AN ANALYSIS OF EMERGENCY VEHICLE CRASH CHARACTERISTICS

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(ABSTRACT)

Crash data suggests that intersections are areas producing conflicts among the various road users because of entering and crossing movements. Traffic signal control systems may not always be sufficient in preventing collisions at intersections between emergency and other vehicles. The Firefighter Fatality Retrospective Study of 2002 illustrates that the second leading cause of fatal injury for firefighters is vehicle collisions. Furthermore, the involvement of an emergency vehicle in a crash can negatively affect the overall efficiency of emergency response services. Thus, there is a need to facilitate the implementation of higher-payoff strategies to improve the safety of emergency vehicle passage through signalized intersections. This research aims to provide a basis for the transportation professionals to identify problem areas and take measures that will potentially enhance intersection safety for emergency vehicles. It includes the presentation and comparison of the EV crash situation in Northern Virginia. The results indicate that 49% of all EV accidents along U.S. Highways in Northern Virginia occurred at signalized intersections. This percentage is 75% along U.S. Highways in Fairfax County, the largest county in Northern Virginia, and it is 79% along U.S. 1 in Fairfax County. The analysis, also, illustrates that the major collision type at signalized intersections was of the angle type, which suggests that an appropriate warning sign may be absent. These findings enhance our understanding of emergency vehicle crash characteristics and thus, may facilitate the identification of possible warrants to be used in determining the appropriateness of installing signal preemption equipment at signalized intersections.

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CHAPTER 1: INTRODUCTION

1.1. PROBLEM STATEMENT

> "In 2001, more than 42,000 Americans lost their lives in highway crashes. There is a highway related death in the United States every 13 minutes and an injury every 11 seconds. The National Highway Traffic Safety Administration (NHTSA) estimates that the total economic impact of traffic crashes in the United States is $231 billion per year. Highway crash related deaths and injuries are a major U.S. public health issue, despite the progress that has been made during the past 40 years to improve highway safety through safer vehicles, safer roadsides and more responsible drivers. Although, the fatality rate has dropped from 5.5 deaths per hundred million vehicle miles traveled to last year's all-time low of 1.52, there remains an ongoing challenge for transportation professionals to do more to improve highway safety" *(Ostensen, 2003).*

> "Historically, professionals in the transportation industry always have had a focus on and an interest in intersection operations and safety" *(Ostensen, 2003).*

Intersections are areas of highways and streets producing conflicts among vehicles and pedestrians because of entering and crossing movements. Reducing fatalities and injuries can be accomplished through a combination of efforts, including the careful use of good road design, traffic engineering, comprehensive traffic safety laws and regulations, consistent enforcement efforts, sustained education of drivers and pedestrians, and a willingness among drivers and pedestrians to obey traffic safety laws. Despite improved intersection design and more sophisticated applications of traffic engineering measures, the annual toll of human loss due to motor vehicle crashes has not substantially changed in more than 25 years.
(http://safety.fhwa.dot.gov/fourthlevel/interbriefing/01prob.htm)

> "With today's increasing and ever changing traffic demands on the highway system and the inherent problem of conflicts when roads intersect, the challenge to improve intersection safety is growing for highway agencies. Every year, there are nearly three million intersection related crashes on U.S. Highways. In year 2001, there were approximately 8,900 intersection related fatalities and 1.5 million injuries. Intersection related crashes cost society nearly $40 billion every year" *(Ostensen, 2003).*

In the area of safety, crashes involving emergency vehicles in terms of either medical emergency or fire rescue incidents play a significant role. Twenty-three firefighters died while responding to or returning from emergency incidents in 2001.
(http://www.usfa.fema.gov/dhtml/inside-usfa//ff_fat.cfm)

The largest loss of firefighter lives in a single incident occurred in Colorado in 2002. A group of firefighters were traveling from Oregon in a van that was involved in a single vehicle collision (Commonwealth Chief, 2003). The Firefighter Fatality Retrospective Study 2002 (http://www.usfa.fema.gov/dhtml/inside-usfa//ff_fat.cfm) illustrates that the third leading cause of fatal injury for firefighters who died in 2001 was vehicle collisions. The same study indicates that this cause is usually the second most common cause of firefighter fatalities.

In addition to national trends, local data from Virginia Department of Transportation (HTRIS, 1992-2001) illustrate that during the ten year period of 1992 to 2001 out of the 658 total crashes involving emergency vehicles 428 occurred in Fairfax County, 48 in Loudoun County, 61 in Arlington County, and 121 in Prince William County resulting in three fatalities including one pedestrian. The Fairfax County's Fire and Rescue Department (http://www.fairfaxcounty.gov/) indicates that in the year 2001 from the 37,336 patients transported 5,906 were involved in a vehicle collision resulting in either injuries or death. Although it is not directly obvious, it is essential to make clear that the involvement of an emergency vehicle in a crash would negatively affect the overall efficiency and quality of emergency response services. In the case of a crash involving an emergency vehicle the personnel would not be able to meet the standards for a quick response to the scene of the emergency set by the departments. A relevant study on response times conducted by Pesek R. (Pesek, 2000) illustrated that the response time to a serious illness or injury directly impacts the outcome. If paramedic-level treatment is begun within three minutes of the onset of a cardiac arrest the survival rate without any permanent injury is around 80%. If CPR started within four minutes, and then paramedic-level treatment is begun within eight minutes of the onset of the heart or breathing stoppage, the survival rate drops to around 30% to 40%.

In light of the fact that traffic safety affects many aspects of the life of a community in several ways, the previous data stress the notion that there is a need to facilitate implementation of shorter-term strategies and define and evaluate longer-term, higher-payoff strategies to improve the safety of emergency vehicle passage through signalized intersections. This broader framework needs to be elevated in scope to identify the most common and severe problems and compile information on the applications and treatments at signalized intersections. A sufficient understanding of traffic collision patterns or trends is necessary when implementing efforts to improve traffic safety. An excellent system for saving and managing these types of data is a Geographic Information System (GIS). This initial effort should reveal strategic operational and research opportunities to further intersection safety.

A geographical information system (GIS) can be simply defined as a collection of hardware and software that is used to edit, analyze, and display geographical information stored in a spatial data base. In recent years, many transportation departments and other related organizations, such as the Federal Highway Administration (FHWA), have examined the feasibility of using GIS for transportation planning, systems management, and engineering applications. In some States and municipalities, GIS is being used to plan transportation routes, manage pavement and bridge maintenance, and perform a variety of other traditional transportation-related functions. One area where GIS has yet to be extensively applied and thus is a challenge is in the analysis and presentation of crash data. Computerized crash analysis systems in which crash data, roadway inventory data, and traffic operations data can be merged are used in many States and municipalities to identify problem locations and assess the effectiveness of implemented countermeasures. By integrating this traditional system with a GIS, which offers spatial referencing capabilities and graphical displays, a more effective crash analysis program can be realized (Miller, 1999; Brose, 2003; Karasahin and Terzi, 2002). This effort will display the crash data involving emergency vehicles in a creative manner and, thus enhance the understanding of the crash situation.

In addition, the system allows traffic engineers to access various types of supplemental information without leaving their desks. Scanned versions of an officer's handwritten crash report can be examined to provide detailed information that may not be contained in the crash event table. Routes and crashes can be overlaid with scanned aerial photography to provide the engineer with a better understanding of the development and roadway configuration of a particular study area, and images from the videolog can be scrutinized to provide an even more detailed view of the roadway. Various attribute tables can be created, edited, and linked to other tables, providing even more flexibility and power. All of these tools combine to form a system that makes locating, editing, and analyzing crashes and other spatial data faster and more efficient.
(http://safety.fhwa.dot.gov/fourthlevel/interbriefing/01prob.htm)

Therefore, this research aims to provide a common and objective basis for the transportation professionals to use the data of crashes involving emergency vehicles for identification of problem areas and to make decisions that potentially will enhance roadway safety.

1.2. RESEARCH OBJECTIVES

The broad-based goal of this thesis is to enhance the understanding of the crash situation involving emergency vehicles in the U.S. and Northern Virginia. The goal of this research is three fold: 1) to acquire and analyze the readily available information regarding crashes involving emergency vehicles along U.S. Highways and Interstates in Northern Virginia, Fairfax County and U.S. Route 1 in Fairfax County for the five year period 1997-2001, 2) to present the results of the analysis using an Excel spreadsheet and GIS software program, and 3) to identify the possible warrants to be used in determining the appropriateness of installing traffic signal preemption equipment at signalized intersections. In breadth, the research will focus on the presentation of the available crash data involving emergency vehicles in Northern Virginia using ArcGIS Desktop. In depth, the effort will include analysis of data on crash situation at the national and local level. The analysis of the crash data involving emergency vehicles in the region, the County of Fairfax, and U.S. Route 1 in Fairfax County will consist of classification of crashes involving emergency vehicles in terms of their severity, type of collision, their relationship to intersections, and EV crash characteristics. The application of a software program of Excel will facilitate this analysis. A further analysis of the crash data, using Excel, will include analysis by County and by road category for each county and will assess the similarities and differences in the crash situation among the four counties in Northern Virginia and the different highway facility types including U.S. Highways and Interstates. The application of the ArcGIS Desktop program will facilitate the presentation of the results from the previous analysis of the local data in order to enhance the understanding of the crash situation. In addition, this research will propose possible warrants to be used in determining the appropriateness of installing traffic signal preemption equipment at signalized intersections.

1.3. THESIS ORGANIZATION

Chapter 2 includes the literature review, which is conducted in order to identify and synthesize appropriate references of research projects regarding crashes in general and crashes involving emergency vehicles, particularly. The focus will be on providing background on the objectives of this thesis in terms of crash analyses. Chapter 3 provides a description of the research approach followed in this thesis and includes the description of the cited crash data involving emergency vehicles, which composes the data base for the analysis, as well as basic principals and definitions of the pc based Geographic Information System software program, ArcGIS Desktop. In Chapter 4 the results of the analysis of the data on crash situation involving emergency vehicles in the regional, county and route level are presented. The analysis of the crash data involving emergency vehicles in the region consists of classification of crashes involving emergency vehicles in terms of their severity, type of collision, their relationship to intersections, and other EV crash characteristics. A further analysis of the crash data includes analysis by county, and by road category for each county. The application of the ArcGIS Desktop facilitates the presentation of the previous analysis of the crash data involving emergency vehicles in Northern Virginia. Chapter 5 includes conclusions and recommendations based on the results of the analysis in Chapter 4. Included in the recommendations is the identification of the possible warrants to be used in determining the appropriateness of installing traffic signal preemption equipment at signalized intersections.

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

The purpose of the literature review is to identify and synthesize appropriate references to demonstrate and illustrate the presence and absence of knowledge and information regarding emergency vehicle safety and operations. These references will include journal articles, conference papers, published technical reports, and other readily available information on the World Wide Web and other sources. The literature review will, also, present evidence that supports the need of this research.

2.2. HIGHWAY CRASHES: AN INTERNATIONAL PERSPECTIVE

The international traffic and highway system includes more than 22 million km of roads in the service of the vehicular traffic and the road users in general, 470 million car passengers and 145 million users of different kinds of vehicles, such as vans, trucks, trailers etc. One third of the vehicles that use the roadway system belong to the United States and one third of the vehicles belong to the countries of the United Nation (Yves, 2001).

It is illustrated that vehicular crashes represent one of the main causes of death having significant social extensions as well as substantial financial consequences. According to the International Health Organization, 600,000 people are killed and 15 million are injured every year in crashes. In addition, the statistical analysis of the readily available crash data conducted by the International Road Federation (IRF) indicates that 320,000 fatal crashes are occurring annually in 108 countries that belong to the five continents, which cooperate with the IRF. The countries that present the highest fatality rate is China with more than 70,000 reported fatalities, Russia comes next with 65,000 fatalities and, last but not least is India with approximately 60,000 fatal crashes (Yves, 2001). Another study (Vasconcellos Alcantara, 1999) illustrated that Brazil started to experience high traffic accident rates since the 1960s, when road transportation began to be dominant and the number of motorized vehicles increased sharply. The severity of the problem was, also, related to the fast and uncontrolled urban growth, which allowed for the organization of an inherently dangerous circulation space, characterized by a complex pattern of traffic conflicts. National statistics report about 28,000 fatalities a year, with more than 340,000 injures people.

Reports from various sources, also, indicate that two thirds of the crashes occur in well developed countries, where the index of car ownership appears to have a strong upward trend. It is worth noting that a percentage of 75% of the crashes, reported in these countries, involve the most vulnerable categories of road users such as pedestrians and drivers of two-wheel vehicles A relevant study (Baker, Waller and Langlois, 1991) illustrates that motor-vehicle-related injury is the leading cause of death in children ages 0-14 years in the United States. Using data from the National Center for Health Statistics and the Fatal Accident Reporting System (FARS), specific types of motor vehicle injury death in children were examined and were mapped to determine patterns of geographic variation. It has been found that, in general, non traffic pedestrian death rates and death rates for crashes involving light trucks and/or rollovers were higher in the West, and rates of pedestrian deaths in traffic were higher in the South.

In most of the countries, the costs from the crashes are indicated to reach a percentage of 97% of all accidents reported in the transportation industry, and a percentage of 1 to 2% of the expenses of the national economy (Frantzeskakis, Golias, 1994). Publications of the Organization for European Economic Co-operation and Development (O.E.C.D.) value the total cost of vehicular crashes as a 2.5% percentage of the Gross National Product (GNDP) (Yves, 2001).

Various surveys in the United States illustrated that out of 180 million drivers, who have in their possession a valid driver's license, a total of 45,000 are killed, annually, while approximately 5 million drivers are heavily injured in vehicular crashes (Leon, 1987).

2.3. EMERGENCY VEHICLE SAFETY RELATED ISSUES

2.3.1. Introduction

Ambulance crashes are one of many hazards faced by Emergency Medical Services (EMS) personnel, often publicized and criticized in the media, and form a very critical aspect of the overall safety problem. Although no complete national count of ground emergency vehicle crashes exists, the total number of fatal crashes involving emergency vehicles can be ascertained by using the National Highway Traffic Safety Administration (NHTSA) Fatality Reporting System (FARS) as indicated in a variety of studies conducted in the area of emergency vehicle safety.
(http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5208a3.htm,
http://www.jems.com/jems/e0212a.html)

The total numbers of fatalities of the Emergency Medical Services (EMS) personnel indicate that the EMS profession is nearly as dangerous as police officer or firefighter as shown in the first-ever national study of EMS fatalities (Maguire, Hunting, Smith and Levick, 2002). FARS does not differentiate ambulance workers from passengers among those experiencing nonfatal injuries in fatal crashes; however the seating positions for all occupants and the severity can be determined from FARS data. Researchers have studied the relative risk of injury and death in ambulances and other emergency vehicles in terms of seating position, restraint use and vehicle response status on injuries and fatalities (Becker, Zaloshnja, Levick, Guohua and Miller, 2003). This study has illustrated that restrained ambulance occupants involved in a crash were significantly less likely to be killed or seriously injured than unrestrained occupants. Ambulance rear occupants as well as occupants traveling non-emergency were significantly more likely to be killed than front-seat and traveling emergency occupants. In the combined ambulance, fire truck and police car model, the likelihood of an occupant fatality for those involved in a crash was higher for routine responses, while relative to police cars and fire trucks, ambulances experienced the highest percentage of fatal and injury crashes. It is also indicated that EMS personnel in the United States have an estimated fatality rate of 12.7 per 100,000 workers, more than twice the national average. In a relevant study (Erich, 2002), it is supported that NHTSA does not track injuries from emergency vehicle crashes, and that there has been relatively little research that has. It is also mentioned that 28 people were killed in ambulance crashes and 20 in fire vehicle crashes in 1998.

In a relevant study (Clawson, Robert, Cady and Maio, 1997) it is indicated that various EMS and insurance industry experts estimate that the number of crashes involving emergency vehicles could approach 12,000 in a given year. The cost of these crashes is estimated to be in the million dollars and constitute the greatest cause of monetary liability loss in EMS, far eclipsing the loss due to malpractice by emergency medical technicians and paramedics. Research indicates that emergency medical collisions (EMVCs) occurring during lights and siren response, pursuit or transport are major drawback on public safety and often are publicized and criticized in the media (Management Focus, 1993; Clawson, 1991).

The Firefighter Fatality Retrospective Study 2002 illustrates that the third leading cause of fatal injury for firefighters who died in 2001 was vehicle collisions. The same study indicates that this cause is usually the second most common cause of firefighter fatalities. (http://www.usfa.fema.gov/dhtml/inside-usfa//ff_fat.cfm)

In addition, it is indicated that many collisions involving emergency vehicles result in significant damages, serious injury, or death and provoke lawsuits and public outrage (Caldwell, 1990; George and Quattrone, 1991). An increased sense of awareness of the problem has resulted in industry-wide introspection regarding ethics of these dilemmas (Leonard, 1991; Wolfberg, 1996; Page, 1993; Meijer, 1981). It is indicated that while the number of lights and siren discussions are growing, not much have been done by the emergency medical services community regarding this issue (NAEMSP, 1994; DeLorenzo and Eilers, 1991). In 1985, James O. Page, reflecting on what appeared to be an industry-wide attitude regarding emergency medical vehicle collisions (EMVCs), stated that:

> "For some reason, most of us don't like to talk about ambulance vehicle accidents-even though most of them are preventable" *(Clawson, Robert, Cady and Maio, 1997).*

In light of the fact that crashes involving emergency vehicles are of critical importance a wide range of research has been engaged in the study of the specific characteristics of these crashes and have tried to develop tools to investigate the potential for crashes between EVs and non-EVs at critical intersections. A critical tool that has been developed by Garber and Hoel (Garber and Hoel, 1999) applies the techniques of Conflict Point Analysis, an analytical approach used by the traffic engineering and safety community to examine the likelihood that crashes may occur. The potential for crashes can be determined using a set of logic rules for the type of conflict, the number of vehicles in each conflict stream, and the degree of situational understanding on the part of the auto drivers as indicated in a relevant study conducted using before and after traffic data on U.S. Route 1 at signalized intersections (Louisell, Collura and Tignor, 2003). The same study illustrates that: 1) the number and severity of EV – specific conflict points are significantly reduced by ensuring that a clear message is delivered to the auto drivers, and 2) extended green phase displays create a clear pathway for the approaching EVs, while simultaneous red displays to all movements on perpendicular and opposing approaches provide a clear message eliminating the most dangerous crossing conflicts.

Another study (Amoros, Martin and Laumon, 2003) has tried to compare traffic safety among several counties in France, and explore whether observed differences can be explained by differences in road types distribution and by differences in socio-economic characteristics between counties.

2.3.2. The Crash Situation Involving Emergency Vehicles

The Emergency Medical Services Network indicates a significant number of reports related to crashes involving emergency vehicles resulting in injuries and deaths. The data are reported as "Ambulance Crashes Log" and cover the last five years of 1999 till 2002 and the present year 2003, which includes data regularly updated. (http://www.emsnetwork.org/ambulance_crashes.htm)

It is important to note that due to the specific interests of this research thesis, the crashes involving emergency vehicles occurring near or at intersections have been included in the following reports and require further investigation.

In the EMS Network Journal crashes involving emergency vehicles in the United States are reported. The sixty three (63) crashes, which occurred in the time frame 1999-2003, which is continuously updated till the end of the year, and reported in the Journal are presented graphically in the following map and are summarized in the table that follows (a more detailed description of these crashes is included in Appendix E).

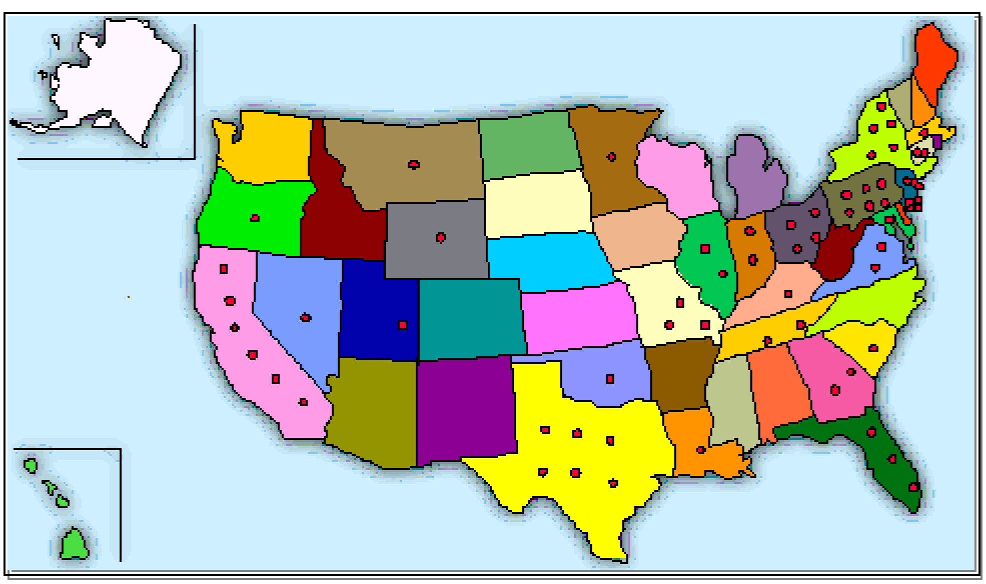


Figure 1: Total crashes involving emergency vehicles according to the EMS Network Journal (1999-2003).

TABLE 1

Total crashes involving emergency vehicles by State in USA *(EMS Network Journal, 1999-2003).*

California	6	**Indiana**	2	**Minnesota**	1	**N. York**	5	**South Carolina**	1
Connecticut	2	**Kentucky**	1	**Montana**	1	**Ohio**	4	**Tennessee**	2
Florida	3	**Louisiana**	1	**Missouri**	3	**Oklahoma**	1	**Texas**	6
Georgia	2	**Maryland**	1	**Nevada**	1	**Oregon**	1	**Virginia**	2
Illinois	2	**Massachusetts**	1	**N. Jersey**	7	**Pennsylvania**	6	**Wyoming**	1

According to various sources during 1991-2000, the most recent year for which data were available, 300 fatal crashes occurred, involving occupied ambulances, resulting to the deaths of 82 ambulance occupants and 275 occupants of other vehicles and pedestrians. The 300 crashes involved a total of 816 ambulance occupants. Between 1992 and 1997, 114 medical emergency medical technicians and paramedics were killed on the job, more than half of them in ambulance crashes.
(http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5208a3.htm,
http://www.jems.com/jems/e0212a.html)

Another article published in the Ohio Beacon Journal illustrates that statewide, ambulance crashes reached a seven-year high in 2000, the most recent year for which records are available. There were 468 ambulance wrecks reported in that year. Particularly in 2001, Columbus ambulances and fire trucks were involved in 111 crashes, 50 of them during emergency responses, 36 of which were determined to be the emergency vehicle driver's fault. Most of the crashes occurred at intersections.
(http://www.ohio.com/mld/beaconjournal/news/state/3066787.htm).

In 1987, Auerbach reported on 102 ambulance collisions that occurred during a three and one-half year period in Tennessee (Auerbach, Morris and Phillips Jr., et al, 1987). More recently, Elling studied 1,412 EMVCs over four years in New York state (Elling, 1988), and Sharp described 250 EMVCs for three years in Alberta, Canada (Sharp, 1990). The government estimate by the U.S. National Safety Council's system reported an estimated

2,400 ambulance and 5,400 fire apparatus collisions in 1990 (Clawson, Robert, Cady and Maio, 1997).

In a previous article it is indicated that a growing number of crashes involving ambulances is causing some officials to question whether emergency vehicles should routinely respond to calls with lights and siren activated. Research shows that speeding to the scene of an emergency does little to improve aid or response time, but many rescue workers are opposed to the idea of limiting use of lights and sirens. Others involved in working with emergency-service personnel claim that responding to all calls in the same manner is an unnecessary risk. An earlier study concluded that lights and sirens saved about a minute off the average response time.
(http://www.ohio.com/mld/beaconjournal/news/state/3066787.htm).

A 1995 study published in the Annals of Emergency Medicine indicated that lights and sirens during patient transport by ambulances to the hospital save about 43.5 seconds on average than transports without lights and sirens. It is concluded that the 43.5-second mean time savings with warning lights and sirens does not warrant use of lights and sirens during ambulance transport, except in extremely rare situational or clinical circumstances. Applicable outcome measures in this study include mortality, lifestyle before illness or injury, return to work, hospital days, and cost. It is, also, suggested that the use of warning lights and siren during an emergency response to the scene and during transport should be based on standardized protocols that take into account situational and patient problem assessments, and that EMS system medical directors should participate directly in the development of policies governing the use of lights and sirens (Hunt, Brown, Cabinum, Whitley, Prasad, Owens and Mayo, 1995).

Although it is not directly obvious, it is essential to make clear that the involvement of an emergency vehicle in a crash would negatively affect the overall efficiency and quality of the emergency response services. In the case of a crash involving an emergency vehicle the personnel would not be able to meet the standards for a quick response to the scene of the emergency set by the departments. A relevant study on response times conducted by

Pesek R. (Pesek, 2000) illustrated that the response time to a serious illness or injury directly impacts the outcome. If paramedic-level treatment is begun within three minutes of the onset of a cardiac arrest the survival rate without any permanent injury is around 80%. If CPR started within four minutes, and then paramedic-level treatment is begun within eight minutes of the onset of the heart or breathing stoppage, the survival rate drops to around 30% to 40%.

2.4. CAUSES OF VEHICULAR CRASHES

Due to the seriousness of the crash situation globally it is highly recommended that the factors, responsible for the lack of traffic and highway safety, are investigated in depth and carefully evaluated. Systematic and detailed studies in the field of safety and crashes identify the following four main causes of crashes:

a) The vehicle,
b) The roadway system and design,
c) The road users, and
d) Police enforcement.

In most of the cases it is indicated that the combination of two or more of the previous factors can lead to significantly worse driving conditions, which can create a cause for a crash to occur. Therefore, while due to the subjective character of these factors, efforts must be made to identify the possible causes of a crash and to further evaluate and correct the current situation.

It is broadly agreed that most of the times that a crash occurs the responsibility weighs on the road user, and specifically on the *driver*. Relevant studies have illustrated that the *road user* is the factor that mostly determines the possibility that a crash will occur (Frantzeskakis and Golias, 1994). This is a common observation among a variety of papers and studies. Kanellaidis, Golias and Zarifopoulos (Kanellaidis, Golias and

Zarifopoulos, 1995) indicate two major factors that are relevant to the road user and under certain circumstances can lead to a crash:

a) Errors in control (excessive speeds, reckless changing lanes, overtaking etc.) and
b) Errors in perception (false perception of speed, distance etc.)

A British study (Sabey and Taylor, 1980) used data from 2,130 vehicular crashes and the analysis of the data produced very useful results regarding the factors that are responsible for the occurrence of crashes. In the following Figure 2 these factors are presented as percentages of a 100% total.

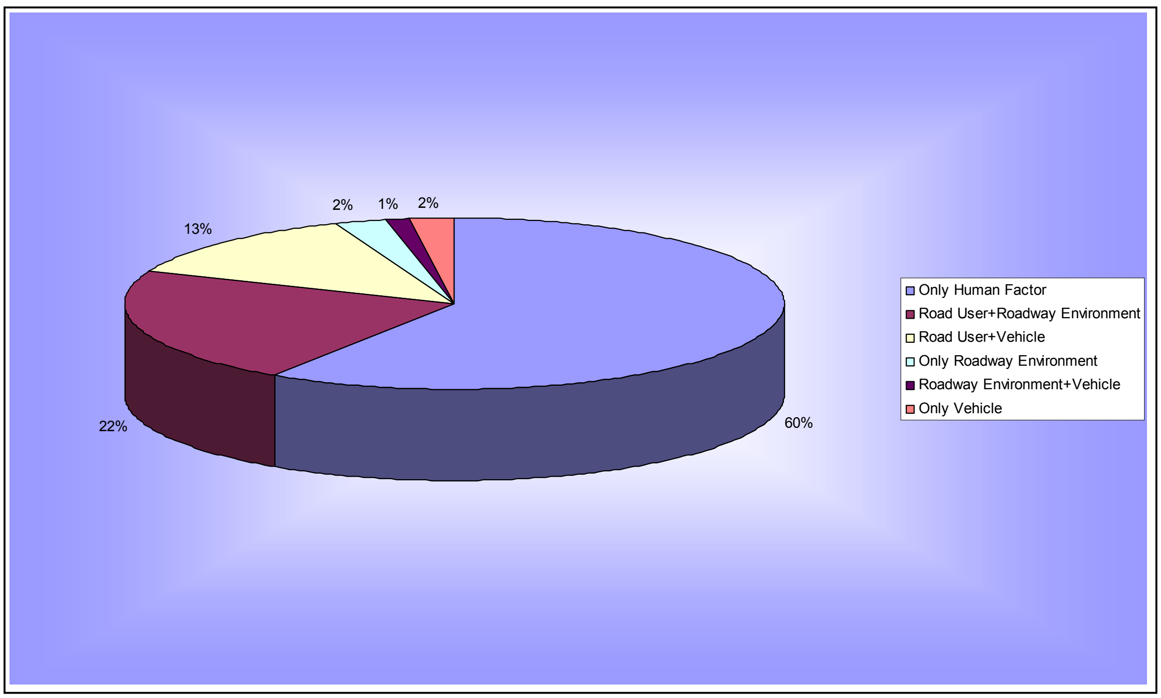


Figure 2: Percentages in the contribution of different combinations of factors in the cause of vehicular crashes *(Source: British study of Sabey and Taylor, 1980).*

The main causes of a crash, that are related to the road user, are identified to be the errors in perception, the wrong actions and controls, the inexperience, the fatigue and the intoxication (Sabey and Taylor, 1980). Another source indicates that the human factor is the only cause of a crash in the 57% of the cases, while it is one of the most important ones in the 90% of the total crashes (Green and Senders; Treat et al., 1977).

Other studies have shown that accidents occur for one of three principle reasons. The first is perceptual error. Sometimes critical information was below the threshold for seeing - the light was too dim, the driver was blinded by glare, or the pedestrian's clothes had low contrast. In other cases, the driver made a perceptual misjudgment (a curve's radius or another car's speed or distance). The second, and far more common cause, is that the critical information was detectable but that the driver failed to attend/notice because his mental resources were focused elsewhere. Often times, a driver will claim that s/he did not "see" a plainly visible pedestrian or car. This is entirely possible because much of the information processing occurs outside of awareness (Green and Senders, 1999).

Mack and Rock (Mack and Rock, 1998) have shown that drivers may be *less* likely to perceive an object if they are looking directly at it than if it falls outside the center of the visual field. This "inattentional blindness" phenomenon is doubtless the cause of many accidents. Lastly, the driver may correctly process the information but fail to choose the correct response ("I'm skidding, so I'll turn away from the skid") or make the correct decision yet fail to carry it out ("I meant to hit the break, but I hit the gas") (Green and Senders, 1999).

It is indicated that the unfriendly *roadway environment* in terms of bad weather, defective maintenance of the pavement, and congestion plays a less significant role in the occurrence of a crash (SARTRE 2 reports, 1998). Regarding to the roadway conditions it is supported that the insufficient design in terms of small radius and inadequate visibility lengths can lead to fatal crashes (Sabey and Taylor, 1980; Kanellaidis, Golias and Zarifopoulos, 1995). A study of the road conditions evaluated the effect of the resurfacing on main roads in Finland on the frequency and severity of crashes (Leden, Hamalainen and Manninen, 1998).

A defective *vehicle* in terms of bad conditions of breaks, lights, and navigation system is considered to have a small contribution in the causes of crashes. It is indicated that a limited number of crashes is caused by mechanical and other damages of the vehicles, and in situations where this is the case, these damages are mainly due to the aging as well as the overweight of trucks (Frantzeskakis, Golias, 1994). In another study it was found that only 2.4% of the crashes were due solely to mechanical fault and only 4.7% were caused only by environmental factors (Green and Senders).

In a study in Israel the vehicle is considered to be an important factor in the occurrence of crashes. It is indicated that the replacement of old vehicles (over 10 years old) could contribute to a reduction of crashes from 0.7 crashes per mile to approximately 0.37 (Beenstock and Gafni, 2000). A more realistic solution of the problem suggests the manufacture of safer and more reliable vehicles as well as their careful evaluation and complete maintenance through the conduction of systematic controls (Frantzeskakis, Golias, 1994).

Other studies support the notion that the weather conditions affect the driving conditions in such a degree that in some cases can lead to a crash (Sabey and Taylor, 1980). Badger (Badger, 1996) claims that weather conditions, such as rain, ice or fog, have the most negative effects on driving in comparison to the rest set of factors. Edwards (Edwards, 1998) indicates that there is a strong relationship between the bad weather conditions and the severity of road accidents.

Another comprehensive study tries to quantify the contribution of each of the major factors into the occurrence of the traffic accidents. It is indicated that the natural phenomena such as the weather and the daylight that affect drivers' visibility contribute significantly into the occurrence of crashes (Fridstrom, Ifver, Ingebrigtsen, Kulmala and Krogsgard Thomsen, 1995).

Another issue that needs to be noted is the indication that car size and mass influences the passive safety of cars as illustrated in a relevant study conducted by Wood (Wood, 1995). The fundamental equations are derived for collisions between cars of similar size and for single vehicle crashes. These are combined with overall injury criteria to give a series of predicted Relative Injury Risk (RIR) relationships. Theory shows that in collisions between cars of similar size and in single vehicle accidents the fundamental parameter which determines RIR is the size, i.e. the length of the car whereas in collisions between dissimilar sized cars the fundamental parameters are the masses and the structural energy absorption properties of the cars. Comparisons between theoretical and field observations show a high level of correlation between the theory and the field evaluations of RIR.

2.5. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

2.5.1. Introduction

In light of the fact that traffic safety affects many aspects of the life of a community in several ways, the previous data stress the notion that there is a need to facilitate implementation of shorter-term strategies and define and evaluate longer-term, higher-payoff strategies to improve intersection safety in terms of emergency vehicle passage through signalized intersections. This broader framework needs to be elevated in scope to identify the most common and severe problems and compile information on the applications and treatments at signalized intersections. A sufficient understanding of traffic collision patterns or trends is necessary when implementing efforts to improve traffic safety. Research, as well as, publications of the Federal Highway Administration indicate as an excellent system for saving and managing these types of data to be a Geographic Information System (GIS) (Brose, 2003; http://rip.trb.org/, FHWA-RD-01-039, FHWA-RD-99-081).

As indicated in a comprehensive study (Miller, 1999) a GIS, simply put, is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information (for example, data that are identified according to their locations). A GIS is frequently, but not always, used along with a Global Positioning System (GPS), which is a satellite system where radio signals are sent from orbiting satellites to receivers on the ground for collecting various kinds of data. It is, also, supported that GIS can be employed to relate, organize, analyze and display the roadway and crash data in a creative manner, thereby facilitating crash countermeasure identification and evaluation. It can, also, be applied at the corridor level for identification of potential problem sites. It is stressed that GIS appears more as an instrument that can help the analyst pinpoint locations that warrant greater study.

In his research Miller (Miller, 1999) supports that although a GIS often serves as both a database and a source of maps, these aspects alone do not fully explain its capabilities when used by persons who are trying to quickly understand large amounts of data. Goh captures this best when he states that:

> "…the fundamental difference of a GIS from any other information systems is that it has the knowledge of how events and features are geographically located" (p. 80) *(Goh, 1993).*

That is, there is a geographical relationship between the various types of data that may be incorporated into a database. An example is a common locating system both for intersection-related crashes and traffic signals. This capability of GIS to relate various types of data in a meaningful way becomes important as one moves beyond using a GIS to simply create a pin map of crash locations. The potential of using GIS to store, query, and analyze crashes as well as their potential root causes has been widely documented. A quick review of the literature suggests several key areas where the use of GIS can help accomplish certain types of analyses. In these articles, simply being able to use a software package that manipulates geographic information is not significant. Instead, the articles illustrate how GIS is an instrument that helps one better understand crash data and use those data to make decisions that potentially will enhance roadway safety. Although there are numerous ways to describe these interdependent analysis methods, it is logical to delineate them into the following categories: simplification of data, creation of collision diagrams, spatial queries, network applications, integration issues, and alternative methods for pinpointing crash locations.

According to the same study (Miller, 1999) considerable resources are being used to make crash data accessible in some type of GIS. These efforts typically include using GPS technology to mark the crash location, combined with recording certain crash data elements (such as the number of vehicles involved or the weather conditions at the crash scene). These crash data may then be used to identify problem areas and develop ways to assist in preventing crashes in these locations. The purpose of this study was to determine how GIS can be employed to analyze crash data and how this information can then be practically used on a day-to-day basis (Figure 3).

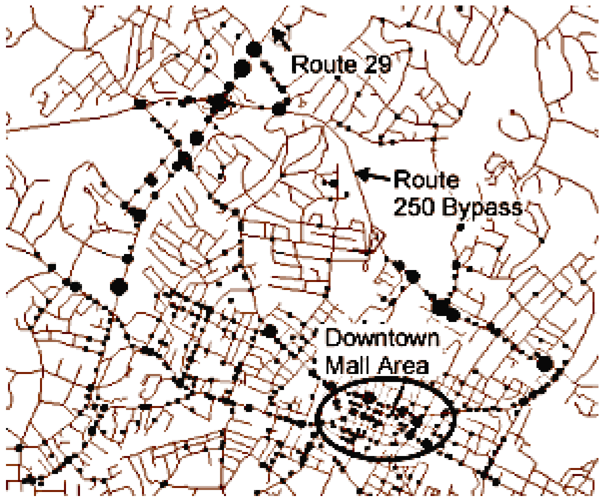


Figure 3: Map of crash sites *(Source: Miller, 1999)*.

2.5.2. Previous Geographic Information System (GIS) Applications

In recent years efforts have been made to expand the analytical features of the Highway Safety Information System (HSIS) by integrating GIS capabilities. The original version of the GIS Safety Analysis Tools was released in 1999 and provided practitioners with programs to perform spot/intersection analysis, cluster analysis, strip analysis, sliding-scale evaluations, and corridor analysis. One of the continuing goals of distributing the GIS Safety Analysis Tools is to encourage the safety engineers and others within State and municipal departments of transportation and metropolitan planning organizations to explore the capabilities of the GIS-based highway safety analysis tools and to adapt those ideas and applications to fit their particular needs as indicated in a recent FHWA publication (U.S.DOT, FHWA-RD-01-039, 2001). In the same publication, it is indicated that the primary goal of the effort made was to discuss GIS/Safety integration in terms that can be understood by both safety engineers and GIS specialists, and to describe issues and solutions involved in the integration of GIS into safety-related analysis efforts.

As indicated in another report (U.S.DOT, FHWA-RD-99-081, 1999) the GIS system allows traffic engineers to access various types of supplemental information without leaving their desks. Scanned versions of an officer's handwritten crash report can be examined to provide detailed information that may not be contained in the crash event table. Routes and crashes can be overlaid with scanned aerial photography to provide the engineer with a better understanding of the development and roadway configuration of a particular study area, and images from the videolog can be scrutinized to provide an even more detailed view of the roadway. Various attribute tables can be created, edited, and linked to other tables, providing even more flexibility and power. All of these tools combine to form a system that makes locating, editing, and analyzing crashes and other spatial data faster and more efficient.

Miller (Miller, 1999) indicates that Virginia Department of Transportation is continually striving to improve the safety of Virginia's roadways through the use of the latest leading edge technology. Use of a Geographic Information System (GIS) to study how, why, where, and when crashes occur on Virginia's roadways is one of the many state-of-the-art tools of interest to agencies concerned with highway safety. The suggested benefits of GIS include not only being able to display the data to the user, but also being able to manipulate the data in a creative manner. Analysis methods such as grid cell modeling, network applications, and risk computations are quite useful. For display purposes, some manipulations of crash data will be necessary in order to make the graphical views more readable. GIS can also be used to identify potential problem sites where these crashes occur. First, the crash could be positioned exactly where it had occurred along a particular route (for example, 61 meters or 200 feet from a particular intersection). Second, how close certain crash locations were to one another could be seen. Third, other data, such as a sharp curve in the roadway, could easily be made part of the analysis. Even without GIS, however, problem areas can be identified with Micro Traffic Records System (MTRS) software and crashes can be positioned exactly with the Highway Traffic Records Information System (HTRIS).

In a research study conducted in Honolulu (Levine and Kim, 1996) it was indicated that the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 has encouraged the development of information management systems to promote safety and efficient expenditure of public resources. This paper therefore describes the development of a traffic safety GIS prototype for spatial analysis of traffic collisions in Honolulu, Hawaii. Various classes of spatial analyses, which involve points, segments, and zones, with special reference to the nature of motor vehicle collisions and traffic safety research have been developed.

In another study conducted by the same researchers (Levine and Kim, 1998) a GIS program was used to geocode motor vehicle crashes by intersections or corner matching. The results have implications for the development of the next generation of georefencing software.

Recognizing the behavioral limitations of crash data, Kam (Kam, 2002) uses a geographic information system based approach to relate crashes records to travel data (collected via travel surveys) to derive a disaggregate measure of crash risk. The methodology used is seen as providing a framework upon which future crash risk measures could be based as the use of spatial tracking devices become prevalent in travel surveys.

In another paper (Karasahin and Terzi, 2002), where GIS software program was used, it was concluded that GIS technology is able to handle traffic crash analysis. Case study was carried out in Isparta-Antalya State Road and the results were given graphically and in a map format, which made it easy to be interpreted. In this study it was, also, indicated that with the help of different queries and the display of the data of interest the new hazardous locations on highways can be easily identified. The GIS applications conducted in this study did not result in a definite identification of problem areas, much less recommendations for how to prevent crashes. Instead, GIS appears to be used more as an instrument that can help the analyst pinpoint locations that require greater study. The common theme between these applications and those in the literature is that a GIS alone cannot replace the need for a systematic evaluation of crashes.

Simplification of Data

(This part is taken from Miller, J., "What Value May Geographic Information Systems Add to the Art of Identifying Crash Countermeasures?", Virginia Transportation Research Council, VTRC 99-R13, Charlottesville, Virginia, April 1999)

One of the most common uses of GIS is to visually digest a large amount of information quickly, such as a map of high accident crash locations. Another use of GIS, as suggested by Crespo Del Río et al., is to use a graphic that outlines the location and extent of poor quality pavement sections (Crespo Del Río et al, 1997). Mohle and Long demonstrated that the reasons for using a GIS are to create collision diagrams (which simplify the presentation of crash information at a specific site) as well as to "accurately spot accident trends" (p. 29) (Mohle and Long, 1996).

A North Carolina study illustrated how one of the uses of GIS related to its ability to display crash sites. In this study, a "sliding scale" was used, whereby a segment of a specific length along a roadway was dynamically moved until that segment met a threshold, such as a minimum number of crashes or crashes of a particular severity (p. 469) (Miller, Johnson, Smith and Raymond, 1995). Thus, the value of this process ensured in a systematic manner that all possible hazardous sites were identified. Conversely, if the segments had been predetermined, it could have been possible that two adjacent segments with crashes close to the common boundary would not have been properly identified as hazardous. The threshold for what constitutes "hazardous" can be varied, which can simplify the presentation of the data for a large area.

Hovenden et al. also have used a GIS to present large amounts of data in a concise manner (Hovenden, Sligoris and Walker, 1995). Similar to what is conventionally done with origin-destination paths for urban transportation planning, the authors displayed a map where a road segment's crash history was reflected in the width of the segment. Wider segments, of course, implied a greater risk. The paper also outlined the use of GIS to find the "worst" 1.5-km section of a road by dynamically moving startpoints along a route. This usage of GIS was similar to the North Carolina research in that it also avoided problems that might have been masked through the arbitrary definition of roadway segments.

In 1992 the Georgia Institute of Technology developed a prototype GIS for transportation that included an accident records component (Meyer and Sarasua, 1992). At least three key types of queries were outlined that could not have been done with a conventional link-node crash records system. The first of these queries involved a map that described crashes by some type of severity category. The advantage of this usage of GIS was that it provided a graphical representation of crash locations. However, the authors acknowledged that a listing of high-accident intersections was available from conventional means. The Georgia Tech study also outlined two other benefits that go beyond the presentation of data—spatial analysis and collision diagrams. Spatial queries, such as the ability to find all crashes within a specified distance of an intersection, became easier to accomplish using GIS. One can quickly envision why such a capability might be useful. For example, in some cases, the geometrics of this situation might have been that all crashes that occurred within 100 m of an intersection were intersection-related, whereas in another situation it might have been that one was searching only for those crashes that occurred within 25 m of the intersection.

Creation of Collision Diagrams

The ability to easily reproduce a detailed collision diagram was offered by the Georgia Tech study. When data were available, one could "zoom" to the location of interest to view crashes in relation to the roadway geometry and safety hardware. A problem statement submitted to the AASHTO Standing Committee on Research noted that, at the microscopic level:

> "Collision diagrams offer one of the few means by which designers today display crash history graphically." *(AASHTO, 1998)*.

The committee's narrative pointed out that while the combined capabilities of CADD and GIS are increasingly offering the potential to use visual information, the challenge is to present meaningful interpretations rather than overwhelming the user. This suggests a microscopic component to GIS capabilities that may be applicable to presenting meaningful interpretations that do not overwhelm the user, depending on the precision of identifying both the crash locations and the roadway geometry features against which crashes are assessed. One can expand this current potential of GIS to reproduce detailed collision diagrams to future uses of GIS as we consider what defines the crash location, which is a key element of any detailed collision diagram.

The U.S. Department of Transportation's Guideline for Minimum Uniform Crash Criteria (MUCC) defines numerous data elements that should be collected at the scene of the crash. Within this Guideline (and with respect to the data element C5), it is stated that the crash roadway location is the "Exact location on the roadway indicating where the crash occurred" (p. 23) (USDOT, 1997). For example, in some cases a law enforcement officer might define element C5 as where the vehicle came to rest after the crash occurred, whereas another officer might define this as the point where a vehicle began a skid or left the roadway. Although such disparities might not be significant at the macroscopic level, it could be of benefit to the person studying the crash history at a specific site, such as at an intersection. In this sense, providing the officer's collision diagram in a GIS would allow the analyst, if necessary, to ensure that all crash locations were represented uniformly. An example of this uniformity would be using the first point of impact consistently as the crash location.

Spatial Queries

The task of studying crashes in a GIS may be represented as a spatial analysis problem. In other disciplines, studying spatial relationships among data is a frequent occurrence. For example, one school district compared the centroids of building permits to the centroids of the locations of school students in order to discern demographic trends (Slagle, 1998). With crash data, a possible extension could be to observe the movement of crash locations as a function of time. The North Carolina DOT reported two chief safety-related benefits of GIS—*(1) the integration of data from other sources that can be facilitated by GIS's geographical linkage capabilities and (2) the results of queries can be viewed in a spatial format rather than only in a tabular format* (BTS, 1998). This report indicated that:

> ". . . it is hard to estimate what impact either of these advantages will have on conduction [of] accident analysis" (p. 5)—as pointed out from the website.

The report also stated that one of these applications of GIS was to select route segments that had high concentrations of truck crashes. GIS graphical representations of crashes in these segments could then facilitate study of these representations in greater detail.

A safety-related short course implied two key benefits that may be gleaned from a visual representation of crash locations (TAI, no date). The first is an understanding of any clustering of high accident locations (HALs). For example, one may determine whether several locations are in geographic proximity to each other, thereby facilitating specific countermeasures, such as selective enforcement or reduced speed limits. The second benefit is subtler, yet of equal importance. Visual patterns may be used to discern geographic relationships based on select variables, such as the driver's age. For example, no discernable patterns may be apparent when looking at the crash locations. However, after limiting examination to those crashes that occurred Friday and Saturday evenings between 9 P.M. and 6 A.M. that involve drivers under 24 years of age for instance, certain types of problem areas could be identified. An extension of this enforcement-based approach would be to include potentially relevant geometric characteristics, such as short yellow signal timings in a progression of streets. While these concepts were developed without GIS per se in mind, it appears that the lessons regarding spatial analysis are certainly transferable to GIS.

While acknowledging that identification of high-accident sites can be accomplished with GIS, Austin et al. bluntly state that other types of inquiry make better use of GIS's potential (Austin, Tight and Kirby, 1997). Two aspects of GIS usage were proposed that go beyond data presentation per se. This first aspect is an error-checking scheme. The features coded by the officer can be compared to the features stored in the roadway database. For example, if the officer codes the speed limit of a route on a crash report that is different from what is recorded in the roadway database, this clearly indicates that there is a discrepancy. The second aspect of GIS usage is to identify high accident regions or zones, as opposed to identifying only specific intersections or segments. This allows the analyst to categorize areas by land use and compare how they affect the number of crashes. Two spatial capabilities were also suggested. One concerns the safety of children walking to school, including selection of sites within proximity of a neighborhood school and the evaluation of the safety of routes where children walk. The second application was risk analysis based on where persons live (such as the number of injuries per 1,000 persons in population).

Panchanathan and Faghri concurred with Austin et al perspective on the additional potential uses of GIS. They believed that the key advantages of GIS included capabilities to do spatial and network analysis and integration of data. One example of this additional potential of GIS was the use of buffers to capture items within a certain distance of one another, such as at-grade rail crossings within a quarter mile of another at-grade rail crossing (Panchanathan and Faghri, 1997). Affum and Taylor exemplified the use of buffers in their consideration of identifying hazardous locations based on land use. For example, they explained that accidents involving children were always found within 1 km (0.6 mi) of schools (Affum and Taylor, 1995). They also outlined a ready-to-use GIS application that integrated some traditional methods of data reduction. For example, they used an automated display of high-accident locations in addition to using the spatial query capabilities of GIS.

Identifying traffic crashes that may have been caused by an earlier incident is a specific analysis capability that is greatly facilitated by the use of GIS, according to Raub (Raub, 1997). By examining crashes that meet both a distance criterion of being within 1600 m of an event—as well as a time criterion of occurring within 15 minutes of the event—one can determine whether two crashes are causally linked. Clearly, this type of spatial analysis query would be restricted with an older system that did not have flexible geographic capabilities. However, such a query could be performed with an older system if only the events along a specified route are being examined.

One can go beyond visual inspection of crash locations in order to add rigor to how trends suggested by a map of crash locations are assessed. Choi and Park suggested a couple of simple yet innovative methods for looking at crash locations (Choi and Park, 1996). The first method was to divide the study area into a grid. For these grid cells, the number of crashes could be regressed to the segment length and/or number of intersections. Provided that a statistically sound relationship and high R^2 value existed, a useful extension of this analysis would be to identify grids where the number of predicted crashes was lower than the actual crashes. The authors also computed a "coefficient of localization" where it could be ascertained whether some type or category of crash tended to be spread throughout the study area or was concentrated in specific locations. (This coefficient essentially stratified crashes by zone and type and used a method of computation very similar to that in determining a chi-square score.) Again, grid cells could have been used to accomplish this analysis. This usage of grid cells provides a mathematical way of quantifying trends that might not be directly observable.

Kim et al. stated that GIS could be used as an exploratory tool, especially for identifying patterns in crashes (Kim, Levin and Nitz, 1995). Examples were given where a spatial analysis could have been quickly accomplished in the GIS. Techniques for this type of analysis included assessing how spatial crash patterns vary by time of day, day of week, injury level, and seeing how crash location patterns changed when the selection criteria are varied, based on factors such as speed or alcohol use.

Network Applications

GIS can facilitate analysis for network routing applications as well as for obtaining characteristics about specific routes that have already been selected. For example, Souleyrette and Sathisan used GIS to characterize the risk of certain routes that were used for moving "high-level radioactive material." (Souleyrette and Sathisan, 1994). Estimates of resident population, visitor population, and ecologically sensitive areas (such as wildlife refuges, wilderness areas, and water surfaces) were obtained within a specified distance from the route that was used for shipments. The authors observed that these data, all taken from disparate sources such as census databases (for residential population) and commercial information (e.g., hotel locations to give visitor estimates) could then be used as inputs for various risk estimation models. Thus, while GIS was not used for all of the computations, it facilitated the application of software already having that specialty. Patel and Horowitz used the capabilities of GIS in a different manner. They selected the "best" route that should have been taken regarding the shipping of hazardous materials (Patel and Horowitz, 1994). These authors discussed how to select a route that minimized risk based on population and environmental considerations, such as wind direction, should a spill occur. This procedure was facilitated by having network capabilities (e.g., finding the shortest path) and supplemental data (e.g., population data) integrated into the same platform.

Further evidence of the networking capabilities was offered by Mefford. He used GIS to graphically display the "shortest and safest" bicycle routes from suburban areas to the Central Business District (CBD). While this type of analysis could have been done without GIS, a key feature of this graphic capability was the ability to envision the impacts of improvements quickly. For example, a high-risk link could have been redesigned. Subsequently, one could observe whether this improvement affected which route was the least risky for cyclists (Mefford, 1995).

Finally, Austin et al. suggested a pedestrian-oriented application that combined the network, display, and integration capabilities of GIS (Austin et al., 1995). A paper survey of routes that children used when they walked to school was coded in a GIS and then checked against accident rates of specific street segments in order to identify where school crossing guards should have been located. Parents were then asked to identify dangerous locations, which the authors then compared with locations having the worst crash history. Although the authors acknowledged that exposure limitations were a problem, since not all routes had equal numbers of pedestrians using them, it was possible to compare what parents thought were the worst locations to those locations where the greatest number of crashes occurred. These network, display, and data integration capabilities can thus facilitate public outreach efforts by better educating parents and school personnel as to which locations should be avoided by children without adult supervision.

Integration Issues

Although not directly focused on analysis capabilities, some articles from the literature review articulated why it is important to assess GIS capabilities before moving forward with its implementation. In a pilot effort by FHWA where laptop computers, GPS receivers, and GIS software were used to record crash locations, one result was that officials learned about the overall capabilities and needs of other agencies with whom they were cooperating (McNight, Mosher and Bozak, 1998). The understanding of how multiple agencies function is especially crucial when considering the diversity of those individuals and agencies involved in highway safety analysis. The crash data are collected, stored, and analyzed by persons with different missions, even if these individuals are in the same agency. Since GIS data collection requires a substantial investment, it is useful for persons to know in advance what the return on that investment will be. In this case, it was beneficial for both data collectors and analysts to know what a GIS can accomplish that could not be achieved without such a system. In short, integration of agencies' missions should be considered.

One of the key benefits of GIS, as outlined in the study by the Georgia Institute of Technology, is the potential of GIS to enhance data integration. This study correlated crash rates with poorly maintained roadways in terms of signs and safety hardware. Not only is a pictorial representation of crashes a benefit, but additionally, the capability to relate these data to other data sets (such as in maintenance information) is of interest. This data integration has value where data sets are being updated. For example, an agency or corporation that maintains a list of utility pole locations has information that would be of interest to the person who keeps the roadway database current.

Aultman-Hall and Hall illustrated this capability of database integration when they estimated crash risk exposure for bicyclists (Aultman-Hall and Hall, 1998). The authors first surveyed cyclists regarding their previous crashes as well as their commute routes, then they digitized the cyclists' routes onto coverages of a roadway network. Finally, the authors related these routes to infrastructure information stored within the GIS coverage. This coverage included such information as distance or road type (paved, unpaved, cut-through, sidewalk, and so forth). Another example of linking crash data to pavement data was presented graphically by Siegel and Yang. They visualized the number of crashes at specific locations, in contrast to pavement conditions at the same locations (Siegel and Yang, 1998). Although Saccomanno et al. discussed the use of GIS for accident risk modeling, it is clear from their work that a key contribution of a GIS is that it can possess the capability to link three disparate databases: roadway geometrical data, traffic volumes, and police accident report data (Saccomanno et al., 1997). The importance of traffic volumes as a normalizing factor was emphasized again by Affum and Taylor, who indicated that failure to incorporate these volumes could result in too much attention being given to high volume roads (Affum and Taylor, 1996). While there are cases where these databases may already be linked through prior planning and interagency coordination, clearly the use of GIS gives one the flexibility to integrate information when such planning has not taken place or when an unforeseen need for a certain type of data arises.

In summarizing NCHRP Project 20-27(2), Opiela pointed out that GIS could be used to enhance integration of data from different sources, especially when technological limitations would otherwise hinder the transfer of data between agencies or even functional units within the same agency (Opiela, 1998). This ability of GIS to enhance integration of data from different sources, in spite of technological barriers, is potentially relevant to crash data analysis, where it is probable that the roadway network, the location of safety hardware, and crash data will come from diverse sources. A practical application of this data integration would be where the state department of transportation maintains guardrail location data, but where updated subdivision location information comes from another source, such as the county planning department or private sector.

Lamm et al. illustrated how GIS integration capabilities were fundamental to a project even when the focus of that project was not GIS (Lamm et al., 1995). In their work, design elements for various roadway sections were assessed using rather complex relationships. For example, in one type of analysis, the accident rate for various sections was regressed to the operating speed and degree of road curvature. The suitability of GIS in this case was that roadway inventory data could be rapidly incorporated. Thus, the focus of their work was not on GIS, but instead, on a type of analysis for which GIS provided a convenient platform.

Miller (Miller, 1999) indicates that not all of the benefits cited in GIS-related articles should necessarily be ascribed solely to GIS. For example, it has been stated that presentation tools such as pie charts of crashes by type are useful. These tools may be easier to use with some of the GIS software packages. However, this use of presentation tools may not necessarily be exclusive to GIS. Link-node based crash data can just as easily be exported to a worksheet to create similar charts. However, since GIS software packages are constantly being upgraded, they are more likely to have many of the newer presentation capabilities. There is a degree of overlap among the benefits of GIS as a tool to study crash countermeasures. For example, being able to see the data visually for one analyst may be useful as a means of understanding a large amount of information, whereas another analyst might use that same GIS capability to discern trends that otherwise would not be apparent. Initially, these GIS applications focused on a graphical display of crash locations; later, these GIS applications became integrated with statistical techniques. It is important to highlight that in many instances the value of the GIS analysis is not only its ability to provide visual representation, but additionally, it is GIS's ability to either organize the data in a different manner than has been done previously or to integrate the crash data with another data set from a different source.

