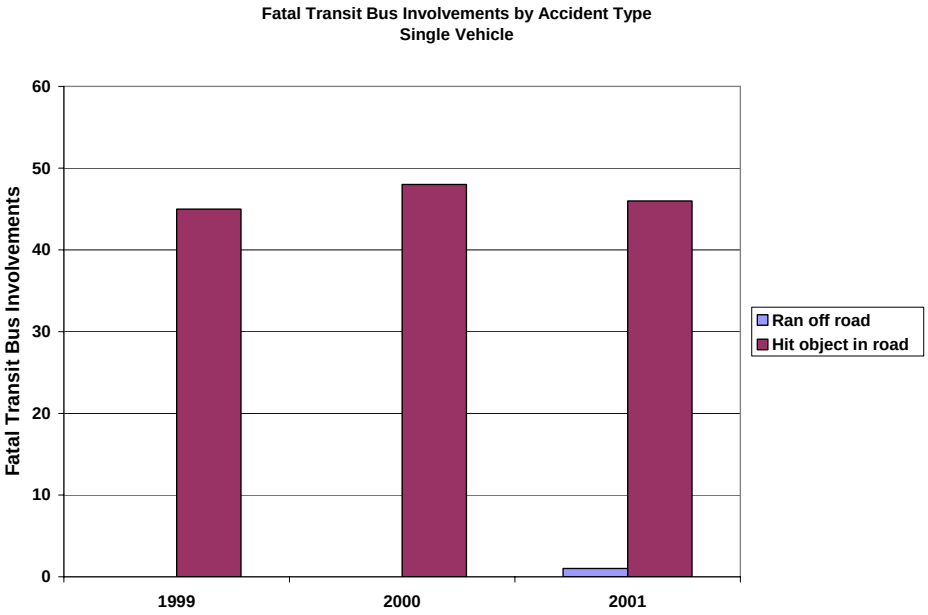


Figure A.15 Fatal Transit Bus Involvements by Accident Type – Single Vehicle.

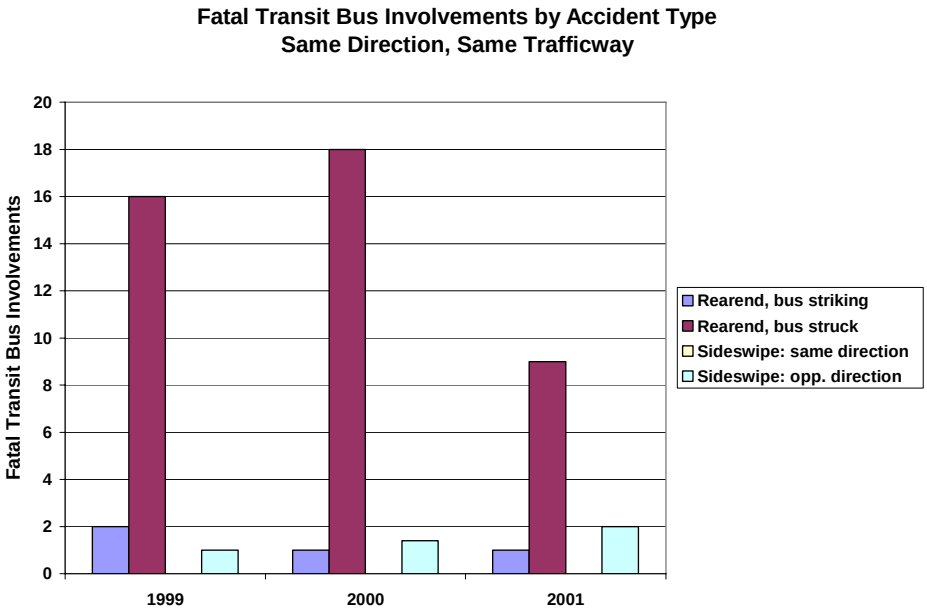


Figure A.16 Fatal Transit Bus Involvements by Accident Type, Same Direction, Same Trafficway.

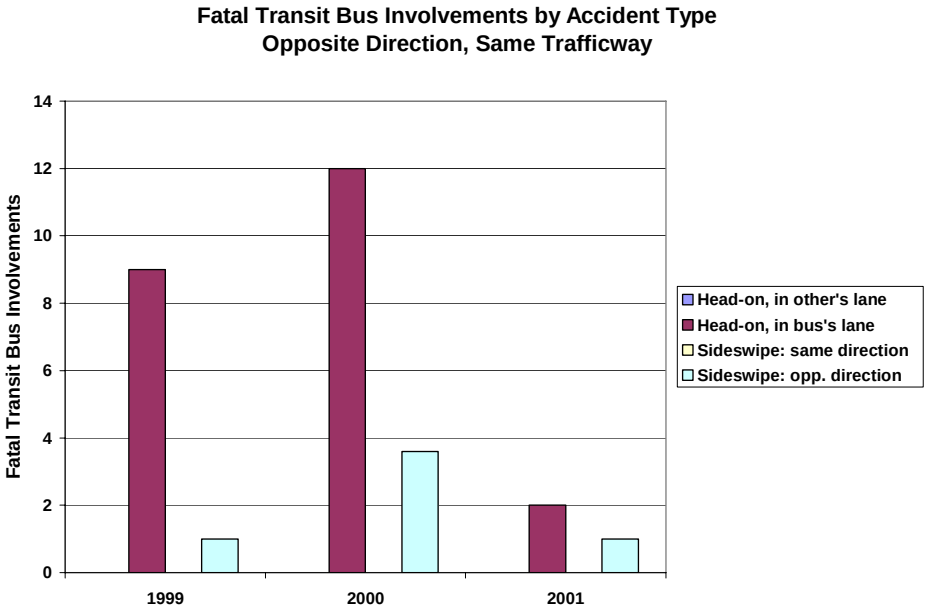


Figure A.17 Fatal Transit Bus Involvements by Accident Type, Opposite Direction, Same Trafficway.

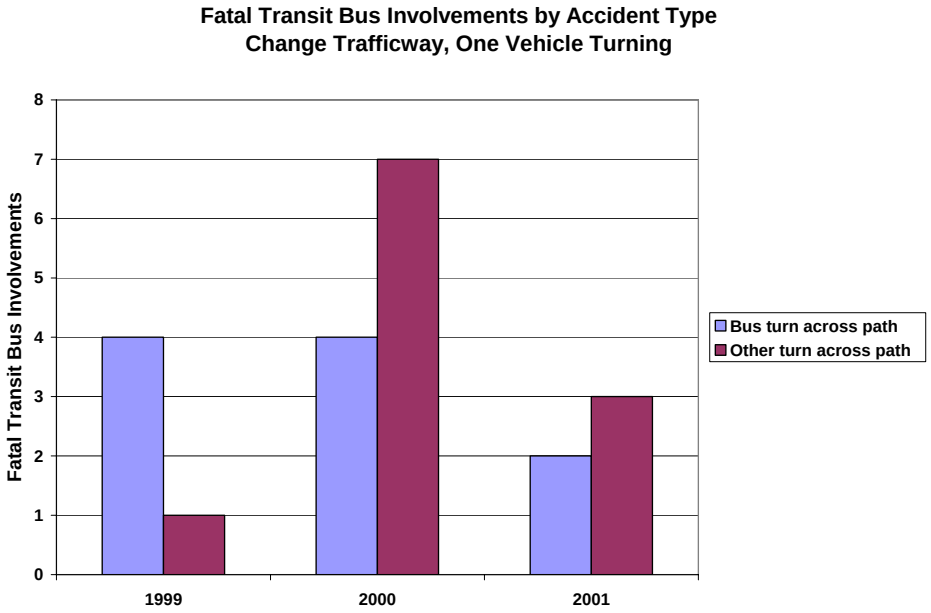


Figure A.18 Fatal Transit Bus Involvements by Accident Type, Change Trafficway, One Vehicle Turning.

