Analysis of the Characteristics of Emergency Vehicle Operations in the Washington D.C. Region

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(ABSTRACT)

Concerns about increased emergency vehicle response times in the Washington D.C. Region, especially during peak periods, have led to the implementation of signal preemption systems to facilitate the efficient and safe movement of emergency vehicles. However, to date only limited research has been carried out on the travel characteristics of emergency vehicles.

This paper presents an analysis of emergency vehicle characteristics to enhance our understanding of emergency vehicle operations and impacts and to assist public agencies and other stakeholders in the planning and deployment of emergency vehicle preemption systems. Emergency vehicle characteristics that merit special attention include temporal and spatial distribution of emergency vehicle travel; frequency and duration of preemption requests; platoon responses; and crashes involving emergency vehicles. Data on major corridors in Fairfax County, Virginia and Montgomery County, Maryland are used in the analysis.

The analysis indicates that such data are useful to assess the need for a preemption system along major arterials. Moreover, the analysis demonstrates the importance of considering emergency vehicle preemption impacts regarding delay to other vehicles. It is also important to note that there is some variability in the emergency vehicle characteristics depending on the proximity of a firehouse to an intersection and other factors. It is proposed that future efforts build upon this research to develop warrants to be used in determining the appropriateness of installing preemption systems at signalized intersections.

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CHAPTER 1: INTRODUCTION

1.1 Problem Statement

> "The characteristics of urban travel flows and the facilities that permit such travel are basic to an understanding of transportation. In fact, it is the relationship between urban travel patterns and urban transportation facilities that forms the basis of most urban transportation problems. Any urban transportation planning process is considered to be related to the characteristics of the urban transportation system and the traffic flows this system permits. Transportation planners need to be familiar with these travel characteristics as they relate to their metropolitan area, because they not only define the substance and scope of transportation problems, but they can also provide useful indications of possible solutions" *(1)*.

While there is a great deal of information available about the travel characteristics of individuals traveling for all kinds of purposes on a day to day basis, little is known about the travel characteristics of emergency vehicles. To this end, an underlying aim of this research is to assist the transportation and emergency vehicle communities in acquiring a better understanding of emergency vehicle operations, travel patterns and associated characteristics. The characteristics that merit special attention include temporal and spatial distribution of emergency vehicle travel; frequency of emergency vehicle responses by time of day; the extent to which such responses include two or more emergency vehicles; and the impacts of emergency vehicle travel on the transportation system.

Understanding the travel characteristics of emergency vehicles is an important and fundamental element in designing and deploying an emergency signal preemption system. Over the last few years, a great deal of attention has been provided for the safe and efficient movement of emergency vehicles. Communities are turning to emergency vehicle preemption systems at traffic signals in order to improve emergency vehicle response time and safety, as well as to resolve the challenges that gridlock situations present to drivers of emergency vehicles. To this context, transportation planners and engineers need knowledge and tools to assist in identifying emergency vehicle preemption candidate intersections based on traffic operations and safety objectives.

1.2 Research Objectives

The primary goal of this research is to assist traffic engineers, as well as public officials in acquiring an enhanced understanding of the travel characteristics of emergency vehicles. This goal can be expressed in six research objectives:

- Identify the travel characteristics of emergency vehicles which are of particular interest to the transportation profession.
- Study the traffic flow characteristics of emergency vehicles, in terms of frequency, distribution by time of day, and average trip length.
- Study the characteristics of emergency vehicles with respect to the preemption strategy deployed, in order to assess the level of frequency of preemption requests and average duration of preemption.
- Study the crash situation involving emergency vehicles in a major corridor of the study area, due to the fact that emergency vehicle safety is extremely important.
- Describe and present the results and findings obtained from the analyses of emergency vehicle travel characteristics, using pc-based analytical tools.
- Formulate conclusions, remarks and recommendations for consideration in the design and deployment of emergency vehicle preemption systems as well as for future research; a special effort will be made to recommend future steps to develop warrants for emergency vehicle preemption.

1.3 Research Approach

A literature review will be conducted to determine if any documentation available can be useful in providing insights pertaining to the travel characteristics of emergency vehicles. Literature will include professional transportation journals and technical reports; papers presented at transportation conferences, and EMS and Firefighter publications. Literature will be obtained through the Virginia Tech library and with the use of the internet.

An analysis of emergency vehicle travel characteristics will be conducted based on the emergency response log data maintained by Fairfax County Fire and Rescue Department. Three fire stations in Fairfax County will be considered for the examination of the characteristics of emergency vehicle trip generation and platoon response.

Another part of this research will focus on the analysis of the emergency vehicle preemption data collected after the deployment of signal preemption systems in Fairfax County, Virginia and in Montgomery County, Maryland. This analysis will attempt to study some of the characteristics of emergency vehicle travel with respect to the frequency of preemption requests and average duration of preemption.

Another part of the analysis will include the study of the emergency vehicle crash history in order to shed light on the safety-related characteristics of emergency vehicle travel. The primary source of information will be crash data provided for signalized intersections in U.S.1, a major arterial in Fairfax County, Virginia.

The results obtained from the above analyses will provide the platform to examine the potential for the development of warrants to be used in determining the appropriateness of installing signal preemption systems at intersections. The main factors that will be examined in the consideration of warrants include: emergency vehicle response times, frequency of emergency runs and platoon responses, crashes involving emergency vehicles, geometrics of the street (width, shoulder areas, sight distance), volumes, and signal phasing. Findings and results will be documented for the purpose of assisting public agencies and practicing professionals contemplating the design and deployment of traffic signal preemption systems.

1.4 Thesis Contributions

The importance of this research in part lies in its novelty. To date, the study of emergency vehicle characteristics has received little to no attention. With the concern for providing "first responders" with efficient transportation resources coupled with the increase in emergency vehicle preemption system deployment, a study on the traffic flow characteristics of emergency vehicles is of great interest. The findings of this research are particularly important to the National Capital Region because of the heavy traffic levels experienced during peak periods and the resulting effect on emergency response times.

This research relies on analyzing traditional elements of traffic engineering to provide insights into transportation planning. It also provides an overview of the components of preferential treatments at signalized intersections, while understanding the temporal and spatial nature of emergency vehicle travel. Furthermore, this research provides the tools required to assist traffic engineers and stakeholders in designing and deploying an emergency signal preemption system. To this end, this research attempts to offer considerations regarding emergency vehicle traffic operations as well as safety issues; in addition, it lays the groundwork to develop possible warrants to be used in determining the appropriateness of installing signal preemption systems at signalized intersections.

1.5 Thesis Organization

This thesis report is organized into four chapters including this introductory chapter. Following the introduction (Chapter 1), Chapter 2 contains a literature review of research on existing studies on emergency vehicle travel characteristics, and on emergency vehicle traffic operations in general. It also provides an overview of traffic signal preemption fundamentals. Chapter 3 presents an analysis of emergency vehicle traffic flow characteristics based on the emergency response log data from three fire stations in Fairfax County, Virginia. This part of the analysis o includes a description of the study area, data collection and associated findings and results. This chapter also presents an analysis of emergency vehicle preemption data from Fairfax County, Virginia and Montgomery County, Maryland and the associated findings and results. At the end of Chapter 3, emergency vehicle involvement in crashes is discussed, which includes the description and analysis of crash data provided for signalized intersections on U.S.1. Finally, in Chapter 4 the findings of the study are summarized and some concluding remarks are offered for consideration in the design and deployment of emergency vehicle preemption systems as well as for future research.

CHAPTER 2:LITERATURE REVIEW

2.1 Introduction

This research relies on analyzing traditional elements of traffic engineering to provide insights into transportation planning. The literature review will enable the reader to establish a good foundation of relevant knowledge and raise an awareness of most of the issues, pitfalls and strategies surrounding emergency vehicle travel and operations. This chapter provides a better understanding and appreciation of the issues, considerations and details associated with emergency vehicle traffic operations as well as emergency vehicle safety. Reviewing the available literature can provide balanced information to both the transportation and emergency vehicle communities in order to enhance their knowledge about the possible benefits, alternative approaches, and issues concerning the improvement of emergency service delivery, while understanding the temporal and spatial nature of emergency vehicle travel. This chapter also provides an overview of the components of preemption treatment at signalized intersections to assist public agencies and other stakeholders in the planning and deployment of emergency vehicle preemption systems. It also presents the main factors that need to be reviewed of emergency vehicle preemption, in order to develop warrants to be used in determining the appropriateness of installing signal preemption systems at signalized intersections. The broader knowledge provided by reviewing the current state of art will encourage better understanding among the communities and their decision makers.

2.2. Overview of Emergency Vehicle Characteristics

2.2.1 Which are the Characteristics of Emergency Vehicle Travel?

Emergency vehicle characteristics that merit special attention include temporal and spatial distribution of emergency vehicle travel; frequency and duration of preemption requests; platoon responses; and crashes involving emergency vehicles. Available literature review led to the conclusion that the frequency of emergency vehicle responses by time of day, the extent to which such responses include two or more emergency vehicles, and the impacts of emergency vehicle travel on the transportation system have not become yet part of the knowledge base of the professional community.

In the remainder of this chapter, the most important findings on the characteristics of emergency vehicle travel will be presented, both traffic and safety-related. Literature includes professional transportation journals and technical reports; papers presented at transportation conferences, and EMS and Firefighter publications. Literature is obtained through the Virginia Tech library and with the use of the internet.

2.2.2 Emergency Vehicle Responses

2.2.2.1 Emergency Response Time

- *Definition*

Response time is a prime measure of a fire department's efficiency. The time it takes for the emergency services personnel to respond to an incident is dependent upon five factors:

✓ The time to recognize that an emergency exists and initiate a call to 911.

✓ The time it takes for the dispatcher to get sufficient information on the emergency type and location, and then transmit it to the fire department (dispatch delay).

✓ The time it takes for the fire department to record the information and start driving to the scene (turnout time).

✓ The driving time from the station to the scene.

✓ The time to get equipment in place and actually begin medical treatment or fire suppression and rescue.

Most departments only record the time in steps 2 to 4 or steps 3 to 4 and call this their 'response time" *(2)*.

- *Why Response Time is Important?*

The response time of fire and emergency medical services (EMS) personnel is crucial; every crash requires an emergency response. If the crash results in a personal injury, the timeliness and the quality of the EMS response is important to the outcome of the injury of the people involved in the crash. For example, 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 it started within eight minutes of the onset of the heart or breathing stoppage, the survival rate drops to around 30% to 40% percent *(2)*. In 1995, 2,211 crash fatalities involved transport time of more than one hour to a hospital *(3)*.

From the above, it becomes obvious that the response time to a serious illness or injury directly impacts the outcome. The American Heart Association recommends a four-minute response and states that longer response time may lead to greater damage to the brain from oxygen deficiency and markedly reduced chances of long-term survival. The American Heart Association also recommends that heart attack victims should get help within three to five minutes and that their chances of survival decrease by 7 to 10 percent for every minute they wait *(4)*. A comparative study of response time and survival in an urban emergency medical services system indicated that emergency calls where response time was less than 5 minutes were associated with improved survival when compared with calls where response time exceeded 5 minutes. The mortality risk was found to be 1.58% for patients provided service in more than 5 minutes, and 0.51% for those provided service in less than 5 minutes *(5)*.

- *"Target Response Time"*

Response time statistics indicate that both Fire and EMS response times are averaging 5 minutes or less; a three-minute or four-minute response is also feasible for some Fire & Rescue Departments. It was interesting to find out that some regions have adopted a so called "Fire & Rescue Master plan" and set a goal to improve Fire & Rescue Unit response time to areas taking more than a critical threshold to reach. This threshold is usually picked after a study which determines that seeking faster responses than that, while more desirable, would be unrealistic *(4)*. This target is set so as to reach 90% or 95% of incidents in less than the "target response time". For example, for the City of Fort Lauderdale, Florida the goal set by the Fire & Rescue Department is to reach 90% of medical and fire incidents in less than 6 minutes and 95% of medical incidents in less than 8 minutes *(6)*. In general, Emergency Medical Services (EMS) agencies are increasingly being held to an ambulance response time criterion of responding to a medical emergency within 8 minutes for at least 90% of calls. Nevertheless, a study evaluating the effect of exceeding the 8-minute response time guideline on patient survival for victims of traumatic injury, treated by an urban paramedic ambulance EMS system, showed that exceeding the ambulance industry response time criterion of 8 minutes does not affect patient survival after traumatic injury *(7)*.

Establishing a "target response time" combined with proper station location is aiming to allow Fire & Rescue to intervene with enough time to save lives and protect property. Data compiled by the Communications Center at the Englewood Fire & Rescue Department verifies the above observation; both fire and EMS response times are averaging 4.69 minutes or less which shows that the five-minute response promise, that has been previously set, is being kept. The improved response time is also the result of a new fire station's strategic location *(8)*.

- *Urban Vs. Rural Fire/EMS Agencies' Response Time*

It is worth mentioning that different areas have different response time requirements, depending on the population. Incorporated cities have a response time requirement of less than 5 or 10 minutes, while outlying areas can have a much higher response time of up to 40 minutes in some cases. Urban and rural EMS agencies have different challenges, and transportation professionals can have a positive impact on both *(9)*.

Urban Fire/EMS agencies are typically staffed with paid professionals providing full-time coverage. One major barrier to prompt an effective response may be traffic congestion, affecting travel both to the scene and to the hospital. Another is efficiency in locating and routing vehicles. *Rural Fire/EMS agencies* rely more heavily on volunteer personnel. In this case, barriers may include delays in incident detection and reporting, periodic lack of skilled responders, prolonged response time complicated by long distances and poor roads, long travel time to the hospital, limited availability of trauma centers and limited air medical coverage and landing sites *(3)*.

- *Barriers to Effective Responses & Potential Solutions*

A review of various EMS and Fire Rescue Journals led to some very interesting findings pertaining to emergency responses. Emergency response times in many States are threatened by a growing population, outdated technology and tight budgets. Getting there quickly is priority No. 1, but sometime staffing, traffic and the location of the emergency can be roadblocks to the timeliest response. A shortage of paramedics is recognized as a key reason why ambulances have been taking too long to arrive at medical emergencies. Heavy traffic is also considered a thorn in the side of firefighters and paramedics. With several construction projects on major roadways and an increasing population, emergency vehicles are having a more difficult time navigating the crowded streets *(10, 11)*.

To this end, Emergency Medical Services and Fire and Rescue administrators seek methods to enhance system performance. One component scrutinized is the response time interval between call receipt and arrival on the scene. Emergency Medical Services and Fire and Rescue Authorities in different regions have considered various methods so as to improve emergency response time; such as, strategic positioning of the new stations, adopting systems of late technology, adding more staff, and prioritizing urgent emergency medical runs versus non-urgent *(10, 12)*.

In the city of Fort Collins, Poudre Valley Hospital EMS and Poudre Fire Authority have improved the response time with the additional manpower and strategic positioning of the new stations. The switch to a new system, from an antiquated one, is also expected to help improve response time in the city *(10)*. With the installment of upgraded 911 equipment that provides digital maps of the regions, emergency dispatchers are hoping to reduce response time for emergency calls *(13)*. Adding more staff is also considered to help emergency medical and fire agencies to improve response time; however, every service has a cost. In the Roanoke County, for example, an addition of 10 firefighters in the fire staff has been estimated to cost roughly $450,000 annually. The County's ambulance service fee is expected to cover about half of those costs *(14)*.

In the District of Columbia, officials seek solutions to an array of problems, including long-standing complaints about ambulance response times and a chronic shortage of paramedics. The number of fire calls has held fairly steady over the years, but the number of calls for medical aid has grown. Meanwhile, ambulance response times have grown worse. The ambulance response time criterion of responding to a medical emergency within 8 minutes is met only 33% of the time- while in 1989, it was met at 49% of the time- and the average response time for critical incidents is nearly 11 minutes *(15)*. D.C. Council Members have suggested that a better use of emergency medical services personnel and more aggressive hiring of firefighters with emergency medical experience would improve staffing shortages, cut a swelling overtime budget and reduce ambulance response time. Over the long term, officials would like to combine the firefighting and medical functions so every employee has equal pay and benefits and the training to work on either firetrucks or ambulances. But the idea has never been fully implemented because of its cost, estimated at $30 million to $70 million *(16)*.

In some regions, when an ambulance does not arrive quickly enough, a fire company's rescue truck takes the patient to the hospital. This strategy seems to result in quicker responses and thus, it is safer for the patient, but it also takes a fire district crew out of service *(17)*. However, the District of Columbia Fire and Emergency Medical Services Department has decided to disband a 3-year-old program that put paramedics on fire engines to deliver emergency medical care before ambulances could respond, although it was considered a successful program. This decision is likely to delay delivery of critical care to the region. Nevertheless, some experts claim this move not only will save money, but also help stabilize ambulance response times by bolstering the allegedly under-manned EMS staff *(18)*.

Prioritizing emergency calls can be another way to enhance system performance in terms of decreased response time. More and more cities apparently are seeing the value of prioritizing EMS runs and they set emergency and non emergency goals to be met. A recent 200-city survey conducted by the Journal of Emergency Medical Services (JEMS) found that only 32% of the 200 largest (by population) cities in the United States responded to all calls with lights and sirens. This figure was down by 37% from the previous year. The survey also found that 36% of those 200 cities prioritize calls by determining the urgency of each medical situation *(12)*. In the city of Fort Collins, Poudre Valley Hospital EMS and Poudre Fire Authority response times for both non-emergencies and emergencies improved from 38.41 minutes in 1998 to 29.89 in 2001. Swirling lights and blaring sirens were used to distinguish emergencies from non-emergencies *(10)*.

Several studies have shown very little decrease in response time when no lights or sirens are used. In many of the studies, using lights and sirens saved less than one minute and 30 seconds on response time. The key to the success of any response system when not using lights and sirens rests on the dispatchers in the communications center. That is why many communication centers have begun using standardized protocols for evaluating or screening 911 calls *(12)*.

Nevertheless, this policy can have a beneficial effect on safety. Several years ago, the St. Louis Fire Department instituted an "On-the-Quiet" policy (no lights and sirens) after Department experienced three apparatus crashes in one day. The policy was intended to stop "lights-and-sirens" runs to incidents that involved no true life or property emergency (such as dumpster and weed fires and sprinkler alarms). This policy also carried over to EMS calls. If the communications center received any additional 911 calls that indicated there was a real threat to property or life, the alarm was upgraded. One year later, the program was evaluated and the end result was 62% fewer crashes and an 81% reduction in injuries *(12)*.

Another reaction to improve emergency response time involves the implementation of emergency vehicle preemption systems that are a part of a fast growing ITS interest area. There is some evidence that the implementation of emergency vehicle preemption strategy may reduce travel times for emergency vehicles, and in addition, it may decrease the number and severity of crashes involving emergency vehicles at signalized intersections *(19, 20)*. Because of the importance of this strategy on traffic operations as well as on safety, it will be more thoroughly discussed later in this chapter.

2.2.2.2 Response Statistics- Fairfax County, VA

Fairfax County includes 395 square miles of land area. There are 35 fire stations providing fire protection to the County residents and businesses, and 470 Firebox areas. The County's Rescue Squad Committee has defined effective response times within 6 minutes of dispatch for providing advanced life support and within 5 minutes of dispatch for providing fire suppression. Statistics presenting the operating performance indicators show that the response time criteria are not often met. Furthermore, the unit arrival rates that satisfy the above response time criteria have deteriorated between the years 2000 and 2002 *(21)*. The following table illustrates the above observations.

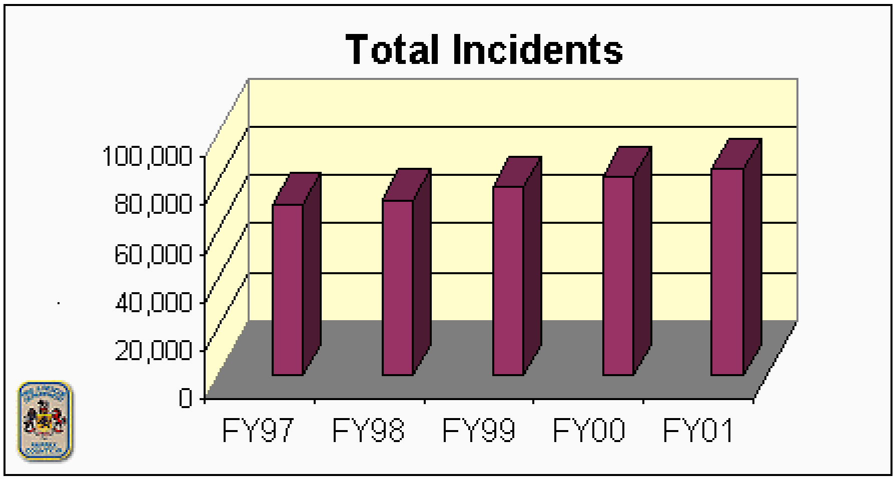
Table 2.1. Appropriate Unit Arrival Rates.

	2000	***2001***	***2002***
ALS	81.31%	78.24%	78.63%
SUPPRESSION	57.93%	54.57%	56.28%

Response statistics maintained by Fairfax County Fire and Rescue Department indicate that the number of incidents as well as the number of vehicle responses has increased the last few years *(21)*. The following charts illustrate the above observation:

(It should be noted that the following charts were compiled by the Data and Information Branch, Support Services Division. Most of the charts represent a five-year period beginning FY97 - FY01. The range for a fiscal year is from July 1 to June 30. For example, FY98 goes from July 1, 1997, through June 30, 1998).

- *Total Incidents:*

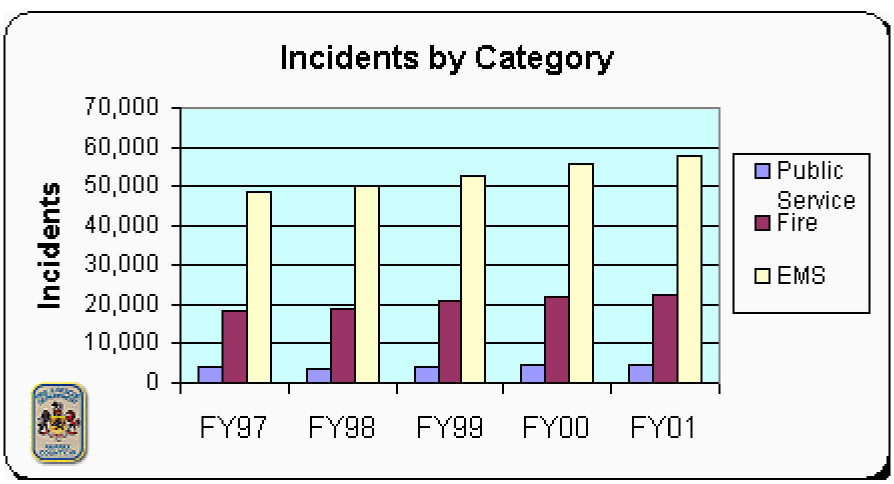


FY97	FY98	FY99	FY00	FY01
70,579	72,618	77,699	81,856	85,119

Figure 2.1. Total Incidents in Fairfax County.

The Annual Report of Fairfax County Fire and Rescue Department indicated that in the year 2002 the total number of incidents has further increased and reached 89,246.

- *Incidents by Category:*

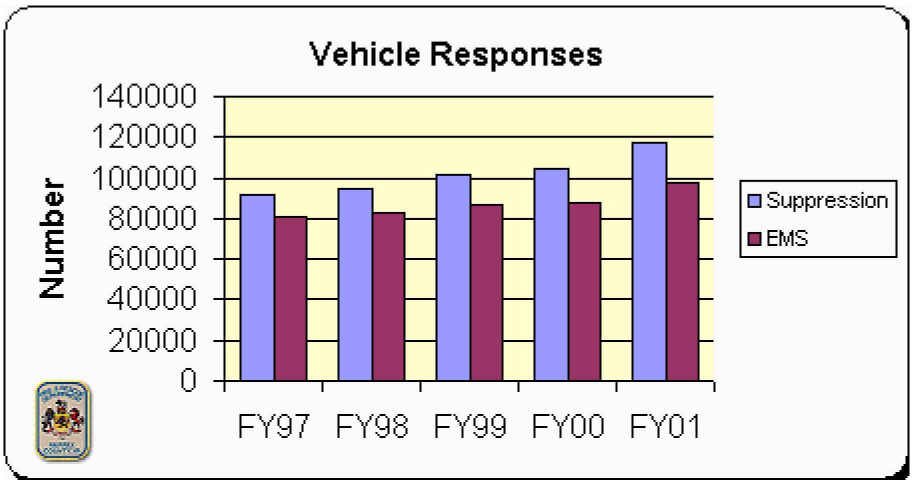


	FY97	FY98	FY99	FY00	FY01
Public Service	3,839	3,771	4,112	4,432	4,642
Fire	18,383	19,011	20,793	21,872	22,677
EMS	48,357	49,836	52,794	55,552	57,800

Figure 2.2. Incidents in Fairfax County by Category.

The Annual Report of Fairfax County Fire and Rescue Department indicated that in the year 2002, there were 60,685 EMS incidents; 23,579 Fire incidents; and 4,982 Public service incidents.

- *Vehicle Responses:*



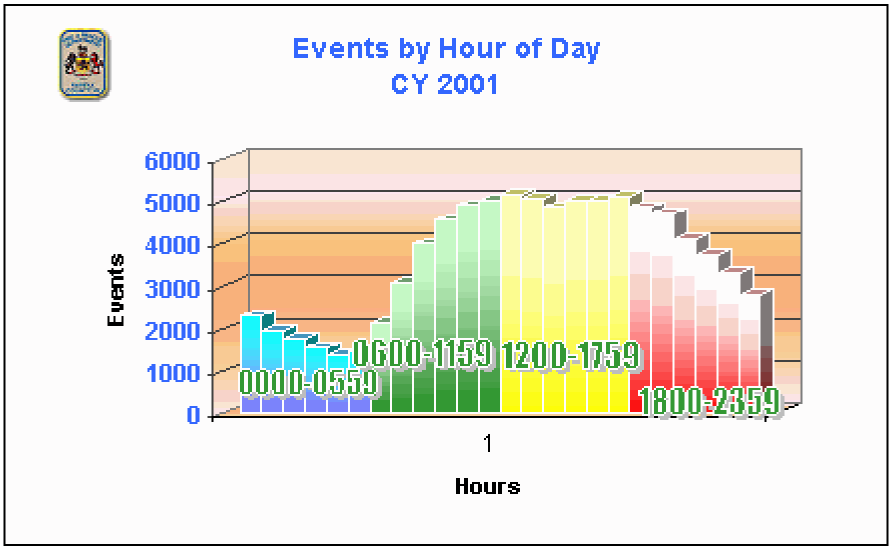
Responses	**FY97**	**FY98**	**FY99**	**FY00**	**FY01**
Suppression	91,979	94,414	101,574	104,875	117,104
EMS	80,867	82,434	86,333	88,059	97,148

Figure 2.3. Vehicle Responses in Fairfax County.

The Annual Report of Fairfax County Fire and Rescue Department indicated that in the year 2002 the EMS responses remained almost the same as in 2001 (97,965 responses); while the Suppression responses decreased to 112,613 responses.

- *Events by Hour of Day:*

The pattern of hourly events (incidents) over the course of day is presented for year 2001. A model of this pattern of variation is very useful in analysis of projected traffic conditions for both emergency vehicles and other vehicles.

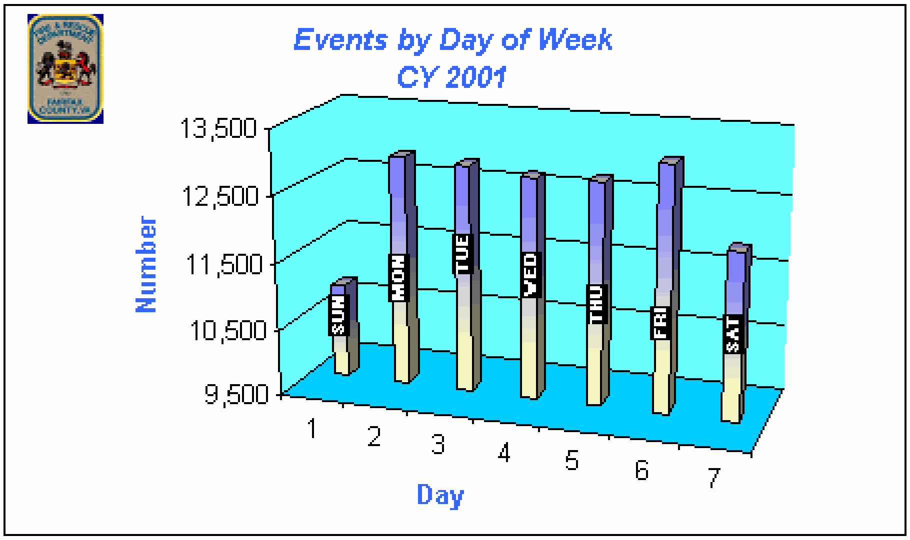


Dispatch Hour (Military Time)	Total Incidents	Dispatch Hour (Military Time)	Total Incidents
0000	2,288	1200	5,159
0100	1,926	1300	5,037
0200	1,737	1400	4,846
0300	1,533	1500	5,023
0400	1,379	1600	5,023
0500	1,472	1700	5,107
0600	2,117	1800	4,845
0700	3,075	1900	4,700
0800	3,994	2000	4,106
0900	4,557	2100	3,714
1000	4,891	2200	3,326
1100	5,006	2300	2,796

Figure 2.4. Events in Fairfax County by Hour of Day.

- *Events by Day of Week:*

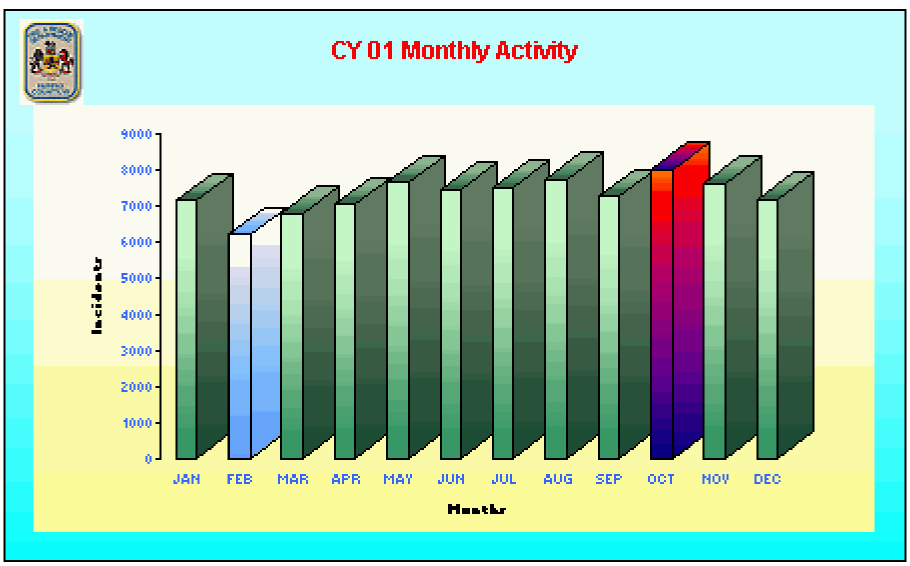
The following figure shows the frequency of incidents according to day of the week for the year 2001.



Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
10,932	12,971	12,922	12,811	12,841	13,170	12,010

Figure 2.5. Events in Fairfax County by Day of Week.

- *Monthly Activity:*



Month	Incidents	Month	Incidents
January	7,157	July	7,504
February	6,197	August	7,749
March	6,805	September	7,260
April	7,033	October	8,018

May	7,659	November	7,619
June	7,462	December	7,194

Figure 2.6. Events in Fairfax County by Month of Year.

2.2.3 Emergency Safety-Related Characteristics

The review of the available literature and Fire and EMS journals indicates that it is crucial for the EMS and Fire & Rescue to arrive at an emergency quickly; however, it is even more critical to get there safely. An urgent response of an ambulance to an incident when it involves speeding to the rescue can have deadly results. According to a 1993 Houston study, ambulances are 13 times more likely to be involved in a crash than other vehicles in terms of the number of crashes per mile driven. The Houston study also showed that ambulances are five times more likely to be involved in a crash that causes an injury *(12)*. The National Highway Traffic Safety Administration (NHTSA) database indicates that there are 15,000 ambulance crashes per year in the United States, or roughly 41 each day. Additionally, in fatal, multi-vehicle ambulance crashes between 1980 and 2000, the number killed in the other vehicle involved was 21 times greater than the number of ambulance drivers who died. The analysis also showed more than three-fourths of the fatalities were people who were not in the ambulance *(12)*. There are also reported crashes involving more than one vehicle responding to the same incident; as it was the case in West Hollywood, LA in April, 2002 where one ambulance collided with a fire engine while the two vehicles with sirens blaring, were responding to the same medical call *(22)*.

The following figures provide a more accurate depiction of the crash situation involving emergency vehicles in the United States.

2.2.3.1 Number of Fatal Crashes Related to Emergency Use

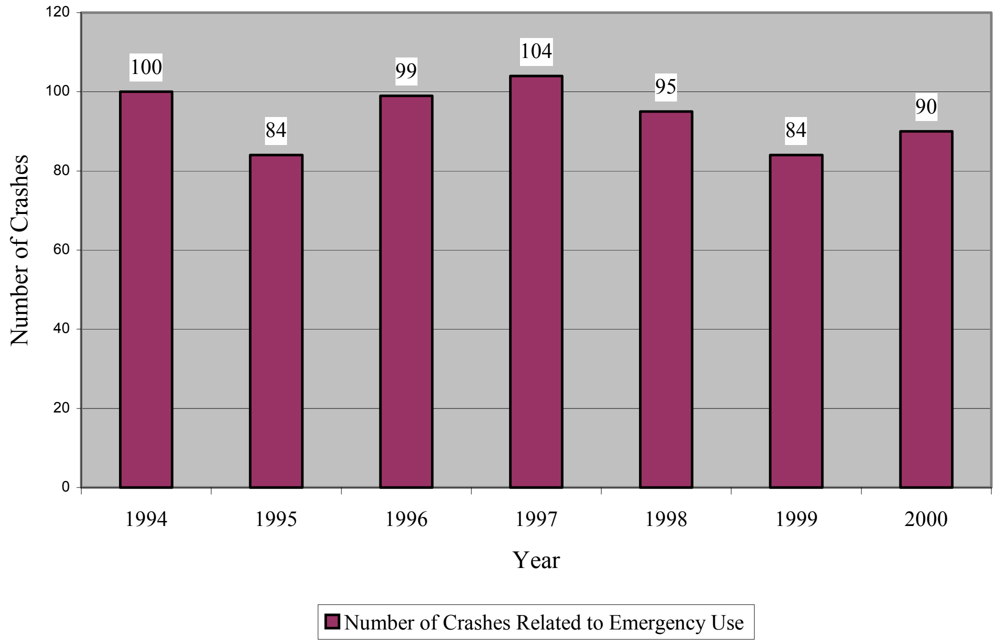


Figure 2.7. Number of Crashes related to Emergency Use.
(Source: Fatality Analysis Reporting System (FARS) Web-Based Encyclopedia)

Each year, there is a significant number of crashes that involve emergency vehicles. While the numbers are low with respect to the total annual fatal crashes (approximately 40,000 per year over the same period), the fact that emergency vehicles are involved in such crashes is not acceptable and should be reduced if appropriate roadway improvements, traffic control devices, or traffic operations concepts are available. It should be noted that emergency vehicle-related property damage and injury crashes are not compiled and reported by NHTSA in the annual traffic safety facts report. Therefore, analysis of fatal EV-related crashes is the best information with which to characterize EV-related crashes.

The above data is extracted from the FARS national database by conducting various queries within the database. The above chart represents national statistics.

2.2.3.2 Number of Vehicles Involved in a Crash Related to Emergency Use

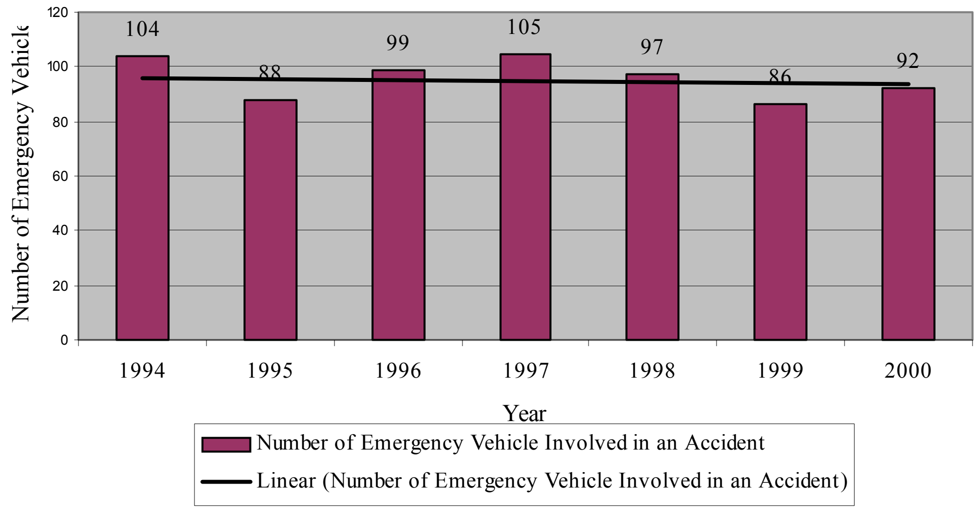


Figure 2.8. Frequency of Crashes Involving Emergency Vehicles.
(Source: Fatality Analysis Reporting System (FARS) Web-Based Encyclopedia)

The statistics obtained in the above figure are extracted from the Fatality Analysis Reporting System (FARS) web-based encyclopedia by conducting numerous queries. The figures shows the total number of vehicles other than the emergency vehicle was involved in a crash related to emergency use. On an average 96 vehicles per year were involved in crashes resulting in fatalities all over the country. (Note: differences in annual totals depicted in Figures 2.7 and 2.8 are inherent in FARS due to the differences in reporting accuracy for each database).

2.2.3.3. Manner of Collision Involving Emergency Use

Table 2.2. Manner of Collision Involving Emergency Use.

Manner of Collision / Year	2000	1999	1998	1997	1996	1995	1994	Total
Not Collision with Motor in Transport	22	25	24	34	24	23	23	175
Rear End	0	4	6	8	8	6	5	37
Head On	8	14	13	16	9	9	8	77
Rear to Rear	1	0	0	0	0	0	0	1
Angle	55	35	49	40	55	46	61	341
Sideswipe, Same Direction	1	1	2	2	0	0	2	8
Side Swipe, Opposite Direction	0	3	0	0	0	0	0	3
Unknown	0	1	0	0	0	0	0	1
	87	83	94	100	96	84	99	643

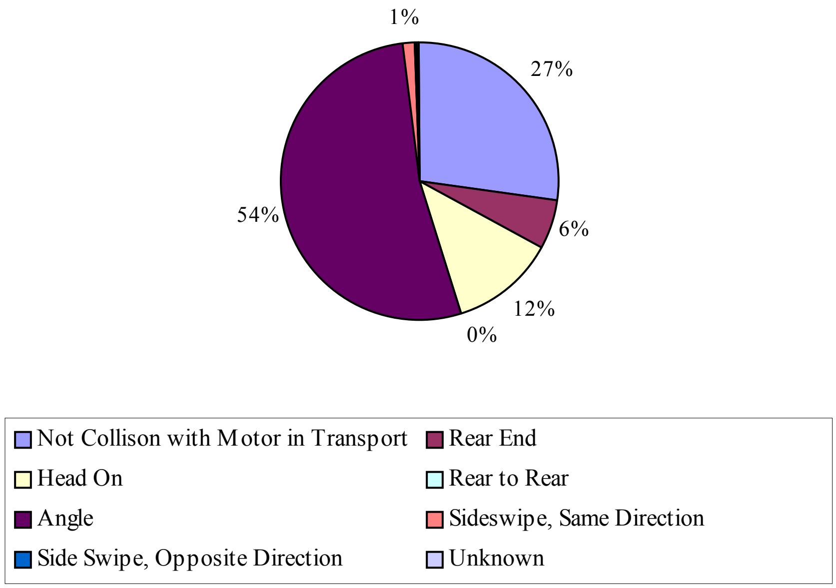


Figure 2.9. Manner of Collison Involving Emergency Vehicles.
(Source: Fatality Analysis Reporting System (FARS) Web-Based Encyclopedia)

Figure 2.9 provides a breakdown of the 1994-2000 EV-related fatal crashes by type. Of specific interest in this study are those that are associated with intersections. The figure illustrates that the most common intersection crash types, rear-end and angle crashes, make up 378 of 643 (58%) fatal EV-related crashes. Other crash types potentially associated with intersection passage are head-on, in cases where emergency vehicles elect to proceed down opposite direction travel lanes, and side-swipe (same direction and opposite direction), where emergency vehicles pass through inadequate openings between autos stopped in queues.

2.3. Overview of Emergency Vehicle Preemption (EVP) Fundamentals

2.3.1 Background

Traffic Signal Preemption is an operational strategy that facilitates the movement of the emergency vehicle through the traffic signal controlled intersection. This strategy enables to reduce the response time for emergency vehicles, and improve the safety of the emergency vehicles traveling through the system. Preemption interrupts the normal signal plan; and results in an immediate green light being provided for emergency vehicles, including fire and rescue.