While the literature illustrates what GIS can help accomplish, it is of interest to this research thesis to assess the feasibility of using GIS to present the results of the analysis of the crash data involving emergency vehicles in Northern Virginia in order to enhance the understanding of the crash situation. In addition, GIS will facilitate the identification of potential problem areas and suitable crash countermeasures, and will propose possible warrants to be used in determining the appropriateness of installing traffic signal preemption equipment at signalized intersections.

CHAPTER 3: RESEARCH APPROACH

3.1. INTRODUCTION

This chapter presents an evaluation framework and plan for the analysis and presentation of the readily available data. The analysis will be followed by the comprehensive interpretation of the results which can lead to useful comments and recommendations regarding the identification of the possible warrants to be used in determining the appropriateness of installing traffic signal preemption equipment at signalized intersections. First the evaluation plan will be presented in terms of the selection of the appropriate data and the analysis performed in order to evaluate and present the selected data. This in turn will lead into the next chapter which will illustrate the use of this plan in conjunction with interpretation of the results.

The evaluation framework establishes the appropriate context in which traffic and highway safety in Virginia State and along the U.S. Highways and Interstates in Northern Virginia will be examined. The evaluation framework provides an important foundation for determining whether a problem regarding crashes involving emergency vehicles exists in the areas under study. Without a framework, there is a risk of attempting to investigate the crash situation involving emergency vehicles without having the appropriate analysis tool to justify any comments and suggestions without reasoning. The evaluation framework, which will be used in this research thesis, is presented in Figure 4.

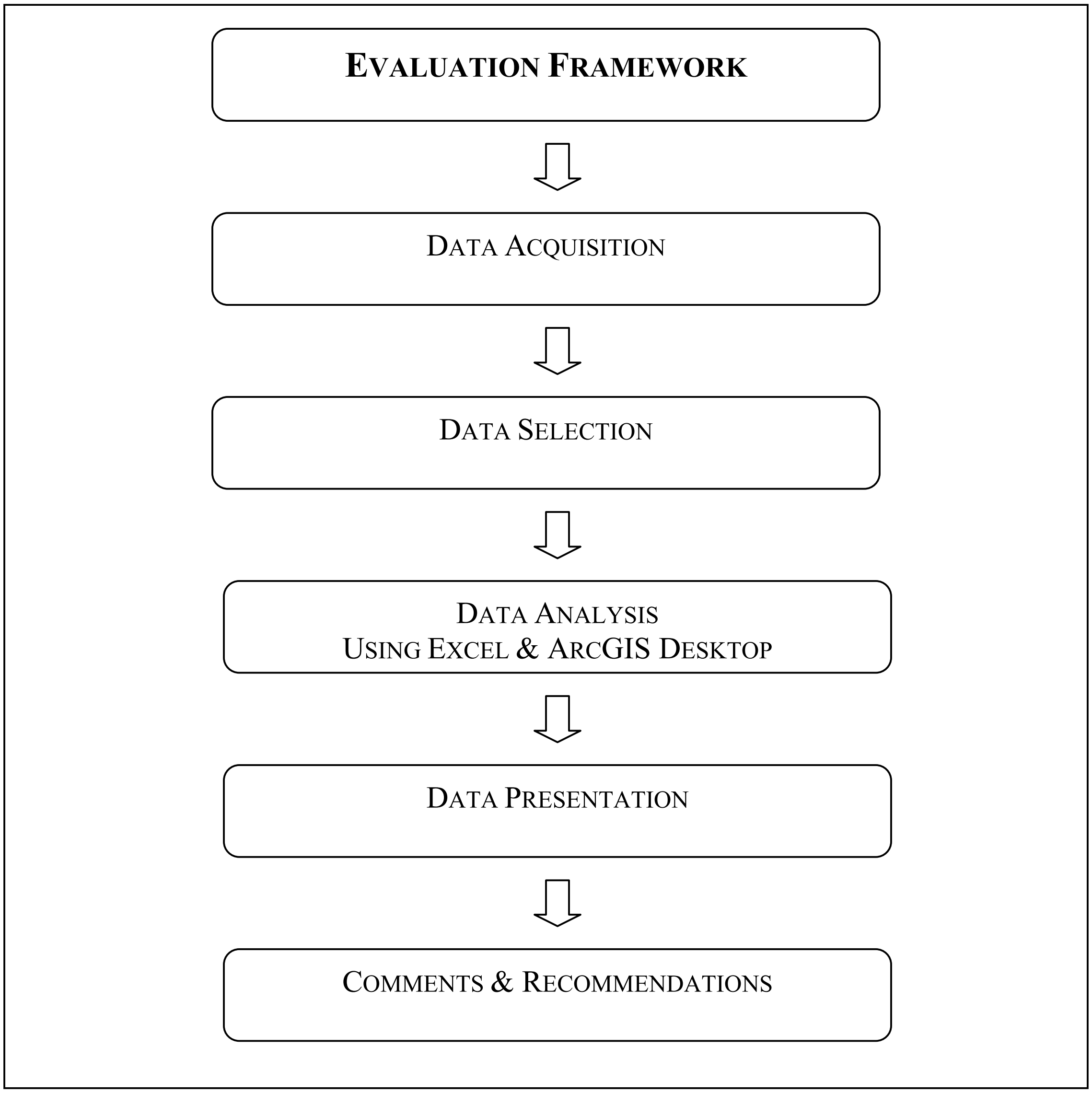


Figure 4: Evaluation Framework.

3.2. DATA ACQUISITION AND DATA SELECTION

3.2.1 Area Description

The State of Virginia

(Source: http://virginiadot.org/infoservice/vdot-welcome.asp#HighwaySystem)

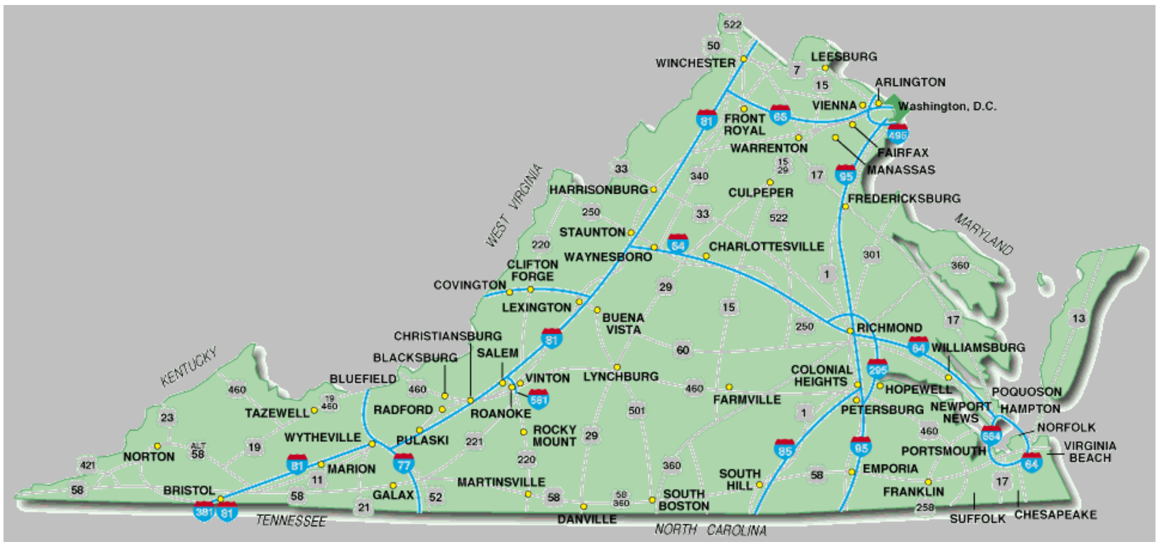


Figure 5: The State of Virginia.

Virginia's Highway System

The 56,941-mile state-maintained system is divided into the following categories:

- Interstate - 1,118 miles of four-to-ten lane highways that connect states and major cities.
- Primary - 8,041 miles of two-to-six-lane roads that connect cities and towns with each other and with interstates.
- Secondary - 47,451 miles of local connector or county roads. These generally are numbered 600 and above. Arlington and Henrico counties maintain their own county roads.
- Frontage - 331 miles of frontage roads.

- A separate system includes 10,287 miles of urban streets, maintained by cities and towns with the help of state funds. Virginia's cities are independent of its counties.

Other Transportation Services

The transportation network comprises more than roads. VDOT also is responsible for:

- More than 12,603 bridges.
- Four underwater crossings in the Hampton Roads area: the mid-town and downtown Elizabeth River tunnels, the Hampton Roads Bridge-Tunnel on Interstate 64 and the Monitor-Merrimac Memorial Bridge-Tunnel on Interstate 664.
- Two mountain tunnels on Interstate 77 in Southwest Virginia: East River and Big Walker.
- Three toll roads: Northern Virginia's Dulles Toll Road and the Powhite Parkway Extension and Pocahontas Parkway in the Richmond area.
- One toll bridge: The George P. Coleman Bridge carries Rt. 17 traffic over the York River between historic Yorktown and Gloucester County. Tolls are collected in the northbound direction only.
- Four ferry services: Jamestown, Sunnybank, Merry Point, and Hatton (seasonal).
- Forty-one rest areas and ten Welcome Centers along major highways.
- 107 commuter parking lots.

For highway purposes, Virginia Department of Transportation divides the state into nine districts: *Bristol, Culpeper, Fredericksburg, Hampton Roads, Lynchburg, Northern Virginia, Richmond, Salem, and Staunton*, each of which oversees maintenance and construction on the state-maintained highways, bridges and tunnels in its region as seen in the following Figure 6.

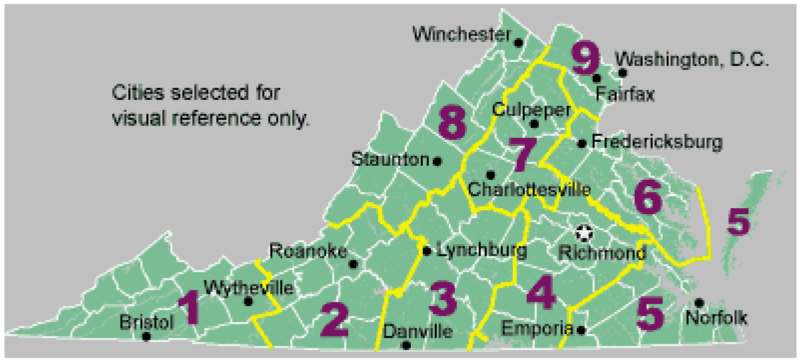


Figure 6: Nine districts of the State of Virginia.

The districts are divided into 42 residencies and two district satellite offices, responsible for one to four counties each. Each of Virginia's counties has at least one area maintenance headquarters strategically located in it. The VDOT central office in Richmond is headquarters for approximately 30 operational and administrative units.

VDOT Budget and Allocations

Obviously, it takes a great deal of financial resources to build and maintain roads, bridges, tunnels and other transportation facilities. VDOT has an annual budget of approximately $3.4 billion. That's almost 14 percent of the total state budget.

Nearly 60 percent of the money goes toward highway construction, with 37 percent going for maintenance. Expenditures include funding for mass transit, airports, seaports, payments to localities for maintaining their own roads, and administration. Funds also are allocated for debt payments on the state's toll roads and for operations, maintenance and improvement costs for these highways.

The money comes from gasoline taxes (17.5 cents per gallon state tax and 18.4 cents per gallon federal), vehicle title fees (three percent of the sales price), license tag fees ($26.50), and one-half cent of the general sales tax. New revenue sources created by the Virginia Transportation Act of 2000 are bond sales based on expected federal revenue, a more efficient method for collecting motor fuel taxes, and a portion of the existing tax on insurance premiums.

Northern Virginia *(Source: http://www.virginiadot.org/quick/nova_quick.asp)*

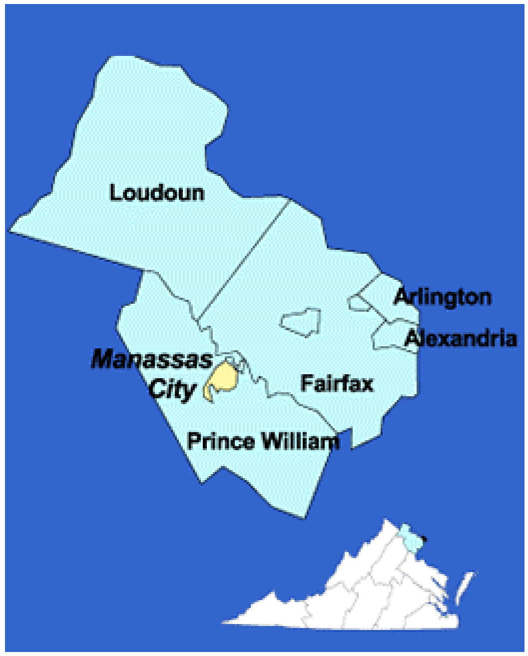


Figure 7: Northern Virginia.

Northern Virginia District

Arlington (maintains local roads), Fairfax, Loudoun and Prince William Counties make the Northern Virginia District:

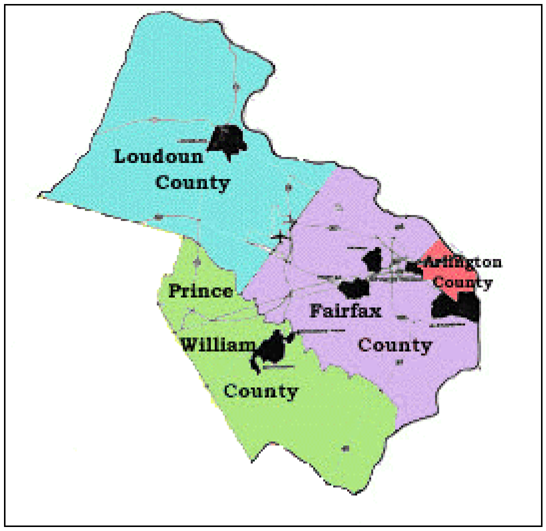


Figure 8: Northern Virginia District.

Fairfax County

(Source: http://www.fairfaxcounty.gov)

Fairfax County, Virginia is a diverse and thriving urban county. It was created by the Virginia Assembly from the northern part of Prince William County in 1742 and originally included all of what are now Loudoun County, Arlington County, and the cities of Alexandria and Falls Church.

As the most populous jurisdiction in both Virginia and the Washington metropolitan area, the County's population exceeds that of seven states. According to the 2000 Census, 969,749 people live in Fairfax County. There are 399 square miles and 255,360 acres of land. The median household income of Fairfax County is one of the highest in the nation and over half of its adult residents have four-year college degrees or more educational attainment. Fairfax County also is home to an extensive commercial office market and is a major employment center.

There are 2,722 miles of road with 48,000 street lights (1999).

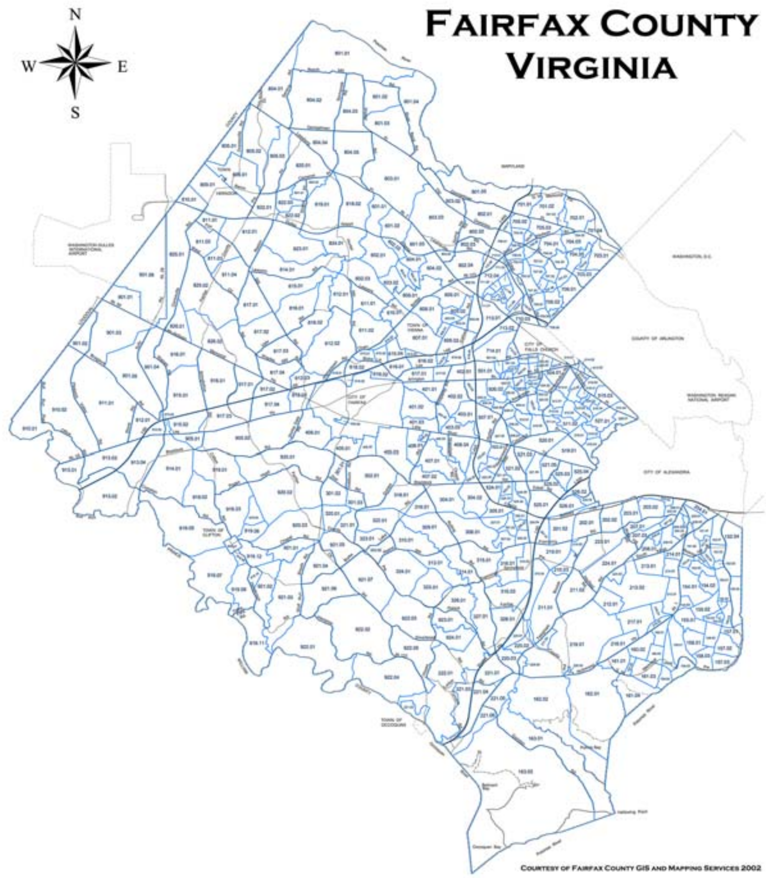


Figure 9: Fairfax County, Virginia.

U.S. Route 1

US Route 1, also known as Richmond Highway is part of a major corridor in Fairfax and Prince William Counties. The purpose of this research is to inventory existing transportation related features in the corridor in terms of traffic safety; document existing conditions and deficiencies; and identify the possible warrants to be used in determining the appropriateness of installing traffic signal preemption equipment at signalized intersections to address transportation safety needs.

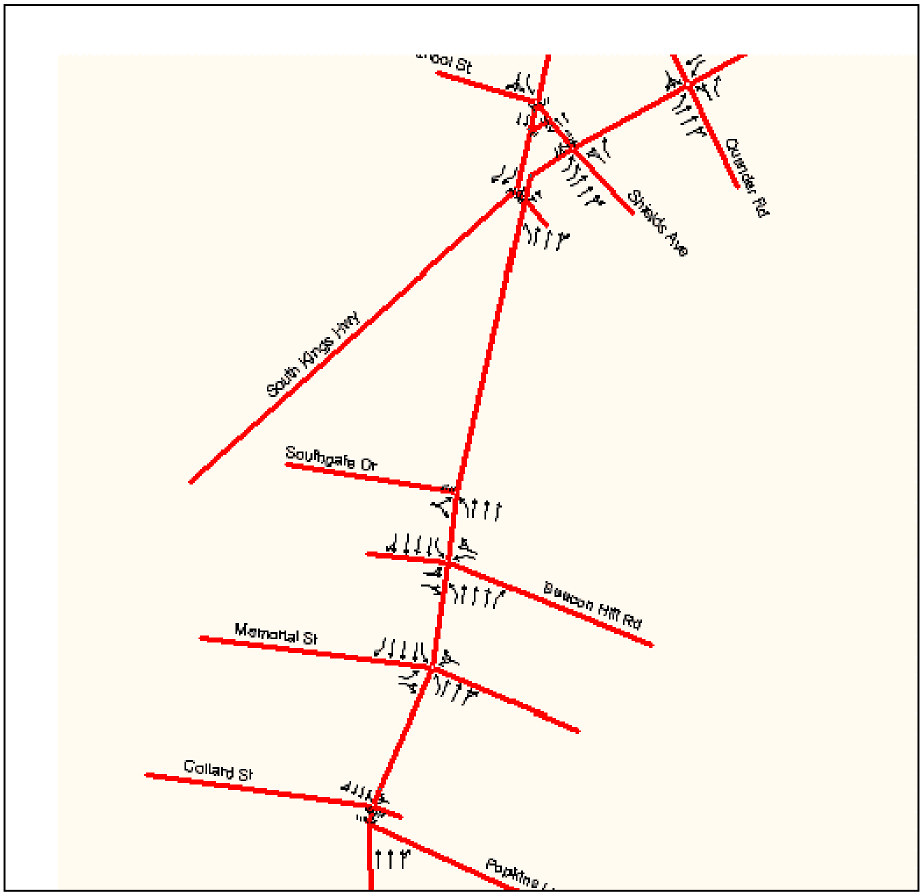


Figure 10: U.S. Route 1, Fairfax County.

3.2.2 Crash Data

Introduction

The crash data which will comprise the database for the analysis conducted in this research was derived from various sources at VDOT and include crashes involving emergency vehicles along U.S. Highways and Interstates in the State of Virginia, Northern Virginia, Fairfax County and U.S. Route 1 in Fairfax County (Figure 11).

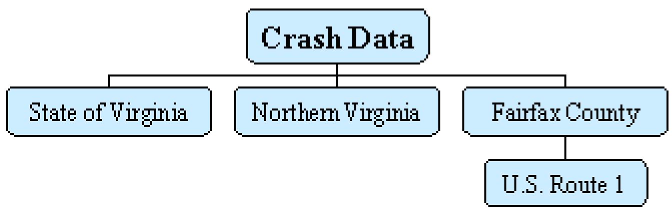


Figure 11: The crash data sets used in the analysis.

Particularly:

- THE STATE OF VIRGINIA

The data includes *crashes involving emergency vehicles* on U.S. Highways and Interstates in Virginia for the time frame 1997-2001.

- NORTHERN VIRGINIA

The data includes *crashes involving emergency vehicles* on U.S. Highways and Interstates in the region for the time frame 1997-2001.

- FAIRFAX COUNTY

The data includes *crashes involving emergency vehicles* on U.S. Highways and Interstates in Fairfax County for the time frame 1997-2001.

- U.S. ROUTE 1

The data includes *crashes involving emergency vehicles* on U.S. 1 in Fairfax County for the time frame 1997-2001.

Description

Virginia accident data are maintained in an accident inventory called HTRIS, which is the acronym for *Highway Transportation Research Information System*.

EXAMINATION OF HTRIS

HTRIS gives the opportunity to gather important information regarding crashes from its updated database. In HTRIS database all accidents between two nodes:

- Reveal all accidents and
- Manually eliminate irrelevant accident data.

Figure 12 illustrates a way to obtain data from the HTRIS system:

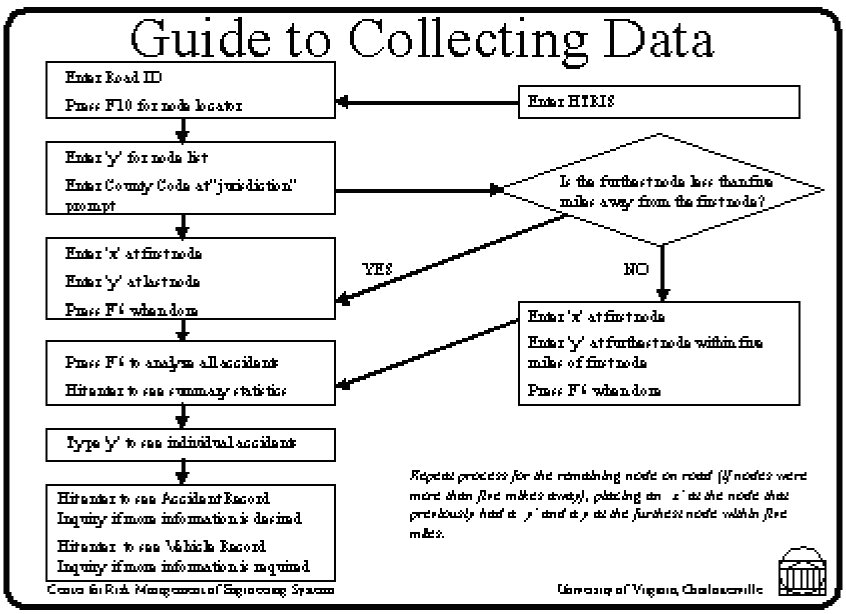


Figure 12: Guide to Collecting Data.

(Source: http://www.virginia.edu/~risk/guardrail/151_175.ppt)

The data that is available from the *Highway Transportation Research Information System* are the following:

- ✓ Summary statistics.
- ✓ Individual accidents.
- ✓ Accident Record.
- ✓ Vehicle Record.

Accident Records

Each record contains the following:

Accident Lane Number: The lane the accident occurred.

City: The city the accident occurred on.

County: The County the accident occurred.

Date: The date the accident occurred.

District: The district of the accident.

Document Number: The number used by the police department to identify the accident.

Driver Action: The action of the driver responsible of the accident (i.e. speeding, sleeping, swerving, drinking etc.).

Driver Age: The age of the driver(s) involved in the accident.

Driver Condition: Defects of the driver(s) involved in the accident.

Driver Sex: The sex of the driver(s) involved in the accident.

Driver Visibility: The vision of the driver at the time of the accident.

Estimated Speed: The estimated speed of the driver(s) involved in the accident.

Facility Type: The type of road.

Fixed Object: The type of fixed object involved in the accident.

Functional Class: Freeway, Rural, Urban.

Light: The lighting at the time of the accident.

Major Factor: The most contributing factor to the accident.

Number of Lanes: The number of lanes on the route.

Number of Persons Injured: The number of injuries.

Number of Persons Killed: The number of fatalities.

Number of Vehicles: The number of vehicles involved in the accident (i.e. emergency vehicle, truck, van, bus etc.).

Offset: The distance in miles from the accident location to the node.

Pedestrians Injured: The number of pedestrians injured due to the accident.

Pedestrians Killed: The number of pedestrians killed due to the accident.

Property Damage: The amount of property damage involved in the accident (in US dollars).

Road Defects: Defects of the road.

Road System: Distinguishes between primary and secondary roads.

Route: The route where the accident occurred on.

Severity: The severity of the accident.

Surface Condition: The condition of the road surface at the time of the accident.

Time: The time the accident occurred.

Traffic Control: The traffic control.

Type of Collision: The type of collision.

Vehicle Condition: Defects in vehicle.

Vehicle Maneuver: The control of the car at the time of the accident (run off the road etc.).

Vehicle Skidding: The involvement of skidding to the accident.

Vehicle Type: The type of the vehicle.

Weather: The numerical code relating to the weather at the time of the accident.

The crash data is contained in an Excel file called New_CrashData_06_02.xls and refers to any information for all reportable motor vehicle accidents in Virginia from January 1997 through December 2001. A reportable accident must have a fatality, an injury, or property damage in excess of $1,000. However, in the data sets crashes that have less damage are reported and analyzed for research reasons. Only the two vehicles in the police reports are part of this data, while data for all vehicles involved in an accident is available through VDOT/DMV. This data is gathered by local and state police and other public safety personnel and fed to the Virginia Department of Motor Vehicles (VDMV). The Virginia Department of Transportation (VDOT) takes the data from the VDMV and loads it into the Highway Traffic Records Information System (HTRIS) where mile point locations are assigned to each accident on a VDOT maintained road by the Mobility Management Division (MMD). MMD's Traffic Management System (TMS) pulls its data from the VDOT (HTRIS) system on an annual basis.

Crash data analysis includes the summary statistics presented in Table 2:

TABLE 2

Summary statistics included in the analysis of crash data

(Source: http://www.virginia.edu/~risk/guardrail/151_175.ppt)

Parameter	Explanation	Significance
Fatal Accidents	The number of accidents involving *fatalities* that have occurred in the specific corridor.	Information on exposure.
Injury Accidents	The number of accidents involving *injuries* that have occurred in the specific corridor.	Information on exposure.
PD Accidents	The number of accidents involving *property damage* that have occurred in the specific corridor.	Information on exposure.
Persons Killed	The number of *fatalities* that have occurred in the specific corridor.	Information on severity.
Persons Killed	The number of *fatalities* that have occurred in the specific corridor.	Information on severity.
Persons Injured	The number of *injuries* that have occurred in the specific corridor.	Information on severity.
Amount of PD	The number of property damage that has occurred in the specific corridor.	Information on severity.
Total Accidents	The number of accidents that have occurred in the specific corridor.	Information on exposure.

3.3 DATA ANALYSIS

3.3.1 Excel Spreadsheet

The main part of the analysis will be conducted using an Excel spreadsheet which includes a variety of useful applications (Appendix C).

3.3.2 ArcGIS Desktop

The crashes involving emergency vehicles in Fairfax County are going to be further analyzed and presented using a GIS program, called *ArcGIS Desktop* and is the collective name for three products: *ArcView, ArcEditor* and *ArcInfo*. These products have the same interface and share much of their functionality. All ArcGIS Desktop products can share the same maps and data.

The crash data is included in a file compatible with the ArcGIS Desktop that is called New_CrashData_06_02.shp and contains the point locations and the related data of all the reportable motor vehicle accidents in Virginia from January 1997 through December 2001. The Traffic Management System (TMS) provides the GIS Integrator a Materialized View of the accident data table which is used to create an event shape file. This shape file is loaded into SDE. Mile-points in urban areas were only coded until December 1997 for roads not maintained by VDOT. The TMS staff makes fixes to the accident data when appropriate. The Materialized view is refreshed every three weeks with these updates.

With ArcView we can create maps, analyze spatial relationships, and edit feature shapes and attributes. With ArcEditor, we can also create and edot certain spatial data formats that can be displayed in ArcView but not edited. ArcInfo has more tools than ArcView or ArcEditor for analyzing certain kinds of spatial data. Each version of ArcGIS Desktop includes the same three applications-ArcMap, ArcCatalog, and ArcToolbox. A GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information (for example, data that are identified according to their locations). It is, also, supported that GIS can be employed to relate, organize, analyze and display the roadway and crash data in a creative manner, thereby facilitating crash countermeasure identification and evaluation. It can, also, be applied at the corridor level for identification of potential problem sites. It is stressed that GIS appears more as an instrument that can help the analyst pinpoint locations that warrant greater study.

GIS Layers

A GIS map is made up of *layers*, or collections of geographic objects that are alike. In order to make a map we can add as many layers as we want.

Layers Features or Surfaces

In a map (Figure 17), the Roads layer includes many different roads and the Accident layer many different traffic accidents. The same is true of the Rivers and Countries layers. Each geographic object in a layer-each city, river, lake, or country-is called a *feature*.

Not all layers contain features. The Oceans layer is not a collection of geographic objects the way the others are. It is a single, continuous expanse that changes from one location to another according to the depth of the water. A geographic expanse of this kind is called a *surface*.

Features have shape and size

Geographic objects have an endless variety of shapes. All of them, however, can be represented as one of three geometrical forms-a polygon, a line, or a point.

Polygons represent things large enough to have boundaries, such as countries, counties, lakes and tracts of land. Lines represent things too narrow to be polygons, such as rivers, roads, and pipelines. In our case we use road polygons instead of road lines. Points are used for things too small to be polygons, such as crash locations, cities, schools, and fire hydrants. (The same object may be represented by a polygon in one layer and a line or a point in a different layer, depending on how large it is presented).

Polygons, lines, and points collectively are called vector data.

Features have locations

GIS uses a fine grid that is called a coordinate system to put features in their proper places on a map. The location of a point feature on a map is defined by a pair of x, y coordinates. A straight line needs two pairs of coordinates-one at the beginning and one at the end. If the line bends, there must be a pair of coordinates at every location where the line changes direction. The same is true for a polygon, which is simply a line that returns to its starting point.

Features have locations

On a GIS map, we can zoom in to see features at closer range. As we do so, the scale of the map changes.

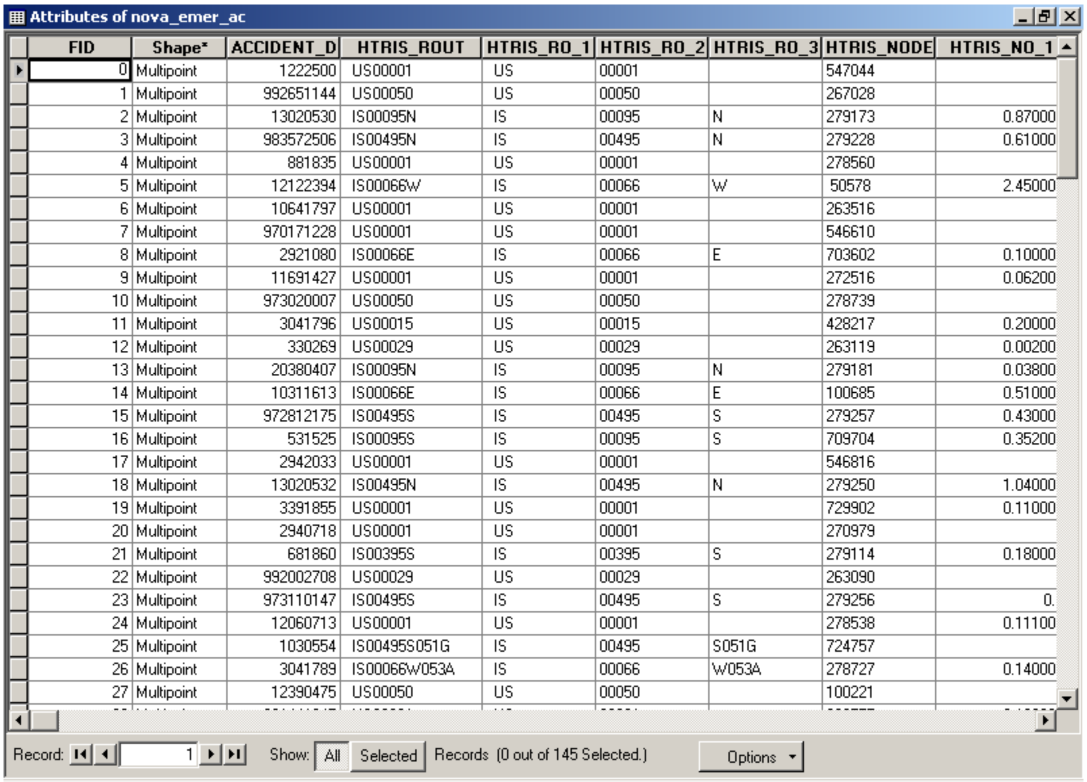
Scale, commonly expressed as ratio, is the relationship between the size of features on a map and the size of the corresponding places in the world. If the scale of a map is 1:100,000,000, it means that features on the map are one hundred million times smaller than their true size.

Zooming in provides with a closer view of features within a smaller area. The amount of detail in the features does not change, however. A river has the same bends, and a coastline the same crenulations, whether we are zoomed in and can discern them or are zoomed out and cannot. The number of detail features that a map has depends on the used layer. GIS layers can contain more future detail or less.

Features are linked to information

There is more to a feature than its shape and location. There is everything else that might happen to be known about it. For a crash, this might include the number of vehicles involved, collision type, major factor contributing to the crash, number of injuries and fatalities, cost etc. for a road, it might be its speed limit, the number of lanes it has, pavement description, and whether it is one-way or two-way.

Information about the features in a layer is stored in a table. The table has a *record* (row) for each feature in the layer and a *field* (column) for each category of information. These categories are called *attributes* (Figure 13).



FID	Shape*	ACCIDENT_D	HTRIS_ROUT	HTRIS_RO_1	HTRIS_RO_2	HTRIS_RO_3	HTRIS_NODE	HTRIS_NO_1
0	Multipoint	1222500	US00001	US	00001		547044	
1	Multipoint	992651144	US00050	US	00050		267028	
2	Multipoint	13020530	IS00095N	IS	00095	N	279173	0.87000
3	Multipoint	983572506	IS00495N	IS	00495	N	279228	0.61000
4	Multipoint	881835	US00001	US	00001		278560	
5	Multipoint	12122394	IS00066W	IS	00066	W	50578	2.45000
6	Multipoint	10641797	US00001	US	00001		263516	
7	Multipoint	970171228	US00001	US	00001		546610	
8	Multipoint	2921080	IS00066E	IS	00066	E	703602	0.10000
9	Multipoint	11691427	US00001	US	00001		272516	0.06200
10	Multipoint	973020007	US00050	US	00050		278739	
11	Multipoint	3041796	US00015	US	00015		428217	0.20000
12	Multipoint	330269	US00029	US	00029		263119	0.00200
13	Multipoint	20380407	IS00095N	IS	00095	N	279181	0.03800
14	Multipoint	10311613	IS00066E	IS	00066	E	100685	0.51000
15	Multipoint	972812175	IS00495S	IS	00495	S	279257	0.43000
16	Multipoint	531525	IS00095S	IS	00095	S	709704	0.35200
17	Multipoint	2942033	US00001	US	00001		546816	
18	Multipoint	13020532	IS00495N	IS	00495	N	279250	1.04000
19	Multipoint	3391855	US00001	US	00001		729902	0.11000
20	Multipoint	2940718	US00001	US	00001		270979	
21	Multipoint	681860	IS00395S	IS	00395	S	279114	0.18000
22	Multipoint	992002708	US00029	US	00029		263090	
23	Multipoint	973110147	IS00495S	IS	00495	S	279256	0.
24	Multipoint	12060713	US00001	US	00001		278538	0.11100
25	Multipoint	1030554	IS00495S051G	IS	00495	S051G	724757	
26	Multipoint	3041789	IS00066W053A	IS	00066	W053A	278727	0.14000
27	Multipoint	12390475	US00050	US	00050		100221	

Figure 13: Attribute Table.

Features on a GIS map are linked to the information in their attribute table. If we highlight a specific crash location on the map, we will be able to bring up all the information stored about it in the attribute table for crashes. If we highlight a record in the table, we will see the corresponding feature on the map.

The link between features and their attributes makes it possible to ask questions and create queries about the information in an attribute table and display the answer on the map (Figure 14).

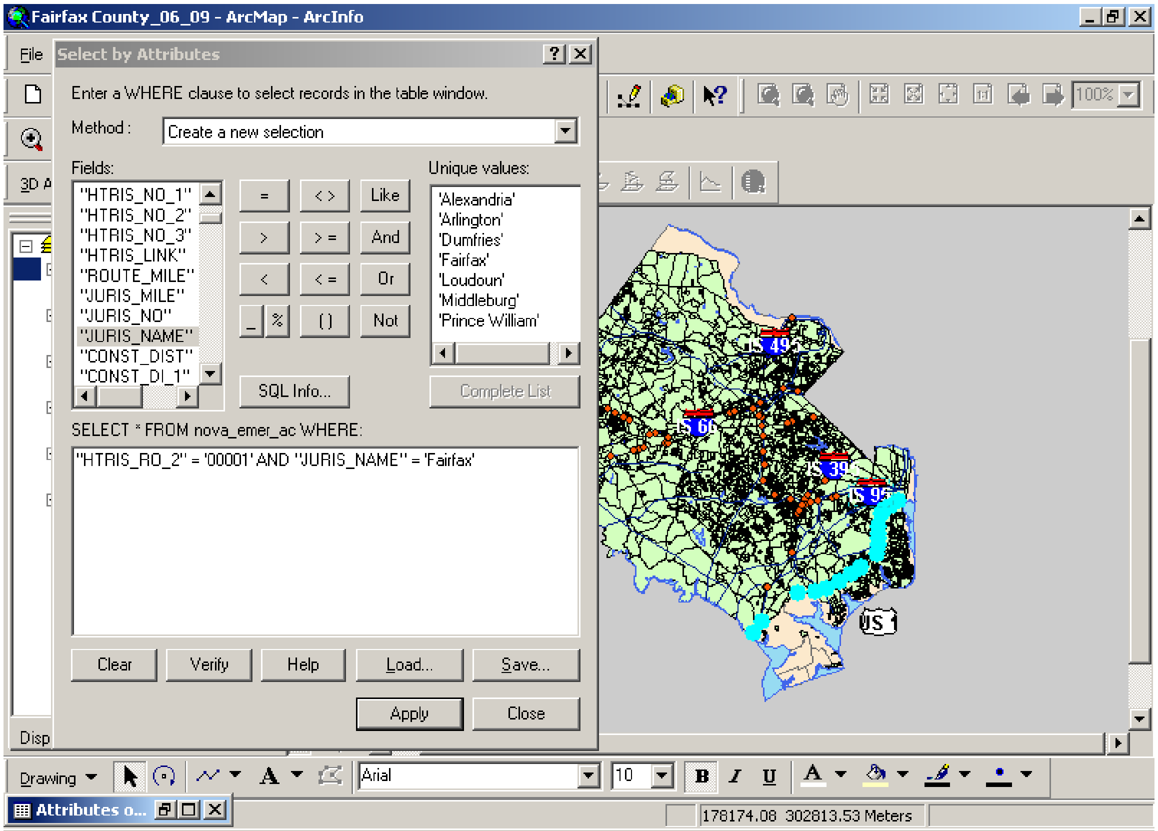


Figure 14: Query on crashes involving EVs on U.S. 1 in Fairfax County and Display on ArcMap.

Similarly, we can use attributes to create *thematic maps*, maps in which colors or other symbols are applied to features to indicate their attributes.

Features have spatial relationships

Besides asking questions about the information in attribute tables, we can also ask questions about the spatial relationships among features-for example, which ones are closer to others, which ones cross others, and which ones contain others. The GIS uses the coordinates of features to compare their locations.

The ArcMap, ArcCatalog, and ArcToolbox applications

In ArcMap we are able to create maps from different layers of spatial data, choose colors and symbols, query attributes, analyze spatial relationships, and design map layouts. The ArcMap interface contains a list (or table of contents) of the layers in the map, a display area for viewing the map, and menus and tools for working with the map (Figure 15).

ArcCatalog is an application for managing geographic data. In ArcCatalog, we browse spatial data contained on our computer's hard disk, on a network, or on the Internet. We can search for spatial data, preview it, and add it to ArcMap. ArcCatalog also includes tools for creating and viewing metadata, which is the information regarding the spatial data, such as who created it and when, its intended use, its accuracy, and so forth. A folder can contain shapefiles, which is a vector data storage format for storing the location, shape, and attributes of geographic features. A shapefile is stored in a set of related files and contains one feature class. Geographic features in a shapefile can be represented by points, lines, or polygons (areas). The folder might also contain dBASE tables, which can store additional attributes that can be joined to a shapefile's features (Figure 16).

In ArcToolbox, we can use tools to convert spatial data from one format to another and to change the map projection of data.

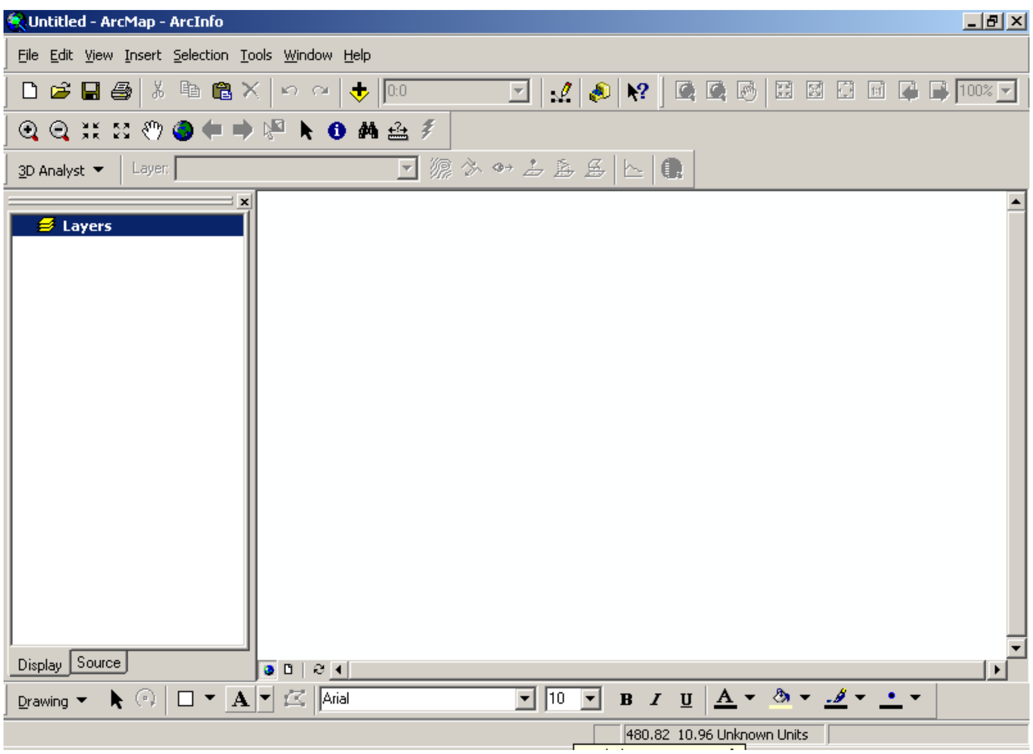


Figure 15: ArcMap Window in ArcGIS Desktop.

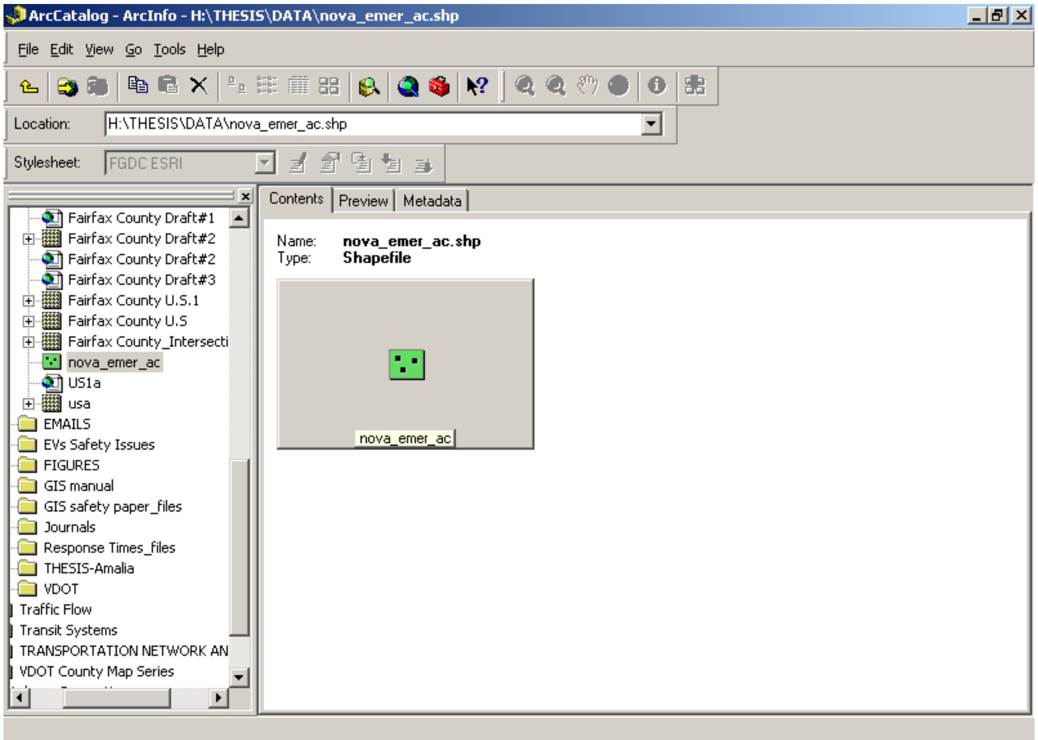


Figure 16: ArcCatalog Window.

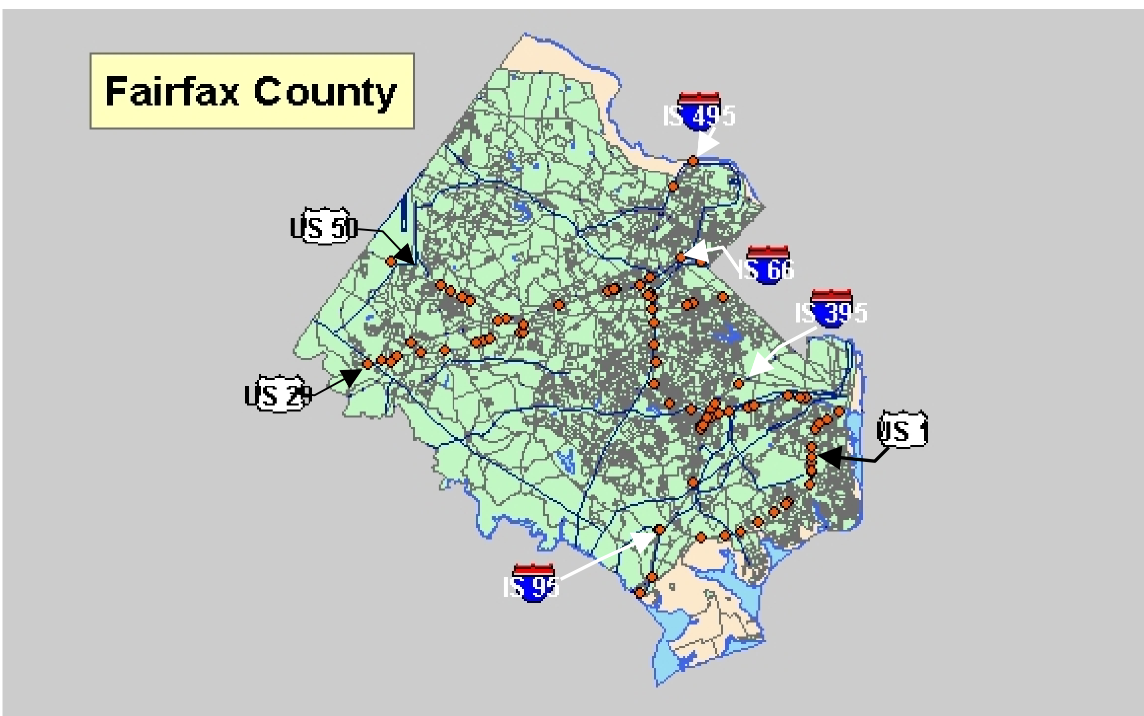


Figure 17: Map of Fairfax County using ArcGIS Desktop.

CHAPTER 4: ANALYSIS AND RESULTS

4.1. DATA DESCRIPTION

The data used in the analysis represents emergency vehicle crashes from 1997 to 2001 along U.S. Highways and Interstates. These data were broken down in the following four data sets (Figure 18).

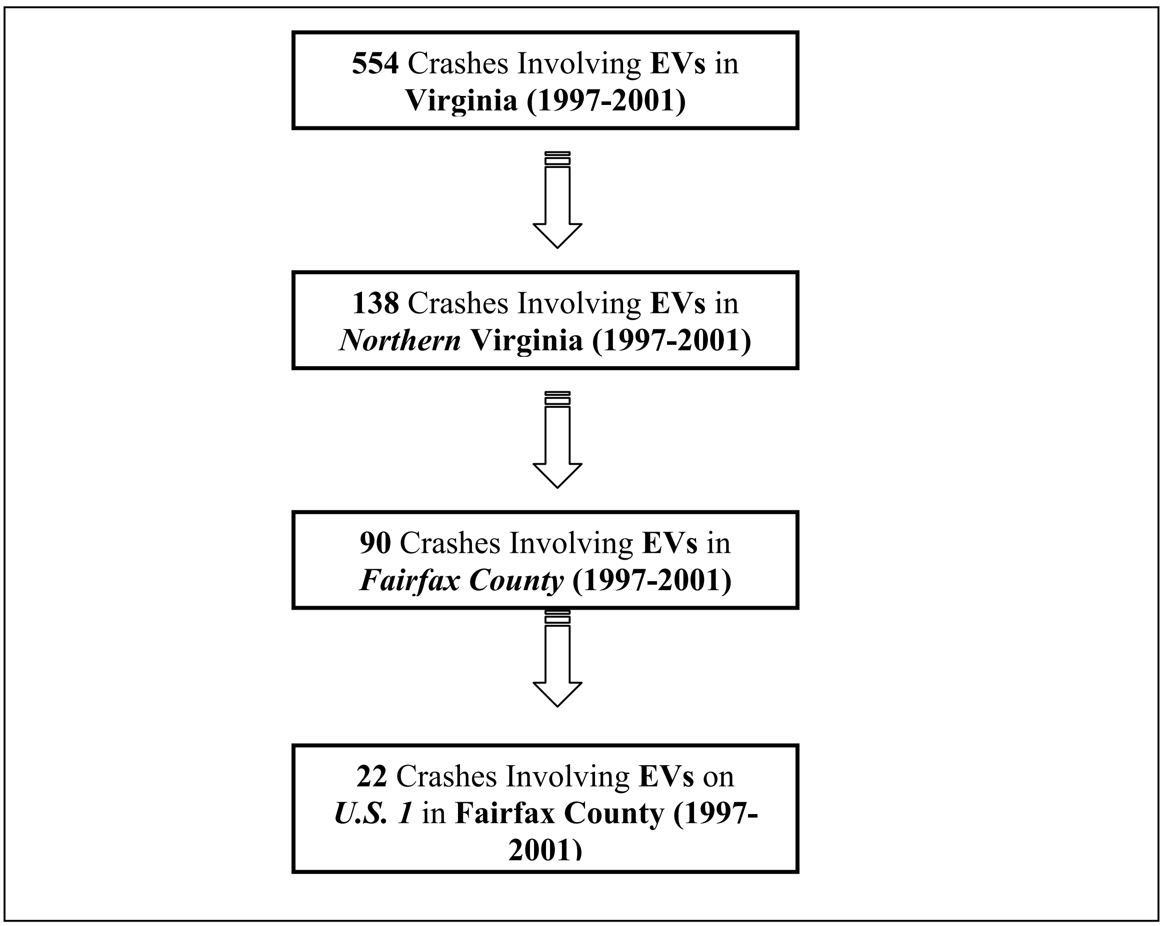


Figure 18: Crash data used in the analysis.

The analysis will be presented as follows:

- Classification of crashes involving EVs by crash severity in the region, county and route level.
- Classification of crashes involving EVs by location description in the region, county and route level.
- Classification of crashes involving EVs by collision type and major factor description in the region, county and route level.
- Description of the major conditions and other EVs crash characteristics in terms of number of lanes, facility type, alignment, weather, surface, lighting and road conditions in the region, county and route level.
- Identification and description of any differences in the crash situation by geographic location and highway classification type.

4.2. DATA ANALYSIS AND RESULTS

4.2.1 Northern Virginia

Data Description

The data set used in this analysis includes all the crashes involving emergency vehicles on U.S. Highways *and* Interstates in Northern Virginia for the five year period of 1997 to 2001.

Figure 19 presents the percentage of the total number of crashes involving emergency vehicles (EVs) by area description in terms of the region of Northern Virginia and the rest of the regions of the State of Virginia. It can be observed that 25% of all crashes (138 out of 554) involving EVs that have occurred in the whole State include crashes in the region of Northern Virginia.

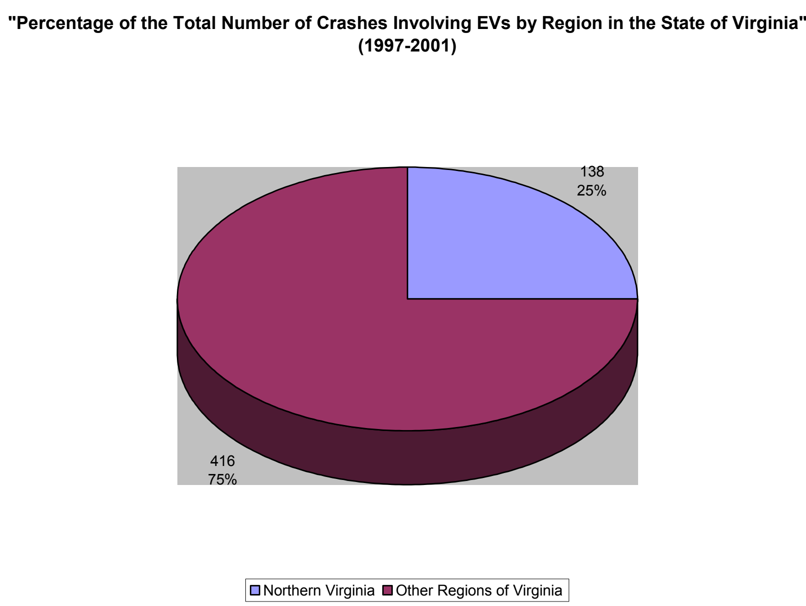


Figure 19: Percentage of the total number of crashes involving emergency vehicles by region in the State of Virginia from 1997 to 2001.

Total Number of Crashes by County

It is indicated that the total number of crashes involving EVs has increased in the past few years in the whole region of Northern Virginia (Figure B.1). Figure 20 presents the total number of crashes involving EVs by county for the Northern Virginia region for the five year period of 1997-2001. It can be observed that approximately 66% of all crashes involving EVs in Northern Virginia have occurred in Fairfax County for the time period 1997-2001. Particularly, Fairfax County has reported 90 crashes involving EVs out of a total of 138 in the whole region for the five year period. Prince William and Arlington Counties appear to have approximately the same number of crashes (average of 20.5 and 15% of all crashes) and Loudoun has the lowest total number of 7 crashes (5% of all crashes).

These differences in the crash situation among the four counties could be roughly explained by the population estimates which appear to be the highest for Fairfax County (969,749 residents in the year 2000) and agree with the highest number of EV crashes reported. Prince William County comes next with a 2000 population of 280,813 people, while in Arlington County 189,453 people were estimated in the same year which is approximately 15,000 more than Loudoun County (172,173 in 2000).