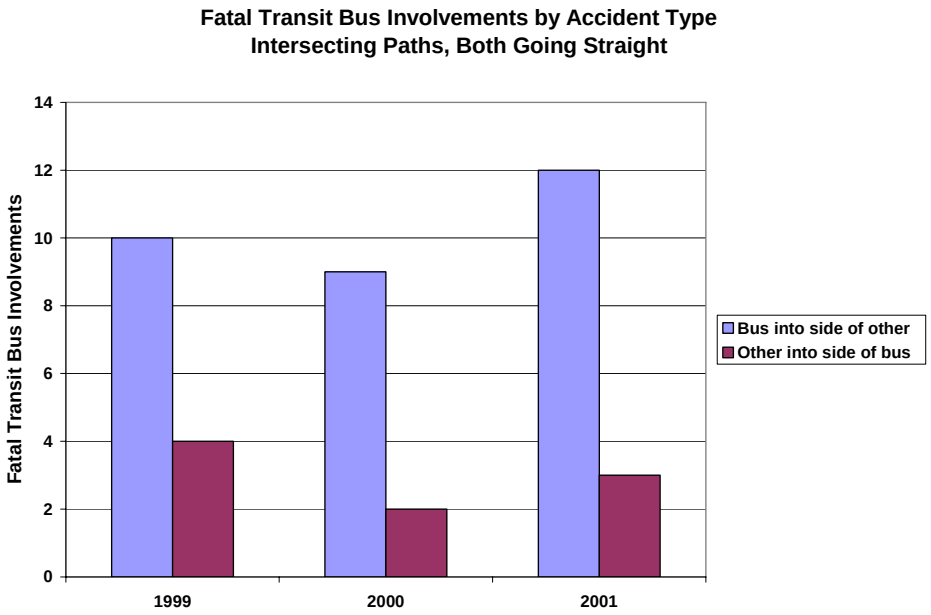


Figure A.19 Fatal Transit Bus Involvements by Accident Type, Intersecting Paths, Both Going Straight.

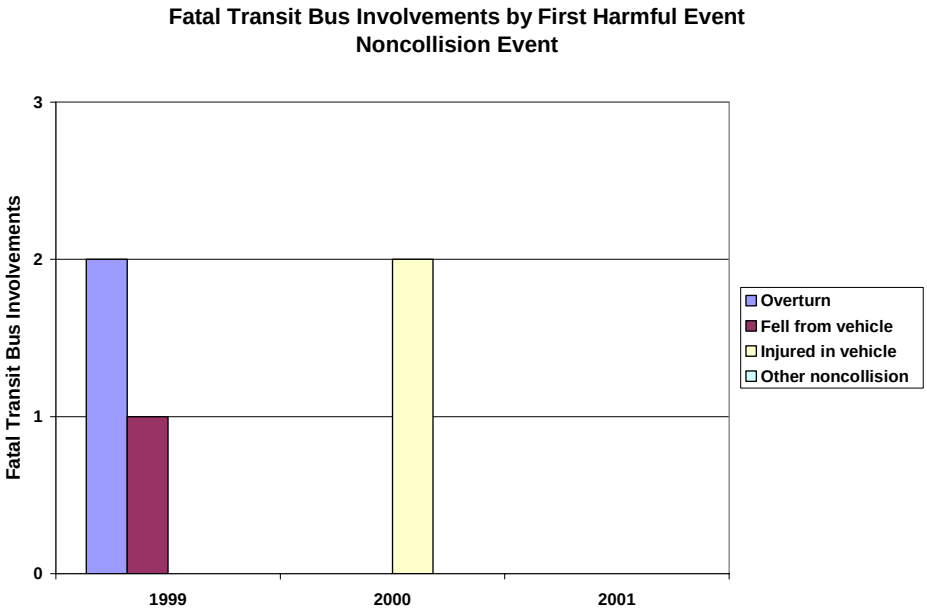


Figure A.20 Fatal Transit Bus Involvements by First Harmful Event, Noncollision Event.

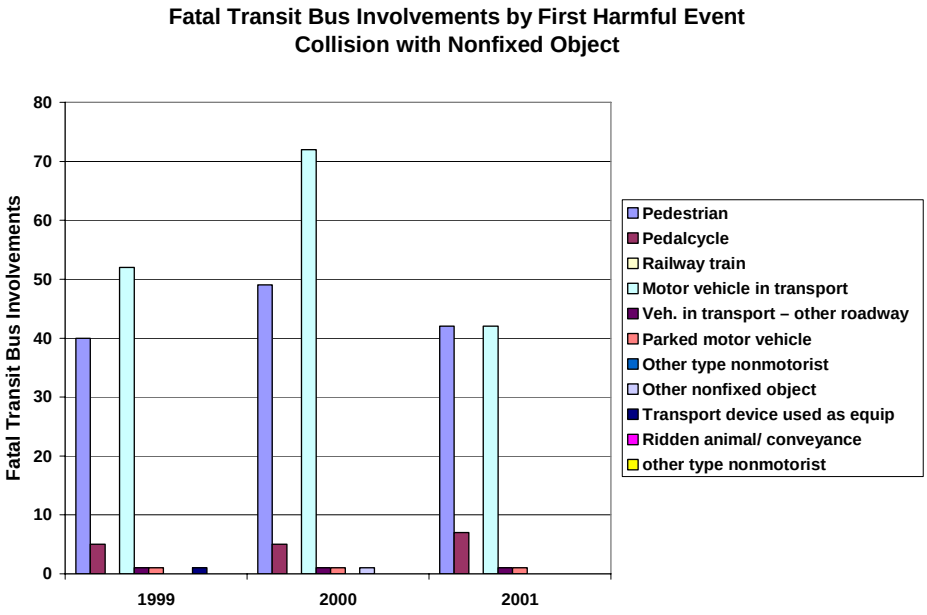


Figure A.21 Fatal Transit Bus Involvements by First Harmful Event, Collision with Nonfixed Object.