A traffic signal preemption system is an electrical device or devices that allow a traffic control signal to respond uniquely to the approach of a particular type of vehicle or the occurrence of an unusual condition at or near a highway intersection. Such systems are designed to increase safety, reduce emergency response time and enhance public transit operations. A signal mounted preemption system requires the installation of receiving device within the traffic control signal cabinet that responds to a remote triggering device attached to specific authorized vehicles. Signal mounted systems generally allow vehicles traveling in the same direction as the emergency vehicle to receive, or continue to receive, a green indication. The green indication provides an opportunity for motorists to clear the road ahead of the advancing emergency vehicle. For signal-mounted systems, if the remote signal from the source is interrupted or terminated for any reason, normal traffic control signal operation will continue. Signal mounted systems may respond to different vehicles or types of vehicles in recognition of different vehicle priorities. Installation and operation of signal-mounted systems are at the discretion of the traffic control signal owner *(19, 20)*.

2.3.2 Critical Factors Affecting the Need for Emergency Vehicle Preemption

Some factors that contribute to need of emergency vehicle preemption (EVP) are as follows *(23)*:

1) Significant congestion and queuing at intersection approaches. It been seen that the need of EVP is most needed when the LOS is poor and becomes even worse during the peak hours. High volumes on the intersection suggest congestion. Thus traffic volumes and the time of the day are two of the main factors that contribute to delays.
2) Number of crashes involving emergency vehicles is a clear indication of need for EVP, but the lack of crashes does not indicate that EVP should not be provided.
3) Lack of shoulders and auxiliary lanes disables the motorists to pull out and provide a clear path to the emergency vehicle. These vehicles can use the right and left turn lanes. But this may not help when the queue length are very long.
4) Number of emergency runs indicates the likelihood of delays to emergency vehicles and the need for EVP.
5) Large sizes of some of the emergency vehicles cause difficulty for the emergency vehicle driver to maneuver. Larger vehicles normally have a low acceleration rate, in which case providing EVP may help.
6) Inadequate corner sight distance could affect the need for EVP, particularly when the emergency run is on the side street entering a more major roadway or arterial.
7) Complex or unusual intersections with severe skewness may make the safe movement of the emergency vehicle difficult. EVP may be definitely useful in such a case.

2.3.3 Impacts of Emergency Vehicle Preemption

- *On Traffic Flow*

Emergency vehicle preemption systems have been widely deployed in the U.S. The experiences of some agencies operating these systems indicate that significant improvements on average EV travel time may result *(19)*. A study was conducted to evaluate the Opticom emergency vehicle traffic signal preemption system deployed in the City of Houston between 1991 and 1992. Field tests were run to measure travel time for emergency vehicles (without sirens activated) before and after installation at 22 intersections within two fire districts (11 per district). After a year of operations, the average emergency vehicle travel time decreased 16% in one district, and 23% in the other *(24)*. Denver, Colorado reported EV response time decreases of 14-23% after the deployment of a traffic signal preemption system; and Addison, Texas claimed a 50% decrease in response time as well *(25)*.

While there is limited empirical data on the impact of emergency vehicle preemption on overall traffic flow, researchers have found using simulation models that travel time impacts of emergency vehicle preemption depends on the intersection spacing, transitioning algorithm, saturation of the intersection, frequency of preemption requests, duration of the preemption phase, and the amount of slack time available in each intersection. A study examining whether the travel time impacts of traffic signal priority treatments for emergency vehicles are a function of the traffic characteristics, roadway geometry, and the deployment configuration of the priority system demonstrated that the travel time impacts of emergency vehicle traffic signal priority are a function of traffic volume. For example, in a high volume environment, the network travel time would taper over time from around 12.2% over normal fifteen minutes after preemption to around 3% over normal sixty minutes after the preemption event *(26)*. As part of the same research, a simulation analysis was performed; the results from the simulation analysis indicated that the non-emergency vehicle travel time impacts were relatively small and ranged from a 1.1% to 3.3% travel time increase for a one-hour analysis period to a 0.6% to 1.7% travel time increase for a two-hour analysis period *(27)*.

Another study illustrated that a preemption event would increase non-EV vehicle delay by less than 3% - a relatively minor impact on the network *(28)*; however, multiple preemption events over a short period of time would cause significant delay to the network *(29)*. It is important to point out that preempting the normal control of a traffic signal has the potential to influence traffic flow at an intersection or at other intersections along a roadway or within the corridor. The impact of signal preemption on side street traffic will be related to several factors including the frequency and the duration of preemption requests. In general, the lower the frequency and the duration of preemption request the less the impact on side street traffic.

Preempting a traffic signal will also unconditionally interrupt the normal timing plan by inserting a special plan or phase that results in reallocation of the time required to serve the special timing plan and to transition back to the normal operation. This reallocation of time, along with the potential disruption to the coordinated progression of traffic between signals, has the potential to affect negatively the flow of traffic at several intersections. The time required to exit a preemption control plan will vary on the basis of the exit transition strategy selected, when this plan terminates, and where the normal signal timing plan would have been if it had not been preempted. As the length of time required to serve a preemption control plan and transition back to the coordinated operation of the normal signal timing plan increases, the impacts to the traveling public typically increase *(30)*.

An undergoing research involves the development of a framework to reveal planning interdependence and operational interaction from the controlling strategy level down to the roadway level. One objective of this research is to develop an evaluation framework for EV preemption; the EV preemption evaluation framework examines potential benefits to emergency vehicles (reduced crash potential and reduced response times), as well as potential impacts to other roadway users, in terms of increased delay at signalized intersections *(31)*.

- *On Safety*

There is evidence to suggest that the deployment of EV preemption may decrease the number and severity of crashes involving emergency vehicles at signalized intersections. St. Paul, Minnesota reported a crash rate reduction of greater than 70% between 1969 and 1976 when 285 signal preemption systems were installed at 308 signalized intersections *(32)*.

Another contribution of the research *(31)* is the development of a method to evaluate potential safety benefits associated with EV preemption. A result of the research conducted for this project is the development of a critical tool to investigate the potential for crashes between emergency vehicles and non-emergency vehicles at critical intersections. This tool 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 *(33)*. The potential for crashes can then be determined using a set of logic rules for the type of conflict, the number of vehicles in each conflict stream, speed of the vehicles in the stream, and the degree of situational understanding on the part of the auto drivers.

2.3.4 Critical Factors in the Development of Emergency Vehicle Preemption Warrants

From the above it becomes clear that accurate knowledge of the travel characteristics of emergency vehicles is a very important consideration in transit research. Understanding the travel characteristics of emergency vehicles can be an important element in designing and deploying an emergency signal preemption system. It can also provide the platform to identify possible warrants to be used in determining the appropriateness of installing signal preemption systems at intersections.

In reviewing the current state of art, it was found that adequate guidelines or warranting criteria have not been developed for the placement of emergency vehicle preemption systems at existing signals. Review of the available literature led to the identification of the main factors that need to be looked during reviewing the application and utilization of emergency vehicle preemption in order to develop emergency vehicle preemption warrants. These factors include *(23)*:

- Emergency Equipment Stations (EES) must show and demonstrate a need (delays, response time, hazards).
- Number of emergency runs.
- Specific routes designated for emergency runs.
- Width of street.
- Sight distances.
- Shoulder areas.
- Crashes involving emergency vehicles.
- Ensuring overall safety and efficient traffic operations are not jeopardized.
- Volumes.
- Signal phasing.

It should be noted that when offering guidelines or warranting criteria for the placement of emergency vehicle preemption systems at existing signals traffic engineers should consult the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD outlines the proper usage of traffic control devices and contains national standards for the design, application and placement of signs, signals, pavement markings and other types of traffic control devices. The MUTCD is an important tool in traffic operations that is most frequently used by traffic engineers when designing roads, during the installation and operation of devices, and for use in inspections. As ITS deployment increases around the United States and allows for more optimal operations, signs and signals affected by the ITS are also reflected and more additions are expected to be made in future MUTCD editions. By using the MUTCD, transportation agencies have another resource to help optimize traffic performance and improve safety for road users *(34)*.

2.4 Studies on Emergency Vehicle Travel Characteristics

2.4.1 "A Case Study on U.S.1 in Fairfax County, Virginia" (35)

One objective of this research was to examine the observed characteristics of emergency vehicle trip generation and platoon response, such as the temporal distribution of emergency vehicle responses, and the size of platoon of emergency vehicles, before and after the deployment of EV preemption. A case study was conducted of the deployment of emergency vehicle preemption at Southgate Drive on U.S.1., which is one of the seven intersections where emergency vehicle preemption equipment has been provided along U.S.1. in Fairfax County, Virginia.

A significant data source was overhead surveillance video of a T-intersection on U.S.1. Two weeks of video were collected for both the before and after cases. The intersection was significant for study due to its location relative to the fire and rescue station and the number of EV passage events per day which average 10 including 2 during the morning peak period in the peak direction. The fire and rescue station is located approximately 1000 feet east of the arterial. Entry to the arterial is aided by an emergency entry signal (EES), which stops the arterial traffic flow both north and southbound during each EV response. The intersection studied is located approximately 250 feet north of the EES serving maximum arterial volumes of 975 vehicles per hour per lane (three through lanes) and maximum side-street volumes of 480 vehicles per hour. The arterial has left turn bays and the side street has a right turn pocket to facilitate right-turn-on-red. The operation of this intersection under semi-actuated control and 3 minute cycle time results in an arterial green time percentage of 84 percent. This arterial green ratio may have excluded the intersection from emergency vehicle preemption deployment because the probability of emergency vehicles experiencing long delays is very low. In fact, the intersection would not meet the green time distribution criteria under consideration by some states.

The results of the analysis on the frequency of emergency calls indicate that are more emergency calls in the daytime between 8 am to 8 pm as compared to nighttime. Since the normal auto traffic during daytime is more than during nighttime, it was concluded that the need for preemption is higher in the first case than the latter. An interesting finding was the fact that there is not much variation in the frequency of emergency calls according to the day of the week. Therefore, high number of preemption calls on the weekdays is likely to cause more disruption to traffic in contrast to high number of preemption calls during the weekends, as there is more traffic on weekdays.

Another analysis was performed to illustrate the number of emergency vehicles involved in responding to a single emergency call. The duration of preemption is considered proportional to the number of the vehicles in a platoon; the greater the number of vehicles in a platoon responding to an emergency call the more the time of preemption. The delay to auto vehicle and disruption of the traffic signal timing also increases as the duration of preemption increases. The results indicate that 90% of time there are just one or two vehicle involved in an emergency response which is considered a positive sign for preemption seekers and traffic engineers because 90% of the times the duration of preemption would be less to minimum.

A comparison of the before and after cases led to the conclusion that after the deployment of EV preemption, the average travel time from the time the emergency call is received to the time the EV arrives at the intersection of Southgate drive at U.S.1. decreased from 4 min 39 seconds to 3 min 46 seconds.

2.4.2 "Improving the Emergency Service Delivery in St. Albert" (36)

This paper summarizes the results of two studies conducted to improve the emergency service delivery in St.Albert, a small city with a population of 50,000 near Edmonton, Alberta. The St. Albert Fire Department is a fulltime, career organization that provides emergency services such as fire prevention, fire suppression, rescue (e.g. traffic crashes, ice/water rescue), hazardous materials response, EMS response, emergency medical transfers, and disaster services. Currently there are two fire stations in St. Albert, and one of these stations (Fire Hall #1) doubles as an ambulance station. Service is provided by a staff of 57. Firefighters can also staff ambulances if EMS staff is absent. The City officials are concerned about deterioration in the quality of the service in the near future as increased call volumes and longer travel distances, coupled with more shifts employing minimum staffing, impose an increased risk of not having sufficient resources available to answer calls; thus, they are interested in finding ways to maintain an acceptable service level. Options considered are the addition of a new fire hall, the addition of staff to each platoon, and the addition of new vehicles (fire trucks or ambulances).

The first study dealt with selecting the location of a new fire station. The goals of the study included an assessment of the performance of the current system, an identification of the area(s) with poor coverage, a selection of a site among a set of given candidate locations, and an assessment of the improvement in the system performance upon the addition of the new fire station. A geographical information system was used for storing and displaying the spatial data, computing service areas for given travel times, and for communicating the results of the study. The database used for the purposes of this study contained every EMS call made during January-June 1999 (total 750 calls). Most importantly this database contained the location of the call and the response time; the response time was used as a measure of service quality. An analysis of this database showed that the system met the widely accepted EMS standard of responding to 90% of calls within 9 minutes. However, it was far from being able to respond to every call within 5 minutes. In fact it was found that the response time was under 5 minutes for about 30% of the calls and the average response time was 6 minutes.

The second study considered an evaluation of the resources available for emergency service. A probabilistic model was used to evaluate labor costs for different platoon sizes and a simulation model was used to evaluate the adequacy of the current staff and fleet sizes. It was found that under the current call rates everyone is idle about 84%. Yet there are some instances that require many more staff than there is available. The maximum number of staff needed during the simulation with the current call volume was 36. The simulation results for the different scenarios considered indicated that platoon sizes must be increased if the call volume increases by 25%. Currently, one fire truck is used 8.0% of the time, two are used 1.8% of the time, and all three are used 0.8% of the time. One ambulance is needed 11.3% of the time, two are used 2.9% of the time, and three are needed 0.4% of the time. In severe incidents, additional staff is brought in so the department can mobilize all of its vehicles (3 fire trucks, one ladder truck, and 3 ambulances). Hence, it seemed that staff is the bottleneck and not the vehicles.

In summary, it was found that the quality of the current service was within acceptable limits. However the planned growth of the city coupled with an increase in the per-capita call volume and an aging staff, will force the city to spend more money to provide the same quality of service to the residents. The authors' recommendations can be summarized as follows:

- Locate a third fire hall to improve coverage.
- Staff a second ambulance to improve response times.
- Consider changing the dispatch and activation process to speed up responses.
- Go to a platoon of size 12.5 by using temporary staff over the summer.

The results of both studies were presented to EMS officers, city staff, as well as the City Council; who seemed to be willing to pay the price of a new fire hall ($2M), new fire truck ($1M), and 16 new staff members ($1M/year) to achieve this increase in emergency service quality.

2.4.3 "Emergency Medical Service Rescue Times in Riyadh" (37)

The emergency medical service (EMS) in Saudi Arabia is managed by each hospital through the Saudi Red Crescent Society (SRCS). There are approximately 165 ambulance stations in the country, each with two ambulances. The SRCS collects data on EMS requests and ambulance arrival times at the crash scene. Each emergency incident has its own implications (crash, fire, injury, etc.) and must be dealt with individually. The aims of this study were: 1) to evaluate ambulance rescue time, which includes response time, in the city of Riyadh, the capital of Saudi Arabia; 2) to analyze this time for road traffic crashes; and, 3) to compare the response time in Riyadh with corresponding times in other countries. A sample of 874 emergency calls was collected during 1999. Ambulance rescue time consists of three components: response time, time at the scene and travel time to the hospital. Data analysis showed that rescue time is, on average, 35.84 min (S.D. =6.43 min). Within this time, the average response time is 10.23 min (S.D. =5.66 min). Other service components (e.g. ambulance time at the crash scene and travel time to the hospital) were analyzed and detailed statistics were given. Ambulance speed to the crash averages ≈ 5.05 km/h (S.D. =27.42 km/h). One primary finding was that there is room for improvement in the rescue time in Riyadh, which would save more lives, through an increase in the efficiency of ambulance team performance. A test statistic was developed in this study to carry out a simple hypothesis testing for percentiles. This test statistic, which is generic and can be used for other applications, was used to compare EMS response time in Riyadh with that in other parts of the world.

CHAPTER 3: ANALYSIS OF EMERGENCY VEHICLE CHARACTERISTICS

3.1 Introduction

Chapter 3 presents an analysis of emergency vehicle operating characteristics based on various datasets obtained from: 1) the Fire and Rescue Community in Fairfax County, VA; 2) the 3M™Opticom™ Priority Control System deployed in Fairfax County, VA; and, 3) the Preemption System deployed in Montgomery County, MD. The analysis of the emergency response log data as well as of the emergency vehicle preemption datasets includes a description of the study area, the data collection and associated findings and results. Several methods and techniques are applied for summarizing and interpreting data, including graphical representations and numerical methods. For a more sound analysis, statistical tools are used that permit a more careful analysis of the data and provide more accurate information than the more general indications conveyed by graphical summaries *(38)*. At the end of Chapter 3, emergency vehicle involvement in crashes is discussed, based on the crash data provided by the Virginia Department of Transportation (VDOT).

3.2 Analysis of Emergency Response Log Data For 3 Fire Stations on U.S.1, Fairfax County, VA

3.2.1 Description of Study Area

U.S.1 is one of the major arterials in Northern Virginia area connecting Prince William County to the Capital Beltway (I-495) which in turn acts as a connector to Washington D.C. The study corridor considered for this study is between Fort Belvoir and Capital Beltway and is approximately 8 miles in length encompassing 28 signalized intersections. The signalized intersections are spaced randomly with a significant variation in the distance between any two intersections. There are three major Fire Stations (station numbers 9, 11, and 24) and two hospitals in the field of interest, which are considered the major sources of emergency vehicle travel. The study area as well as the location of the different stations is shown in Appendix A1 and A2 respectively.

3.2.2 Data Collection and Compilation

The data collected include the emergency vehicle response data maintained by Fairfax County Fire and Rescue Department for one-year 2000. Mainly three major Fire Stations are considered for analysis: Fire Station 9, Mt Vernon; Fire Station 11, Penn Daw; and Fire Station 24, Woodlawn. The service areas of the three fire stations are shown in Appendix A3, A4, and A5 respectively.

The data provided by the Fairfax County Fire and Rescue Department are attached in Appendix A6 and provide the following information:

- *Firebox Number:*

  The number assigned by Fairfax County Fire and Rescue Department for easy identification of the area.
- *Incident Number:*

  It includes the year of the incident, the Julian date of the incident and an incident number. For example, the incident or event number 20001610931 can be broken down to the year 2000, the Julian date or the chronological day of the year 161, and the number of incidents that have occurred on that chronological day. The Julian calendar is attached in Appendix A7.
- *Event Type:*

  It indicates the type of the event; for example, Fire (FIR), Basic Life Support (BLS), and Advanced Life Support (ALS).
- *Dispatch Hour*
- *Day of the Week*
- *Location of the Incident*
- *Month*
- *Unit ID:*

  It indicates the type of the emergency vehicle responding to an incident. The different types of emergency vehicles are: Ambulance/ Advanced Life Support

(A); Rescue Engine (R); Fire Truck equipped with ladder (T); Engine / Paramedic Engine (E); Medic (M); and other. For example, T424 etc T indicates a truck, 4 indicates the fire box jurisdiction, and 24 indicates the Fire Station number from which the emergency vehicle is dispatched. The various types of emergency vehicles and the associated engineering characteristics are discussed in more detail in Appendix A8.

3.2.3 Analysis Objectives

The obtained data were analyzed to determine the following:

- *Frequency of Emergency Calls Per Fire Station:*
  - By Hour of Day
  - By Time of Day
  - By Day of Week
  - By Month

Different months of the year, different days of the week and different hours of the day, as well as different time periods of the day, are compared to assess the variability in the frequency of emergency calls. The different time periods of the day include four 3-hr periods:

- AM peak period (6:00AM-9:00AM)
- Midday (11:00AM-14:00PM)
- PM peak period (16:00PM-19:00PM)
- Night (20:00PM-23:00PM)

Statistical tests are then applied to assess whether the observed differences between the different time periods and between the three fire stations can be explained by the natural sampling variability or are attributed to other factors.

- *Type of Events Per Fire Station:*
  - Fire (FIR)
  - Advanced Life Support (ALS)

- Basic Life Support (BLS)

➢ *Type of Emergency Vehicle Responding to an Incident Per Fire Station:*

- Ambulance (A)
- Rescue Engine (R)
- Fire Truck (T)
- Engine/Paramedic Engine (E)
- Medic (M)
- Other

The various types of emergency vehicles and their associated engineering characteristics are discussed in more detail in Appendix A8.

3.2.4 Analysis and Results

3.2.4.1 Frequency of Emergency Calls Per Fire Station

Figure 3.1 presents the frequency of emergency calls during the year 2000 for the three fire stations under study (9, 11, and 24). The Y-axis represents the annual number of emergency calls and the X-axis represents the three fire stations. It can be observed that Fire Station 11 received a higher number of calls in comparison to the other two stations; twice as many as Fire Station 24 received.

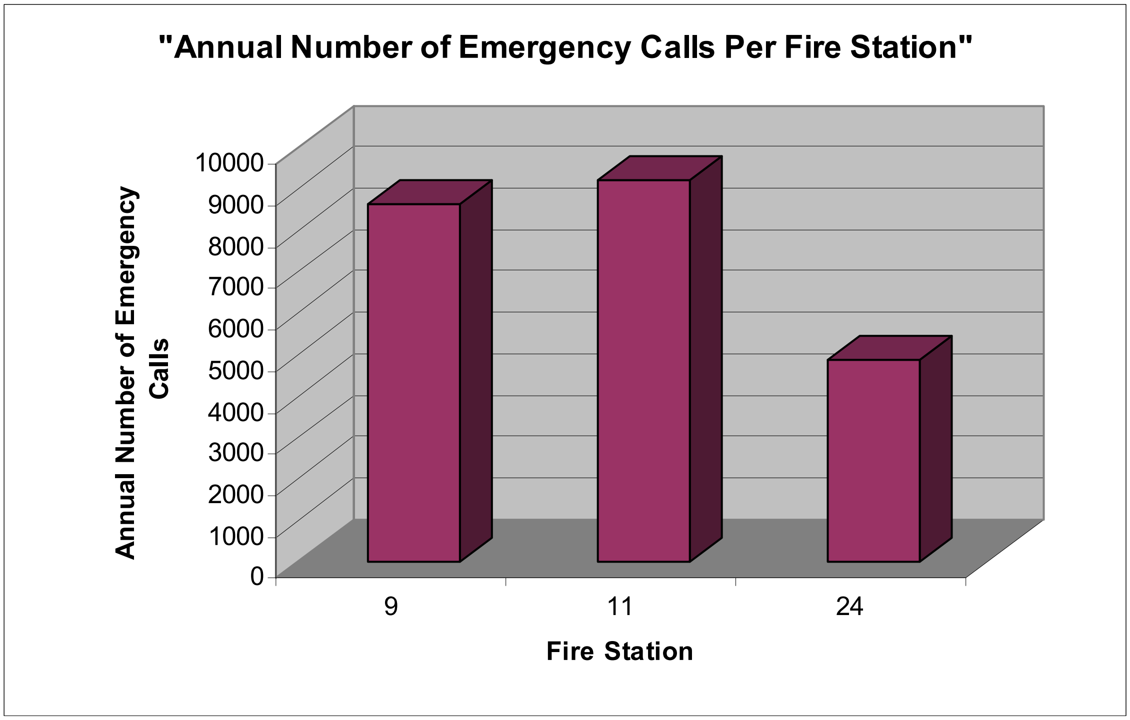


Figure 3.1. Annual Number of Emergency Calls Per Fire Station.

The next figure shows the average number of emergency calls per day received by the three fire stations during the year 2000. The Y-axis represents the annual daily average number of emergency calls and the X-axis represents the three fire stations. It seems that Fire Stations 9 and 11 received on average per day nearly the same number of calls (25.5 and 25.8 calls, respectively); twice as many as Fire Station 24 received on average per day (13.3 calls).

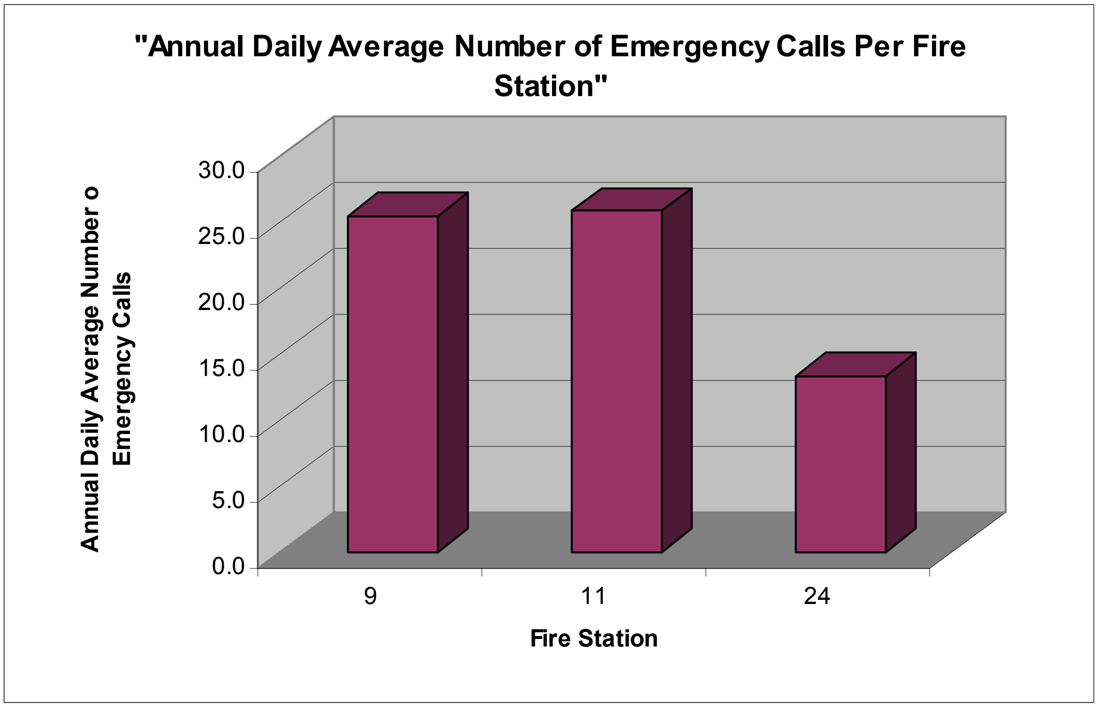


Figure 3.2. Annual Daily Average Number of Emergency Calls Per Fire Station.

Figure 3.3 shows that the frequency of emergency calls received by all fire stations under study is more during the day, between 8am to 8pm, than it is during the night. The Y-axis represents the annual number of emergency calls per fire station and the X-axis represents the hour of day. It is important to know the temporal distribution of emergency vehicle travel by hour of day; a higher frequency of emergency calls during the daytime is likely to result in greater implications to the other traffic since the traffic is more during the daytime. In turn, because of higher levels of traffic during the daytime, emergency vehicle response times are anticipated to be higher in comparison to nighttime.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by hour of day between the three fire stations (Appendix A9.1). The results indicate that there is evidence to infer that the frequency of emergency calls by hour of day is different among the three fire stations for different hours of day at the 95% confidence interval.

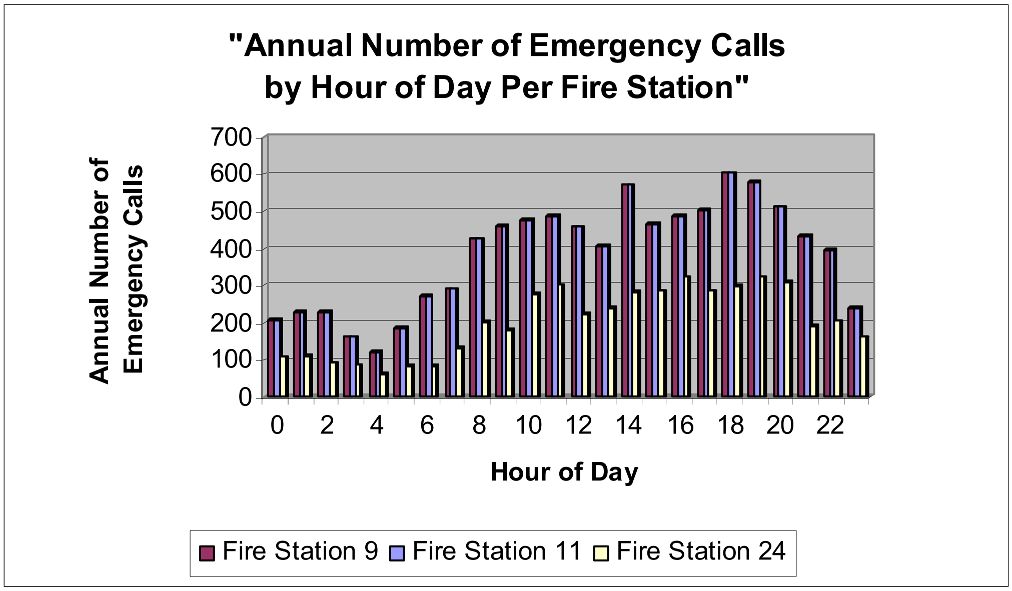


Figure 3.3. Annual Number of Emergency Calls By Hour of Day Per Fire Station.

Different time periods of the day are considered that include four 3-hr periods: AM peak period, Midday, PM peak period and Night. Figure 3.4 shows the average number of emergency calls per hour by time of day received by the three fire stations during the year 2000. The Y-axis represents the annual hourly average number of emergency calls and the X-axis represents the time of the day. It can be observed that the frequency of emergency calls is higher during the PM peak period and lower during the AM peak period for all three stations. Thus, emergency vehicle travel is expected to be more during the PM peak period than during the other time periods of day.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by time of day between the three fire stations (Appendix A9.2). The results indicate that there is evidence to infer that the frequency of emergency calls by time of day is different among the four time periods and among the three fire stations at the 95% confidence interval.

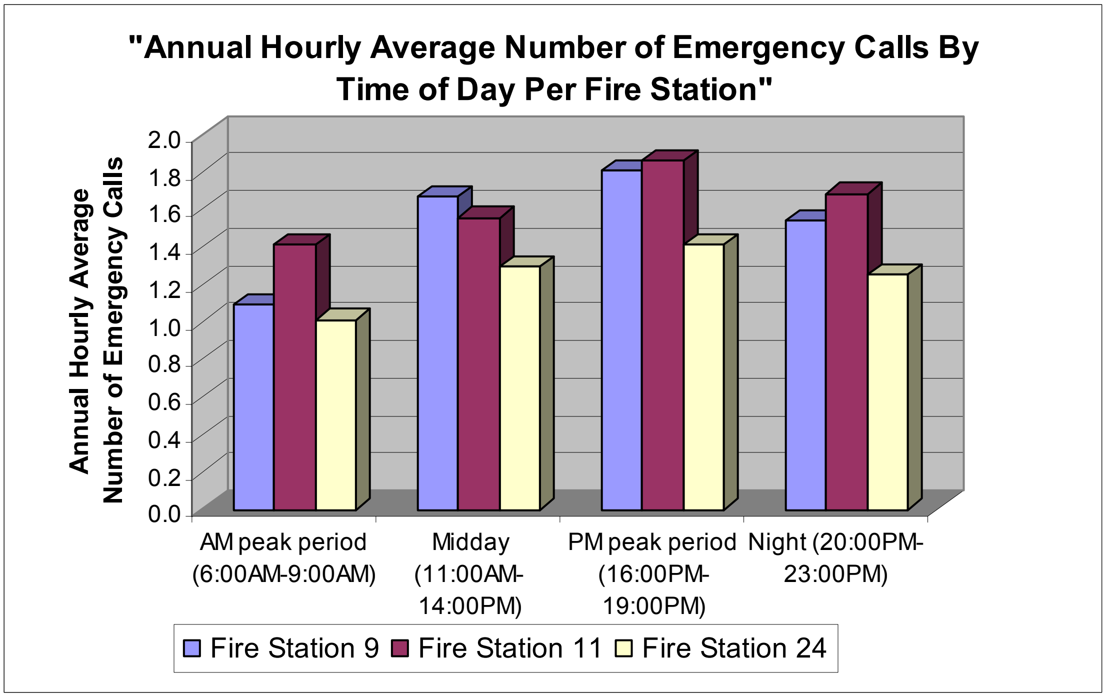


Figure 3.4. Annual Hourly Average Number of Emergency Calls By Time of Day Per Fire Station.

Figures 3.5 and 3.6 show the frequency of emergency calls according to the day of the week. In Figure 3.5, the Y-axis represents the annual number of emergency calls and the X-axis represents the day of the week. In Figure 3.6, the Y-axis represents the annual average number of emergency calls per week and the X-axis represents the day of the week. It seems that there is not much variability in the frequency of emergency calls according to the day of the week; in addition, there does not seem to be a clear pattern in the number of emergency calls received during the weekdays and the weekends.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by day of week between the three fire stations (Appendix A9.3). The results indicate that there is no evidence to infer that the annual frequency of emergency calls received by each station is different at the 95% confidence interval among different days of the week. However, the test supports the notion that the annual number of emergency calls by day of week differs among the three fire stations at the selected significance level (0.05). We can conclude that the frequency of emergency calls is independent of the day of the week but not independent of the fire station where the calls are received.

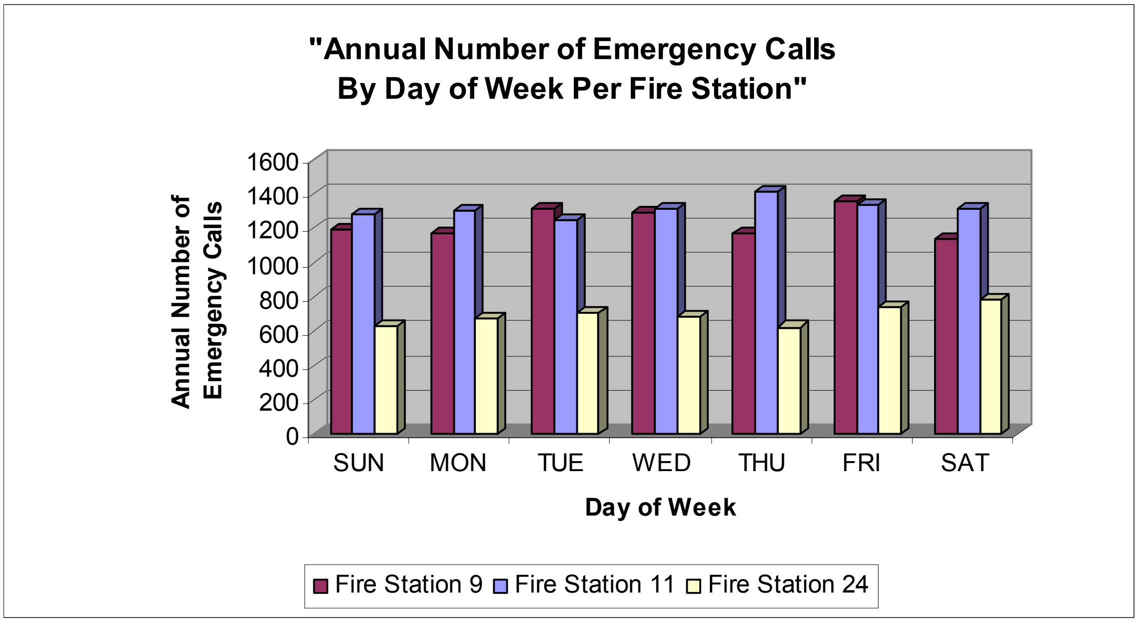


Figure 3.5. Annual Number of Emergency Calls By Day of Week Per Fire Station.

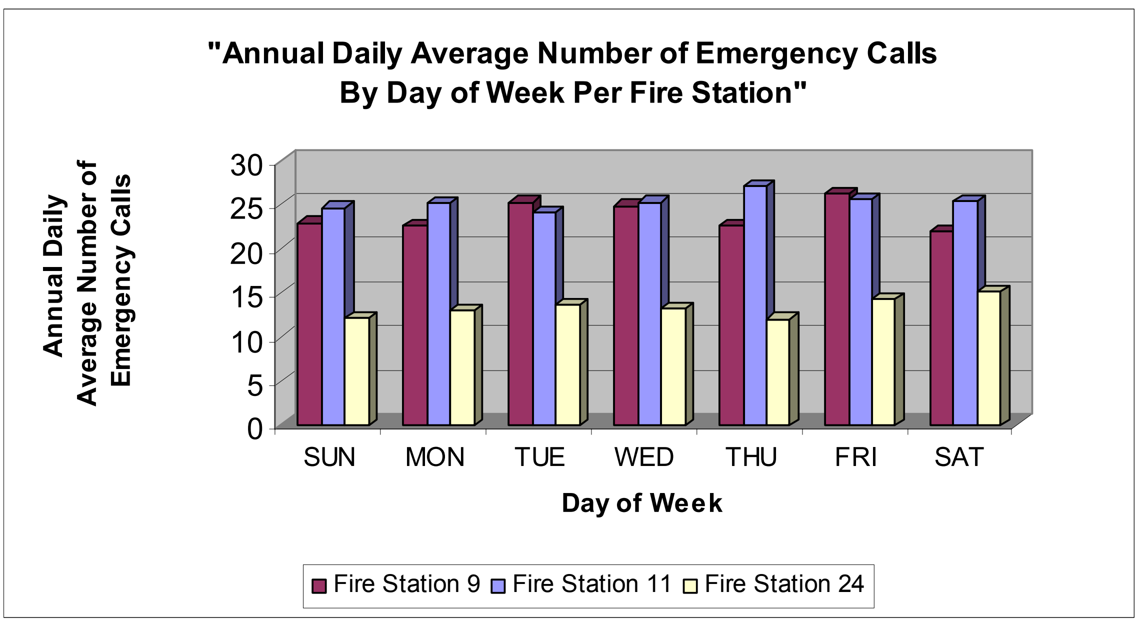


Figure 3.6. Annual Daily Average Number of Emergency Calls By Day of Week Per Fire Station.

The monthly activity of each fire station in terms of received emergency calls is presented in Figure 3.7. The Y-axis represents the annual number of emergency calls per month and the X-axis represents the month of the year. It seems that there is not much variability in the frequency of emergency calls according to the month of the year; in addition there does not seem to be a clear pattern in the number of emergency calls received during the wintertime and the summertime.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by month of year between the three fire stations (Appendix A9.4). The results indicate that the difference in the frequency of emergency calls received by each station among different months of the year is rather marginal. However, the test supports the notion that the annual number of emergency calls by month of year differs among the three fire stations at the selected significance level (0.05). We can conclude that the frequency of emergency calls is not that much dependent of the month of year as of the fire station where the calls are received.

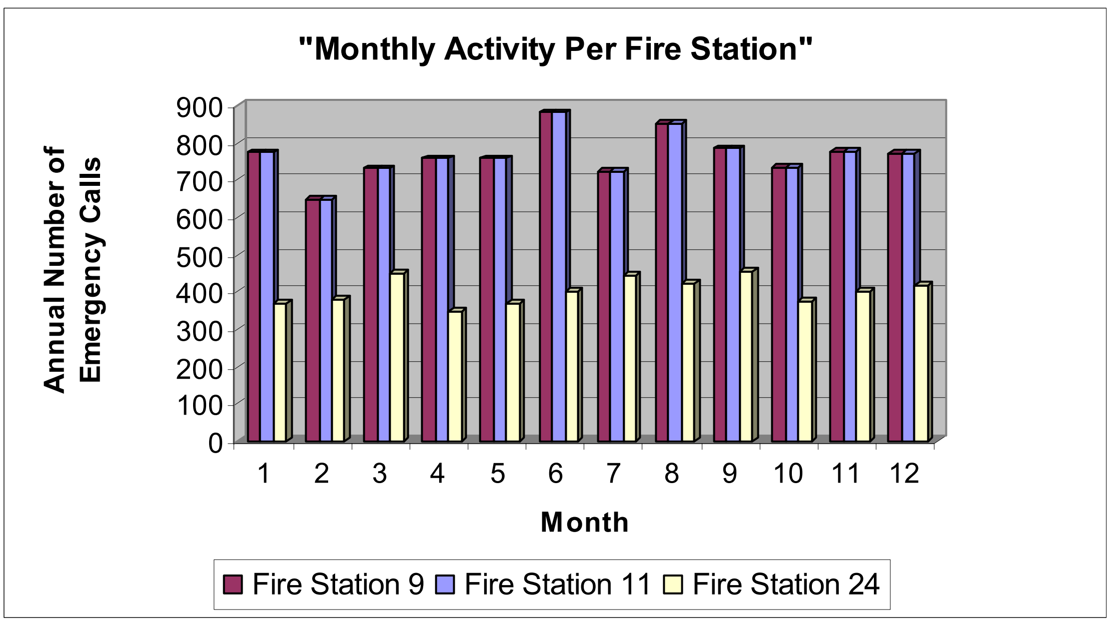


Figure 3.7. Annual Number of Emergency Calls By Month of the Year Per Fire Station.

3.2.4.2 Type of Events Per Fire Station

Figure 3.8 shows the type of events that emergency vehicles dispatched from the three fire stations have to respond to. The Y-axis represents the annual number of emergency calls by type of event and the X-axis represents the fire stations. The different types of events are classified in three categories: Fire (FIR), Basic Life Support (BLS), and Advanced Life Support (ALS). It can be observed that there is not much variability in the type of events the fire stations have to deal with. Most of the incidents require advanced life support; a smaller proportion requires fire suppression and, an even smaller requires basic life support.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by type of event between the three fire stations (Appendix A9.5). The results reinforce the observations noted previously; there is not significant variability in the distribution of emergency calls by type of event among the three fire stations, but the annual number of emergency calls is different for different types of events at each fire station.