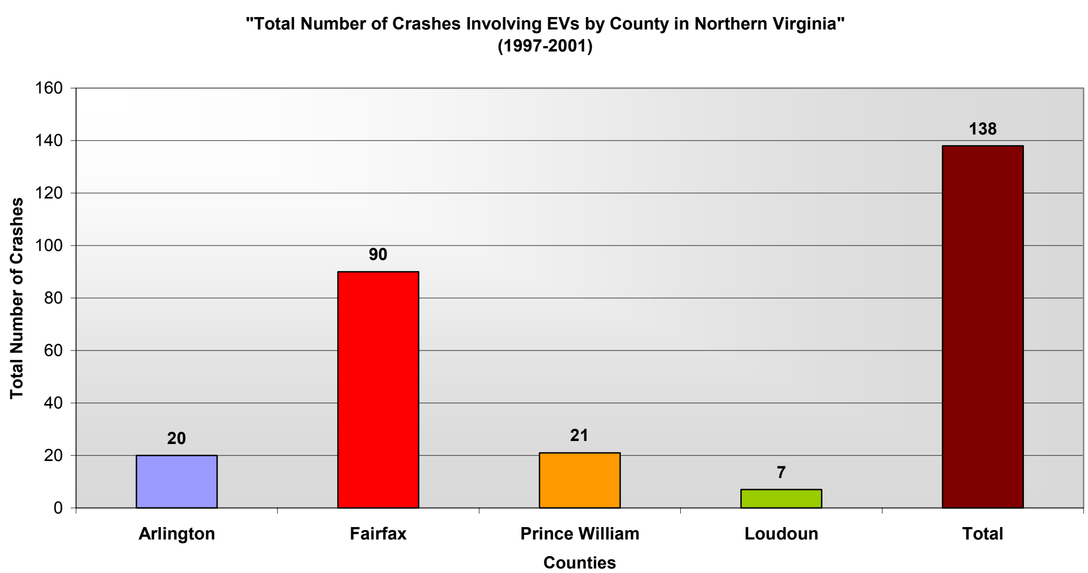
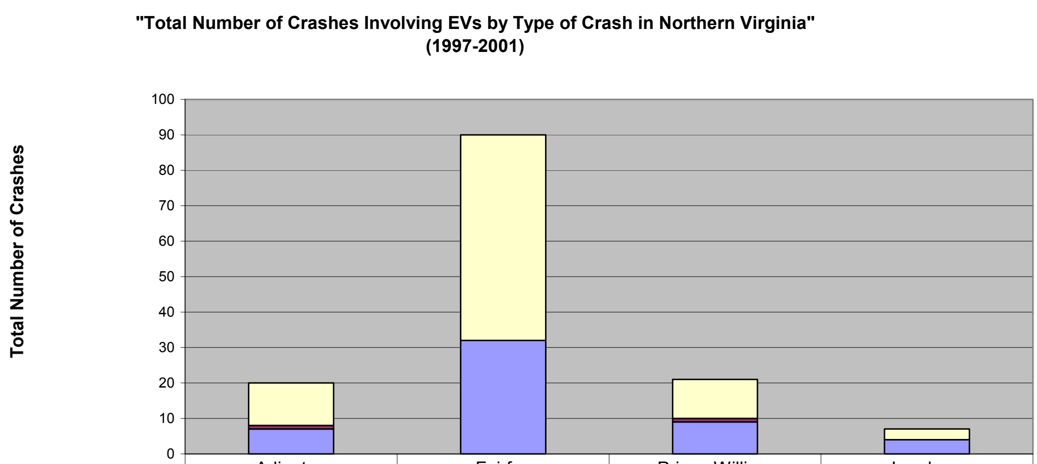


Figure 20: Total number of crashes involving emergency vehicles by County in Northern Virginia from 1997 to 2001.

Crash Severity: Type of Crash

Figure 21 presents the total number of crashes in the region by type of crash: *property damage only, injury crash with no fatalities, and fatality crash with one or more fatalities*. It is indicated that in Arlington, Fairfax, and Prince William Counties the highest number of crashes are property damage only. However, it is important to note that the number of injury crashes is significantly high, too. Loudoun County reported 4 injury crashes versus 3 property damage crashes. Fairfax County appears to have 64% property damage only crashes and the remaining 36% are injury crashes with no fatalities. Both Arlington and Prince William Counties have reported one fatal crash each, while an average of 55% are property damage crashes only and an average of 40% are injury crashes with no fatalities. The reports have indicated that the 138 crashes involving emergency vehicles in Northern Virginia resulted in 87 injuries and 2 fatalities, including 1 pedestrian, which occurred on U.S. Route 1 in Prince William County.



	Arlington	Fairfax	Prince William	Loudoun
Property Damage Crashes	12	58	11	3
Fatality Crashes	1	0	1	0
Injury Crashes	7	32	9	4

Figure 21: Total number of crashes involving emergency vehicles by type of crash in Northern Virginia from 1997 to 2001.

Crash Severity: Type of Crash and Damage Cost

Figure 22 and Table A.1 present the total number of crashes involving emergency vehicles versus injury crashes only involving emergency vehicles, while the bubble size represents the total cost in U.S. dollars of the property damage of all the crashes involving emergency vehicles in the four counties of the region. It can be observed that Fairfax County presents the highest number of total crashes as well as injury crashes involving emergency vehicles; while the total damage cost of all the crashes ($528,135) reported in the County is the highest among the four counties (approximately 66% of total damage amount in the region includes the crashes involving EVs in Fairfax County). This is important because Fairfax County presents the worst crash situation in terms of total number of crashes, injury crashes and total damage cost in the region, and needs further investigation and analysis. The damage costs for the remaining three counties are as follows: Arlington $83,295, Prince William $138,304 and Loudoun $46,825.

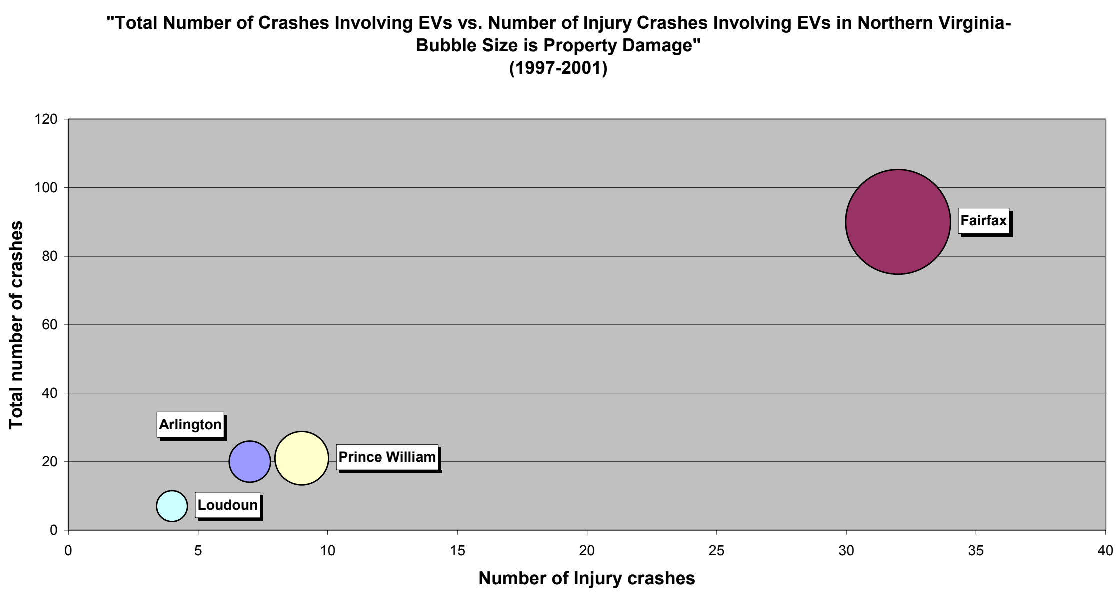


Figure 22: Total number of EV crashes versus injury crashes involving emergency vehicles in Northern Virginia from 1997 to 2001 (Bubble Size is Property Damage Cost).

Location Description

Figure 23 presents the proportion of crashes involving EVs in terms of their locations' relationship to intersection. It can be observed that 47 crashes have occurred at intersections (34%), while the remaining 91 include crashes occurring at non-intersection sites (66%). It is important to note that this classification of crashes involving emergency vehicles includes crashes on *both U.S. Highways and Interstates* and this affects the results of the analysis. An analysis of crashes involving EVs on the *U.S. Highways only* is following.

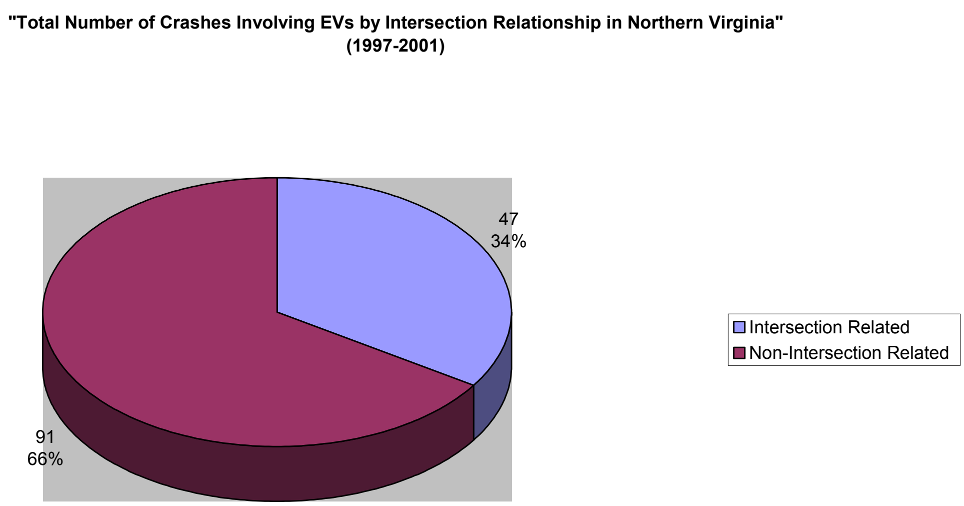


Figure 23: Total number of crashes involving emergency vehicles by intersection relationship in Northern Virginia from 1997 to 2001.

Intersection Description

Figure 24 presents the proportion of crashes involving EVs that occurred at intersections on U.S. Highways in terms of the intersections' relationship to signalization. It can be observed that out of a total of 47 crashes, which have occurred at the intersections along the U.S. Highways in Northern Virginia, 23 have occurred at signalized intersections (49%), while 24 at non-signalized intersections (51%). This is important to note because it illustrates that for approximately half of the crashes occurring at intersections the presence of a traffic signal was not a significant deterrent factor for the occurrence of traffic accidents involving emergency vehicles. The distribution of crashes among the different type of intersections is presented in Figure 25, where it is indicated that 13 crashes have occurred at a tee ("T") intersection (the "leg" enters between 80 degree and 100 degree angle), 4 in a branch (one leg enters at angle other than "T" angle), 6 in a crossing (all crossroads at grade regardless of intersecting angle), and 1 is characterized as an offset intersection (all offset intersections when offset does not exceed 150 feet). The statistical independence between the intersection type and the number of EV crashes is studied with the application of the Chi-Square statistical test (Table F.2). It is illustrated that there is a statistically significant difference between the signalized and non-signalized intersections. It can be observed that the number of EV crashes at signalized intersections is significantly higher compared to non-signalized ones.

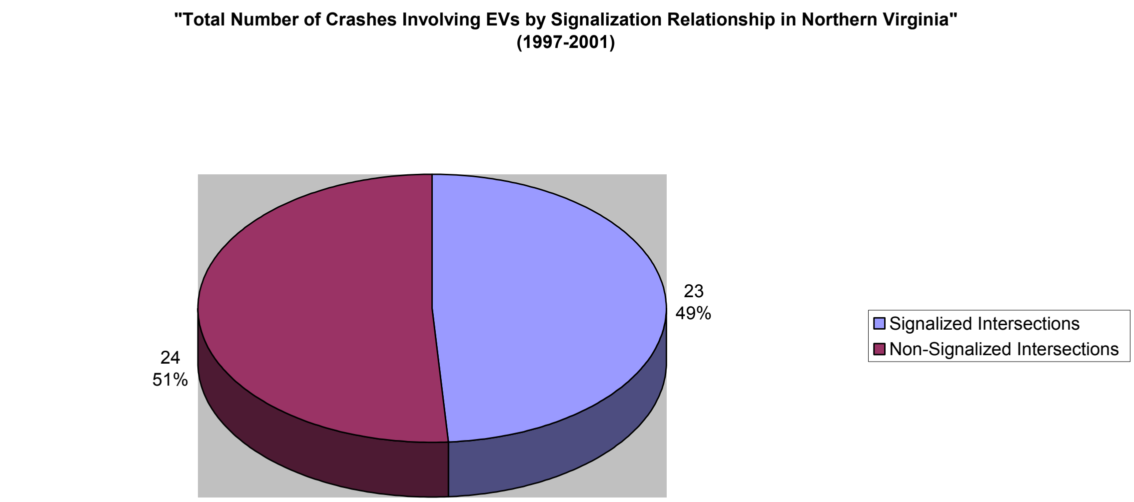


Figure 24: Total number of crashes involving emergency vehicles by signalization relationship on the U.S. Highways in Northern Virginia from 1997 to 2001.

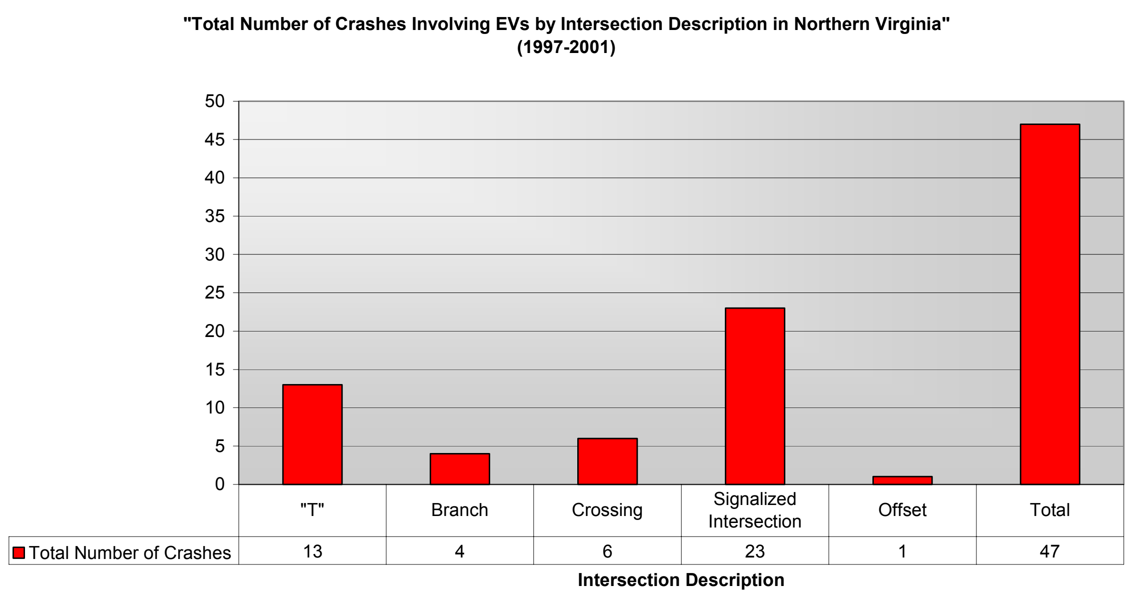


Figure 25: Total number of crashes involving emergency vehicles by intersection description on the U.S. Highways in Northern Virginia from 1997 to 2001. [1]

[1] When an intersection is signalized it is defined as "Signalized Intersection". All the other intersection types ("T", branch, crossing and offset) are non-signalized.

Collision Type

Figure 26 presents the total number of crashes involving emergency vehicles by type of collision as reported by the enforcement official. It can be observed that in 51 crashes the collision type were of the rear end type, 38 out of the total of 138 crashes included sideswipe collisions, while the vehicles were traveling in the same direction, and in 25 cases the vehicles collided at an angle. The remaining 24 crashes were reported to have various collision types such as fixed object in and off road (2 and 8 crashes, respectively), backed into collision (3 crashes) and 1 crash involving a pedestrian etc. This observation is important because it offers an indication of the reasons that have led to the actual collisions in terms of the vehicles positions while traveling, as well as, the type of movements and actions a driver may choose to perform in case of an emergency vehicle approaching in order to accommodate its passage.

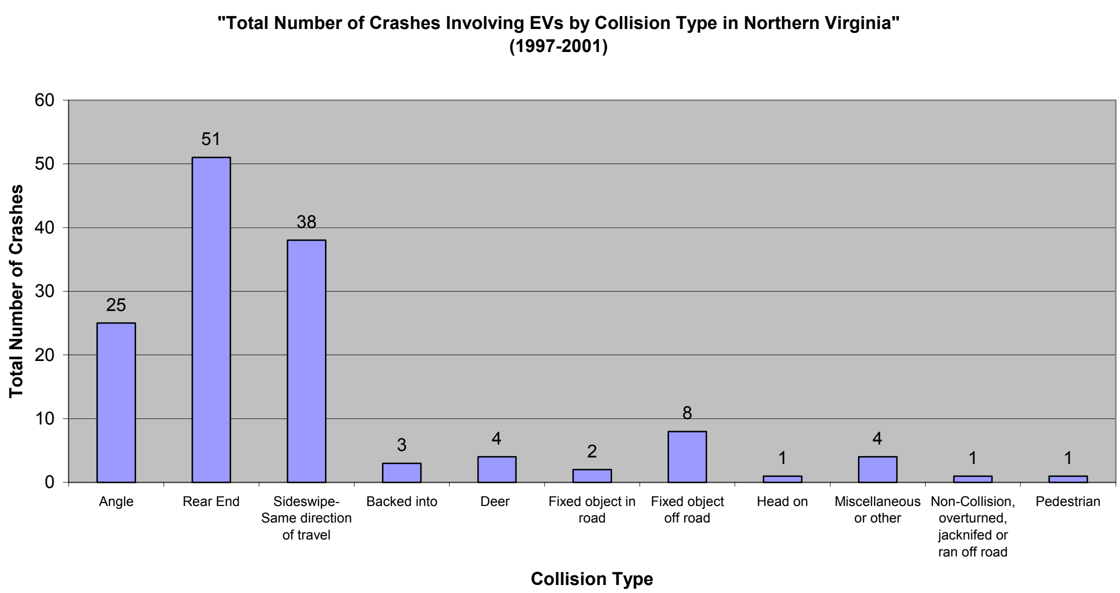


Figure 26: Total number of crashes involving emergency vehicles by collision type in Northern Virginia from 1997 to 2001.

Collision Type and Crash Site Type

Table 3 presents the different collision types that are reported in the crashes involving EVs that have occurred at intersections and at non-intersections on the *U.S. Highways* in Northern Virginia. It can be observed that approximately 63% of all crashes involving EVs on the U.S. Highways have occurred at intersections (47 out of 75). This classification illustrates that the major collision type of the crashes occurring at intersections is *angle* (38% or 18 out of 47), while the major collision types for crashes occurring at non-intersection sites is found to be *rear end* (36% or 10 out of 28), and *sideswipe* (29% or 8 out of 28). The different types of collisions reported at these two types of crash sites implies that the vehicles make different maneuvers when passing through an intersection and when traveling along the route far from an intersection. Therefore, it can be concluded that the fact that vehicles collide in an angle when traveling through an intersection indicates that this could be due to the absence of an appropriate warning signal for the perpendicular and the opposing moving traffic streams in order to stop moving when the emergency vehicle makes a turn or clears the intersection while facing opposing traffic with a high risk of collision (Figure B.2). The statistical independence between crash site type and collision type on the U.S. Highways in Northern Virginia for the time frame (1997-2001) is studied with the application of the Chi-Square statistical test presented in Table F.3. The analysis indicates that, at the 0.05 level of significance, the crash site type and the collision type are statistically independent due to the statistically limited number of counts of EV crashes.

TABLE 3

Total number of crashes involving EVs by crash site type and collision type along the U.S. Highways in Northern Virginia (1997-2001)

	Crash Site Type	
Collision Type	**Intersections**	**Non-Int/ions**
Angle	18	6
Rear End	11	10
Head on	1	0
Sideswipe-Same direction of travel	11	8
Other	6	4
Total	***47***	***28***

Major Factor Description

Figure 27 presents the total number of crashes involving emergency vehicles by major factor description as reported by the enforcement official. It can be observed that in 84% of all cases the road user appears to have the major responsibility of the traffic accidents occurrence and particularly 98 out of a total of 138 crashes (71%) are indicated to have occurred due to driver's or pedestrian's inattention or error, in 8 cases (6%) the road user (driver or pedestrian) was found under the influence of alcohol, drugs, or other agents, and 10 crashes (7%) occurred due to driver's speed. The remaining 22 crashes were reported to have different causes. In this point, it is important to note that this major factor description was reported by a police officer at the accident site and therefore, a degree of subjectivity may exist. Moreover, a police officer is not requested to perform any precise and detailed analysis of the crash site like a traffic engineer and this point must be taken into account when interpreting the results.

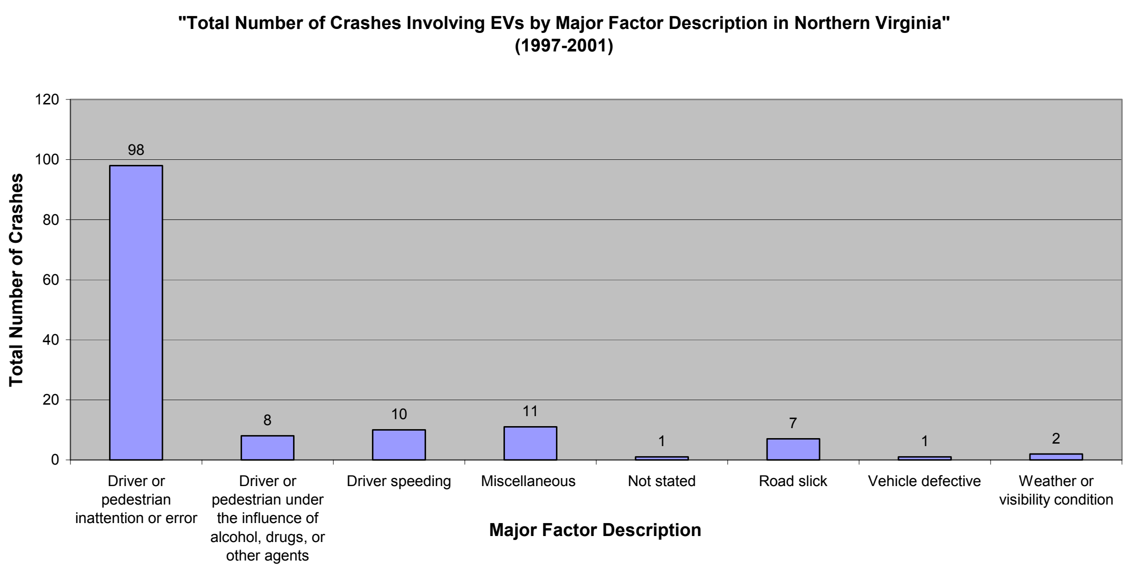


Figure 27: Total number of crashes involving emergency vehicles by major factor description in Northern Virginia from 1997 to 2001.

Route Description

The crash distribution among the routes of Northern Virginia is presented in Figure 28. It is indicated that among all routes studied (U.S. Highways and Interstates) the highest number of crashes (31 out of 138) involving emergency vehicles have occurred on U.S. Route 1 (Richmond Highway). The routes that have a lower number of crashes involving EVs are I.S. 66, I.S. 95, U.S. Route 29 and U.S. Route 50 with an average of 20.5 crashes involving EVs, while the smallest number of crashes has been reported on routes I.S. 395, I.S. 495 and U.S. Route 15 for the five year period. On the U.S. Highways 54% of all crashes involving EVs have been reported (75 out of 138), while the remaining 46% of crashes involving EVs have occurred on the Interstates (63 out of 138).

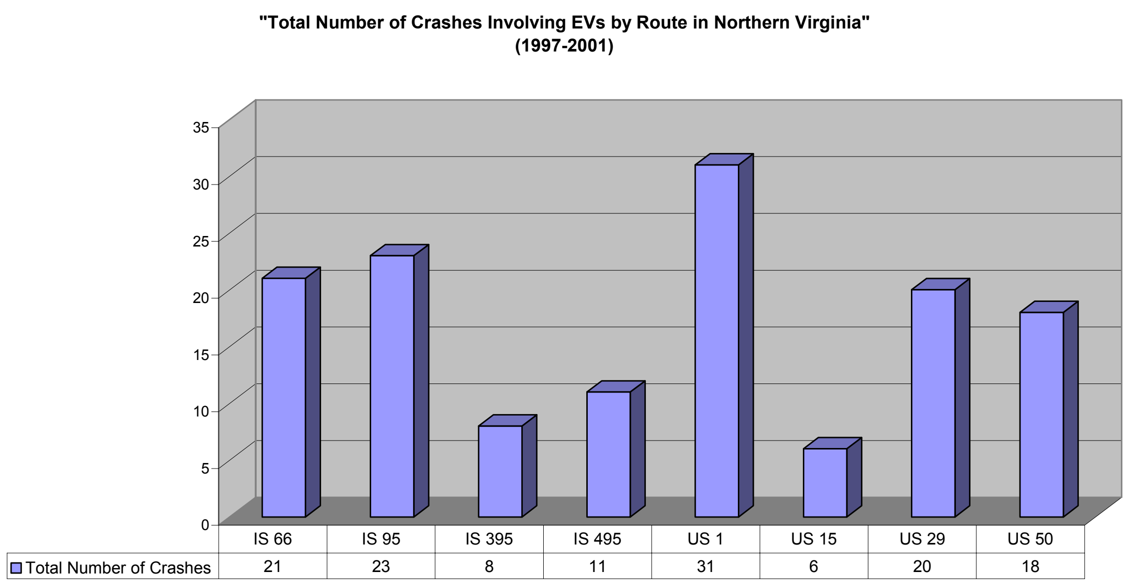


Figure 28: Total number of crashes involving emergency vehicles for the U.S. Highways and the Interstates in Northern Virginia from 1997-2001.

Route Description and Crash Severity

Figure 29 presents the total number of crashes involving emergency vehicles versus injury crashes only, involving emergency vehicles, while the bubble size represents the total cost in U.S. dollars of the property damage of all the crashes involving emergency vehicles on the U.S. Highways and Interstates in Northern Virginia. Figure 30 presents the total number of crashes involving emergency vehicles versus property damage crashes only, involving emergency vehicles, while the bubble size represents the total cost in U.S. dollars of the property damage of all the crashes involving emergency vehicles on the U.S. Highways and Interstates in Northern Virginia. The total amount of damage cost in U.S. dollars by route is presented in Figure 31. Table A.2 presents the total number of crashes involving EVs by crash type and property damage. It can be observed that U.S. Route 1 includes the highest number of total crashes (31) as well as injury (10) and property damage (20) crashes involving emergency vehicles; while the total damage cost of all the crashes reported on this route is the highest (approximately 21% of the total damage amount in the region includes the crashes involving EVs on U.S. Route 1). It is also indicated that approximately 32% of all crashes involving EVs on U.S. Route 1 are injury crashes, while double the number (20) are property damage only. This is important because U.S. Route 1 presents the worst crash situation in terms of total number of crashes, injury and property damage crashes and therefore total damage cost in the region ($165,820), and needs further investigation and analysis.

Regarding, the other routes it is indicated that on I.S. 95 14 property damage crashes out of a total of 23 crashes and a damage cost of $150,940 were reported, I.S. 66 included 14 property damage crashes, 6 injury crashes and 1 fatality crash with a total property damage cost of $162,169, on U.S. 50 8 injury and 10 property damage crashes were reported with a total damage cost of $137,576, I.S. 495 included 8 injury and 3 property damage crashes with a total damage cost of $64,410, U.S. 29 included 16 property damage and 4 injury crashes with a total cost of $71,965, I.S. 395 included 8 crashes (5 injury and 3 PD crashes) and a total cost of $30,350 and U.S. 15 had the least damage amount of $13,329 and the smallest number of crashes (2 injury and 4 PD crashes). U.S. 1 presents the highest number of EV crashes in the region and thus greater damage cost among the U.S. Highways that have similar functional and operational characteristics. (U.S.1:U.S.50:U.S.29=2.3:1.9:1). U.S. 15 has been excluded from the analysis since it is a rural highway and has different operation performance.

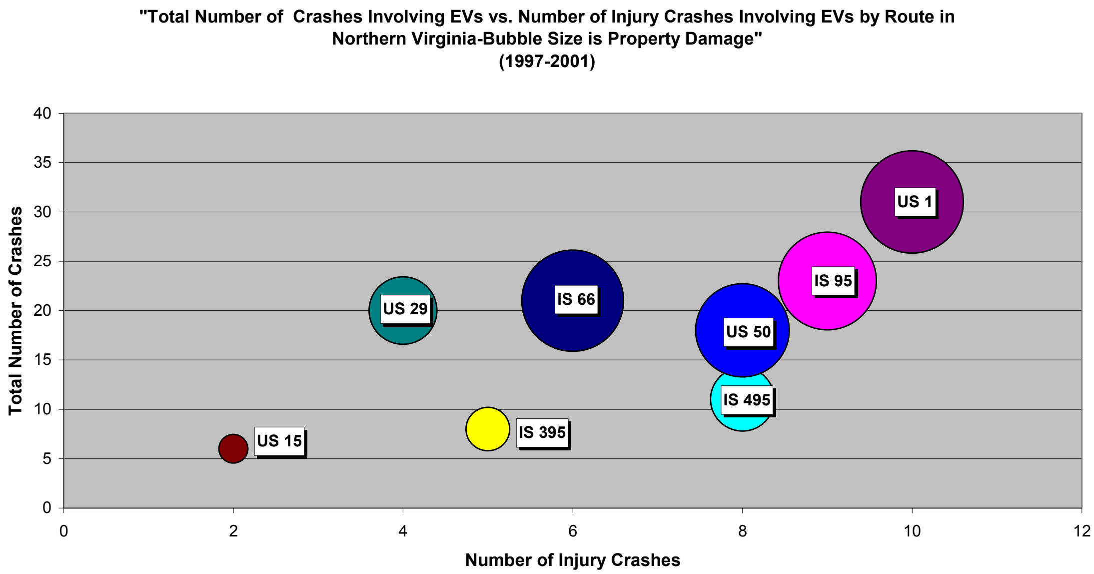


Figure 29: Total number of EV crashes versus injury crashes involving emergency vehicles by route in Northern Virginia from 1997 to 2001 (Bubble Size is Property Damage Cost).

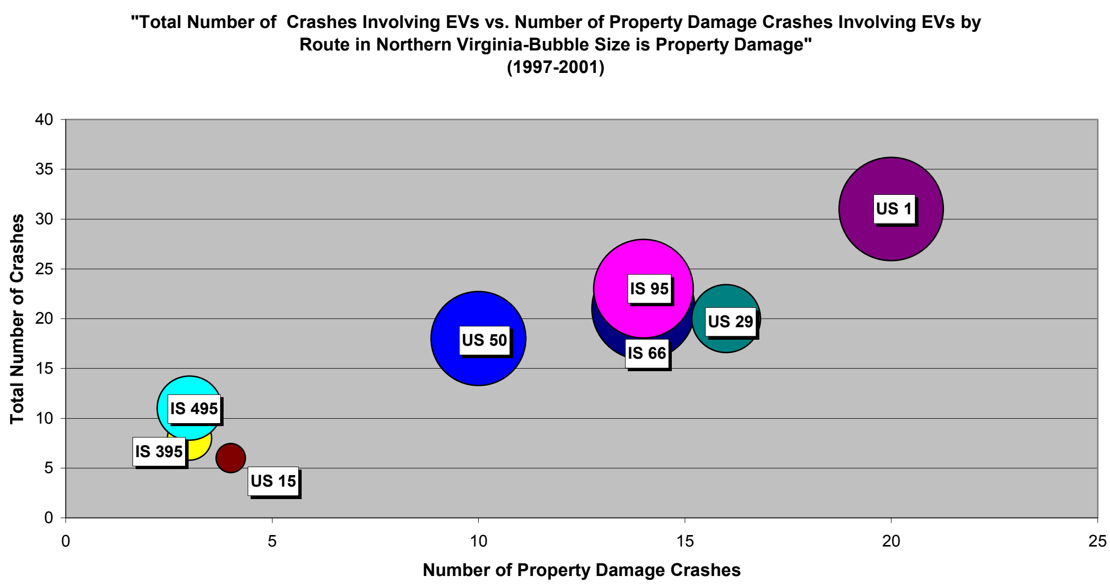


Figure 30: Total number of EV crashes versus property damage crashes involving emergency vehicles by route in Northern Virginia from 1997 to 2001 (Bubble Size is Property Damage Cost).

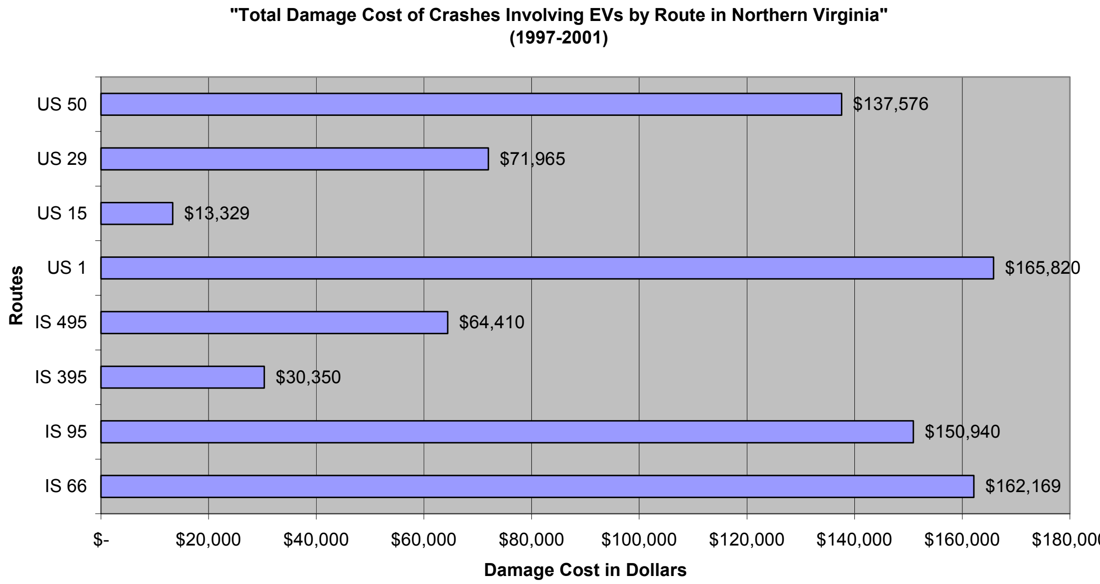


Figure 31: Total damage cost in U.S. dollars by route in Northern Virginia from 1997 to 2001.

By Route and Location Description

The next step of the analysis includes the identification of the crash locations in terms of whether a crash occurred at an intersection or not along each of the eight routes under consideration. The results are presented in Figure 32.

U.S. Highways

U.S. 1: it can be observed that out of the 90 total number of crashes involving EVs that have occurred on U.S. 1, approximately 65% have occurred at intersections. It is indicated that 13 out of the 20 (65%) crashes have occurred at signalized intersections. This suggests that while conventional traffic signals are used to control and guide traffic, they are, in some cases, unsuccessful in preventing accidents involving emergency vehicles from occurring.

U.S. 15*:* for this route 5 out of 6 EV crashes (approximately 83%) have occurred at non-intersection sites. This result could be explained by the fact that U.S. 15 is mostly a rural highway and the crash sites are different compared to the three highways (U.S. 1, U.S. 29 and U.S. 50).

_U.S. 29_: the analysis indicates that 14 out of a total of 20 (70%) crashes involving EVs on U.S. 29 have occurred at intersections, while 5 out of the 14 crashes that have occurred at intersections include crashes at signalized intersections.

_U.S. 50_: 67% (or 12 out of 18) EV crashes include intersection related crashes, while 5 out of the 12 crashes at intersections (approximately 42%) have occurred at signalized intersections. The analysis indicates that U.S. 50 includes the same number of EV crashes at signalized intersections as well as at non-intersection sites (5 crashes).

U.S. Interstates

The interstates by definition do not include intersecting roads for safety reasons. Traffic enters and exits this type of roads through interchanges and ramps. Therefore, the results of the analysis indicate that crashes involving emergency vehicles have occurred either at an interchange or at a non-interchange location along an interstate route. The analysis illustrates that most of the crashes involving EVs have occurred along these routes, while a smallest percentage includes crashes that have occurred at interchanges (approximately 75% and 25%, respectively).

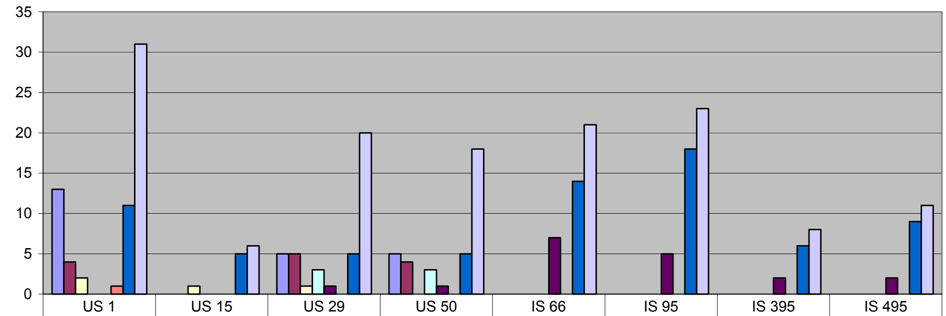
_IS 66_: out of a total number of 21 crashes involving EVs that have occurred on I.S. 66, there were 7 crashes involving EVs at interchanges, while double the number of crashes involving EVs (14 crashes) appear to have occurred along the route.

_IS 95:_ it can be observed that 18 out of a total of 23 crashes involving EVs have occurred along the route (approximately 78%), while the remaining 22% includes crashes at interchanges (5 crashes).

_IS 395:_ out of a total of 8 crashes involving EVs that have occurred on IS 395, 6 appears to have occurred along the route (75%), and the remaining 2 include crashes occurring at an interchange (25%).

IS 495: it is indicated that out of a total of 11 crashes involving EVs, 9 crashes have occurred along the route (82%), and the remaining 2 are crashes that have occurred at interchanges (18%).

"Total Number of Crashes Involving EVs by Type of Crash Site and by Route in Northern Virginia"
(1997-2001)



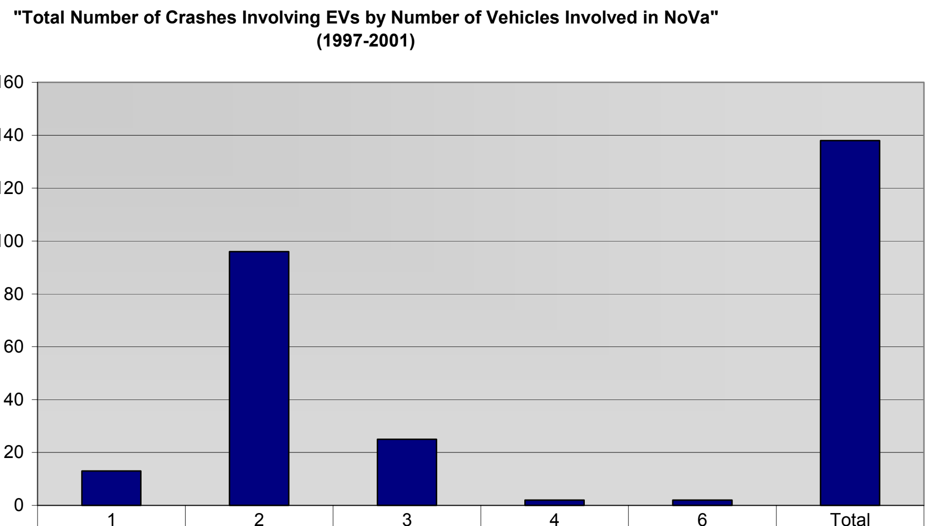
	US 1	US 15	US 29	US 50	IS 66	IS 95	IS 395	IS 495
Signalized Intersection	13	0	5	5	0	0	0	0
"T" Intersection	4	0	5	4	0	0	0	0
Branch Intersection	2	1	1	0	0	0	0	0
Crossing Intersection	0	0	3	3	0	0	0	0
Interchange	0	0	1	1	7	5	2	2
Offset	1	0	0	0	0	0	0	0
Non-Intersection/Interchange	11	5	5	5	14	18	6	9
Total	31	6	20	18	21	23	8	11

Figure 32: Total number of crashes involving emergency vehicles on the U.S. Highways and Interstates by type of crash site in Northern Virginia from 1997 to 2001.

Other Emergency Vehicles' Crash Characteristics

Number of vehicles involved

Figure 33 illustrates the total number of crashes involving emergency vehicles by number of vehicles involved in these crashes in the region. This graph indicates that in 70% of all cases a crash involved two vehicles that have collided (96 crashes). In 18% of all crashes three vehicles were involved (25 crashes), while there were 13 cases where only one vehicle was crashed.



	1	2	3	4	6	Total
Total Number of Crashes	13	96	25	2	2	138

Figure 33: Total number of crashes involving emergency vehicles by number of vehicles involved in Northern Virginia from 1997 to 2001.

Geometric, physical, weather and lighting conditions at the crash sites

Figures B.3-B.9 present some of the geometric characteristics as well as the physical conditions in terms of weather and lighting conditions at the crash sites the time of the crash. It can be observed that 62 EV crashes have occurred at a 4-lane road segment, 27 EV crashes have occurred at a 6-lane road segment, 22 crashes have occurred at a 2-lane road segment, 19 crashes have occurred at a 3-lane road segment, 5 crashes have occurred at a 5-lane road segment and 3 crashes have occurred at a 1-lane road segment (Figure B.3). Figure B.4 indicates that in 45% of all EV crashes (62 out of 138) the facility was divided and there was a full control of access, 28% of all EV crashes (38 out of 138) occurred at divided facilities with no control of access, and in 18% (25 out of 138) of all crashes the facility was divided and had partial control of access. Figure B.5 presents the alignment description at the crash sites, and indicates that in 67% of all EV crashes (93 out of 138) there was a straight level, and in 18% of all EV crashes (25 out of 138) the alignment was straight and upgrade. This is important because it appears that most of the crashes involving emergency vehicles have occurred at a site with a straight level, in which the visibility conditions are usually good. Figure B.6 presents the road conditions at the crash sites, and illustrates that in 93% of all EV crashes (130 out of 138) the road appeared to have no defects. Figure B.7 presents the surface conditions at the crash sites. It can be observed that 79% of all EV crashes (109 out of 138) have occurred on a dry road surface, while a 14% of all EV crashes (20 out of 138) have occurred on a wet surface. The weather conditions at the time of the crashes are presented in Figure B.8, which illustrates that in 67% of all cases (92 out of 138) the weather was clear, while in 20% of all cases (28 out of 138) the weather was cloudy. Figure B.9 presents the lighting conditions at the crash sites. It can be observed that in 54% of all EV crashes (75 out of 138) there was daylight while 43% of all EV crashes (59 out of 138) have occurred in darkness, with 28% of these crashes (38 out of 138) on a the street or a highway that was lighted and 15% not lighted (21 out of 138).

4.2.2 Fairfax County

Data Description

The data set used in this analysis includes all the crashes involving emergency vehicles on U.S. Highways *and* Interstates in Fairfax County for the five year period from 1997 to 2001. It is indicated that the total number of crashes involving EVs has increased in the past few years in Fairfax County (Figure B.10).

Total Number of Crashes by Route

Figure 34 presents the total number of crashes by route in Fairfax County from 1997 to 2001. It can be observed that ¼ of all crashes on the U.S. Highways and Interstates in Fairfax County have occurred on U.S. 1, which includes the highest number of crashes among all routes in Fairfax County under study with a total of 22 out of the 90 crashes (approximately 24%). I.S. 95 follows with a total of 18 crashes (20%) and I.S. 66 with 14 crashes involving emergency vehicles (16%). On U.S. 29 12 crashes involving EVs have been reported in the five year period (13%), while on I.S. 495 11 crashes involving EVs (12%) have occurred and 10 crashes (11.5%) have been reported on U.S. 15. The remaining 3 crashes (3.5%) on Fairfax County's U.S. Highways and Interstates have occurred on I.S. 395 for the five year period. The analysis also illustrates that 51% of EV crashes (46 out of 90) have occurred along the Interstates while the remaining 49% along the U.S. Highways (44 EV crashes).

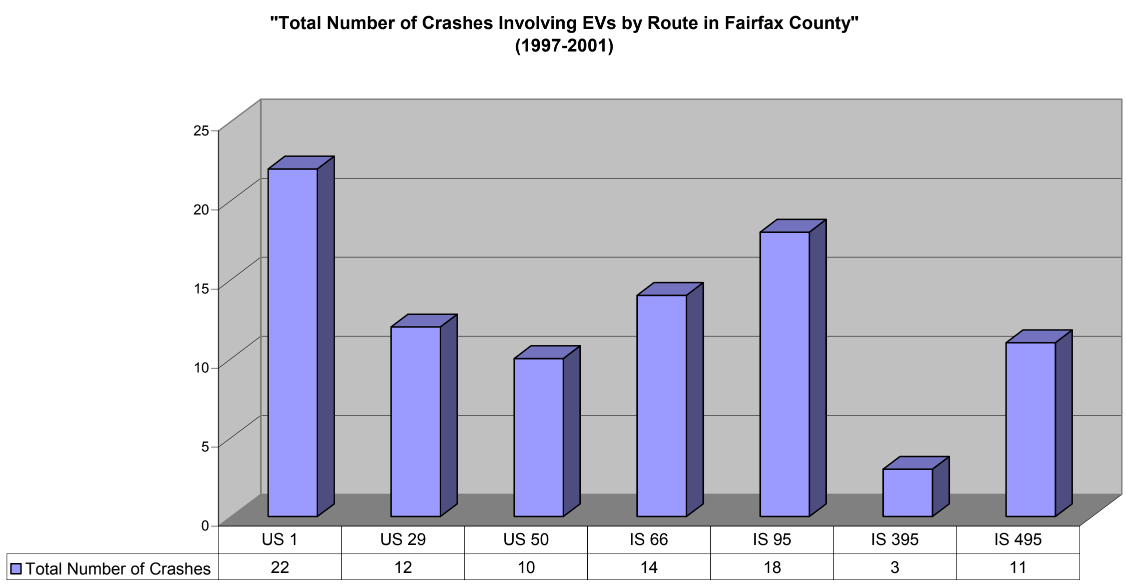


Figure 34: Total number of crashes involving emergency vehicles by route in Fairfax County from 1997 to 2001.

Crash Severity: Type of Crash

It is illustrated that 64% (58 out of 90) of all crashes involving emergency vehicles were property damage only, and 36% (32 out of 90) were injury crashes with no fatalities (Figure B.11), while the total amount of damage cost in Fairfax County for the five year period came up to $528,135. Figure 35 presents the total number of crashes involving emergency vehicles for each of the seven routes under consideration by the two types of crash reported in Fairfax County: *property damage only and injury with no fatalities*. It can be observed that on U.S. 1 16 crashes were property damage only, while the remaining 6 included injury crashes with no fatalities. U.S. 29 and I.S. 66 have, approximately, the same proportion of property damage versus injury crashes like U.S. 1 (75% PD vs. 25% injury crashes), while for I.S. 95 and U.S. 50 the percentage of injury crashes is slightly higher (33-40%, respectively), and for I.S. 395 and 495 the percentage of injury crashes is significantly higher than the one for PD crashes (average of 70%). The reports illustrate that the 90 crashes involving emergency vehicles resulted in 54 injuries and no fatalities on the U.S. Highways and Interstates in Fairfax County.

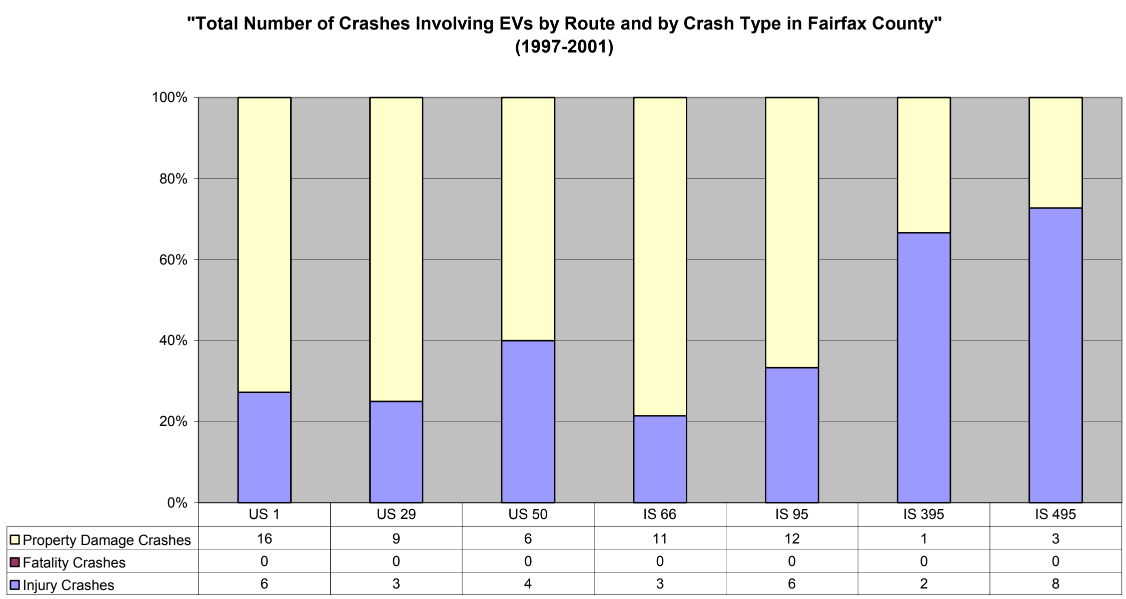


Figure 35: Total number of crashes involving emergency vehicles by type of crash on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001.

Crash Severity: Type of Crash and Damage Cost

Figure 36 presents the total number of crashes involving emergency vehicles versus injury crashes only, involving emergency vehicles, while the bubble size represents the total cost in U.S. dollars of the property damage of all the crashes involving emergency vehicles on the U.S. Highways and Interstates in Fairfax County. Figure 37 presents the total number of crashes involving emergency vehicles versus property damage crashes only, involving emergency vehicles, while the bubble size represents the total cost in U.S. dollars of the property damage of all the crashes involving emergency vehicles on the U.S. Highways and Interstates in Fairfax County. Table A.3 presents the total number of crashes involving EVs by crash type and property damage in Fairfax County. It can be observed that U.S. Route 1 includes the highest number of total crashes (22) as well as injury (16) crashes involving emergency vehicles; while the total damage cost of all the crashes reported on this route is the highest $124,570 (approximately 24% of the total damage amount in the County includes the crashes involving EVs on U.S. Route 1). This is important because U.S. Route 1 presents the worst crash situation in terms of total number of crashes, and property damage crashes and therefore total damage cost in the county, while it is among the three top routes with the highest number of injury crashes (I.S. 495, I.S.95 and U.S. 1) and needs further investigation and analysis. Regarding, the other routes it is indicated that on I.S. 95 12 property damage crashes out of a total of 18 crashes were reported and a damage cost of $109,040, I.S. 66 included 11 property damage crashes, and 3 injury crashes with a total property damage cost of $81,719, on U.S. 50 4 injury and 6 property damage crashes were reported with a total damage cost of $75,716, I.S. 495 included 8 injury and 3 property damage crashes with a total damage cost of $64,410, U.S. 29 included 9 property damage and 3 injury crashes with a total cost of $55,880, and I.S. 395 included 3 crashes (2 injury and 1 PD crashes) and a total cost of $16,800.

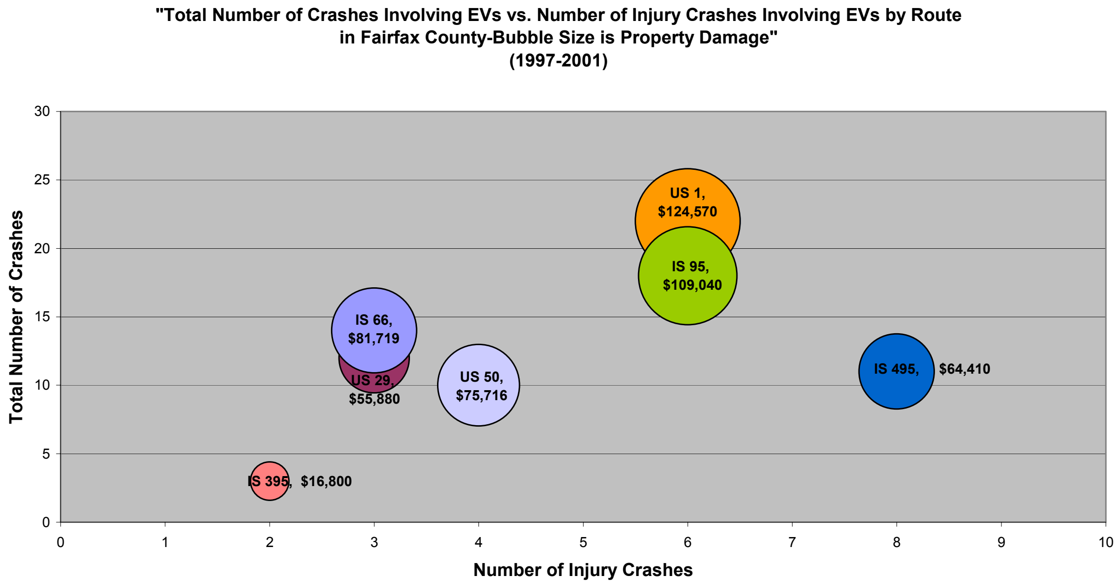


Figure 36: Total number of EV crashes versus injury crashes involving emergency vehicles by route in Fairfax County from 1997 to 2001 (Bubble Size is Property Damage Cost).

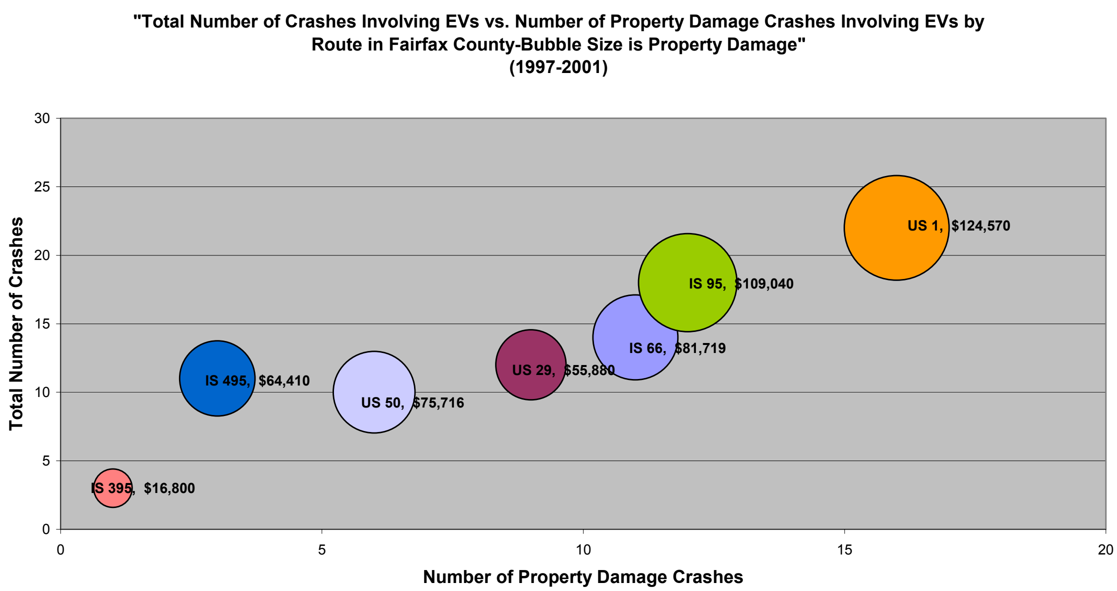


Figure 37: Total number of EV crashes versus property damage crashes involving emergency vehicles by route in Fairfax County from 1997 to 2001 (Bubble Size is Property Damage Cost).

Location Description

Figure 38 presents the proportion of crashes involving EVs in terms of crash site relationship to intersection. It can be observed that 28 crashes have occurred at intersections (31%), while the remaining 62 (69%) include crashes occurring at non-intersection sites. It is important to note that this classification of crashes involving emergency vehicles includes crashes along *both U.S. Highways and Interstates* and this affects the results of the analysis.

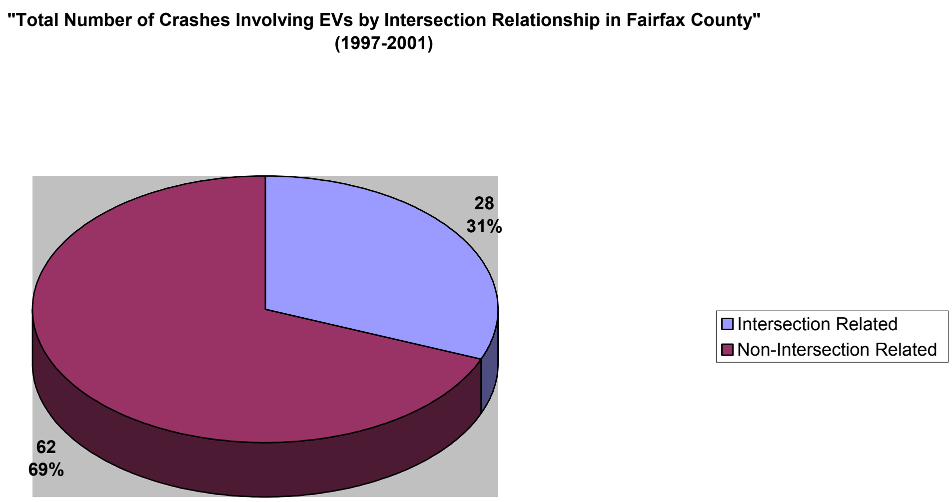


Figure 38: Total number of crashes involving emergency vehicles by intersection relationship in Fairfax County from 1997 to 2001.