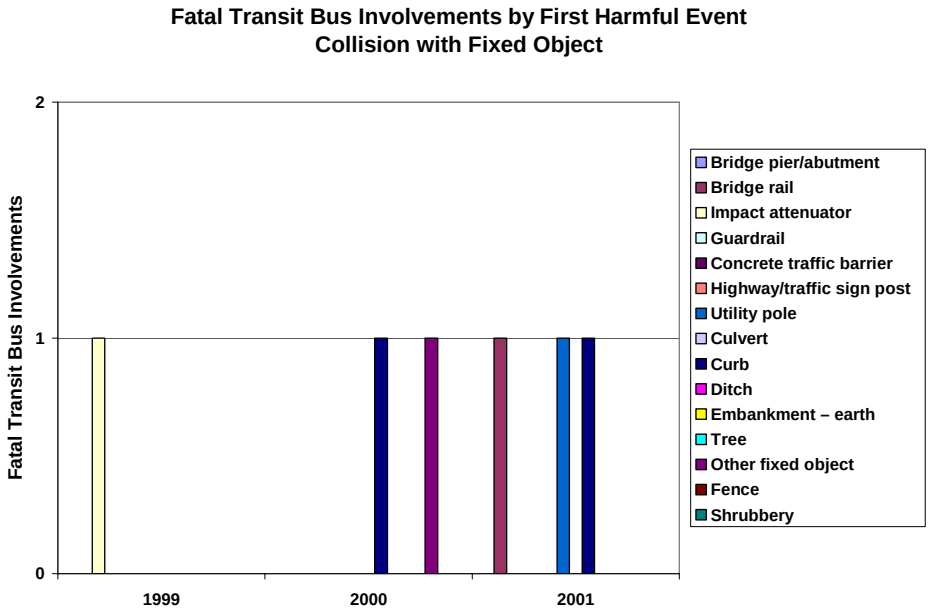


Figure A.22 Fatal Transit Bus Involvements by First Harmful Event, Collision with Fixed Object.

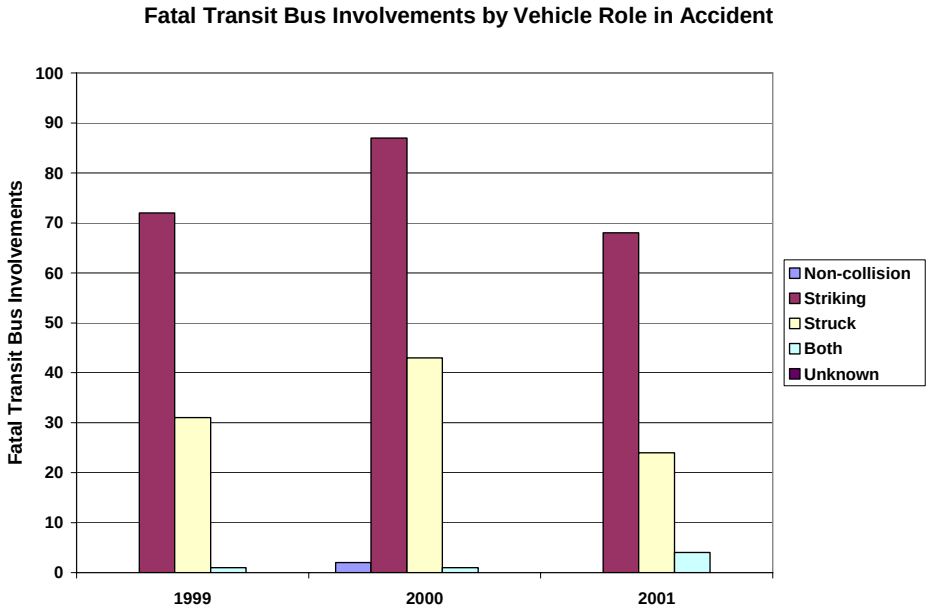


Figure A.23 Fatal Transit Bus Involvements by Vehicle Role in Accident.

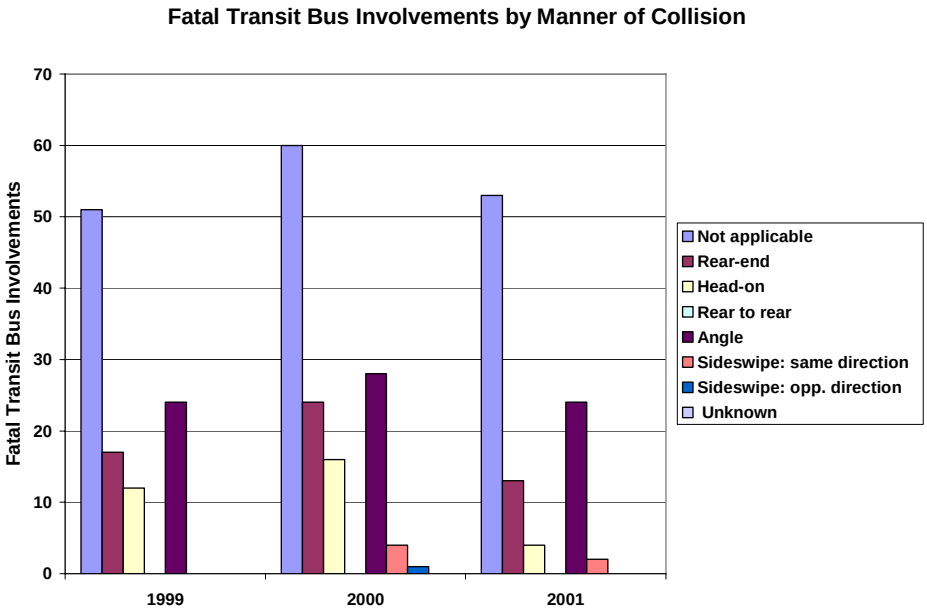


Figure A.24 Fatal Transit Bus Involvements by Manner of Collision.

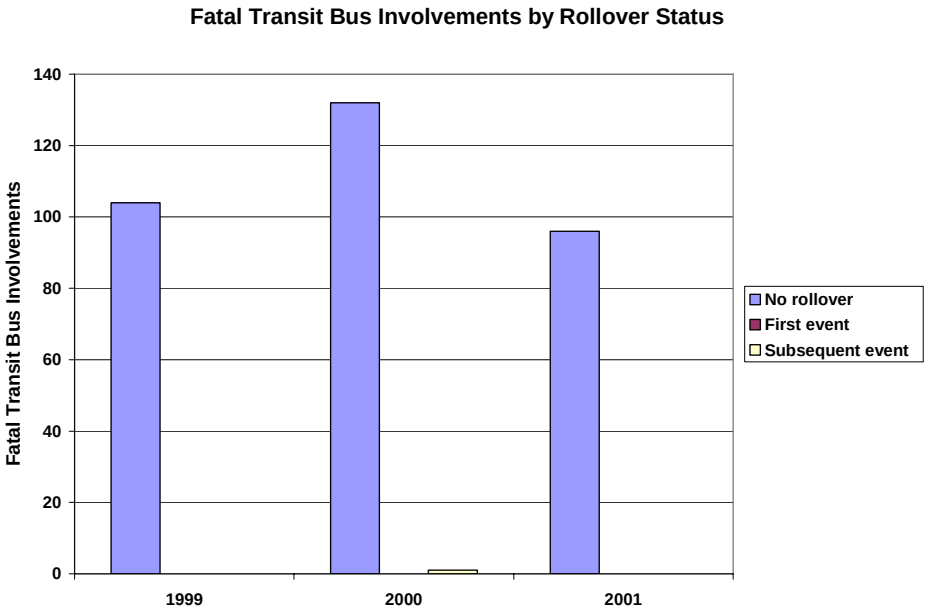


Figure A.25 Fatal Transit Bus Involvements by Rollover Status.