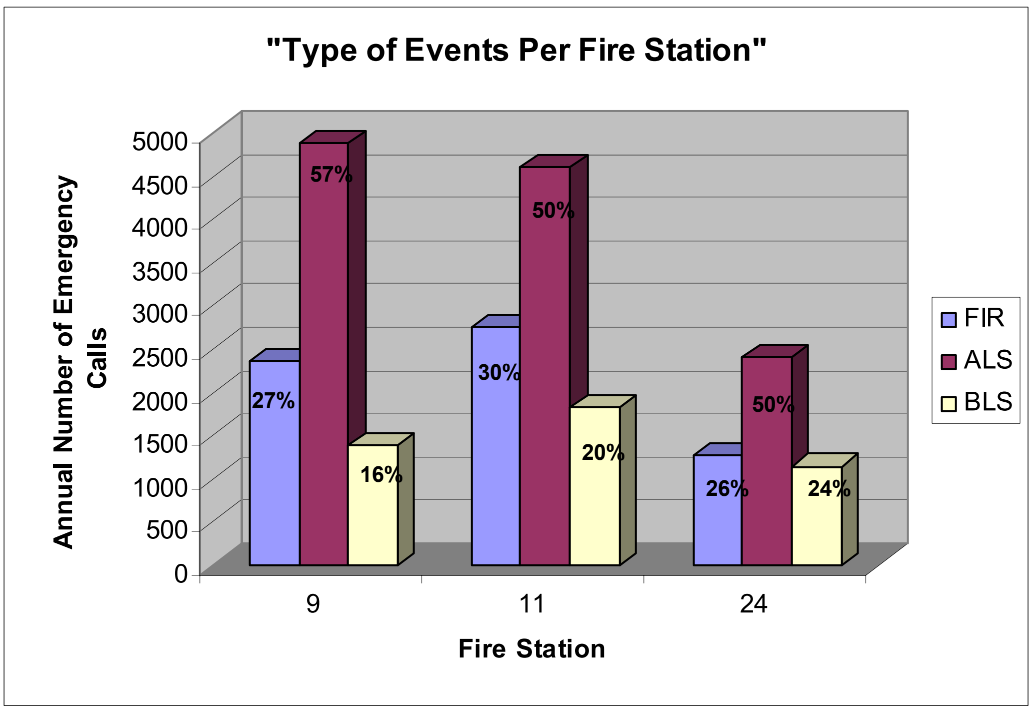


Figure 3.8. Type of Events Per Fire Station.

3.2.4.3 Type of Emergency Vehicle Responding to an Incident Per Fire Station

Figure 3.9 presents the frequency of the various types of emergency vehicles involved in responding to an emergency call per fire station. The vertical axis represents the total number of emergency calls that each type of vehicle responds to and the horizontal axis represents the fire stations. The different types of emergency vehicles responding to an incident are: Ambulance/ Advanced Life Support (A); Rescue Engine (R); Fire Truck equipped with ladder (T); Engine / Paramedic Engine (E); Medic (M); and other. These emergency vehicles vary by size and shape; their acceleration rate and capability to maneuver in heavy traffic vary according to the size of the vehicle. It is important to know the frequency of the various types of emergency vehicles involved in responding to an emergency call as vehicles of larger size have low acceleration rate, find more difficulty in maneuvering in traffic and thus, they are likely to impact more the other traffic as they require more road space *(35)*.

From the Figure 3.9, it can be observed that there is not much variability in the distribution of type of vehicles responding to an incident among the fire stations. For the majority of emergency calls paramedic engines and medic vehicles are dispatched. This observation is consistent with the results of the previous analysis presented in Figure 3.8 that indicated that most of the events that the fire stations have to deal with require advanced life support. As it is illustrated in Appendix A8, every engine is 'Advanced Life Support' equipped with life saving equipment and at least one paramedic and thus can be used for both type of events (FIR, ALS) and can be regarded as a large vehicle. Medic vehicles are used to transport emergency medical patients and can be regarded as small vehicles. We can conclude that in most cases a large vehicle is involved in an emergency response; a finding that needs to be considered when studying the impacts of emergency vehicle travel.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by type of vehicle responding to an incident among the three fire stations (Appendix A9.6). The results indicate that there is a significant difference in the frequency of the various types of emergency vehicles involved in responding to an emergency call per fire station.

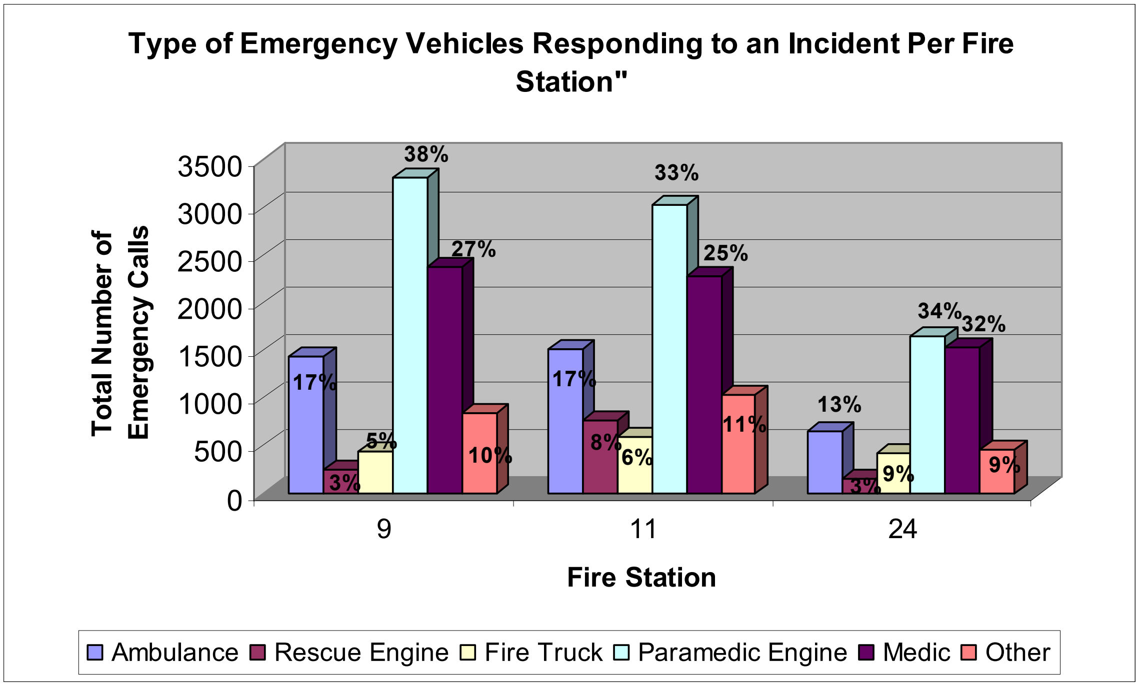


Figure 3.9. Type of Emergency Vehicle Responding to an Incident Per Fire Station.

3.2.5 Major Findings and Results

The findings of the analysis of the emergency vehicle response data for three fire stations, maintained by Fairfax County Fire and Rescue Department, for the year 2000 are summarized below:

- ✓ Fire Stations 9 and 11 received twice as many calls Fire Station 24 received during the year 2000.
- ✓ The frequency of emergency calls received by all fire stations under study is more during the daytime, between 8am to 8pm, than it is during the nighttime.
- ✓ The frequency of emergency calls is higher during the PM peak period (on average, two calls per hour) than the AM peak period (on average, one call per hour) for all three stations.
- ✓ The frequency of emergency calls is independent of the day of the week; in addition there does not seem to be a clear pattern in the number of emergency calls received during the weekdays and the weekends.

- ✓ There is not much variability in the frequency of emergency calls according to the month of the year; in addition there does not seem to be a clear pattern in the number of emergency calls received during the wintertime and the summertime.
- ✓ There is not much variability in the type of events all three fire stations have to deal with; most of the incidents require advanced life support; a smaller proportion requires fire suppression and an even smaller requires basic life support.
- ✓ Regarding the distribution of type of vehicles responding to an incident, for the majority of emergency calls paramedic engines and medic vehicles are dispatched. At least one heavy vehicle is involved in each response.

3.3 Analysis of Emergency Preemption Data From The 3M™ Opticom™ Priority Control System on U.S.1, Fairfax County, VA

3.3.1 Description of Study Area

The corridor considered for this study is a segment of U.S.1 between Popkins Rd. and North Kings Hwy and is approximately 1.4 miles in length encompassing 7 signalized intersections. The signalized intersections are spaced randomly with a significant variability in the distance between any two intersections. Two of the 7 intersections are very closely spaced (distance less than 200 ft); hence, a total of 6 intersections will be considered in the analysis. This segment of U.S.1 is under the service area of Fire Station 11, which is considered the major source of emergency vehicle travel. The Fire Station under study is located on Beedoo Str. (between Beacon Hill Rd. and Southgate Dr.). The corridor under study is shown in Appendix B1.

It should be noted that all 6 intersections are equipped with the 3M™Opticom™ Priority Control System that provides preferential treatment to emergency services (fire, medical) and other vehicles such as transit, as needed. Emergency vehicles have first priority, thus eliminating any confusion. The whole procedure is achieved in three steps that occur within seconds:

1) An emitter mounted on the emergency vehicle or bus is activated to send encoded infrared communication.

2) A detector located near the intersection receives the signal and converts it into electronic communication.

3) A phase selector, housed in the controller cabinet, discriminates and authorizes the user, logs management information and requests priority advantage for the controller to extend a green light or truncate a red light (only in the case of emergency vehicles), thus giving the vehicle an efficient, natural appearing right of way *(35)*.

The Transit Signal Priority and Preemption System as well as the components of the 3M™Opticom™ Priority Control System are presented in Appendix B2 and B3, respectively.

3.3.2 Data Collection and Compilation

The data collected include the emergency vehicle preemption request data obtained after the deployment of the 3M™Opticom™ Priority Control System at 6 intersections along U.S.1. The data represent a 53-day period from July 16, 2002 to September 6, 2002; during this period preferential treatment was provided only for emergency vehicles.

The preemption data obtained with the use of the 3M™Opticom™ System, as call history logs in the phase selector memory, are attached in Appendix B4. The data provide the following information as it is illustrated in the 3M™Opticom™ Help file:

Log #	Number of a call history entry. Entries are numbered chronologically as they occur. The most current entry (#1) is listed first. The phase selector can store up to 1,000 entries. After entry 1,000 occurs, new entries are written over the oldest entries.
Date	Date when the call started. This is always displayed in MM/DD/YY format. The clock in the phase selector is used as the basis for the fields; Date, Start Time, and End Time.
Start Time	Time-of-day when a call started. This is always displayed using a 24-hour clock. The start of a call is considered to be the time when the call delay time (if any) expires. The call delay time starts when the emitter signal is validated by the phase selector.

End Time	Time-of-day when a call ended. This is always displayed using a 24-hour clock. The end of a call is considered to be the time when the call hold time (if any) expires. The call hold time starts when the phase selector no longer senses a valid emitter signal.
Duration	Duration of call is the elapsed time from Start Time to End Time.
Class	Vehicle Class (0 to 9) of the received emitter signal.
ID	Vehicle ID (0 to 999) of the received emitter signal. The Vehicle ID is a code that is transmitted by encoded vehicle emitters and is used to identify the vehicle. It consists of two parts, the class and the ID. There are ten Classes, 0-9 and one thousand ID's per Class for a total of 10,000 unique codes. Each priority (High, Low, and Probe) has a unique set of 10,000 codes.
Chan.	Channel on which the emitter signal was sensed. It indicates the direction of travel of emergency vehicles requesting preemption; for example, "A" denotes southbound direction, and "B" denotes northbound direction.
Priority	Priority of the received emitter signal. This is indicated as High, Low, or Probe. A high priority emitter has the highest priority. A high priority emitter is typically used by emergency vehicles such as fire, ambulance, and police. A low priority emitter is lower priority than a high priority emitter. A low priority emitter is typically used by transit vehicles or other vehicles that are intended to be aided by the Opticom system, but have a lower priority of service than vehicles with high priority emitters. When a high priority emitter and one or more low priority emitters are requesting control of an intersection, the high priority emitter will always gain control.
G. Time	Number of seconds that the Final Greens were active during the call (between Start Time and End Time.)
Final G.	Indication of the green sense inputs which were active at the End Time. Green sense must be connected for this function to get valid Final G. information.
Intensity	Maximum measured intensity of an emitter's signal during the whole time of the call. This is a value from 0 to 1200 that indicates the relative strength of the emitter's optical signal received by the detector and measured at the phase selector. This intensity will always exceed the corresponding preset detection threshold; a threshold of intensity equal to 200 has been set, below which the preemption request might be denied.

Preempt	Indicates whether the phase selector output on the Channel was active during the call. "Yes" indicates it was active, and "No" indicates it was not active during the call. In other words, it indicates whether a preemption request was granted ("Yes") or not ("No").

A glossary of terms used in the Call History Logs is attached in Appendix B5.

3.3.3 Analysis Objectives

The obtained data were analyzed to determine the following:

- *Number of Preemption Requests Granted and Denied Per Day Per Intersection:*
  - If it was denied, identification of possible reason.

From the call history logs in the phase selector memory, under the column ***Preempt***, the information whether a preemption request was granted ("Yes") or not ("No") can be obtained. Possible reasons for a request to be denied are identified after thoroughly examining the data for each case; these may include low measured intensity of an emitter's signal during the whole time of the call (below the set threshold of 200); or interference with other preemption request. Another possible reason could be the existence of a pedestrian phase; with the exception of intersections RT.1 & Popkins Lane and RT.1 & South Kings Hwy in all other intersections a pedestrian phase (7sec-walk time) is included in the signal timing plan.

- *Frequency of Emergency Preemption Requests Per Intersection:*
  - By Time of Day
  - By Day of Week
  - By Direction of Travel

Different days of the week and different time periods of the day are compared to assess the variability in the frequency of emergency preemption requests. The different time periods of the day include four 3-hr periods:

- AM peak period (6:00AM-9:00AM)
- Midday (11:00AM-14:00PM)

- PM peak period (16:00PM-19:00PM)
- Night (20:00PM-23:00PM)

Statistical tests are then applied to assess whether the observed differences in the frequency of emergency preemption requests between the different time periods and among the six intersections can be explained by the natural sampling variability or are attributed to other factors.

In addition, from the call history logs in the phase selector memory, under the column ***Channel***, the information whether an emergency vehicle was moving southbound ("A") or northbound ("B") can be obtained. Accurate knowledge of the direction travel of emergency vehicles is important in order to assess the impacts on the other vehicles, particularly when they move at the peak direction. Moreover, it is useful information when estimating response times. Finally, knowing the directional split of preemption requests can be useful in examining whether the preemption system is utilized in the proper way, that is a request is made when an emergency vehicle responds to an incident and not when it returns to the fire station.

- *Size of Platoon of Emergency Vehicles:*

An important consideration when deploying a preemption system is the size of platoon of emergency vehicles; the greater the number of simultaneous preemption requests the more the likelihood of having some denied because of interference with another request. Moreover, the duration of preemption is proportional to the number of vehicles in a platoon responding to an emergency call; the higher the number of vehicles in a platoon the longer the duration of the preemption resulting in a higher disruption to the traffic signal timing and in consequence, to the general-purpose traffic.

- *Duration of Preemptions Per Intersection:*

- By Time of Day
- By Day of Week
- By Direction of Travel

From the call history logs in the phase selector memory, under the column ***Duration***, the duration of calls can be obtained, as the elapsed time from Start Time to

End Time. Different days of the week and different time periods of the day are compared to assess the variability in the length of the preemption phase. The same time periods of the day as previously, are considered for analysis:

- AM peak period (6:00AM-9:00AM)
- Midday (11:00AM-14:00PM)
- PM peak period (16:00PM-19:00PM)
- Night (20:00PM-23:00PM)

Statistical tests are then applied to assess whether the observed differences in the duration of preemptions between the different time periods and among the six intersections can be explained by the natural sampling variability or are attributed to other factors.

3.3.4 Analysis and Results

3.3.4.1 Frequency of Emergency Vehicle Preemption Requests Per Intersection

Table 3.1 presents the average number of preemption requests per day for the six intersections under study. It can be observed that the daily occurrence of preemption requests ranges from 0 to 21 requests with the average value fluctuating from 6 to 12 requests, depending on the intersection. The highest number of preemption requests seems to be made at the intersection RT.1 & Southgate Dr, which is the first intersection emergency vehicles have to clear after they are dispatched from the Fire Station 11 when traveling in the northbound direction. This finding demonstrates that the frequency of preemption requests depends on the proximity of the intersection to the firehouse, among other factors.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability among the six intersections (Appendix B6.1). The results indicate that there is evidence to infer that the average number of emergency vehicle preemption requests per day varies by intersection.

Table 3.1. Number of EV Preemption Requests Per Day Per Intersection.

Intersection	***Number of EV Requests/day***			
	Mean	*Standard Deviation*	*Min*	*Max*
RT.1 & Popkins Lane	5.7	3.7	0	18
RT.1 & Memorial St.	6.9	4.0	1	21
RT.1 & Beacon Hill Rd.	6.6	3.4	1	18
RT.1 & Southgate Dr.	11.6	4.4	1	21
RT.1 & South Kings Hwy	8.5	4.1	0	21
RT.1 & North Kings Hwy	8.4	4.1	0	21

From the following table, it can be observed that the number of preemption requests denied is very low; it ranges from 1 to 2% of the total number of requests. In most cases, it appears that the reason for a request been denied is when having two or more simultaneous preemption requests. After thoroughly examining the data for each case, requests were denied when they were made a few seconds to half a minute later than a previously granted one. Another reason that was identified is a low measured intensity of an emitter's signal during the whole time of the call (below the set threshold of 200). In a few cases, a request was probably denied when made within the pedestrian phase.

Table 3.2. Number of EV Requests Denied Per Intersection and Reasons why.

Intersection	**Number of EV Requests Denied**	**Total Number of EV Requests**	**Percentage of EV Requests Denied**	**Reasons**
RT.1 & Popkins Lane	3	301	1.0	interference with other EV request
RT.1 & Memorial St.	6	368	1.6	low intensity (2 cases), interference with other EV request
RT.1 & Beacon Hill Rd.	3	350	0.9	low intensity (1 case), interference with other EV request (1 case), other
RT.1 & Southgate Dr.	5	615	0.8	low intensity (2 cases), interference with other EV request
RT.1 & South Kings Hwy	10	448	2.2	low intensity (3 cases), interference with other EV request
RT.1 & North Kings Hwy	8	438	1.8	low intensity (1 case), interference with other EV request (7 cases), other

Different time periods of the day are considered that include four 3-hr periods: AM peak period, Midday, PM peak period and Night. Figure 3.10 shows the average number of preemption requests per hour by time of day per intersection. The Y-axis represents the hourly average number of preemption requests and the X-axis represents the time of the day. It can be observed that the number of preemptions requested is lower during the AM peak period at all intersections; it ranges from one request in six hours to one in three hours. During the other three time periods of day the frequency of preemption requests ranges between one and two requests in three hours. It can be concluded that the frequency of preemption requests is lower than expected during all four time periods and thus, the disruption to the other traffic is anticipated to be low or even negligible. Appendix B7 provides supplemental information indicating the standard deviations and the minimum and maximum number of preemption requests by time of day at the six intersections of U.S.1.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by time of day among the six intersections (Appendix B6.2). The results indicate that there is evidence to infer that the frequency of emergency vehicle preemption requests varies by time of day and among the six intersections.

Various t-tests were performed to test for statistical differences in the results obtained for the four different time periods of the day for each intersection separately (Appendix B6.3). The results indicate that at intersections RT.1 & Popkins Lane, RT.1 & Memorial St and RT.1 & Beacon Hill Rd., the AM cases are different from the other time periods at the 95% confidence. At the intersection RT.1 & Southgate Dr. the AM cases are different from the Midday and Night cases; at the intersection RT.1 & South Kings Hwy, the AM cases are different from the PM and Night cases; while for the intersection RT.1 & North Kings Hwy no significance difference was found between the four different time periods.

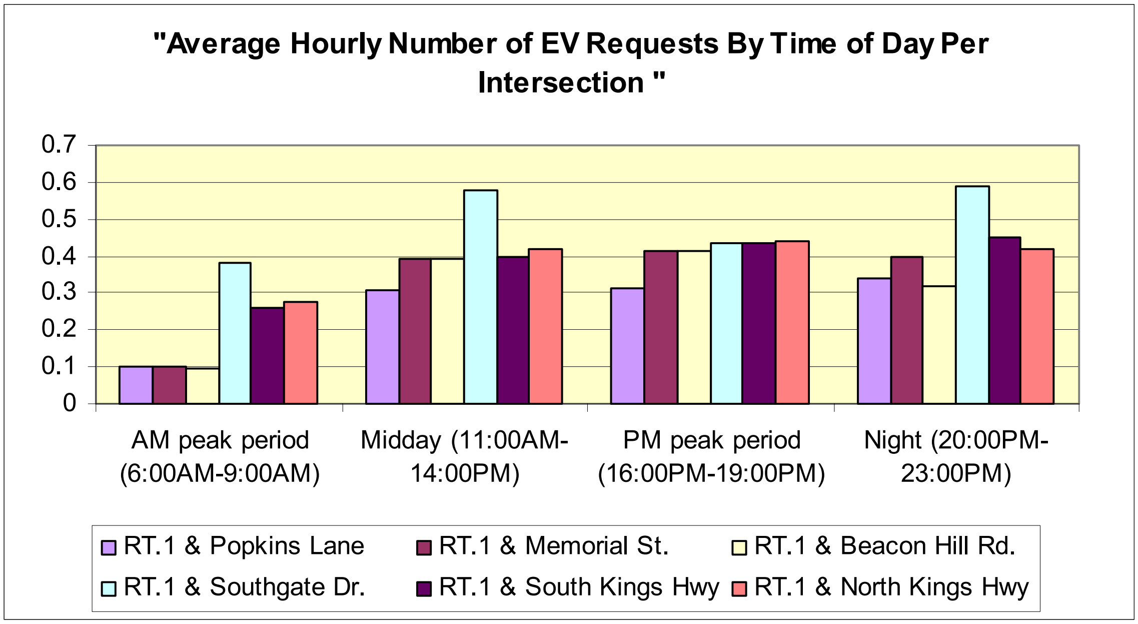


Figure 3.10. Average Hourly Number of EV Requests By Time of Day Per Intersection.

Figure 3.11 shows the frequency of preemption requests according to the day of the week. The Y-axis represents the average number of preemption requests per week and the X-axis represents the day of the week. It seems that there is some variability in the frequency of preemption requests according to the day of the week; it appears that the number of preemption requests during the weekends is a little higher or equal the number of request during weekdays but still there does not seem to be a clear pattern. Higher number of preemption requests on weekends is a positive sign since the preemption system is likely to cause less disruption to traffic than on weekdays, as the normal auto traffic on weekdays is more than on weekends.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by day of week among the six intersections (Appendix B6.4). The results indicate that there is evidence to infer that the frequency of preemption requests is different for different days of the week and among the intersections at the 95% confidence interval.

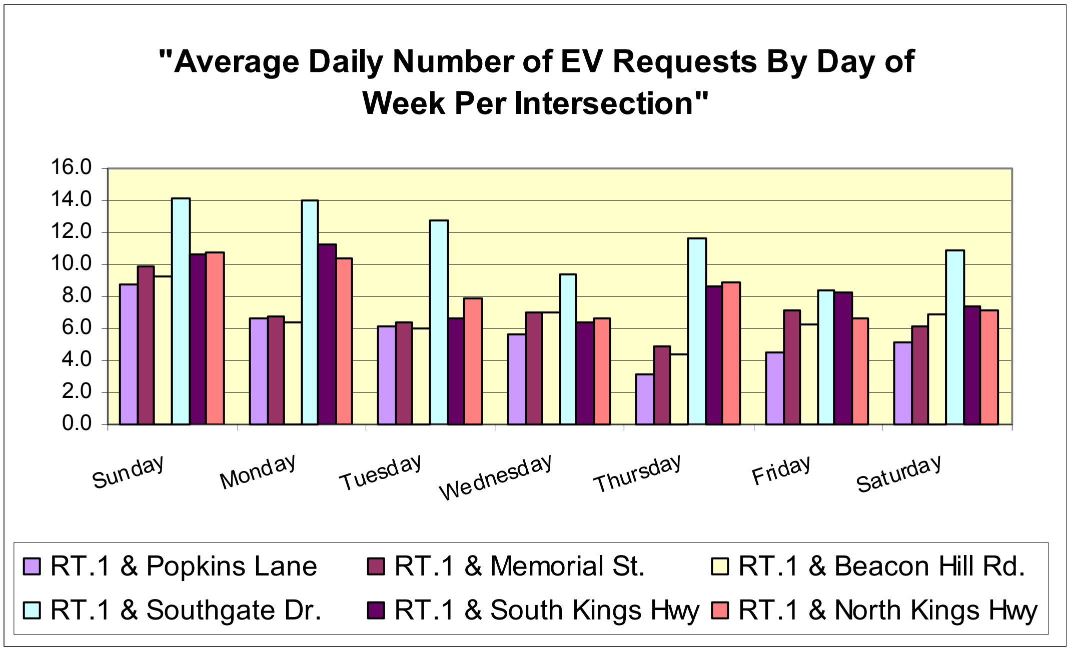


Figure 3.11. Average Daily Number of EV Requests By Day of Week Per Intersection.

Figure 3.12 presents the directional split of the total number of preemption requests made at each intersection during the 53-day period of study. The vertical axis represents the total number of preemption requests per direction and the horizontal axis represents the six intersections. It should be noted that the Fire Station that serve the area under study is located on Beedoo Str. (between Beacon Hill Rd. and Southgate Dr.). Considering the map of the corridor under study (Appendix B1), we would expect northbound preemption requests at intersections RT.1 & Southgate Dr., RT.1 & South Kings Hwy, and RT.1 & North Kings Hwy; and southbound requests at intersections RT.1 & Popkins Lane, RT.1 & Memorial St and RT.1 & Beacon Hill Rd. This observation is verified and illustrated in Figure 3.12. It is interesting to note that a small percentage of requests are made at the opposite direction of the anticipated one. This can be explained by the fact that in some cases emergency vehicles are dispatched to respond to an incident after having served another incident or while they are on their way to return to the fire station.

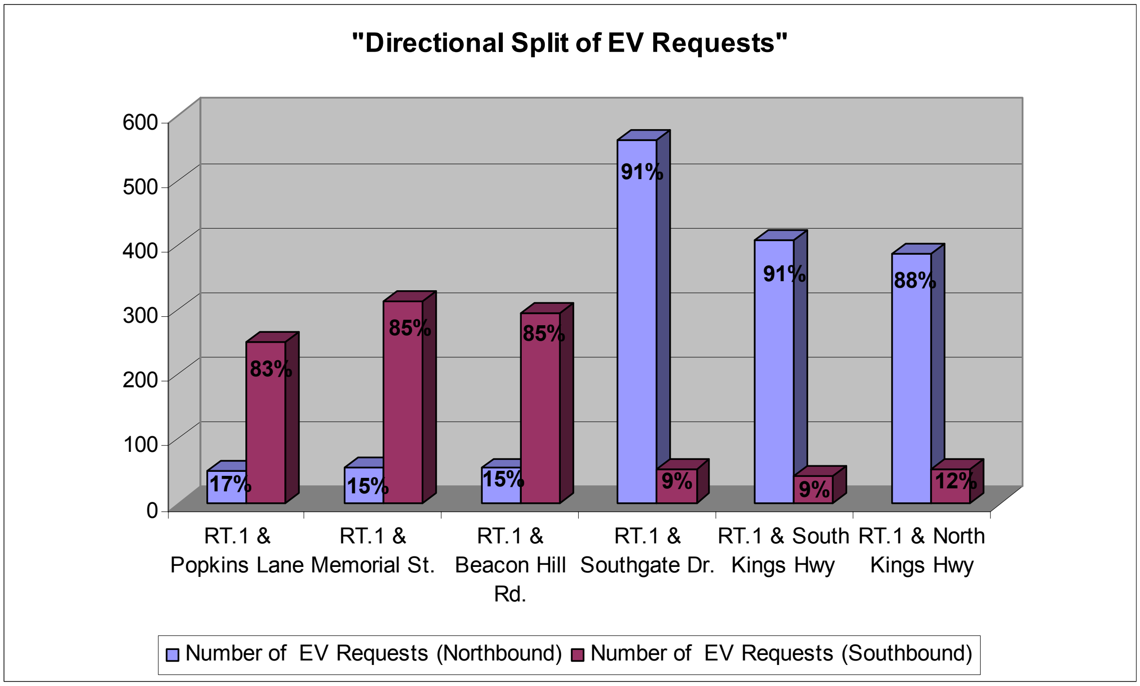
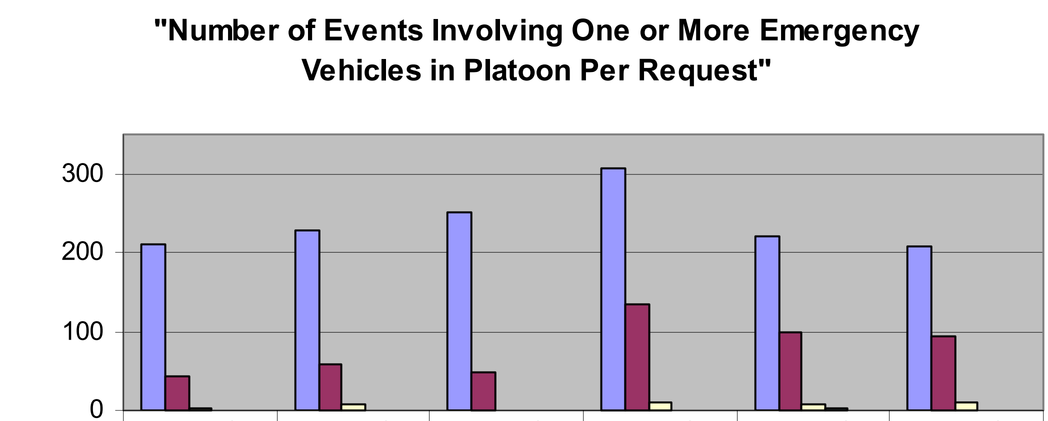


Figure 3.12. Number of EV Preemption Requests Per Direction Per Intersection.

3.3.4.2 Size of Platoon of Emergency Vehicles

Figure 3.13 shows the number of emergency vehicles in platoon per request. In most cases, there is one vehicle in platoon per request. The vertical axis represents the total number of events per intersection and the horizontal axis the six intersections. Figure 3.14 derives from aggregating the results presented in Figure 3.13. It can be observed that in 73% of the cases each platoon includes only one emergency vehicle. This finding can be considered a positive sign for the traffic engineers engaged with preemption systems as it indicates that in most cases the duration of preemption would be low resulting in less disruption to traffic signal timing and in consequence, to the general-purpose traffic. In addition, it appears that the likelihood of having some requests denied because of interference with another request is relatively low. This observation is consistent with the results presented previously in Table 3.2.



	RT.1 & Popkins Lane	RT.1 & Memorial St.	RT.1 & Beacon Hill Rd.	RT.1 & Southgate Dr.	RT.1 & South Kings Hwy	RT.1 & North Kings Hwy
One	211	227	251	306	220	209
Two	42	58	48	134	98	95
Three	2	8	1	11	7	9
Four	0	0	0	1	2	1
Six	0	0	0	0	0	1

Figure 3.13. Number of Events Involving One or More Emergency Vehicles in Platoon Per Request.

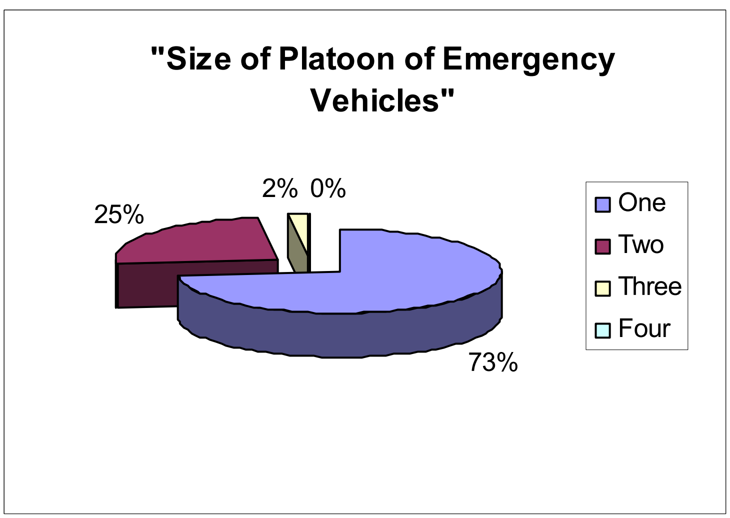


Figure 3.14. Size of Platoon of Emergency Vehicles.

3.3.4.3 Length of Preemption Phase Per Intersection

Table 3.3 presents the average duration of preemptions for the six intersections under study. It can be observed that the average duration of preemptions is lower than expected; it ranges from 6 sec to 131 sec with the average value fluctuating from 16 to 26 sec, depending on the intersection. This is a positive sign since the longer the preemption phase, the higher the disruption to the traffic signal timing and the greater the impact to the side-street traffic.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability between the six intersections (Appendix B6.5). The results indicate that there is evidence to infer that the average duration of emergency vehicle preemptions varies by intersection.

Table 3.3. Length of Preemption Phase Per Intersection (sec).

Intersection	***Length of Preemption Phase (sec)***			
	Mean	*Standard Deviation*	*Min*	*Max*
RT.1 & Popkins Lane	20.9	7.4	6	106
RT.1 & Memorial St.	26.4	10.4	6	131
RT.1 & Beacon Hill Rd.	18.7	9.8	6	131
RT.1 & Southgate Dr.	15.7	6.0	6	47
RT.1 & South Kings Hwy	22.7	6.8	6	86
RT.1 & North Kings Hwy	17.1	6.9	6	55

Figure 3.15 shows the average length of preemption phase by time of day for the six intersections under study. The Y-axis represents the average duration of preemptions and the X-axis the time of the day. It appears that there is not much variability in the average duration of preemptions by time of day for most intersections. In addition, there does not seem to be a clear pattern of the length of the preemption phase during the daytime and nighttime. Appendix B7 provides supplemental information indicating the standard deviations and the minimum and maximum length of preemption phase by time of day at the six intersections on U.S.1.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by time of day between the six intersections (Appendix

B6.6). The results indicate that there is not evidence to infer that the average length of preemption phase is different at the 95% confidence interval among different time periods of the day. However, the test supports the notion that the average duration of preemptions by time of day differs among the six intersections at the selected significance level (0.05). We can conclude that the average duration of preemptions is independent of the time of day but not independent of the intersection where the preemption system is installed.

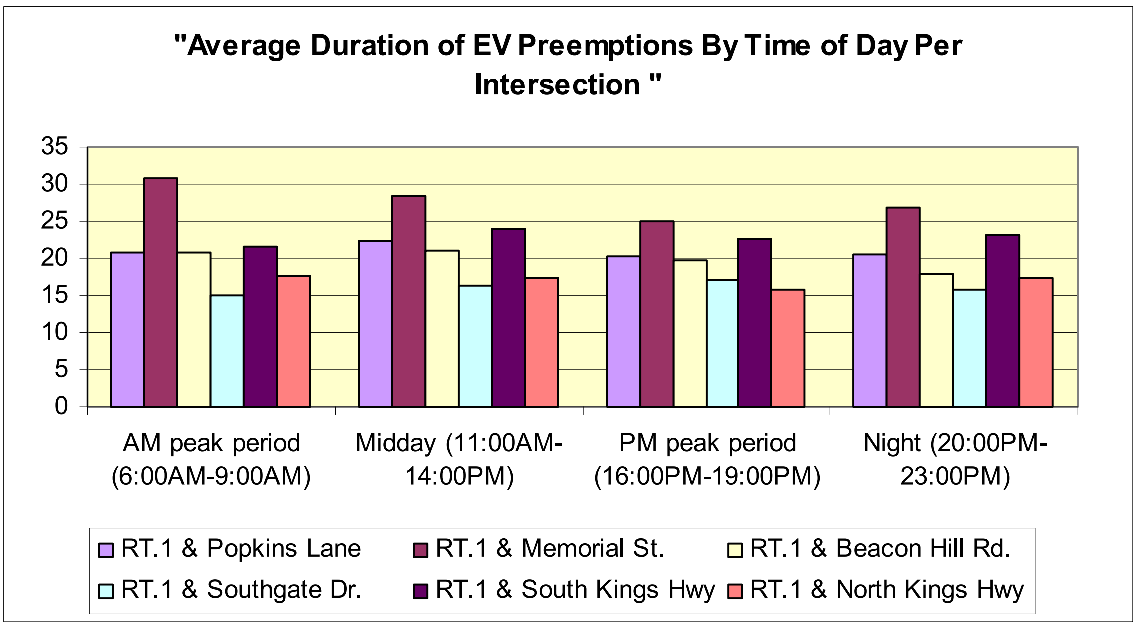


Figure 3.15. Average Duration of Preemptions By Time of Day Per Intersection (sec).

Figure 3.16 shows the average length of preemption phase by day of week for the six intersections under study. The Y-axis represents the average duration of preemptions and the X-axis the day of the week. It appears that there is not much variability in the average duration of preemptions by day of week for most intersections. In addition, there does not seem to be a clear pattern of the length of preemption phase during the weekends and weekdays. Appendix B7 provides supplemental information indicating the standard deviations and the minimum and maximum length of preemption phase by day of week at the six intersections of U.S.1.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by day of week between the six intersections (Appendix B6.7). The results indicate that there is not evidence to infer that the average length of preemption phase is different at the 95% confidence interval among different days of week. However, the test supports the notion that the average duration of preemptions by time of day differs among the six intersections at the selected significance level (0.05). We can conclude that the average duration of preemptions is independent of day of week but depends on the intersection where the preemption system is installed.

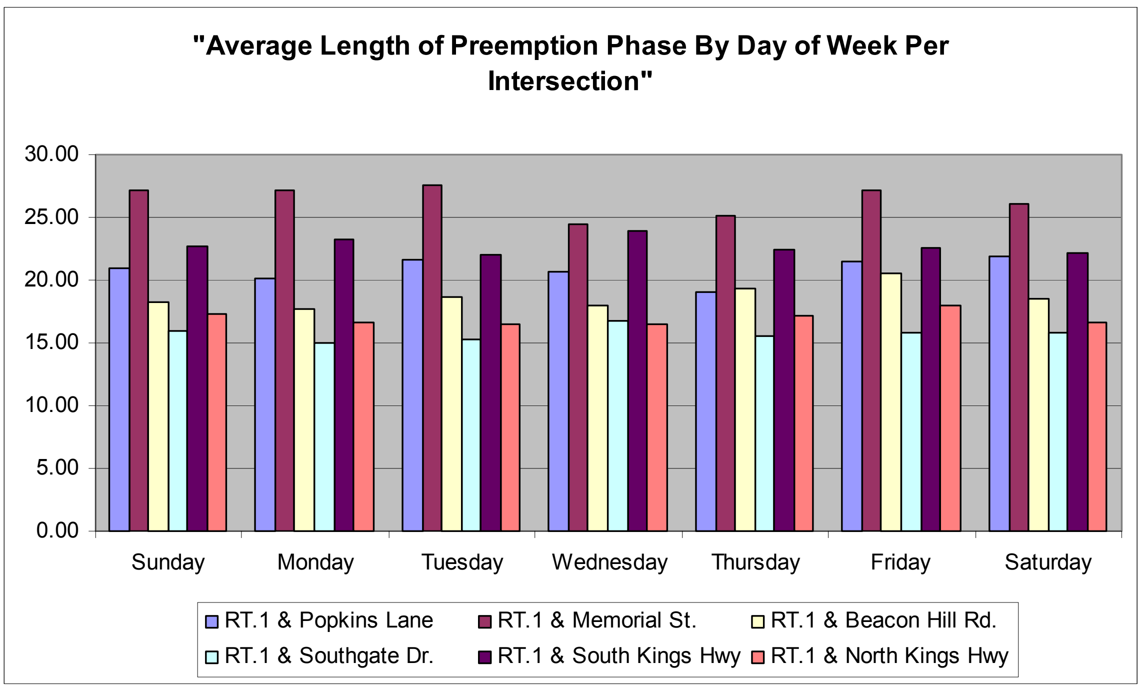


Figure 3.16. Average Duration of Preemptions By Day of Week Per Intersection (sec).

Figure 3.17 shows the average length of preemption phase by direction (northbound, southbound) for the six intersections under study. The Y-axis represents the average duration of preemptions by direction of travel and the X-axis the intersections. It appears that there is some variability in the average duration of preemptions by direction of movement for most intersections. An Analysis of Variance (ANOVA) Test indicates that the above observation is not statistically significant at the 95% confidence interval (Appendix B6.8).