Intersection Description

Figure 39 presents the percentages of crashes involving EVs at different intersection types on U.S. Highways in terms of signalization. It can be observed that out of a total of 28 crashes, which have occurred at intersections 21 (75%) have occurred at signalized intersections, while 7 (25%) at non-signalized intersections. This is important to note because it is illustrated that for 75% of the crashes occurring at intersections the presence of a traffic signal was not a significant deterrent factor for the occurrence of traffic accidents involving emergency vehicles. The distribution of crashes among the different type of intersections is presented in Figure 40, where it is indicated that 3 crashes have occurred at a tee ("T") intersection (the "leg" enters between 80 degree and 100 degree angle), 2 in a branch (one leg enters at angle other than "T" angle), and 2 in a crossing (all crossroads at grade regardless of intersecting angle).

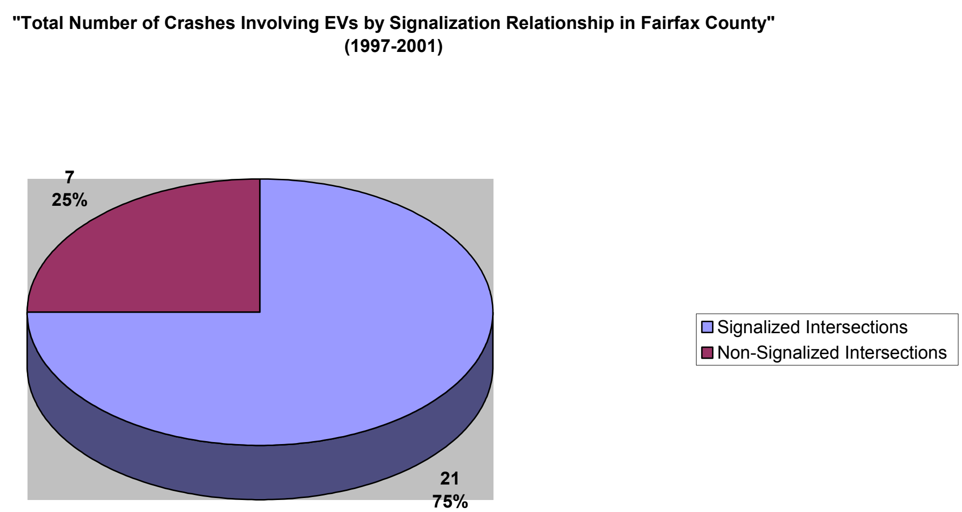


Figure 39: Total number of crashes involving emergency vehicles by signalization relationship on the U.S. Highways in Fairfax County from 1997 to 2001.

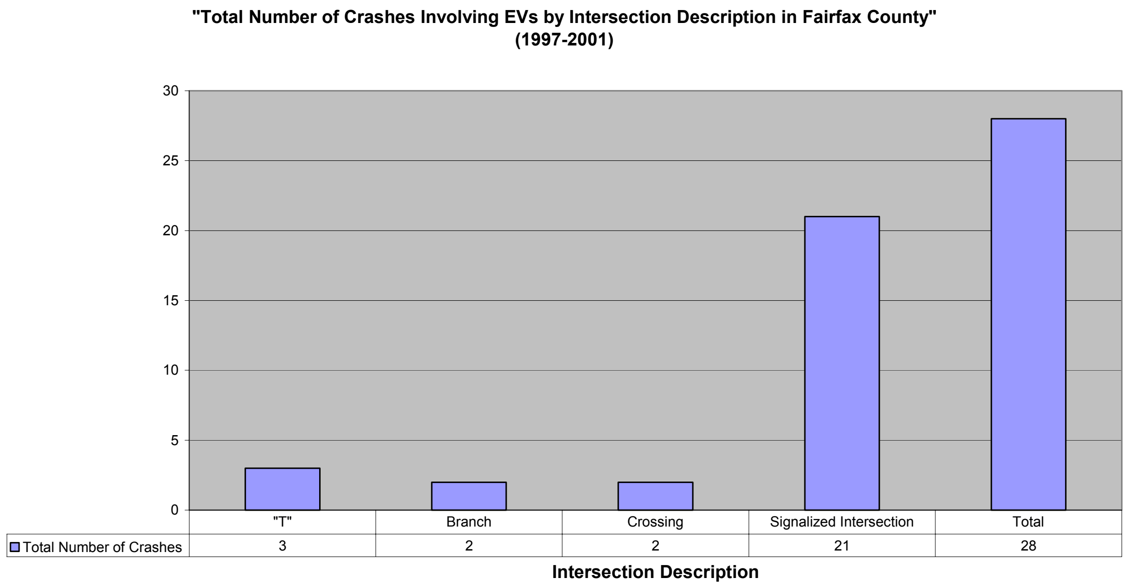


Figure 40: Total number of crashes involving emergency vehicles by intersection description on the U.S. Highways in Fairfax County from 1997 to 2001. [1]

[1] When an intersection is signalized it is defined as "Signalized Intersection". All the other intersection types ("T", branch, crossing and offset) are non-signalized.

By Route and Location Description

Figure 41 presents the total number of crashes involving emergency vehicles along the U.S. Highways and Interstates in Fairfax County.

U.S. Highways

U.S. 1: it can be observed that out of the 22 total number of crashes involving EVs that have occurred on U.S. 1, 14 have occurred at intersections (approximately 64%) and 8 (36%) along the route. Particularly, it is indicated that 11 out of the 14 EV crashes (79%) that have occurred at intersections refer to signalized intersections, which indicates notion traffic signals were unsuccessful in preventing EV accidents.

U.S. 29: the analysis indicates that 8 out of a total of 12 (67%) crashes involving EVs on U.S. 29 have occurred at intersections, while 5 out of the 8 (63%) crashes that have occurred at intersections include crashes at signalized intersections.

U.S. 50: it is illustrated that 6 out of a total of 10 crashes involving EVs (approximately 60% of all cases) include intersection related crashes, while 5 out of the 6 crashes at intersections (approximately 83%) have occurred at signalized intersections.

U.S. Interstates

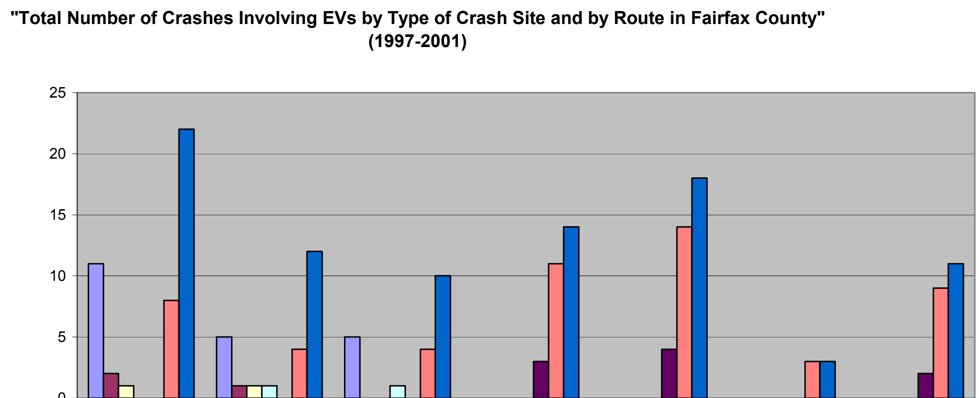
The analysis illustrates that 37 out of 46 EV crashes have occurred along the route at a non-interchange site, while the remaining 9 include EV crashes that have occurred at interchanges (approximately 80% and 20%, respectively).

IS 66: out of a total number of 14 crashes involving EVs that have occurred on I.S. 66, there were 11 crashes involving EVs (79%) that have occurred along the route, while the other 3 (21%) have occurred at interchanges.

IS 95: it can be observed that 14 out of a total of 18 crashes involving EVs have occurred along the route (approximately 78%), while the remaining 4 include crashes at interchanges (22%).

IS 395: it is illustrated all 3 crashes on I.S. 395 have occurred along the route.

IS 495: it is indicated that out of a total of 11 crashes involving EVs, 9 crashes have occurred along the route (82%), and the remaining 2 are crashes that have occurred at interchanges (18%).



	US 1	US 29	US 50	IS 66	IS 95	IS 395	IS 495
Signalized Intersection	11	5	5	0	0	0	0
"T" Intersection	2	1	0	0	0	0	0
Branch Intersection	1	1	0	0	0	0	0
Crossing Intersection	0	1	1	0	0	0	0
Interchange	0	0	0	3	4	0	2
Non-Intersection/Interchange	8	4	4	11	14	3	9
Total	22	12	10	14	18	3	11

Figure 41: Total number of crashes involving emergency vehicles along the U.S. Highways and Interstates by type of crash site in Fairfax County from 1997 to 2001.

Collision Type

Figure 42 presents the total number of crashes involving emergency vehicles by type of collision as reported by the enforcement official. It can be observed that 39 crashes were of rear end type, 23 out of the total of 138 crashes included sideswipe collision, while the vehicles were traveling in the same direction, and in 15 cases the vehicles were collided in an angle. The remaining 13 crashes were reported to have various collision types such as fixed object off road (5 crashes), 1 backed into collision and 1 head on etc. This observation is important because it offers an indication of the reasons that have led to the actual collisions in terms of the vehicles positions while traveling, as well as, the type of maneuvers and actions a driver may choose to perform in case of an emergency vehicle's approach in order to accommodate its passage.

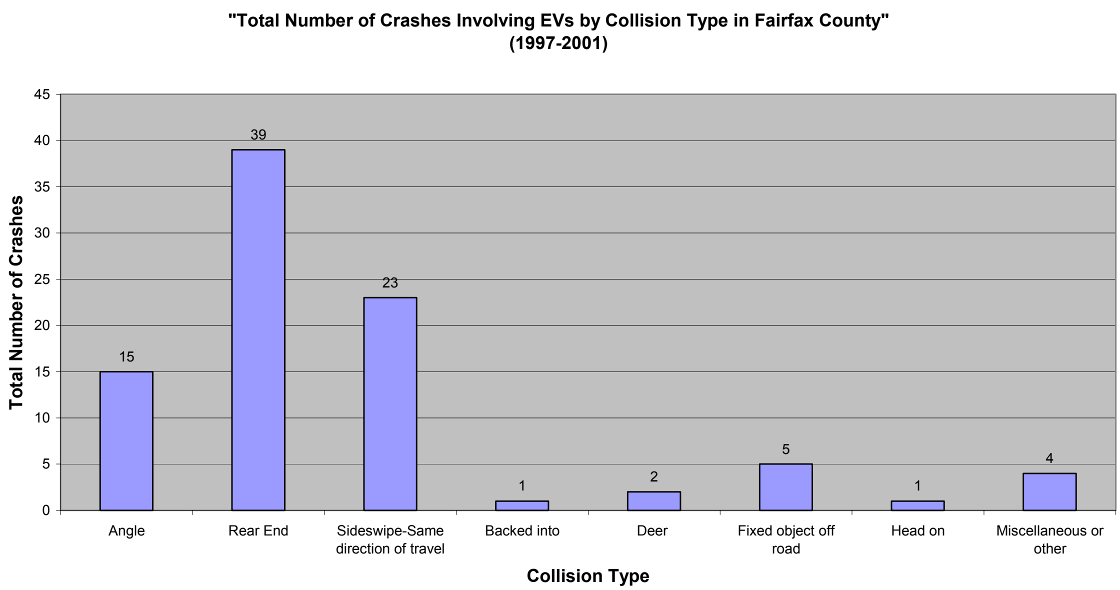


Figure 42: Total number of crashes involving emergency vehicles by collision type in Fairfax County from 1997 to 2001.

Collision Type and Crash Site Type

Table 4 presents the different collision types that are reported in crashes occurring at intersections and at non-intersections on the U.S. Highways in Fairfax County. This classification illustrates that the major collision type of the crashes occurring at intersections is *angle* (39% or 11 out of 28), while for crashes occurring at non-intersection sites the three top collision types are indicated to be *rear end* (38% or 6 out of 16)*, sideswipe* (25% or 4 out of 16) *and angle* (25%). The different type of collisions reported at these two types of crash sites in terms of intersection relationship implies that the vehicles make different maneuvers when they are traveling through an intersection and when approaching a different location far from an intersection. Therefore, it can be concluded that the fact that vehicles collide in an angle when traveling through an intersection indicates that this could be due to the absence of an appropriate warning signal for the perpendicular and opposing traffic streams in order to stop moving, appropriately, when the emergency vehicle makes a turn or clears the intersection and thus interferes with the opposing traffic with a risk of collision (Figure B.2).

TABLE 4

Total number of crashes involving EVs by crash site and collision type along the U.S. Highways in Fairfax County (1997-2001)

	Crash Site Type	
Collision Type	**Intersections**	**Non-Int/ions**
Angle	11	4
Rear End	9	6
Head on	1	0
Sideswipe-Same direction of travel	6	4
Other	1	2
Total	**28**	**16**

Major Factor Description

Figure 43 presents the total number of crashes involving emergency vehicles by major factor description as reported by the enforcement official. It can be observed that in 82% of all cases the road user appears to have the major responsibility of the traffic accidents occurrence and particularly 64 out of a total of 90 crashes (71%) are indicated to have occurred due to driver's or pedestrian's inattention or error, in 5 cases (6%) the road user (driver or pedestrian) was found under the influence of alcohol, drugs, or other agents, and 5 crashes (6%) occurred due to driver's speed. The remaining 16 crashes were reported to have different causes.

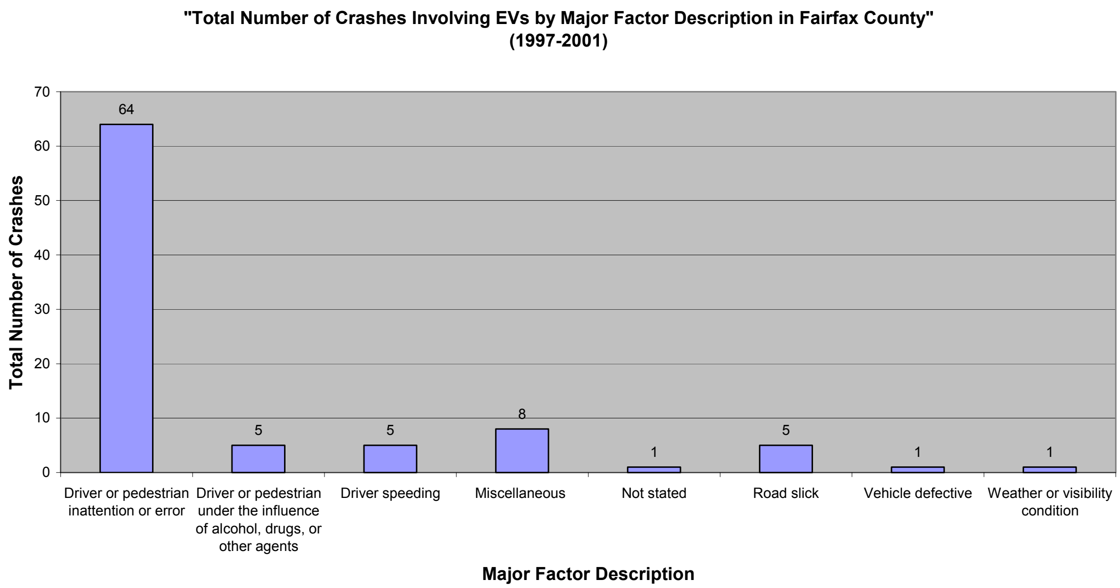


Figure 43: Total number of crashes involving emergency vehicles by major factor description in Fairfax County from 1997 to 2001.

Other Emergency Vehicles' Crash Characteristics

Number of vehicles involved

Figure 44 presents the total number of crashes involving emergency vehicles by number of vehicles involved in these crashes in the region. This graph indicates that in 68% of all cases a crash involved two vehicles that have collided (61 crashes). In 24% of all crashes three vehicles were involved (22 crashes), while there were 4 cases where only one vehicle was crashed.

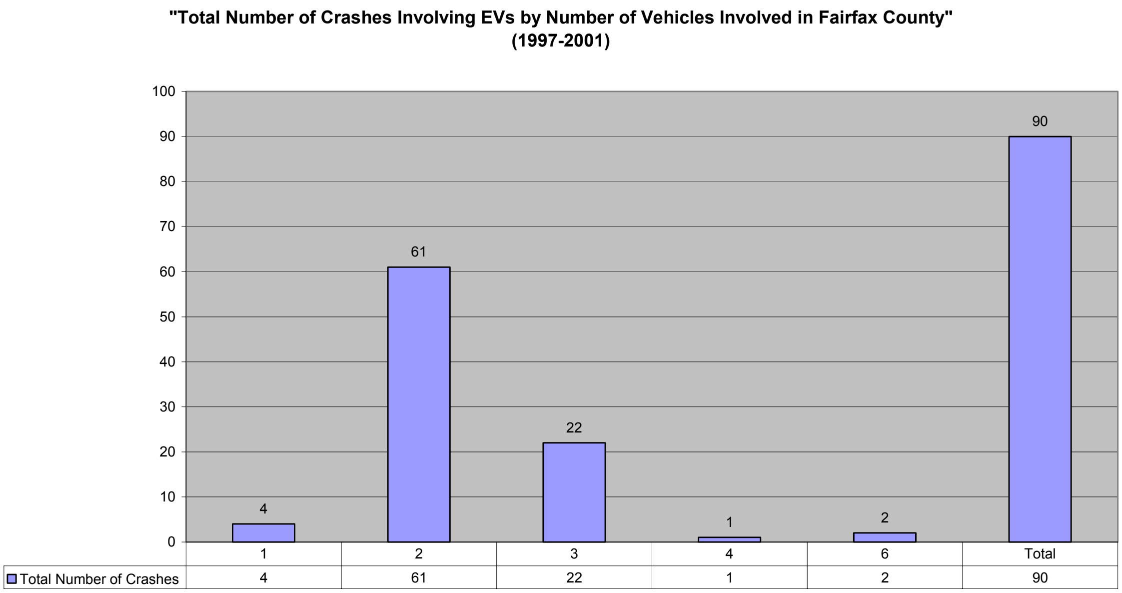


Figure 44: Total number of crashes involving emergency vehicles by number of vehicles involved in Fairfax County from 1997 to 2001.

Geometric, physical, weather and lighting conditions at the crash sites

Figures B.12-B.18 present some of the geometric characteristics as well as the physical conditions, in terms of weather and lighting conditions, at the crash sites the time of the crash. It can be observed that 46 crashes have occurred at a 4-lane road segment, 20 crashes have occurred at a 6-lane road segment, 13 crashes have occurred at a 3-lane road segment, 5 crashes have occurred at a 5-lane road segment, 3 crashes have occurred at a 2-lane road segment and 3 crashes have occurred at a 1-lane road segment (Figure B.12). Figure B.13 indicates that in 49% of all EV crashes (43 out of 90) the facility was divided and there was a full control of access, 32% of all EV crashes (29 out of 90) occurred at divided facilities with no control of access, and in 11% of all EV crashes (10 out of 90) the facility was two way and non-divided. Figure B.14 presents the alignment description at the crash sites, and indicates that in 66% of all EV crashes (59 out of 90) there was a straight level, and in 21% of all EV crashes (19 out of 90) the alignment was straight and upgrade. Figure B.15 presents the road conditions at the crash sites, and illustrates that in 96% of all EV crashes (86 out of 90) the road appeared to have no defects. Figure B.16 presents the surface conditions at the crash sites. It can be observed that 81% of EV all crashes (72 out of 90) have occurred on a dry road surface, while a 13% of all EV crashes (12 out of 90) have occurred on a wet surface. The weather conditions at the time of the crashes are presented in Figure B.17, which illustrates that in 67% of all cases (60 out of 90) the weather was clear, while in 19% of all cases (17 out of 90) the weather was cloudy. Figure B.18 presents the lighting conditions at the crash sites. It can be observed that in 52% of all EV crashes (46 out of 90) there was daylight while 46% of all EV crashes (42 out of 90) have occurred in darkness, with 32% of these crashes (29 out of 900 on a the street or a highway that was lighted and 14% (13 crashes) not lighted.

4.2.3 U.S. Route 1 in Fairfax County

The previous analysis illustrated that 22 crashes involving emergency vehicles including 14 crashes at intersections (64%) and the remaining 8 at non-intersection sites (36%) were reported on U.S. 1 in Fairfax County. Out of the 14 EV crashes at intersections, 11 occurred at signalized intersections (79%), while the remaining 3 included crashes at non-signalized intersections (21%) (Figure B.19). The 22 crashes included 6 injury crashes, which resulted in 9 injuries with no fatalities and 16 property damage only crashes with no injuries and fatalities and cost $124,570 (24% of the total damage cost on the U.S. Highways and Interstates in Fairfax County).

Crash Severity: Type of Crash and Damage Cost

Figures 45 and 46 present the total number of crashes involving EVs versus the injury crashes and the property damage crashes involving EVs respectively at intersections and not intersections. It can be observed that crash severity in terms of injury EV crashes, property damage EV crashes and damage cost is higher at intersections than at crash sites, which are not intersections. This is important to note because it indicates that intersection-related crashes involve a higher cost and any decrease in the number of crashes at intersections would include significant financial benefits for the County. The geometric design characteristics of each intersection need further analysis and any recommendation for safety improvements should result from the evaluation of the crash site.

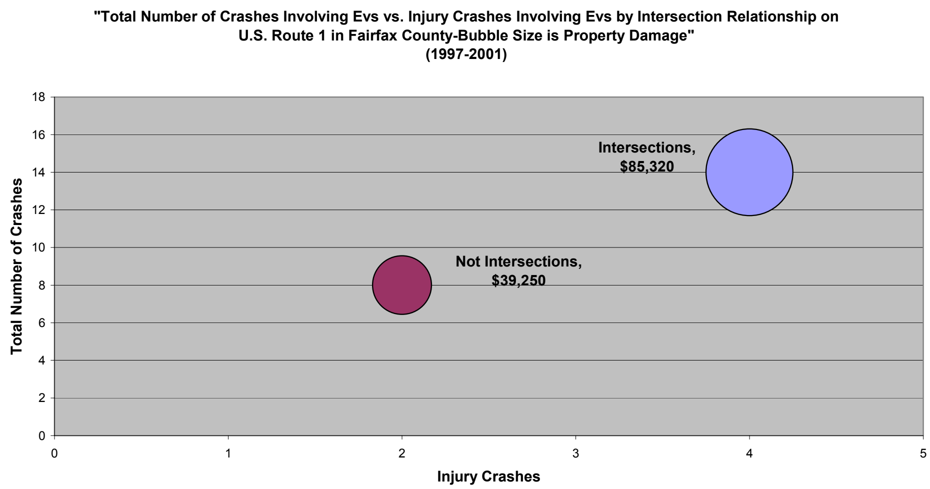


Figure 45: Total number of EV crashes versus injury crashes involving emergency vehicles on U.S. Route 1 in Fairfax County from 1997 to 2001 (Bubble Size is Property Damage Cost).

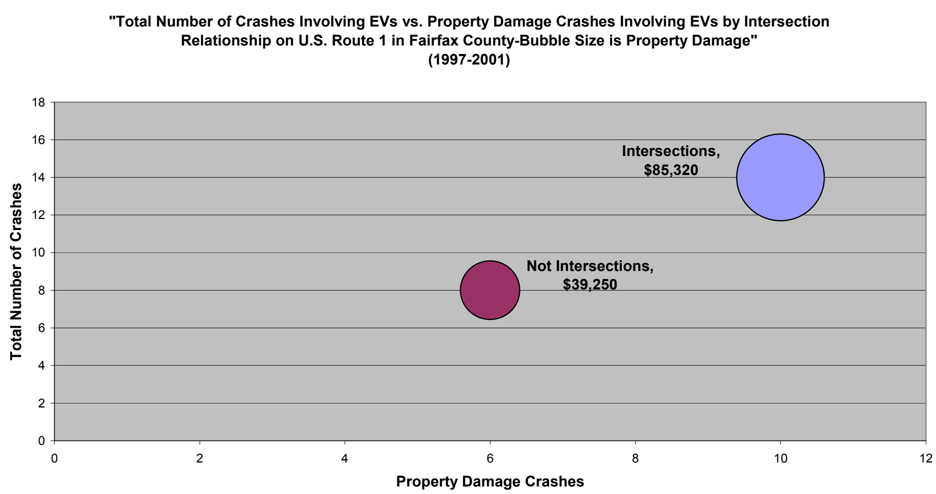


Figure 46: Total number of EV crashes versus property damage crashes involving emergency vehicles on U.S. Route 1 in Fairfax County from 1997 to 2001 (Bubble Size is Property Damage Cost).

Collision Type

Figure 47 presents the total number of crashes involving emergency vehicles by type of collision as reported by the enforcement official. It can be observed that 9 out of 22 EV crashes were of angle type (41%), in 7 EV crashes the collision type was rear end (32%), 4 out of the total of 22 crashes included sideswipe collision (18%), while the vehicles were traveling in the same direction, 1 backed into crash and 1 crash with a different collision type (9% both).

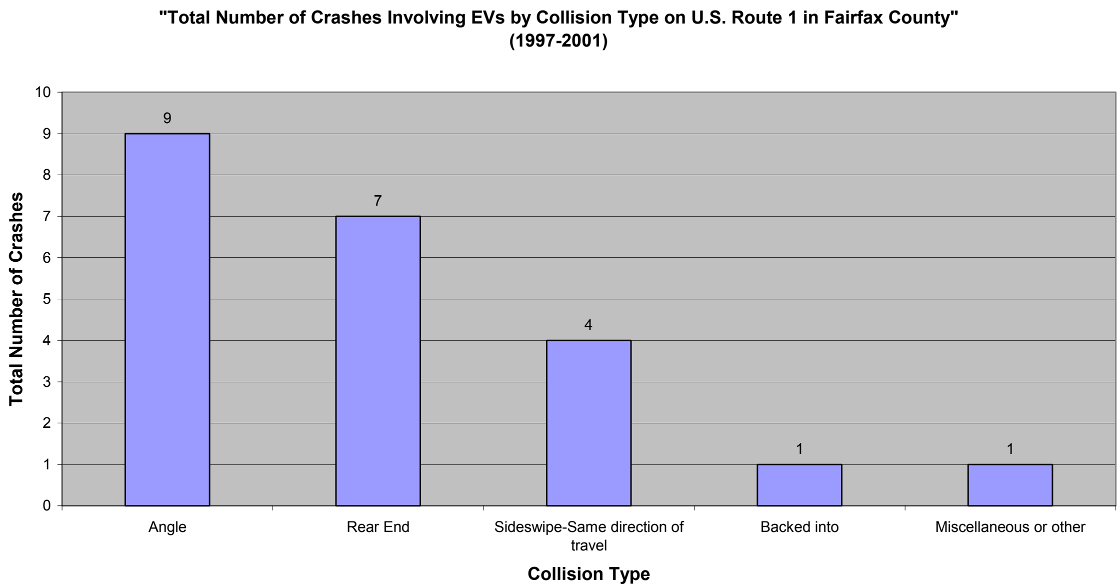


Figure 47: Total number of crashes involving emergency vehicles by collision type on U.S. Route 1 in Fairfax County from 1997 to 2001.

Collision Type and Crash Site Type

Table 5 presents the different collision types that are reported in crashes occurring at intersections and at non-intersections on U.S. 1 in Fairfax County. This classification illustrates that the two major collision types of EV crashes occurring at intersections is *angle* (43%) and *rear end* (43%), while for crashes occurring at non-intersection sites the two top collision types are indicated to be *sideswipe* (38%) *and angle* (38%). The different type of collisions reported at these two types of crash sites in terms of intersection relationship implies that the vehicles make different maneuvers when they are traveling through an intersection and when approaching a different location far from an intersection. Therefore, it can be concluded that the fact that vehicles collide in an angle when traveling through an intersection indicates that this could be due to the absence of an appropriate warning signal for the perpendicular and opposing traffic streams in order to stop moving, appropriately, when the emergency vehicle makes a turn or clears the intersection and thus interferes with the opposing traffic with a risk of collision (Figure B.2).

TABLE 5

Total number of crashes involving EVs by crash site and collision type along U.S. 1 in Fairfax County (1997-2001)

	Crash Site Type	
Collision Type	**Intersections**	**Non-Int/ions**
Angle	6	3
Rear End	6	1
Head on	0	0
Sideswipe-Same direction of travel	1	3
Other	1	1
Total	**14**	**8**

Major Factor Description

Figure 48 presents the total number of crashes involving emergency vehicles by major factor description as reported by the enforcement official. It can be observed that in 82% of all cases the road user appears to have the major responsibility of the traffic accidents occurrence and particularly 16 out of a total of 22 crashes (73%) are indicated to have occurred due to driver's or pedestrian's inattention or error, in 1 case (5%) the road user (driver or pedestrian) was found under the influence of alcohol, drugs, or other agents, and 1 crash (5%) occurred due to driver's speed. The remaining 4 crashes were reported to have different causes.

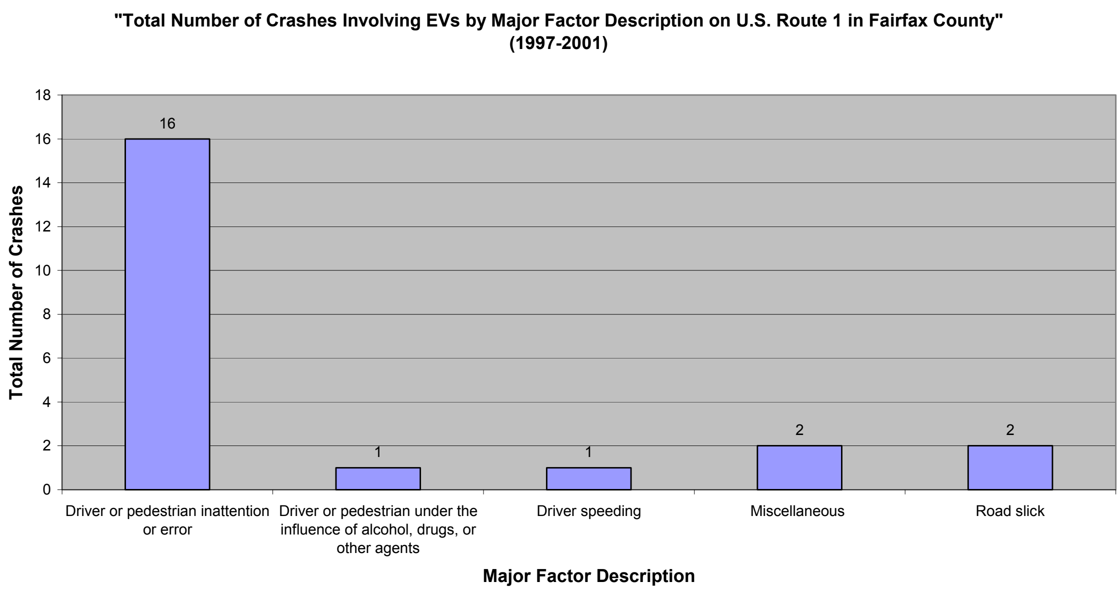


Figure 48: Total number of crashes involving emergency vehicles by major factor description on U.S. Route 1 in Fairfax County from 1997 to 2001.

Other Emergency Vehicles' Crash Characteristics

Number of vehicles involved

Figure 49 presents the total number of crashes involving emergency vehicles by number of vehicles involved in these crashes in the region. This graph indicates that in 86% of all cases a crash involved two vehicles that have collided (19 crashes) and the remaining 14% includes crashes where three vehicles were involved (3 crashes).

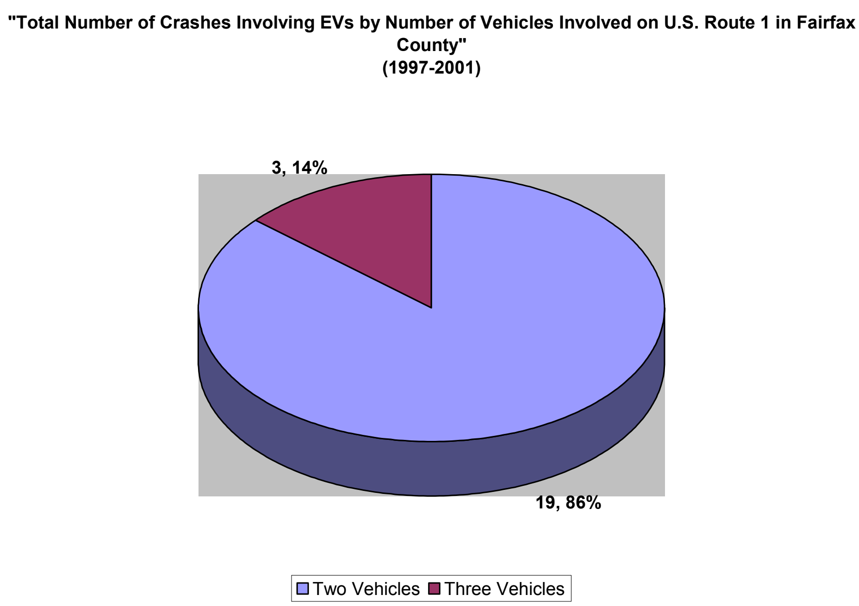


Figure 49: Total number of crashes involving emergency vehicles by number of vehicles involved on U.S. Route 1 in Fairfax County from 1997 to 2001.

Geometric, physical, weather and lighting conditions at the crash sites

Figures B.20- B.25 present some of the geometric characteristics as well as the physical conditions, in terms of weather and lighting conditions, at the crash sites the time of the crash. It can be observed that 11 crashes have occurred on a 6-lane road segment, 9 crashes have occurred on a 4-lane road segment, and 2 crashes have occurred on a 5-lane road segment (Figure B.20). Figure B.21 indicates that in 64% of all EV crashes (14 out of 22) the facility was divided and there was no control of access, while the remaining 36% includes EV crashes (8 out of 22) that have occurred at a facility, which was two way and non-divided. Figure B.22 presents the alignment description at the crash sites, and indicates that in 54% of all EV crashes (12 out of 22) there was a straight level, and in 27% of all EV crashes (6 out of 22) the alignment was straight and upgrade. In 21 out of the 22 (95%) crashes the road had no defects. Figure B.23 presents the surface conditions at the crash sites. It can be observed that 72% of all EV crashes (16 out of 22) have occurred on a dry road surface, while a 14% of all EV crashes (3 out of 22) have occurred on a wet surface and 9% on a snowy surface (2 crashes). The weather conditions at the time of the crashes are presented in Figure B.24, which illustrates that in 54% of EV all cases (12 out of 22) the weather was clear, while in 23% of all cases (5 out of 22) the weather was cloudy. Figure B.25 presents the lighting conditions at the crash sites. It can be observed that in 45% of all EV crashes there was daylight (10 out of 22) while 54% of all EV crashes (12 out of 22) have occurred in darkness on a street or a highway that was lighted or not.

4.3. COMPARISON TABLES

This paragraph includes the presentation of tabulated data counts as well as percentages of total number of crashes involving EVs by area under study and by highway facility type (U.S. Highways and Interstates) in terms of collision type and crash severity in comparison tables. This summary of the major findings of the previous analysis will facilitate in the identification of any differences in the crash situation involving EVs by geographic location and by highway facility type. It can be observed that:

- The major collision type for EV crashes along the U.S. Highways and Interstates in Northern Virginia and Fairfax County is *rear end* (39.5%) and *angle* on U.S. 1 (41%) (Table 6).
- The major collision type for EV crashes along 3 out of the 4 Interstates (IS 66, 95 and 495) is *rear end* (52%), while on IS 395 is *sideswipe (same direction of travel)* (63%) (Table 7).
- The major collision type for EV crashes on U.S.1 and U.S.29 is *angle* (42%), on U.S.15 is 50% *sideswipe* and 50% *rear end*, and on U.S.50 *rear end* (33%) (Table 8). U.S. 1, 29 and 50 have similar design and operational characteristics while U.S. 15 is mostly a rural highway with different traffic operations.

- Approximately 66% of all EV crashes are *property damage only* in the region, county and route level (Table 9).
- On I.S.66 and I.S.95 64% of all crashes involving EVs is *property damage only*, while on I.S.395 and I.S.495 68% of all EV crashes resulted in 1 or more injuries with no fatalities (Table 10).
- On the U.S. Highways 67% of all EV crashes is *property damage only* (Table 11).

Table 6 presents the difference of EV crashes in collision type along the U.S. Highways and Interstates in the region, Fairfax County and on U.S. 1 in the County. The statistical independence between the geographic area and collision type is presented in Appendix F (Table F.4). We cannot find any statistical difference between the different areas and the collision types of EV crashes. This result could be due to the fact that the observed counts of EV crashes reported in the region for the five year period are well distributed among the classification categories and in the 0.05 level of significance result in no statistical difference. The three geographic areas share also the same roadway characteristics since Fairfax County is included in Northern Virginia and U.S. 1 is obtained in Fairfax County.

TABLE 6

Total number of crashes involving emergency vehicles by collision type along the U.S. Highways and Interstates in the region, the County of Fairfax and on U.S. 1 in Fairfax County from 1997 to 2001

	Area		
Collision Type	**Region**	**County**	**U.S. 1**
Angle	25 *(18%)*	15 *(17%)*	9 *(41%)*
Rear End	51 *(36%)*	39 *(43%)*	7 *(32%)*
Sideswipe-Same direction of travel	38 *(28%)*	23 *(26%)*	4 *(18%)*
Backed into	3 *(2%)*	1 *(1%)*	1 *(4.5%)*
Deer	4 *(3%)*	2 *(2%)*	0 *(0%)*
Fixed object in road	2 *(1%)*	0 *(0%)*	0 *(0%)*
Fixed object off road	8 *(6%)*	5 *(6%)*	0 *(0%)*
Head on	1 *(1%)*	1 *(1%)*	0 *(0%)*
Miscellaneous or other	4 *(3%)*	4 *(4%)*	1 *(4.5%)*
Non-Collision	1 *(1%)*	0 *(0%)*	0 *(0%)*
Pedestrian	1 *(1%)*	0 *(0%)*	0 *(0%)*
Total Number of Crashes	***138***	***90***	***22***

Table 7 presents the difference of EV crashes in collision type for EV crashes along the U.S. Interstates in Northern Virginia.

TABLE 7

Total number of crashes involving emergency vehicles by collision type along the Interstates in Northern Virginia from 1997 to 2001

	Interstate ID			
Collision Type	**IS 66**	**IS 95**	**IS 395**	**IS 495**
Angle	1 (4.8%)	0 (0%)	0 (0%)	0 (0%)
Rear End	10 (48%)	12 (52%)	2 (25%)	6 (55%)
Sideswipe-Same direction of travel	6 (28%)	5 (22%)	5 (63%)	3 (27%)
Backed into	0 (0%)	1 (4.3%)	1 (12%)	0 (0%)
Deer	1 (4.8%)	1 (4.3%)	0 (0%)	0 (0%)
Fixed object in road	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Fixed object off road	2 (9.6%)	3 (13%)	0 (0%)	1 (9%)
Head on	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Miscellaneous or other	1 (4.8%)	1 (4.3%)	0 (0%)	1 (9%)
Non-Collision	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Pedestrian	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total Number of Crashes	***21***	***23***	***8***	***11***

Table 8 presents the difference of EV crashes in collision type along the U.S. Highways in Northern Virginia. The statistical independence between the Highway ID and collision type can be obtained with the Chi-Square statistical test presented in Appendix F (Table F.5). The analysis indicates that along the three U.S. Highways (U.S. 1, 29 and 50) that share similar roadway and operational characteristics EV crashes have no significant differences in their type of collision. U.S. 15 is excluded from the analysis since it is mostly a rural highway with different roadway design and operational performance. The analysis illustrates that the highway ID and the collision type are statistically independent. Therefore, even though the analysis illustrates U.S. 1 includes the highest number of angle type EV crashes no conclusions can be drawn regarding a crash of a specific collision type and the route at which it occurred.

TABLE 8

Total number of crashes involving emergency vehicles by collision type along the U.S. Highways in Northern Virginia from 1997 to 2001

	U.S. Highway ID			
Collision Type	**US 1**	**US 15**	**US 29**	**US 50**
Angle	12 (39%)	0 (0%)	9 (45%)	3 (17%)
Rear End	7 (23%)	3 (50%)	5 (25%)	6 (33%)
Sideswipe-Same direction of travel	8 (26%)	3 (50%)	3 (15%)	5 (28%)
Backed into	1 (3%)	0 (0%)	0 (0%)	0 (0%)
Deer	0 (0%)	0 (0%)	1 (5%)	1 (5.5%)
Fixed object in road	1 (3%)	0 (0%)	1 (5%)	0 (0%)
Fixed object off road	0 (0%)	0 (0%)	1 (5%)	1 (5.5%)
Head on	0 (0%)	0 (0%)	0 (0%)	1 (5.5%)
Miscellaneous or other	1 (3%)	0 (0%)	0 (0%)	0 (0%)
Non-Collision	0 (0%)	0 (0%)	0 (0%)	1 (5.5%)
Pedestrian	1 (3%)	0 (0%)	0 (0%)	0 (0%)
Total Number of Crashes	***31***	***6***	***20***	***18***

Table 9 presents the difference of EV crashes in crash severity along the U.S. Highways and Interstates in the region, Fairfax County and on U.S. 1 in the County. The statistical independence between the geographic area and the crash severity is studied with the use of the Chi-Square statistical test in Appendix F (Table F.6). The analysis illustrates that we cannot find any statistical difference between the different geographic areas and the crash severity. This result can be explained as previously.

TABLE 9

Total number of crashes involving emergency vehicles by crash severity along the U.S. Highways and Interstates in the region, the County of Fairfax and on U.S. 1 in Fairfax County from 1997 to 2001

	Area		
Crash Severity	**Region**	**County**	**U.S. 1**
Injury Crashes	52 (38%)	32 (36%)	6 (27%)
Fatality Crashes	2 (1%)	0 (0%)	0 (0%)
Property Damage Crashes	84 (61%)	58 (64%)	16 (73%)
Total Number of Crashes	***138***	***90***	***22***

Table 10 presents the difference of EV crashes in crash severity along the Interstates in Northern Virginia.

TABLE 10

Total number of crashes involving emergency vehicles by crash severity along the Interstates in Northern Virginia from 1997 to 2001

	Interstate ID			
Crash Severity	**IS 66**	**IS 95**	**IS 395**	**IS 495**
Injury Crashes	6 (29%)	9 (39%)	5 (63%)	8 (73%)
Fatality Crashes	1 (5%)	0 (0%)	0 (0%)	0 (0%)
Property Damage Crashes	14 (66%)	14 (61%)	3 (37%)	3 (27%)
Total Number of Crashes	***21***	***23***	***8***	***11***

Table 11 presents the difference of EV crashes in crash severity along the U.S. Highways in Northern Virginia.

TABLE 11

Total number of crashes involving emergency vehicles by crash severity along the U.S. Highways in Northern Virginia from 1997 to 2001

	U.S. Highway ID			
Crash Severity	**US 1**	**US 15**	**US 29**	**US 50**
Injury Crashes	10 (32%)	2 (33%)	4 (20%)	8 (44%)
Fatality Crashes	1 (3%)	0 (0%)	0 (0%)	0 (0%)
Property Damage Crashes	20 (65%)	4 (67%)	16 (80%)	10 (56%)
Total Number of Crashes	***31***	***6***	***20***	***18***

The statistical difference between the route highway facility type (U.S. Highways and Interstates) and the crash severity is studied with the Chi-Square statistical test in Appendix F (Table F.7). The analysis illustrates that there is no statistical difference between the different highway facility types and the crash severity. On both U.S. Highways and Interstates in Northern Virginia the highest percentage of EV crashes are property damage only without injuries, and therefore the highway classification type plays no significant role to the identification of the severity of crashes. This means that we cannot draw any conclusions regarding the severity of a crash if the functional class at which the crash occurred is known.

The Chi-Square statistical test is also applied to test whether the crash site type and the lighting conditions along the U.S. Highways in Northern Virginia are statistically independent (Table F.8). The statistical independence of the alignment and the lighting conditions for EV crashes along the Interstates in the region is also studied with the application of the same statistical test (Table F.9). The analysis illustrates that no significant difference exists between the classification categories for both the U.S. Highways and Interstates in Northern Virginia. It is indicated that for both intersections and non-intersections along the U.S. Highways in Northern Virginia the number of crashes occurring during daylight is greater than EV crashes occurring at night. This result could be due to the fact that during the day the traffic volumes on the U.S. Highways are heavier and thus, the challenges the emergency vehicles face in order to reach their destination become greater. It can also be observed that the number of EV crashes at intersections is higher than those at not intersections for day and night.

4.4 GIS Maps

Figures 50-59 present the crash situation involving emergency vehicles along the U.S. Highways and Interstates in Northern Virginia as well as on U.S. Route 1 in Fairfax County (a better view of the maps without the tables of contents is provided in Appendix D).

4.4.1 Fairfax County

Intersection Relationship

In Figure 50 the crashes involving EVs are classified by their crash sites' relationship to intersections on the U.S. Highways and Interstates in Fairfax County for the five year period (1997-2001). The "cross" symbol indicates all EV crashes that have occurred at *intersections* (signalized, "T", branch, crossing and offset), while the "pin" symbol includes all the crashes involving EVs that have occurred at *non-intersections* (interchange or along the route). It can be observed that along the U.S. Highways the crash sites are mostly intersections while northbound of U.S. 1 presents the highest number of intersection related EV crashes. Along the Interstates EV crashes are reported either at interchanges or along the route.

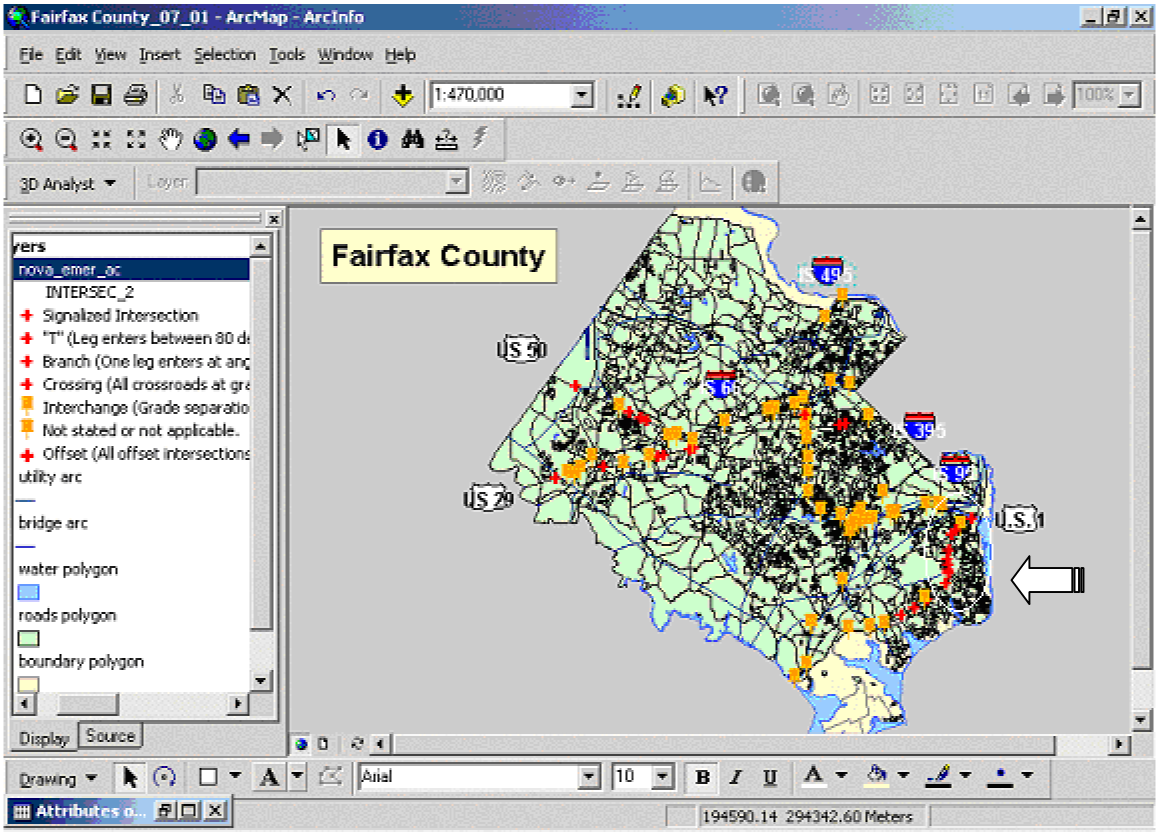


Figure 50: Total number of crashes involving EVs by intersection relationship on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

Location Description

Figure 51 presents the crashes involving EVs by location description along the U.S. Highways and Interstates in Fairfax County (signalized intersections, “T”, branch, crossing, offset, interchange and along the route). The “cross” symbol includes EV crashes at *signalized intersections*, while the *other* crash sites are indicated by different colors of the “cycle” symbol. The graphical presentation illustrates that U.S. 1 presents a significant number of EV crashes at signalized intersections compared to other routes and different crash site types.

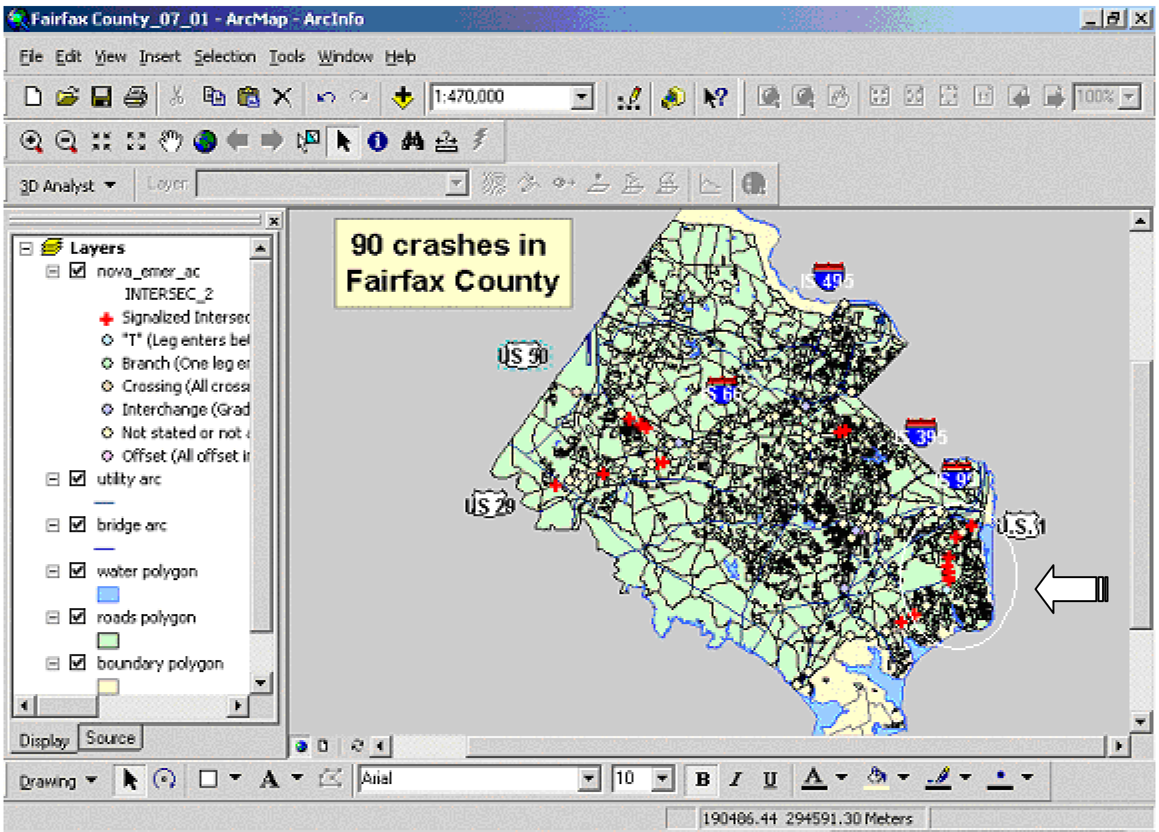


Figure 51: Total number of crashes involving EVs by location description in terms of signalization on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

Signalization at Intersections along the U.S. Highways

In Figure 52 the 28 crashes involving EVs that have occurred *only* at the *intersections* on the *U.S. Highways* in Fairfax County are presented. The "star" symbol includes the 21 EV crashes occurring at *signalized* intersections, while the remaining 16 EV crashes at different intersection types are indicated by the same color of the "cycle" symbol.

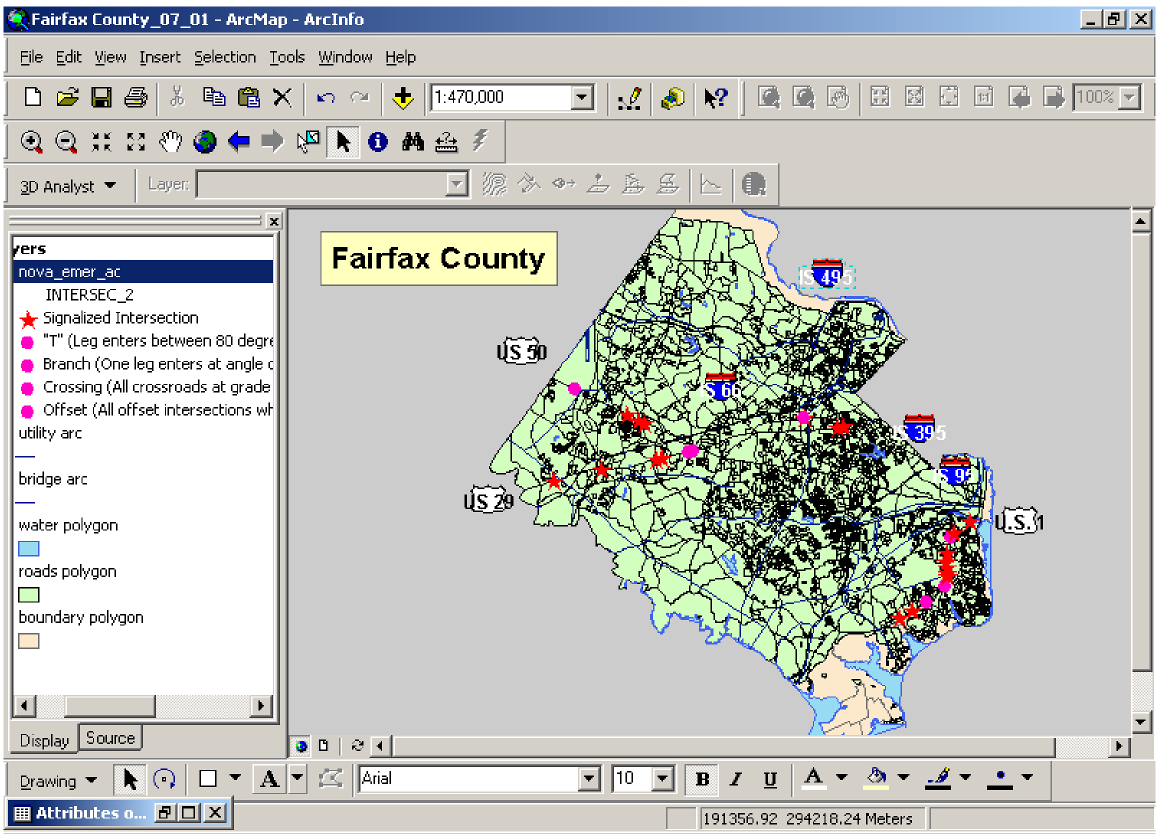


Figure 52: Total number of crashes involving EVs at *intersections* in terms of signalization on the U.S. Highways in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

Collision Type

Figure 53 presents the total number of EV crashes along the U.S. Highways and Interstates in Fairfax County by the three top collision types reported and illustrated from the previous analysis using the Excel spreadsheet. The different colors of the "cycle" symbol indicate the three different collision types (angle, rear end and sideswipe-same direction of travel). It can be observed that on U.S. 1 9 out of 22 EV crashes were of angle type (41%) (red "cycle") while 7 out of 22 of rear end (32%) (blue "cycle").Along the Interstates sideswipe and rear end are the two collision types that were most frequently reported (yellow and pink "cycle" symbols).

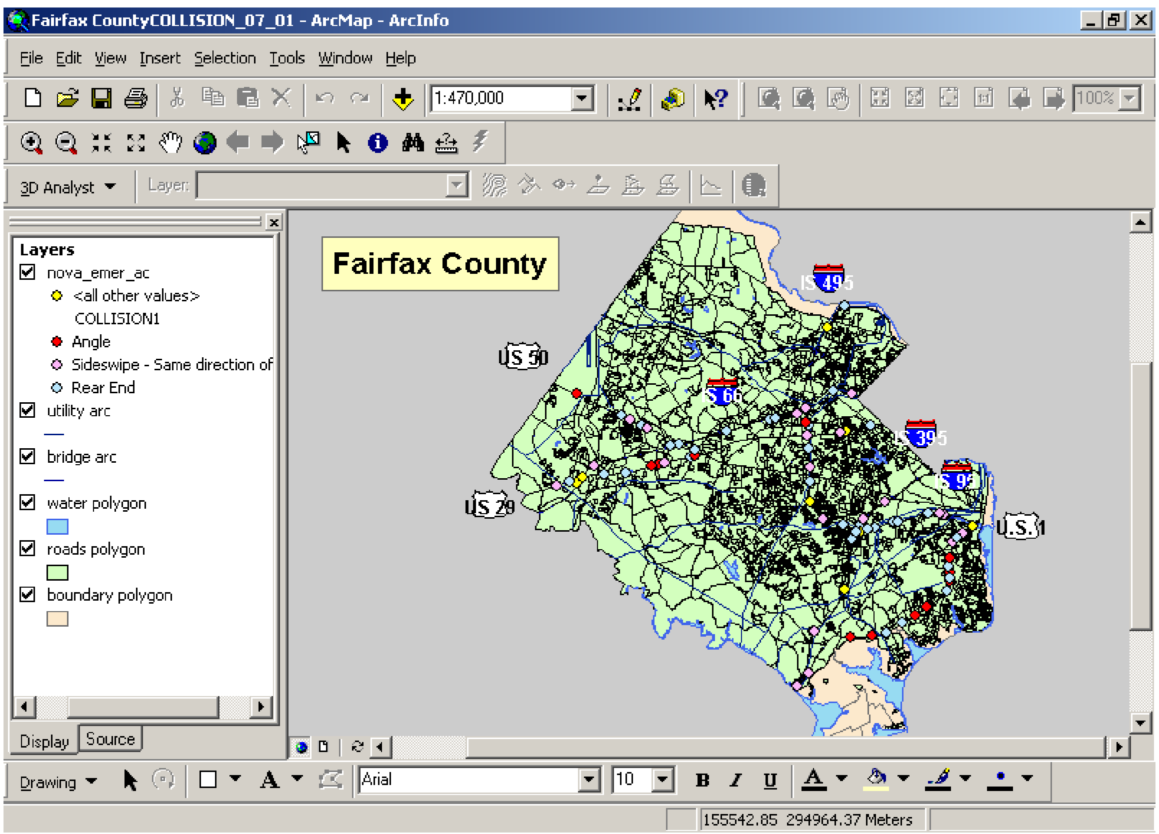


Figure 53: Total number of crashes involving EVs by three top collision types on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

Number of Vehicles Involved

Figure 54 presents the total number of crashes involving EVs along the U.S. Highways and Interstates in Fairfax County by number of vehicles involved as indicated in the table of contents ("Display" window). The different sizes of the red "cycle" symbol indicate the different number (from 1 to 6) of vehicles involved in a crash. This graph indicates that in 86% of all cases a crash involved two vehicles that have collided (19 out of 22) and the remaining 14% includes crashes where three vehicles were involved (3 out of 22).