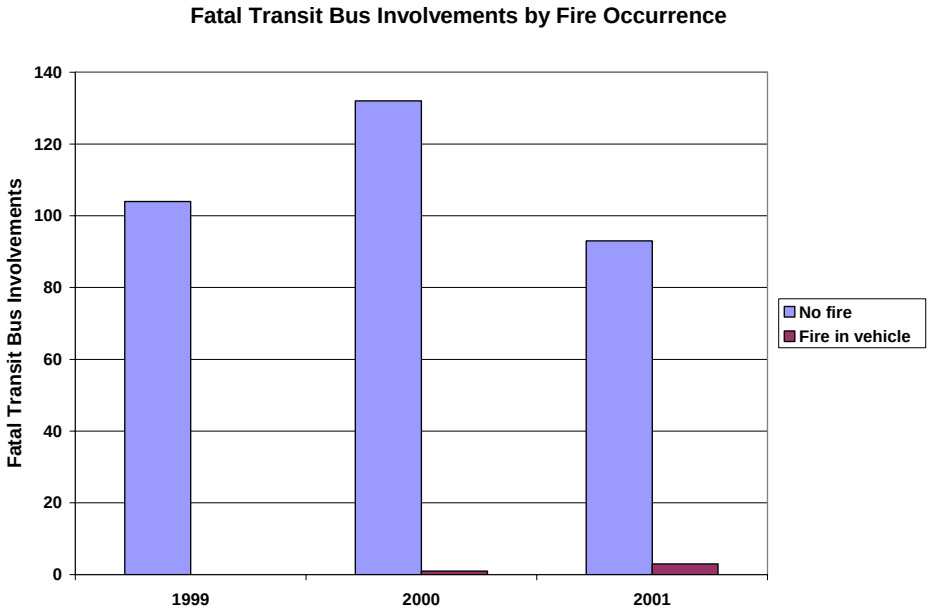


Figure A.26 Fatal Transit Bus Involvements by Fire Occurrence.

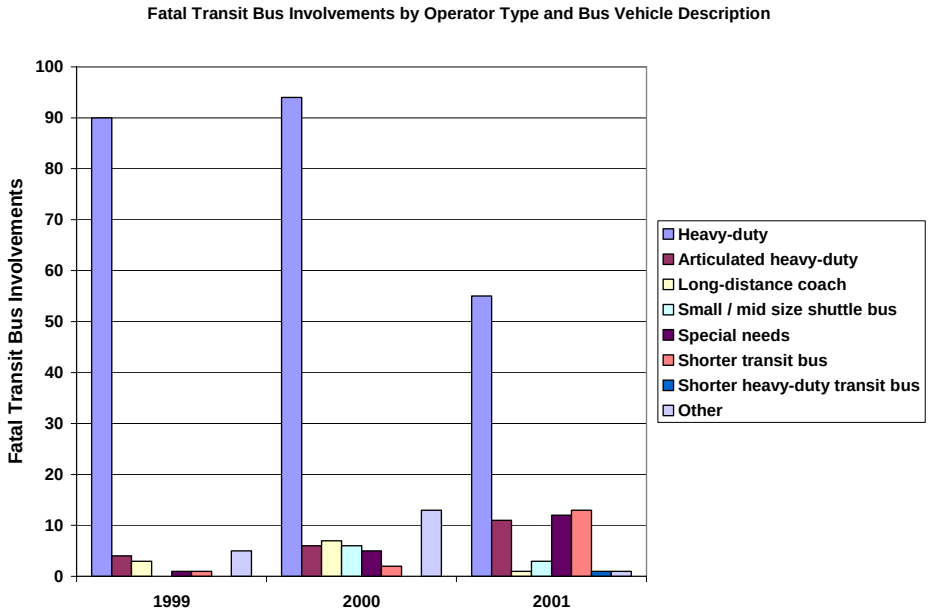


Figure A.27 Fatal Transit Bus Involvements by Operator Type and Bus Vehicle Description.

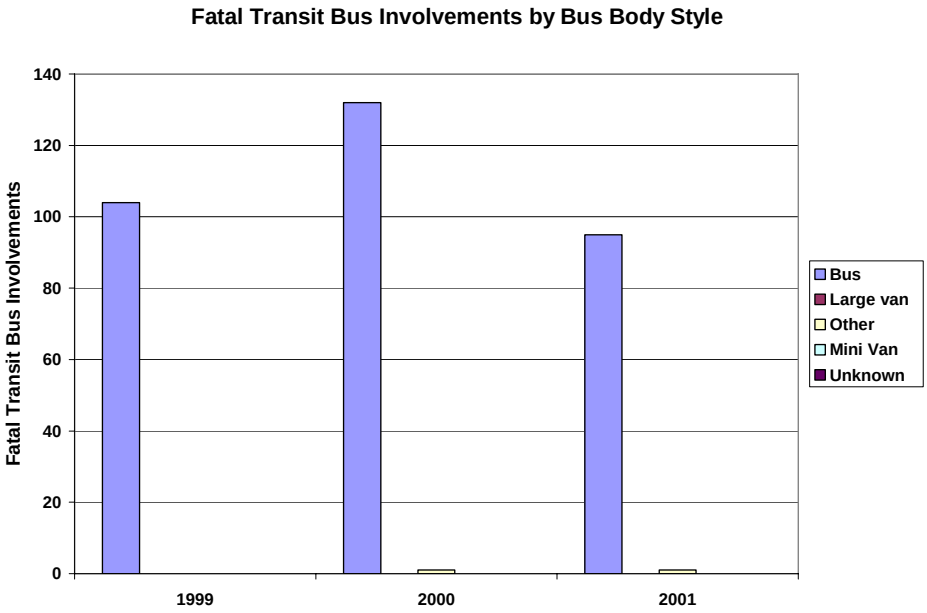


Figure A.28 Fatal Transit Bus Involvements by Bus Body Style.

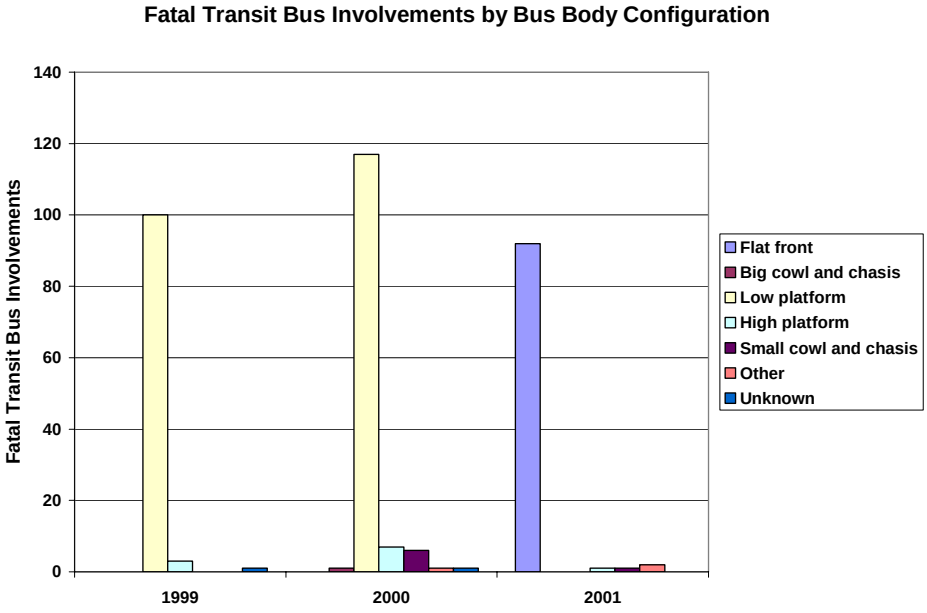


Figure A.29 Fatal Transit Bus Involvements by Bus Body Configuration.