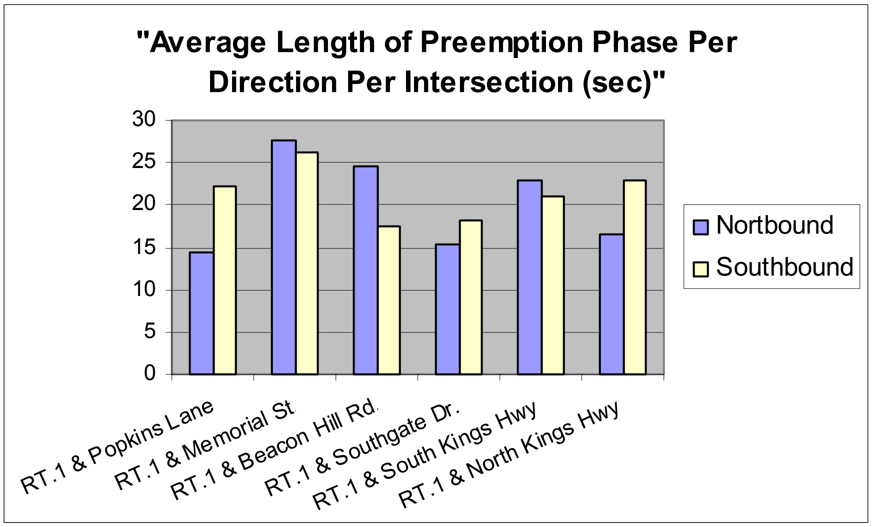


Figure 3.17. Average Duration of Preemptions By Direction Per Intersection (sec).

3.3.5 Major Findings and Results

The findings of the analysis of the emergency vehicle preemption request data, obtained after the deployment of the 3M™Opticom™ Priority Control System at 6 intersections along U.S.1, and represent a 53-day period from July 16, 2002 to September 6, 2002 are summarized below:

- ✓ The daily occurrence of preemption requests fluctuates from 6 to 12 requests per day, depending on the intersection.
- ✓ Only a small percentage of the total number of preemption requests is denied (1 to 2%).
- ✓ The frequency of preemption requests varies by time of day among the six intersections. It is lower during the AM peak period at all intersections (up to one request in three hours); during the other three time periods of the day it ranges between one and two requests in three hours.
- ✓ The frequency of preemption requests varies by day of week among the six intersections. In most cases, the number of requests is a little higher during the weekends than during weekdays.

- ✓ The size of vehicle platoons per preemption request on U.S.1 is relatively small; in 73% of the cases each platoon included only one emergency vehicle.
- ✓ The average duration of preemptions is lower than expected; on average it ranges from 16 to 26 sec, depending on the intersection with no significant variability by time of day, day of week or direction of travel.

3.4 Analysis of Emergency Preemption Data in Montgomery County, MD

3.4.1 Description of Study Area

Complementary to the previous analysis, it is of interest to know how the frequency and duration of emergency vehicle preemption requests vary by geographic location. To this end, 25 major signalized intersections in Montgomery County, Maryland where a preemption system is installed are considered for this analysis.

Montgomery County is Maryland's most populous jurisdiction and the most affluent. The County is located adjacent to the nation's capital, Washington, D.C., and includes 497 square miles of land area. There are 19 fire stations providing fire protection to the County residents and businesses and 535 Firebox areas. The County's Rescue Squad Committee has defined effective rescue squad coverage as reaching 90% of the population within 10 minutes' response time after placing a 911 call (which translates to 5 miles travel distance) *(39)*.

Appendix C1 shows the Montgomery County map. The location of the Fire Stations is presented in Appendix C2 and in more detail in terms of response areas, Fire Districts and Corporations in Appendix C3, C4 and C5. The location of the major signalized intersections is presented in more detail in terms of intersection number, the main street, cross street name, and type of preemption in Appendix C6.

3.4.2 Data Collection and Compilation

The data were obtained from Department of Public Works and Transportation (DPWT) in Montgomery County, MD. The preemption data represent a 5-weekday period from April 20, 2000 to April 26, 2000 and offer the following information:

- Date: The date of the preemption.
- Time: Start and end time of the preemption mode.
- Preemption Status: On/Off.
- Intersection Number.

A sample sheet of data obtained from Montgomery County, MD is given in the Appendix C7.

3.4.3 Analysis Objectives

The obtained data were analyzed to determine the following:

- Number of preemption requests at each of the signalized intersections and the 3 railroad crossings.
- Number of preemption requests by hour of the day and day of the week at 25 major signalized intersections along the arterials and 3 railroad crossings.
- Average duration of preemptions at the 25 major signalized intersections along arterials and 3 major railroad crossings.

Different weekdays are compared to assess the variability in the above-mentioned objectives. The weekends are not consideration since the obtained data did not contain any information about the weekend preemptions.

The preemption status in the obtained data allowed counting the number of preemption calls within each hour of the day. Similarly the number of preemption calls at any particular signalized intersection on any day was calculated by adding the total number of preemption calls during each hour of the day at the particular intersection. Excel with the use of queries as the backhand tool was used to count the number of preemption calls since the manual count would be both laborious and time consuming.

The 'On' Preemption status was taken to be the start time and the 'Off' preemption status was taken to be the stop time of the emergency preemption time. The duration was obtained by finding the difference between the start and stop time of the preemption calls. An outlier observation of 149.6 seconds of average preemption duration at intersection number 219 on a Wednesday was observed. This particular observation was taken to as an error in the given data and hence the particular value was substituted with the average of the duration of the preemption time on other weekdays.

3.4.4 Analysis and Results

3.4.4.1 Signalized Intersections Along Arterials

Table 3.4 shows the number of preemption requests at the 25 intersections under study during a day. Figure 3.18 represents those data graphically. The location of the major signalized intersections is presented in more detail in terms of intersection number, the main street, cross street name, and type of preemption in Appendix C6.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by day of week among the 25 intersections under study (Appendix C8.1). The results indicate that the difference in the frequency of preemption requests between different days of the week is rather marginal. However, the test supports the notion that the number of preemption requests during a day differs among the 25 intersections under study at the selected significance level (0.05). We can conclude that the frequency of preemption requests is not that much dependent of the day of week as of the location where the preemption system is installed.

Table 3.4. Number of Preemption Requests at Signalized Intersections By Day of Week.

INT	MON	TUE	WED	THU	FRI	Avg	Stdev
1	4	2	9	7	10	6.4	3.4
8	24	20	20	26	25	23	2.8
65	13	7	5	10	12	9.4	3.4
82	0	0	4	0	0	0.8	1.8
96	19	40	36	38	44	35.4	9.6
102	11	1	10	7	10	7.8	4.1
129	12	19	14	17	18	16	2.9
160	15	23	13	18	20	17.8	4.0
173	17	33	18	19	20	21.4	6.6
210	11	11	5	12	4	8.6	3.8
243	11	3	8	13	8	8.6	3.8
251	16	13	16	15	17	15.4	1.5
285	6	7	6	8	10	7.4	1.7
288	5	6	6	9	9	7	1.9
297	31	29	38	45	36	35.8	6.3
318	34	37	27	39	35	34.4	4.6
333	16	14	7	14	9	12	3.8
349	5	9	9	9	12	8.8	2.5
392	1	2	2	4	15	4.8	5.8
426	0	1	1	0	0	0.4	0.5
657	8	6	8	12	3	7.4	3.3
666	0	1	1	0	0	0.4	0.5
681	20	9	11	12	15	13.4	4.3
697	3	2	3	10	15	6.6	5.7
704	3	2	3	6	12	5.2	4.1
						12.6	10.3

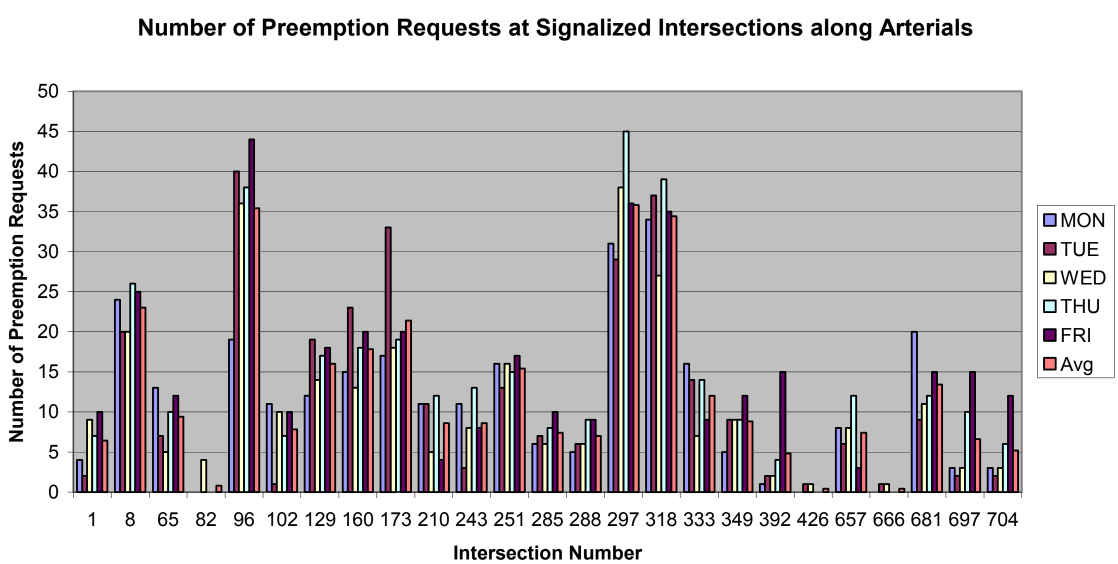


Figure 3.18 . Number of Preemption Requests at Signalized Intersections.

The following figure shows that the frequency of preemption requests at the 25 intersections under study is more during the daytime, between 8am to 8pm, than it is during the nighttime. The vertical axis represents the number preemption requests per day per intersection and the horizontal axis represents the intersections. It is important to know the temporal distribution of emergency vehicle preemption requests by hour of day; a higher frequency of preemption requests during the daytime is likely to result in greater implications to the other traffic since the traffic is more during the daytime. In turn, higher traffic volumes during the daytime result in a higher need for preemptions, since emergency vehicle travel as well as emergency vehicle response times are anticipated to be higher.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by hour of day (Appendix C8.2). The results indicate that there is evidence to infer that the frequency of emergency preemption requests is different for different hours of the day at the 95% confidence interval, with higher occurrence during the daytime.

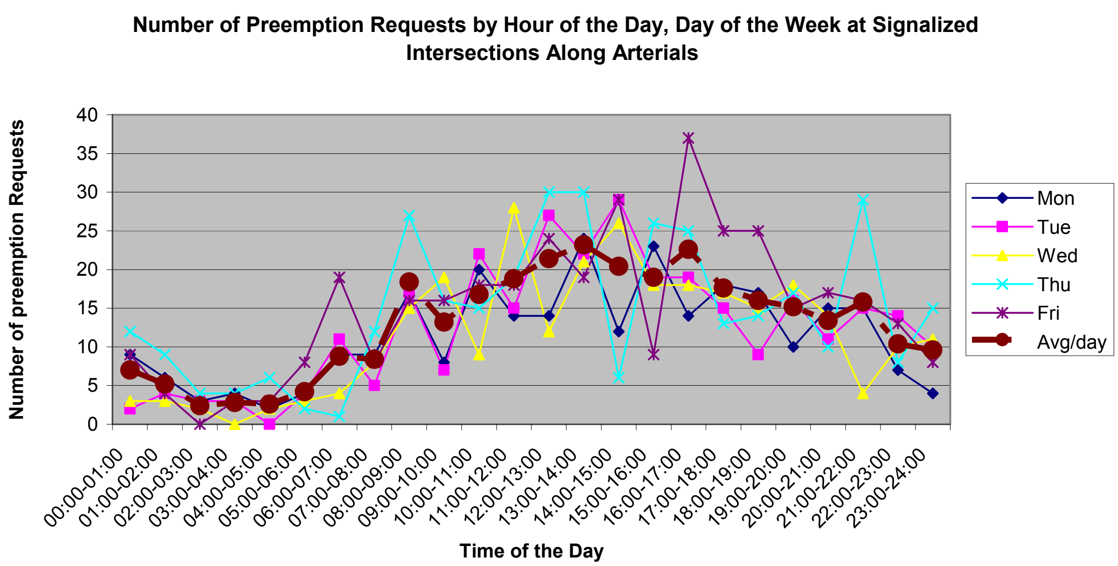


Figure 3.19. Number of Preemption Requests by Hour of the Day and Day of the Week.

Different time periods of the day are considered that include four 3-hr periods: AM peak period, Midday, PM peak period and Night. Figure 3.20 shows the number of emergency preemption requests by time of day made during the 5-weekday period under study. The Y-axis represents the number of emergency preemption requests and the X-axis represents the time of the day. It can be observed that the frequency of emergency preemption requests is higher during Midday and lower during the AM peak period in most days of week. Thus, the disruption to the other traffic is expected to be more during the daytime than during the nighttime.

A t-test was performed to test for statistical differences in the results obtained for the four different time periods of the day (Appendix C8.3). The results indicate that the AM and Midday cases; the AM and PM cases as well as the Midday and Night cases are different at the 95% confidence interval.

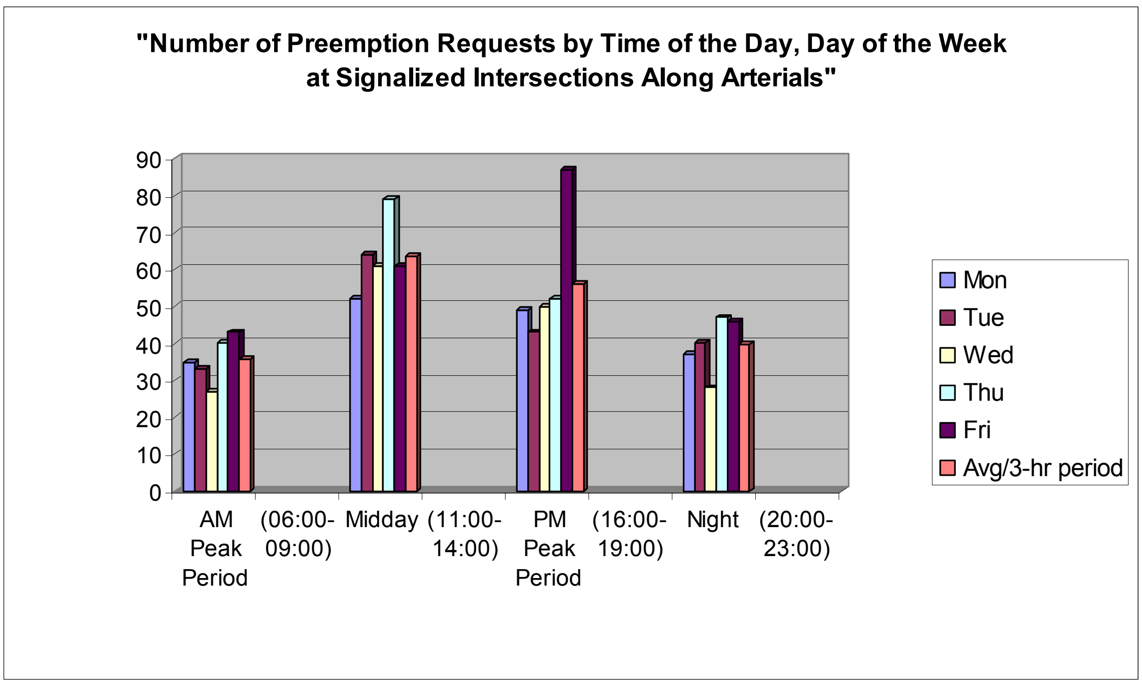


Figure 3.20. Number of Preemption Requests by Time of the Day and Day of the Week.

Figure 3.21 shows the average duration of preemption time at 25 signalized intersections along arterials by day of week. There were two outliers (average duration 149.6 seconds at intersection number 210 on a Wednesday and 127.6 seconds at intersection 704 on a Friday) that were removed and their values were replaced with the average value on other days. The average duration of preemption time at all the intersections is 47.5 seconds; the intersection number 129 is an exception and has an average duration of 118.2 seconds.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by day of week among the 25 intersections under study (Appendix C8.4). The results indicate that there is no evidence to infer that the average duration of preemption requests is different between different days of the week. However, the test supports the notion that the average duration of preemption requests during a day differs among the 25 intersections under study at the selected significance level (0.05). We can conclude that the average duration of preemption requests is not dependent of the day of the week but of the location where the preemption system is installed.

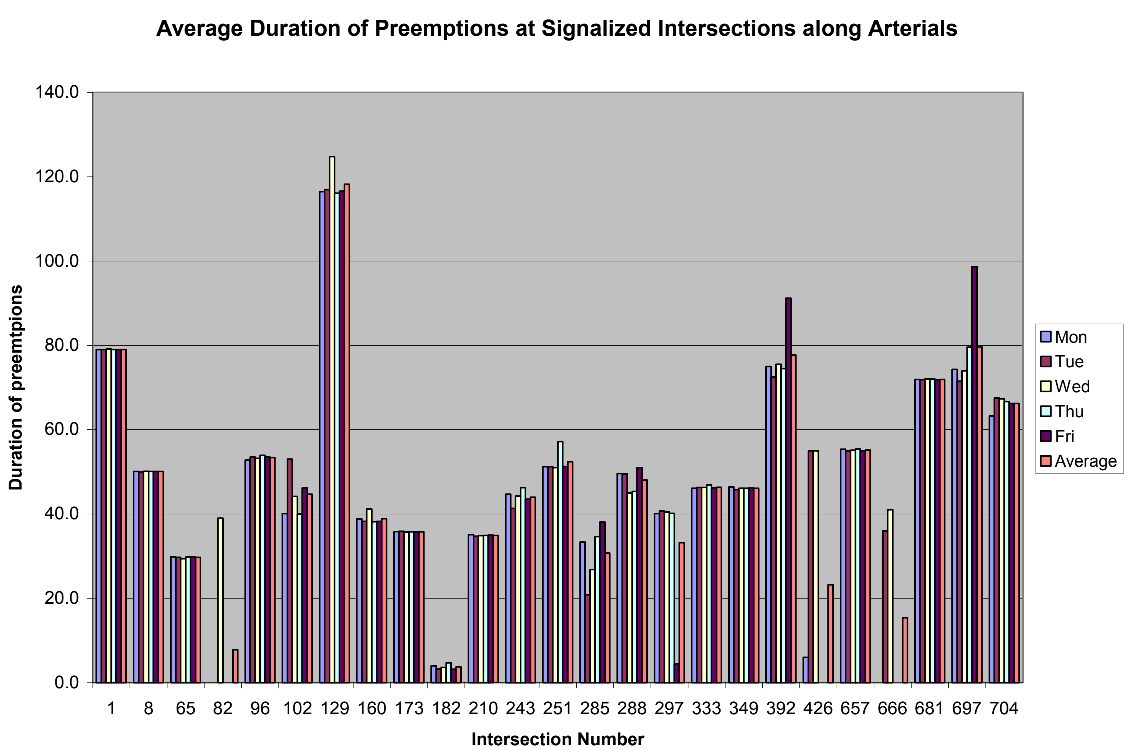


Figure 3.21. Average Duration of Preemptions at Signalized Intersections along Arterials.

3.4.4.2 Signalized Railroad Crossings

A similar kind of analysis for the three signalized railroad crossings under study is presented in Appendix C9.

3.4.5 Comparison of Frequency and Duration of Preemptions at Signalized Intersections Along Arterials in Fairfax County, VA and in Montgomery County, MD

As it is illustrated in sections 3.3 and 3.4, a major part of this research is engaged with the study of the emergency vehicle characteristics with respect to the preemption strategy deployed, in order to assess the level of frequency of preemption requests and average duration of preemption. Complementary to this analysis, it is of interest to know how the above characteristics related to emergency vehicle preemption vary by geographic location. To this end, the emergency preemption data obtained from preemption systems deployed at signalized intersections in Fairfax County, VA and in Montgomery County, MD are compared with the use of statistical tools.

A t-test assuming unequal variances was performed to test for statistical differences in the results obtained for the two different geographic locations (Appendix C8.5). This t-test form assumes that the variances of both ranges of data are unequal and it is used to determine whether two sample means are equal; it is appropriate in this case since the two groups under study are distinct. The results indicate that the difference in the daily frequencies of preemption requests between the two Counties under study appears to be rather marginal at the 95% confidence interval. In other words, there is no statistical evidence to infer that the average daily number of preemption requests in Montgomery County, MD is greater than the corresponding number in Fairfax County, VA, as it was observed.

However, there seems to be a significant difference in the duration of preemptions between the two Counties. It appears that in Montgomery County, MD the average duration of preemptions is higher. This fact could be attributed to several factors including the proximity of the firehouse to the intersection, roadway geometrics, and traffic and operating characteristics of the intersection at which the preemption system is deployed. Moreover, the longer duration of preemption phase in Montgomery County could be possibly attributed to larger platoons of emergency vehicles responding to an emergency call.

3.4.6 Major Findings and Results

The findings of the analysis of the emergency preemption data obtained from Montgomery County, MD for a 5-weekday period (04/20/00-04/26/00) are summarized below:

- ✓ At any particular intersection, the number of preemption requests as well as the average duration of the signal preemption time within any weekday is similar.
- ✓ The frequency of emergency preemption requests is different for different hours of the day and different time periods of the day, with higher occurrence during the daytime.
- ✓ Both the frequency of emergency preemption requests and the average duration of preemptions are dependent on the location where the preemption system is installed; a finding with practical implications that need to be considered in the design and deployment of emergency vehicle preemption systems as well as for future research.
- ✓ There seems to be a significant difference in the duration of preemptions between Fairfax County, VA and Montgomery County, MD; with the latter County exhibiting higher duration of preemptions.
- ✓ The difference in the daily frequencies of preemption requests between the two Counties under study appears to be rather marginal at the 95% confidence interval.

3.5 Supplemental Analysis –Study period (04/07/03-04/14/03)

3.5.1 Analysis of Preemption & Priority Data from the 3M™ Opticom™ Priority Control System on U.S.1, Fairfax County, VA

As it was mentioned before, the 3M™Opticom™ Priority Control System is designed for joint use of emergency services (police, fire, medical) and other vehicles such as transit. Since the beginning of year 2003, transit vehicles serving the 7-intersection segment of U.S.1, are provided preferential treatment with the use of the

3M™Opticom™ Priority Control System that provides also preemption to emergency vehicles. When an emergency vehicle and one or more buses are requesting control of an intersection, the emergency vehicle has first priority and will always gain control. The corridor under study is shown in Appendix D1.

Data on preemption and priority requests were collected with the use of the 3M™Opticom™ System in order to verify the latter observation as well as to examine how well the system performs for both emergency vehicles and transit, and whether there has been a change in the number of preemption requests granted as a result of simultaneous priority requests.

In addition, since both emergency preemption (high priority) and transit signal priority (low priority) can be given to vehicles on this route, if there are more preemptions in a particular hour, and if the transit buses are also given priority in the same hour, then there would be delay to the other vehicles. Hence, the results of this analysis are anticipated to be useful for traffic engineers planning transit signal priority strategies.

The data collected are attached in Appendix D2 and represent a one-week period from April 7, 2003 to April 14, 2003; during this period preferential treatment was provided for both emergency and transit vehicles. The data provide the same information as the one described earlier in section 3.3.2. The two datasets differ in the fact that under the column of Priority both High and Low requests have been recorded.

3.5.1.1 Analysis Objectives

The obtained data were analyzed to determine the following:

- *Number of Preemption & Priority Requests Per Day Per Intersection*
- *Number of Preemption & Priority Requests Denied Per Intersection*
- *Number of Preemption & Priority Requests Per Direction Per Intersection*
- *Length of Preemption and Priority Phase Per Intersection*

Statistical tests are then applied to assess whether the observed differences in the frequency of preemption requests and the number of preemption requests denied, as well as in the duration of preemptions, among the six intersections before and after the deployment of transit priority can be explained by the natural sampling variability or are attributed to other factors.

3.5.1.2 Analysis and Results

Figure 3.22 presents the average number of preemption and priority requests per day in comparison to the total daily number of requests for the six intersections under study. It can be observed that during the one-week period from April 7, 2003 to April 14, 2003 the daily frequency of priority requests is higher in comparison to that of preemption requests at five out of six intersections. The daily occurrence of priority requests ranges from 0 to 43 requests with the average value fluctuating from 4 to 18 requests, depending on the intersection. The daily occurrence of preemption requests is lower; it ranges from 0 to 19 requests with the average value fluctuating from 5 to 9 requests, depending on the intersection.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability of the frequency of preemption requests (Appendix D3.1) as well as of priority requests (Appendix D3.2) among the six intersections. The results indicate that there is no evidence to infer that the average number of emergency vehicle preemption requests per day as well as the average number of transit priority requests varies by intersection.

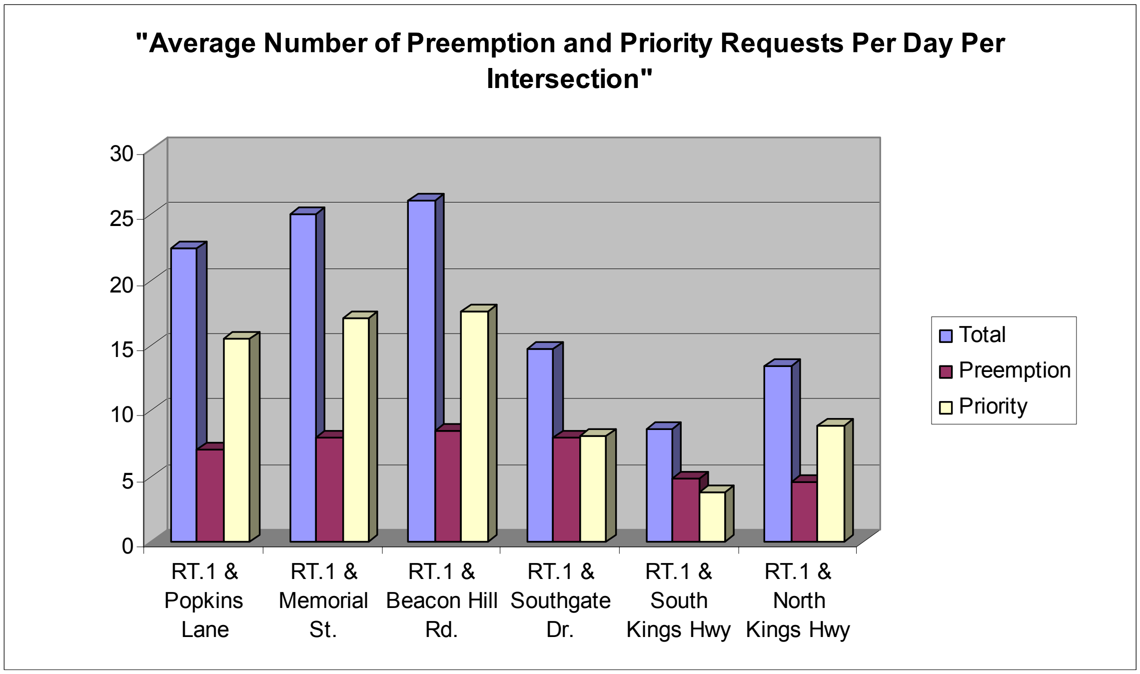


Figure 3.22. Average Number of Preemption and Priority Requests Per Day Per Intersection.

From the following table, it can be observed that both the number of preemption and priority requests denied is relatively low; it ranges from 0 to 4% of all the total number of requests. It appears that more preemption requests are denied than priority requests. In most cases, it appears that the reason for a preemption request been denied is when having two or more simultaneous preemption requests. In the case of transit priority, several factors could be responsible for a request to be denied; a simultaneous request from an emergency vehicle could be identified as the main factor, since the emergency vehicle has first priority and will always gain control.

Table 3.5. Number of Preemption and Priority Requests Denied Per Intersection.

Intersection	*Number of Requests Denied*	*Number of Preemption Requests Denied*	*Number of Priority Requests Denied*	*Total Number of Requests*	*Percentage of Requests Denied*
RT.1 & Popkins Lane	0	0	0	180	0%
RT.1 & Memorial St.	5	3	2	201	2%
RT.1 & Beacon Hill Rd.	5	4	1	209	2%
RT.1 & Southgate Dr.	5	5	0	128	4%
RT.1 & South Kings Hwy	0	0	0	68	0%
RT.1 & North Kings Hwy	0	0	0	107	0%

Figures 3.23 and 3.24 present the directional split of the total number of preemption and priority requests made at each intersection during the 7-day period of study. The vertical axis represents the total number of requests per direction and the horizontal axis represents the six intersections. It should be noted that the Fire Station that serve the area under study is located on Beedoo Str. (between Beacon Hill Rd. and Southgate Dr.). Considering the map of the corridor under study (Appendix B1), we would expect northbound preemption requests at intersections RT.1 & Southgate Dr., RT.1 & South Kings Hwy, and RT.1 & North Kings Hwy; and southbound request at intersections RT.1 & Popkins Lane, RT.1 & Memorial St and RT.1 & Beacon Hill Rd. This observation is verified and illustrated in Figure 3.23. It is interesting to note that a small percentage of requests are made at the opposite direction of the anticipated one. This can be explained by the fact that in some cases emergency vehicles are dispatched to respond to an incident after having served another incident or while they are on their way to return to the fire station; and thus, a preemption request is justified. As we might have expected, there does not seem to be a clear pattern in the directional split of priority requests, like the one we noted for the preemption requests.

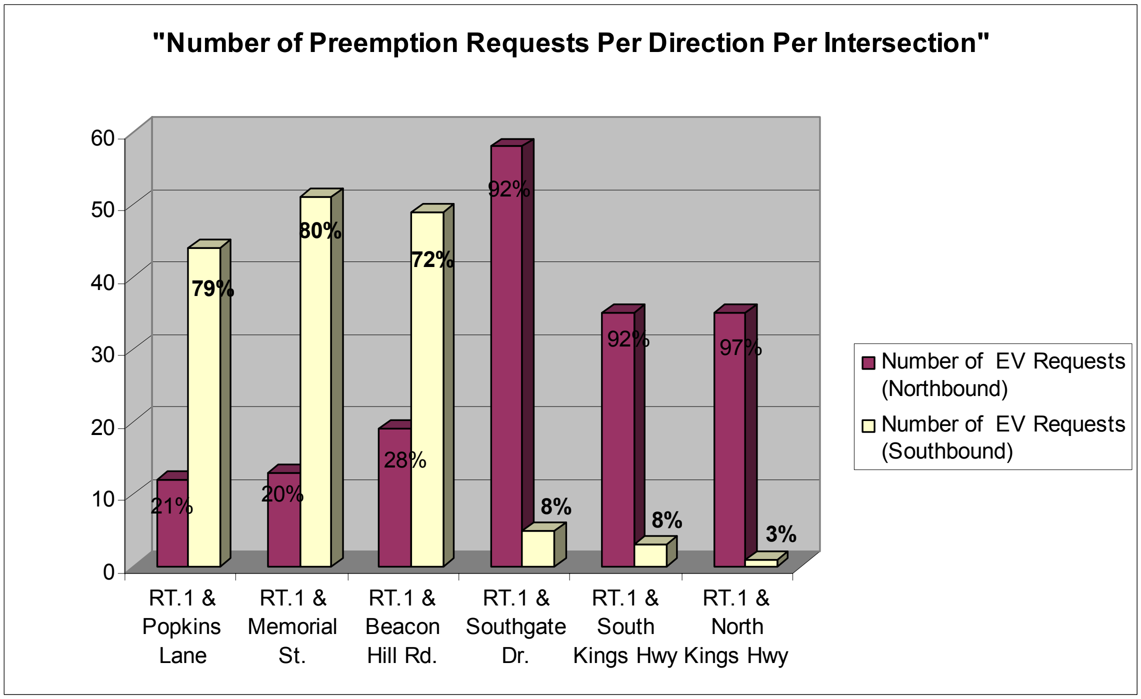


Figure 3.23. Number of Preemption Requests Per Direction Per Intersection.

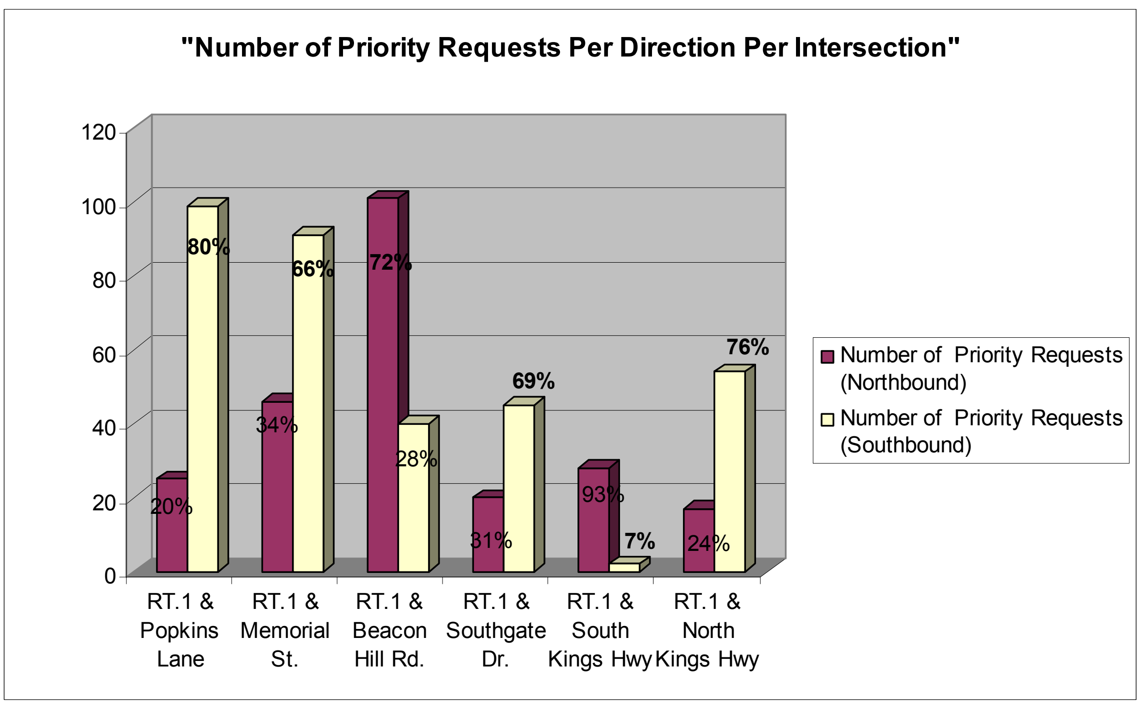


Figure 3.24. Number of Priority Requests Per Direction Per Intersection.

Figure 3.25 presents the average length of the preemption and priority phase for the six intersections under study. It can be observed that the average duration of preemptions is lower than expected; it ranges on average from 17 to 27 sec, depending on the intersection. The average length of the priority phase is also low; it lies between 15 and 28 sec, depending on the intersection. These findings are a positive sign for the traffic engineers engaged with preemption systems since the shorter the preemption phase, the less the disruption to the traffic signal timing and the lower the impact to the side-street traffic.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability of the duration of preemption phase (Appendix D3.3), as well as of priority (Appendix D3.4) among the six intersections. The results indicate that there is evidence to infer that the average length of preemption phase, as well as the average length of priority phase varies by intersection.

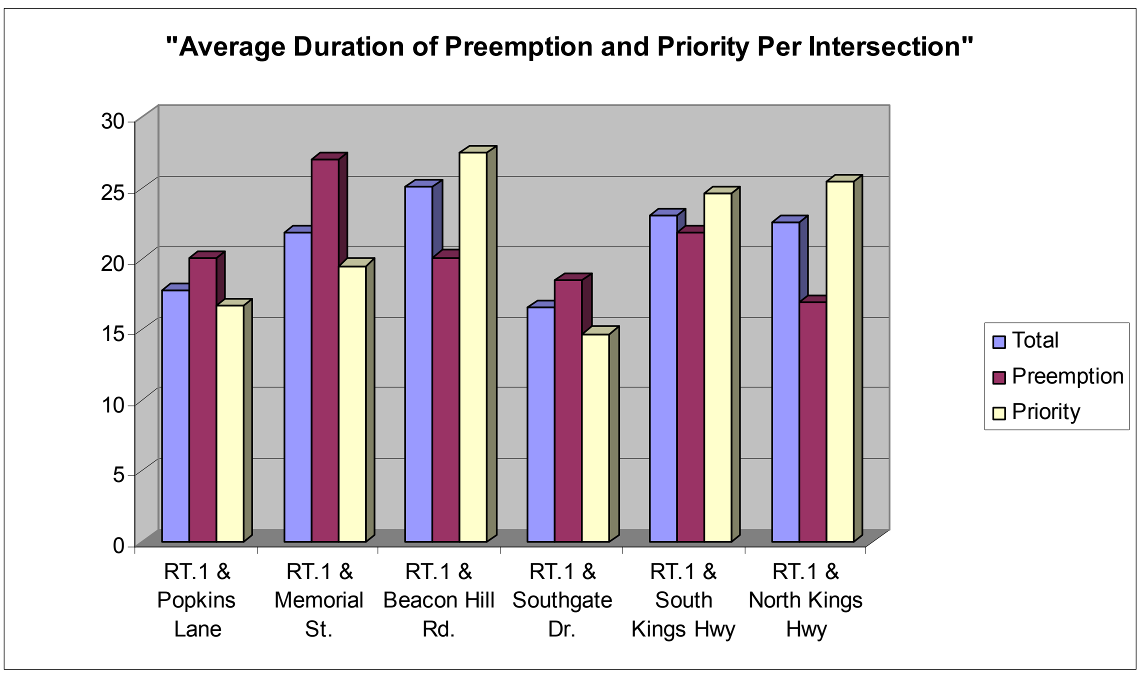


Figure 3.25. Average Duration of Preemption and Priority Per Intersection.

3.5.1.3 Comparison of the 3M™ Opticom™ Preemption Data Before and After the Deployment of Transit Priority on U.S.1.

Complementary to this analysis, it is of interest to know whether frequency of preemption requests and number of preemption requests denied, as well as the duration of preemptions are different before and after the deployment of transit priority at the six intersections. To this end, the emergency preemption data obtained from preemption systems deployed at the six signalized intersections on U.S.1 for the two different periods are compared with the use of statistical tools.

A t-test assuming equal variances was performed to test for statistical differences in the results obtained for the two different periods (Appendix D3.5). This t-test form assumes that the variances of both ranges of data are equal and it is used to determine whether two sample means are equal. The results indicate that at half the intersections under study there is a rather marginal difference in the daily frequencies of preemption requests in the before and after cases at the 95% confidence interval. In response to the question whether there has been a change in the number of preemption requests granted as a result of simultaneous priority requests, the statistic test indicated that at only two intersections the number of requests denied increased; but this is mainly due to other factors discussed earlier when presenting Table 3.4. Finally, no statistical difference was found for the duration of preemptions before and after the deployment of transit priority at most intersections.

We can conclude that it is not clear from the results what is the impact of transit priority requests on the performance of the preemption system. The results are dependent on the intersection where the systems are deployed and the differences found can be well attributed to other factors than the testing hypothesis.

3.5.1.4. Major Findings and Results

The findings of the analysis of the emergency vehicle preemption and priority request data, obtained after the deployment of the 3M™Opticom™ Priority Control

System at 6 intersections along U.S.1, and represent a 7-day period from April 7, 2003 to April 14, 2003 are summarized below:

- ✓ The daily occurrence of preemption requests fluctuates from 5 to 9 requests per day. The daily occurrence of priority requests is a little higher; on average it fluctuates from 4 to 18 requests per day.
- ✓ Only a small percentage of the total number of requests is denied (0 to 4%).
- ✓ The average length of the preemption phase as well as of the priority phase is lower than expected; on average it ranges from 17 to 27 sec and from 15 to 28 sec, respectively.
- ✓ It is not clear from the results what is the impact of transit priority requests on the performance of the preemption system; the differences found can be well attributed to other factors than the testing hypothesis, and they are strongly related to the intersection under testing.

3.5.2 Analysis of Log Data from Fire Station #11 on U.S.1, Fairfax County, VA

For the purposes of this supplemental analysis, data were collected on emergency calls in the major Fire Station in the field of interest (station number 11), for the same period (April 7, 2003 to April 14, 2003). The service area of the fire station under study is presented in Appendix E1. The main aim of this analysis is to improve our understanding of emergency vehicle operations from the time a call is dispatched till the time the emergency vehicles respond to an incident, when preemption is provided.

The data collected is attached in Appendix E2 and provides the same information as the one described earlier in section 3.3.1.

3.5.2.1 Analysis Objectives

The obtained data were analyzed to determine the following:

- *Frequency of Emergency Calls in Fire Station 11:*
    - By Hour of Day
    - By Time of Day
    - By Day of Week

Different days of the week, different hours of the day as well as different time periods of the day are compared to assess the variability in the frequency of emergency calls. The different time periods of the day include four 3-hr periods:

- AM peak period (6:00AM-9:00AM)
- Midday (11:00AM-14:00PM)
- PM peak period (16:00PM-19:00PM)
- Night (20:00PM-23:00PM)

Statistical tests are then applied to assess whether the observed differences between the different time periods can be explained by the natural sampling variability or are attributed to other factors.

- *Type of Emergency Vehicle Responding to an Incident:*
    - Ambulance (A)
    - Rescue Engine (R)
    - Fire Truck (T)
    - Engine/Paramedic Engine (E)
    - Medic (M)
    - Other

The various types of emergency vehicles and their associated engineering characteristics are discussed in more detail in Appendix A8.