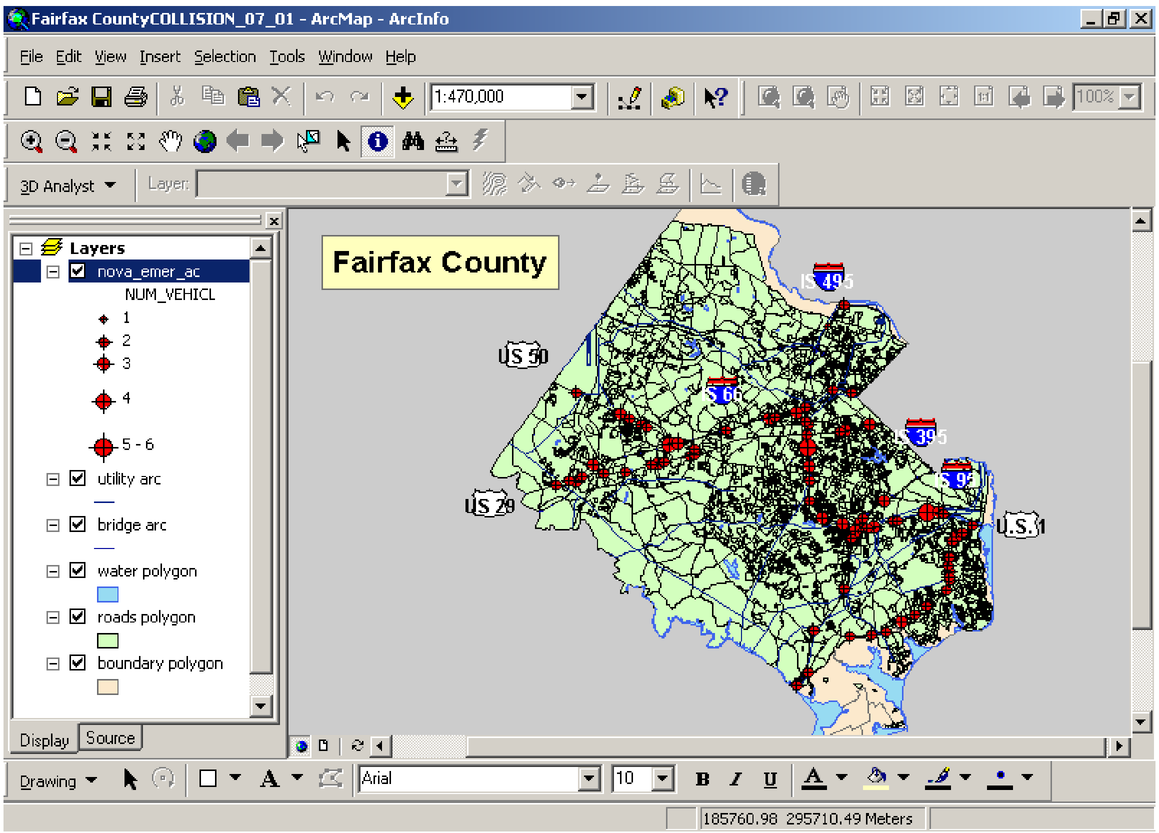


Figure 54: Total number of crashes involving EVs by number of vehicles involved on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

4.4.2 U.S. Route 1 in Fairfax County

In Figure 55 the 22 crashes involving EVs on U.S. Route 1 in Fairfax County are presented in an enlarged view. The different symbols and colors indicate the different location types in terms of intersection and signalization. It can be observed that the highest number of EV crashes (14 out of 22) have occurred at intersections (64%). Particularly 11 out of the 22 EV crashes have occurred at signalized intersections (50%) (red “star” symbol), while a smaller number of EV crashes (8 out of 22) have occurred along the route (36%) (pink “cycle” symbol).

Figure 56 presents the 14 crashes involving EVs that have occurred at intersections on U.S. 1 in Fairfax County. The different colors of the “cross” symbol include the EV crashes that have occurred at *non-signalized* intersection types, while the red “star” symbol indicates the EV crashes that have occurred at *signalized* intersections. It can be observed that 11 out of the 14 EV crashes have occurred at signalized intersections, while the remaining 3 at non-signalized intersections, as illustrated by the previous analysis with the Excel spreadsheet. It is also illustrated that in 4 sites more than 1 EV crash have been reported. Moreover, the analysis indicates that 3 out of the 4 crash sites, at which more than one EV accident has occurred, were *signalized intersections*.

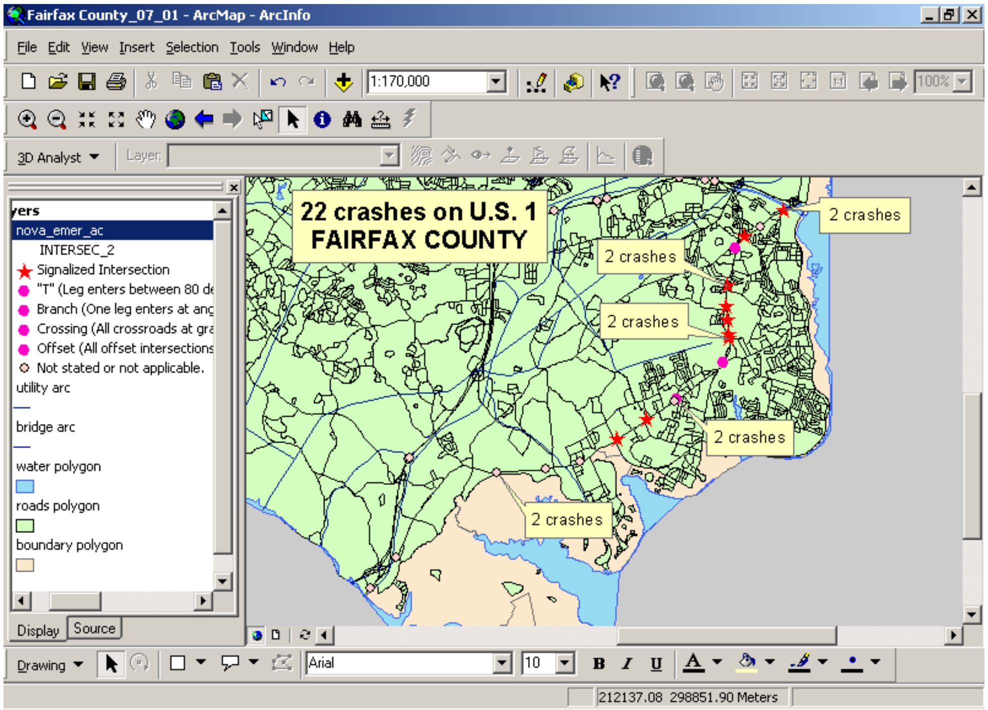


Figure 55: Total number of crashes involving EVs by location description on U.S. Route 1 in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

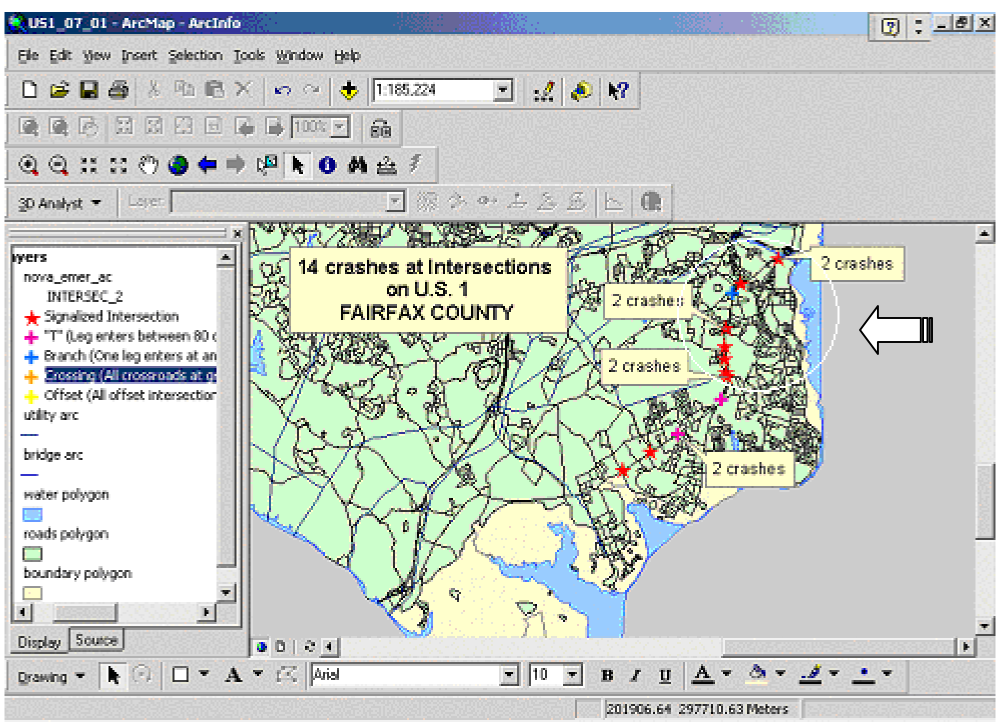


Figure 56: Total number of crashes involving EVs by intersection description on U.S. Route 1 in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

4.4.3 Arlington County

In Figure 57 the 20 crashes involving EVs along the U.S. Highways and Interstates in Arlington County are presented. The “cross” symbol indicates the EV crashes that have occurred at *intersections* while the “pin” symbol includes all the crashes involving EVs that have occurred at *non-intersections* (interchange or along the route) with different colors of the symbols to indicate the different types of the crash site. It can be observed that 6 out of 20 EV crashes (30%) have occurred at a “T” intersection, 4 (20%) at a crossing intersection, 6 at an interchange (30%), and 4 out of 20 EV crashes (20%) have occurred along the route.

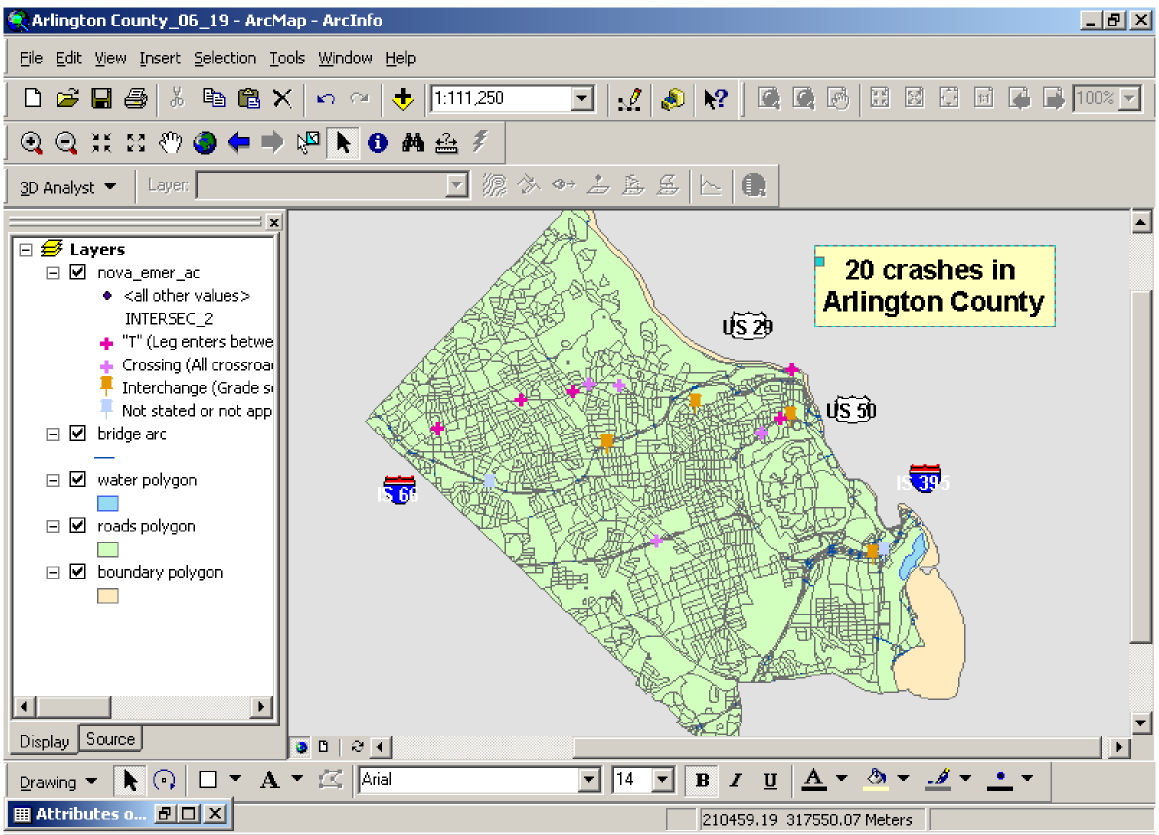


Figure 57: Total number of crashes involving EVs by location description on the U.S. Highways and Interstates in Arlington County from 1997 to 2001 using ArcGIS Desktop.

4.4.4 Loudoun County

Figure 58 presents the 7 crashes involving EVs along the U.S. Highways and Interstates in Loudoun County. The "cross" symbol indicates the EV crashes that have occurred at *intersections* while the "pin" symbol includes all the crashes involving EVs that have occurred at *non-intersections* (interchange or along the route) with the different colors of the symbols to indicate the different types of the crash site. It can be observed that 2 out of 7 EV crashes (29%) have occurred at a "T" intersection, while the remaining 5 (71%) have occurred along the route. It can be observed that along U.S. 15 the 4 EV crashes have occurred along the route while on U.S. 50 2 crashes have occurred at a "T" intersection and 1 along the route.

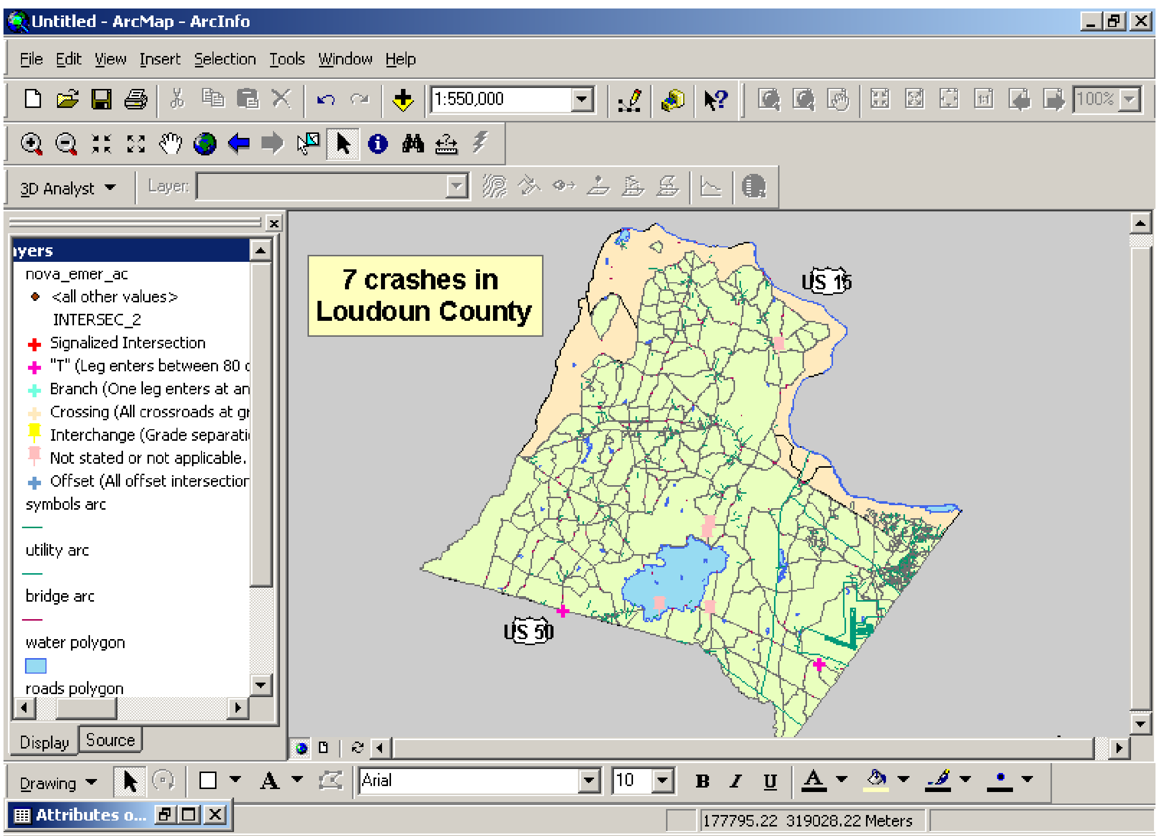


Figure 58: Total number of crashes involving EVs by location description on the U.S. Highways and Interstates in Loudoun County from 1997 to 2001 using ArcGIS Desktop.

4.4.5 Prince William County

In Figure 59 the 21 crashes involving EVs along the U.S. Highways and Interstates in Prince William County are presented. The "star" symbol includes EV crashes at signalized intersections, the "cross" symbol indicates the crashes involving EVs that have occurred at *intersections* while the "pin" symbol includes all the EV crashes at *non-intersections* (interchange or along the route) with different colors of the symbols to indicate the different types of the crash site. It can be observed that 2 out of the 21 EV crashes (9.5%) have occurred at a signalized intersection, 2 (9.5%) at a branch intersection, 2 (9.5%) at a "T" intersection, 1 at an offset (5%), 3 (14%) at an interchange and 11 (52.5%) EV crashes have occurred along the route. On U.S. 1 9 EV crashes have been reported. It is illustrated that 6 out of 9 EV crashes (67%) have occurred at intersections and the remaining 3 along the route. The analysis indicates that 2 out of the 6 intersections, at which accidents occurred, were signalized and are the only two signalized intersections at which accidents occurred in Prince William County.

U.S. 1 extends in Fairfax County as well as in Prince William County. The previous analysis illustrated that on U.S. 1 in Fairfax County the number of EV crashes at signalized intersections is significantly higher 79% (11 out of 14 EV crashes) compared to 29% in Prince William County (2 out of 7 EV crashes at intersections). This result could be explained by the fact that three fire stations are located along U.S. 1 in Fairfax County which may produce frequent EV movements through signalized intersections on U.S. 1. The high frequencies of EV passage through signalized intersections with the combination of the high volume of traffic leads to a relatively higher number of EV crashes at signalized intersections in Fairfax County (Figure B.26).

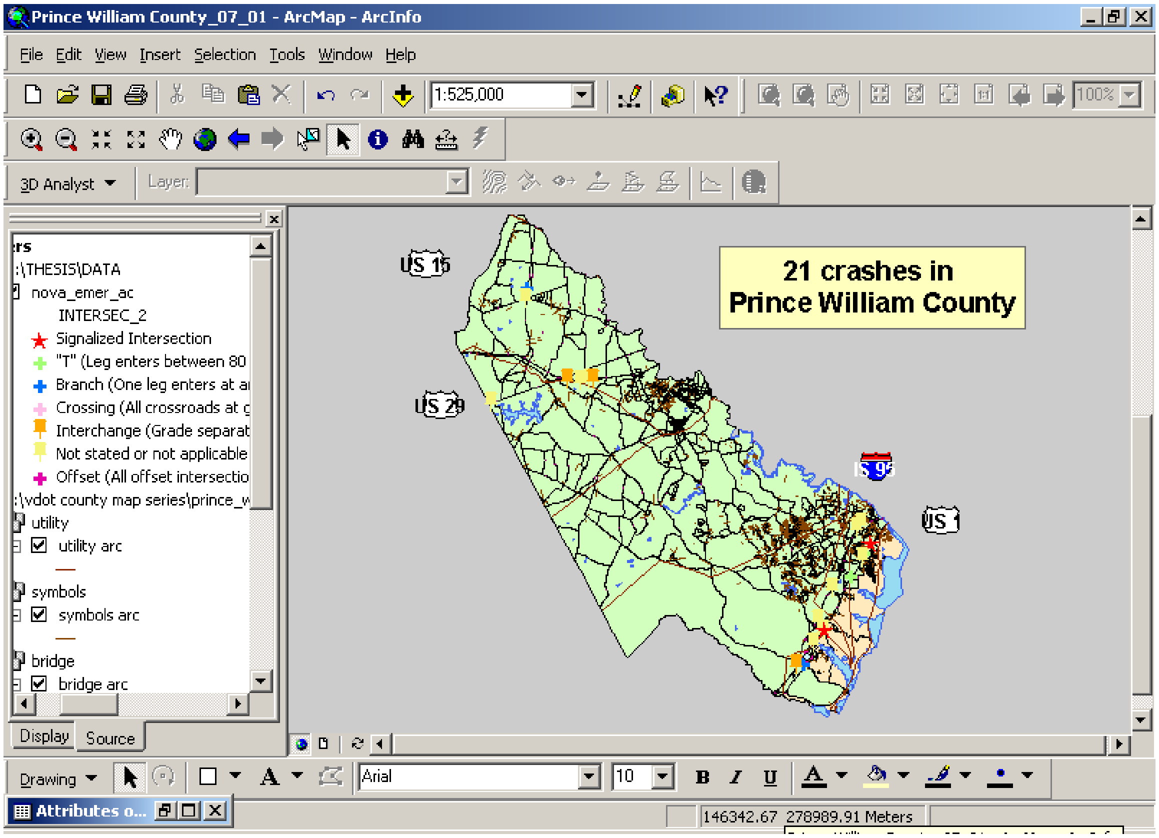


Figure 59: Total number of crashes involving EVs by location description on the U.S. Highways and Interstates in Prince William County from 1997 to 2001 using ArcGIS Desktop.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

This research resulted in a comprehensive and useful presentation of the crash situation involving emergency vehicles along the U.S. Highways and Interstates in Northern Virginia for the five year period of 1997 to 2001. The analysis intended to improve the understanding of the emergency vehicle crash characteristics and to provide a common and objective basis for the transportation professionals to identify potential problem areas and to make decisions that will enhance the roadway safety. Four major categories of crash characteristics were considered:

- ✓ Crash severity
- ✓ Collision type
- ✓ Location
- ✓ Other geometric and physical conditions

Different classification types of crashes involving EVs were presented and similarities and differences in the EV crash situation by geographic area and by highway facility type were investigated. This analysis was conducted using Excel. Further analysis of the data was facilitated with the application of the ArcGIS Desktop, which offered a graphical presentation of the crash situation for the same time frame (1997-2001). The analysis illustrated that 54% (75 out of 138) of all EV crashes in the region have been along the U.S. Highways, while the remaining 46% of EV crashes (63 out of 138) along the Interstates. Moreover, 63% of EV crashes (47 out of 75) along the U.S. Highways in the region have occurred at *intersections* and the remaining 37% (28 out of 75) at non-intersections. The results also indicate that 49% (23 out of 47) of all EV crashes at intersections along U.S. Highways in Northern Virginia were at signalized intersections. This percentage is 75% (21 out of 28) along U.S. Highways in Fairfax County, the largest county in Northern Virginia, and it is 79% (11 out of 14) along U.S. 1 in Fairfax County. The analysis, also, illustrates that the major collision type at the intersections of Northern Virginia was of angle type, which stresses the notion that an appropriate warning sign is absent when an emergency vehicle needs to make a turn or clear the intersection. These conclusions regarding the characteristics of EV crashes enhance our understanding and thus, may facilitate the identification of possible warrants to be used in determining the appropriateness of installing signal preemption equipment at signalized intersections.

5.2 Major Findings and Conclusions

The major findings of this research are summarized below:

State of Virginia

- 554 EV crashes have occurred on the U.S. Highways and Interstates in the State for the five year period (1997-2001).

Northern Virginia vs. rest of the State

- 25% of all EV crashes (138 out of 554) along the U.S. Highways and Interstates in Virginia have occurred in Northern Virginia (1997-2001).

Northern Virginia

- 138 EV crashes have occurred on the U.S. Highways and Interstates in the region for the five year period (1997-2001).

U.S. Highways vs. Interstates in the region

- 54% (75 out of 138) of all EV crashes in the region have been reported along the U.S. Highways, while the remaining 46% of EV crashes (63 out of 138) along the Interstates.

U.S. Highways in the Region

- 75 EV crashes have occurred on U.S. Highways in the region for the five year period (1997-2001).

Intersections vs. Non-Intersections

- 63% of EV crashes (47 out of 75) along the U.S. Highways in the region have occurred at *intersections* and the remaining 37% (28 out of 75) at non-intersections.

INTERSECTIONS ALONG U.S. HIGHWAYS IN THE REGION

- 47 EV crashes have occurred at intersections along the U.S. Highways in the region for the five year period (1997-2001).

Signalized vs. Non-Signalized Intersections

- 49% (23 out of 47) of the intersections along the U.S. Highways in the region, at which EV accidents occurred, were *signalized* and the remaining 51% (24 out of 47) non-signalized.

SIGNALIZED INTERSECTIONS ALONG U.S. HIGHWAYS IN THE REGION

- 23 EV crashes have occurred at signalized intersections along the U.S. Highways in the region for the five year period (1997-2001).

Emergency vehicle crash characteristics at signalized intersections on the U.S. Highways in the region (1997-2001)

- The analysis illustrated that the 23 EV crashes at signalized intersections along the U.S. Highways in the region share the following characteristics:
  - *Major Collision Type* – Angle: 34% (8 out of 23)
    Sideswipe (SD): 26% (6 out of 23)
    Rear End: 26% (6 out of 23)
  - *Major Factor* - Driver or Pedestrian Inattention or Error: 83% (19 out of 23)
  - *Alignment* – Straight: 74% (17 out of 23)
  - *Weather* – Clear: 61% (14 out of 23)
  - *Surface Conditions* – Dry: 70% (16 out of 23)
  - *Lighting Conditions* – Daylight: 52% (12 out of 23)
    Darkness: 48% (11 out of 23)
  - *Number of Vehicles Involved per Accident* – Two: 74% (17 out of 23)
  - *Damage Cost* - $136,436 (48% of total damage amount of $285,721 of EV crashes at intersections along the U.S. Highways in the region)
  - *Crash Severity* – Property Damage crashes: 65% (15 out of 23)
    Injury crashes: 30% (7 out of 23)
    Fatal crashes: 5% (1 out of 23)

The EV crashes at signalized intersections resulted in 14 injuries and 1 fatality including 1 pedestrian.

FAIRFAX COUNTY

- 66% (90 out of 138) of EV crashes in Northern Virginia have occurred in Fairfax County. This result could be explained from the County's highest population estimates in the region (969,749 residents in the year 2000).

U.S. Highways vs. Interstates in the County

- 49% (44 out of 90) of all EV crashes in the County have been reported along the U.S. Highways, while the remaining 51% of EV crashes (46 out of 90) along the Interstates.

U.S. HIGHWAYS IN THE COUNTY

- 44 EV crashes have occurred on the U.S. Highways in the County for the five year period (1997-2001).

Intersections vs. Non-Intersections

- 64% of EV crashes (28 out of 44) along the U.S. Highways in the County have occurred at *intersections* and the remaining 36% (16 out of 44) at non-intersections.

INTERSECTIONS ALONG U.S. HIGHWAYS IN THE COUNTY

- 28 EV crashes have occurred at intersections along the U.S. Highways in the County for the five year period (1997-2001).

Signalized vs. Non-Signalized Intersections

- 75% (21 out of 28) of the intersections along the U.S. Highways in the County, at which EV accidents occurred, were *signalized* and the remaining 25% (7 out of 28) non-signalized.

SIGNALIZED INTERSECTIONS ALONG U.S. HIGHWAYS IN THE COUNTY

- 21 EV crashes have occurred at signalized intersections along the U.S. Highways in the County for the five year period (1997-2001).

Emergency vehicle crash characteristics at signalized intersections on the U.S. Highways in the County (1997-2001)

- The analysis illustrated that the 21 EV crashes at signalized intersections along the U.S. Highways in the County share the following characteristics:
  - *Major Collision Type* – Angle: 38% (8 out of 21)
    Rear End: 29% (6 out of 21)
    Sideswipe (SD): 24% (5 out of 21)
  - *Major Factor* - Driver or Pedestrian Inattention or Error: 86% (18 out of 21)
  - *Alignment* – Straight: 71% (15 out of 21)
  - *Weather* – Clear: 62% (13 out of 21)
  - *Surface Conditions* – Dry: 67% (14 out of 21)
  - *Lighting Conditions* – Daylight: 52% (11 out of 21)
    Darkness: 48% (10 out of 21)
  - *Number of Vehicles Involved per Accident* – Two: 76% (16 out of 21)
  - *Damage Cost* - $132,936 (73% of the total damage amount of $180,936 of EV crashes at intersections along the U.S. Highways in the County)
  - *Crash Severity* – Property Damage crashes: 67% (14 out of 21)
    Injury crashes: 33% (7 out of 21)
    Fatal crashes: 0% (0 out of 21)

  The EV crashes at signalized intersections resulted in 11 injuries.

U.S. ROUTE 1 IN FAIRFAX COUNTY

- Approximately ¼ of EV crashes on the U.S. Highways and Interstates in Fairfax County have occurred on U.S. 1 (22 out of 90) resulting in a cost of $124,570, the highest damage cost in the County (approximately 24% of the total damage amount in the County includes EV crashes on U.S. Route 1) for the five year period (1997-2001).

Intersections vs. Non-Intersections

- 64% of EV crashes (14 out of 22) on U.S. 1 in the County have occurred at *intersections* and the remaining 36% (8 out of 22) at non-intersections.

Signalized vs. Non-Signalized Intersections

- 79% (11 out of 14) of the intersections on U.S. 1 in the County, at which EV accidents occurred, were *signalized* and the remaining 21% (3 out of 14) non-signalized.

SIGNALIZED INTERSECTIONS ON U.S. 1 IN THE COUNTY

- 11 EV crashes have occurred at signalized intersections on U.S. 1 in the County for the five year period (1997-2001).

Emergency vehicle crash characteristics at signalized intersections on U.S. 1 in the County (1997-2001)

- The analysis illustrated that the 11 EV crashes at signalized intersections on U.S. 1 in the County share the following characteristics:
  - *Major Collision Type* – Angle: 55% (6 out of 11)
    Rear End: 36% (4 out of 11)
  - *Major Factor* - Driver or Pedestrian Inattention or Error: 91% (10 out of 11)
  - *Alignment* – Straight: 64% (7 out of 11)
  - *Weather* – Clear: 73% (8 out of 11)
  - *Surface Conditions* – Dry: 73% (8 out of 11)
  - *Lighting Conditions* – Daylight: 55% (6 out of 11)
    Darkness: 45% (5 out of 11)
  - *Number of Vehicles Involved per Accident* – Two: 73% (8 out of 11)

- *Damage Cost* - $72,320 (85% of the total damage amount of $85,320 of EV crashes at intersections along U.S. 1 in the County)
- *Crash Severity* – Property Damage crashes: 64% (7 out of 11)

  Injury crashes: 36% (4 out of 11)

  Fatal crashes: 0% (0 out of 11)

  The EV crashes at signalized intersections resulted in 7 injuries.

- The previous analysis illustrates that most of the EV crashes at signalized intersections along the U.S. Highways in Northern Virginia, Fairfax County and on U.S. 1 in the County are of angle type. In addition, the other emergency vehicle crash characteristics in terms of straight alignment and clear weather are not considered to have been major contributing factors to a crash since they appeared to be of little or no hazard to the drivers. This suggests that an appropriate warning signal sending a clear message to the drivers of an emergency vehicle's passage through a signalized intersection may be absent.
- Some potential factors that could serve as warrants for the EVP installation should be considered. Since EV crashes at signalized intersections along the U.S. Highways in the region and particularly on U.S. 1 form a major safety issue with significant socioeconomic consequences the EVP installation may be warranted. The findings of this analysis suggest that consideration should be given to EVP investments in case of 1 or more EV crashes at the same signalized intersection in a 12-month period.
- From the safety point of view, strategies to eliminate the problem could result in a major decrease in the number of injuries and fatalities involved in an EV crash and positively affect the overall efficiency and quality of emergency response services. In case of a crash involving an emergency vehicle the personnel would then be able to meet the standards for a quick response to the scene of the emergency set. From the financial point of view, efforts to solve the problem could result in major financial benefits for the region as well as the medical services due to the damage cost involved in an EV crash. A detailed benefit cost analysis would better assess the situation.

- The results also indicate that an EV crash has a large negative magnitude to the communities since it increases significantly the response times and affects the effectiveness of the medical service. While this result may suggest that an EVP investment is warranted, consideration must also be given to the investment requirements associated with EVP installation and operation. Such an installation needs to identify the directions of flow to be provided EVP and the corresponding initial costs of detectors, phase selectors, emitters, warning lights (if, desired), software, and other necessary equipment and anticipated operating and maintenance costs. These costs will vary depending on the type of EVP system selected and the vendor.

5.3 SIGNIFICANCE OF RESEARCH

This research has contributed to the body of knowledge relating to emergency vehicle crash characteristics. Due to the absence of a complete analysis and a comprehensive presentation of the crash situation involving emergency vehicles', there is a need for a background which will offer a better understanding of the crash situation involving EVs, which is one of the objectives of this thesis. Furthermore, it offers a creative and realistic graphical presentation of the crashes involving EVs using the GIS software program, where routes and crashes are overlaid to provide the engineer with a better understanding of the development and roadway configuration of the study areas without leaving their desks. This research focused on the overall crash situation involving EVs on the U.S. Highways and the Interstates in Northern Virginia and Fairfax County as well as on a specific corridor, where the crash situation in terms of crash severity and damage cost was indicated to be severe. The results are important to the region and Fairfax County because of the relatively high number of crashes involving emergency vehicles that have occurred at intersections and especially at signalized intersections on the U.S. Highways, which indicate that the traffic signalization may, in some cases, be insufficient to reduce the number of crashes involving EVs and thus, more drastic actions must be taken. A sufficient understanding of traffic collision patterns and trends is necessary when implementing efforts to improve traffic safety. As indicated by Johnson, Mirmiran and

Thompson in the “Emergency Vehicle Pre-Emption and Emergency Traffic Signals: Suggested Guidelines” (Johnson, Mirmiran and Thompson, 2000), the preferential treatment of emergency vehicles may be granted, in case of the occurrence of accidents involving emergency vehicles, and could alleviate these crashes while it may decrease erratic movements by motorists, since there is going to be a clear message sent to the drivers of an emergency vehicle’s passage. A Conflict Point Analysis of before and after traffic data on U.S. Route 1 at signalized intersections illustrated that: 1) the number and severity of EV – specific conflict points are significantly reduced by ensuring that a clear message is delivered to the auto drivers, and 2) extended green phase displays create a clear pathway for the approaching EVs, while simultaneous red displays to all movements on perpendicular and opposing approaches provide a clear message eliminating the most dangerous crossing conflicts (Louisell, Collura, and Tignor, 2003). As illustrated by the St. Paul Minnesota study there was an accident rate reduction of greater than 70% between 1969 and 1976, when it installed 285 signal preemption systems on 308 signalized intersections.
(http://www.benefitcost.its.dot.gov/ITS/benecost.nsf)

In addition to the previous conclusions, this research is significant because it supports the notion that a safety issue exists at signalized intersections and could warrant EVP investments. In the academic environment, this research provides a holistic treatment of emergency vehicle crash characteristics and provides an evaluation of the components that can cause an accident and need to be identified and further analyzed in any the traffic safety related research. In its totality, this research should perform an integrating function capturing traditional analysis tools and recent research to assess the evaluation of crash situation involving emergency vehicles.

5.4 Recommendations for Further Research

While this thesis has developed a foundation for the analysis and presentation of the crash situation involving emergency vehicles in the region of Northern Virginia, future efforts can build upon this research. Future work may include:

- Acquisition of the accident reports at the 23 signalized intersections in the region, identified in this research, and evaluation of their geometrics, volumes (ADT), adjacent land use and other design characteristics may result in a more comprehensive and detailed analysis of the crash situation involving EVs at these sites and facilitate the identification of candidate signalized intersections for EVP installation.
- Further analysis of the crashes involving emergency vehicles in the other counties of Northern Virginia: Arlington, Loudoun and Prince William County, using an Excel spreadsheet and presentation of the crash situation with the application of the ArcGIS Desktop or another GIS software program with similar or advanced capabilities.
- Analysis of the crashes involving emergency vehicles in the other routes of the region of Northern Virginia such as State Highways, using an Excel spreadsheet and presentation of the crash situation with the ArcGIS Desktop or another GIS software program with similar or advanced capabilities. This effort could provide the transportation industry with the necessary background for identifying High Accident Locations (HAL) in the area of interest, while having a better understanding of the emergency vehicle crash characteristics provided in this research thesis.
- The GIS capabilities could be expanded in order to facilitate the integration of the developed system into the other State data bases resulting into the analysis and presentation of their crash situation involving emergency vehicles.
- Work is also underway to develop GIS analysis tools to improve pedestrian and bicycle safety. The pedestrian application involves the development of a system to identify safe routes to school, and the bicycle application is exploring the use of GIS to assess the bicycle compatibility of roadways (FHWA-RD-99-081).

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APPENDIX A: TABLES

This appendix includes tables that are supplemental to some of the figures presented in Chapter 4.

TABLE A.1

Total number of crashes involving emergency vehicles by type of crash and total damage cost on the U.S. Highways and Interstates in Northern Virginia from 1997 to 2001

County	Number of Injury Crashes	Number of Fatality Crashes	Number of PD Crashes	PD ($)
Arlington	7	1	12	83,295
Fairfax	32	0	58	528,135
Prince William	9	1	11	138,304
Loudoun	4	0	3	46,825
Total	***52***	***2***	***84***	***796,559***

TABLE A.2

Total number of crashes involving emergency vehicles by type of crash and total damage cost on the U.S. Highways and Interstates in Northern Virginia from 1997 to 2001

Route	Number of Injury Crashes	Number of Fatality Crashes	Number of PD Crashes	PD ($)	Total
IS 66	6	1	14	162,169	21
IS 95	9	0	14	150,940	23
IS 395	5	0	3	30,350	8
IS 495	8	0	3	64,410	11
US 1	10	1	20	165,820	31
US 15	2	0	4	13,329	6
US 29	4	0	16	71,965	20
US 50	8	0	10	137,576	18
Total	***52***	***2***	***84***	***796,559***	***138***

TABLE A.3

Total number of crashes involving emergency vehicles by type of crash and total damage cost on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001

	Route ID							
Crashes	**US 1**	**US 29**	**US 50**	**IS 66**	**IS 95**	**IS 395**	**IS 495**	***Total***
Injury	6	3	4	3	6	2	8	*32*
Fatality	0	0	0	0	0	0	0	*0*
Property Damage	16	9	6	11	12	1	3	*58*
Cost ($)	124,570	55,880	75,716	81,719	109,040	$16,800	64,410	*528,135*
Total	**22**	**12**	**10**	**14**	**18**	**3**	**11**	***90***

APPENDIX B: FIGURES

This appendix includes figures that derive from the analysis of the crash data sets in Chapter 4. These figures refer to other emergency vehicle crash characteristics and facilitate in the understanding of the overall crash situation in Northern Virginia, Fairfax County and U.S. Route 1 in Fairfax County.

NORTHERN VIRGINIA

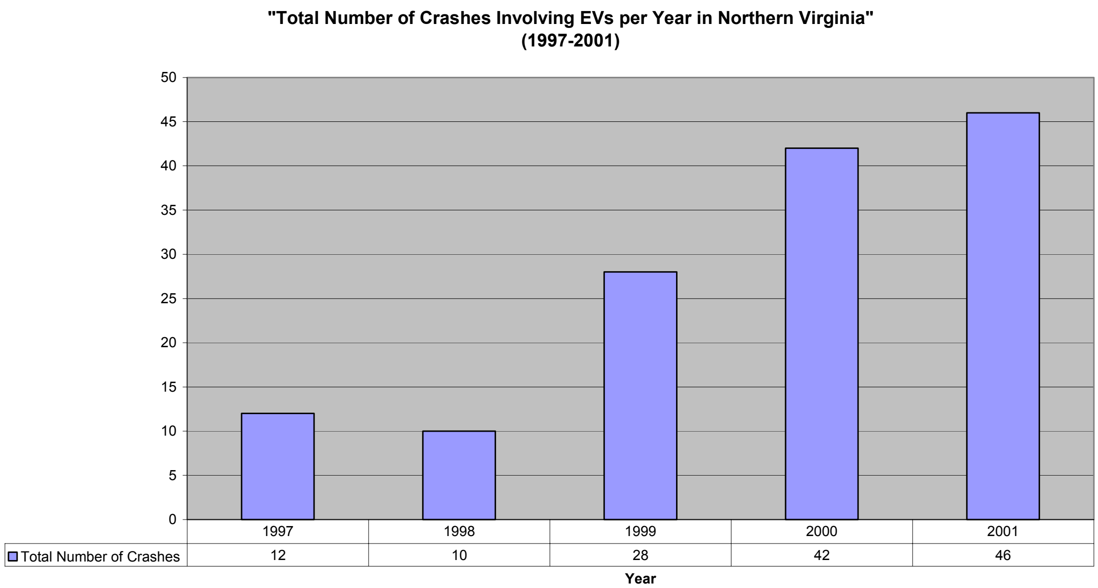


Figure B.1: Total number of crashes involving emergency vehicles per year in Northern Virginia from 1997 to 2001.

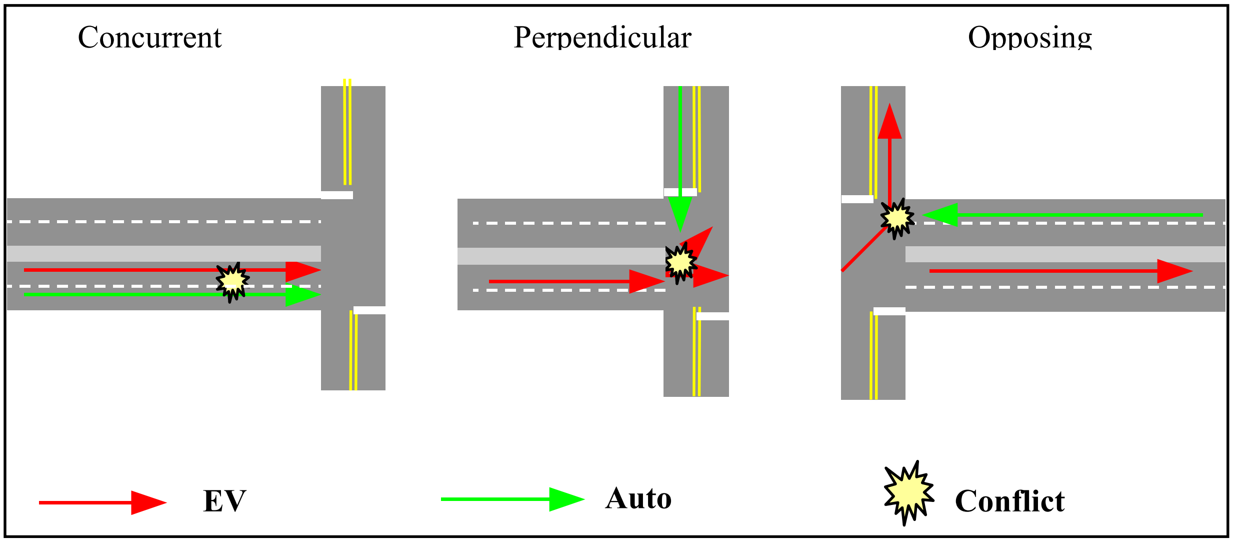


Figure B.2: EV Crash Potential *(Source: Louisell, C., J. Collura and S. Tignor, "Proposed Method to Evaluate Emergency Vehicle Preemption and Impact on Safety", Transportation Research Board, No. 3739, January, 2003).*

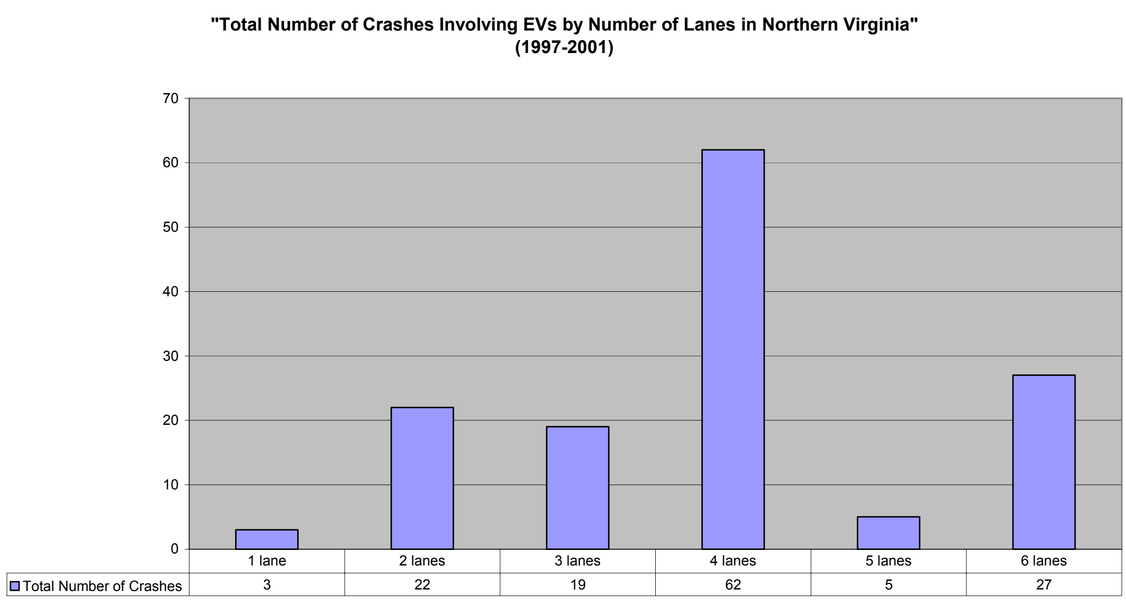


Figure B.3: Total number of crashes involving emergency vehicles by number of lanes in Northern Virginia from 1997 to 2001.

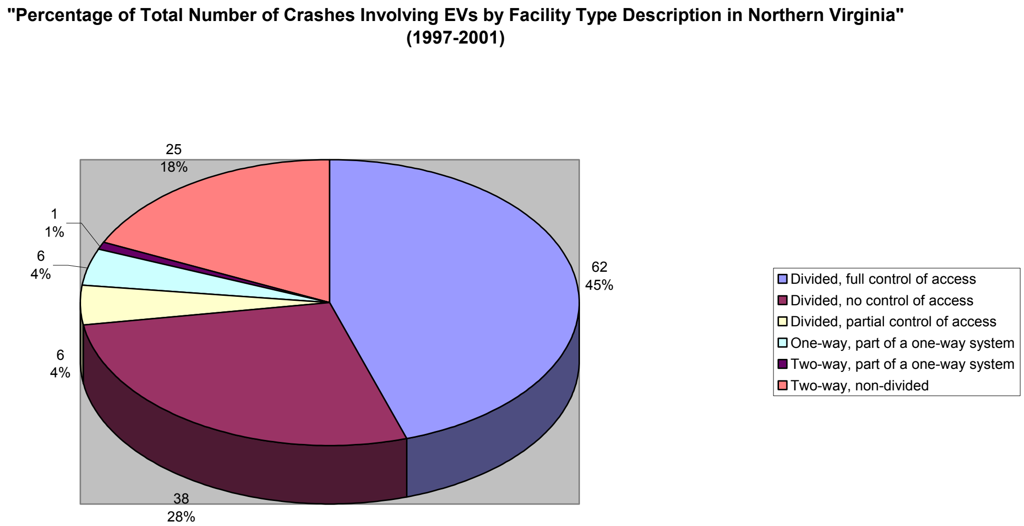


Figure B.4: Percentage of total number of crashes involving emergency vehicles by facility type description in Northern Virginia from 1997 to 2001.

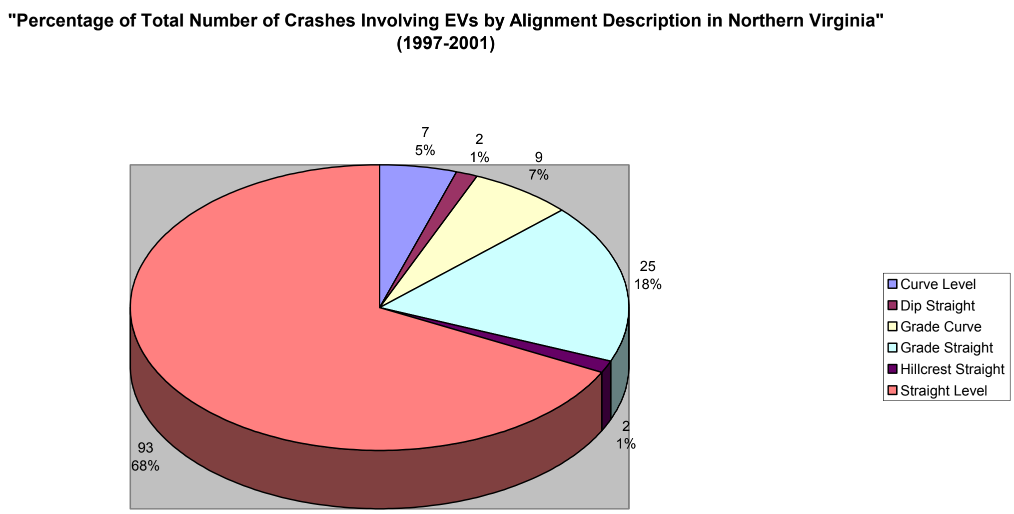


Figure B.5: Percentage of total number of crashes involving emergency vehicles by alignment description in Northern Virginia from 1997 to 2001.

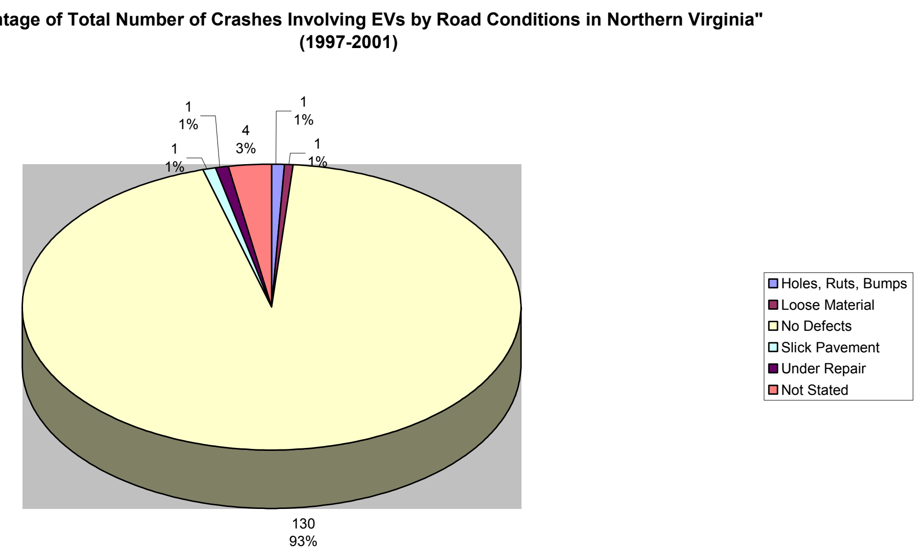


Figure B.6: Percentage of total number of crashes involving emergency vehicles by road conditions in Northern Virginia from 1997 to 2001.

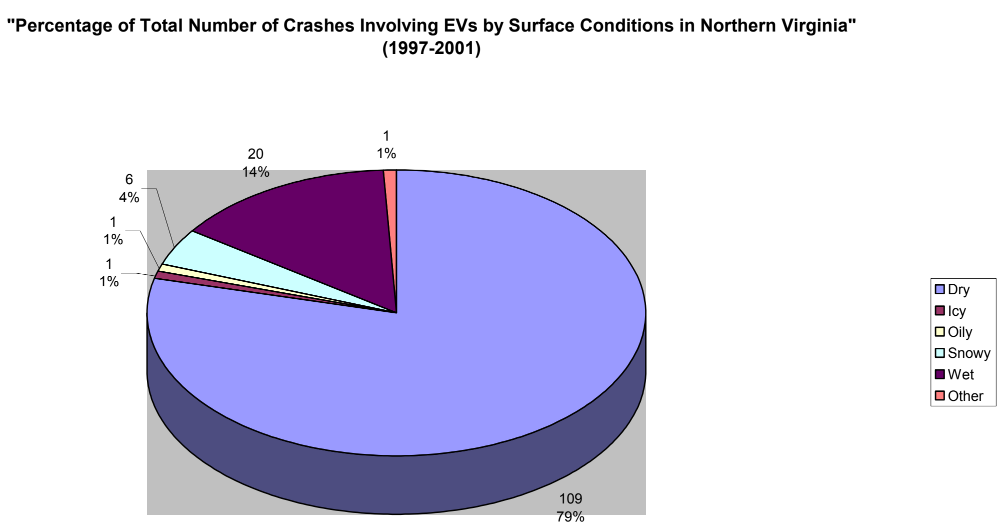


Figure B.7: Percentage of total number of crashes involving emergency vehicles by surface conditions in Northern Virginia from 1997 to 2001.

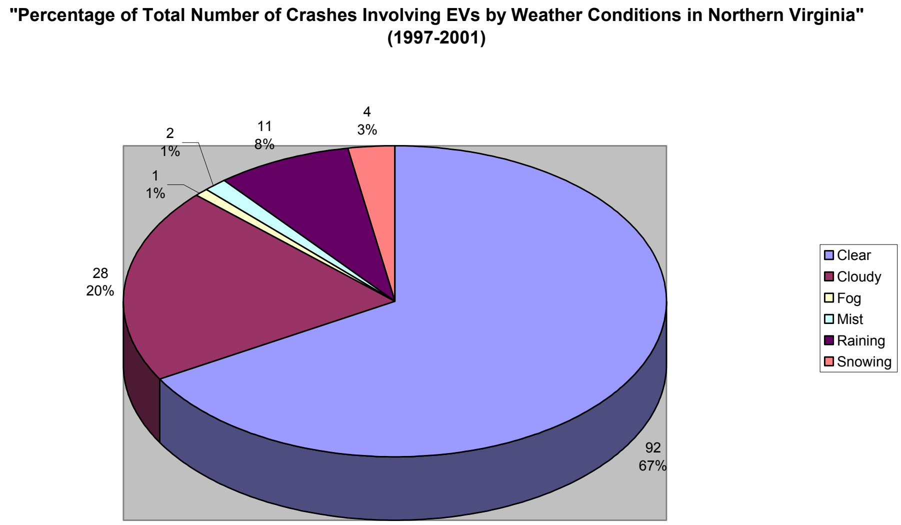


Figure B.8: Percentage of total number of crashes involving emergency vehicles by weather conditions in Northern Virginia from 1997 to 2001.

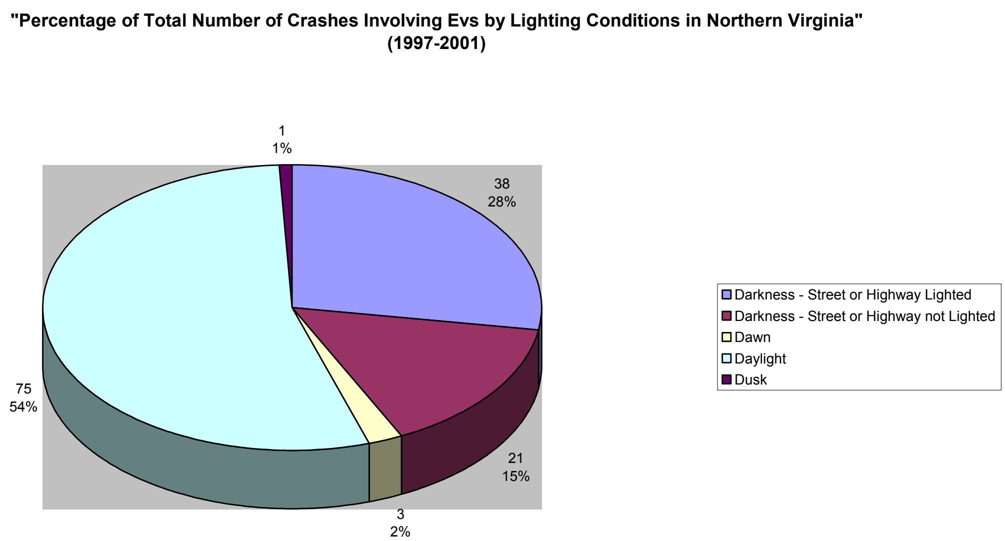


Figure B.9: Percentage of total number of crashes involving emergency vehicles by lighting conditions in Northern Virginia from 1997 to 2001.