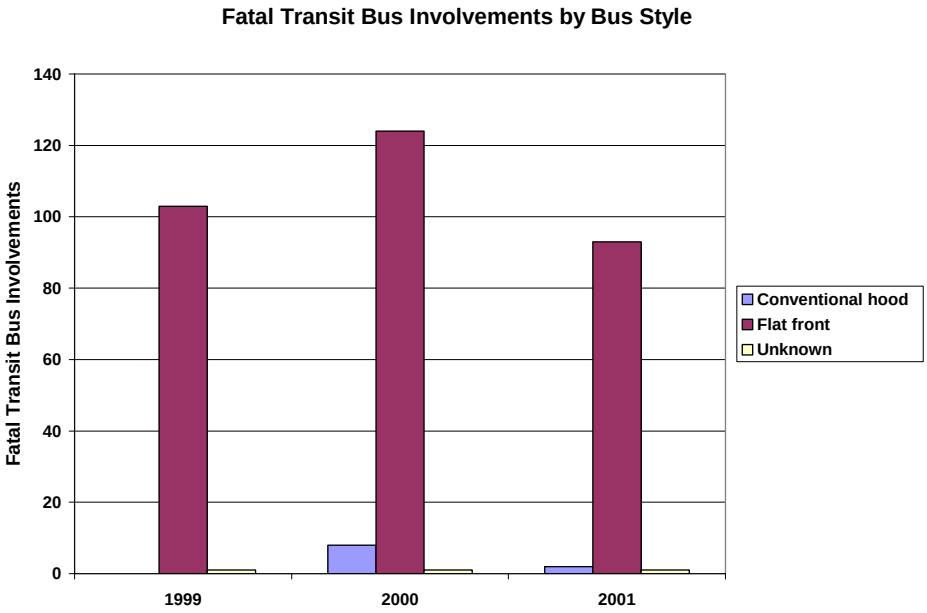


Figure A.30 Fatal Transit Bus Involvements by Bus Style.

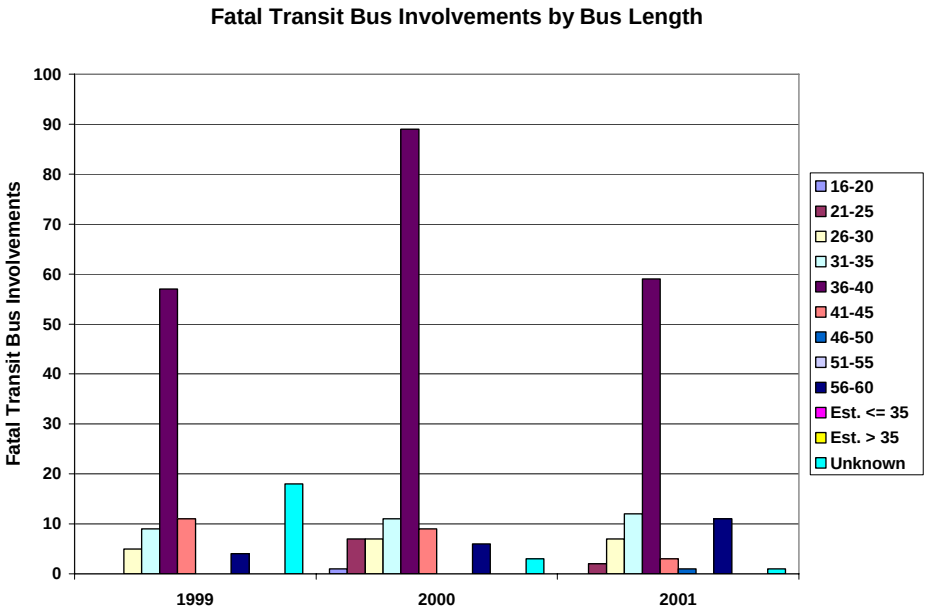


Figure A.31 Fatal Transit Bus Involvements by Bus Length.

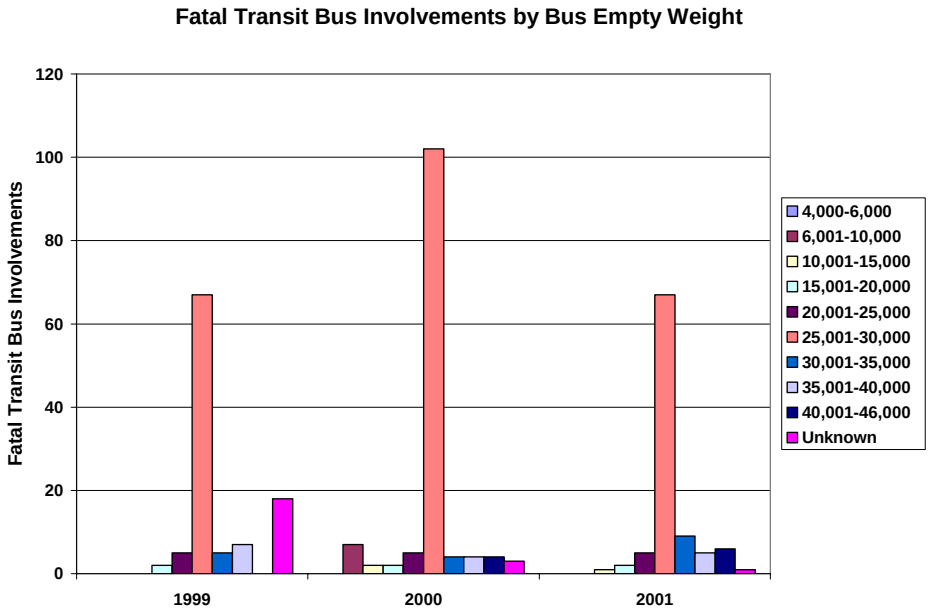


Figure A.32 Fatal Transit Bus Involvements by Bus Empty Weight.

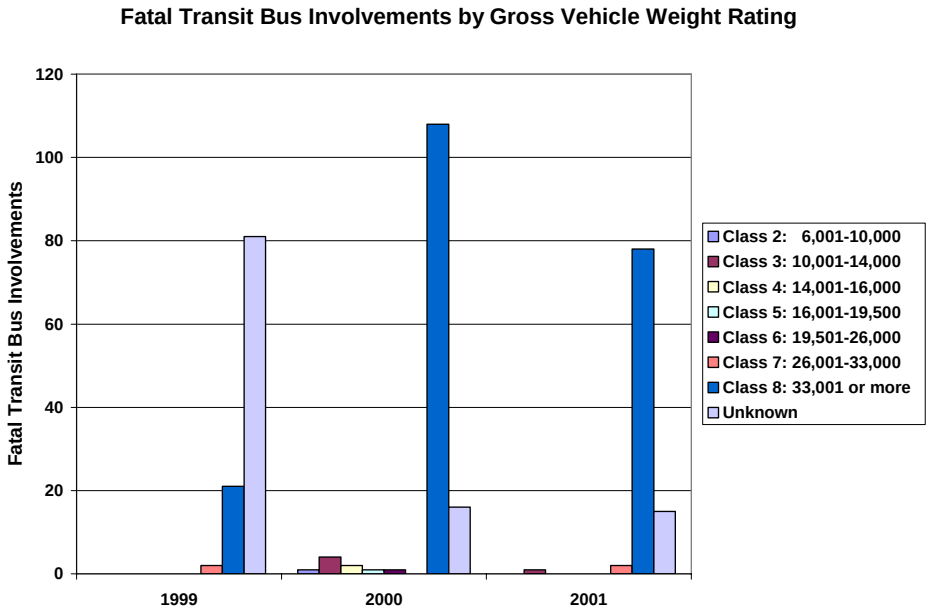


Figure A.33 Fatal Transit Bus Involvements by Gross Vehicle Weight Rating.