➢ *Number of Emergency Vehicles Responding to a Single Incident:*

An important issue that needs to be considered when deploying a preemption system is the size of emergency vehicle platoons per request; the more the number of simultaneous preemption requests the more the likelihood of having some denied because of interference with another request. Information on the number of emergency vehicles that respond to a single incident might be useful in assisting the traffic engineers to deal with the above situation.

Additional information is provided in terms of the distribution of emergency vehicles in a two-vehicle response to a single incident, according to the type of emergency vehicle: Ambulance/ Advanced Life Support (A); Rescue Engine (R); Fire Truck equipped with ladder (T); Engine / Paramedic Engine (E); and Medic (M).

3.5.2.2 Analysis and Results

❖ *Frequency of Emergency Calls in Fire Station 11:*

During the study period (April 7, 2003 to April 14, 2003), Fire Station 11 received on average per day 24.9 emergency calls (S.D. =5.4 calls). Figure 3.26 shows that the frequency of emergency calls received by fire station 11 is more during the daytime, between 8am to 8pm, than is during the nighttime. The Y-axis represents the number of emergency calls and the X-axis represents the hour of the day. It is important to know the temporal distribution of emergency vehicle travel by hour of day; a higher frequency of emergency calls during the daytime is likely to result in greater implications to the other traffic since the traffic is more during the daytime.

An Analysis of Variance (ANOVA) Test was conducted as a parametric method to test the sample variability by hour of day (Appendix E3.1). The results indicate that the difference in the frequency of emergency calls by hour of day is rather marginal at the 95% confidence interval.

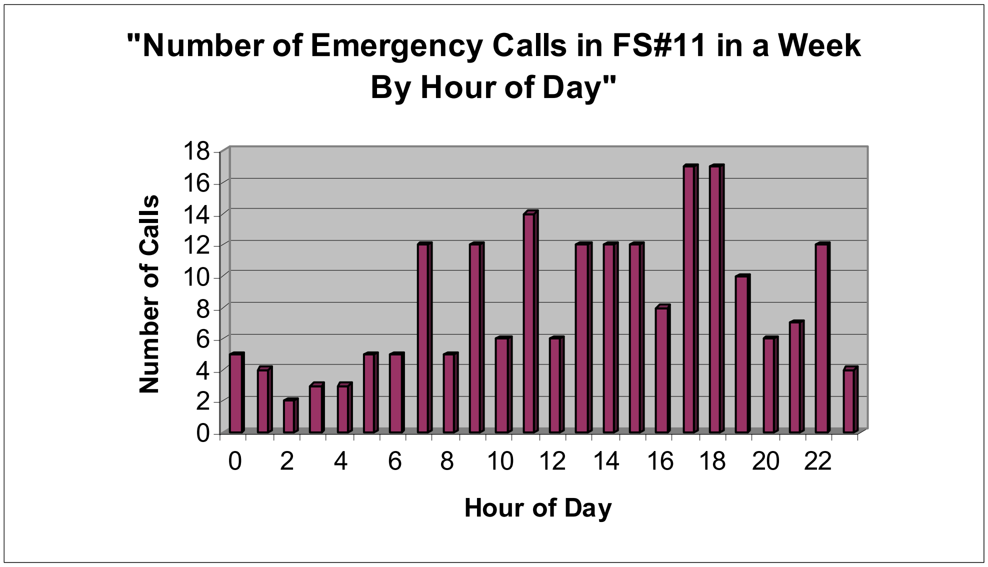


Figure 3.26. Number of Emergency Calls in FS#11 in Week (04/07-04/14/03) By Hour of Day.

Different time periods of the day are considered that include four 3-hr periods: AM peak period, Midday, PM peak period and Night. Figure 3.27 shows the average number of emergency calls per hour by time of day received fire station 11 during the week (04/07-04/14/03). The Y-axis represents the average number of emergency calls and the X-axis represents the time of the day. It can be observed that the frequency of emergency calls is higher during the PM peak period and lower during the AM peak period. Thus, the disruption to the other traffic is expected to be more during the PM peak period than during the other time periods of the day.

A t-test was performed to test for statistical differences in the results obtained for the four different time periods (Appendix E3.2). The results indicate that the AM and PM cases are different at the 95% confidence interval; with a higher frequency of emergency calls during the PM peak period than during the AM peak period.

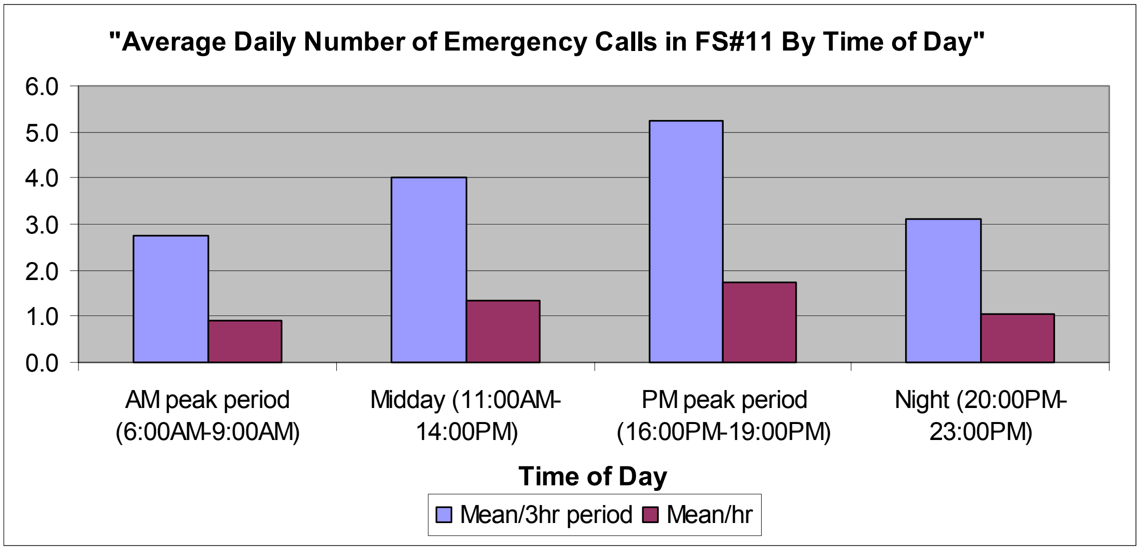


Figure 3.27. Average Daily Number of Emergency Calls in FS#11 in Week (04/07-04/14/03) By Time of Day.

Figure 3.28 shows the frequency of emergency calls according to the day of the week. The Y-axis represents the number of emergency calls and the X-axis represents the day of the week. It seems that there is some variability in the frequency of emergency calls according to the day of the week. However, the results of an Analysis of Variance (ANOVA) Test (Appendix E3.3) indicate that there is no evidence to infer that the frequency of emergency calls is different at the 95% confidence interval among different days of the week.

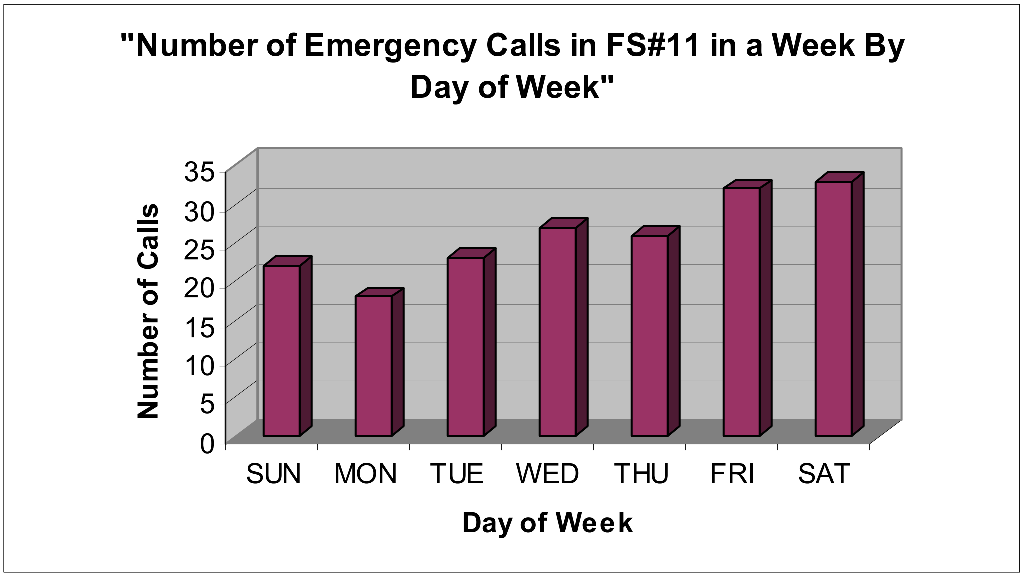


Figure 3.28. Number of Emergency Calls in FS#11 in Week (04/07-04/14/03) By Day of Week.

❖ *Type of Emergency Vehicle Responding to an Incident:*

Figure 3.29 presents the frequency of the various types of emergency vehicles involved in responding to an emergency call. The vertical axis represents the total number of emergency calls that each type of vehicle responds to and the horizontal axis represents the fire station. It can be observed that for the majority of emergency calls paramedic engines and medic vehicles are dispatched. This observation is consistent with the results of a previous analysis presented in Figure 3.9.

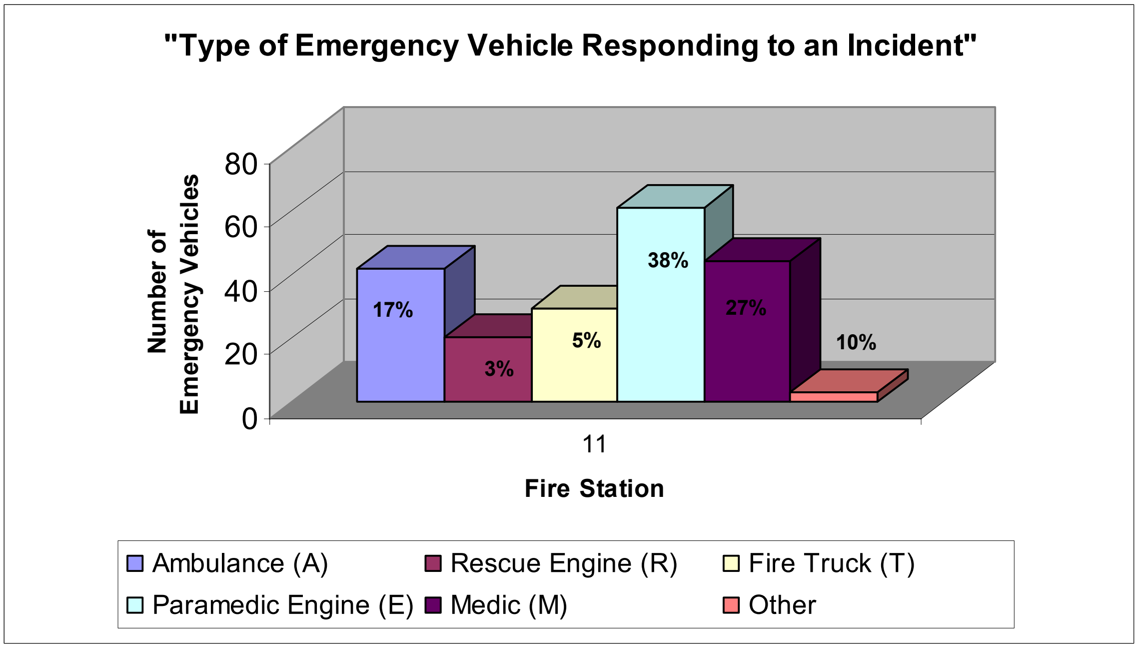


Figure 3.29. Type of Emergency Vehicle from FS#11 Responding to an Incident.

❖ *Number of Emergency Vehicles Responding to a Single Incident:*

Figure 3.30 shows the number of emergency vehicles that respond to a single incident. It can be observed that in 90% of the cases each platoon includes one or two emergency vehicles. Since the emergency vehicles from Fire Station 11 benefit from the preemption system deployed on U.S.1, the above finding can be considered a positive sign for the traffic engineers engaged with preemption systems. It appears that the likelihood of having some requests denied because of interference with another request is relatively low. In addition, it indicates that in most cases the duration of preemption would be low resulting in less disruption to the traffic signal timing and in consequence, to the general-purpose traffic.

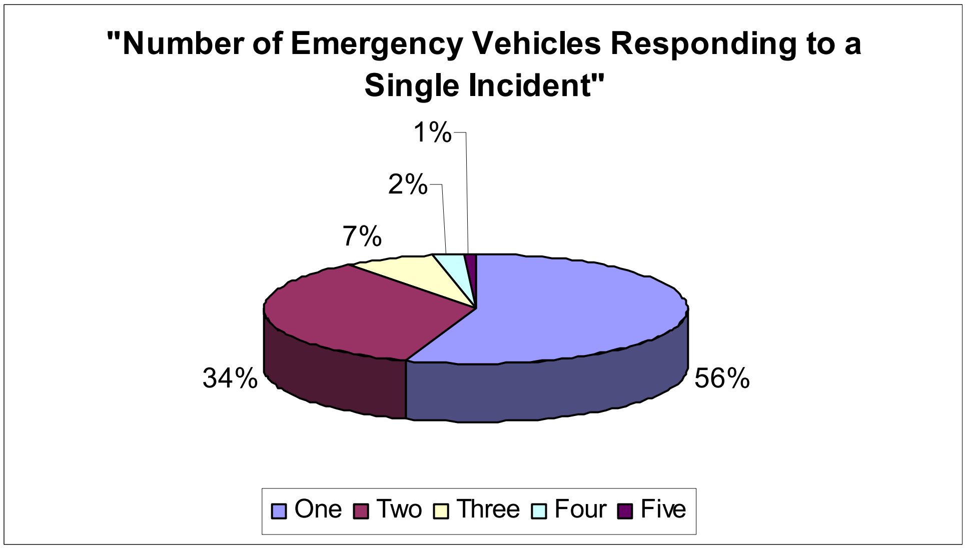


Figure 3.30. Number of Emergency Vehicles from FS#11 Responding to a Single Incident.

Figure 3.31 provides additional information in terms of the distribution of emergency vehicles in a two-vehicle response to a single incident, according to the type of emergency vehicle. It is important to know the frequency of the various types of emergency vehicles involved in responding to an emergency call as vehicles of larger size have low acceleration rate, find more difficulty in maneuvering in traffic and thus, are likely to impact more the other traffic since they require more road space *(35)*. In most cases, a paramedic engine is dispatched along with a medic vehicle (44%) or a fire truck (19%). Paramedic engines and fire trucks can be regarded as large vehicles, while medic vehicles are considered small vehicles. Since in most cases a large vehicle is involved in an emergency response, we can conclude that the deployment of a preemption system may be beneficial under these circumstances.

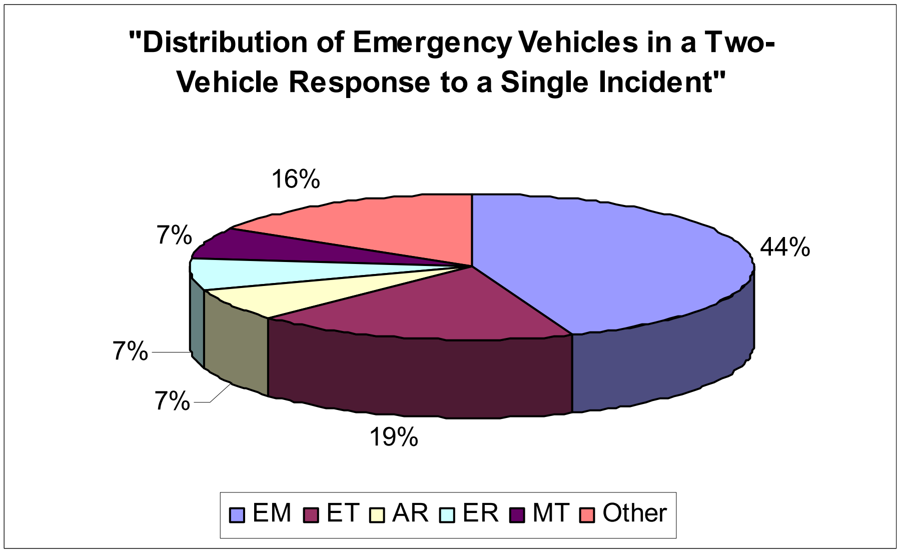


Figure 3.31. Distribution of Emergency Vehicles in a Two-Vehicle Response to a Single Incident.

3.5.2.3. Major Findings and Results

The analysis of the emergency vehicle response data for the fire station 11, maintained by Fairfax County Fire and Rescue Department, for the week (04/07-04/14/03) led to similar results as the ones presented in section 3.2 for the same fire station but for the year 2000. It seems that the patterns of emergency vehicle travel have not changed through time. The main findings are summarized below:

- ✓ The frequency of emergency calls is higher during the daytime, between 8am to 8pm, than it is during the nighttime.
- ✓ The frequency of emergency calls is higher during the PM peak period and lower during the AM peak period.
- ✓ The frequency of emergency calls is independent of the day of the week.
- ✓ In 90% of the cases each platoon includes one or two emergency vehicles.
- ✓ Regarding the distribution of type of vehicles responding to an incident, for the majority of emergency calls paramedic engines and medic vehicles are dispatched. In most cases a large vehicle is involved in an emergency response.

3.6 Analysis of Crash Data for U.S.1, Fairfax County, VA

3.6.1 Data Collection and Compilation

The data collected include the emergency vehicle crash data maintained by the Virginia Department of Transportation (VDOT) for a five-year period 1997-2001. The main goal of this data analysis is to provide information on the crash situation involving emergency vehicles on a major arterial (U.S.1) in Fairfax County, VA.

The data provided by the Virginia Department of Transportation (VDOT) are presented in Appendix F and provide information in terms of the crash date and time; description of the location (type of intersection, type of facility, type of traffic control, number of lanes); collision type and severity; number of fatalities, injuries and amount of property damage; number of vehicles involved; environmental conditions; and other contributing circumstances. The data are attached in Appendix F1.

3.6.2 Analysis Objectives

The obtained data were analyzed to determine the following:

- *Number of Crashes involving Emergency Vehicles on U.S.1, Fairfax County during the 5-year period (1997 to 2001).*
- *Distribution of Crashes by Collision Type.*
- *Distribution of Crashes by Crash Severity.*
- *Major Factor responsible for the crash.*
- *Number of Fatalities and Injuries; Amount of Property Damage and Number of Vehicles involved in each crash.*
- *Type of Intersection; Type of Traffic Control; Type of Facility; Number of Lanes.*
- *Weather and Lighting Conditions.*
- *Surface Type and Condition.*
- *Alignment and Road Defects.*

3.6.3 Analysis and Results

Figure 3.32 illustrates the trend of the number of crashes involving emergency vehicles during the 5-year period under study (1997-2001). It can be observed that from 1998 to 2000, the number of emergency vehicles involved in a crash on U.S.1, Fairfax County increased. In total, they were involved in 22 crashes. The highest annual number of crashes is 8 and occurred during 2000; while the next year, there seems to be a slight reduction by only one crash. We can conclude that the safe movement of emergency vehicles along this corridor is an issue that needs to be addressed.

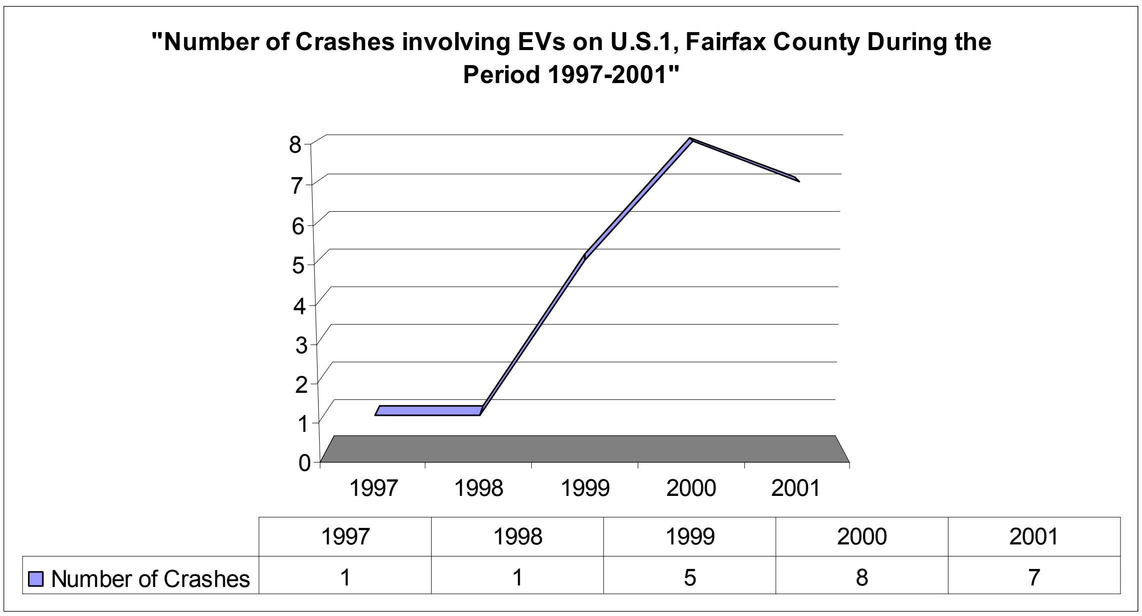


Figure 3.32. Number of Crashes involving EVs on U.S.1, Fairfax County (1997-2001).

The next figure shows the distribution of the total 22 crashes involving emergency vehicles that occurred on U.S.1, Fairfax County by collision type. It appears that more crashes (41%) were identified as angle type in comparison to other types of collisions such as rear end (32%) or sideswipe (18%). This suggests that more crashes occurred when the emergency vehicle was maneuvering trying to pass vehicles or was making a left turn. This information can be useful to traffic engineers considering a preemption system at signalized intersections for safety purposes.

It should be noted that the statistics obtained from the Fatality Analysis Reporting System (FARS) web-based encyclopedia by conducting numerous queries, which are presented in Figure 2.9 (Chapter 2), illustrate that the most common intersection crash types, rear-end and angle crashes, make up 378 of 643 (58%) fatal EV-related crashes during the study period 1994-2000.

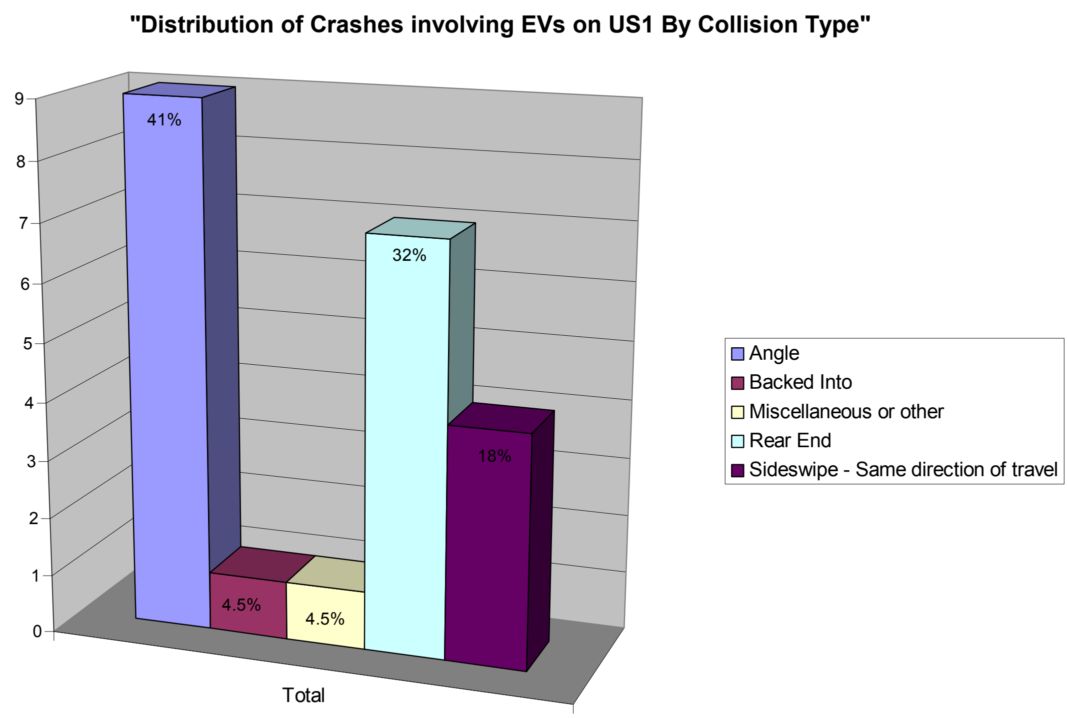


Figure 3.33. Distribution of Crashes involving EVs on U.S.1, Fairfax County by Collision Type.

Figure 3.34 presents the distribution of the total 22 crashes involving emergency vehicles that occurred on U.S.1, Fairfax County by crash severity. It can be observed that the majority of crashes were not of great severity: in 73% of all crashes (16 crashes), there was no visible injury, while 27% of the crashes (6 crashes) resulted in a visible injury.

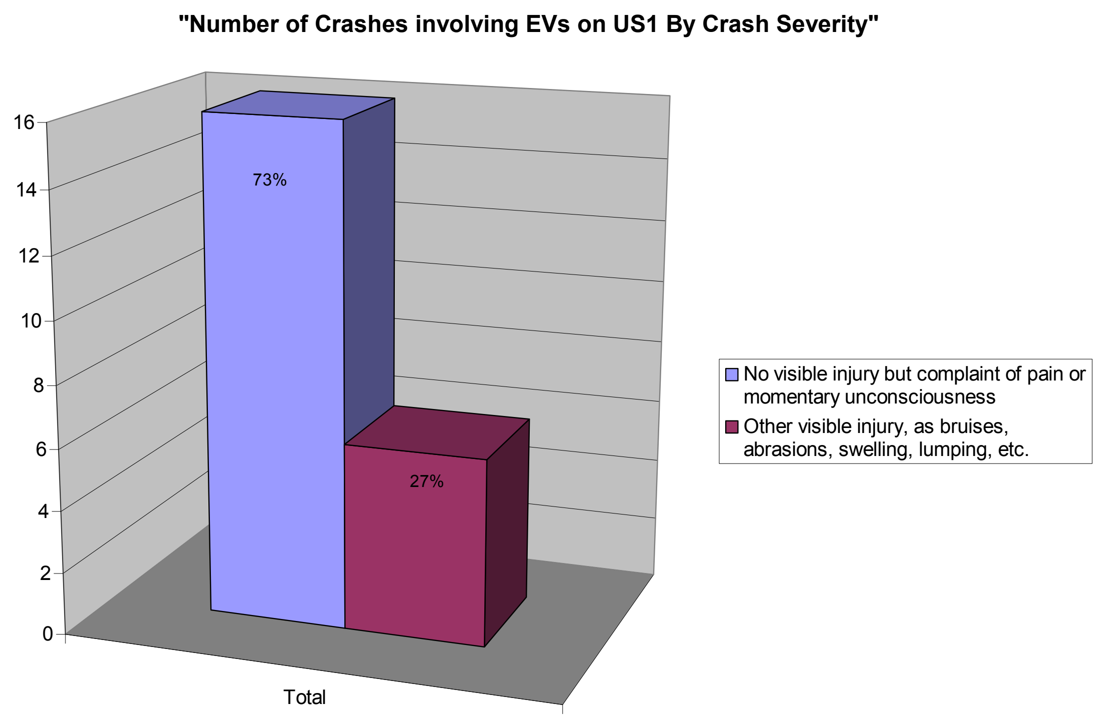


Figure 3.34. Distribution of Crashes involving EVs on U.S.1, Fairfax County by Crash Severity.

The following figure provides information on the major factor identified responsible for the crash. 73% of the crashes occurred due to driver's inattention or error; in one case the driver was speeding and in another case the driver was under the influence of alcohol. It should be noted that in only two crashes (9%) the road condition was considered the major factor responsible for the crash.

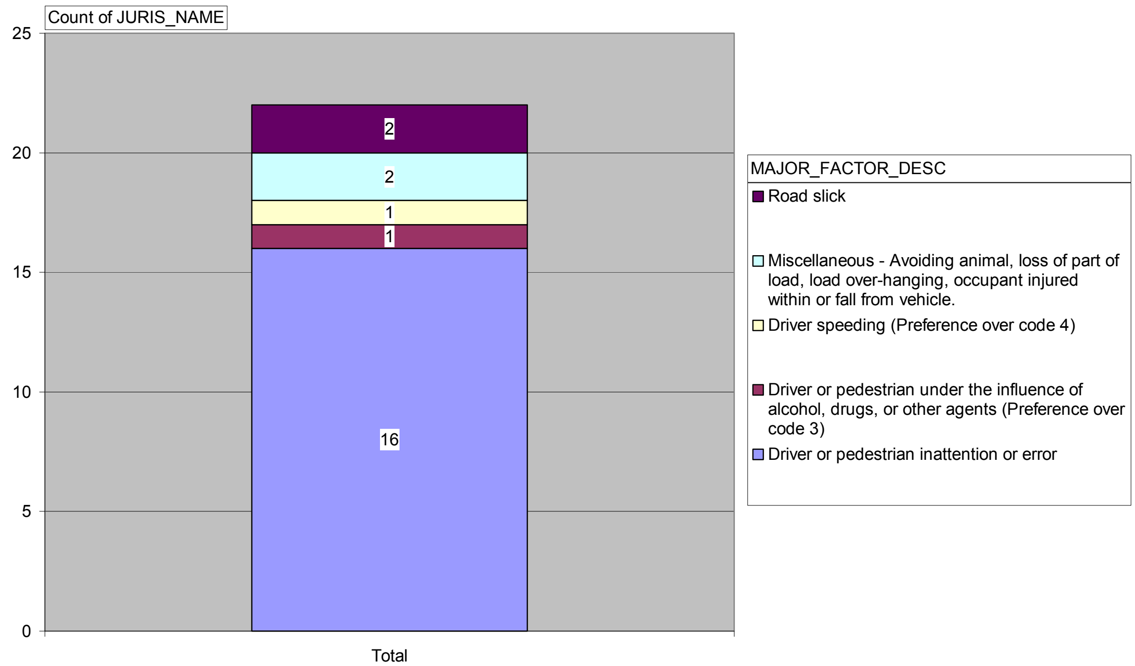


Figure 3.35. Major Factor responsible for Crashes involving EVs on U.S.1, Fairfax County.

As it was illustrated in Figure 3.34, the severity of crashes was rather low; there were no fatalities reported. Analyzing more thoroughly the data, it was found that in total there were 6 injury crashes that resulted in injuries to nine individuals. It is interesting to see that when only two vehicles were involved in a crash, there were more injuries than in the case where three vehicles were involved. In total, in 86% of all crashes two vehicles were involved. Figure 3.36 illustrates the above observations.

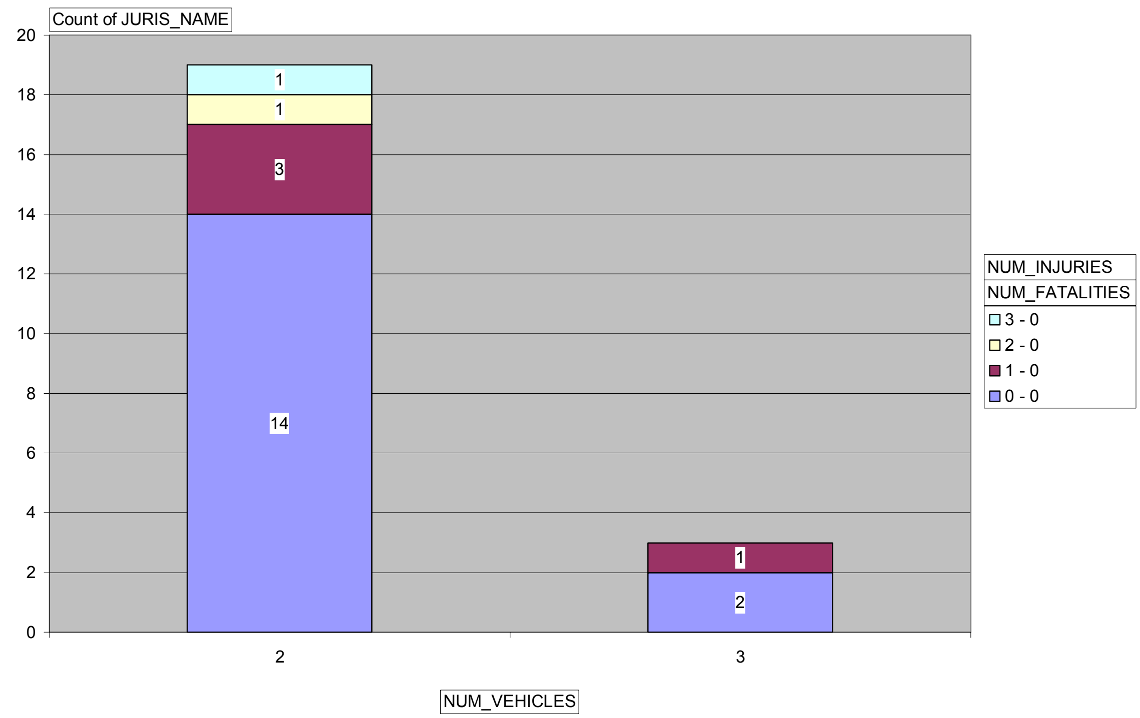


Figure 3.36. Number of Fatalities and Injuries per Number of Vehicles involved in the crash.

Of the 22 crashes involving emergency vehicles on U.S.1 during the period 1997-2001 a total damage cost of $124,570 was estimated; on average, this cost is about $5,700 per crash. As it can be observed in the following figure, there were crashes of cost as low as $250 to as high as $21,000. This finding reinforces the notion that providing a safer movement of emergency vehicles can save money to the Fire and Rescue Community, money that could be possibly allocated in improving emergency vehicle operations. A detailed benefit cost analysis would better assess the situation.

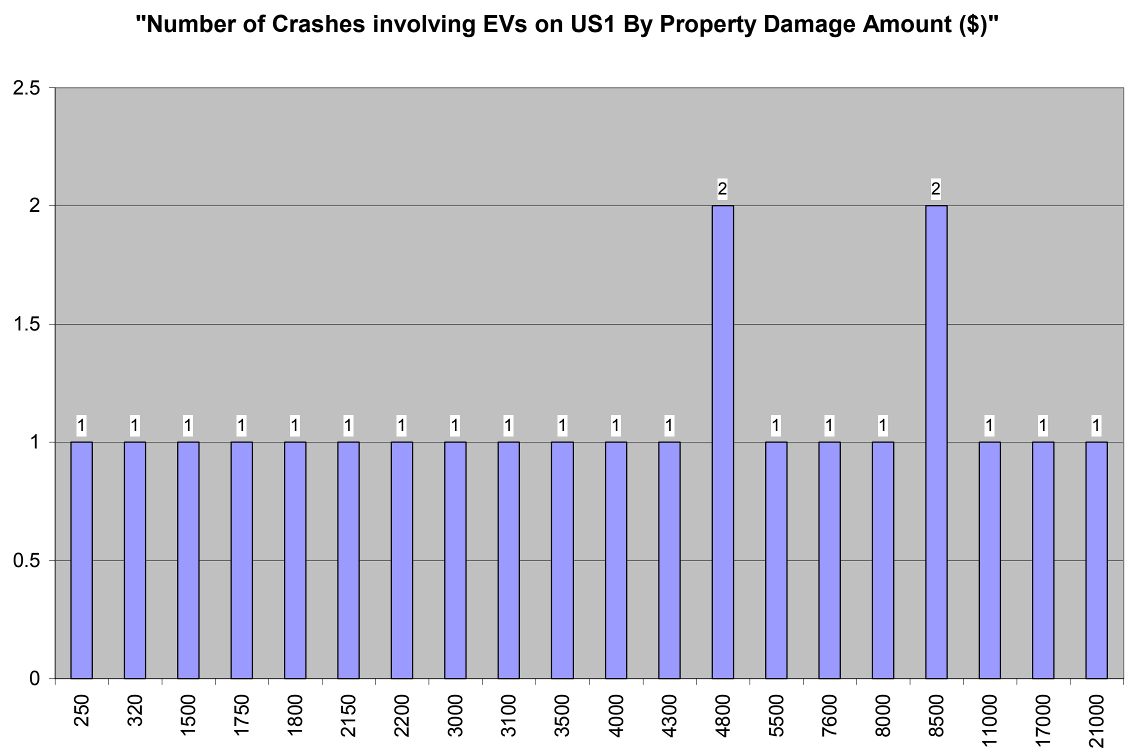


Figure 3.37. Distribution of Crashes involving EVs on U.S.1, Fairfax County by Property Damage Amount.

Another important consideration when analyzing crash data is identifying the type of location where the crashes occurred. It is of great interest to gather information on whether the crashes occurred at an intersection and whether the intersection was a signalized one; and furthermore, on what type of facility, with what type of access control and number of lanes. The answers to all these questions are presented in Figures 3.38 and 3.39. It can be observed that out of the total number of crashes occurred at intersections (14 crashes), 11 (79%) of them occurred at signalized ones. This finding is of great interest and can be useful information for public agencies and traffic engineers wondering whether a preemption system at traffic signals can be also beneficial for the safety of emergency vehicles, apart from improving their response times.

Moreover, it can be observed from Figure 3.39 that 64% of the crashes occurred on a divided type of facility with no control of access, with the majority of crashes (11 crashes) having occurred at a 6-lane segment.

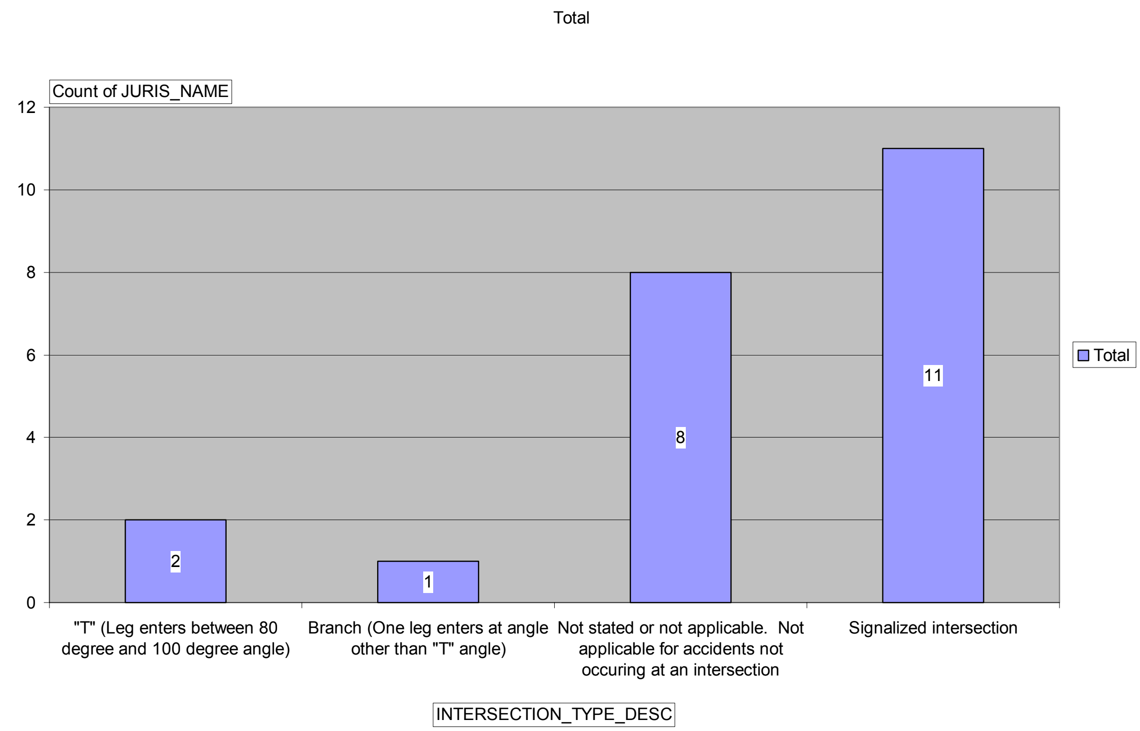


Figure 3.38. Distribution of Crashes by Type of Location and Intersection.