FAIRFAX COUNTY

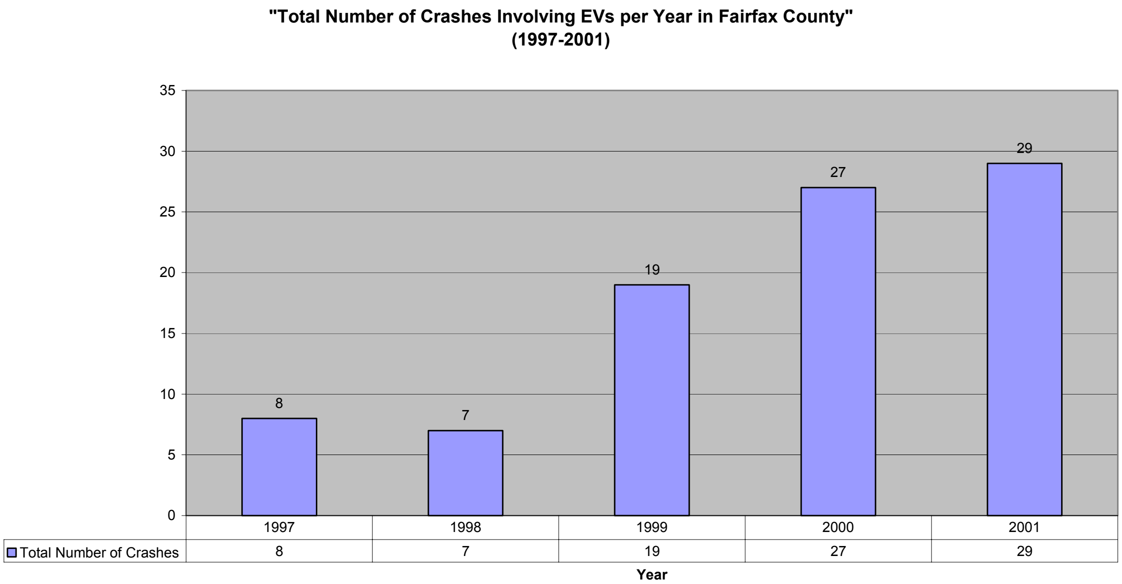


Figure B.10: Total number of crashes involving emergency vehicles per year in Fairfax County from 1997 to 2001.

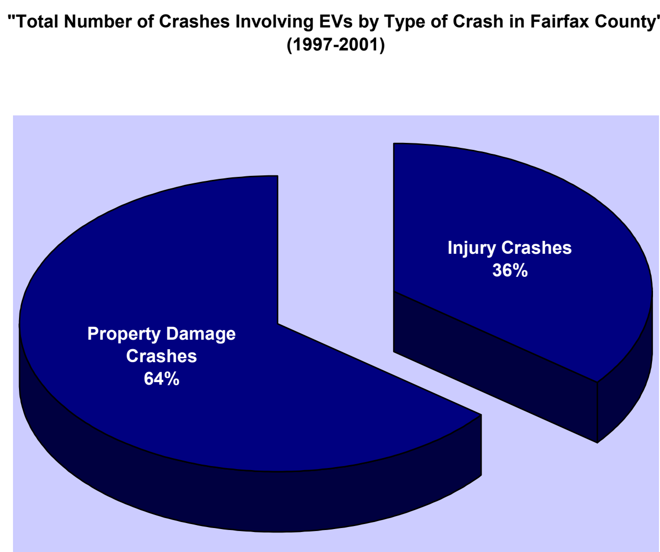


Figure B.11: Percentage of total number of crashes involving emergency vehicles by type of crash in Fairfax County from 1997 to 2001.

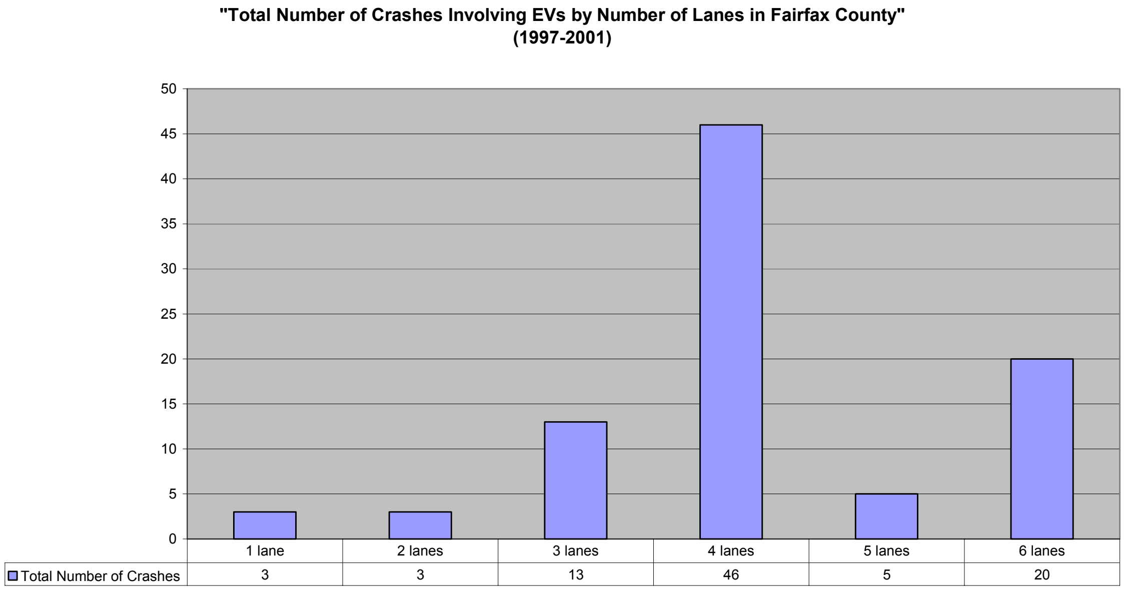


Figure B.12: Total number of crashes involving emergency vehicles by number of lanes in Fairfax County from 1997 to 2001.

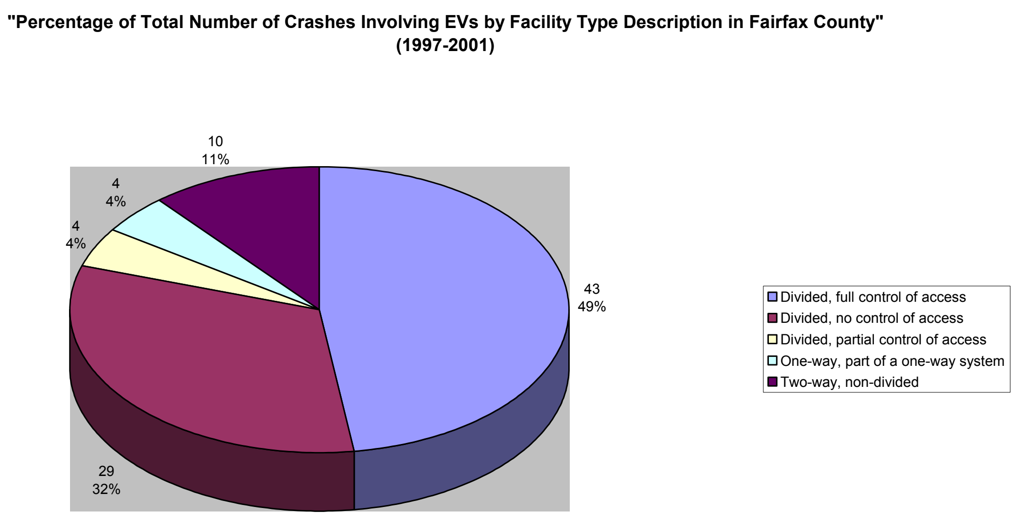


Figure B.13: Percentage of total number of crashes involving emergency vehicles by facility type description in Fairfax County from 1997 to 2001.

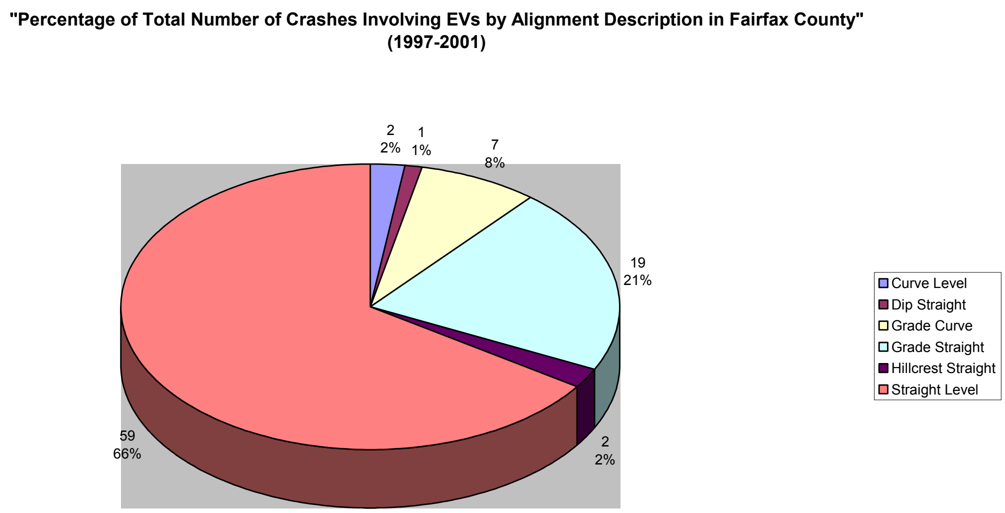


Figure B.14: Percentage of total number of crashes involving emergency vehicles by alignment description in Fairfax County from 1997 to 2001.

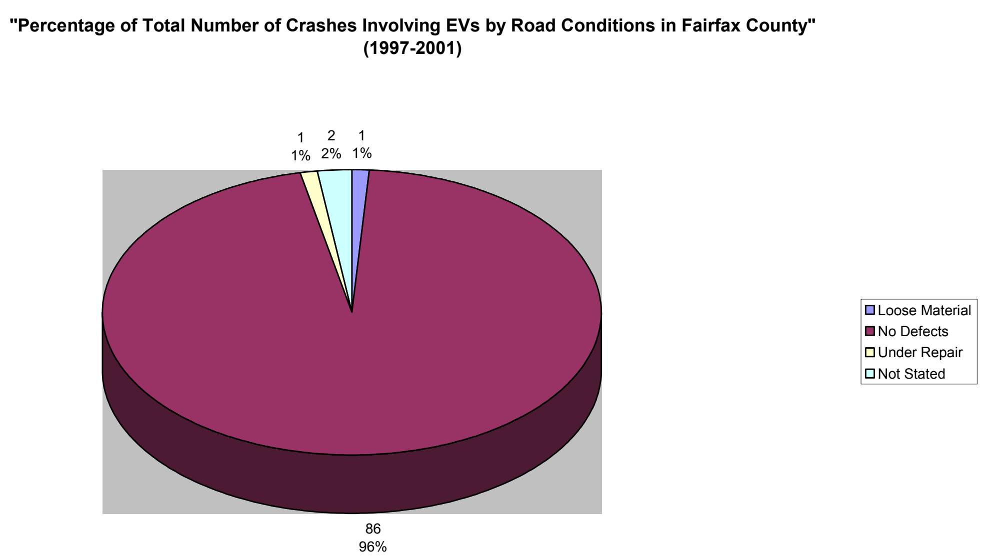


Figure B.15: Percentage of total number of crashes involving emergency vehicles by road conditions in Fairfax County from 1997 to 2001.

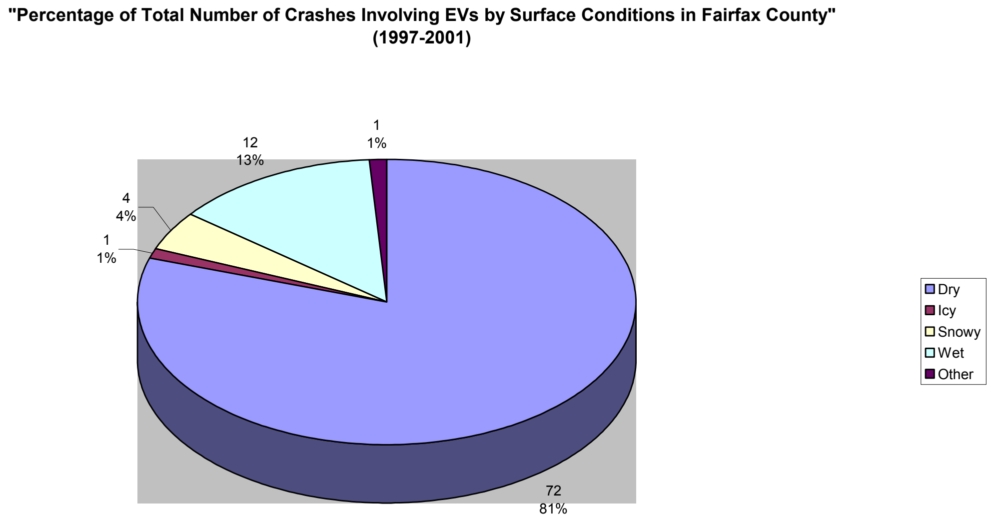


Figure B.16: Percentage of total number of crashes involving emergency vehicles by surface conditions in Fairfax County from 1997 to 2001.

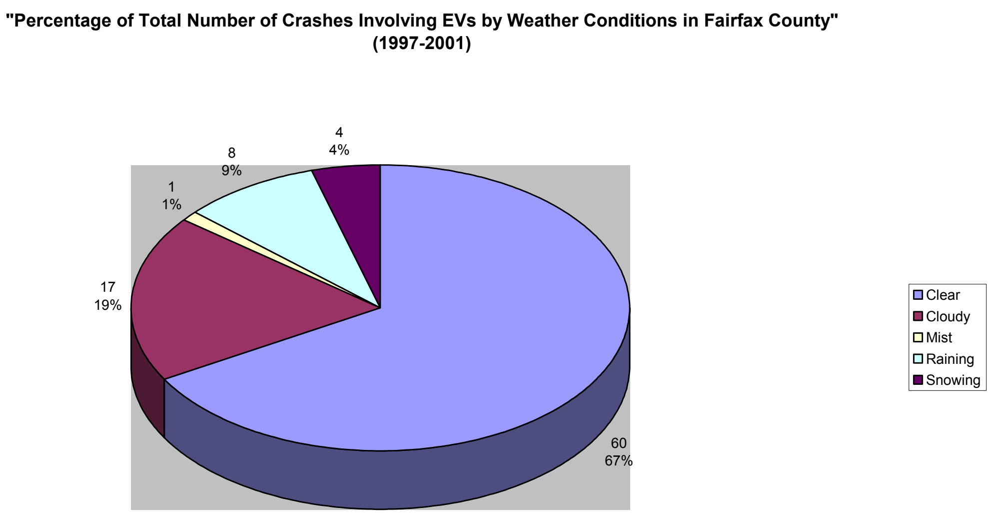


Figure B.17: Percentage of total number of crashes involving emergency vehicles by weather conditions in Fairfax County from 1997 to 2001.

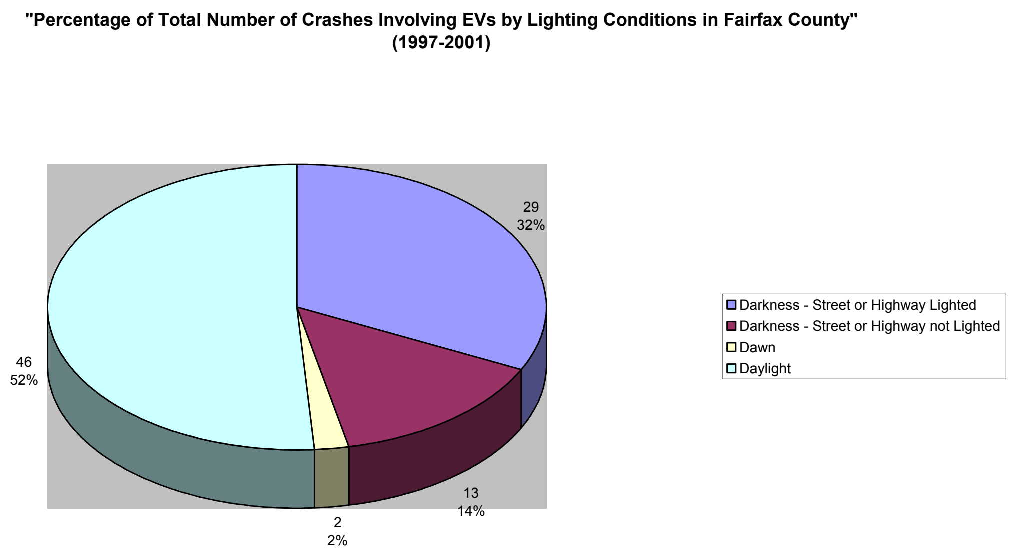


Figure B.18: Percentage of total number of crashes involving emergency vehicles by lighting conditions in Fairfax County from 1997 to 2001.

U.S. ROUTE 1 IN FAIRFAX COUNTY

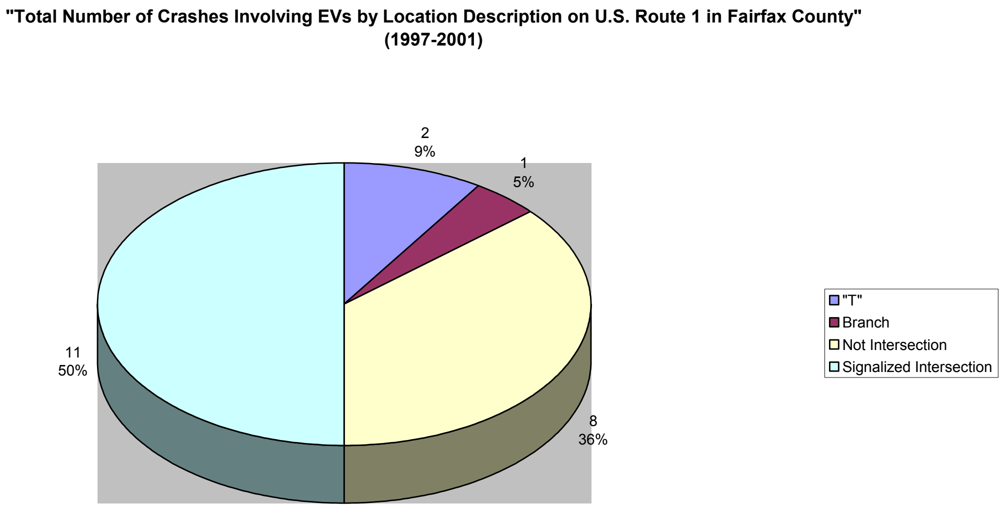
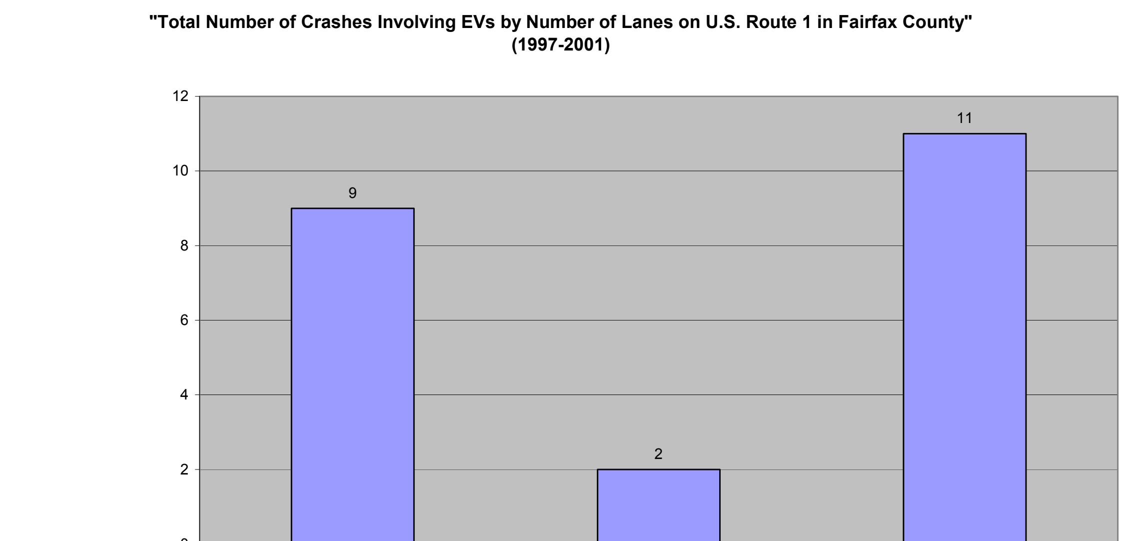


Figure B.19: Total number of crashes involving emergency vehicles by location description on U.S. Route 1 in Fairfax County from 1997 to 2001.



	4 lanes	5 lanes	6 lanes
Total Number of Crashes	9	2	11

Figure B.20: Total number of crashes involving emergency vehicles by number of lanes on U.S. Route 1 in Fairfax County from 1997 to 2001.

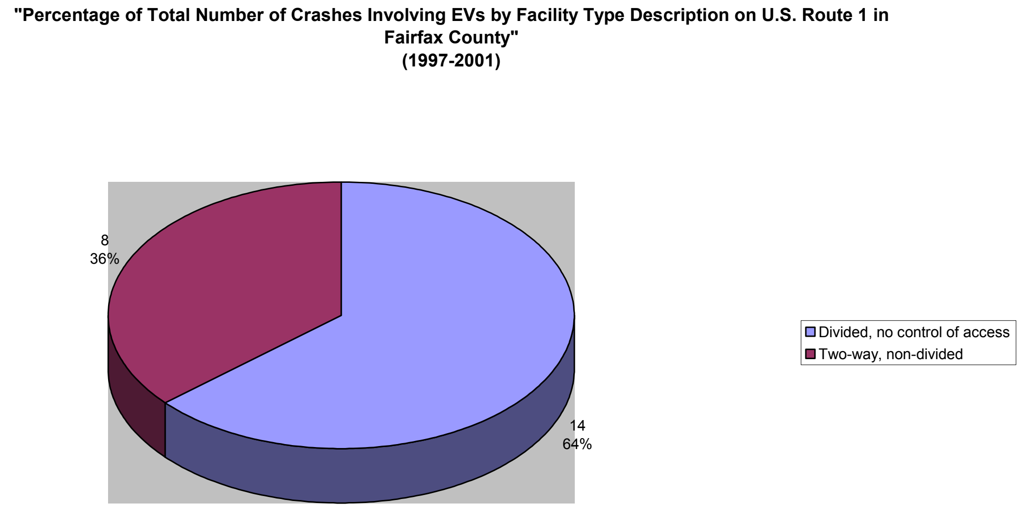


Figure B.21: Percentage of total number of crashes involving emergency vehicles by facility type description on U.S. Route 1 in Fairfax County from 1997 to 2001.

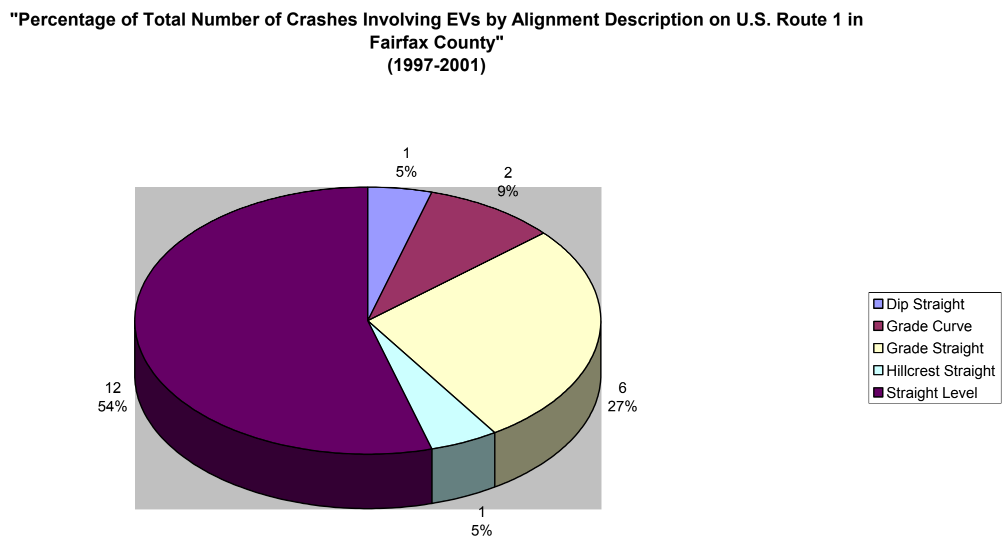


Figure B.22: Percentage of total number of crashes involving emergency vehicles by alignment description on U.S. Route 1 in Fairfax County from 1997 to 2001.

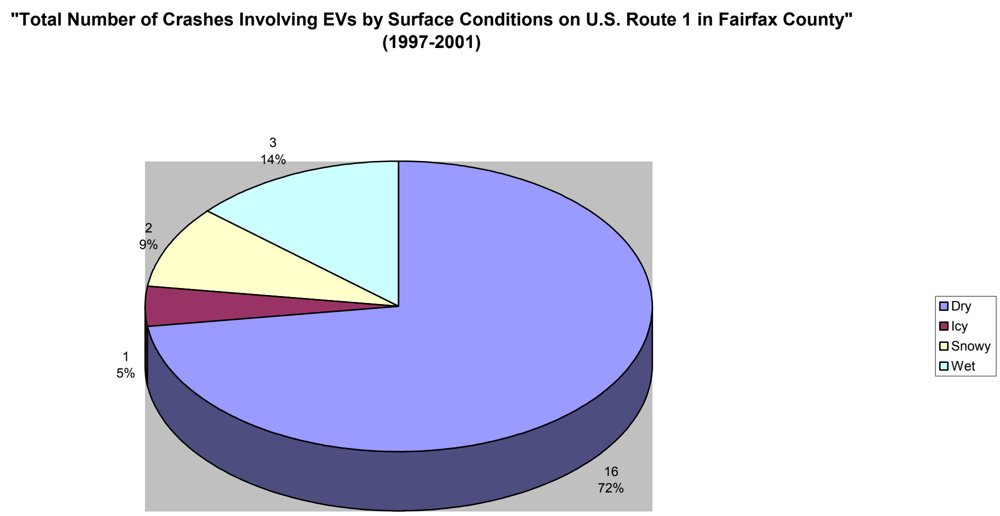


Figure B.23: Percentage of total number of crashes involving emergency vehicles by surface conditions on U.S. Route 1 in Fairfax County from 1997 to 2001.

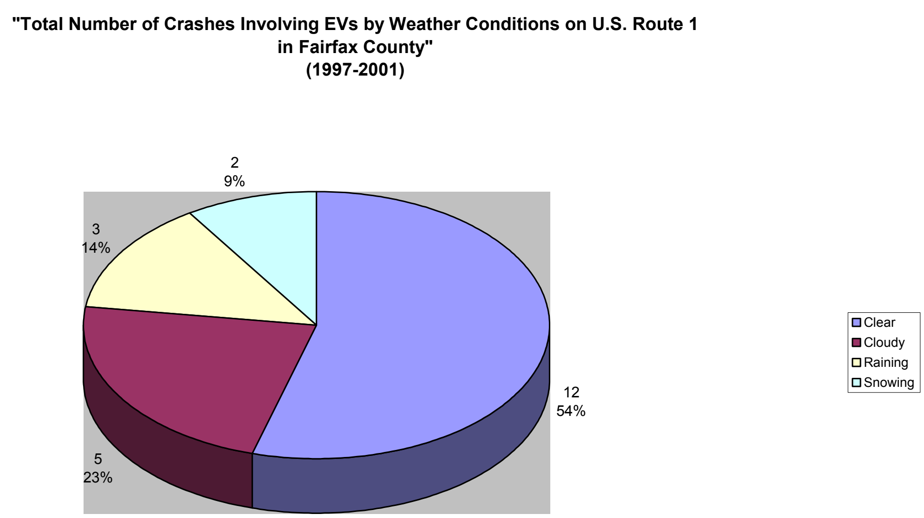


Figure B.24: Percentage of total number of crashes involving emergency vehicles by weather conditions on U.S. Route 1 in Fairfax County from 1997 to 2001.

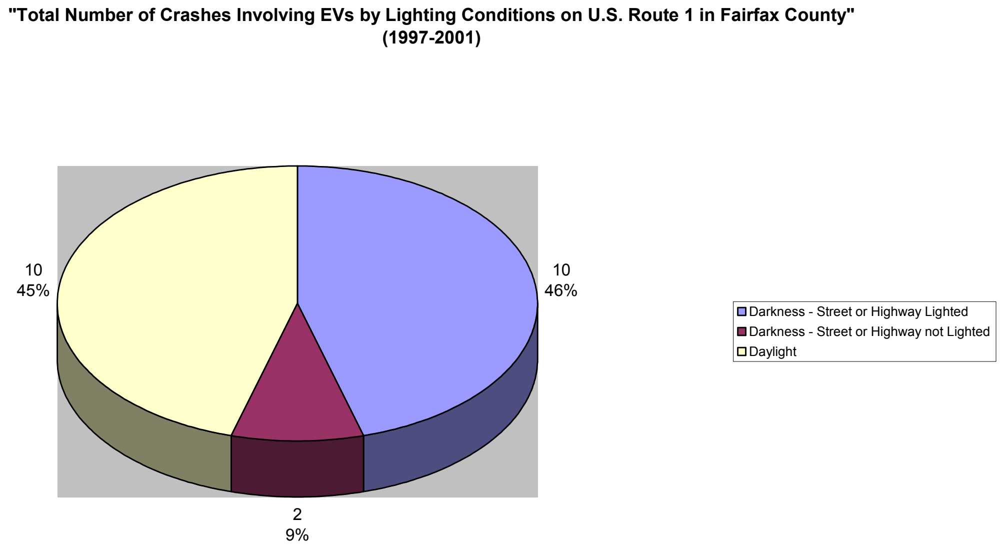


Figure B.25: Percentage of total number of crashes involving emergency vehicles by lighting conditions on U.S. Route 1 in Fairfax County from 1997 to 2001.

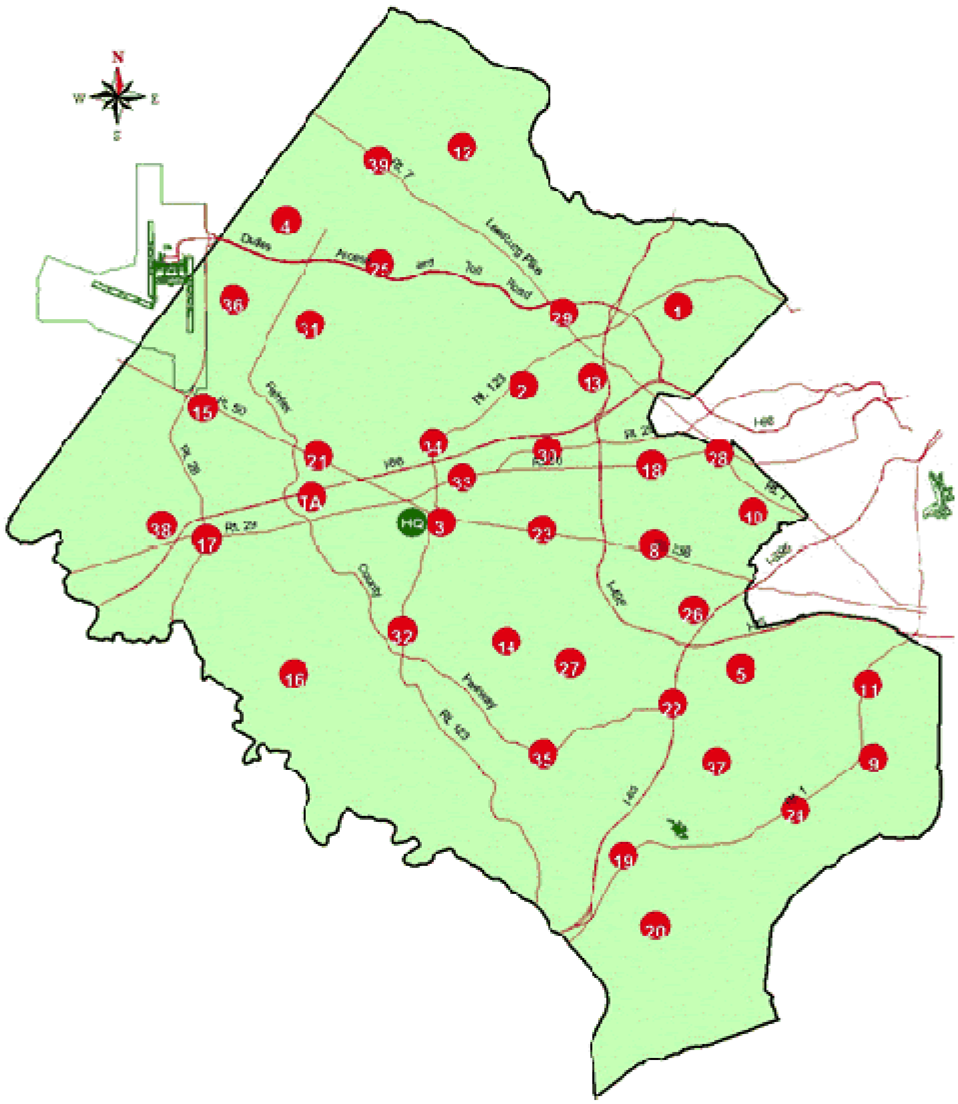


Figure B.26: Location of Fire Station in Fairfax County *(Source: Mittal M., "Assessing the Performance of an Emergency Vehicle Preemption System: A Case Study on U.S. 1 in Fairfax County, Virginia",* thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, Virginia, July 30, 2003.

APPENDIX C: EXCEL SPREADSHEET

This part is drawn from the books of Weiss, N. and M. Hassett, *Introductory Statistics*, Addison-Wesley, Philippines, 1982, and Lyman, R. and M. Longnecker, *An Introduction to Statistical Methods and Data Analysis*, 5th Edition, Thomson Learning, U.S.A., 2001.

Basic Definitions

Statistics is a set of scientific principles and techniques that are useful in reaching conclusions about populations and processes when the available information is both limited and variable; that is statistics is the science of *learning from data*. *The objective of the statistics is to make an inference about a population of interest based on information obtained from a sample of measurements from that population*. There are two kinds of statistics: *descriptive statistics* and *inferential statistics*.

DEFINITIONS:

Descriptive Statistics

It consists of methods for organizing and summarizing information.

Inferential statistics

It consists of methods for making inferences about a population based on information obtained from a sample of the population.

Population

The set of all individuals or items under consideration.

Sample

That subset of the population from which information is collected.

Data

The information collected and analyzed by statisticians. There are different kinds of data, and the statistician's choice of methodology is partly determined by the kind of the available data.

Qualitative Data

Data that refers to non-numerical qualities or attributes, such as gender, sex, collision type etc.

Ordinal Data

Data about order or rank on a scale such as 1, 2, 3,…or A, B, C,…

Metric Data

Data obtained from measurement of such quantities as time, number of vehicles, number of fatalities, injuries, accidents etc.

County Data

Data on the number of individuals or items falling into certain classes or categories.

Qualitative and *ordinal data* are referred to by statisticians as *discrete data*, because they sort things into separate, discrete classes. On the other hand, most *metric data* is called *continuous* because it involves measurement on a continuous scale.

Data Description

After the measurements of interest have been collected, ideally the data are organized, displayed, and examined by using various graphical techniques. As a general rule, the data should be arranged into categories so that *each measurement is classified into one, and only one, of the categories*. This procedure eliminates any ambiguity that might otherwise arise when categorizing measurements.

The first and simplest graphical procedure for data organized in this manner is the *pie chart*. It is used to display the percentage of the total number of measurements falling into each of the categories of the variable by partitioning a circle.

The data of Table C.1 represent a summary of a study to determine paths to authority for individuals occupying top positions of responsibility in key public-interest organizations. Using biographical information, each of 1,345 individuals was classified according to how she or he was recruited for the current elite position.

TABLE C.1

Recruitment to top public-interest positions *(Source: Lyman, R. and M. Longnecker, An Introduction to Statistical Methods and Data Analysis, 5th Edition, Thomson Learning, U.S.A., 2001)*

Recruitment From	*Number*	*Percentage*
Corporate	501	37.2%
Public-interest	683	50.8%
Government	94	7.0%
Other	67	5.0%
Total	***1345***	***100.0%***

Although the data can be seen in Table C.1, the results are more easily interpreted by using a pie chart. From Figure C.1 certain inferences can be made about channels to positions of authority.

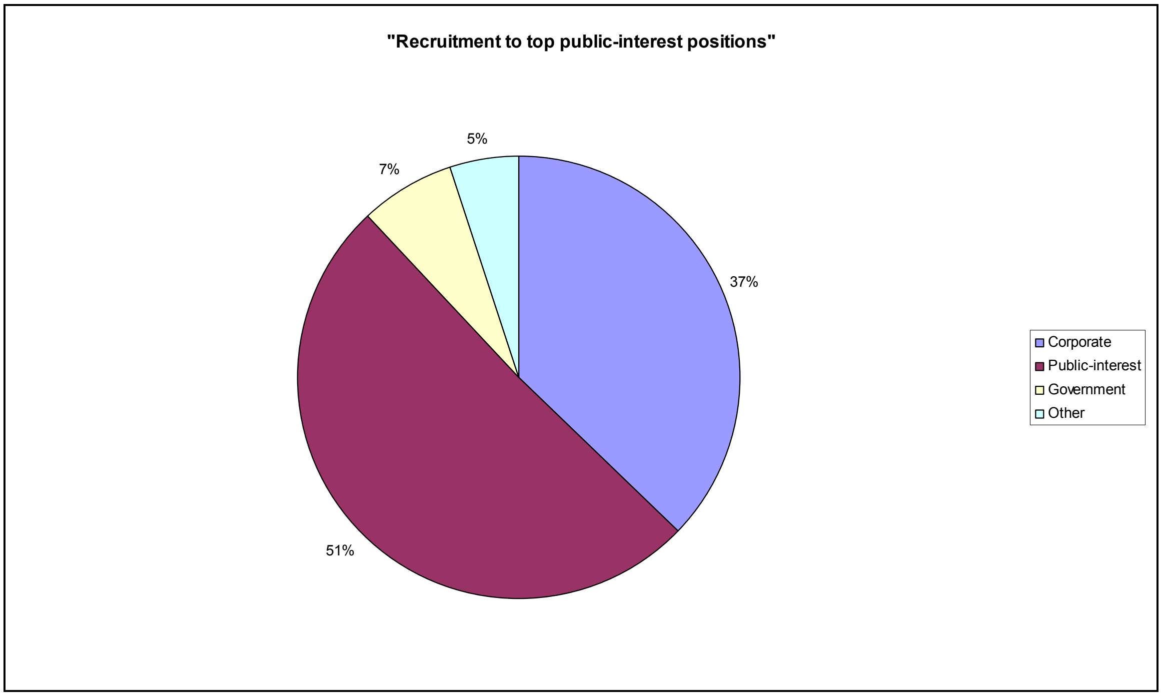


Figure C.1: Pie chart for the data of Table C.1.

A second graphical technique for data organization is the *bar chart*, or the bar graph. Figure C.2 displays the data of Table C.1 in a bar graph.

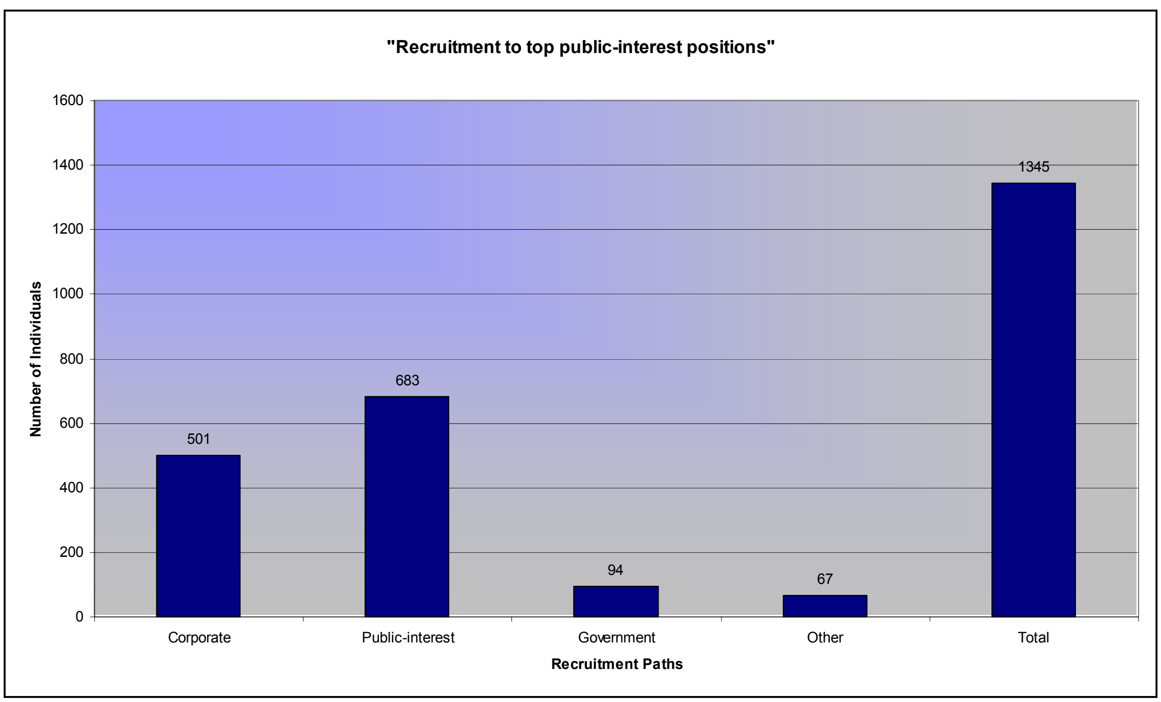


Figure C.2: Graph chart for the data of Table C.1.

The next two graphical techniques that are used are the *frequency histogram* and the *relative frequency histogram*. Regarding the *frequency histogram* the height of each bar is equal to the frequency of the class it represents. Each bar extends from its lower class limit on the left to the lower class limit of the next class on the right. Percentage data is displayed using a bar graph in which the bar heights are relative frequencies of classes. Such a graph is called *relative frequency histogram*. Both of these graphical techniques are applicable only to quantitative (measured) data. The data presented in Table C.2 are used as an example.

TABLE C.2

Grades assignments *(Source: Weiss, N. and M. Hassett, Introductory Statistics, Addison-Wesley, Philippines, 1982)*

Class	*Frequency*	*Relative Frequency*
0-9	0	0.00
10-19	0	0.00
20-29	0	0.00
30-39	2	0.10
40-49	0	0.00
50-59	0	0.00
60-69	3	0.15
70-79	3	0.15
80-89	8	0.40
90-99	3	0.15
100-109	1	0.05
Total	***20***	***1.00***

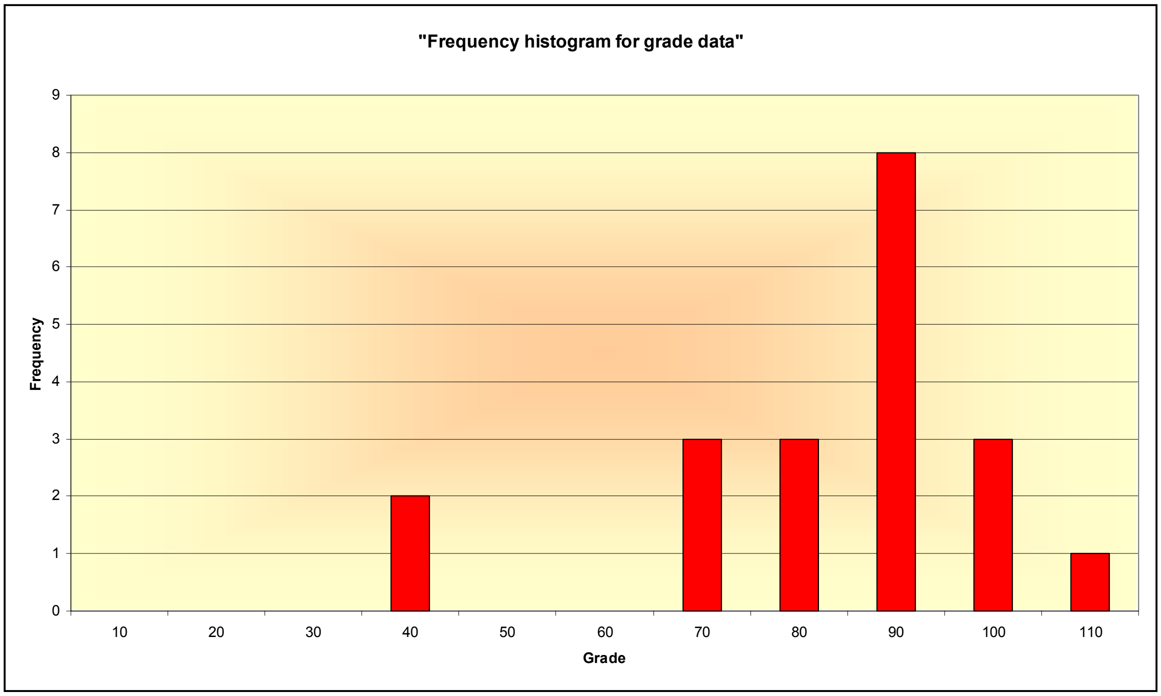


Figure C.3: Frequency histogram for the grade data of Table C.2.

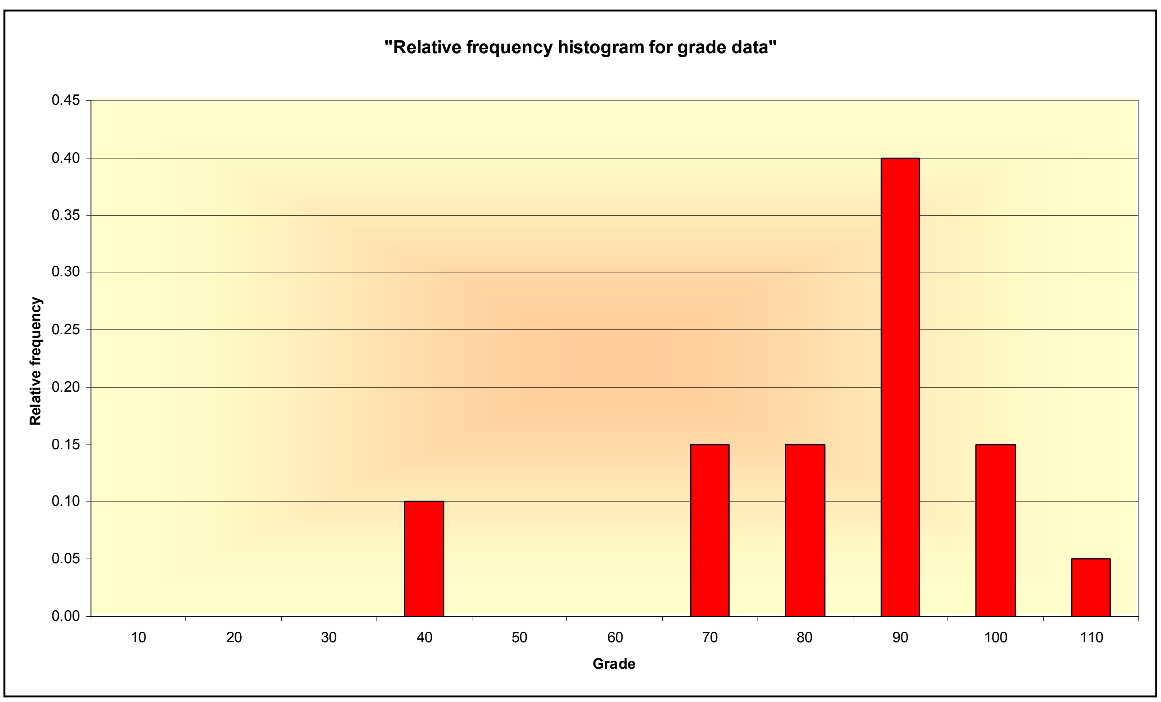


Figure C.4: Relative frequency histogram for the grade data of Table C.2.

APPENDIX D: GIS MAPS

This appendix includes all the GIS maps presented in Chapter 4 in a more detailed view with the exclusion of the table of contents.

FAIRFAX COUNTY

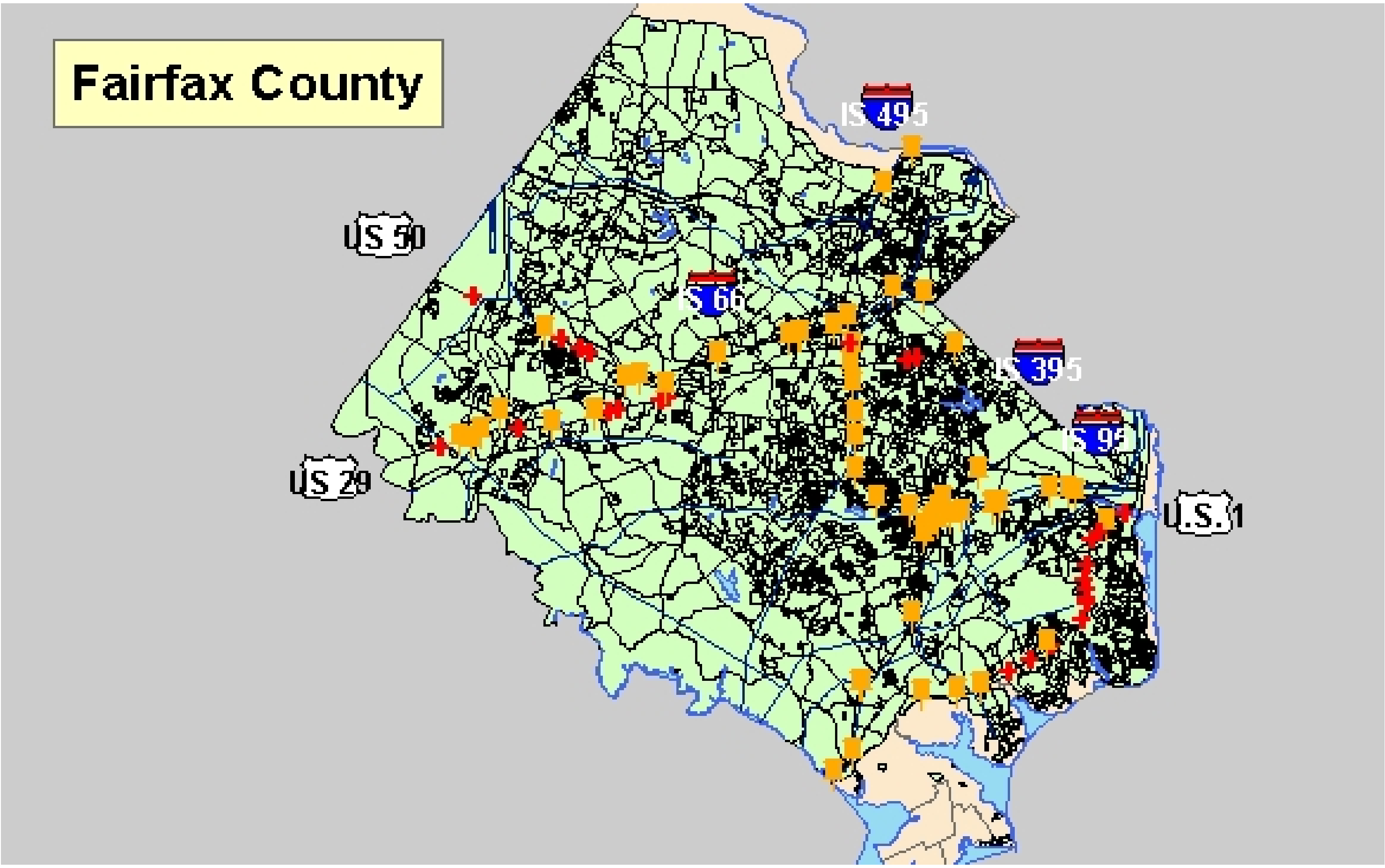


Figure D.1: Total number of crashes involving EVs by location description in terms of intersection relationship on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

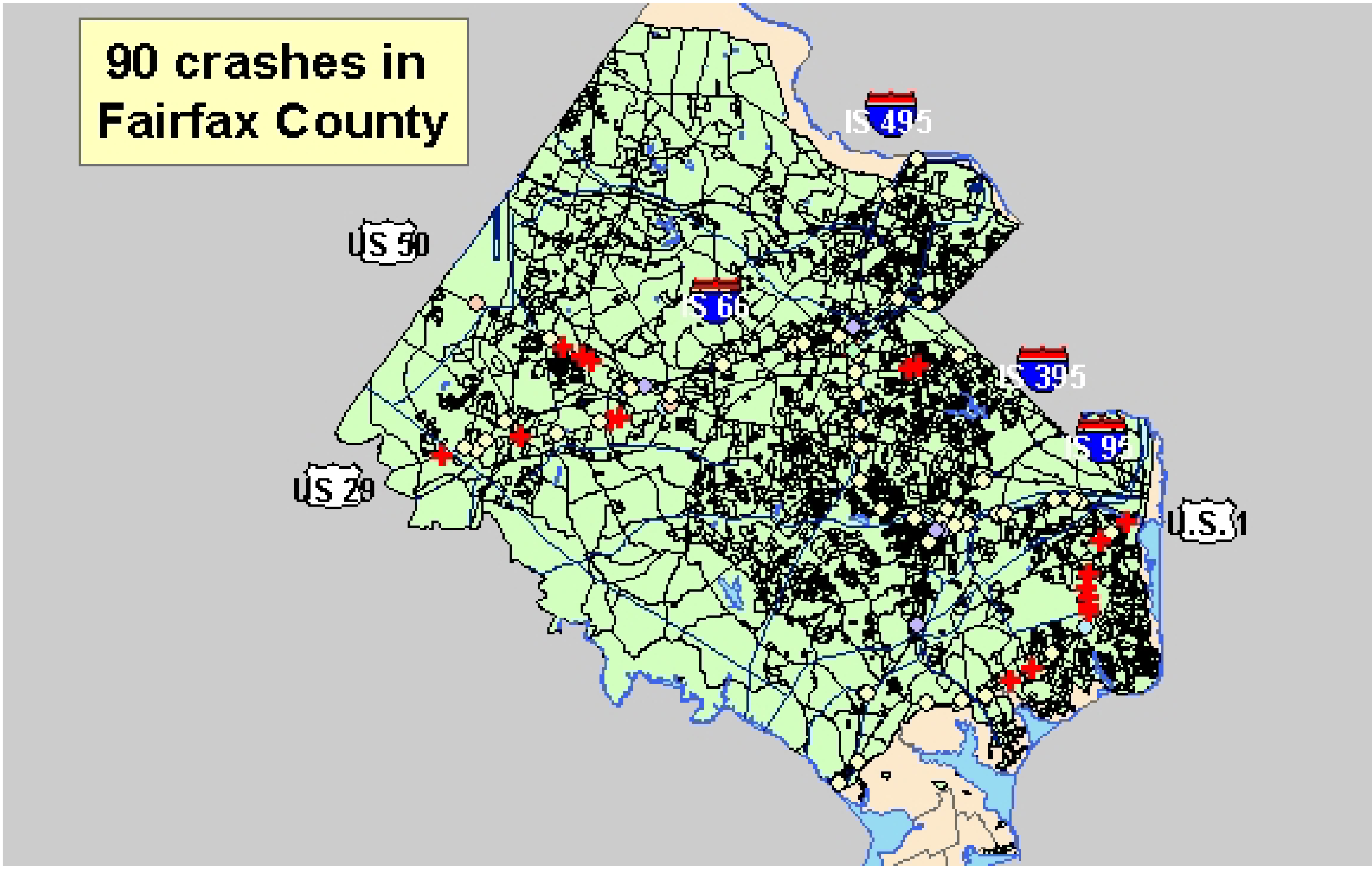


Figure D.2: Total number of crashes involving EVs by location description in terms of signalization relationship on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