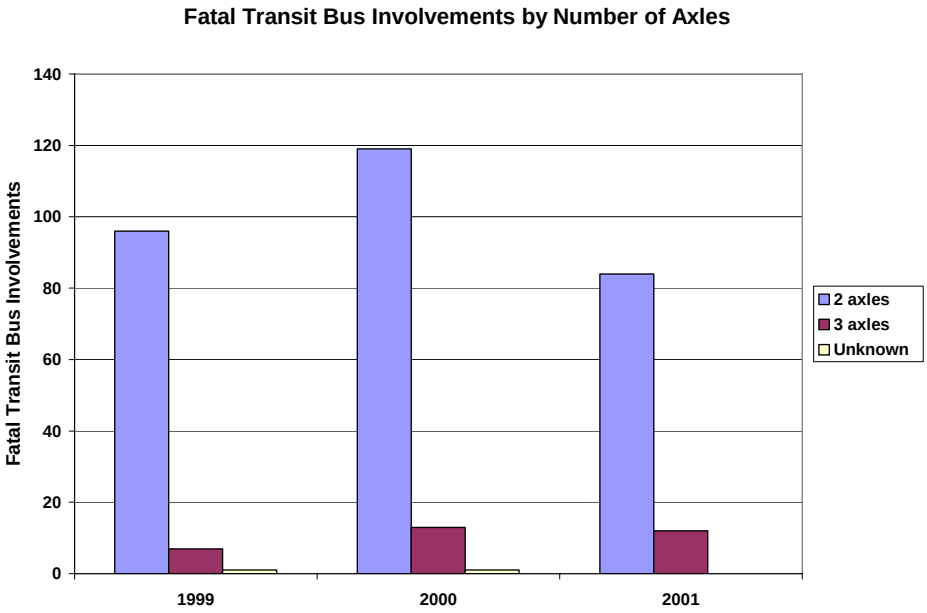


Figure A.34 Fatal Transit Bus Involvements by Number of Axles.

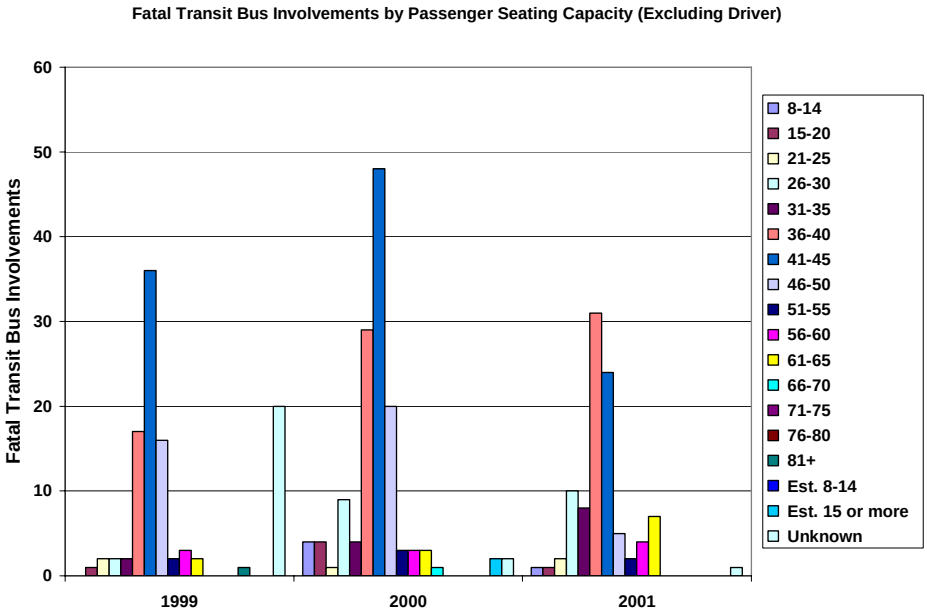


Figure A.35 Fatal Transit Bus Involvements by Passenger Seating Capacity (Excluding Driver).

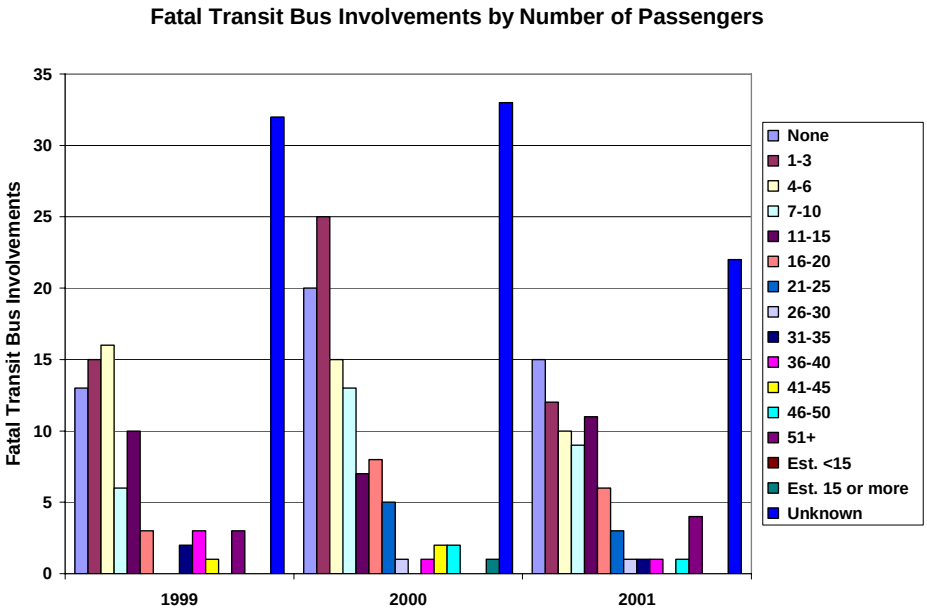


Figure A.36 Fatal Transit Bus Involvements by Number of Passengers.