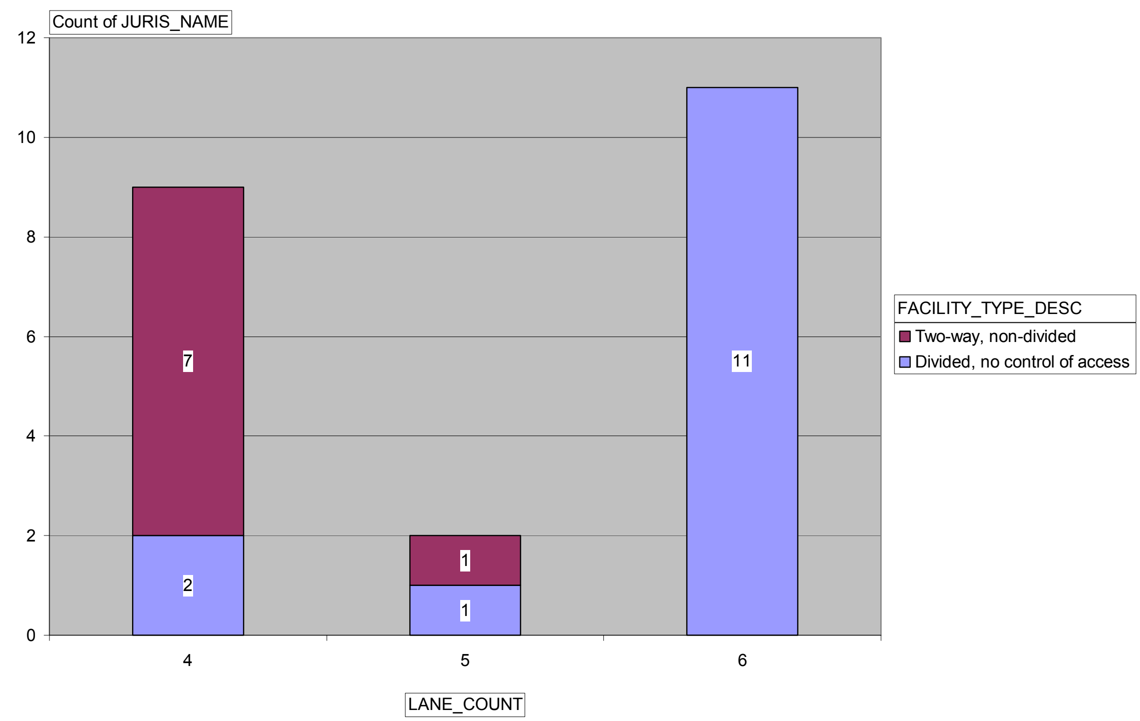


Figure 3.39. Distribution of Crashes by Type of Facility and Number of Lanes.

Figure 3.40 illustrates the weather and lighting conditions that prevailed at the time of each crash. It can be observed that 10 crashes (46%) occurred during the daytime and 12 (54%) during the nighttime. In 2 crashes out of 12 that occurred in darkness, the street or highway was not lighted. Regarding the weather conditions, in 55% of all cases the weather was stated as clear (there were no clouds, rain or snow reported).

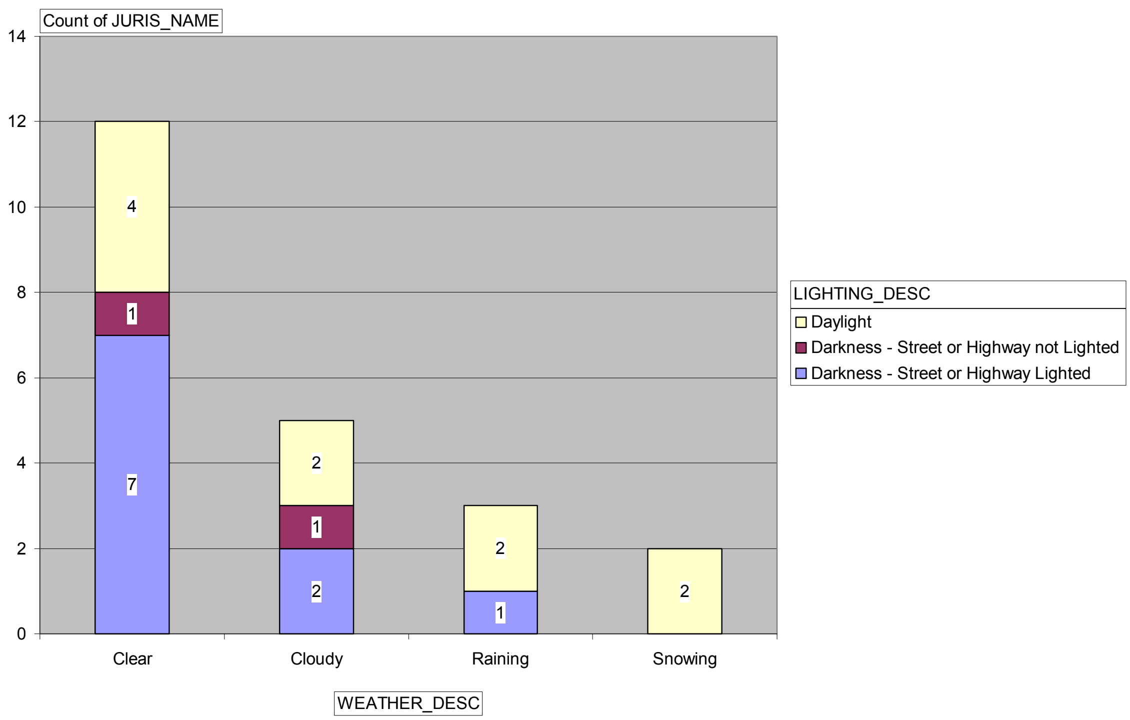


Figure 3.40. Weather and Lighting Conditions at the time of crash.

The following figure provides information on the type and condition of the surface of the pavement of the street or highway where the crashes took place. It appears that in most cases (21 crashes) the surface was of plant mix (bituminous concrete and sand asphalt). Moreover, it can be observed that 73% of all crashes (16 crashes) have occurred on a dry road surface.

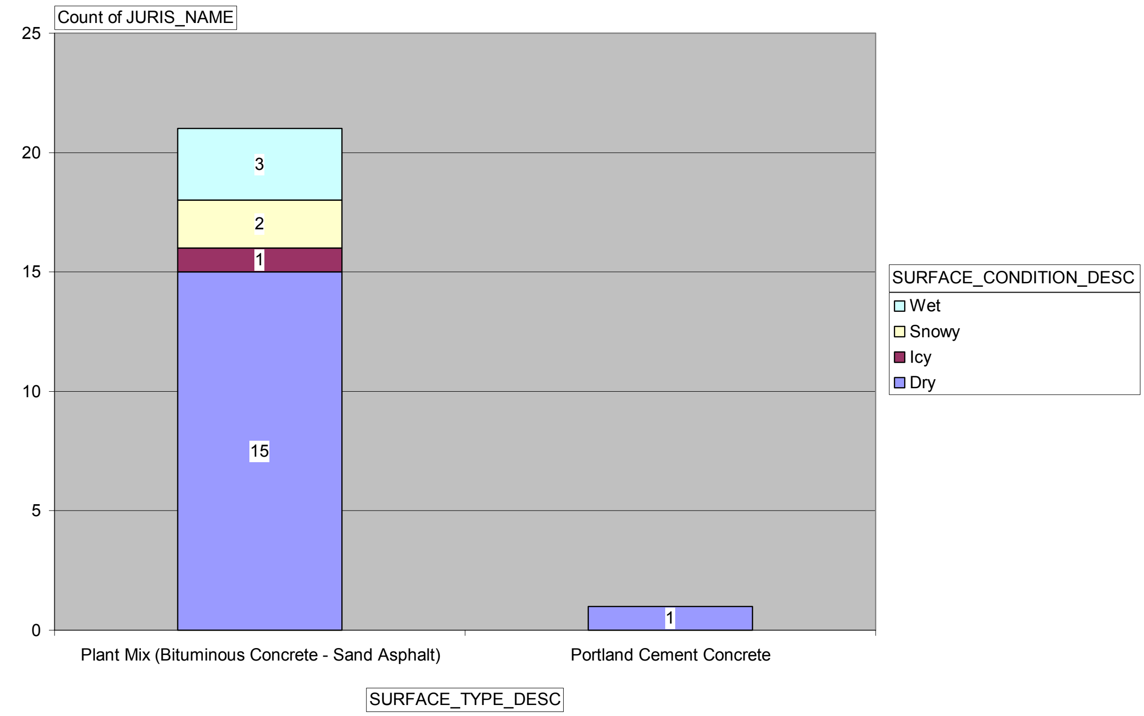


Figure 3.41. Surface Type and Condition of Road Pavement.

A final observation that can be conveyed by analyzing the crash data under study pertains to two other characteristics of the road: road alignment and defects. As it is illustrated in the following figure, 54% of all crashes (12 crashes) occurred on a straight level and in 95% of the cases (21 crashes) the road appeared to exhibit no defects.

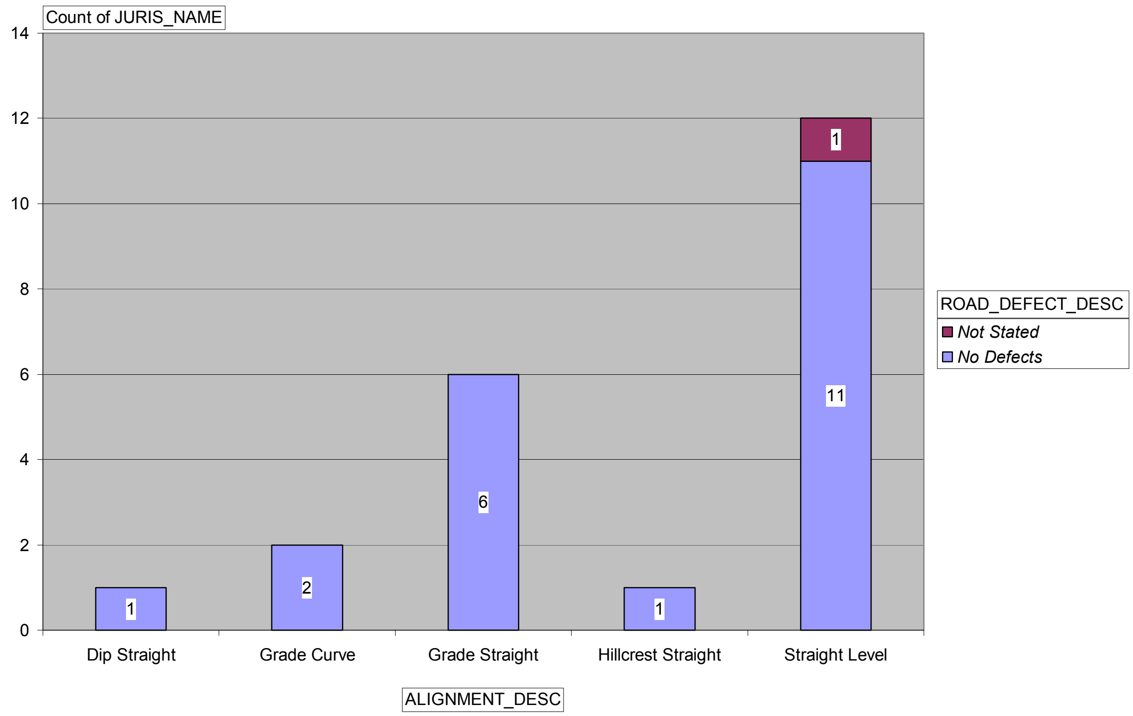


Figure 3.42. Alignment and Road Defects.

3.6.4 Major Findings and Results

The findings of the analysis of the emergency vehicle crash data, obtained from the Virginia Department of Transportation (VDOT) for a five-year period 1997-2001 are summarized below:

- ✓ The crash situation involving emergency vehicles worsened from 1998 to 2000 on U.S.1 in Fairfax County, Virginia. In total, they were reported 22 crashes during the period of study.
- ✓ There were no fatalities reported. In total there were 6 injury crashes that resulted in injuries to nine individuals. In addition, in 86% of all crashes two vehicles were involved.
- ✓ The total damage cost of the 22 crashes is $124,570; on average, this cost is about $5,700 per crash.

- ✓ More crashes (41%) were identified as angle type in comparison to other types of collision such as rear end or sideswipe.
- ✓ Out of the total number of crashes occurred at intersections (14 crashes), 11 (79%) of them occurred at signalized ones.
- ✓ 73% of all crashes occurred due to driver's inattention or error; in only two crashes (9%) the road condition was considered the major factor responsible for the crash.
- ✓ 64% of the crashes occurred on a divided type of facility with no control of access, with the majority of crashes (11 crashes) having occurred at a 6-lane segment.
- ✓ 10 crashes (46%) occurred during daytime and 12 (54%) during nighttime among which, in 2 cases the street or highway was not lighted. In 55% of all cases the weather was stated as clear (there were no clouds, rain or snow reported).
- ✓ 73% of all crashes (16 crashes) occurred on a dry road surface; 54% of all crashes (12 crashes) occurred on a straight level; and in 95% of the cases (21 crashes) the road appeared to exhibit no defects.

3.7 Summary of Findings

The major findings of the analysis pertaining to emergency vehicles characteristics, in terms of both traffic operations and safety, are summarized below:

1. **The characteristics of emergency vehicle trip generation in terms of temporal distribution of emergency vehicle travel vary by Fire Station.**
   Fire Stations 9 and 11 received on average per day nearly the same number of calls (25.5 and 25.8 calls, respectively); twice as many as Fire Station 24 received on average per day (13.3 calls). The temporal distribution of emergency vehicle travel by time of day, day of week and month of year exhibits significant variability among the three fire stations.

2. **The frequency of emergency calls is higher during the daytime, with higher frequency during the PM peak period than the AM peak period.**

The pattern of variation of emergency calls over the course of day is very useful in an analysis of projected traffic conditions for both emergency vehicles and other vehicles. A higher frequency of emergency calls during the daytime is likely to result in greater implications to the other traffic since the traffic is more during the daytime. In turn, because of higher levels of traffic during the daytime, emergency vehicle response times are anticipated to be higher in comparison to nighttime. Thus, it becomes more difficult for the fire and emergency medical services personnel to reach an incident during the daytime in less than the "target response time" set by the Fire & Rescue Department. Effective implementation of operational improvements, such as signal preemption systems, can enhance the performance of the emergency vehicle operations in terms of reduced response times and thus, provide a better environment for just in-time delivery.

3. **Heavy emergency vehicles are garaged at all three fire stations; at least one is involved in each response.**

   Each fire station has heavy rescue vehicles and ladder mounted trucks with heavy axle weights, large turning radii and low acceleration rates, which make the navigation of the emergency vehicle difficult through congested intersections. Furthermore, vehicles of larger size are likely to impact more the other traffic since they require more road space. Since at least one large vehicle was found to be included in each platoon per emergency call, we can conclude that the need for emergency vehicle preemption to facilitate heavy vehicle movements (especially, turning ones) is warranted.

4. **The crash situation involving emergency vehicles worsened from 1998 to 2000 on U.S.1 in Fairfax County, Virginia; more crashes occurred at signalized intersections and were of the angle type.**

   From 1998 to 2000 the number of emergency vehicles involved in a crash on U.S.1, Fairfax County increased. Thus, the safe movement of emergency vehicles along this corridor is an issue that needs to be addressed. The majority of crashes (64%) occurred at intersections, most of which (79%) occurred at signalized ones.

Furthermore, more crashes (9 out of total 22) were identified as angle type in comparison to other types of collision such as rear end or sideswipe. This suggests that more crashes occurred when the emergency vehicle was maneuvering trying to pass vehicles or was making a left turn. This information can be useful to traffic engineers considering a preemption system at signalized intersections for safety purposes.

5. **The frequency of emergency vehicle preemption varies by time of day; it is lower during the AM peak period than the other time periods of the day.**

   The daily occurrence of preemption requests fluctuates from 6 to 12 requests per day; thus, the disruption to the other traffic is anticipated to be low or even negligible. The frequency of preemption requests varies by time of day; it is lower during the AM peak period at all intersections (up to one request in three hours); during the other three time periods of the day it ranges between one and two requests in three hours.

6. **Very few emergency vehicle preemption requests are denied**.

   The number of preemption requests denied is very low; it ranges from 1 to 2% of the total number of requests. In most cases, it appears that the reason for a request been denied is when having two or more simultaneous preemption requests. Another reason that was identified is a low measured intensity of an emitter's signal during the whole time of the call; a threshold of intensity equal to 200 has been set below which, the preemption request might be denied. In a few cases, a request was probably denied when made within the pedestrian phase.

7. **The average duration of emergency vehicle preemptions is lower than expected with no significant variability by time of day.**

   The average duration of preemptions is lower than expected; on average, it ranges from 16 to 26 sec, depending on the intersection. Since the length of time required to serve a preemption control plan and transition back to the coordinated operation of the normal signal timing plan is small, the disruption to the traffic signal timing is anticipated to be low and the impact to the side-street traffic minimal.

8. **The size of vehicle platoons per preemption request on U.S.1 is relatively small; in most cases each platoon included only one emergency vehicle.**

   In 73% of the cases under study each platoon included only one emergency vehicle. This finding can be considered a positive sign for the traffic engineers engaged with preemption systems as it indicates that in most cases the duration of preemption would be low resulting in less disruption to traffic signal timing and in consequence, to the traffic. In addition, it appears that the likelihood of having some requests denied because of interference with another request is relatively low.

9. **The characteristics of emergency vehicle preemption requests are dependent on the proximity of a firehouse to an intersection and other factors.**

   Both the frequency of emergency preemption requests and the average duration of preemptions are dependent on the intersection where the preemption system is installed. This fact could be attributed in several factors including the proximity of the firehouse to the intersection, roadway geometrics, traffic characteristics and traffic control capabilities at the intersection at which the preemption system is deployed. There is also some variability of these characteristics by geographic location; a finding with practical implications that need to be considered in the design and deployment of emergency vehicle preemption systems as well as for future research.

10. **The frequency as well as the average duration of transit priority requests is lower than expected**.

    The average daily occurrence of priority requests ranges from 4 to 18 requests, depending on the intersection. The average length of the priority phase is also low; it lies between 15 and 28 sec, depending on the intersection.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Response time is a prime measure of emergency vehicle operational efficiency. Emergency response times in many States are threatened by a growing population, outdated technology and tight budgets. This is especially important in the National Capital Region where heavy traffic is considered a thorn in the side of firefighters and paramedics. The heavy traffic levels experienced during peak periods have a negative impact on emergency vehicle response times. Concerns about increased emergency vehicle response times in the region have led to the implementation of traffic signal control strategies, such as signal preemption systems, to facilitate the efficient and safe movement of emergency vehicles, as well as to resolve the challenges that gridlock situations present to drivers of emergency vehicles.

Understanding the travel characteristics of emergency vehicles is an important and fundamental element in designing and deploying an emergency signal preemption system. In reviewing the current state of art, it was found that adequate guidelines or criteria have not been developed for the placement of emergency vehicle preemption systems at existing signalized intersections. Transportation planners and engineers need knowledge and tools to assist in identifying emergency vehicle preemption candidate intersections based on traffic operations and safety objectives. This research presents the results of an analysis of emergency vehicle operations in the Washington D.C. Region to assist traffic engineers, as well as other public officials contemplating the design and deployment of preemption systems.

The analysis of the emergency vehicle characteristics in the Washington D.C. Region revealed the following:

- The characteristics of emergency vehicle trip generation in terms of temporal distribution of emergency vehicle travel vary by fire station.
- The frequency of emergency calls is higher during the daytime than the nighttime, with higher frequency during the PM peak period (on average, two calls per hour) than the AM peak period (on average, one call per hour).

- Heavy emergency vehicles are garaged at all three fire stations; at least one heavy emergency vehicle is involved in each response. Heavy emergency vehicles are difficult to maneuver and impact the traffic more than do other emergency vehicles.
- The crash situation involving emergency vehicles worsened from 1998 to 2000 on U.S.1 in Fairfax County, Virginia. Most crashes occurred at intersections (64%), most of which were signalized (79%); in addition, more crashes were identified as angle type (41%) in comparison to other collision types such as rear end or sideswipe.
- The frequency of emergency vehicle preemption requests on U.S.1 is lower during the AM peak period at all intersections (up to one request in three hours) than the other time periods of the day (between one and two requests in three hours).
- Very few emergency vehicle preemption requests on U.S.1 are denied (1 to 2%).
- The average duration of emergency vehicle preemptions on U.S.1 is lower than expected; on average, it ranges from 16 to 26 sec with no significant variability by time of day. The relatively short duration is expected to contribute to a shorter transition-recovery period.
- The size of vehicle platoons per preemption request on U.S.1 is relatively small; in 73% of the cases, each platoon included only one emergency vehicle.
- The characteristics of emergency vehicle preemption requests are dependent on the conditions specific to each intersection at which the preemption system is installed. There is also some variability of the frequency as well as the average duration of preemption requests by geographic location. This could be attributed to several factors including the proximity of the firehouse to the intersection, roadway geometrics, traffic characteristics, traffic control capabilities as well as to the size of the emergency vehicle platoons responding to an incident.

It can be suggested that the need exists for a preemption system to enhance the performance of emergency vehicle operations along U.S.1 in Fairfax County, Virginia, considering the critical factors affecting the need for preemption including emergency runs and time of day; emergency vehicle crash history; and heavy emergency vehicles.

A major concern pertaining to the deployment of signal preemption systems pertains to the implications that such systems could have on the general-purpose traffic. Preempting a traffic signal will unconditionally interrupt the normal timing plan by inserting a special plan or phase to accommodate a request from an emergency vehicle that has the potential to affect negatively the flow of traffic *(30)*. It is important to point out that the impacts of emergency vehicle preemption on the general-purpose traffic will be related to several factors including:

- Frequency of preemption requests; the lower the number of preemption requests the less the impact on the other traffic.
- Platoon responses; the smaller the size of vehicle platoons the shorter the duration of the preemption phase.
- Average duration of preemption phases; the shorter the duration of the preemption phase the less the disruption to the traffic signal timing.
- Transition strategy selected; the shorter the time required to serve a preemption control plan and transition back to the coordinated operation of the normal signal timing plan, the less the impact on the traveling public.
- Side street volume.

The analysis of emergency vehicle preemption requests on U.S.1 suggests that the disruption to the other traffic is anticipated to be low or even negligible. Field results from a preemption study on U.S.1 on delay and queue lengths on the side streets reinforce the above notion *(31, 35)*.

The results of this research can provide the platform to examine the potential for the development of warrants to be used in determining the appropriateness of installing signal preemption systems at signalized intersections. The main factors that need to be examined in the consideration of warrants include: emergency vehicle response times; frequency of emergency runs and platoon responses; crashes involving emergency vehicles; and geometrics and operating characteristics of the candidate intersection such as width, shoulder areas, sight distance, intersection spacing, volumes, signal phasing, and transitioning strategies to exit preemption control.

Finally, consideration must also be given to the investment requirements associated with emergency vehicle preemption installation and operation. Such an installation needs to identify the directions of flow to be provided emergency vehicle preemption 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 emergency vehicle preemption system selected and the vendor.

4.2 Recommendations For Future Research

While this research has provided a foundation for understanding the characteristics of emergency vehicle travel and operations in the Washington DC Metropolitan area, it is proposed that future efforts build upon this research. Some of the potential areas for future research are mentioned here:

- Further research is needed to evaluate the performance of the signal preemption systems deployed at intersections on U.S.1 in terms of improvements in response times and in safety. The origins and destinations of emergency vehicle travel should be studied as part of the trip distribution process to assess any benefits accrued in travel time as well as on operating speeds. Furthermore, it is of great interest to study the crash situation on U.S.1 for some time after the deployment of emergency vehicle preemption in order to offer quantitative results in terms of crash reductions.
- A similar study at some other location with similar operating conditions, including the use of a signal preemption system, should be conducted and a comparison should be made between the two studies. This comparative analysis would help in enhancing our understanding of the characteristics of emergency vehicle travel and preemption strategies and how these characteristics vary by geographic location.
- It is also recommended that a study be conducted some time after the deployment of transit priority along this corridor (with more data available) to assess the functionality of both systems. Considerations for overlap detections can be useful in enhancing the system’s performance.

- Finally, findings and results need to be documented and translated to warrants for the purpose of assisting public agencies and practicing professionals contemplating the design and deployment of traffic signal preemption systems; Institutional challenges, traffic characteristics, traffic signal control capabilities, operational limitations, and roadway geometric constraints should be included in this consideration of warrants.

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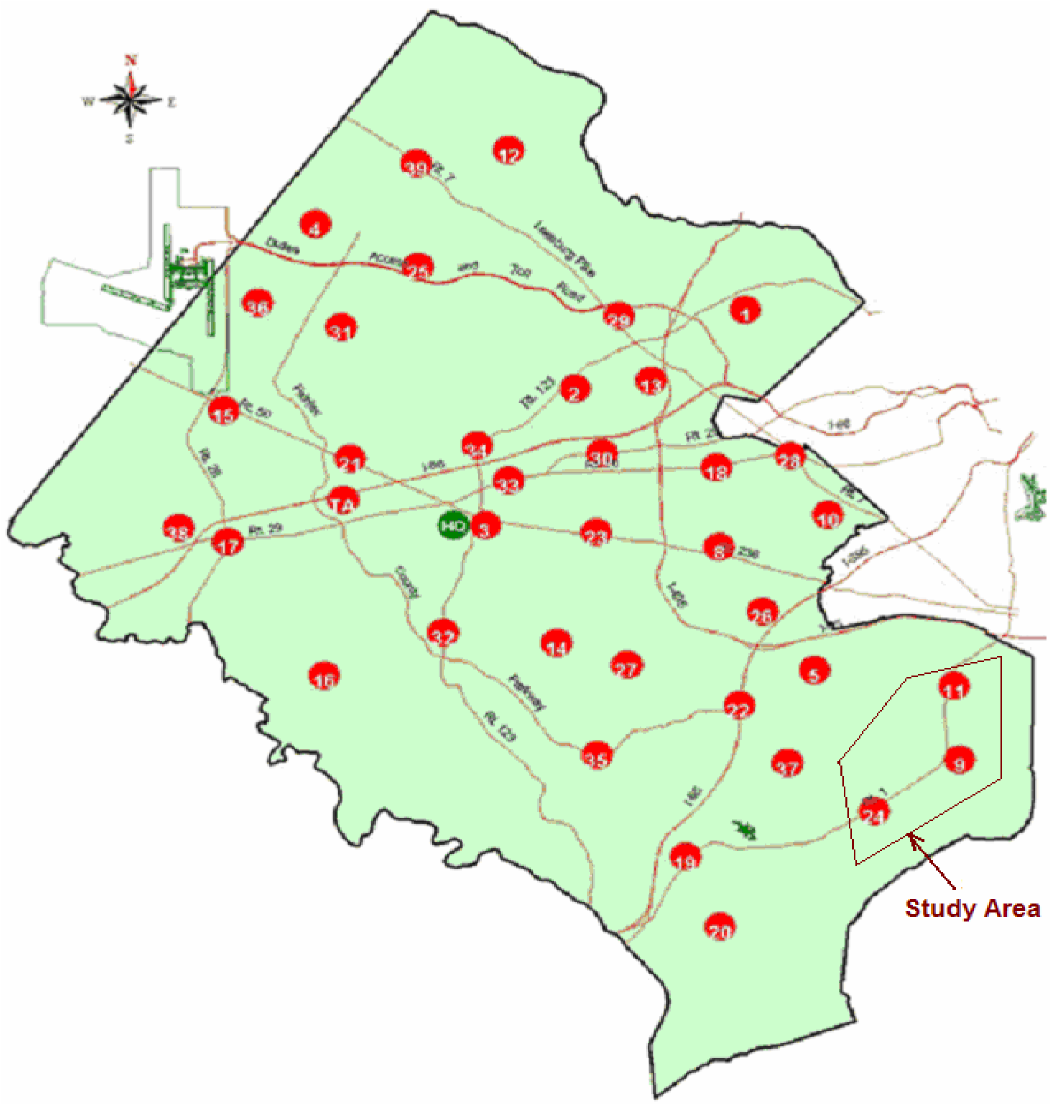
Appendix A

Analysis of Emergency Response Log Data From 3 Fire Stations on U.S. 1, Fairfax County, VA

Appendix A1. Study Area Map *(39)*.

Appendix A2. Fairfax County Fire Station Locations *(39)*.



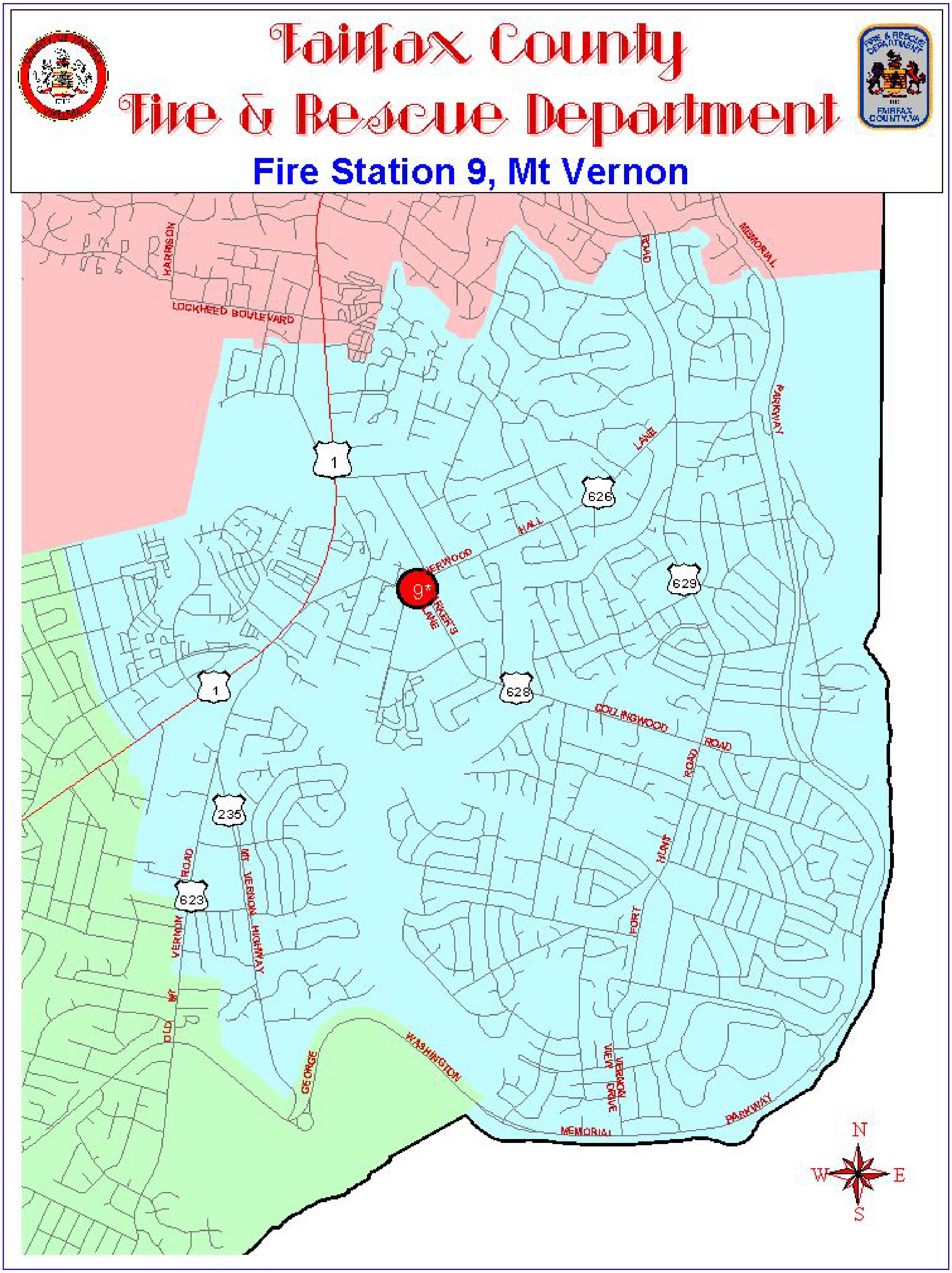
❖ ***Fire Station Locations:***

Mount Vernon, Station 9:2601 Sherwood Hall La.,Alexandria, VA 22306-3143

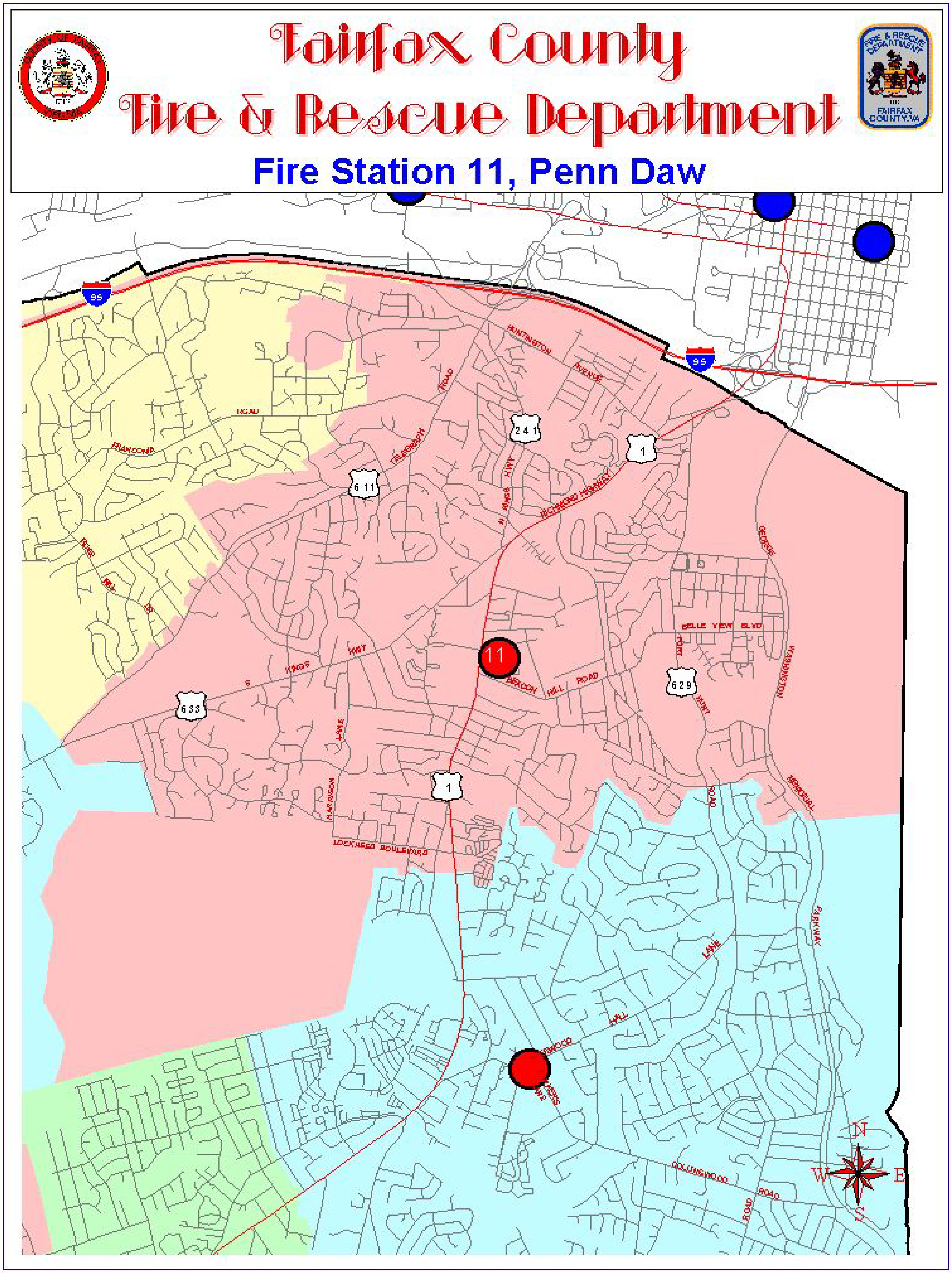
Penn Daw, Station 11: 6624 Hulvey Terrace, Alexandria, VA 22306-6631

Woodlawn, Station 24: 8701 Lukens Lane, Alexandria, VA 22309-4100

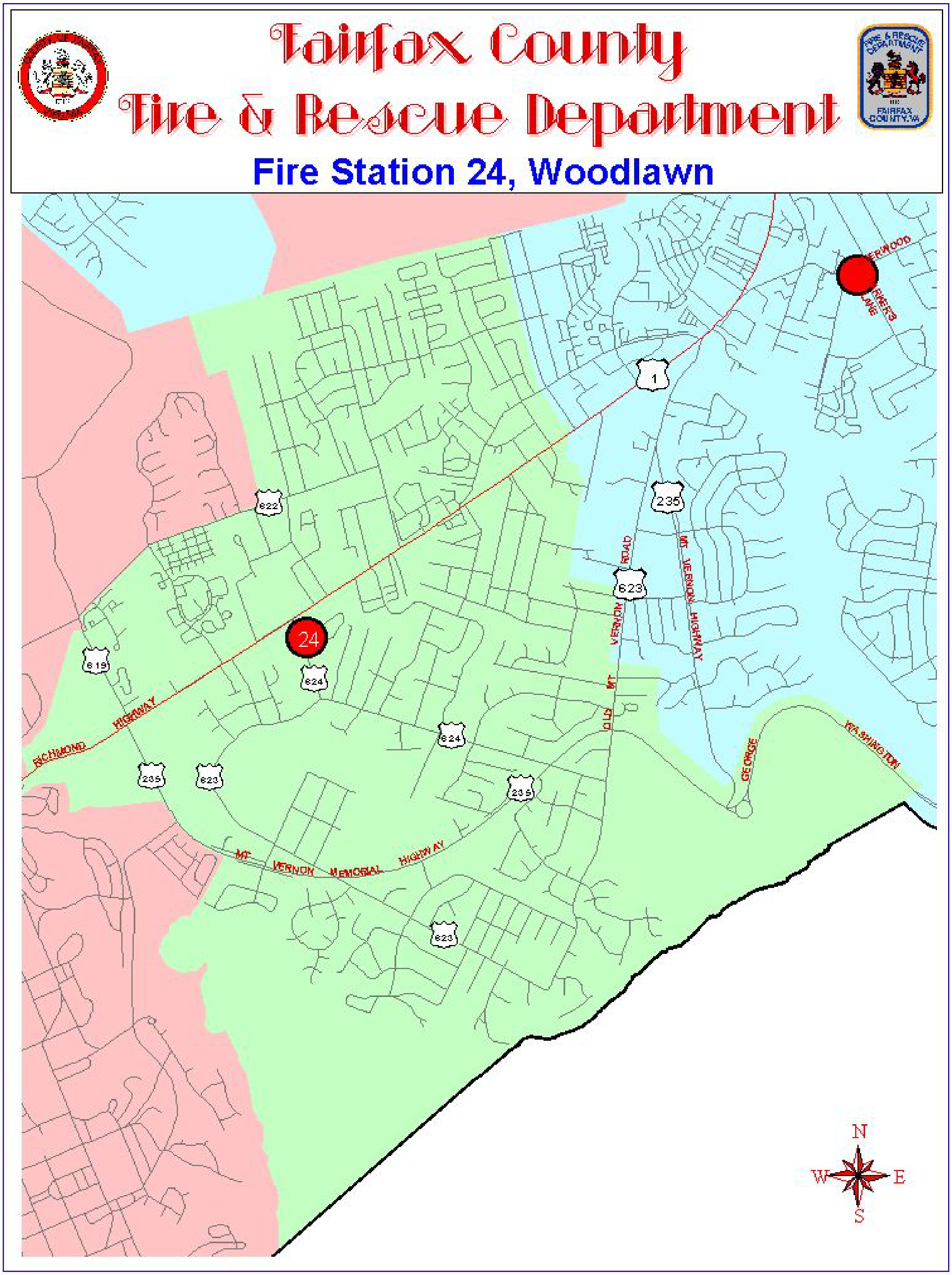
Appendix A3. Service Area of Fire Station 9.



Appendix A4. Service Area of Fire Station 11.



Appendix A5. Service Area of Fire Station 24.



Appendix A6. Sample of the Emergency Call Data Obtained from Fire and Rescue Department.

Firebox	Incident_Number	Event_Type	Dispatch_Hour	Day_of_Week	Location	Month	Unit_ID
0900	20000160001	ALS	0	1	1510 DARE	1	M409
0900	20000160001	ALS	0	1	1510 DARE	1	E409
0900	20000230051	FIR	0	1	3007 WES	1	T411
0900	20000230051	FIR	0	1	3007 WES	1	E409
0900	20000230051	FIR	0	1	3007 WES	1	E424
0900	20000230051	FIR	0	1	3007 WES	1	R411
0900	20000230051	FIR	0	1	3007 WES	1	A409
0900	20000230051	FIR	0	1	3007 WES	1	E411
0900	20000230051	FIR	0	1	3007 WES	1	BC06
0900	20000230051	FIR	0	1	3007 WES	1	EMS6
0900	20000440046	ALS	0	1	3037 FORD	2	M409
0900	20000440046	ALS	0	1	3037 FORD	2	E409
0900	20000930011	ALS	0	1	7703 RIDG	4	M409
0900	20000930011	ALS	0	1	7703 RIDG	4	EMS6
0900	20000930011	ALS	0	1	7703 RIDG	4	E409
0900	20001000045	ALS	0	1	1510 COLL	4	E409
0900	20001000045	ALS	0	1	1510 COLL	4	M409
0900	20002820028	ALS	0	1	8112 WELI	10	E409
0900	20002820028	ALS	0	1	8112 WELI	10	M409
0900	20003030022	BLS	0	1	2511 PARK	10	A409
0900	20003310035	FIR	0	1	2500 PARK	11	E411
0900	20003310035	FIR	0	1	2500 PARK	11	T411
0900	20003310035	FIR	0	1	2500 PARK	11	E424
0900	20003520042	ALS	0	1	1510 COLL	12	E409
0900	20003520042	ALS	0	1	1510 COLL	12	M409
0900	20000230142	FIR	1	1	2500 PARK	1	E411
0900	20000230142	FIR	1	1	2500 PARK	1	T411
0900	20000230142	FIR	1	1	2500 PARK	1	E409
0900	20000510134	ALS	1	1	8500 CON(	2	E409
0900	20000510134	ALS	1	1	8500 CON(	2	M409
0900	20001490096	ALS	1	1	8111 TIS W	5	M409
0900	20001490096	ALS	1	1	8111 TIS W	5	E409
0900	20002750115	BLS	1	1	2511 PARK	10	A411
0900	20002750115	BLS	1	1	2511 PARK	10	M409
0900	20000020198	ALS	2	1	1116 GLAD	1	E409
0900	20000020198	ALS	2	1	1116 GLAD	1	M409
0900	20001560182	BLS	2	1	1116 GLAD	6	A409
0900	20002190193	BLS	2	1	2511 PARK	8	M409
0900	20002330202	BLS	2	1	2511 PARK	8	A409
0900	20002400184	FIR	2	1	7837 KENT	8	E409
0900	20000440298	ALS	3	1	2416 SHEF	2	E409
0900	20000440298	ALS	3	1	2416 SHEF	2	M409
0900	20000930178	ALS	3	1	1801 STRA	4	M409
0900	20000930178	ALS	3	1	1801 STRA	4	E409
0900	20001840263	BLS	3	1	2511 PARK	7	A409
0900	20001910322	FIR	3	1	1301 COLL	7	T411
0900	20001910322	FIR	3	1	1301 COLL	7	E409
0900	20002260289	BLS	3	1	8201 CHOI	8	A409
0900	20000300290	ALS	4	1	1800 COLL	1	E409
0900	20000300290	ALS	4	1	1800 COLL	1	M409
0900	20001700314	BLS	4	1	2511 PARK	6	A409
0900	20001910352	ALS	4	1	8208 HOLL	7	M409

Appendix A7. Julian Date Calendar

(http://www.dscr.dla.mil/sbo1/julian_date_calendar.htm).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

Appendix A8. Types of Emergency Vehicles *(35)*.