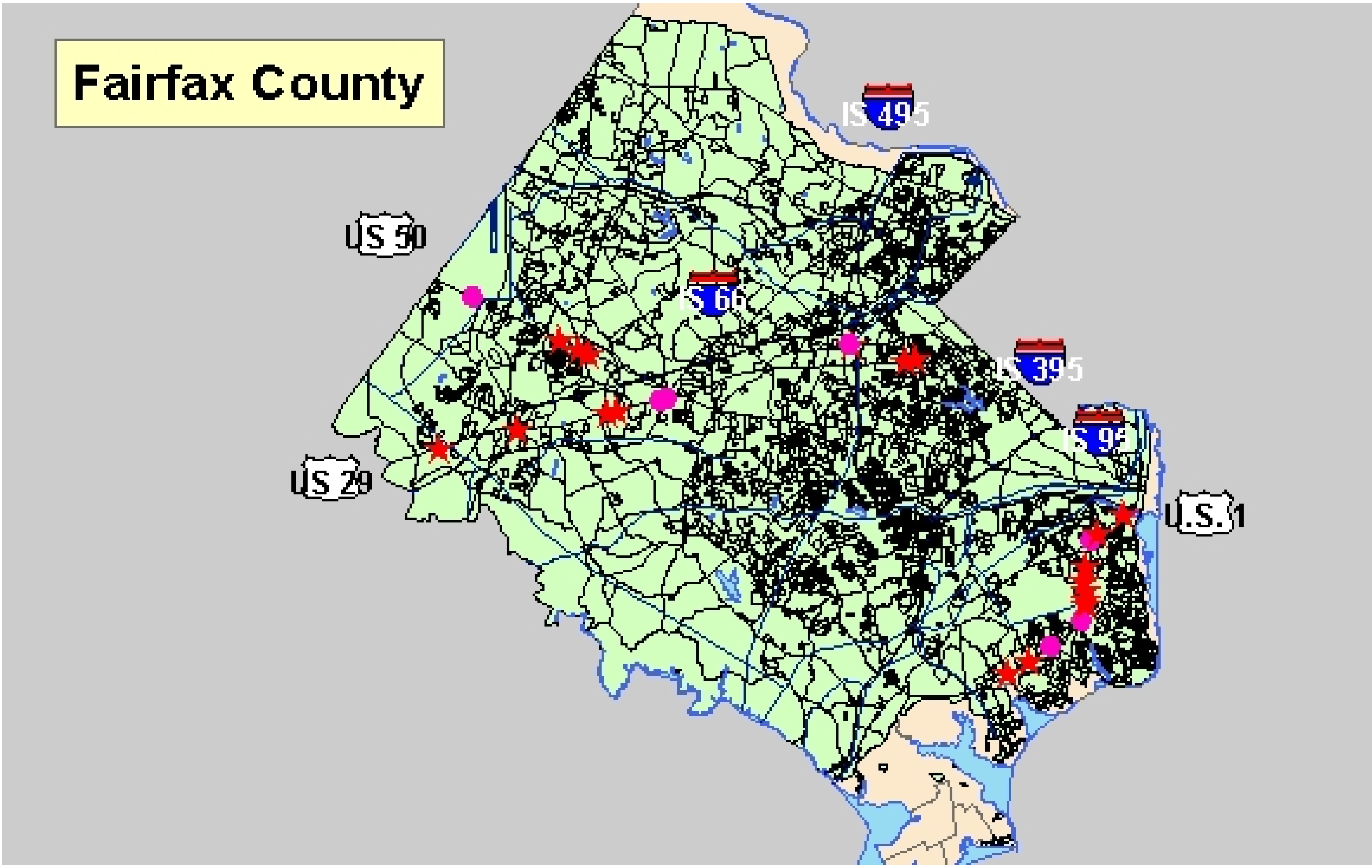


Figure D.3: Total number of crashes involving EVs at *intersections* by signalization relationship on the *U.S. Highways* in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

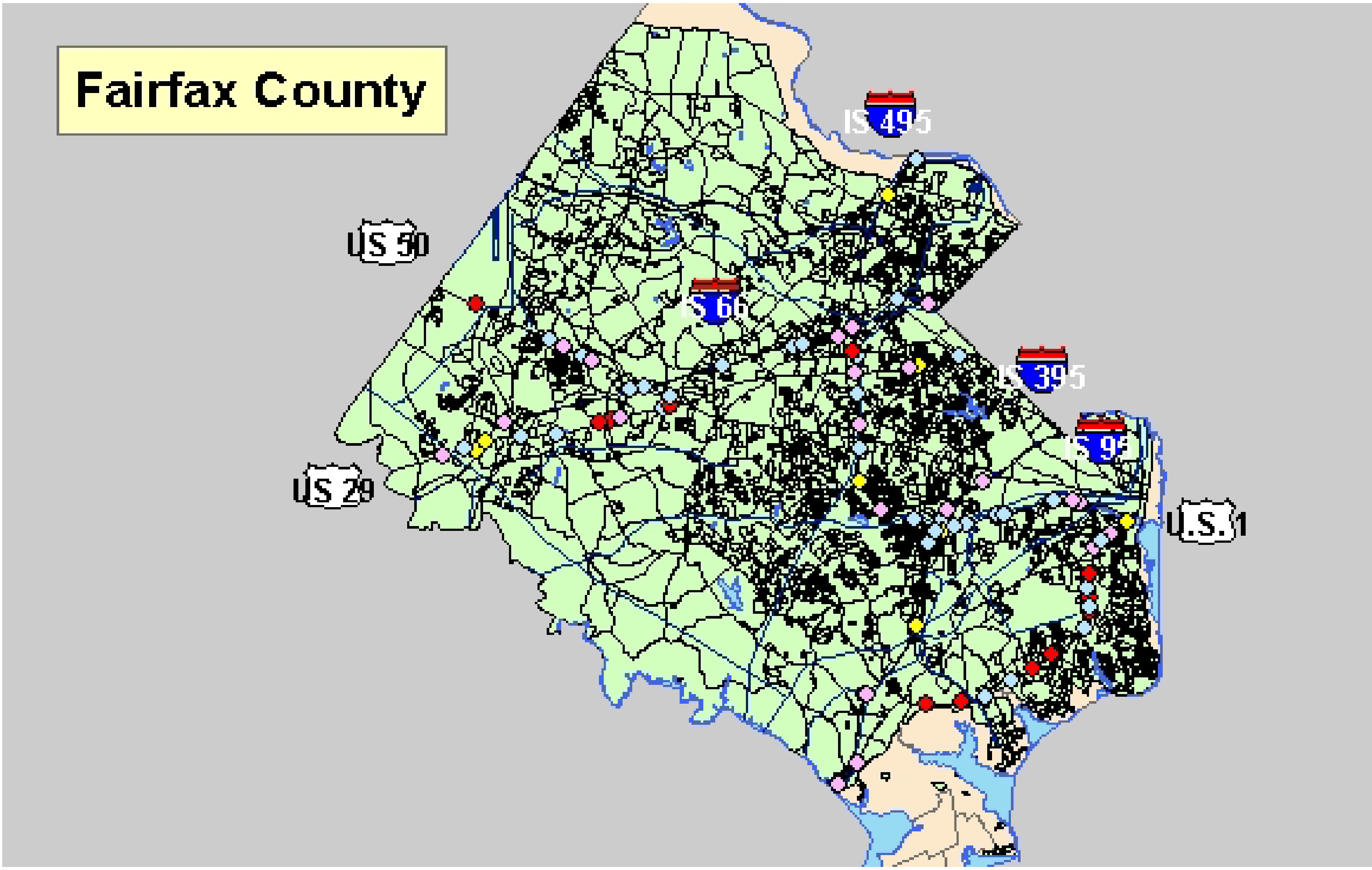


Figure D.4: Total number of crashes involving EVs by three top collision types on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

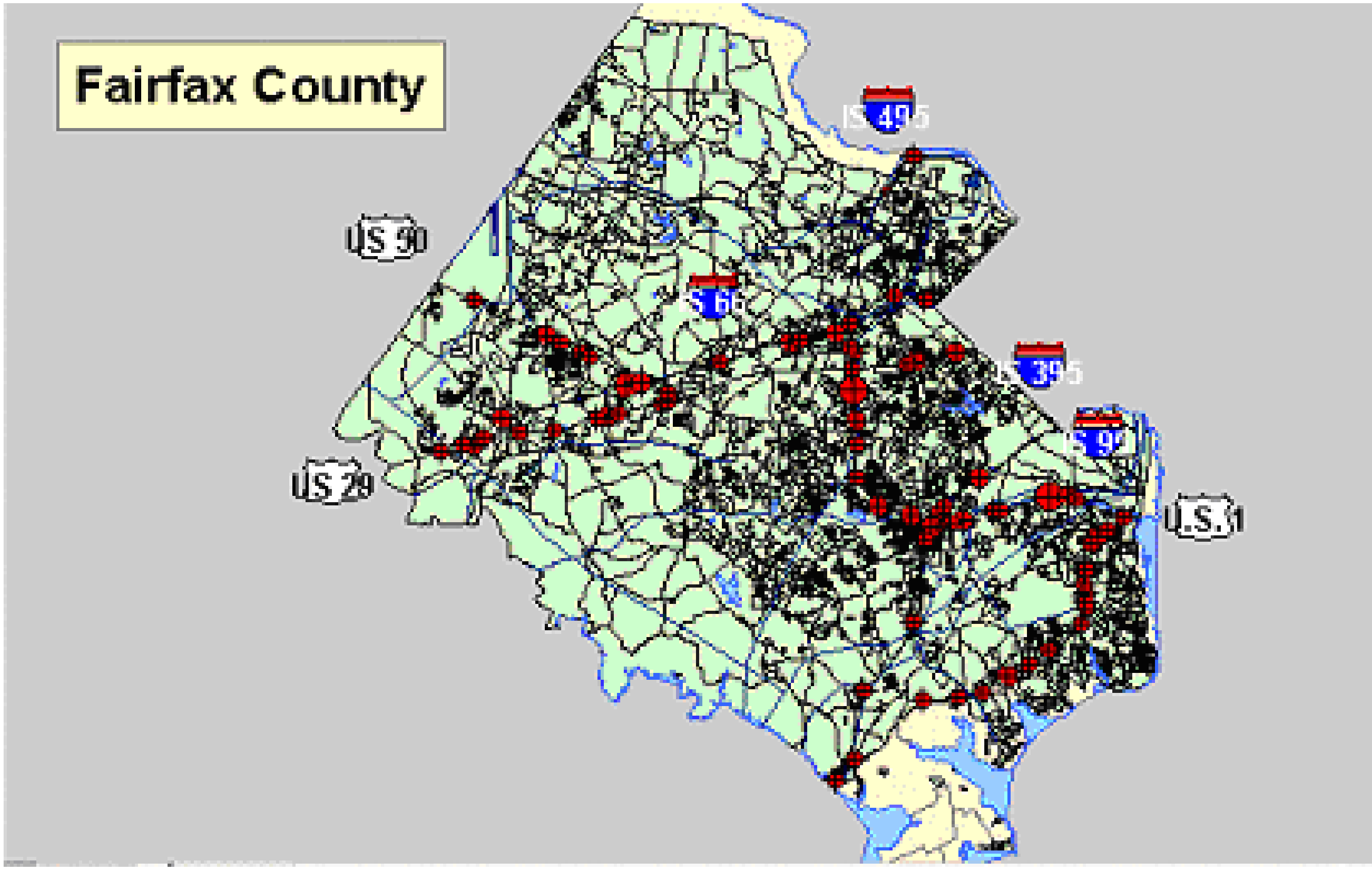


Figure D.5: Total number of crashes involving EVs by number of vehicles involved on the U.S. Highways and Interstates in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

U.S. ROUTE 1 IN FAIRFAX COUNTY

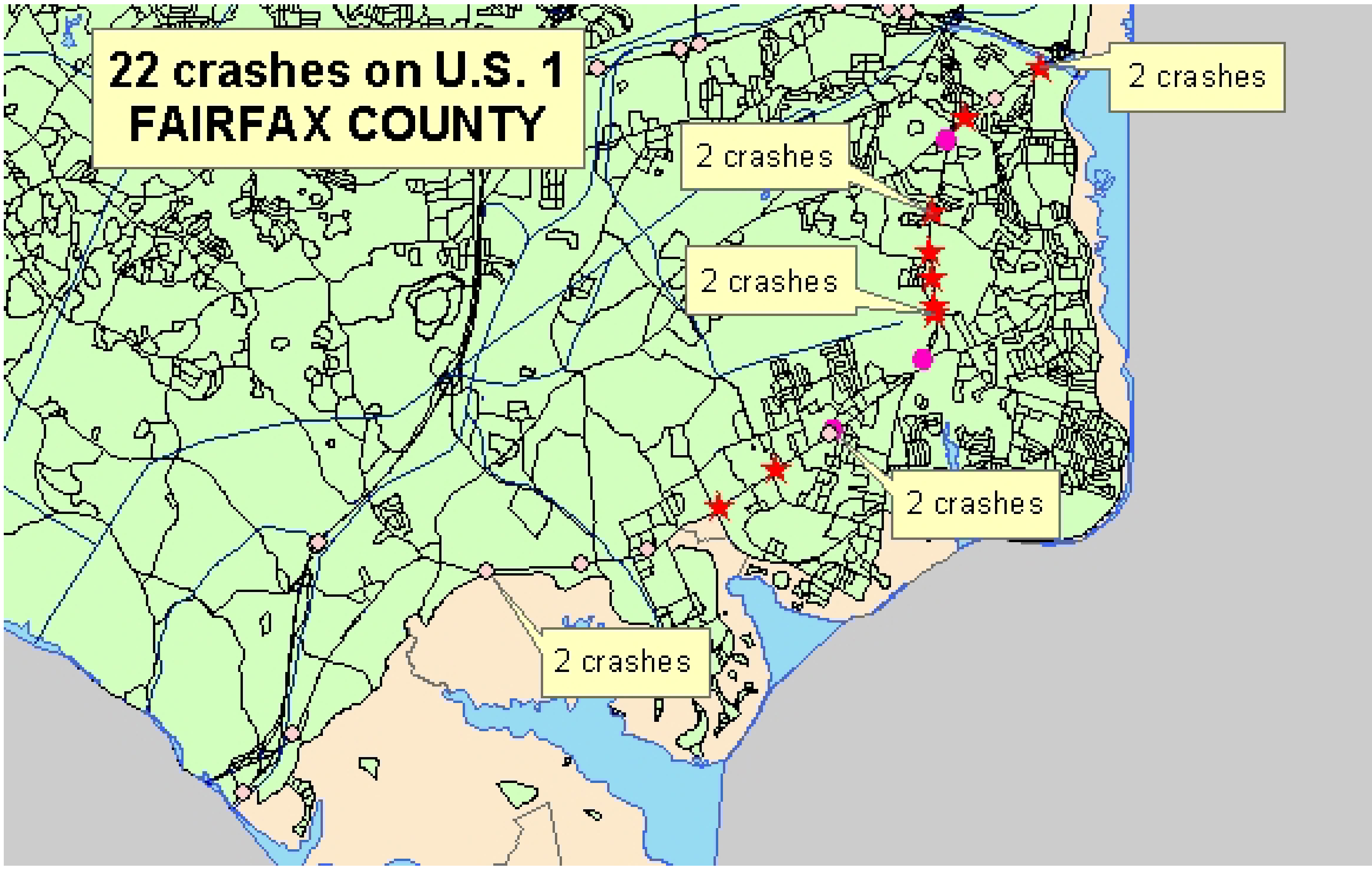


Figure D.6: Total number of crashes involving EVs by location description on U.S. Route 1 in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

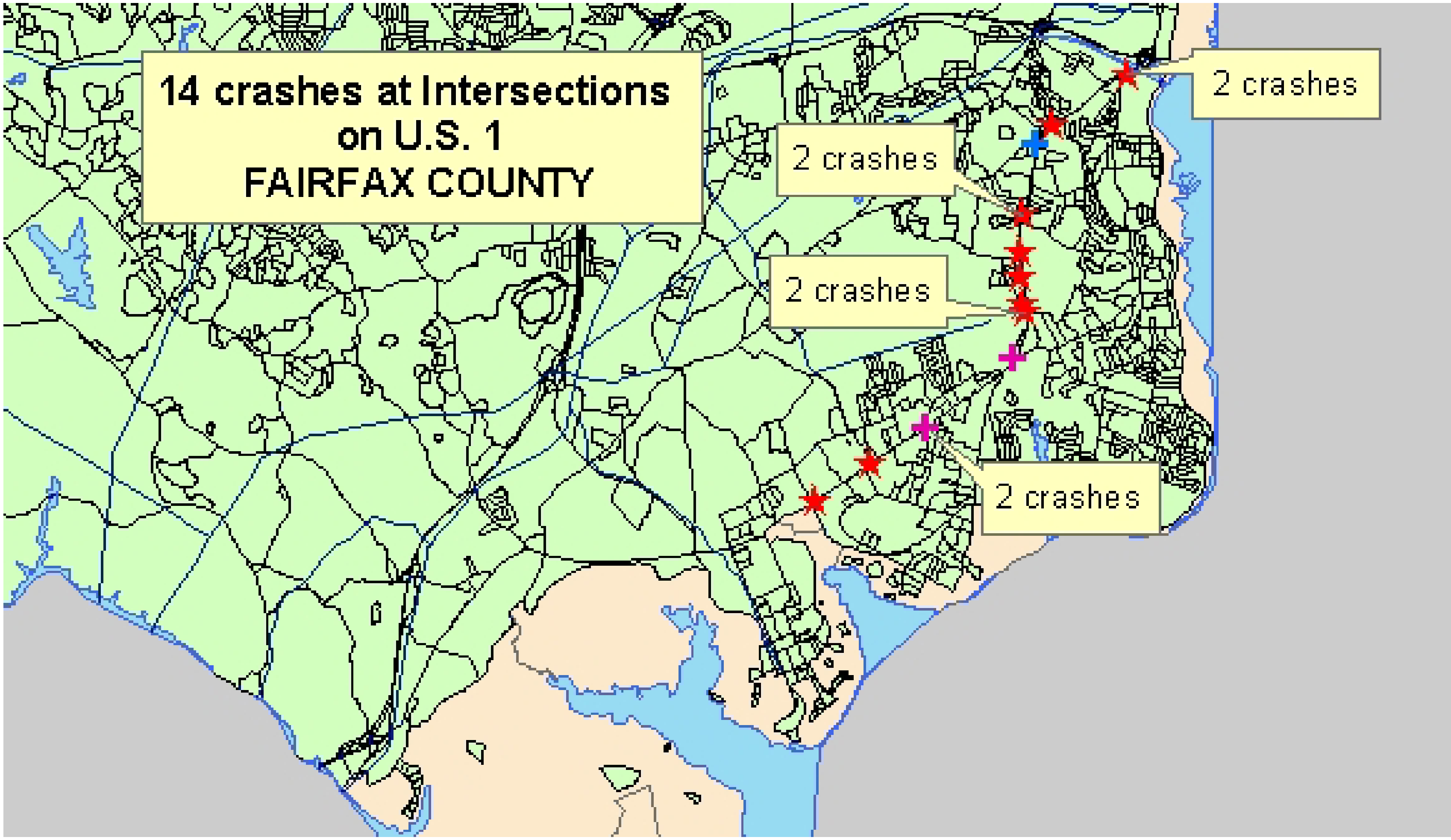


Figure D.7: Total number of crashes involving EVs by intersection description on U.S. Route 1 in Fairfax County from 1997 to 2001 using ArcGIS Desktop.

ARLINGTON COUNTY

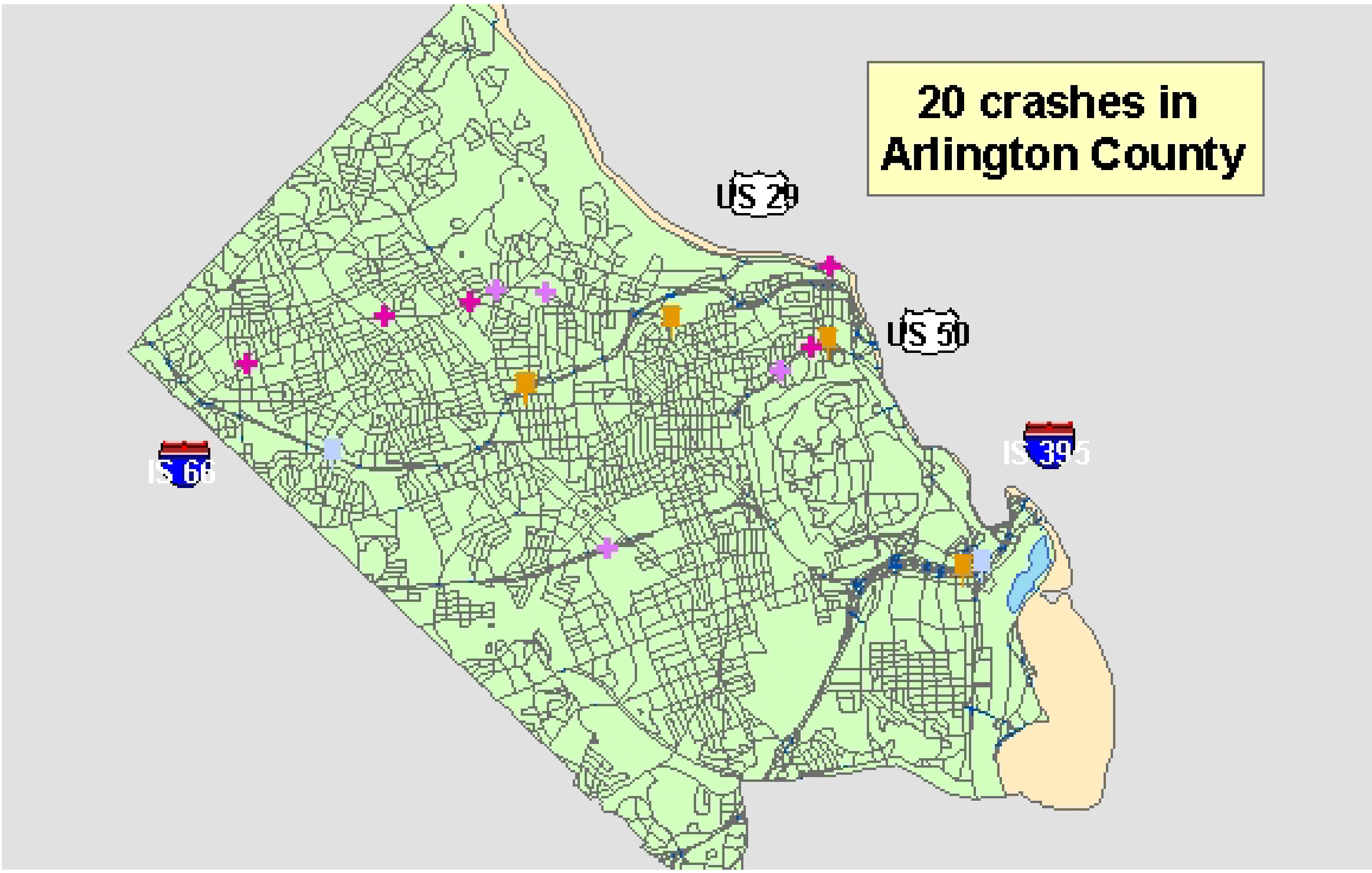


Figure D.8: Total number of crashes involving EVs by location description on the U.S. Highways and Interstates in Arlington County from 1997 to 2001 using ArcGIS Desktop.

LOUDOUN COUNTY

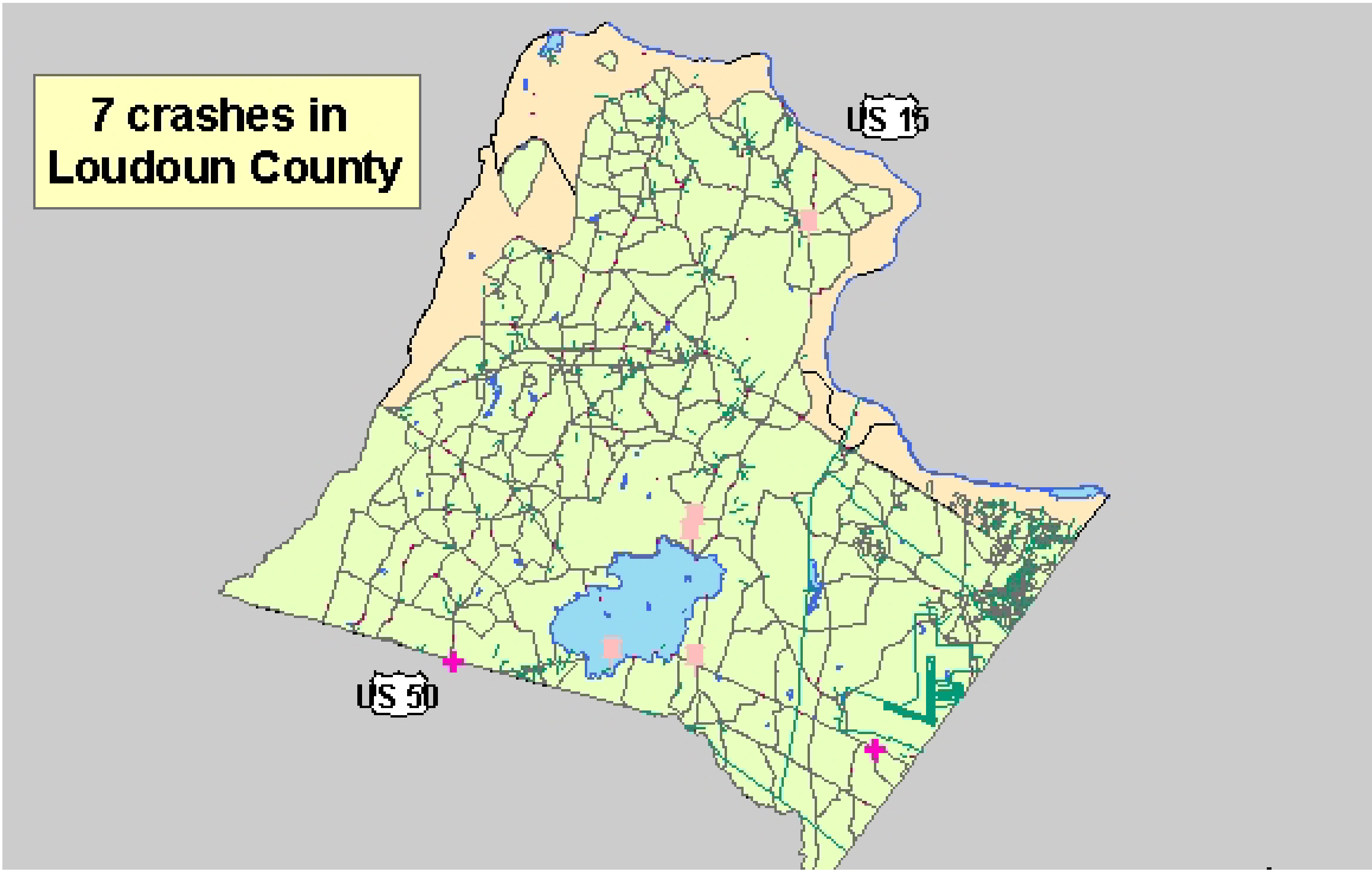


Figure D.9: Total number of crashes involving EVs by location description on the U.S. Highways and Interstates in Loudoun County from 1997 to 2001 using ArcGIS Desktop.

PRINCE WILLIAM COUNTY

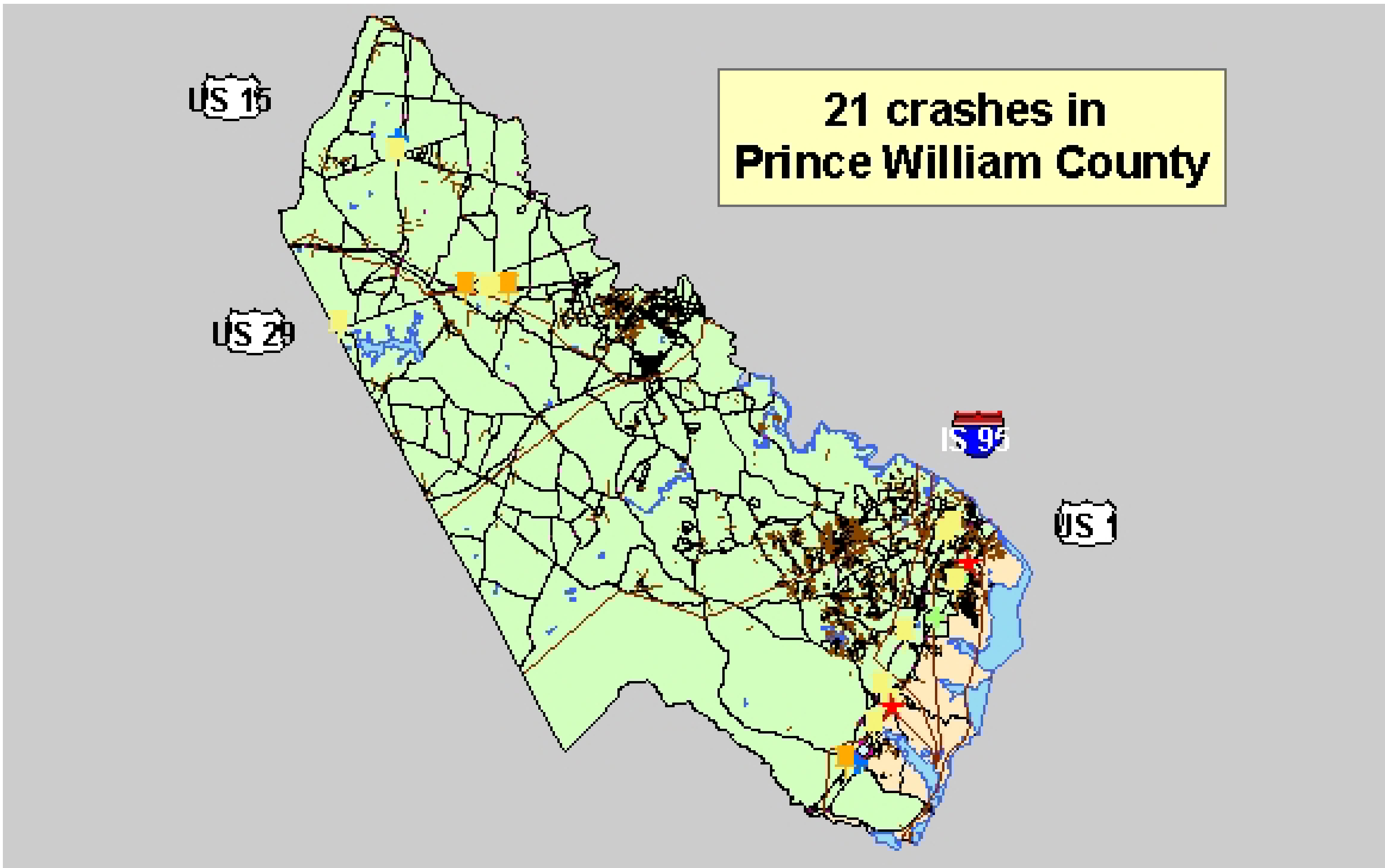


Figure D.10: Total number of crashes involving EVs by location description on the U.S. Highways and Interstates in Prince William County from 1997 to 2001 using ArcGIS Desktop.

APPENDIX E: THE CRASH SITUATION INVOLVING EVS IN THE U.S.

This part is drawn from the EMS Network Journal, which includes crashes involving emergency vehicles in the United States.
(http://www.emsnetwork.org/ambulance_crashes.htm)

In the year 1999 the following crashes involving emergency vehicles in the United States were reported in the EMS Network Journal:

Connecticut, New Haven. Four paramedics and an 8-year-old girl were injured when their ambulance collided with a car near the hospital on the 5th of October. The girl was in critical condition following the ambulance crash.

Louisiana, Deridder. A paramedic was killed in a crash involving an 18 wheeler on the 20th of May. The other paramedic on the ambulance was critically injured.

In the year 2000 the following crashes involving emergency vehicles in the United States were reported in the EMS Network Journal:

Pennsylvania, Uniontown. The Mutual Aid Ambulance Service ambulance transporting a patient collided with a car at the intersection of state routes 981 and 1020 on the 15th of August. The ambulance had its lights and siren operating.

In the year 2001 the following crashes involving emergency vehicles in the United States were reported in the EMS Network Journal:

South Carolina. An ambulance hit a car that ran a traffic signal on St. Andrews Road near Interstate 26 on the 18th of December. The lights and siren on the ambulance were operating while the driver did not heed the traffic signal and pulled in front of the ambulance.

New Jersey, Galloway. A car first sideswiped a southbound car stopped for a red light before proceeding into the road's intersection, where it was struck by a westbound ambulance.

In the year 2002 the following crashes involving emergency vehicles took place:

New Jersey, Morristown. An ambulance responding to a call on the 27th of December struck a car on South Street. The car was heavily damaged but no one was injured in the crash.

Ohio, Cincinnati. Four people were injured, including two Cincinnati firefighters on an emergency run when a vehicle crossed the center line on Columbia Parkway on the 19th of December and struck an ambulance. The ambulance's lights and siren were activated before the crash.

Florida, Volusia County. An ambulance transporting a patient was hit head-on by a pick-up truck on the 2nd of December. The patient was reportedly injured in the crash along with a paramedic and an ambulance driver. The driver of the other vehicle was not injured.

Mason Valley An ambulance carrying a patient was struck by a car on the 7th of December at the intersection of Saliman Road and Highway 50 East. No one was injured in the crash. The ambulance had its lights and sirens activated.

Missouri, Kansas City. An ambulance carrying an injured girl was involved in a hit-and-run crash on the way to the hospital on the 17th of November.

Oregon, North Keizer. An ambulance and two medics found themselves in a crash just a block away from the fire station. Fortunately, no one was injured in the crash. The emergency vehicle had its lights and siren blazing. Police indicated that the best reaction of the drivers in case of an emergency vehicle approaching them is to pull to the right side of the road and come to a complete stop until the emergency vehicle passes. Motorists must, also, remain 500 feet back of emergency vehicles. There have been records of drivers not stopping at all, others pulling to the center of the road, as well as observations of erratic driving behaviors as accelerating.

Chicago. A Chicago Fire Department spokesman reported that a department ambulance rolled over after it was involved in a crash with another vehicle on the 8th of November. Five people were light injured, including two paramedics. The ambulance had its lights and siren on at the time of the crash.

Ohio, Avondale. One person received minor injuries after an ambulance collided with a car near the corner of Oak and Reading roads on the 15th of November. The patient in the ambulance suffered no additional injuries because of the wreck.

Ohio, Cleveland. An Emergency Medical System paramedic on a medical run became a patient in his own ambulance after he was struck by a sport-utility vehicle on the 6th of November.

New York. An Emergency Medical System ambulance and a vehicle collided on the 1st of November. The ambulance had its lights and sirens on, heading to a call. Police reported that the second vehicle went through the intersection, right into the ambulance. There were three injuries resulted from the collision.

New Jersey. Police reported no serious injuries when a city ambulance was involved in a three-vehicle crash at Boulevard and Park Avenue on the 26th of October. The ambulance had its lights and siren in operation.

Virginia, Newport News. Five people suffered minor injuries on the 29th of October when an ambulance en route to a six-vehicle crash, swerved to avoid a collision, flipped onto its side and struck a minivan.

California, Fresno. An ambulance was involved in a crash with a vehicle, which proceeded through an intersection on the 23rd of October. The driver claimed that he felt having a green light gave her the right away in spite of the emergency warning lights and siren that stopped everyone else.

New Jersey, Hammonton. A head-on collision between an ambulance and another vehicle claimed the life of two people including the patient transported on the 26th of October.

California, Los Angeles. An ambulance was involved in a crash in California Highway, when a vehicle moved from the middle to the left lane striking the ambulance on the 17th of October. No one appeared to be seriously hurt.

Tennessee. A crash on the 17th of October sent four people to the hospital when a bus carrying four passengers collided with an ambulance on its way to pick up a patient. No serious injuries were reported.

Georgia, DeKalb County. A motorist was killed on the 22nd of September when his car collided with an ambulance that was en route to an earlier wreck. The fatal wreck occurred at the intersection of North Druid Hills and Clairmont Roads. The ambulance had emergency lights flashing and siren blaring.

Nevada, Reno. A motorist charged with failure to yield to an emergency vehicle after she ran into an ambulance on the 23rd of September. The ambulance was operating its siren and emergency lights and transporting a critically ill patient to the hospital when the crash occurred. One paramedic and an emergency technician were treated for minor injuries.

New Jersey. Two emergency medical technicians were taken to the hospital after their ambulance was struck by a sport-utility vehicle as it crossed the intersection of Arlington and Wilkinson avenues, causing the EMTs to crash into a tree on the 17th of September. The ambulance passed the intersection with its lights and siren on.

Virginia, Roanoke. An ambulance collided with a pickup truck on the 6th of September. The ambulance, which went through a red light, had its emergency lights and sirens on. The pickup truck had a green light and the driver claimed that he did not hear the sirens until too late. Authorities indicate that emergency vehicles are allowed to go through red traffic signals with their equipment activated and still use caution through intersections.

Pennsylvania, Lancaster. An ambulance sideswiped by a car as it went through a Springettsbury Township intersection on the 6th of September. The ambulance facing a red light stopped and then drove through the intersection with its lights and siren activated.

Indiana. Two people were hurt when a paramedic vehicle responding to an injury call collided with another vehicle at the intersection of River Road and State Road 32 on the 21st of August. The emergency's vehicle lights and siren were activated when the collision occurred.

Georgia, Bartow. An ambulance, with lights and sirens blaring, traveling westbound was involved in a collision with a vehicle after the motorist failed to yield on the 16th of August. There were no serious injuries in the crash.

Minnesota, Fergus Falls. An ambulance while responding to an emergency was struck hit head by a car rolled multiple times and caught fire on the 26th of July.

New York. The driver of a motorcycle was critically injured on the 9th of August when his motorcycle collided with an ambulance and burst into flames. The ambulance had its lights and siren on.

Kentucky. Two paramedics and the driver of another car were treated after a two-car crash on the 10th of July.

Wyoming, Cheyenne. A pickup full of passengers collided with an ambulance carrying a woman involved in another crash on the 9th of July. The ambulance was not running its siren or driving at a high rate of speed.

New Jersey. An ambulance, traveling with its lights and siren activated, was hit by a cab, which failed to yield on the 8th of July.

Maryland, Wheaton. An ambulance was going to pick up a stroke victim when it collided with a sport-utility vehicle on the 8th of July.

Missouri, Camden County. An ambulance transporting a patient and a passenger was hit head on and rolled on the 4th of July. Eleven people were hurt in the crash.

Texas, Denton. A van full of children slammed into an ambulance running to an emergency medical call sending nine people to area hospitals but resulting in no life-threatening injuries on the 7th of June.

New York, Rochester. An ambulance had its lights and siren on going to a call, when it collided with a tractor trailer at an intersection on the 23rd of June. There were minor injuries.

California, Los Angeles. An ambulance answering an emergency call crashed into a commuter train at an intersection, where no crossing gate exists on the 5th of June. There were minor injuries.

Texas, Lubbock. An ambulance with lights and siren activated collided with another vehicle, which had the green light at the intersection of Brownfield Highway on the 1st of June. There were minor injuries.

Montana, Great Falls. An ambulance was knocked over in a collision with a second vehicle at the intersection of Central Avenue and 25th Street on the 31st of May. There were minor injuries.

New Jersey, Ridgefield. An ambulance was sideswiped by a truck near the intersection of Fairview Terrace on the 1st of May. There were minor injuries.

New York. An emergency vehicle was struck at the intersection of U.S. Route 209 and state Route 213 by another vehicle on the 27th of April. There were minor injuries.

New York. An ambulance rushing to a scene of a reported shooting was struck by a van that ran a stop sign at a Brooklyn intersection on the 19th of April resulting in the death of an emergency medical technician and serious injuries of four other people.

Texas. An ambulance, with its lights and siren activated, collided with another car, which had the green light but did not slow down at an intersection on the 17th of April.

Indiana. A driver of a pickup truck was injured when his vehicle collided with an ambulance, which burst into flames on the 11th of April.

Pennsylvania, Morgantown. An ambulance was involved in a crash at an intersection on the 17th of March resulting in a death of an infant.

CT, New Haven. A two-vehicle crash involving an ambulance, using lights and sirens, sent occupants of the car to the hospital. The crash occurred at an intersection on the 16th of March.

Pennsylvania, Waynesburg. A car sideswiped an ambulance, not responding to an emergency at the time of the crash, with no injuries on the 7th of February.

Pennsylvania, Abigton. An ambulance, which was not on an emergency call, collided with a sport-utility vehicle at an intersection on the 10th of February.

Texas, Houston. An ambulance was involved in a crash with another vehicle while heading to a crash scene on the 24th of January.

Missouri. A medic unit toppled onto its side after being hit by a car. Two paramedics were slightly injured along with the driver who struck the ambulance on the 22nd of January.

California, Los Angeles. An ambulance, with its emergency lights and siren activated, collided with another vehicle, when it entered a signal-controlled intersection on the 14th of January. A total of five vehicles were involved in the collision or its aftermath, bringing to six the total of patients.

Texas. An ambulance was hit by a car running a red light at an intersection on the 8th of January. Neither was injured.

In the year 2003 the following crashes involving emergency vehicles in the United States were reported in the EMS Network Journal:

Texas. A man was killed on the 8th of February when his vehicle crossed over into oncoming traffic and collided with an ambulance.

Massachusetts, Acton. A paramedic was injured on the 14th of February when the emergency vehicle she was driving rolled over after colliding with a sport-utility vehicle.

Illinois, Springfield. An ambulance, operating its flashing lights and siren, was hit by another car when it crossed an intersection against a red stop on the 20th of February. Both drivers suffered injuries in the crash.

Ohio, Lorain. An ambulance on an emergency run flipped onto its side apparently after a collision with a car near an intersection on the 24th of February.

Pennsylvania. A 3-day-old baby survived after the ambulance it was on had been crashed head-on by a car, whose driver was killed on the 25th of February.

California, Los Angeles. A Fire Department ambulance and fire engine responding to the same call collided at a busy intersection on the 5th of March resulting in minor injuries.

Florida, Key West. An ambulance, traveling with its lights and siren activated, hit a motorcyclist, who did not yield the right-of way at an intersection on the 6th of March.

California, Long Beach. On the 7th of March a crash involving a paramedic vehicle on its way to the fire house and a pick-up truck at an intersection resulted to minor injuries.

Tennessee. On the 8th of March a crash involving an ambulance and another car took place resulting in minor injuries.

Florida, South Daytona. A male driver was arrested and charged with drunken driving after his car pulled in front of an EVAC ambulance at the intersection of U.S. Route 1 and Reed Canal Road on the 8th of March.

Oklahoma, South Tulsa. On the 9th of March an ambulance was heavily damaged and had to be taken out of service after it was hit by a tow truck while responding to another crash.

APPENDIX F: NONPARAMETRIC METHODS AND THE CHI-SQUARE STATISTICAL TESTS

This part includes a short description of the main principals of the nonparametric methods and the chi-square statistical test and it is drawn from the book of Washington S. P., Karlaftis M.G. and Mannering F.L., *Statistical and Econometric Methods for Transportation Data Analysis,* Chapman & Hall/CRC, U.S.A, 2003. In addition, it includes the presentation of statistical tests performed with the application of the chi-square statistical test on the crash data obtained.

F.1 NONPARAMETRIC METHODS

Nonparametric methods typically require fewer stringent assumptions than do their parametric alternatives and they use less information contained in the data. A nonparametric technique should be considered under the following conditions:

1. The sample data are frequency counts and a parametric test is not available.
2. The sample data are measured on the ordinal scale.
3. The research hypotheses are not concerned with specific population parameters such as μ and σ^2.
4. Requirements of parametric tests such as approximate normality, large sample sizes, and interval or ratio scale data, are grossly violated.
5. There is moderate violation of parametric test requirements, as well as a test result of marginal statistical significance.

F.2 The Chi-Square Test

The χ^2 test sees widespread use in a variety of transportation analyses. Its popularity stems from its versatility and its ability to help assess a large number of questions. The data uses in χ^2 tests are either counts or frequencies measured across categories that may be measured on any scale. Examples include the number of accidents by accident type, number of people who fall into different age and gender categories, number of speeding tickets by roadway functional class, number of vehicles purchased per year by household type, etc. The χ^2 distribution and associated statistical tests are very common and useful. All versions of the χ^2 test follow a common five-step process (Aczel, 1993):

1. Competing hypotheses for a population are stated (null and alternative).
2. Frequencies of occurrence of the events expected under the null are computed. This provides expected counts or frequencies based on some "statistical model", which may be a theoretical distribution, an empirical distribution, an independence model, etc.
3. Observed counts of data falling in the different cells are noted.
4. The difference between the observed and the expected counts are computed and summed. The difference leads to a computed value of the χ^2 test statistic.
5. The test statistic is compared to the critical points of the χ^2 distribution and a decision on the null hypothesis is made.

More statistical software packages that compare actually observed data to hypothesized distributions use and report the X^2 test statistic. Caution should be exercised, however, when applying the χ^2 test on small sample sizes or where cells are defined such that small expected frequencies are obtained. In these instances the χ^2 test is inappropriate and exact methods should be applied (see Mehta and Patel, 1983, for details).

Contingency tables can be helpful in determining whether two classification criteria, such as age and satisfaction with transit services, are independent of each other. The technique makes use of tables with cells corresponding to cross-classification of attributes or events. The null hypothesis that factors are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for a contingency table are as follows (the general form of a contingency table is shown in Table F.1):

TABLE F.1

General Layout of a Contingency Table

Second Classification	**First Classification Category**			
Category	**1**	**.**	**j**	**Total**
1	C_{11}	.	.	R_1
i	.	.	C_{ij}	R_i
Total	C_1	.	C_j	n

H_0: The two classification variables are statistically independent.

H_a: The two classification variables are not statistically independent.

The test statistics X^2 of Equation F.1 for a two-way contingency table is rewritten as follows:

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} \tag{F.2}$$

where the differences between observed and expected frequencies are summed over all rows and columns (r and c, respectively). The test statistic in Equation F.2 is approximately χ^2 distributed with degrees of freedom, $df = (r-1)(c-1)$. Finally, the expected count in cell (i, j), where R_j and C_i are the row and column totals, respectively, is

$$E_{ij} = \frac{R_i C_j}{n} \tag{F.3}$$

The expected counts obtained from Equation F.3 along with the observed cell counts are used to compute the value of the X^2 statistic, which provides objective information needed to accept or reject the null hypothesis. The X^2 test statistic can easily be extended to three or more variables, where summation is simply extended to cover all cells in the multiway contingency table. As tested previously, caution must be applied to contingency tables based on small sample sizes or when expected cell frequencies become small; in these instances X^2 statistic is unreliable, and exact methods should be used.

Contingency tables and the X^2 test statistic are also useful for assessing whether the proportion of some characteristic is equal in several populations. A transit agency, for example, may be interested in knowing whether the proportion of people who are satisfied with transit quality of service is about the same for three age groups: under 25, 25 to 44, and 45 and over. Whether the proportions are equal is of paramount importance in assessing whether the three age populations are homogeneous with respect to satisfaction with the quality of service. Therefore, tests of equality of proportions across several populations are called tests of homogeneity.

Homogeneity tests are conducted similarly to previously described tests, but with two important differences. First, the populations of interest are identified prior to the analysis and sampling is done directly from them, unlike contingency tables analysis where a sample is drawn from one population and then cross-classified according to some criteria. Second, because the populations are identified and sampled from directly, the sample sizes representing the different populations of interest are fixed. This experimental setup is called a fixed marginal totals χ^2 analysis and does not affect the analysis procedure in any way.

F.3 STATISTICAL TESTS

F.3.1 Introduction

This part of the analysis includes the application of a nonparametric method known as the chi-square test which will assess if two or more classification variables are statistically independent.

Contingency tables can be helpful in determining whether two or more classification criteria are independent of each other. This technique makes use of tables with cells corresponding to cross-classification of attributes or events. The null H_0 and alternative H_a hypotheses are obtained as follows:

H_0: The two or more classification variables are statistically independent.
H_a: The two or more classification variables are not statistically independent.

The null hypothesis is used to obtain the expected distribution of frequencies in each of the contingency table cells.

F.3.2 Intersection type and number of EV crashes on the U.S. Highways in Northern Virginia

The chi-square test will be applied to test whether the intersection type (*first classification category*) and the number of EV crashes (*second classification category*) on the U.S. Highways in Northern Virginia are *statistically independent*.

The null hypothesis that the intersection type and the number of EV crashes are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0: The intersection type and the number of EV crashes are statistically independent.

H_a: The intersection type and the number of EV crashes are not statistically independent.

CONTINGENCY TABLE F.2

Intersection type vs. Number of EV crashes on the U.S. Highways in Northern Virginia

Intersection Type	# of EV Crashes ($E_{\cdot 1}$)[1]
"T"	13 (11.5)
Branch	4 (11.5)
Crossing	6 (11.5)
Signalized	23 (11.5)
Total	*46*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 19.2174.$$

$$df = r - 1 = 4 - 1 = 3.$$

From Table F.10: $\chi^2_{0.05,3\cdot} = 7.8147$ and therefore, $X^2 > \chi^2_{0.05,3}$ (19.2174>7.8147).

At the 0.05 level of significance we reject the null hypothesis that the intersection type and the number of EV crashes are statistically independent. This means that when the intersection type is known we can draw a conclusion regarding the number of EV crashes that have occurred at the site at the 0.05 level of significance. It can be observed that the number of EV crashes at signalized intersections is significantly higher compared to non-signalized intersections.

F.3.3 Crash site type and collision type on the U.S. Highways in Northern Virginia

The chi-square test will be applied to test whether the crash site type in terms of relationship to intersection (*first classification category*) and the collision type (*second classification category*) for the EV crashes on the U.S. Highways in Northern Virginia are *statistically independent*.

The null hypothesis that the crash site type and the collision type are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0: The crash site type and the collision type are statistically independent.

H_a: The crash site type and the collision type are not statistically independent.

CONTINGENCY TABLE F.3

Crash site type vs. Collision type for EV crashes on the U.S. Highways in Northern Virginia

Collision Type	**Crash Site Type**		
	Int/ions ($E_{\cdot 1}$)[1]	**Non-Int/ions ($E_{\cdot 2}$)**	***Total***
Angle	18 (15.0)	6 (9.0)	*24*
Rear end	11 (13.1)	10 (7.9)	*21*
Sideswipe-Same direction of travel	11 (11.9)	8 (7.1)	*19*
Total	*40*	*24*	*64*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 2.6894.$$

$$df = (r-1)(c-1) = (3-1)(2-1) = 2 \times 1 = 2.$$

From Table F.10: $\chi^2_{0.05,2} \cdot = 5.9915$ and therefore, $X^2 < \chi^2_{0.05,2}$ (2.6894<5.9915).

At the 0.05 level of significance we accept the null hypothesis that the crash site type and the collision type are statistically independent. This result even though it is not the expected one, it can be explained with the statistically limited number of crashes involving EVs that have occurred on the U.S. Highways in Northern Virginia which can lead to a poor distribution among the two classification categories.

F.3.4 Geographic area and collision type

The chi-square test will be applied to test whether the geographic area (*first classification category*) and the collision type (*second classification category*) for EV crashes along the U.S. Highways and Interstates in Northern Virginia are *statistically independent*.

The null hypothesis that the geographic area and the collision type are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0: The geographic area and the collision type are statistically independent.

H_a: The geographic area and the collision type are not statistically independent.

CONTINGENCY TABLE F.4

Geographic area vs. Collision type for EV crashes on the U.S. Highways and Interstates in Northern Virginia

Collision Type	Geographic Area			
	Region ($E_{\cdot 1}$)[1]	**County ($E_{\cdot 2}$)**	**U.S. 1 ($E_{\cdot 3}$)**	***Total***
Angle	25 (26.5)	15 (17.9)	9 (4.6)	*49*
Rear end	51 (52.4)	39 (35.4)	7 (9.2)	*97*
Sideswipe	38 (35.1)	23 (23.7)	4 (6.2)	*65*
Total	*114*	*77*	*20*	*211*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 6.5751.$$

$$df = (r-1)(c-1) = (3-1)(3-1) = 2 \times 2 = 4.$$

From Table F.10: $\chi^2_{0.05,4}. = 9.4877$ and therefore, $X^2 < \chi^2_{0.05,4}$ (6.5751<9.4877).

We accept the null hypothesis that the geographic area and the collision type are statistically independent. This means that no conclusions can be drawn for the collision type when the geographic area is known and the opposite. This result could be due to the fact that Fairfax County as well as U.S. Route 1 are subsets of the whole region of Northern Virginia and the crashes occurred on the U.S. Highways and Interstates in the County and the crash situation in respect to crash severity presents no difference among the three different geographic areas.

F.3.5 U.S. Highway ID and collision type

The chi-square test will be applied to test whether the U.S. Highway ID (*first classification category*) and the collision type (*second classification category*) for EV crashes along the U.S. Highways with the exclusion of U.S. 15 in Northern Virginia are *statistically independent*.

The null hypothesis that the U.S. Highway ID and the collision type are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0: The U.S. Highway ID and the collision type are statistically independent.

H_a: The U.S. Highway ID and the collision type are not statistically independent.

CONTINGENCY TABLE F.5

U.S. Highway ID vs. Collision type for EV crashes along the U.S. 1, 29 and 50 in Northern Virginia

Collision Type	**U.S. Highway ID**			
	U.S. 1 ($E_{\cdot 1}$)[1]	**U.S. 29 ($E_{\cdot 2}$)**	**U.S. 50 ($E_{\cdot 3}$)**	***Total***
Angle	12 (11.2)	9 (7.0)	3 (5.8)	*24*
Rear end	7 (8.4)	5 (5.3)	6 (4.3)	*18*
Sideswipe	8 (7.4)	3 (4.7)	5 (3.9)	*16*
Total	*27*	*17*	*14*	*58*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 3.8141.$$

$$df = (r-1)(c-1) = (3-1)(3-1) = 2 \times 2 = 4.$$

From Table F.10: $\chi^2_{0.05,4}. = 9.4877$ and therefore, $X^2 < \chi^2_{0.05,4}$ (3.8141<9.4877).

We accept the null hypothesis that the highway ID and the collision type are statistically independent. This means that no conclusions can be drawn for the collision type when the highway ID is known and the opposite. The three highways analyzed present similar roadway design characteristics in respect to the geometrics and traffic operations at the crash sites. Therefore, even though the analysis illustrates U.S. 1 includes the highest number of angle type EV crashes no conclusions can be drawn regarding a crash of a specific collision type and the route at which it occurred.

F.3.6 Geographic area and crash severity in Northern Virginia

The chi-square test will be applied to test whether the geographic area (*first classification category*) and the crash severity (*second classification category*) for the crashes along the U.S. Highways and Interstates in Northern Virginia are *statistically independent*.

The null hypothesis that the geographic area and the crash severity are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0: The geographic area and the crash severity are statistically independent.

H_a: The geographic area and the crash severity are not statistically independent.

CONTINGENCY TABLE F.6

Geographic area vs. Crash Severity for EV crashes on the U.S. Highways and Interstates in Northern Virginia

Crash Severity	**Geographic Area**			
	Region (E.1)[1]	**County (E.2)**	**U.S. 1 (E.3)**	***Total***
Injury	52 (49.4)	32 (32.7)	6 (80)	*90*
PD	84 (86.6)	58 (57.3)	16 (14)	*158*
Total	*136*	*90*	*22*	*248*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 1.0173.$$

$$df = (r-1)(c-1) = (2-1)(3-1) = 1 \times 2 = 2.$$

From Table F.10: $\chi^2_{0.05,2}. = 5.9915$ and therefore, $X^2 < \chi^2_{0.05,2}$ (1.0173<5.9915).

We accept the null hypothesis that the geographic area and the crash severity are statistically independent. This means that no conclusions can be drawn for the crash severity when the geographic area is known and the opposite. This result could be due to the fact that Fairfax County as well as U.S. Route 1 are subsets of the whole region of Northern Virginia and the crashes occurred on the U.S. Highways and Interstates in the County and the crash situation in respect to crash severity presents no difference among the three different geographic areas.

F.3.7 Highway facility type and crash severity in Northern Virginia

The chi-square test will be applied to test whether the highway facility type (*first classification category*) and the crash severity (*second classification category*) for the crashes along the U.S. Highways and Interstates in Northern Virginia are *statistically independent*.

The null hypothesis that the highway facility type and the crash severity are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0 : The highway facility type and the crash severity are statistically independent.

H_a : The highway facility type and the crash severity are not statistically independent.

CONTINGENCY TABLE F.7

Highway facility type vs. Crash severity for EV crashes on the U.S. Highways and Interstates in Northern Virginia

Crash Severity	Highway Facility Type		
	Interstates ($E_{\cdot 1}$)[1]	**Highways ($E_{\cdot 2}$)**	***Total***
Injury	28 (33.1)	24 (20.4)	*52*
PD	34 (30.2)	50 (54.7)	*84*
Total	*62*	*74*	*136*

[1] The numbers in the parentheses include the expected count in cell (i, j) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 2.3145.$$

$$df = (r-1)(c-1) = (2-1)(2-1) = 1 \times 1 = 1.$$

From Table F.10: $\chi^2_{0.05,1} \cdot = 3.8415$ and therefore, $X^2 < \chi^2_{0.05,1}$ (2.3145<3.8415).

We accept the null hypothesis that the highway facility type and the crash severity are statistically independent. This means that no conclusions can be drawn for the crash severity when the highway facility type is known and the opposite. In both U.S. Highways and Interstates in Northern Virginia the highest percentage of crashes involving EVs are property damage without injuries, and therefore the highway classification type plays no significant role in the crash severity type.

F.3.8 Crash site type and lighting conditions on the U.S. Highways in Northern Virginia

The chi-square test will be applied to test whether the crash site type in terms of relationship to intersection (*first classification category*) and the lighting conditions (*second classification category*) for the crashes on the U.S. Highways in Northern Virginia are *statistically independent*.

The null hypothesis that the crash site type and the lighting conditions are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0 : The crash site type and the lighting conditions are statistically independent.

H_a : The crash site type and the lighting conditions are not statistically independent.

CONTINGENCY TABLE F.8

Crash site type vs. Lighting conditions for the crashes on the U.S. Highways in Northern Virginia

Lighting Conditions	**Crash Site Type**		
	Int/ions ($E_{\cdot 1}$)[1]	**Non-Int/ions ($E_{\cdot 2}$)**	***Total***
Daylight	27 (27.6)	17 (16.43)	*44*
Darkness	20 (19.43)	11 (11.57)	*31*
Total	*47*	*28*	*75*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 0.0773$$

$df = (r-1)(c-1) = (2-1)(2-1) = 1 \times 1 = 1.$

From Table F.10: $\chi^2_{0.05,1}. = 3.8415$ and therefore, $X^2 < \chi^2_{0.05,1}$ (0.0773<3.8415).