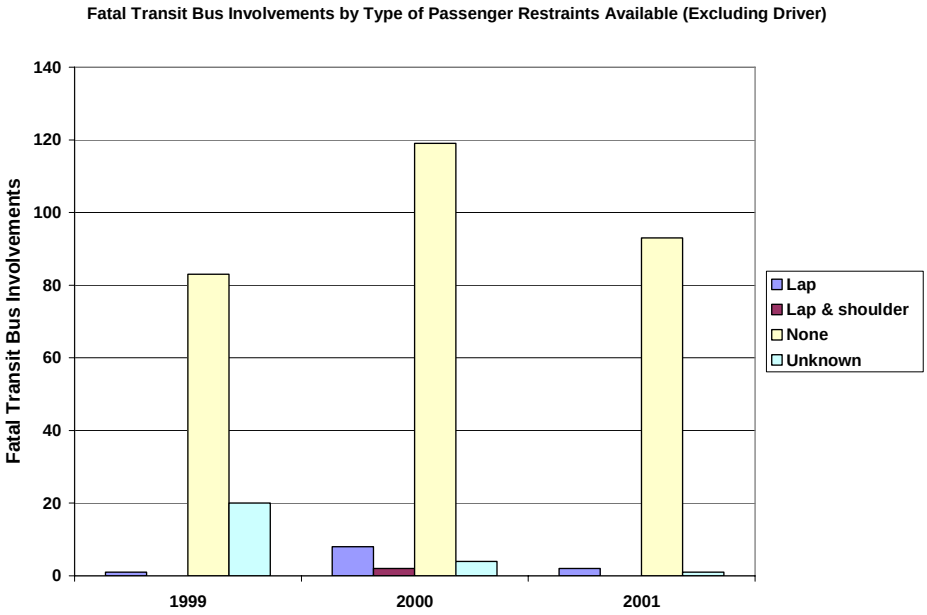


Figure A.37 Fatal Transit Bus Involvements by Type of Passenger Restraints Available (Excluding Driver).

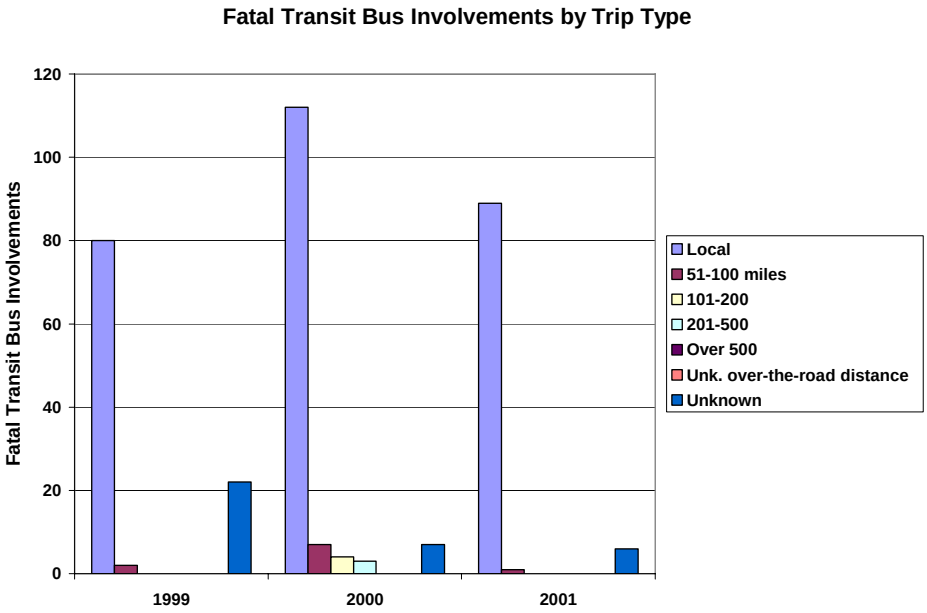


Figure A.38 Fatal Transit Bus Involvements by Trip Type.

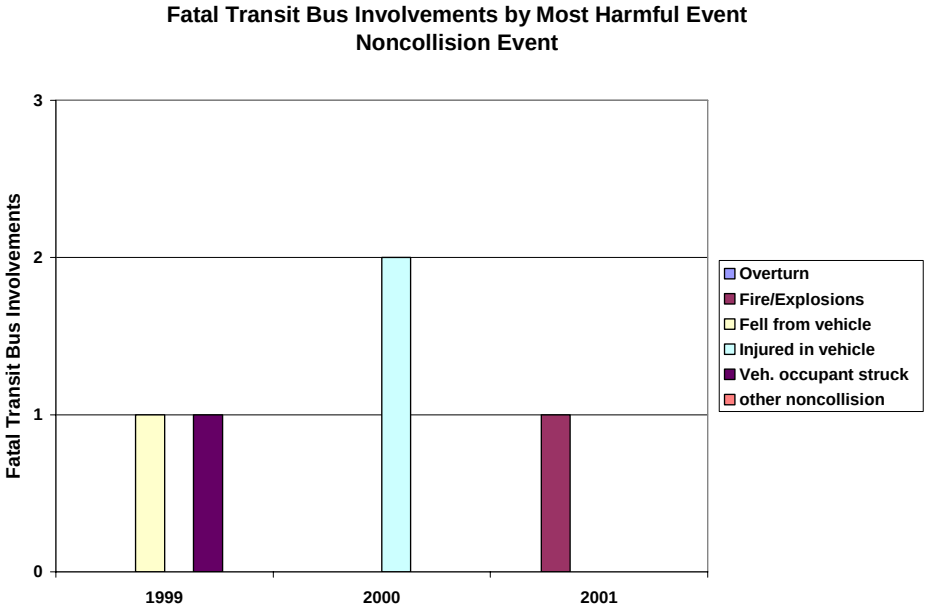


Figure A.39 Fatal Transit Bus Involvements by Most Harmful Event, Noncollision Event.

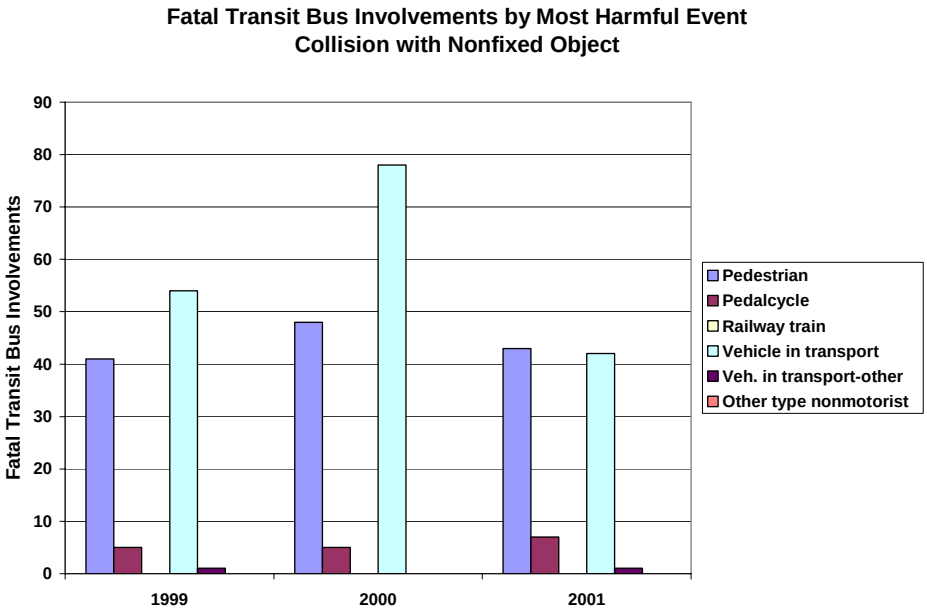


Figure A.40 Fatal Transit Bus Involvements by Most Harmful Event, Collision with Nonfixed Object.