The various types of Emergency Vehicles present at Fire Stations are as follows:

1. Ambulance/ Advanced Life Support (A)

Ambulance is an emergency vehicle with advanced skills to provide service to paramedics, usually to intervene in life threatening situation. It is also used to transport patients in medical emergencies.

Fig. A8.1. Ambulance/ Advanced Life Support (A)

2. Rescue Engine (R)

It is a vehicle that is equipped to perform both as a fire engine and a heavy rescue squad. It is designed to handle fire suppression, vehicle rescue, forcible entry and medical emergencies.

Fig. A8.2. Rescue Engine (R)

3. Fire Truck equipped with ladder (T)

This type of vehicle is equipped with a ladder. It is designed to handle fire suppression in multi storied buildings and apartments

Fig. A8.3. Fire Truck equipped with ladder (T)

4. Engine / Paramedic Engine (E)

Every fire engine is 'Advanced Life Support' equipped with life saving equipment and at least one Paramedic.

Fig. A8.4. Engine / Paramedic Engine (E)

5. Medic (M)

This type of emergency vehicle is used to transport emergency medical patients.

Fig. A8.5. Medic (M)

Table A8.1. Summary of Emergency Vehicle Characteristics.

	Ambulance (A)	Rescue Engine (R)	Fire Truck (T)	Engine (E)	Medic (M)
Axle Weight					
Front Axle	4500 lbs	14000 lbs	18000 lbs	14000 lbs	9000 lbs
Rear Axle	6000 lbs	26000 lbs	45000 lbs	22000 lbs	13000 lbs
Total	10500 lbs	40000 lbs	63000 lbs	36000 lbs	21000 lbs
Turning Radius	27’0”	40’0”	49’0”	40’0”	30’0’’
Overall height	9’4”	11’0”	11’0”	10’0”	10’0”
Overall Width	8’0”	8’0”	8’0”	8’0”	8’0”
Overall Length	25’0”	34’0”	45’6”	34’0”	24’0”

Table A8.1 displays the engineering characteristics of the various types of emergency vehicles at fire station 411. These vehicles vary in terms of weight and vehicle dimensions. Some vehicles are heavier and larger than the others. Heavy vehicles have low acceleration rate. Low acceleration rate and large size of the emergency vehicle reduce the capability of EV to maneuver smoothly through traffic. Moreover, the larger vehicles require more road space and it is important that there be minimum obstruction to these vehicles for easy and safe passage of the emergency vehicle.

The other types of emergency vehicles, which are not present at fire station 411 but are, owned by other fire stations in Fairfax County, are as follows:

1. Command Function
2. Quint
3. Hazardous Material
4. Support (Repair) Vehicle
5. Platform on Demand

Appendix A9. Significance Tests.

The ANOVA analysis tool is a parametric testing methodology that requires assumptions to be made about the distributions of the population of interest and provides different types of variance analysis. The tool to use depends on the number of factors and the number of samples you have from the populations you want to test. The *ANOVA Two-Factor without Replication* Test performs a two-factor ANOVA that does not include more than one sampling per group, testing the hypothesis that means from two or more samples are equal (drawn from populations with the same mean). This technique expands on tests for two means, such as the t-test *(38)*.

A9.1. ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Hour of Day among the three Fire Stations.

ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Hour of Day among the three fire stations

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	557	185.6667	4830.333
Row 2	3	532	177.3333	3606.333
Row 3	3	485	161.6667	4762.333
Row 4	3	416	138.6667	2008.333
Row 5	3	344	114.6667	2502.333
Row 6	3	420	140	2676
Row 7	3	488	162.6667	9730.333
Row 8	3	689	229.6667	7445.333
Row 9	3	955	318.3333	12629.33
Row 10	3	1002	334	20275
Row 11	3	1296	432	19408
Row 12	3	1310	436.6667	13857.33
Row 13	3	1161	387	20059
Row 14	3	1088	362.6667	11342.33
Row 15	3	1401	467	26047
Row 16	3	1181	393.6667	8966.333
Row 17	3	1249	416.3333	7109.333
Row 18	3	1329	443	19047
Row 19	3	1455	485	27037
Row 20	3	1462	487.3333	20344.33
Row 21	3	1260	420	10633
Row 22	3	1066	355.3333	20510.33
Row 23	3	907	302.3333	9041.333
Row 24	3	575	191.6667	2002.333
Column 1	24	8633	359.7083	23389.95
Column 2	24	9177	382.375	21203.55
Column 3	24	4818	200.75	8136.891

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1111212	23	48313.56	21.87698	1.16E-17	1.766804
Columns	470153.4	2	235076.7	106.4457	5.52E-18	3.199588
Error	101587.3	46	2208.42			
Total	1682952	71				

Since F> Fcr. for both rows and columns (hours of day, fire stations),there is evidence to support the notion that there exists a significant difference at the 95% confidence interval in the frequency of emergency calls between different hours of day and among the three fire stations.

A9.2. ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Time of Day among the three Fire Stations.

ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Time of Day among the three fire stations

Anova: Two-Factor Without Replication

Row 1	3	2132	710.6667	82594.33
Row 2	3	4033	1344.333	145601.3
Row 3	3	3559	1186.333	133729.3
Row 4	3	3233	1077.667	111057.3
Column 1	4	4891	1222.75	130060.3
Column 2	4	5276	1319	61872
Column 3	4	2790	697.5	42574.33

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	652773.6	3	217591.2	25.72701	0.000798	4.757055
Columns	895218.5	2	447609.3	52.92332	0.000154	5.143249
Error	50746.17	6	8457.694			
Total	1598738	11				

Since F> Fcr. for both rows and columns (time periods of day, fire stations),there is evidence to support the notion that there exists a significant difference at the 95% confidence interval in the frequency of emergency calls between different time periods of day and among the three firestations.

A9.3. ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Day of Week among the three Fire Stations.

ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Day of Week among the three fire stations

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	3100	1033.333	122826.3
Row 2	3	3150	1050	110887
Row 3	3	3269	1089.667	110244.3
Row 4	3	3282	1094	127452
Row 5	3	3203	1067.667	161436.3
Row 6	3	3431	1143.667	123634.3
Row 7	3	3237	1079	73633
Column 1	7	8633	1233.286	7321.905
Column 2	7	9199	1314.143	2421.81
Column 3	7	4840	691.4286	3222.619

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	22718.29	6	3786.381	0.824924	0.572094	2.996117132
Columns	1605147	2	802573.5	174.8535	1.33E-09	3.885290312
Error	55079.71	12	4589.976			
Total	1682945	20				

Since F< Fcr. for rows (days of week),there is no evidence to support the notion that the frequency of emergency calls is different by day of week.
Since F> Fcr. for columns (fire stations),there is evidence to support the notion that the frequency of emergency calls per week is different among the three fire stations.

A9.4. ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Month of Year among the three Fire Stations.

ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Month of Year among the three fire stations

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	1923	641	55492
Row 2	3	1678	559.3333	24390.33
Row 3	3	1885	628.3333	23810.33
Row 4	3	1734	578	44181
Row 5	3	1848	616	45439
Row 6	3	2058	686	63675
Row 7	3	1817	605.6667	20881.33
Row 8	3	2160	720	66001
Row 9	3	1961	653.6667	30426.33
Row 10	3	1776	592	36081
Row 11	3	1887	629	39532
Row 12	3	1945	648.3333	39880.33
Column 1	12	8633	719.4167	5164.629
Column 2	12	9199	766.5833	3529.538
Column 3	12	4840	403.3333	1287.879

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	66558.89	11	6050.808	3.078322	0.011922	2.25851693
Columns	936335.7	2	468167.9	238.1784	1.24E-15	3.44336115
Error	43243.61	22	1965.619			
Total	1046138	35				

Since F> Fcr. for columns (fire stations),there is evidence to support the notion
that the frequency of emergency calls per month is different among the three fire stations.
The difference in the frequency of emergency calls received by each station
in different months of the year is rather marginal at the 95% confidence interval.

A9.5. ANOVA Testing the Sample Variability of the Distribution of Emergency Calls by Type of Event among the three Fire Stations.

ANOVA Testing the Sample Variability of Distribution of Emergency Calls By Type of Event among the three fire stations

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	6398	2132.667	587162.3
Row 2	3	11905	3968.333	1832556
Row 3	3	4369	1456.333	122390.3
Column 1	3	8633	2877.667	3270292
Column 2	3	9199	3066.333	1982610
Column 3	3	4840	1613.333	485156.3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	10137243	2	5068621	15.14293	0.013611	6.944276
Columns	3745343	2	1872671	5.594761	0.069348	6.944276
Error	1338875	4	334718.8			
Total	15221461	8				

Since F> Fcr. for rows (type of events),there is evidence to support the notion
that the distribution of emergency calls is different by type of event at the 95% confidence interval.
Since F< Fcr. for columns (fire stations),there is no evidence to support the notion
that the distribution of emergency calls by type of event is different among the three fire stations
at the 95% confidence interval.

A9.6. ANOVA Testing the Sample Variability of the Distribution of Emergency Calls by Type of Emergency Vehicle responding to an Incident among the three Fire Stations.

ANOVA Testing the Sample Variability of Distribution of Emergency Calls By Type of Emergency Vehicle responding to an incident among the three fire stations

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	3610	1203.333	230286.3
Row 2	3	1151	383.6667	107033.3
Row 3	3	1436	478.6667	9172.333
Row 4	3	7964	2654.667	797326.3
Row 5	3	6174	2058	208699
Row 6	3	2337	779	88336
Column 1	6	8633	1438.833	1428213
Column 2	6	9199	1533.167	900158.2
Column 3	6	4840	806.6667	390383.1

ANOVA

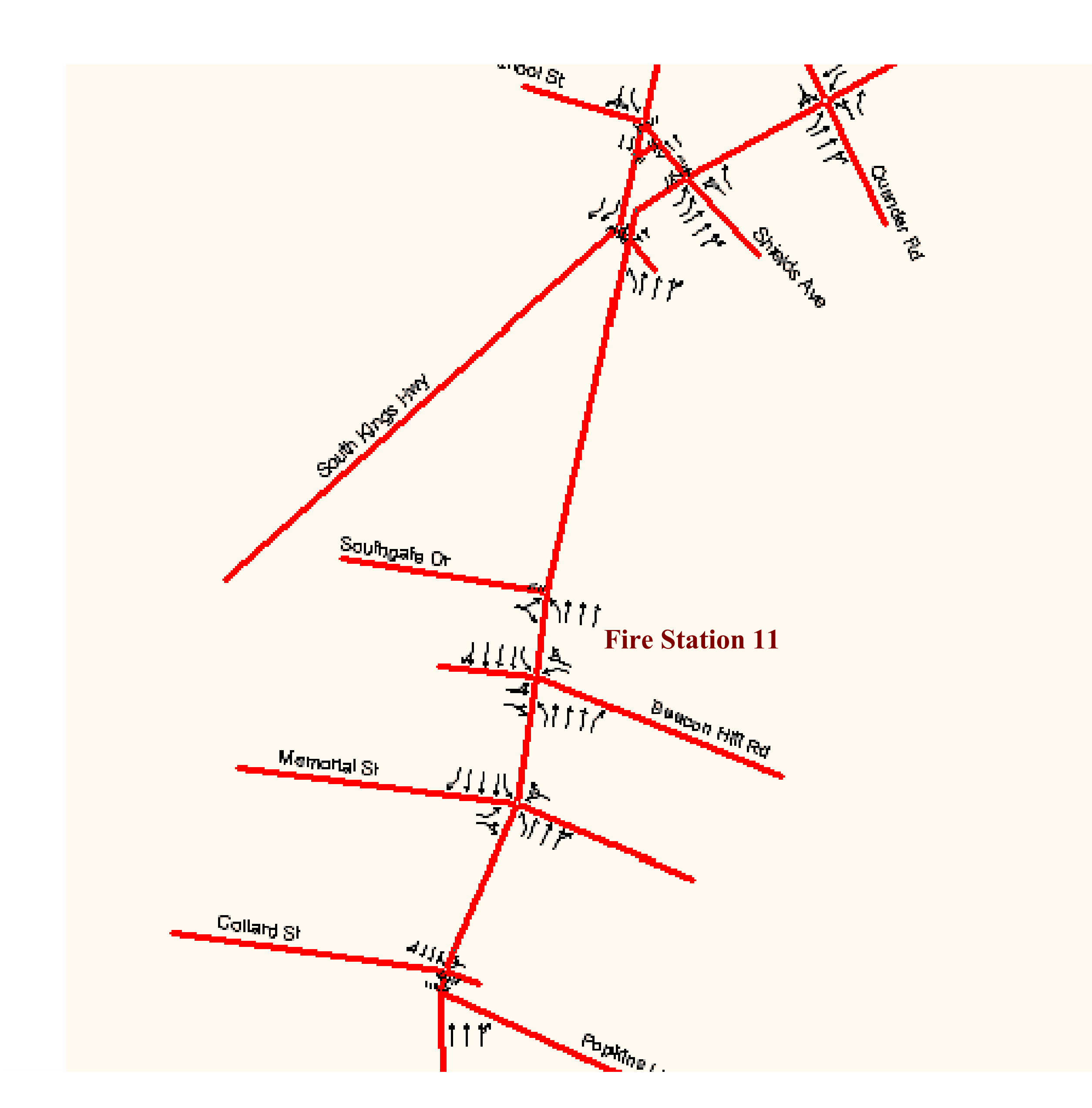
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	12584736	5	2516947	24.9441	2.4E-05	3.325837383
Columns	1872671	2	936335.7	9.279515	0.005264	4.102815865
Error	1009035	10	100903.5			
Total	15466442	17				

Since F> Fcr. for both rows and columns (type of EVs, fire stations),there is evidence to support the notion that there exists a significant difference at the 95% confidence interval in the frequency of the various types of emergency vehicles involved in responding to an emergency call per fire station.

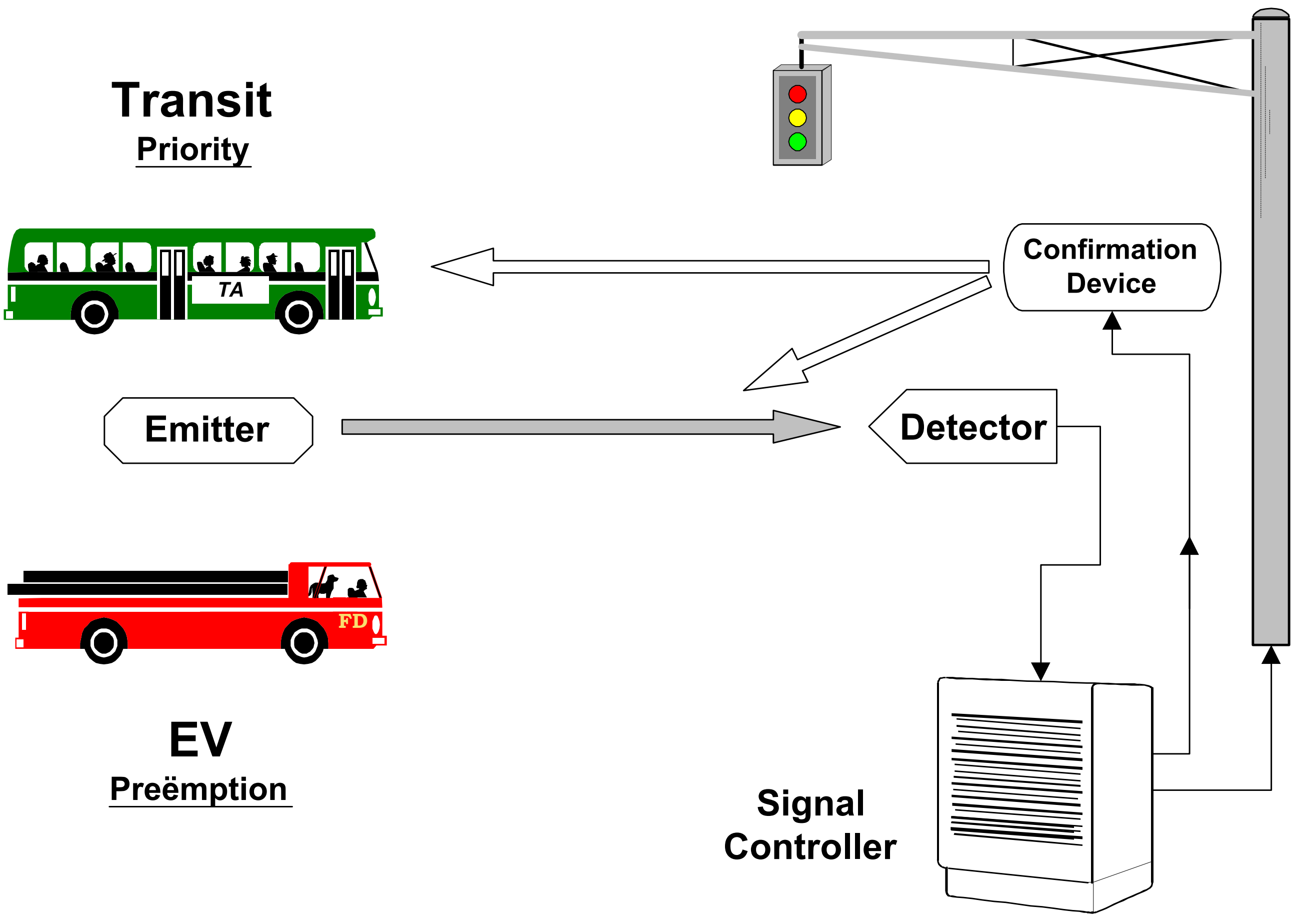
Appendix B:

Analysis of Emergency Preemption Data From The 3M™ Opticom™ Priority Control System on U.S.1, Fairfax County, VA

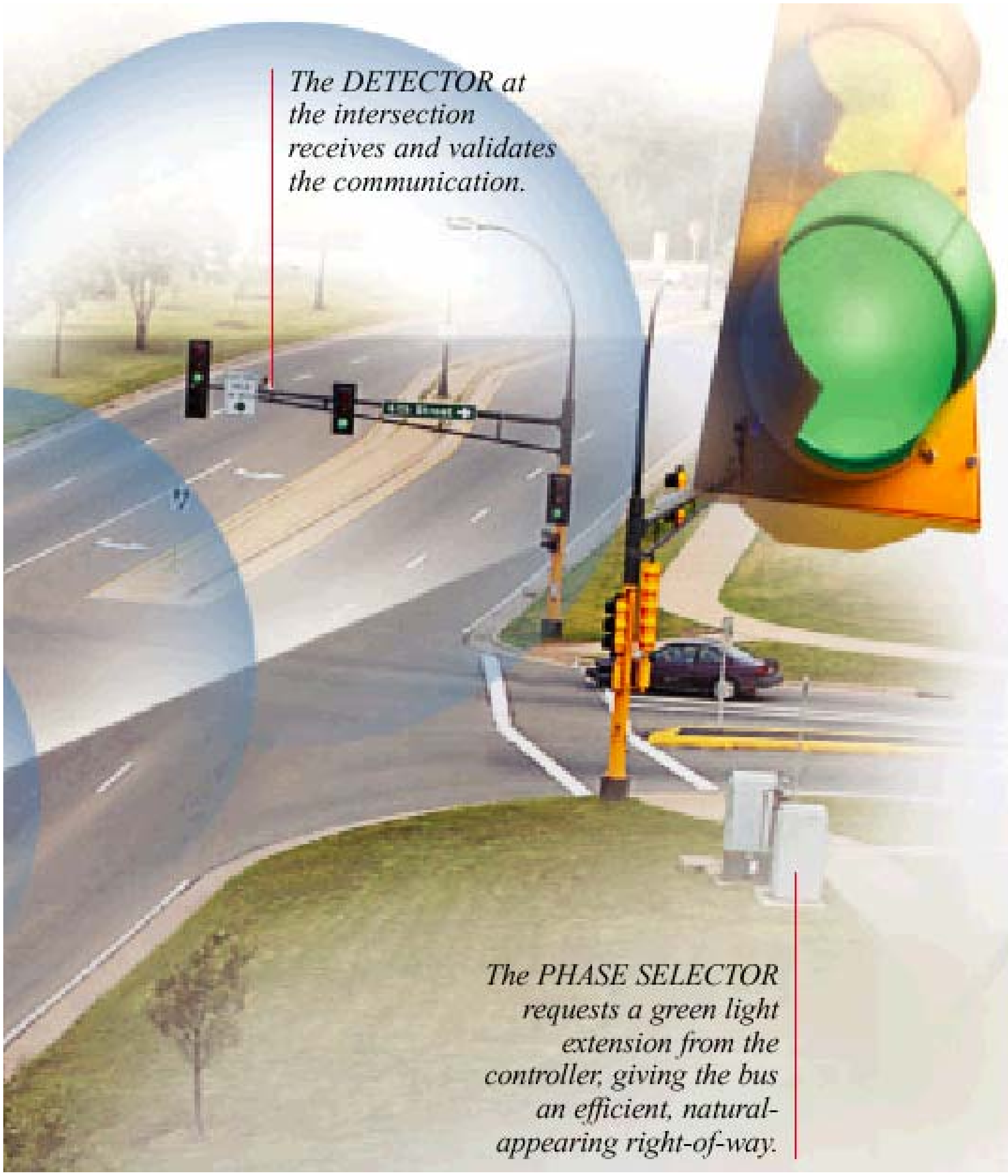
Appendix B1. U.S.1 Study Area Map.



Appendix B2. Transit Signal Priority and Preemption System *(35)*.



Appendix B3. 3M™ Opticom™ Detector and Phase Selector *(35)*.



Appendix B4. Sample of the Emergency Vehicle Preemption Request Data Obtained from the 3M Opticom System.

Log #	Date	Start Time	End Time	Duration	Class	ID	Chan	Priority	G. Time	Final G.	Intensity	PRE-EMPT
1	9/6/2002	9:10:08	9:10:23	15	0	0	A	High	9	2+5	904	Yes
2	9/6/2002	5:53:52	5:54:07	15	6	17	A	High	9	2+5	901	Yes
3	9/6/2002	5:53:05	5:53:20	15	0	0	A	High	3	2+5	923	Yes
4	9/6/2002	1:03:31	1:03:43	12	6	103	A	High	12	2+5	825	Yes
5	9/6/2002	1:03:25	1:03:39	14	0	1	A	High	8	2+5	818	Yes
6	9/5/2002	21:47:27	21:47:44	17	6	103	A	High	16	2+5	926	Yes
7	9/5/2002	15:24:34	15:25:02	28	6	17	A	High	22	2+5	903	Yes
8	9/5/2002	9:10:34	9:10:50	16	6	17	A	High	6	2+5	910	Yes
9	9/4/2002	18:27:51	18:28:27	36	6	17	A	High	30	2+5	919	Yes
10	9/4/2002	17:51:25	17:51:42	17	6	103	A	High	11	2+5	942	Yes
11	9/4/2002	17:48:41	17:48:59	18	0	1	A	High	12	2+5	898	Yes
12	9/4/2002	14:07:34	14:08:03	29	6	17	B	High	27	1+6	1001	Yes
13	9/4/2002	5:21:48	5:22:02	14	0	0	A	High	8	2+5	992	Yes
14	9/4/2002	1:10:10	1:10:25	15	0	0	A	High	9	2+5	921	Yes
15	9/3/2002	21:30:35	21:31:00	25	6	17	B	High	19	1+6	1001	Yes
16	9/3/2002	21:16:40	21:17:04	24	0	0	B	High	18	1+6	998	Yes
17	9/3/2002	21:15:20	21:15:27	7	----	----	A	High	1	2+5	317	Yes
18	9/3/2002	21:05:09	21:05:22	13	6	17	A	High	14	2+5	928	Yes
19	9/3/2002	21:05:02	21:05:17	15	0	0	A	High	9	2+5	922	Yes
20	9/3/2002	17:53:19	17:53:38	19	6	103	A	High	13	2+5	909	Yes
21	9/3/2002	17:09:26	17:09:48	22	6	17	A	High	13	2+5	901	Yes
22	9/3/2002	11:05:41	11:05:55	14	6	17	A	High	8	2+5	930	Yes
23	9/3/2002	10:32:35	10:32:54	19	6	17	A	High	13	2+5	919	Yes
24	9/3/2002	4:28:41	4:28:56	15	6	17	A	High	18	2+5	916	Yes
25	9/3/2002	4:28:32	4:28:46	14	0	0	A	High	8	2+5	976	Yes
26	9/2/2002	20:02:07	20:02:21	14	0	0	B	High	8	1+6	538	Yes
27	9/2/2002	16:20:30	16:20:47	17	6	103	A	High	11	2+5	906	Yes
28	9/2/2002	14:49:07	14:49:15	8	----	----	B	High	8	1+6	512	Yes
29	9/2/2002	14:49:01	14:49:11	10	0	0	B	High	4	1+6	495	Yes
30	9/2/2002	6:27:09	6:27:24	15	6	103	A	High	9	2+5	943	Yes
31	9/2/2002	3:41:50	3:42:07	17	6	17	B	High	11	1+6	1003	Yes
32	9/2/2002	3:18:31	3:18:46	15	6	17	A	High	8	2+5	915	Yes
33	9/2/2002	3:18:01	3:18:17	16	0	0	A	High	10	2+5	922	Yes
34	9/1/2002	22:46:07	22:46:23	16	6	103	A	High	10	2+5	836	Yes
35	9/1/2002	22:18:36	22:18:56	20	0	0	B	High	20	1+6	940	Yes
36	9/1/2002	19:16:22	19:16:35	13	6	17	A	High	17	2+5	914	Yes
37	9/1/2002	19:16:12	19:16:27	15	0	0	A	High	9	2+5	920	Yes
38	9/1/2002	13:06:58	13:07:26	28	6	17	A	High	16	2+5	909	Yes
39	9/1/2002	12:07:08	12:07:22	14	0	0	A	High	8	2+5	919	Yes
40	9/1/2002	6:42:46	6:43:01	15	6	17	A	High	4	2+5	914	Yes
41	9/1/2002	6:42:21	6:42:36	15	0	0	A	High	9	2+5	932	Yes
42	9/1/2002	5:29:55	5:30:12	17	6	103	A	High	11	2+5	910	Yes
43	9/1/2002	3:09:18	3:09:51	33	6	17	A	High	27	2+5	905	Yes
44	9/1/2002	2:05:10	2:05:26	16	0	0	A	High	10	2+5	921	Yes
45	8/31/2002	22:38:13	22:38:27	14	6	17	A	High	13	2+5	921	Yes
46	8/31/2002	22:38:08	22:38:22	14	0	0	A	High	8	2+5	994	Yes
47	8/31/2002	22:34:15	22:34:32	17	6	103	A	High	11	2+5	911	Yes
48	8/31/2002	12:53:34	12:54:14	40	6	103	B	High	34	1+6	924	Yes
49	8/31/2002	12:22:10	12:23:47	97	6	103	A	High	89	2+5	602	Yes
50	8/31/2002	12:09:39	12:09:48	9	6	103	A	High	25	2+5	597	Yes
51	8/31/2002	12:09:13	12:09:34	21	0	150	A	High	11	2+5	603	Yes
52	8/31/2002	11:49:59	11:50:10	11	0	0	B	High	5	1+6	437	Yes
53	8/31/2002	10:18:54	10:19:07	13	0	0	A	High	7	2+5	991	Yes
54	8/31/2002	2:07:31	2:07:49	18	6	103	A	High	12	2+5	901	Yes
55	8/30/2002	16:41:15	16:41:42	27	6	103	B	High	24	1+6	991	Yes
56	8/30/2002	13:07:05	13:07:18	13	6	17	A	High	13	2+5	919	Yes
57	8/30/2002	13:06:55	13:07:10	15	0	0	A	High	5	2+5	924	Yes
58	8/30/2002	12:31:24	12:31:45	21	6	103	B	High	15	1+6	994	Yes
59	8/29/2002	20:14:08	20:14:38	30	0	1	B	High	24	1+6	911	Yes
60	8/29/2002	14:52:41	14:52:59	18	6	17	A	High	24	2+5	910	Yes

Appendix B5. Glossary Terms (Source: 3M™Opticom™ Help file).

Approach Phase

Each separate control circuit from an intersection controller that is allocated to a specific traffic movement is referred to as a *phase*. The approach phase(s) are the phase(s) used to signal a specific approach to an intersection. For example, if an intersection has a separately controlled through signal and an arrow for its northerly approach, those would be the approach phases for that approach.

Call Output

A call output is an output from the phase selector. It is typically connected to the preempt input on an intersection controller. A call output generates a call when the phase selector requests the controller to provide green lights for an approaching vehicle.

Call

A call is an output signal that is generated by one of the phase selector's call outputs that makes a priority request to an intersection controller.

Called Direction

The called direction is the direction from which a vehicle with an active emitter is approaching an intersection. This term is typically used in conjunction with confirmation lights. With confirmation lights there will often be a need to have a different indication pattern (a flashing indication or steady indication) in the called direction vs. the non-called direction.

Channel

Opticom 700 series phase selectors are available in two and four channel models. Each channel can be used to detect and setup a unique indication pattern of green lights for approaching priority vehicles. Each channel has one or more call outputs, depending on how the phase selector's Output Mode is configured.

Class

See Vehicle ID.

Code(s)

Same as Vehicle ID.

Confirmation Light

Confirmation lights are lights that are placed at the intersection to signal that a priority request has been received by the phase selector and is being processed. Confirmation lights are used by maintenance people to determine that the priority control system is working properly and as a feedback mechanism to emergency vehicle drivers. Vehicle drivers should always respect the (red, yellow, green) signal lights even if a confirmation light is lit steadily or is flashing.

Desired Greens

The desired green(s) are the green light phases that are displayed at the intersection when the intersection has reached the correct display for an approaching priority vehicle. There can be different desired greens for high and low priority.

Detector

The detector is a device positioned in the intersection to detect approaching vehicles equipped with the Opticom system. Detectors are connected to Opticom phase selectors using Model 138 detector cable.

Emitter

The emitter is the activating device in the Opticom system. They are attached to vehicles that are intended to get priority at intersections. Emitters make intense infrared signals that are detected by the detector/phase selector. Each emitter has a priority and some emitters are programmable with a specific vehicle ID.

Also see High Priority, Low Priority, and Probe Frequency.

Flash

When a call indicator on the front of the phase selector flashes, it indicates that the call has been recognized by the phase selector, but it is not generating a call output. There can be several reasons for this situation. A higher priority vehicle may already have control of the phase selector, or an equal priority vehicle may have gained control at an earlier time, or the vehicle may have been present for longer than the Max Call Time, etc.

Green(s)

These are signals from the traffic controller that are wired to the phase selector that indicate which signal(s) are currently in the green state.

Green Sense

Green Sense is a feature that allows the Model 750 phase selector to monitor which signals are currently displaying a green indication. There are several features in the 750 phase selector that require green sense to be connected in order to operate correctly:
Confirmation Lights
Logging Final Greens and Green Time in the Call History Log
Manual Control Enable
Gated Advantage Priority.
Green sense is connected using either a Model 757 Auxiliary Harness or a Model 758/759 Auxiliary Interface Panel.

High Priority

A high priority emitter has the highest priority. A high priority emitter is typically used by emergency vehicles such as fire, ambulance, and police. When a high priority emitter and one or more low priority emitters are requesting control of an intersection, the high priority emitter will always gain control.

ID

Same as Vehicle ID.

Intensity

This is a value from 0 to 1200 that indicates the relative strength of the emitter's optical signal received by the detector and measured at the phase selector. Below is a table to help you estimate the detection range that may result from a given signal intensity threshold value:

Value	Range
350	2250 ft. to 2500 ft.
380	1950 ft. to 2250 ft.
435	1650 ft. to 1950 ft.
470	1350 ft. to 1650 ft.
500	1050 ft. to 1350 ft.
570	750 ft. to 1050 ft.
675	450 ft. to 750 ft.
790	150 ft. to 450 ft.
840	100 ft. or less

Low Priority

A low priority emitter is lower priority than a high priority emitter. A low priority emitter is typically used by transit vehicles or other vehicles that are intended to be aided by the Opticom system, but have a lower priority of service than vehicles with high priority emitters. A vehicle with a low priority emitter will lose control of the intersection when a vehicle with a high priority emitter is requesting priority from the same intersection.

Non-Approach Phase

Each separate control circuit from an intersection controller is referred to as a phase. The Approach Phase(s) are the phases available on a specific approach. The Non-Approach Phase(s) are all of the other phases. For example, if an intersection has a separately controlled through signal and an arrow for its northerly approach, the Non-Approach Phase(s) would be all of the other phases.

Non-Called Direction

The Non-Called Directions are all of the directions from which a priority vehicle is not approaching. This term is typically used in conjunction with confirmation lights. With confirmation lights there will often be a need to have a different indication pattern (a flashing verses a solid indication) in the Called Direction verses the Non-Called Directions.

Non-Desired Green

The Non-Desired Green(s) are any green light phases that are not desired to be displayed at the intersection when the intersection has reached the correct display for an approaching priority vehicle. This term is typically used in conjunction with confirmation lights. With confirmation lights there can be a different indication pattern (a flashing verses a solid indication or no indication at all) when the intersection is cycling to the Desired Greens (hence displaying the Non-Desired Greens) verses when it is in the Desired Greens.

Preemption

Preemption is the act of leaving normal traffic control patterns. This is a function typically performed by the intersection controller in response to a priority request from an Opticom phase selector.

Priority

The priority of an emitter's signal is used by the phase selector to determine which emitter will result in a priority request. A High Priority emitter always has higher priority than an Low Priority emitter. Relative Priorities that can be setup independently for High Priority and Low Priority emitters can be used to further distinguish the priority of certain classes of vehicles as being higher than other classes of vehicles.

Priority Greens Phasing

Same as Desired Greens.

Priority Request

Same as Call.

Probe Frequency

Probe Frequency is a special emitter priority used for vehicle identification only. Probe Frequency does not cause the phase selector to place a call to the intersection controller. Valid signals received from Probe Frequency emitters may be logged in the phase selector's call history log.

Vehicle ID

The Vehicle ID is a code that is transmitted by encoded vehicle emitters and is used to identify the vehicle. It consists of two parts, the class and the ID. There are ten Classes, 0-9 and one thousand ID's per Class for a total of 10,000 unique codes. Each priority (High, Low, and Probe) has a unique set of 10,000 codes.

Appendix B6. Significance Tests.

The ANOVA analysis tool is a parametric testing methodology that provides different types of variance analysis. The tool to use depends on the number of factors and the number of samples you have from the populations you want to test. The *ANOVA Single-Factor* Test performs a simple ANOVA. The *ANOVA Two-Factor without Replication* Test performs a two-factor ANOVA that does not include more than one sampling per group, testing the hypothesis that means from two or more samples are equal (drawn from populations with the same mean). This technique expands on tests for two means, such as the t-test *(38)*.

The t-Test analysis tool is a parametric testing methodology and is an appropriate test for small sample sizes assuming that the underlying populations follow a normal distribution with equal variances. The *t-Test: Two-Sample Assuming Equal Variances* analysis tool performs a two-sample student's t-test. This t-test form assumes that the means of both data sets are equal; it is referred to as a homoscedastic t-test. It can be used to determine whether two sample means are equal.

A test statistic for a difference between two population means with equal population variances is given by *(38)*:

$$t^* = \frac{(\overline{X_1} - \overline{X_2}) - (\mu_1 - \mu_2)}{\sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})}},$$

where the term $(\mu_1 - \mu_2)$ is the difference between μ_1 and μ_2 under the null hypothesis. The degrees of freedom of the test statistic are $n_1 + n_2 - 2$, which are the degrees of freedom associated with the pooled estimate of the population variance s_p^2. This pooled variance s_p^2, is based on the sample variance s_1^2 obtained from a sample of size n_1, and a sample variance s_2^2 obtained from a sample of size n_2, and is given by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

B6.1. ANOVA Testing the Sample Variability of Frequency of Emergency Vehicle Preemption Requests among the six Intersections.

ANOVA Testing the Sample Variability of Frequency of Preemption Requests among the six intersections

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	53	301	5.679245	13.56821
Column 2	53	368	6.943396	16.66981
Column 3	53	350	6.603774	11.85922
Column 4	53	615	11.60377	19.32075
Column 5	53	448	8.45283	17.32946
Column 6	53	446	8.415094	16.63208

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1155.459	5	231.0918	14.5372	8.22E-13	2.242928
Within Groups	4959.736	312	15.89659			
Total	6115.195	317				

Since F> Fcr. ,there is evidence to support the notion that the frequency of preemption requests is different among the six intersections.

B6.2. ANOVA Testing the Sample Variability of Frequency of Emergency Vehicle Preemption Requests By Time of Day among the six Intersections.

ANOVA Testing the Sample Variability of the Frequency of EV Requests By Time of Day among the six intersections

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	6	1.213836	0.202306	0.014769
Row 2	6	2.49	0.415	0.00795
Row 3	6	2.45283	0.408805	0.002247
Row 4	6	2.52	0.42	0.00932
Column 1	4	1.065094	0.266274	0.012369
Column 2	4	1.305723	0.326431	0.022767
Column 3	4	1.219434	0.304858	0.021316
Column 4	4	1.98761	0.496903	0.010787
Column 5	4	1.541824	0.385456	0.00767
Column 6	4	1.556981	0.389245	0.005718

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.20319	3	0.06773	26.25717	3.22E-06	3.287383
Columns	0.132735	5	0.026547	10.29158	0.000198	2.901295
Error	0.038692	15	0.002579			
Total	0.374617	23				

Since F> Fcr. for both rows and columns (time of day, intersections),there is evidence to infer that the frequency distribution of EV preemption requests vary between different time periods in a day and among the six intersections.

B6.3 T-tests Testing for Statistical Differences in the Frequency of Emergency Vehicle Preemption Requests By Time of Day at each intersection.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day at Rt1&Popkins Lane

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	0.301887	0.943396
Variance	0.445573	1.939042
Observations	53	53
Pooled Variance	1.192308	
Hypothesized Me	0	
df	104	
t Stat	-3.024348	
P(T<=t) one-tail	0.00157	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.003139	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	0.943396	1.018868
Variance	1.939042	1.82656
Observations	53	53
Pooled Variance	1.882801	
Hypothesized Mea	0	
df	104	
t Stat	-0.283142	
P(T<=t) one-tail	0.388815	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.777631	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	0.301887	0.90566
Variance	0.445573	1.164006
Observations	53	53
Pooled Variance	0.80479	
Hypothesized Me	0	
df	104	
t Stat	-3.464622	
P(T<=t) one-tail	0.000386	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.000773	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	0.90566	1.018868
Variance	1.164006	1.82656
Observations	53	53
Pooled Variance	1.495283	
Hypothesized Mea	0	
df	104	
t Stat	-0.476581	
P(T<=t) one-tail	0.31733	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.63466	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	0.301887	1.018868
Variance	0.445573	1.82656
Observations	53	53
Pooled Variance	1.136067	
Hypothesized Me	0	
df	104	
t Stat	-3.462811	
P(T<=t) one-tail	0.000389	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.000777	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	0.90566	0.943396
Variance	1.164006	1.939042
Observations	53	53
Pooled Variance	1.551524	
Hypothesized Mea	0	
df	104	
t Stat	-0.155954	
P(T<=t) one-tail	0.438186	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.876371	
t Critical two-tail	1.983035	

Since t Stat >t Critical (two tail), we can conclude that the AM and PM cases; the AM and Midday cases; and the AM and Night cases are different at the 95% confidence interval.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day at Rt1&Memorial Str.