At the 0.05 level of significance we accept the null hypothesis that the crash site type and the lighting conditions are statistically independent. This means that we can not draw any conclusions for the number of crashes involving EVs that occur at intersections or not in respect to the lighting conditions. It is indicated that for both intersections and non-intersections the number of crashes occurring during daylight is greater than the EV crashes occurring at night. This result could be due to the fact that during the day the traffic volumes on the U.S. Highways in Northern Virginia are heavier and thus, the challenges the emergency vehicles face in order to reach their destination become greater. It can also be observed that EV crashes at intersections are more than those at not intersections for day and night.

F.3.9 Alignment and lighting conditions on the Interstates in Northern Virginia

The chi-square test will be applied to test whether the alignment (*first classification category*) and the lighting conditions (*second classification category*) for the crashes on the Interstates in Northern Virginia are *statistically independent*.

The null hypothesis that the alignment and the lighting conditions are independent is used to obtain the expected distribution of frequencies in each of the contingency table cells. The competing hypotheses for the contingency table are as follows:

H_0: The alignment and the lighting conditions are statistically independent.

H_a: The alignment and the lighting conditions are not statistically independent.

CONTINGENCY TABLE F.9

Alignment vs. Lighting conditions for the crashes on the Interstates in Northern Virginia

Lighting Conditions	Alignment		
	Curve ($E_{\cdot 1}$)[1]	**Tangent ($E_{\cdot 2}$)**	***Total***
Daylight	6 (5.9)	28 (28.1)	*34*
Darkness	5 (5.1)	24 (23.9)	*29*
Total	*11*	*52*	*63*

[1] The numbers in the parentheses include the expected count in cell (*i*, *j*) which is obtained from the equation: $E_{ij} = \frac{R_i C_j}{n}$, where R_j and C_i are the row and column totals, respectively.

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} = 0.0018$$

$$df = (r-1)(c-1) = (2-1)(2-1) = 1 \times 1 = 1.$$

From Table F.10: $\chi^2_{0.05,1}. = 3.8415$ and therefore, $X^2 < \chi^2_{0.05,1}$ (0.0018<3.8415).

At the 0.05 level of significance we accept the null hypothesis that the alignment and the lighting conditions are statistically independent. This means that we can not draw any conclusions for the number of crashes involving EVs that occur at curves or tangents in respect to the lighting conditions. It can be observed that the number of crashes occurring at tangents is significantly higher. However the distribution of EV crashes among day and night is similar for each of the two alignments with more EV crashes occurring under daylight.

TABLE F.10

Critical Values for the Chi-Square Distribution $\chi^2_{\alpha,v}$ *(Washington S. P., Karlaftis M.G. and Mannering F.L., Statistical and Econometric Methods for Transportation Data Analysis, Chapman & Hall/CRC, U.S.A, 2003)*

	α							
v	.10	.05	.025	.01	.005	.001	.0005	.0001
1	2.7055	3.8415	5.0239	6.6349	7.8794	10.8276	12.1157	15.1367
2	4.6052	5.9915	7.3778	9.2103	10.5966	13.8155	15.2018	18.4207
3	6.2514	7.8147	9.3484	11.3449	12.8382	16.2662	17.7300	21.1075
4	7.7794	9.4877	11.1433	13.2767	14.8603	18.4668	19.9974	23.5127
5	9.2364	11.0705	12.8325	15.0863	16.7496	20.5150	22.1053	25.7448
6	10.6446	12.5916	14.4494	16.8119	18.5476	22.4577	24.1028	27.8563
7	12.0170	14.0671	16.0128	18.4753	20.2777	24.3219	26.0178	29.8775
8	13.3616	15.5073	17.5345	20.0902	21.9550	26.1245	27.8680	31.8276
9	14.6837	16.9190	19.0228	21.6660	23.5894	27.8772	29.6658	33.7199
10	15.9872	18.3070	20.4832	23.2093	25.1882	29.5883	31.4198	35.5640
11	17.2750	19.6751	21.9200	24.7250	26.7568	31.2641	33.1366	37.3670
12	18.5493	21.0261	23.3367	26.2170	28.2995	32.9095	34.8213	39.1344
13	19.8119	22.3620	24.7356	27.6882	29.8195	34.5282	36.4778	40.8707
14	21.0641	23.6848	26.1189	29.1412	31.3193	36.1233	38.1094	42.5793
15	22.3071	24.9958	27.4884	30.5779	32.8013	37.6973	39.7188	44.2632
16	23.5418	26.2962	28.8454	31.9999	34.2672	39.2524	41.3081	45.9249
17	24.7690	27.5871	30.1910	33.4087	35.7185	40.7902	42.8792	47.5664
18	25.9894	28.8693	31.5264	34.8053	37.1565	42.3124	44.4338	49.1894
19	27.2036	30.1435	32.8523	36.1909	38.5823	43.8202	45.9731	50.7955
20	28.4120	31.4104	34.1696	37.5662	39.9968	45.3147	47.4985	52.3860
21	29.6151	32.6706	25.4789	38.9322	41.4011	46.7970	49.0108	53.9620
22	30.8133	33.9244	36.7807	40.2894	42.7957	48.2679	50.5111	55.5246
23	32.0069	35.1725	38.0756	41.6384	44.1813	49.7282	52.0002	57.0746
24	33.1962	36.4150	39.3641	42.9798	45.5585	51.1786	53.4788	58.6130
25	34.3816	37.6525	40.6465	44.3141	46.9279	52.6197	54.9475	60.1403
26	35.5632	38.8851	41.9232	45.6417	48.2899	54.0520	56.4069	61.6573
27	36.7412	40.1133	43.1945	46.9629	49.6449	55.4760	57.8576	63.1645
28	37.9159	41.3371	44.4608	48.2782	50.9934	56.8923	59.3000	64.6624
29	39.0875	42.5570	45.7223	49.5879	52.3356	58.3012	60.7346	66.1517
30	40.2560	43.7730	467.9792	50.8922	53.6720	59.7031	62.1619	67.6326

APPENDIX G: SAMPLE OF THE EV CRASH DATA IN NORTHERN VIRGINIA (1997-2001)

This appendix includes a sample of the Excel file called New_CrashData_06_02.xls which contains the EV crash data and refers to any information for all reportable motor vehicle accidents in Virginia from January 1997 through December 2001.

Each column includes particular information for all EV accidents.

Each row includes any information for each EV accident, which is identified by a document number.

ACCIDENT_DOCUMENT_NUMBER	HTRIS_ROUTE_ID	HTRIS_ROUTE_PREFIX
1222500	US00001	US
992651144	US00050	US
13020530	IS00095N	IS
881835	US00001	US
12122394	IS00066W	IS
10641797	US00001	US
970171228	US00001	US
2921080	IS00066E	IS
11691427	US00001	US
973020007	US00050	US
3041796	US00015	US
330269	US00029	US
10311613	IS00066E	IS
972812175	IS00495S	IS
531525	IS00095S	IS
2942033	US00001	US
13020532	IS00495N	IS
2940718	US00001	US
681860	IS00395S	IS
992002708	US00029	US
973110147	IS00495S	IS
12060713	US00001	US
1030554	IS00495S051G	IS
3041789	IS00066W053A	IS
12390475	US00050	US
991441045	US00001	US
992421038	IS00095S	IS
10781658	US00015	US
992000261	US00001	US
991740038	IS003951	IS
980561411	US00001	US
992860779	US00001	US
1711445	IS003953	IS
991650698	US00001	US
10640231	US00001	US
12270939	US00050	US
11141568	US00001	US
993072584	US00029	US
11570349	US00029	US
980140193	US00029	US
971780795	US00029	US
2621879	US00050	US
970570913	IS00066W	IS

ACCIDENT_DOCUMENT_NUMBER	HTRIS_ROUTE_NUMBER	HTRIS_ROUTE_SUFFIX
1222500	00001	
992651144	00050	
13020530	00095	N
881835	00001	
12122394	00066	W
10641797	00001	
970171228	00001	
2921080	00066	E
11691427	00001	
973020007	00050	
3041796	00015	
330269	00029	
10311613	00066	E
972812175	00495	S
531525	00095	S
2942033	00001	
13020532	00495	N
2940718	00001	
681860	00395	S
992002708	00029	
973110147	00495	S
12060713	00001	
1030554	00495	S051G
3041789	00066	W053A
12390475	00050	
991441045	00001	
992421038	00095	S
10781658	00015	
992000261	00001	
991740038	00395	1
980561411	00001	
992860779	00001	
1711445	00395	3
991650698	00001	
10640231	00001	
12270939	00050	
11141568	00001	
993072584	00029	
11570349	00029	
980140193	00029	
971780795	00029	
2621879	00050	
970570913	00066	W

ACCIDENT_DOCUMENT_NUMBER	HTRIS_NODE	HTRIS_NODE_OFFSET
1222500	547044	0
992651144	267028	0
13020530	279173	0.870000005
881835	278560	0
12122394	50578	2.450000048
10641797	263516	0
970171228	546610	0
2921080	703602	0.100000001
11691427	272516	0.061999999
973020007	278739	0
3041796	428217	0.200000003
330269	263119	0.002
10311613	100685	0.50999999
972812175	279257	0.430000007
531525	709704	0.351999998
2942033	546816	0
13020532	279250	1.039999962
2940718	270979	0
681860	279114	0.180000007
992002708	263090	0
973110147	279256	0.5
12060713	278538	0.111000001
1030554	724757	0
3041789	278727	0.140000001
12390475	100221	0
991441045	263557	0.133000001
992421038	279187	0.349999994
10781658	546442	0
992000261	729893	0.100000001
991740038	724407	0.569999993
980561411	276980	0
992860779	278574	0.200000003
1711445	700834	0
991650698	263516	0
10640231	276985	0
12270939	271911	0
11141568	278550	0.02
993072584	100161	0
11570349	50034	0.07
980140193	266124	0.199000001
971780795	100140	0.029999999
2621879	728445	0
970570913	722674	0.01

ACCIDENT_DOCUMENT_NUMBER	HTRIS_NODE_TYPE_ID	HTRIS_NODE_TYPE_DESC
1222500	IN	Intersection Normal
992651144	IT	Intersection Tee
13020530	RP	Ramp Intersection
881835	IN	Intersection Normal
12122394	JB	Jurisdictional Boundary
10641797	IN	Intersection Normal
970171228	IT	Intersection Tee
2921080	RP	Ramp Intersection
11691427	IT	Intersection Tee
973020007	IN	Intersection Normal
3041796	IN	Intersection Normal
330269	IN	Intersection Normal
10311613	RP	Ramp Intersection
972812175	RP	Ramp Intersection
531525	RP	Ramp Intersection
2942033	IT	Intersection Tee
13020532	RP	Ramp Intersection
2940718	IT	Intersection Tee
681860	RP	Ramp Intersection
992002708	IT	Intersection Tee
973110147	RP	Ramp Intersection
12060713	IN	Intersection Normal
1030554	RP	Ramp Intersection
3041789	RP	Ramp Intersection
12390475	IN	Intersection Normal
991441045	IT	Intersection Tee
992421038	RP	Ramp Intersection
10781658	IN	Intersection Normal
992000261	IT	Intersection Tee
991740038	JB	Jurisdictional Boundary
980561411	IN	Intersection Normal
992860779	RP	Ramp Intersection
1711445	JB	Jurisdictional Boundary
991650698	IN	Intersection Normal
10640231	IT	Intersection Tee
12270939	IN	Intersection Normal
11141568	IN	Intersection Normal
993072584	IT	Intersection Tee
11570349	JB	Jurisdictional Boundary
980140193	IT	Intersection Tee
971780795	IT	Intersection Tee
2621879	IT	Intersection Tee
970570913	RP	Ramp Intersection

ACCIDENT_DOCUMENT_NUMBER	HTRIS_LINK_SEQUENCE	ROUTE_MILEPOST
1222500	62600	175.14
992651144	24700	77.78
13020530	18200	171.72
881835	66800	184.35
12122394	3500	51.79
10641797	75500	191.44
970171228	62200	174.42
2921080	4800	62.97
11691427	70600	187.322
973020007	24500	77.49
3041796	47400	225.83
330269	55200	224.992
10311613	6100	69.61
972812175	400	3.11
531525	17700	171.112
2942033	58700	167.19
13020532	3600	12.8
2940718	72100	188.35
681860	300	0.71
992002708	58400	230.63
973110147	300	0.92
12060713	72300	188.651
1030554	9999998	0.02
3041789	100	0.14
12390475	31900	84.45
991441045	75100	190.743
992421038	16700	164.63
10781658	42500	199.64
992000261	59225	168.23
991740038	400	1.09
980561411	71300	187.92
992860779	64100	177.95
1711445	300	0.49
991650698	75500	191.44
10640231	73200	189.14
12270939	16900	66.4
11141568	68900	185.95
993072584	72300	245.42
11570349	52300	213.4
980140193	58200	230.229
971780795	70200	244.12
2621879	14050	59.79
970570913	2950	44.31

ACCIDENT_DOCUMENT_NUMBER	JURIS_MILEPOST	JURIS_NO	JURIS_NAME
1222500	10.6	076	Prince William
992651144	16.11	029	Fairfax
13020530	10.32	029	Fairfax
881835	7.62	029	Fairfax
12122394	2.45	029	Fairfax
10641797	14.71	029	Fairfax
970171228	9.88	076	Prince William
2921080	14.02	029	Fairfax
11691427	10.592	029	Fairfax
973020007	15.82	029	Fairfax
3041796	22.3	053	Loudoun
330269	1.602	029	Fairfax
10311613	1.69	000	Arlington
972812175	3.11	029	Fairfax
531525	9.672	029	Fairfax
2942033	2.65	076	Prince William
13020532	12.8	029	Fairfax
2940718	11.62	029	Fairfax
681860	0.71	029	Fairfax
992002708	7.24	029	Fairfax
973110147	0.92	029	Fairfax
12060713	11.921	029	Fairfax
1030554	0.02	029	Fairfax
3041789	0.14	029	Fairfax
12390475	3.42	000	Arlington
991441045	14.013	029	Fairfax
992421038	3.19	029	Fairfax
10781658	8	076	Prince William
992000261	3.69	076	Prince William
991740038	1.09	000	Arlington
980561411	11.19	029	Fairfax
992860779	1.22	029	Fairfax
1711445	0.49	000	Arlington
991650698	14.71	029	Fairfax
10640231	12.41	029	Fairfax
12270939	4.73	029	Fairfax
11141568	9.22	029	Fairfax
993072584	2.74	000	Arlington
11570349	0.07	076	Prince William
980140193	6.839	029	Fairfax
971780795	1.44	000	Arlington
2621879	26.46	053	Loudoun
970570913	7.51	076	Prince William

ACCIDENT_DOCUMENT_NUMBER	CONST_DIST_NO	CONST_DIST_NAME
1222500	0A	Northern Virginia
992651144	0A	Northern Virginia
13020530	0A	Northern Virginia
881835	0A	Northern Virginia
12122394	0A	Northern Virginia
10641797	0A	Northern Virginia
970171228	0A	Northern Virginia
2921080	0A	Northern Virginia
11691427	0A	Northern Virginia
973020007	0A	Northern Virginia
3041796	0A	Northern Virginia
330269	0A	Northern Virginia
10311613	0A	Northern Virginia
972812175	0A	Northern Virginia
531525	0A	Northern Virginia
2942033	0A	Northern Virginia
13020532	0A	Northern Virginia
2940718	0A	Northern Virginia
681860	0A	Northern Virginia
992002708	0A	Northern Virginia
973110147	0A	Northern Virginia
12060713	0A	Northern Virginia
1030554	0A	Northern Virginia
3041789	0A	Northern Virginia
12390475	0A	Northern Virginia
991441045	0A	Northern Virginia
992421038	0A	Northern Virginia
10781658	0A	Northern Virginia
992000261	0A	Northern Virginia
991740038	0A	Northern Virginia
980561411	0A	Northern Virginia
992860779	0A	Northern Virginia
1711445	0A	Northern Virginia
991650698	0A	Northern Virginia
10640231	0A	Northern Virginia
12270939	0A	Northern Virginia
11141568	0A	Northern Virginia
993072584	0A	Northern Virginia
11570349	0A	Northern Virginia
980140193	0A	Northern Virginia
971780795	0A	Northern Virginia
2621879	0A	Northern Virginia
970570913	0A	Northern Virginia

ACCIDENT_DOCUMENT_NUMBER	MAINTENANCE_JURIS_NO	MAINTENANCE_JURIS_NAME
1222500	076	Prince William
992651144	029	Fairfax
13020530	029	Fairfax
881835	029	Fairfax
12122394	029	Fairfax
10641797	029	Fairfax
970171228	076	Prince William
2921080	029	Fairfax
11691427	029	Fairfax
973020007	029	Fairfax
3041796	053	Loudoun
330269	029	Fairfax
10311613	000	Arlington
972812175	029	Fairfax
531525	029	Fairfax
2942033	076	Prince William
13020532	029	Fairfax
2940718	029	Fairfax
681860	029	Fairfax
992002708	029	Fairfax
973110147	029	Fairfax
12060713	029	Fairfax
1030554	029	Fairfax
3041789	029	Fairfax
12390475	000	Arlington
991441045	029	Fairfax
992421038	029	Fairfax
10781658	076	Prince William
992000261	076	Prince William
991740038	000	Arlington
980561411	029	Fairfax
992860779	029	Fairfax
1711445	000	Arlington
991650698	029	Fairfax
10640231	029	Fairfax
12270939	029	Fairfax
11141568	029	Fairfax
993072584	000	Arlington
11570349	076	Prince William
980140193	029	Fairfax
971780795	000	Arlington
2621879	053	Loudoun
970570913	076	Prince William

ACCIDENT_DOCUMENT_NUMBER	RESIDENCY	ACCIDENT_DATE
1222500	48	4/22/2000
992651144	47	9/4/1999
13020530	47	9/22/2001
881835	47	3/11/2000
12122394	47	7/21/2001
10641797	47	12/23/2000
970171228	48	1/11/1997
2921080	47	9/30/2000
11691427	47	5/19/2001
973020007	47	10/18/1997
3041796	49	3/11/2000
330269	47	1/5/2000
10311613		1/7/2001
972812175	47	10/2/1997
531525	47	9/28/1999
2942033	48	9/6/2000
13020532	47	10/1/2001
2940718	47	10/2/2000
681860	47	2/21/2000
992002708	47	6/14/1999
973110147	47	10/27/1997
12060713	47	7/9/2001
1030554	47	3/20/2000
3041789	47	6/12/2000
12390475		8/13/2001
991441045	47	5/3/1999
992421038	47	6/7/1999
10781658	48	3/12/2001
992000261	48	7/5/1999
991740038		6/14/1999
980561411	47	2/9/1998
992860779	47	9/27/1999
1711445		6/12/2000
991650698	47	5/24/1999
10640231	47	1/8/2001
12270939	47	7/30/2001
11141568	47	4/9/2001
993072584		10/25/1999
11570349	48	5/21/2001
980140193	47	12/29/1997
971780795		6/18/1997
2621879	49	9/6/2000
970570913	48	2/2/1997

ACCIDENT_DOCUMENT_NUMBER	ACCIDENT_HOUR	DAY_OF_WEEK_ID	DAY_OF_WEEK_DESC
1222500	23	6	Saturday
992651144	20	6	Saturday
13020530	23	6	Saturday
881835	15	6	Saturday
12122394	14	6	Saturday
10641797	2	6	Saturday
970171228	0	6	Saturday
2921080	15	6	Saturday
11691427	15	6	Saturday
973020007	3	6	Saturday
3041796	13	6	Saturday
330269	12	3	Wednesday
10311613	9	7	Sunday
972812175	20	7	Sunday
531525	12	2	Tuesday
2942033	19	3	Wednesday
13020532	10	1	Monday
2940718	20	1	Monday
681860	7	1	Monday
992002708	18	1	Monday
973110147	16	1	Monday
12060713	14	1	Monday
1030554	8	1	Monday
3041789	3	1	Monday
12390475	23	1	Monday
991441045	23	1	Monday
992421038	20	1	Monday
10781658	7	1	Monday
992000261	23	1	Monday
991740038	2	1	Monday
980561411	14	1	Monday
992860779	6	1	Monday
1711445	10	1	Monday
991650698	8	1	Monday
10640231	10	1	Monday
12270939	22	1	Monday
11141568	21	1	Monday
993072584	19	1	Monday
11570349	11	1	Monday
980140193	10	1	Monday
971780795	12	3	Wednesday
2621879	8	3	Wednesday
970570913	2	7	Sunday

ACCIDENT_DOCUMENT_NUMBER	INTERSECTING_ROUTE_NUMBER
1222500	00001
992651144	00050
13020530	00095
881835	00001
12122394	00066
10641797	00001
970171228	00001
2921080	00066
11691427	00001
973020007	00050
3041796	00015
330269	00029
10311613	00066
972812175	00495
531525	00095
2942033	00001
13020532	00495
2940718	00001
681860	00395
992002708	00029
973110147	00495
12060713	00001
1030554	00495
3041789	00066
12390475	00050
991441045	00001
992421038	00095
10781658	00015
992000261	00001
991740038	00395
980561411	00001
992860779	00001
1711445	00395
991650698	00001
10640231	00001
12270939	00050
11141568	00001
993072584	00029
11570349	00029
980140193	00029
971780795	00029
2621879	00050
970570913	00066

ACCIDENT_DOCUMENT_NUMBER	SURFACE_TYPE_ID	SURFACE_TYPE_DESC
1222500	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
992651144	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
13020530	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
881835	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
12122394	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
10641797	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
970171228	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
2921080	8	Portland Cement Concrete
11691427	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
973020007	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
3041796	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
330269	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
10311613	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
972812175	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
531525	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
2942033	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
13020532	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
2940718	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
681860	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
992002708	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
973110147	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
12060713	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
1030554	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
3041789	8	Portland Cement Concrete
12390475	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
991441045	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
992421038	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
10781658	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
992000261	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
991740038	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
980561411	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
992860779	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
1711445	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
991650698	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
10640231	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
12270939	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
11141568	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
993072584	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
11570349	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
980140193	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
971780795	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
2621879	6	Plant Mix (Bituminous Concrete - Sand Asphalt)
970570913	6	Plant Mix (Bituminous Concrete - Sand Asphalt)

ACCIDENT_DOCUMENT_NUMBER	LANE_COUNT	FACILITY_TYPE_ID	FACILITY_TYPE_DESC
1222500	4	1	Divided, no control of access
992651144	4	2	Divided, partial control of access
13020530	4	3	Divided, full control of access
881835	5	0	Two-way, non-divided
12122394	4	3	Divided, full control of access
10641797	6	1	Divided, no control of access
970171228	4	0	Two-way, non-divided
2921080	3	3	Divided, full control of access
11691427	5	1	Divided, no control of access
973020007	5	2	Divided, partial control of access
3041796	2	0	Two-way, non-divided
330269	4	1	Divided, no control of access
10311613	2	3	Divided, full control of access
972812175	4	3	Divided, full control of access
531525	2	3	Divided, full control of access
2942033	4	0	Two-way, non-divided
13020532	4	3	Divided, full control of access
2940718	6	1	Divided, no control of access
681860	4	3	Divided, full control of access
992002708	6	1	Divided, no control of access
973110147	4	3	Divided, full control of access
12060713	6	1	Divided, no control of access
1030554	1	4	One-way, part of a one-way system
3041789	1	4	One-way, part of a one-way system
12390475	6	2	Divided, partial control of access
991441045	6	1	Divided, no control of access
992421038	3	3	Divided, full control of access
10781658	2	0	Two-way, non-divided
992000261	2	5	Two-way, part of a one-way system
991740038	2	3	Divided, full control of access
980561411	6	1	Divided, no control of access
992860779	4	1	Divided, no control of access
1711445	2	3	Divided, full control of access
991650698	6	1	Divided, no control of access
10640231	6	1	Divided, no control of access
12270939	6	1	Divided, no control of access
11141568	4	0	Two-way, non-divided
993072584	4	1	Divided, no control of access
11570349	4	1	Divided, no control of access
980140193	6	1	Divided, no control of access
971780795	4	0	Two-way, non-divided
2621879	4	1	Divided, no control of access
970570913	2	3	Divided, full control of access

ACCIDENT_DOCUMENT_NUMBER	INTERSECTION_TYPE_ID	INTERSECTION_TYPE_DESC
1222500	1	Signalized Intersection
992651144	1	Signalized Intersection
13020530	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
881835	1	Signalized Intersection
12122394	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
10641797	1	Signalized Intersection
970171228	3	"T" (Leg enters between 80 degree and 100 degree angle)
2921080	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
11691427	3	"T" (Leg enters between 80 degree and 100 degree angle)
973020007	1	Signalized Intersection
3041796	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
330269	1	Signalized Intersection
10311613	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
972812175	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
531525	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
2942033	5	Offset (All offset intersections when offset does not exceed 150 feet)
13020532	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
2940718	1	Signalized Intersection
681860	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
992002708	1	Signalized Intersection
973110147	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
12060713	1	Signalized Intersection
1030554	8	Interchange (Grade separation of intersection leg) (Includes the entire interchange area)
3041789	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
12390475	2	Crossing (All crossroads at grade regardless of intersecting angle)
991441045	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
992421038	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
10781658	4	Branch (One leg enters at angle other than "T" angle)
992000261	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
991740038	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
980561411	1	Signalized Intersection

992860779	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
1711445	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
991650698	1	Signalized Intersection
10640231	1	Signalized Intersection
12270939	1	Signalized Intersection
11141568	3	"T" (Leg enters between 80 degree and 100 degree angle)
993072584	2	Crossing (All crossroads at grade regardless of intersecting angle)
11570349	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
980140193	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection
971780795	3	"T" (Leg enters between 80 degree and 100 degree angle)
2621879	3	"T" (Leg enters between 80 degree and 100 degree angle)
970570913	9	Not stated or not applicable. Not applicable for accidents not occuring at an intersection

ACCIDENT_DOCUMENT_NUMBER	TRAFFIC_CONTROL_ID	TRAFFIC_CONTROL_DESC
1222500	03	Traffic Signal
992651144	03	Traffic Signal
13020530	06	Traffic Lanes Marked
881835	03	Traffic Signal
12122394	06	Traffic Lanes Marked
10641797	03	Traffic Signal
970171228	06	Traffic Lanes Marked
2921080	06	Traffic Lanes Marked
11691427	06	Traffic Lanes Marked
973020007	03	Traffic Signal
3041796	07	No Passing Lanes
330269	03	Traffic Signal
10311613	06	Traffic Lanes Marked
972812175	06	Traffic Lanes Marked
531525	06	Traffic Lanes Marked
2942033	06	Traffic Lanes Marked
13020532	06	Traffic Lanes Marked
2940718	03	Traffic Signal
681860	06	Traffic Lanes Marked
992002708	03	Traffic Signal
973110147	06	Traffic Lanes Marked
12060713	06	Traffic Lanes Marked
1030554	08	Yield Sign
3041789	06	Traffic Lanes Marked
12390475	03	Traffic Signal
991441045	06	Traffic Lanes Marked
992421038	06	Traffic Lanes Marked
10781658	01	No Traffic Control
992000261	06	Traffic Lanes Marked
991740038	06	Traffic Lanes Marked
980561411	03	Traffic Signal
992860779	06	Traffic Lanes Marked
1711445	06	Traffic Lanes Marked
991650698	03	Traffic Signal
10640231	03	Traffic Signal
12270939	06	Traffic Lanes Marked
11141568	06	Traffic Lanes Marked
993072584	03	Traffic Signal
11570349	06	Traffic Lanes Marked
980140193	03	Traffic Signal
971780795	06	Traffic Lanes Marked
2621879	03	Traffic Signal
970570913	06	Traffic Lanes Marked

ACCIDENT_DOCUMENT_NUMBER	ALIGNMENT_ID	ALIGNMENT_DESC
1222500	1	Straight Level
992651144	1	Straight Level
13020530	3	Grade Straight
881835	1	Straight Level
12122394	3	Grade Straight
10641797	1	Straight Level
970171228	3	Grade Straight
2921080	1	Straight Level
11691427	3	Grade Straight
973020007	1	Straight Level
3041796	3	Grade Straight
330269	1	Straight Level
10311613	1	Straight Level
972812175	1	Straight Level
531525	4	Grade Curve
2942033	2	Curve Level
13020532	4	Grade Curve
2940718	1	Straight Level
681860	1	Straight Level
992002708	3	Grade Straight
973110147	1	Straight Level
12060713	3	Grade Straight
1030554	4	Grade Curve
3041789	4	Grade Curve
12390475	1	Straight Level
991441045	1	Straight Level
992421038	1	Straight Level
10781658	1	Straight Level
992000261	1	Straight Level
991740038	1	Straight Level
980561411	1	Straight Level
992860779	7	Dip Straight
1711445	2	Curve Level
991650698	1	Straight Level
10640231	4	Grade Curve
12270939	1	Straight Level
11141568	3	Grade Straight
993072584	1	Straight Level
11570349	1	Straight Level
980140193	1	Straight Level
971780795	1	Straight Level
2621879	1	Straight Level
970570913	2	Curve Level

ACCIDENT_DOCUMENT_NUMBER	WEATHER_ID	WEATHER_DESC
1222500	2	Cloudy
992651144	5	Raining
13020530	1	Clear
881835	2	Cloudy
12122394	1	Clear
10641797	1	Clear
970171228	5	Raining
2921080	1	Clear
11691427	2	Cloudy
973020007	5	Raining
3041796	2	Cloudy
330269	1	Clear
10311613	2	Cloudy
972812175	1	Clear
531525	2	Cloudy
2942033	1	Clear
13020532	1	Clear
2940718	1	Clear
681860	1	Clear
992002708	2	Cloudy
973110147	1	Clear
12060713	1	Clear
1030554	1	Clear
3041789	1	Clear
12390475	2	Cloudy
991441045	2	Cloudy
992421038	1	Clear
10781658	1	Clear
992000261	1	Clear
991740038	1	Clear
980561411	1	Clear
992860779	2	Cloudy
1711445	1	Clear
991650698	5	Raining
10640231	5	Raining
12270939	1	Clear
11141568	5	Raining
993072584	1	Clear
11570349	5	Raining
980140193	2	Cloudy
971780795	2	Cloudy
2621879	1	Clear
970570913	1	Clear

ACCIDENT_DOCUMENT_NUMBER	SURFACE_CONDITION_ID	SURFACE_CONDITION_DESC
1222500	1	Dry
992651144	2	Wet
13020530	1	Dry
881835	1	Dry
12122394	1	Dry
10641797	1	Dry
970171228	2	Wet
2921080	1	Dry
11691427	1	Dry
973020007	2	Wet
3041796	2	Wet
330269	1	Dry
10311613	2	Wet
972812175	1	Dry
531525	2	Wet
2942033	1	Dry
13020532	1	Dry
2940718	1	Dry
681860	1	Dry
992002708	2	Wet
973110147	1	Dry
12060713	1	Dry
1030554	1	Dry
3041789	1	Dry
12390475	2	Wet
991441045	1	Dry
992421038	1	Dry
10781658	1	Dry
992000261	1	Dry
991740038	1	Dry
980561411	1	Dry
992860779	1	Dry
1711445	1	Dry
991650698	2	Wet
10640231	2	Wet
12270939	1	Dry
11141568	2	Wet
993072584	1	Dry
11570349	2	Wet
980140193	7	Other
971780795	1	Dry
2621879	6	Oily
970570913	1	Dry

ACCIDENT_DOCUMENT_NUMBER	ROAD_DEFECT_ID	ROAD_DEFECT_DESC
1222500	2	Holes, Ruts, Bumps
992651144	1	No Defects
13020530	1	No Defects
881835	1	No Defects
12122394	1	No Defects
10641797	1	No Defects
970171228	1	No Defects
2921080	1	No Defects
11691427	1	No Defects
973020007	1	No Defects
3041796	1	No Defects
330269	1	No Defects
10311613	1	No Defects
972812175	1	No Defects
531525	1	No Defects
2942033	1	No Defects
13020532	5	Loose Material
2940718	1	No Defects
681860	1	No Defects
992002708	1	No Defects
973110147	1	No Defects
12060713	1	No Defects
1030554	1	No Defects
3041789	1	No Defects
12390475	0	Not Stated
991441045	1	No Defects
992421038	1	No Defects
10781658	1	No Defects
992000261	1	No Defects
991740038	1	No Defects
980561411	1	No Defects
992860779	1	No Defects
1711445	1	No Defects
991650698	1	No Defects
10640231	1	No Defects
12270939	1	No Defects
11141568	1	No Defects
993072584	1	No Defects
11570349	1	No Defects
980140193	1	No Defects
971780795	1	No Defects
2621879	7	Slick Pavement
970570913	1	No Defects

ACCIDENT_DOCUMENT_NUMBER	LIGHTING_ID	LIGHTING_DESC
1222500	5	Darkness - Street or Highway not Lighted
992651144	4	Darkness - Street or Highway Lighted
13020530	5	Darkness - Street or Highway not Lighted
881835	2	Daylight
12122394	2	Daylight
10641797	4	Darkness - Street or Highway Lighted
970171228	4	Darkness - Street or Highway Lighted
2921080	2	Daylight
11691427	2	Daylight
973020007	4	Darkness - Street or Highway Lighted
3041796	2	Daylight
330269	2	Daylight
10311613	2	Daylight
972812175	5	Darkness - Street or Highway not Lighted
531525	2	Daylight
2942033	5	Darkness - Street or Highway not Lighted
13020532	2	Daylight
2940718	4	Darkness - Street or Highway Lighted
681860	1	Dawn
992002708	2	Daylight
973110147	2	Daylight
12060713	2	Daylight
1030554	2	Daylight
3041789	4	Darkness - Street or Highway Lighted
12390475	4	Darkness - Street or Highway Lighted
991441045	4	Darkness - Street or Highway Lighted
992421038	4	Darkness - Street or Highway Lighted
10781658	2	Daylight
992000261	5	Darkness - Street or Highway not Lighted
991740038	4	Darkness - Street or Highway Lighted
980561411	2	Daylight
992860779	5	Darkness - Street or Highway not Lighted
1711445	2	Daylight
991650698	2	Daylight
10640231	2	Daylight
12270939	4	Darkness - Street or Highway Lighted
11141568	4	Darkness - Street or Highway Lighted
993072584	4	Darkness - Street or Highway Lighted
11570349	2	Daylight
980140193	2	Daylight
971780795	2	Daylight
2621879	2	Daylight
970570913	5	Darkness - Street or Highway not Lighted

ACCIDENT_DOCUMENT_NUMBER	COLLISION_TYPE_ID	COLLISION_TYPE_DESC
1222500	12	Pedestrian
992651144	03	Head on
13020530	01	Rear End
881835	01	Rear End
12122394	16	Miscellaneous or other
10641797	02	Angle
970171228	04	Sideswipe - Same direction of travel
2921080	01	Rear End
11691427	01	Rear End
973020007	04	Sideswipe - Same direction of travel
3041796	04	Sideswipe - Same direction of travel
330269	04	Sideswipe - Same direction of travel
10311613	01	Rear End
972812175	16	Miscellaneous or other
531525	01	Rear End
2942033	02	Angle
13020532	09	Fixed object off road (from outside of ditch)
2940718	02	Angle
681860	01	Rear End
992002708	02	Angle
973110147	01	Rear End
12060713	01	Rear End
1030554	01	Rear End
3041789	10	Deer
12390475	09	Fixed object off road (from outside of ditch)
991441045	04	Sideswipe - Same direction of travel
992421038	09	Fixed object off road (from outside of ditch)
10781658	01	Rear End
992000261	04	Sideswipe - Same direction of travel
991740038	04	Sideswipe - Same direction of travel
980561411	02	Angle
992860779	04	Sideswipe - Same direction of travel
1711445	04	Sideswipe - Same direction of travel
991650698	15	Backed Into
10640231	02	Angle
12270939	01	Rear End
11141568	01	Rear End
993072584	09	Fixed object off road (from outside of ditch)
11570349	01	Rear End
980140193	02	Angle
971780795	02	Angle
2621879	08	Non-Collision, overturned, jacknifed or ran off road (no object)
970570913	04	Sideswipe - Same direction of travel

ACCIDENT_DOCUMENT_NUMBER	MAJOR_FACTOR_ID	MAJOR_FACTOR_DESC
1222500	2	Driver or pedestrian under the influence of alcohol, drugs, or other agents (Preference over code 3)
992651144	8	Road slick
13020530	4	Driver or pedestrian inattention or error
881835	4	Driver or pedestrian inattention or error
12122394	5	Vehicle defective
10641797	4	Driver or pedestrian inattention or error
970171228	4	Driver or pedestrian inattention or error
2921080	4	Driver or pedestrian inattention or error
11691427	4	Driver or pedestrian inattention or error
973020007	8	Road slick
3041796	4	Driver or pedestrian inattention or error
330269	4	Driver or pedestrian inattention or error
10311613	8	Road slick
972812175	0	Miscellaneous - Avoiding animal, loss of part of load, load over-hanging, occupant injured within or fall from vehicle.
531525	8	Road slick
2942033	3	Driver speeding (Preference over code 4)
13020532	3	Driver speeding (Preference over code 4)
2940718	4	Driver or pedestrian inattention or error
681860	2	Driver or pedestrian under the influence of alcohol, drugs, or other agents (Preference over code 3)
992002708	4	Driver or pedestrian inattention or error
973110147	4	Driver or pedestrian inattention or error
12060713	4	Driver or pedestrian inattention or error
1030554	4	Driver or pedestrian inattention or error
3041789	0	Miscellaneous - Avoiding animal, loss of part of load, load over-hanging, occupant injured within or fall from vehicle.
12390475	0	Miscellaneous - Avoiding animal, loss of part of load, load over-hanging, occupant injured within or fall from vehicle.
991441045	0	Miscellaneous - Avoiding animal, loss of part of load, load over-hanging, occupant injured within or fall from vehicle.
992421038	0	Miscellaneous - Avoiding animal, loss of part of load, load over-hanging, occupant injured within or fall from vehicle.
10781658	3	Driver speeding (Preference over code 4)
992000261	3	Driver speeding (Preference over code 4)
991740038	4	Driver or pedestrian inattention or error

980561411	4	Driver or pedestrian inattention or error
992860779	4	Driver or pedestrian inattention or error
1711445	4	Driver or pedestrian inattention or error
991650698	4	Driver or pedestrian inattention or error
10640231	4	Driver or pedestrian inattention or error
12270939	4	Driver or pedestrian inattention or error
11141568	4	Driver or pedestrian inattention or error
993072584	4	Driver or pedestrian inattention or error
11570349	4	Driver or pedestrian inattention or error
980140193	4	Driver or pedestrian inattention or error
971780795	6	Weather or visibility condition
2621879	4	Driver or pedestrian inattention or error
970570913	2	Driver or pedestrian under the influence of alcohol, drugs, or other agents (Preference over code 3)

ACCIDENT_DOCUMENT_NUMBER	SEVERITY_ID	SEVERITY_DESC
1222500	0	
992651144	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
13020530	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
881835	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
12122394	4	No visible injury but complaint of pain or momentary unconsciousness
10641797	4	No visible injury but complaint of pain or momentary unconsciousness
970171228	4	No visible injury but complaint of pain or momentary unconsciousness
2921080	4	No visible injury but complaint of pain or momentary unconsciousness
11691427	4	No visible injury but complaint of pain or momentary unconsciousness
973020007	4	No visible injury but complaint of pain or momentary unconsciousness
3041796	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
330269	4	No visible injury but complaint of pain or momentary unconsciousness
10311613	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
972812175	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
531525	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
2942033	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
13020532	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
2940718	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
681860	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
992002708	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
973110147	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
12060713	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
1030554	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
3041789	4	No visible injury but complaint of pain or momentary unconsciousness
12390475	4	No visible injury but complaint of pain or momentary unconsciousness
991441045	4	No visible injury but complaint of pain or momentary unconsciousness
992421038	4	No visible injury but complaint of pain or momentary

		unconsciousness
10781658	4	No visible injury but complaint of pain or momentary unconsciousness
992000261	4	No visible injury but complaint of pain or momentary unconsciousness
991740038	4	No visible injury but complaint of pain or momentary unconsciousness
980561411	4	No visible injury but complaint of pain or momentary unconsciousness
992860779	4	No visible injury but complaint of pain or momentary unconsciousness
1711445	4	No visible injury but complaint of pain or momentary unconsciousness
991650698	4	No visible injury but complaint of pain or momentary unconsciousness
10640231	4	No visible injury but complaint of pain or momentary unconsciousness
12270939	4	No visible injury but complaint of pain or momentary unconsciousness
11141568	4	No visible injury but complaint of pain or momentary unconsciousness
993072584	4	No visible injury but complaint of pain or momentary unconsciousness
11570349	4	No visible injury but complaint of pain or momentary unconsciousness
980140193	4	No visible injury but complaint of pain or momentary unconsciousness
971780795	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
2621879	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.
970570913	3	Other visible injury, as bruises, abrasions, swelling, lumping, etc.

ACCIDENT_DOCUMENT_NUMBER	NUM_FATALITIES	NUM_PEDESTRIAN_FATALITIES
1222500	1	1
992651144	0	0
13020530	0	0
881835	0	0
12122394	0	0
10641797	0	0
970171228	0	0
2921080	0	0
11691427	0	0
973020007	0	0
3041796	0	0
330269	0	0
10311613	0	0
972812175	0	0
531525	0	0
2942033	0	0
13020532	0	0
2940718	0	0
681860	0	0
992002708	0	0
973110147	0	0
12060713	0	0
1030554	0	0
3041789	0	0
12390475	0	0
991441045	0	0
992421038	0	0
10781658	0	0
992000261	0	0
991740038	0	0
980561411	0	0
992860779	0	0
1711445	0	0
991650698	0	0
10640231	0	0
12270939	0	0
11141568	0	0
993072584	0	0
11570349	0	0
980140193	0	0
971780795	0	0
2621879	0	0
970570913	0	0

ACCIDENT_DOCUMENT_NUMBER	NUM_INJURIES	NUM_PEDESTRIAN_INJURIES	NUM_VEHICLES
1222500	0	0	1
992651144	1	0	3
13020530	1	0	3
881835	1	0	3
12122394	0	0	2
10641797	0	0	2
970171228	0	0	2
2921080	0	0	2
11691427	0	0	2
973020007	0	0	2
3041796	1	0	2
330269	0	0	2
10311613	1	0	2
972812175	1	0	2
531525	1	0	3
2942033	3	0	2
13020532	1	0	1
2940718	3	0	2
681860	2	0	3
992002708	4	0	3
973110147	1	0	3
12060713	2	0	2
1030554	1	0	2
3041789	0	0	1
12390475	0	0	2
991441045	0	0	2
992421038	0	0	2
10781658	0	0	2
992000261	0	0	2
991740038	0	0	3
980561411	0	0	2
992860779	0	0	2
1711445	0	0	2
991650698	0	0	2
10640231	0	0	3
12270939	0	0	2
11141568	0	0	2
993072584	0	0	1
11570349	0	0	2
980140193	0	0	2
971780795	1	0	2
2621879	1	0	1
970570913	3	0	3

ACCIDENT_DOCUMENT_NUMBER	VEHICLE_1_TYPE_ID	VEHICLE_1_TYPE_DESC
1222500	12	Emergency Vehicle
992651144	12	Emergency Vehicle
13020530	12	Emergency Vehicle
881835	12	Emergency Vehicle
12122394	00	Not Stated
10641797	12	Emergency Vehicle
970171228	01	Passenger Car
2921080	01	Passenger Car
11691427	12	Emergency Vehicle
973020007	01	Passenger Car
3041796	12	Emergency Vehicle
330269	04	Straight Truck, Flatbed, Dump Truck, Tractor Truck
10311613	01	Passenger Car
972812175	12	Emergency Vehicle
531525	12	Emergency Vehicle
2942033	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
13020532	12	Emergency Vehicle
2940718	12	Emergency Vehicle
681860	12	Emergency Vehicle
992002708	12	Emergency Vehicle
973110147	05	Tractor-Trailer
12060713	01	Passenger Car
1030554	12	Emergency Vehicle
3041789	12	Emergency Vehicle
12390475	01	Passenger Car
991441045	01	Passenger Car
992421038	12	Emergency Vehicle
10781658	12	Emergency Vehicle
992000261	12	Emergency Vehicle
991740038	01	Passenger Car
980561411	12	Emergency Vehicle
992860779	01	Passenger Car
1711445	12	Emergency Vehicle
991650698	12	Emergency Vehicle
10640231	03	Van
12270939	12	Emergency Vehicle
11141568	12	Emergency Vehicle
993072584	12	Emergency Vehicle
11570349	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
980140193	12	Emergency Vehicle
971780795	12	Emergency Vehicle
2621879	12	Emergency Vehicle
970570913	12	Emergency Vehicle

ACCIDENT_DOCUMENT_NUMBER	VEHICLE_2_TYPE_ID	VEHICLE_2_TYPE_DESC
1222500		
992651144	01	Passenger Car
13020530	12	Emergency Vehicle
881835	01	Passenger Car
12122394	12	Emergency Vehicle
10641797	01	Passenger Car
970171228	12	Emergency Vehicle
2921080	12	Emergency Vehicle
11691427	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
973020007	12	Emergency Vehicle
3041796	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
330269	12	Emergency Vehicle
10311613	12	Emergency Vehicle
972812175	01	Passenger Car
531525	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
2942033	12	Emergency Vehicle
13020532		
2940718	01	Passenger Car
681860	01	Passenger Car
992002708	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
973110147	12	Emergency Vehicle
12060713	12	Emergency Vehicle
1030554	01	Passenger Car
3041789		
12390475	12	Emergency Vehicle
991441045	12	Emergency Vehicle
992421038	05	Tractor-Trailer
10781658	04	Straight Truck, Flatbed, Dump Truck, Tractor Truck
992000261	01	Passenger Car
991740038	12	Emergency Vehicle
980561411	03	Van
992860779	12	Emergency Vehicle
1711445	03	Van
991650698	01	Passenger Car
10640231	12	Emergency Vehicle
12270939	01	Passenger Car
11141568	02	Passenger Truck, Pickup, Bronco, Jeeps, SUV
993072584		
11570349	12	Emergency Vehicle
980140193	01	Passenger Car
971780795	01	Passenger Car
2621879		
970570913	01	Passenger Car

ACCIDENT_DOCUMENT_NUMBER	DAMAGE_AMOUNT	SHAPE_FID
1222500	1000	27
992651144	9716	28
13020530	1100	29
881835	250	31
12122394	7000	32
10641797	7600	33
970171228	2200	34
2921080	2100	35
11691427	3000	36
973020007	7000	37
3041796	825	38
330269	1500	39
10311613	2800	41
972812175	500	42
531525	250	43
2942033	14100	44
13020532	6000	1
2940718	17000	3
681860	8000	4
992002708	19000	5
973110147	3300	6
12060713	3100	7
1030554	100	8
3041789	2500	9
12390475	800	10
991441045	2150	11
992421038	9500	12
10781658	2500	13
992000261	4500	14
991740038	2750	15
980561411	4300	16
992860779	1800	17
1711445	2600	18
991650698	1750	19
10640231	3500	20
12270939	2100	21
11141568	8500	22
993072584	250	23
11570349	6000	26
980140193	2050	24
971780795	3600	45
2621879	3000	46
970570913	18600	47

The following table includes the accident document numbers for all EV crashes at the 13 signalized intersections along U.S. Route 1 for the five year period (1997-2001).

TABLE G.1:

JURIS_NAME	ACCIDENT_DOCUMENT_NUMBER
Prince William	1222500
Fairfax	881835
Fairfax	10641797
Fairfax	2940718
Fairfax	12060713
Fairfax	980561411
Fairfax	991650698
Fairfax	10640231
Fairfax	10091618
Fairfax	12971341
Fairfax	2760300
Prince William	973650393
Fairfax	681518

TABLE G.2:

Table G.2 includes the name of each column in the crash data that was used in the analysis and a short explanation

COLUMN NAME	EXPLANATION
ACCIDENT_DOCUMENT_ NUMBER	The document number that is given to each accident report from the police
HTRIS_ROUTE_ID	Route number for the route on which the accident occurred
HTRIS_ROUTE_PREFIX	Route highway facility type
HTRIS_ROUTE_NUMBER	Route number
HTRIS_ROUTE_SUFFIX	Route direction
HTRIS_NODE	This field represents a unique five or six digit number assigned to a location representing either a jurisdictional boundary, intersection of two routes, or intersection of a ramp with route. It can also be an ending node or gap terminus
HTRIS_NODE_OFFSET	Measurement of the crash site from the closest node along the route
HTRIS_NODE_TYPE_ID	Node type code
HTRIS_NODE_TYPE_DESC	Node type description
HTRIS_LINK_SEQUENCE	An internal number used to identify each individual section of road
ROUTE_MILEPOST	A measurement along an entire route state wide
JURIS_MILEPOST	A measurement along an entire route in each jurisdiction
JURIS_NO	Jurisdiction identification code
JURIS_NAME	Jurisdiction name
CONST_DIST_NO	District identification code
CONST_DIST_NAME	District name
MAINTENANCE_JURIS_NO	Maintenance jurisdiction identification code
MAINTENANCE_JURIS_ NAME	Maintenance jurisdiction name
RESIDENCY	Residency identification code
ACCIDENT_DATE	Accident date
ACCIDENT_HOUR	Accident hour (0-23)
DAY_OF_WEEK_ID	Day of week, at which the accident occurred, identification code (1-7)
DAY_OF_WEEK_DESC	Day of week, at which the accident occurred, description
INTERSECTING_ROUTE_ NUMBER	Route number

(Table G.2 continues to the following page)

(Table G.2 continues from the previous page)

COLUMN NAME	EXPLANATION
SURFACE_TYPE_ID	Surface type identification code
SURFACE_TYPE_DESC	Surface type description
LANE_COUNT	Number of lanes where the accident occurred
FACILITY_TYPE_ID	Facility type identification code
FACILITY_TYPE_DESC	Facility type description
INTERSECTION_TYPE_ID	Intersection type identification code
INTERSECTION_TYPE_ DESC	Intersection type description
TRAFFIC_CONTROL_ID	Traffic control identification code at accident site
TRAFFIC_CONTROL_DESC	Traffic control description at accident site
ALIGNMENT_ID	Alignment identification code
ALIGNMENT_DESC	Alignment description
WEATHER_ID	Weather identification code
WEATHER_DESC	Weather description
SURFACE_CONDITION_ID	Surface condition identification code
SURFACE_CONDITION_ DESC	Surface condition description
ROAD_DEFECT_ID	Road defects identification code
ROAD_DEFECT_DESC	Road defects description
LIGHTING_ID	Lighting identification code
LIGHTING_DESC	Lighting description
COLLISION_TYPE_ID	Collision type identification code
COLLISION_TYPE_DESC	Collision type description
MAJOR_FACTOR_ID	Major factor identification code
MAJOR_FACTOR_DESC	Major factor description
SEVERITY_ID	Severity identification code
SEVERITY_DESC	Severity description
NUM_FATALITIES	Number of fatalities
NUM_PEDESTRIAN_ FATALITIES	Number of pedestrian fatalities
NUM_INJURIES	Number of injuries

(Table G.2 continues to the following page)

(Table G.2 continues from the previous page)

COLUMN NAME	EXPLANATION
NUM_PEDESTRIAN_ INJURIES	Number of pedestrian injuries
NUM_VEHICLES	Number of vehicles involved in the accident
VEHICLE_1_TYPE_ID	Vehicle 1 type identification code
VEHICLE_1_TYPE_DESC	Vehicle 1 type description
VEHICLE_2_TYPE_ID	Vehicle 2 type identification code
VEHICLE_2_TYPE_DESC	Vehicle 2 type description
DAMAGE_AMOUNT	Damage amount in US dollars from the accident
SHAPE_FID	Identification number for shape file

Explanation of codes: the following tables include a detailed explanation of the classification codes used for each characteristics category.

TABLE G.3

ID	HTRIS_NODE_TYPE_DESC
IN	**Intersection Normal**
IT	**Intersection Tee**
RP	**Ramp Intersection**
JB	**Jurisdictional Boundary**

TABLE G.4

ID	JURIS_NAME
029	**Fairfax**
000	**Arlington**
076	**Prince William**
053	**Loudoun**

TABLE G.5

ID	MAINTENANCE_JURIS_ NAME
029	**Fairfax**
000	**Arlington**
076	**Prince William**
053	**Loudoun**

TABLE G.6

ID	DAY_OF_WEEK_DESC
1	**Monday**
2	**Tuesday**
3	**Wednesday**
4	**Thursday**
5	**Friday**
6	**Saturday**
7	**Sunday**

TABLE G.7

ID	SURFACE_TYPE_DESC
6	**Plant Mix (Bituminous Concrete - Sand Asphalt)**
8	**Portland Cement Concrete**

TABLE G.8

ID	FACILITY_TYPE_DESC
0	**Two-way, non-divided**
1	**Divided, no control of access**
2	**Divided, partial control of access**
3	**Divided, full control of access**
4	**One-way, part of a one-way system**
5	**Two-way, part of a one-way system**

TABLE G.9

ID	INTERSECTION_TYPE_DESC
1	**Signalized Intersection**
2	**Crossing (All crossroads at grade regardless of intersecting angle)**
3	**"T" (Leg enters between 80 degree and 100 degree angle)**
4	**Branch (One leg enters at angle other than "T" angle)**
5	**Offset (All offset intersections when offset does not exceed 150 feet)**
8	**Interchange (Grade separation of intersection leg) (Includes the entire interchange area)**
9	**Not stated or not applicable. Not applicable for accidents not occurring at an intersection**

TABLE G.10

ID	TRAFFIC_CONTROL_DESC
01	**No Traffic Control**
02	**Officer or Watchman**
03	**Traffic Signal**
04	**Stop Sign**
05	**Slow or Warning Sign**
06	**Traffic Lanes Marked**
07	**No Passing Lanes**
08	**Yield Sign**
13	**Other**

TABLE G.11

ID	ALIGNMENT_DESC
1	**Straight Level**
2	**Curve Level**
3	**Grade Straight**
4	**Grade Curve**
5	**Hillcrest Straight**
7	**Dip Straight**

TABLE G.12

ID	WEATHER_DESC
1	**Clear**
2	**Cloudy**
3	**Fog**
4	**Mist**
5	**Raining**
6	**Snowing**

TABLE G.13

ID	SURFACE_CONDITION_DESC
1	**Dry**
2	**Wet**
3	**Snowy**
4	**Icy**
6	**Oily**
7	**Other**

TABLE G.14

ID	ROAD_DEFECT_DESC
0	**Not Stated**
1	**No Defects**
2	**Holes, Ruts, Bumps**
4	**Under Repair**
5	**Loose Material**
7	**Slick Pavement**

TABLE G.15

ID	LIGHTING_DESC
1	**Dawn**
2	**Daylight**
3	**Dusk**
4	**Darkness - Street or Highway Lighted**
5	**Darkness - Street or Highway not Lighted**

TABLE G.16

ID	COLLISION_TYPE_DESC
01	**Rear End**
02	**Angle**
03	**Head on**
04	**Sideswipe - Same direction of travel**
06	**Fixed object in road (from ditch to ditch)**
08	**Non-Collision, overturned, jacknifed or ran off road (no object)**
09	**Fixed object off road (from outside of ditch)**
10	**Deer**
12	**Pedestrian**
15	**Backed Into**
16	**Miscellaneous or other**

TABLE G.17

ID	MAJOR_FACTOR_DESC
0	**Miscellaneous - Avoiding animal, loss of part of load, load over-hanging, occupant injured within or fall from vehicle.**
2	**Driver or pedestrian under the influence of alcohol, drugs, or other agents (Preference over code 3)**
3	**Driver speeding (Preference over code 4)**
4	**Driver or pedestrian inattention or error**
5	**Vehicle defective**
6	**Weather or visibility condition**
8	**Road slick**
9	**Not stated**

TABLE G.18

ID	SEVERITY_DESC
0	**No visible injury**
1	**Dead before report made**
3	**Other visible injury, as bruises, abrasions, swelling, lumping, etc.**
4	**No visible injury but complaint of pain or momentary unconsciousness**

TABLE G.19

ID	VEHICLE_1_TYPE_DESC
00	**Not Stated**
01	**Passenger Car**
02	**Passenger Truck, Pickup, Bronco, Jeeps, SUV**
03	**Van**
04	**Straight Truck, Flatbed, Dump Truck, Tractor Truck**
05	**Tractor-Trailer**
12	**Emergency Vehicle**
13	**City Transit Bus, Privately Owned Bus, Church Bus**

TABLE G.20

ID	VEHICLE_2_TYPE_DESC
00	**Not Stated**
01	**Passenger Car**
02	**Passenger Truck, Pickup, Bronco, Jeeps, SUV**
03	**Van**
04	**Straight Truck, Flatbed, Dump Truck, Tractor Truck**
05	**Tractor-Trailer**
12	**Emergency Vehicle**

VITA

Amalia Vrachnou, the daughter of George P. and Christina E. Vrachnos, was born on August 8, 1978, in Athens, Greece. She graduated from High School in June 1996 with honors. She was accepted to the National Technical University of Athens, where she completed her undergraduate studies in civil engineering with qualification in transportation. She received multiple scholarships for her academic performance from the National Technical University of Athens and from the Technical Chamber of Greece. While preparing for her admission in Virginia Tech she worked at the National Technical University of Athens in the field of operation research and statistical analysis. She was awarded a complete graduate assistantship for her Master's of Science in Civil and Environmental Engineering. This thesis completes her M.S. degree in Civil and Environmental Engineering from Virginia Polytechnic Institute and State University.