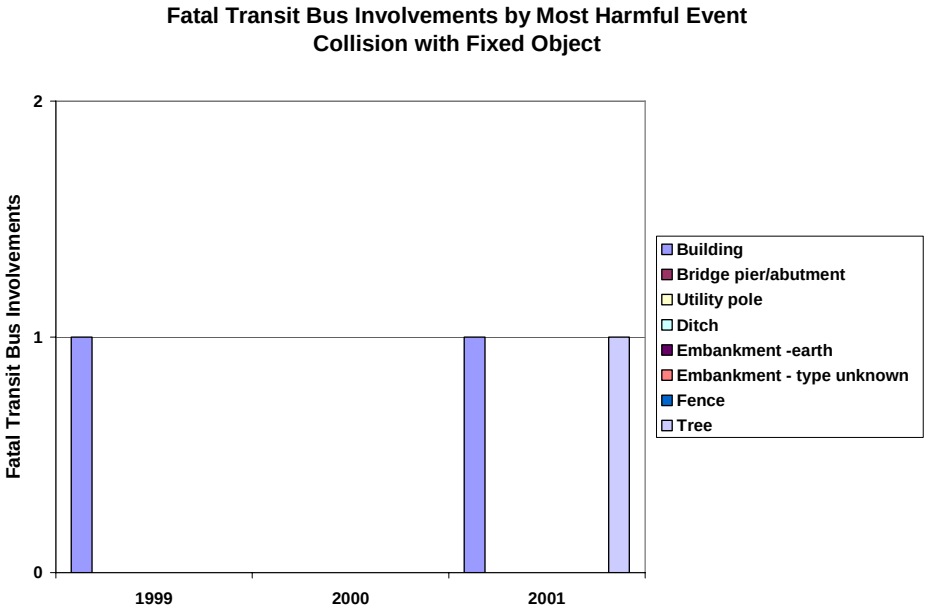


Figure A.41 Fatal Transit Bus Involvements by Most Harmful Event, Collision with Fixed Object.

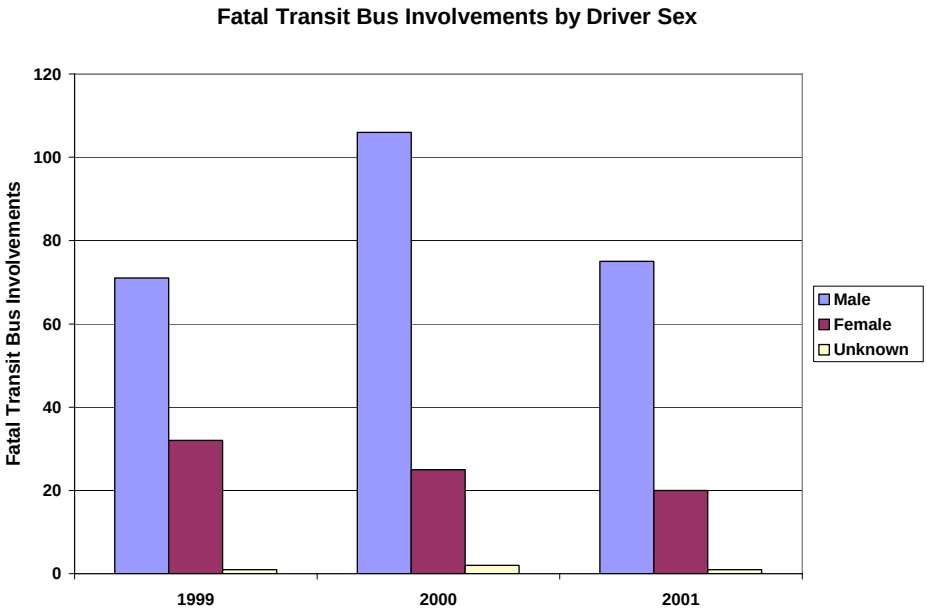


Figure A.42 Fatal Transit Bus Involvements by Driver Sex.

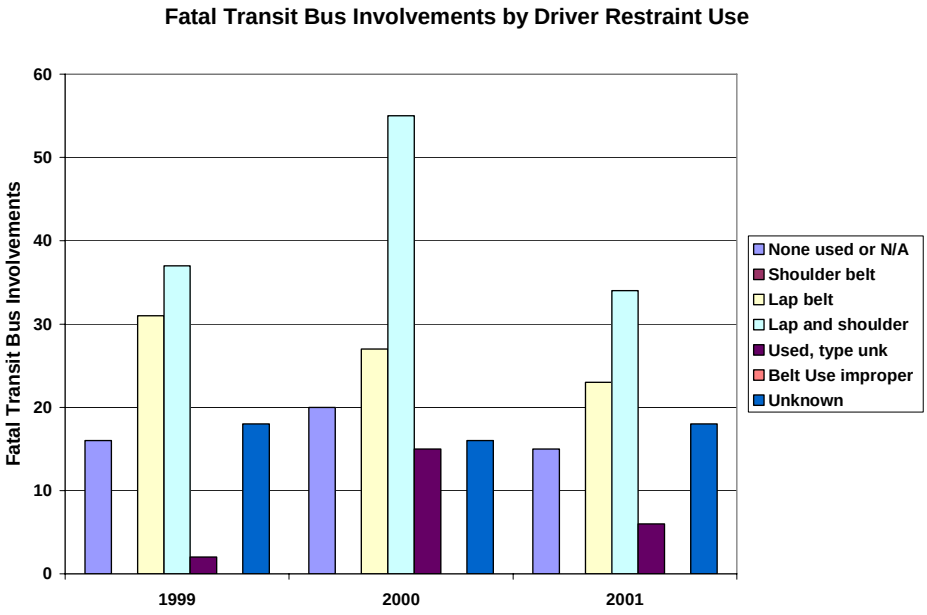


Figure A.43 Fatal Transit Bus Involvements by Driver Restraint Use.

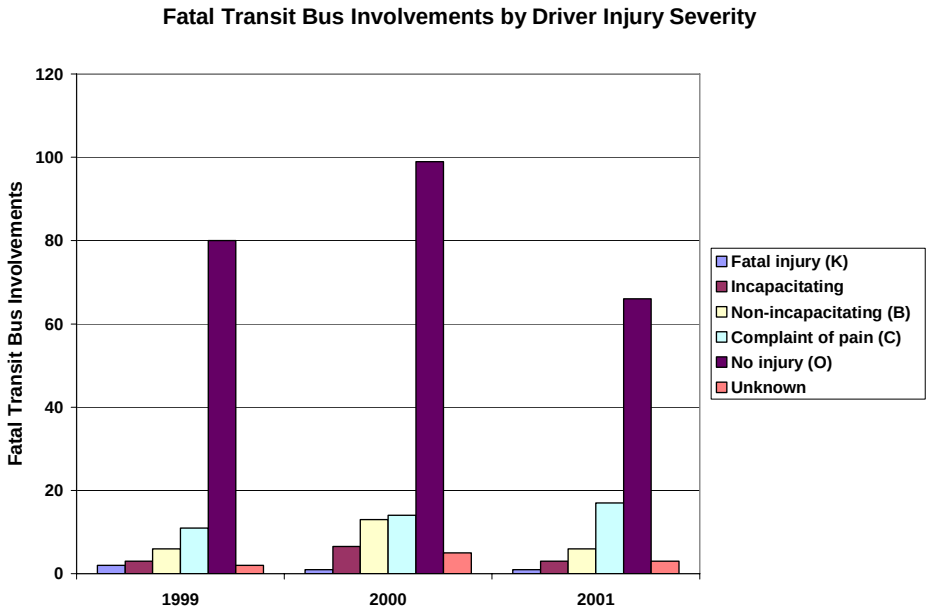


Figure A.44 Fatal Transit Bus Involvements by Driver Injury Severity.