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	0.301887	1.245283
Variance	0.484035	2.534833
Observations	53	53
Pooled Variance	1.509434	
Hypothesized Mear	0	
df	104	
t Stat	-3.952847	
P(T<=t) one-tail	7.05E-05	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.000141	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	1.245283	1.207547
Variance	2.534833	2.590711
Observations	53	53
Pooled Variance	2.562772	
Hypothesized Mea	0	
df	104	
t Stat	0.121345	
P(T<=t) one-tail	0.451826	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.903652	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Am	*Midday*
Mean	0.301887	1.169811
Variance	0.484035	2.143687
Observations	53	53
Pooled Variance	1.313861	
Hypothesized Mear	0	
df	104	
t Stat	-3.897896	
P(T<=t) one-tail	8.6E-05	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.000172	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	1.169811	1.207547
Variance	2.143687	2.590711
Observations	53	53
Pooled Variance	2.367199	
Hypothesized Mea	0	
df	104	
t Stat	-0.126258	
P(T<=t) one-tail	0.449886	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.899771	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	0.301887	1.207547
Variance	0.484035	2.590711
Observations	53	53
Pooled Variance	1.537373	
Hypothesized Mear	0	
df	104	
t Stat	-3.760094	
P(T<=t) one-tail	0.00014	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.000281	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	1.169811	1.25
Variance	2.143687	2.583333
Observations	53	52
Pooled Variance	2.361376	
Hypothesized Mea	0	
df	103	
t Stat	-0.267347	
P(T<=t) one-tail	0.394868	
t Critical one-tail	1.659782	
P(T<=t) two-tail	0.789737	
t Critical two-tail	1.983262	

Since t Stat >t Critical (two tail), we can conclude that the AM and PM cases; the AM and Midday cases; and the AM and Night cases are different at the 95% confidence interval.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day at Rt1&Beacon Hill Rd.

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	0.283019	1.245283
Variance	0.437591	2.150218
Observations	53	53
Pooled Variance	1.293904	
Hypothesized Mean I	0	
df	104	
t Stat	-4.35478	
P(T<=t) one-tail	1.56E-05	
t Critical one-tail	1.659637	
P(T<=t) two-tail	3.13E-05	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	1.245283	0.962264
Variance	2.150218	1.690856
Observations	53	53
Pooled Variance	1.920537	
Hypothesized Mean	0	
df	104	
t Stat	1.051301	
P(T<=t) one-tail	0.147779	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.295557	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	0.283019	1.169811
Variance	0.437591	1.682148
Observations	53	53
Pooled Variance	1.059869	
Hypothesized Mean I	0	
df	104	
t Stat	-4.434235	
P(T<=t) one-tail	1.15E-05	
t Critical one-tail	1.659637	
P(T<=t) two-tail	2.3E-05	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	1.169811	0.962264
Variance	1.682148	1.690856
Observations	53	53
Pooled Variance	1.686502	
Hypothesized Mean	0	
df	104	
t Stat	0.822709	
P(T<=t) one-tail	0.206278	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.412556	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	0.283019	0.962264
Variance	0.437591	1.690856
Observations	53	53
Pooled Variance	1.064224	
Hypothesized Mean I	0	
df	104	
t Stat	-3.389481	
P(T<=t) one-tail	0.000495	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.00099	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Midday*
Mean	1.245283	1.169811
Variance	2.150218	1.682148
Observations	53	53
Pooled Variance	1.916183	
Hypothesized Mean	0	
df	104	
t Stat	0.280665	
P(T<=t) one-tail	0.389762	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.779525	
t Critical two-tail	1.983035	

Since t Stat >t Critical (two tail), we can conclude that the AM and PM cases; the AM and Midday cases; and the AM and Night cases are different at the 95% confidence interval.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day at Rt1&Southgate Dr.

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	1.150943	1.301887
Variance	1.861393	1.714804
Observations	53	53
Pooled Variance	1.788099	
Hypothesized Mea	0	
df	104	
t Stat	-0.581087	
P(T<=t) one-tail	0.281219	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.562439	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	1.301887	1.773585
Variance	1.714804	3.063135
Observations	53	53
Pooled Variance	2.38897	
Hypothesized Mea	0	
df	104	
t Stat	-1.57102	
P(T<=t) one-tail	0.059608	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.119215	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	1.150943	1.735849
Variance	1.861393	2.390421
Observations	53	53
Pooled Variance	2.125907	
Hypothesized Mea	0	
df	104	
t Stat	-2.065079	
P(T<=t) one-tail	0.020701	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.041403	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	midday	*Night*
Mean	1.735849	1.773585
Variance	2.390421	3.063135
Observations	53	53
Pooled Variance	2.726778	
Hypothesized Mea	0	
df	104	
t Stat	-0.117639	
P(T<=t) one-tail	0.45329	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.90658	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	1.150943	1.773585
Variance	1.861393	3.063135
Observations	53	53
Pooled Variance	2.462264	
Hypothesized Mea	0	
df	104	
t Stat	-2.042649	
P(T<=t) one-tail	0.021808	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.043617	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	1.735849	1.307692
Variance	2.390421	1.746606
Observations	53	52
Pooled Variance	2.071639	
Hypothesized Mea	0	
df	103	
t Stat	1.52402	
P(T<=t) one-tail	0.065284	
t Critical one-tail	1.659782	
P(T<=t) two-tail	0.130568	
t Critical two-tail	1.983262	

Since t Stat >t Critical (two tail), we can conclude that the AM and Midday cases as well as the AM and Night cases are different at the 95% confidence interval.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day at Rt1&South Kings Hwy

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	0.773585	1.301887
Variance	1.486212	1.714804
Observations	53	53
Pooled Variance	1.600508	
Hypothesized Mea	0	
df	104	
t Stat	-2.149692	
P(T<=t) one-tail	0.016949	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.033898	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	1.301887	1.339622642
Variance	1.714804	2.420899855
Observations	53	53
Pooled Variance	2.067852	
Hypothesized Mea	0	
df	104	
t Stat	-0.135088	
P(T<=t) one-tail	0.446402	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.892803	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	0.773585	1.188679
Variance	1.486212	1.694485
Observations	53	53
Pooled Variance	1.590348	
Hypothesized Mea	0	
df	104	
t Stat	-1.69443	
P(T<=t) one-tail	0.046588	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.093176	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	1.188679	1.339622642
Variance	1.694485	2.420899855
Observations	53	53
Pooled Variance	2.057692	
Hypothesized Mea	0	
df	104	
t Stat	-0.541685	
P(T<=t) one-tail	0.294597	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.589194	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	0.773585	1.339623
Variance	1.486212	2.4209
Observations	53	53
Pooled Variance	1.953556	
Hypothesized Mea	0	
df	104	
t Stat	-2.084757	
P(T<=t) one-tail	0.01977	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.03954	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	1.188679	1.307692308
Variance	1.694485	1.746606335
Observations	53	52
Pooled Variance	1.720293	
Hypothesized Mea	0	
df	103	
t Stat	-0.464877	
P(T<=t) one-tail	0.3215	
t Critical one-tail	1.659782	
P(T<=t) two-tail	0.643001	
t Critical two-tail	1.983262	

Since t Stat >t Critical (two tail), we can conclude that the AM and PM cases as well as the AM and Night cases are different at the 95% confidence interval.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day at Rt1&North Kings Hwy

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	0.830189	1.320755
Variance	2.682148	2.106676
Observations	53	53
Pooled Variance	2.394412	
Hypothesized Mear	0	
df	104	
t Stat	-1.632003	
P(T<=t) one-tail	0.052852	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.105703	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	1.320755	1.245283
Variance	2.106676	2.611756
Observations	53	53
Pooled Variance	2.359216	
Hypothesized Mea	0	
df	104	
t Stat	0.252943	
P(T<=t) one-tail	0.400406	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.800811	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	0.830189	1.245283
Variance	2.682148	2.073295
Observations	53	53
Pooled Variance	2.377721	
Hypothesized Mear	0	
df	104	
t Stat	-1.385764	
P(T<=t) one-tail	0.084392	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.168783	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	1.245283	1.245283
Variance	2.073295	2.611756
Observations	53	53
Pooled Variance	2.342525	
Hypothesized Mea	0	
df	104	
t Stat	0	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.659637	
P(T<=t) two-tail	1	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	0.830189	1.245283
Variance	2.682148	2.611756
Observations	53	53
Pooled Variance	2.646952	
Hypothesized Mear	0	
df	104	
t Stat	-1.313399	
P(T<=t) one-tail	0.095969	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.191939	
t Critical two-tail	1.983035	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	1.245283	1.320755
Variance	2.073295	2.106676
Observations	53	53
Pooled Variance	2.089985	
Hypothesized Mea	0	
df	104	
t Stat	-0.268742	
P(T<=t) one-tail	0.39433	
t Critical one-tail	1.659637	
P(T<=t) two-tail	0.788661	
t Critical two-tail	1.983035	

Since t Stat <t Critical (two tail), we can conclude that there is no evidence that the frequency of EV preemption requests vary by time of day at the 95% confidence interval at this intersection.

B6.4. ANOVA Testing the Sample Variability of Frequency of Emergency Vehicle Preemption Requests By Day of Week among the six Intersections.

ANOVA Testing the Sample Variability of the Frequency of EV Requests By Day of Week among the six intersections

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	6	63.28571	10.54762	3.676871
Row 2	6	55.42857	9.238095	9.931973
Row 3	6	45.75	7.625	6.75625
Row 4	6	42.05357	7.008929	1.599585
Row 5	6	41.5	6.916667	10.78542
Row 6	6	41.125	6.854167	2.058854
Row 7	6	43.57143	7.261905	3.77483
Column 1	7	46.19643	6.59949	2.150282
Column 2	7	48.08929	6.869898	2.297164
Column 3	7	58.28571	8.326531	2.969357
Column 4	7	39.80357	5.686224	3.068543
Column 5	7	81.125	11.58929	4.908588
Column 6	7	59.21429	8.459184	3.511981

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	72.80747	6	12.13458	8.960253	1.23E-05	2.420521
Columns	152.2909	5	30.45818	22.49052	2.52E-09	2.533554
Error	40.62802	30	1.354267			
Total	265.7264	41				

Since F> Fcr. for both rows and columns (days of week, intersections),there is evidence to support the notion that there exists a significant difference at the 95% confidence interval in the weekly frequency of EV requests between different days of week and among the six intersections.

B6.5. ANOVA Testing the Sample Variability of Duration of Emergency Vehicle Preemptions among the six Intersections.

ANOVA Testing the Sample Variability of Duration of Preemptions among the six intersections

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	298	6230	20.90604	54.85983
Column 2	362	9568	26.43094	107.3041
Column 3	347	6482	18.68012	96.5072
Column 4	610	9556	15.66557	35.53001
Column 5	438	9949	22.71461	46.13576
Column 6	438	7490	17.10046	47.25762

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34053.41	5	6810.681	112.2682	3.2E-107	2.217696
Within Groups	150872.3	2487	60.66438			
Total	184925.7	2492				

Since F> Fcr.,there is evidence to support the notion that the duration of preemptions is different among the six intersections.

B6.6. ANOVA Testing the Sample Variability of Duration of Emergency Vehicle Preemptions by Time of Day among the six Intersections.

ANOVA Testing the Sample Variability of Duration of Preemptions By Time of Day among the six intersections

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	6	126.7	21.11667	29.29767
Row 2	6	129.7	21.61667	19.25367
Row 3	6	120.5	20.08333	11.49767
Row 4	6	121.7	20.28333	17.30967
Column 1	4	84.1	21.025	0.9025
Column 2	4	111.1	27.775	6.395833
Column 3	4	79.5	19.875	1.909167
Column 4	4	64.2	16.05	0.87
Column 5	4	91.4	22.85	0.936667
Column 6	4	68.3	17.075	0.749167

ANOVA

rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	9.271667	3	3.090556	1.781756	0.193779	3.287383
Columns	360.775	5	72.155	41.59855	2.87E-08	2.901295
Error	26.01833	15	1.734556			
Total	396.065	23				

Since F< Fcr. for rows (time of day),there is no evidence to support the notion that the duration of preemptions is different by time of day.
Since F> Fcr. for columns (intersections),there is evidence to support the notion that the duration of preemptions is different among the six intersections.

B6.7. ANOVA Testing the Sample Variability of Duration of Emergency Vehicle Preemptions by Day of Week among the six Intersections.

ANOVA Testing the Sample Variability of Duration of Preemptions By Day of Week among the six intersections

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	6	122.2196	20.36994	17.09712
Row 2	6	119.7691	19.96151	20.74159
Row 3	6	121.6695	20.27825	20.00479
Row 4	6	120.334	20.05567	12.30207
Row 5	6	118.6046	19.76744	12.24423
Row 6	6	125.4748	20.91247	15.33365
Row 7	6	120.9405	20.15675	15.23627
Column 1	7	145.7459	20.82084	0.970393
Column 2	7	184.5673	26.36676	1.41183
Column 3	7	131.0525	18.72179	0.933044
Column 4	7	109.9734	15.71049	0.332878
Column 5	7	159.0079	22.71542	0.406217
Column 6	7	118.6651	16.95216	0.318453

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	4.846938	6	0.807823	1.132994	0.367484	2.420521
Columns	543.4086	5	108.6817	152.4291	2.21E-20	2.533554
Error	21.38995	30	0.712998			
Total	569.6455	41				

Since F< Fcr. for rows (days of week),there is no evidence to support the notion that the duration of preemptions is different by day of week.
Since F> Fcr. for columns (intersections),there is evidence to support the notion that the duration of preemptions is different among the six intersections.

B6.8. ANOVA Testing the Sample Variability of Duration of Emergency Vehicle Preemptions by Direction among the six Intersections.

ANOVA Testing the Sample Variability of Duration of Preemptions By Direction among the six intersections

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	2	36.62761	18.3138	31.067
Row 2	2	53.88044	26.94022	1.03725
Row 3	2	42.24346	21.12173	25.13316
Row 4	2	33.63985	16.81993	3.873165
Row 5	2	43.99658	21.99829	1.502374
Row 6	2	39.33141	19.66571	21.09041
Column 1	6	121.4113	20.23521	30.74641
Column 2	6	128.3081	21.38468	10.22146

ANOVA

rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	125.0998	5	25.01996	1.568855	0.316608	5.050339
Columns	3.963824	1	3.963824	0.248548	0.639253	6.607877
Error	79.73953	5	15.94791			
Total	208.8032	11				

Since F< Fcr. for both rows and columns (intersections, direction of travel),there is no evidence to support the notion that there exists a significant difference at the 95% confidence interval in the length of preemption phase northbound and southbound among the six intersections.

Appendix B7. Supplemental Tables & Figures.

Table B7.1. Number of EV Preemption Requests Granted Per Day Per Intersection.

Intersection	***Number of EV Requests Granted/day***			
	Mean	*Standard Deviation*	*Min*	*Max*
RT.1 & Popkins Lane	5.6	3.7	0	18
RT.1 & Memorial St.	6.8	4.0	1	21
RT.1 & Beacon Hill Rd.	6.5	3.5	1	18
RT.1 & Southgate Dr.	11.5	4.0	1	21
RT.1 & South Kings Hwy	8.3	3.9	0	20
RT.1 & North Kings Hwy	8.3	4.1	0	19

Table B7.2. Frequency of EV Requests By Time of Day Per Intersection.

Intersection	Emergency Vehicle Preemption Requests During the AM Peak Period (6:00 AM-9:00AM)*					
	Mean/3 hr period		Mean/hr		Minimum	Maximum
RT.1 & Popkins Lane	0.30	(0.67)	0.10	(0.22)	0	3
RT.1 & Memorial St.	0.30	(0.70)	0.10	(0.23)	0	3
RT.1 & Beacon Hill Rd.	0.28	(0.66)	0.09	(0.22)	0	3
RT.1 & Southgate Dr.	1.15	(1.36)	0.38	(0.45)	0	5
RT.1 & South Kings Hwy	0.77	(1.22)	0.26	(0.41)	0	4
RT.1 & North Kings Hwy	0.83	(1.64)	0.28	(0.55)	0	10

Intersection	Emergency Vehicle Preemption Requests During the PM Peak Period (16:00PM-19:00PM)*					
	Mean/3 hr period		Mean/hr		Minimum	Maximum
RT.1 & Popkins Lane	0.94	(1.39)	0.31	(0.46)	0	6
RT.1 & Memorial St.	1.25	(1.59)	0.42	(0.53)	0	7
RT.1 & Beacon Hill Rd.	1.25	(1.47)	0.42	(0.49)	0	7
RT.1 & Southgate Dr.	1.30	(1.79)	0.43	(0.60)	0	4
RT.1 & South Kings Hwy	1.30	(1.31)	0.43	(0.44)	0	4
RT.1 & North Kings Hwy	1.32	(1.45)	0.44	(0.48)	0	7

Intersection	Emergency Vehicle Preemption Requests During Midday (11:00AM-14:00PM)*					
	Mean/3 hr period		Mean/hr		Minimum	Maximum
RT.1 & Popkins Lane	0.91	(1.08)	0.31	(0.36)	0	5
RT.1 & Memorial St.	1.17	(1.46)	0.39	(0.49)	0	9
RT.1 & Beacon Hill Rd.	1.17	(1.30)	0.39	(0.43)	0	5
RT.1 & Southgate Dr.	1.74	(1.55)	0.58	(0.52)	0	6
RT.1 & South Kings Hwy	1.19	(1.30)	0.40	(0.43)	0	5
RT.1 & North Kings Hwy	1.25	(1.44)	0.42	(0.48)	0	6

Intersection	Emergency Vehicle Preemption Requests During Night (20:00PM-23:00PM)*					
	Mean/3 hr period		Mean/hr		Minimum	Maximum
RT.1 & Popkins Lane	1.02	(1.35)	0.34	(0.45)	0	6
RT.1 & Memorial St.	1.21	(1.61)	0.4	(0.54)	0	6
RT.1 & Beacon Hill Rd.	0.96	(1.30)	0.32	(0.44)	0	5
RT.1 & Southgate Dr.	1.77	(1.75)	0.59	(0.58)	0	6
RT.1 & South Kings Hwy	1.34	(1.56)	0.45	(0.52)	0	7
RT.1 & North Kings Hwy	1.25	(1.62)	0.42	(0.54)	0	9

** Emergency Vehicle preemption request data represents a 53 day period from July 16, 2002 to September 6, 2002. Values in parentheses are the standard deviations.*

Table B7.3. Average Duration of Preemptions By Time of Day Per Intersection (sec).

Intersection	***Average Duration of Emergency Vehicle Preemptions By Time of Day***			
	AM Peak Period (6:00AM-9:00AM)	*PM Peak Period (16:00PM-19:00PM)*	*Midday (11:00AM-14:00PM)*	*Night (20:00PM-23:00PM)*
RT.1 & Popkins Lane	20.9 (4.3)	20.3 (5.5)	22.4 (15.6)	20.5 (4.4)
RT.1 & Memorial St.	30.9 (8.4)	24.9 (8.1)	28.4 (18.4)	26.9 (6.9)
RT.1 & Beacon Hill Rd.	20.7 (9.1)	19.7 (7.8)	21.1 (18.8)	18.0 (6.2)
RT.1 & Southgate Dr.	14.9 (3.4)	17.1 (7.70)	16.4 (7.0)	15.8 (7.1)
RT.1 & South Kings Hwy	21.6 (4.1)	22.7 (4.9)	23.9 (5.0)	23.2 (6.6)
RT.1 & North Kings Hwy	17.7 (6.2)	15.8 (5.4)	17.5 (7.5)	17.3 (7.6)

(Values in parentheses indicate the standard deviations).

Table B7.4. Average Duration of Preemptions By Day of Week Per Intersection (sec).

	RT.1 & Popkins Lane	***RT.1 & Memorial St.***	***RT.1 & Beacon Hill Rd.***
Sunday	20.98 *(4.54)*	27.13 *(7.61)*	18.29 *(6.38)*
Monday	20.13 *(4.60)*	27.13 *(7.22)*	17.69 *(5.44)*
Tuesday	21.59 *(15.55)*	27.59 *(5.56)*	18.65 *(6.83)*
Wednesday	20.67 *(4.81)*	24.46 *(7.44)*	18.04 *(7.67)*
Thursday	19.04 *(3.60)*	25.13 *(9.89)*	19.37 *(6.57)*
Friday	21.44 *(3.18)*	27.11 *(16.71)*	20.56 *(17.07)*
Saturday	21.89 *(4.23)*	26.02 *(13.84)*	18.46 *(13.09)*

	RT.1 & Southgate Dr.	***RT.1 & South Kings Hwy***	***RT.1 & North Kings Hwy***
Sunday	15.89 *(7.12)*	22.67 *(4.85)*	17.25 *(8.51)*
Monday	14.94 *(4.54)*	23.25 *(11.32)*	16.63 *(7.67)*
Tuesday	15.33 *(5.61)*	22.05 *(4.29)*	16.46 *(5.14)*

Wednesday	16.80 *(6.92)*	23.86 *(6.07)*	16.51 *(4.69)*
Thursday	15.52 *(5.89)*	22.39 *(5.75)*	17.15 *(6.78)*
Friday	15.75 *(5.29)*	22.60 *(5.59)*	18.02 *(6.05)*
Saturday	15.75 *(6.04)*	22.18 *(5.49)*	16.64 *(7.31)*

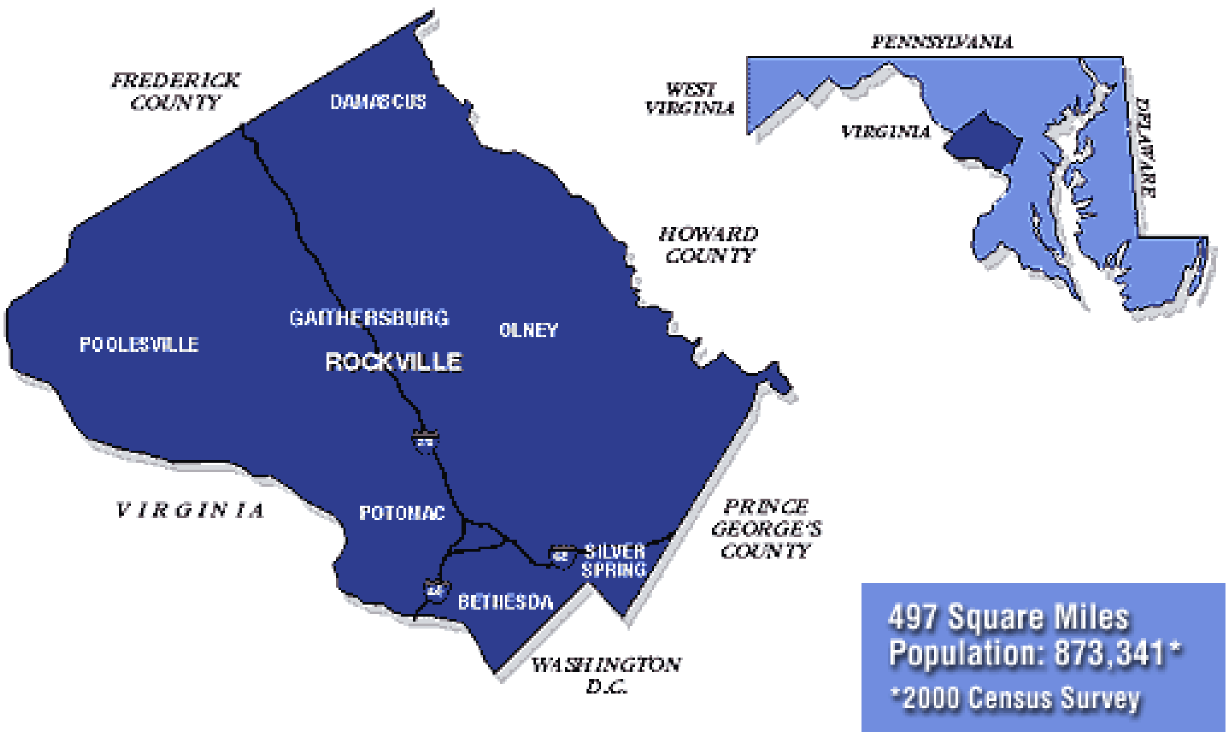
(Values in parentheses indicate the standard deviations).

Appendix C:

Analysis of Emergency Preemption Data, Montgomery County, MD

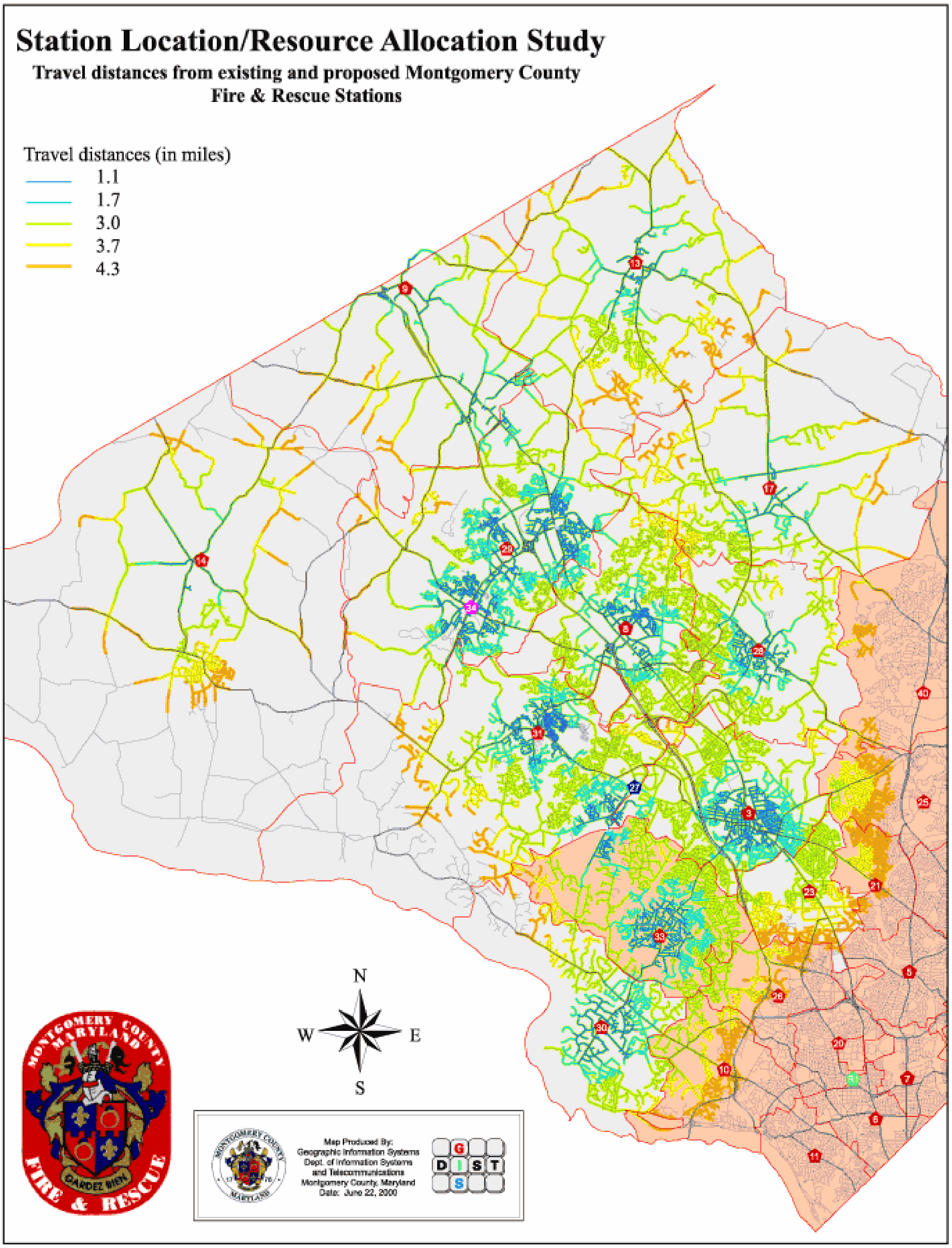
Appendix C1. Montgomery County Map.

(http://www.montgomerycounty.gov/mc/dfrs/index.asp)



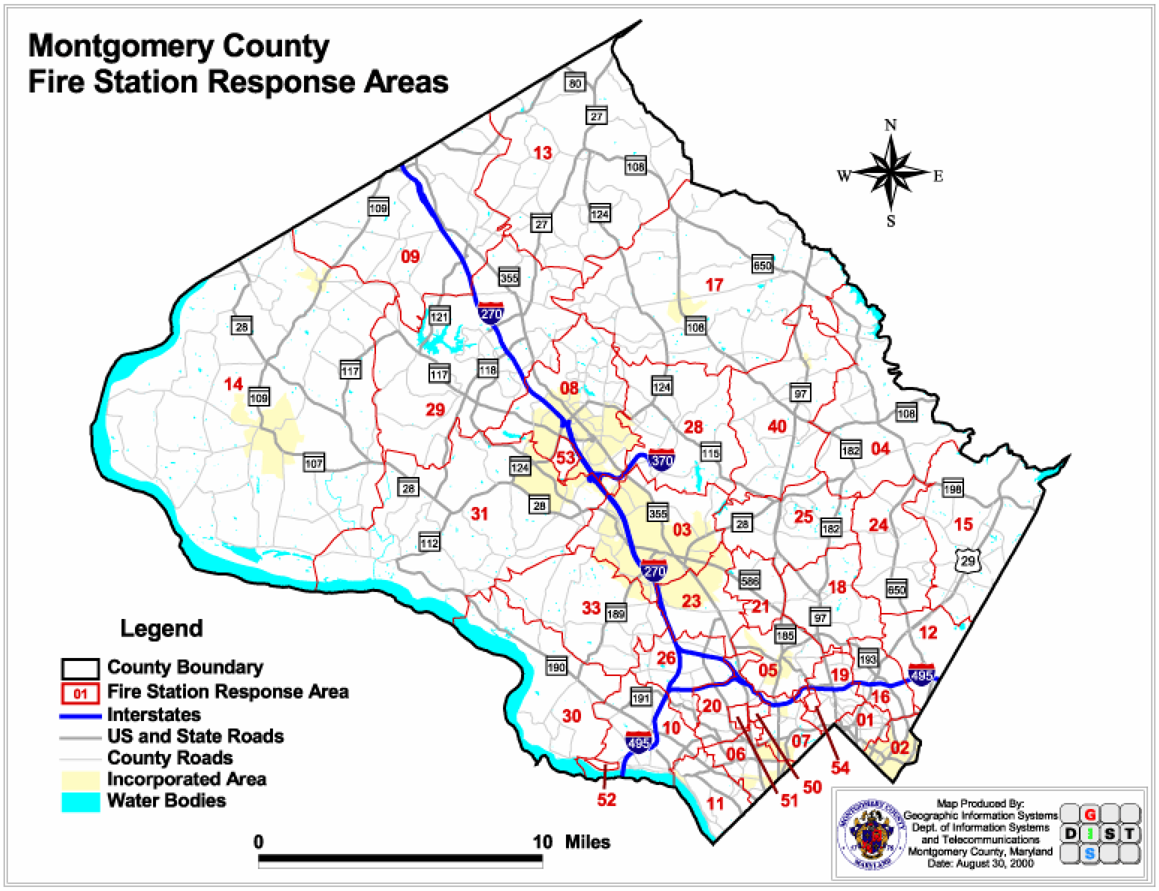
Appendix C2. Montgomery County Fire Station Locations.

(http://www.montgomerycounty.gov/mc/dfrs/index.asp)



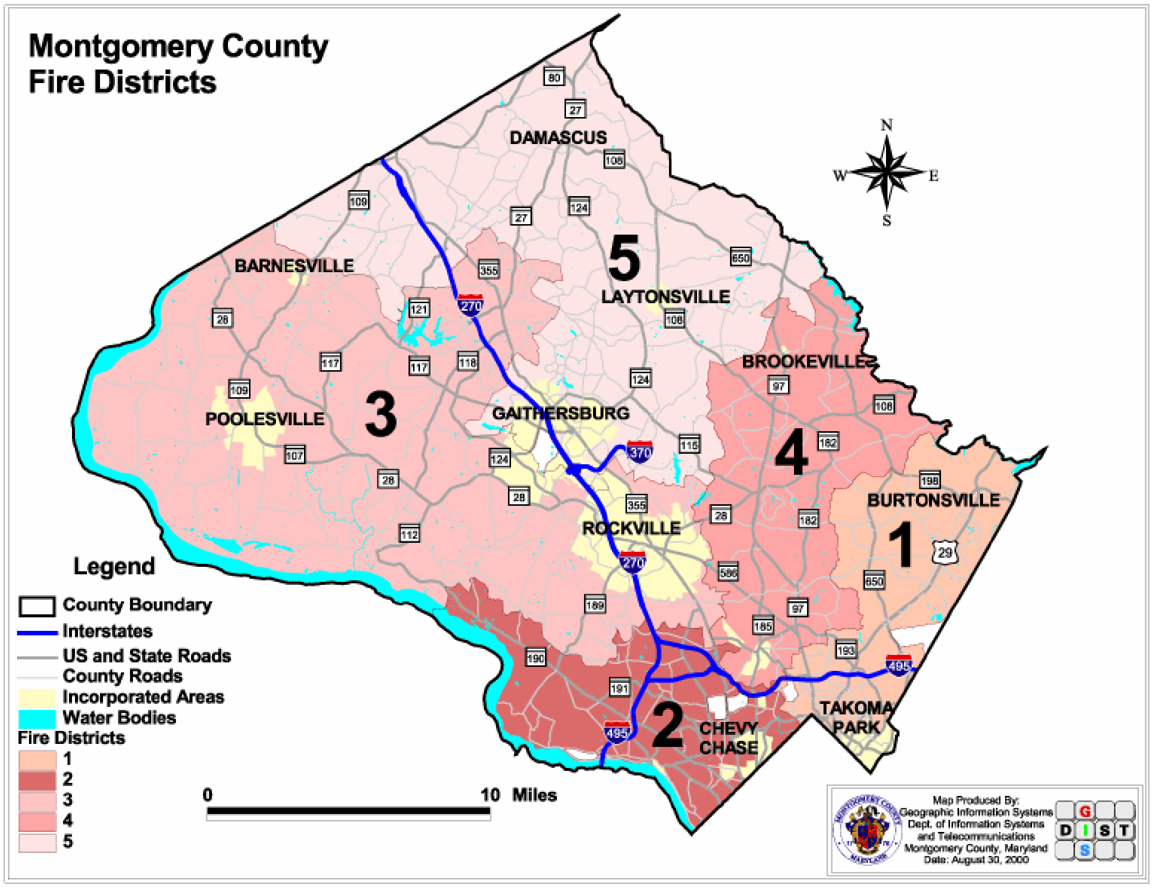
Appendix C3. Montgomery County Fire Station Response Areas.

(http://www.montgomerycounty.gov/mc/dfrs/index.asp)



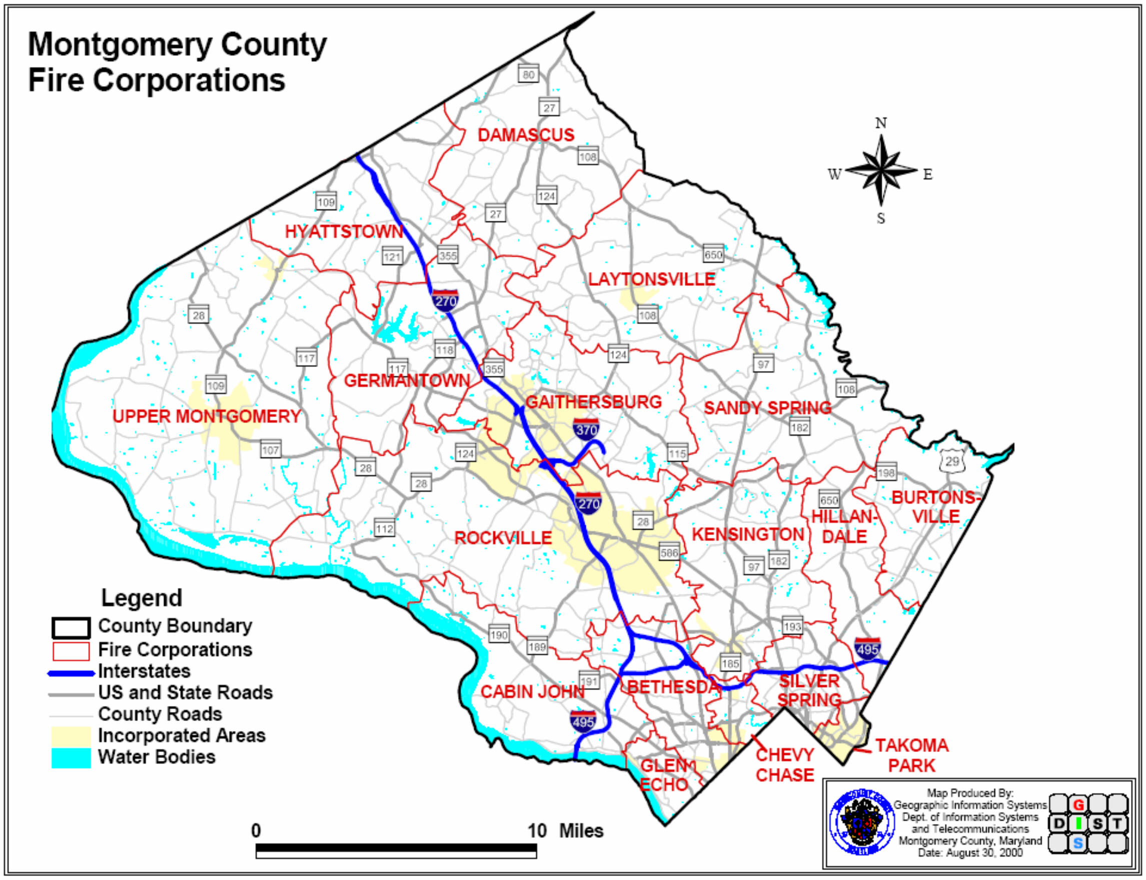
Appendix C4. Montgomery County Fire Districts.

(http://www.montgomerycounty.gov/mc/dfrs/index.asp)



Appendix C5. Montgomery County Fire Station Corporations

(http://www.montgomerycounty.gov/mc/dfrs/index.asp)



Appendix C6. Location of Various Intersections in Montgomery County *(39)*.

Intersection Number	Main Street Name	Cross Street Name	Cross Street Name	Type of Pre Empt
1	FREDERICK AVE. (MD.355)	MONTGOMERY VILLAGE AVE. MD 124		Controlled by FIREHOUSE DRWY. CO.#8
0	MONTGOMERY VILLAGE AVE.	RUSSELL AVE.		FIREHOUSE DRWY. CO.#8
29	NEBEL ST.	RANDOLPH RD.		Railroad
52	N/A not a PE signal probaly error msg in events.			
65	GAYNOR RD.	PARKLAND DR.	VEIRS MILL RD. (MD.586)	FIREHOUSE DRWY. CO.#21
83	AIRPARK RD.	MUNCASTER MILL RD. (MD.115)	SHADY GROVE RD	FIREHOUSE DRWY. CO.#28
90	BEALL AVE.	HUNGERFORD DR. (MD.355)		FIREHOUSE DRWY. CO.#3
102	ROCKVILLE PK. (MD.355) &	ROLLINS AVE.	TWINBROOK PKWY.	FIREHOUSE CO.#23
118	EAST DIAMOND AVE.	N. SUMMIT AVE.		Railroad
120	BEL PRE RD.	CONNECTICUT AVE. (MD 185)		FIREHOUSE CO.#25
134	N/A not a PE signal probaly error msg in events.			
153	N/A not a PE signal probaly error msg in events			
160	CEDAR LA.	OAKMONT AVE.	OLD GEORGETOWN RD. (MD.187)	FIREHOUSE DRWY. CO.#20
173	CONNECTICUT AVE. (MD.185)	FLYERS MILL RD. (MD.192)		FIREHOUSE CO.#5
182	N/A not a PE signal probaly error msg in events.			
230	GEORGIA AVE. (MD.97)	RANDOLPH RD.		FIREHOUSE CO.#18
243	BRADLEY BLVD. (MD.191)	BRADLEY LA. (MD.192)	WISC. AVE. (MD.355)	FIREHOUSE CO.#6
251	BATTERY LA.	OLD GEORGETOWN RD. (MD.187)		B.C.C. RESCUE SQUAD DRWY.CO.#
285	BRIGGS CHANEY RD.	OLD COLUMBIA PK.		FIREHOUSE CO.#15
289	BRIGGS CHANEY RD.	COLUMBIA PK. (US 29)		Controlled by FIREHOUSE DRWY. CO #15
296	N/A not a PE signal probaly error msg in events.			
297	CHALMERS RD.	NEW HAMPSHIRE AVE. (MD.650)		FIRE HOUSE DRWY. CO.#12
318	GEORGIA AVE. (US 29)	SILVER SPRING AVE.		FIREHOUSE CO.#1
339	UNIV. BLVD. E. (MD.193)	WILLIAMSBURG DR.		FIRE HOUSE DRWY. CO.#15
348	NEW HAMPSHIRE AVE. (MD.650)	WOLF DR.		FIRE HOUSE DRWY. CO.#24
358	N/A not a PE signal probaly error msg in events.			
392	DARNESTOWN RD. (MD.28)	QUINCE ORCHARD RD. (MD.124)		Controlled by FIREHOUSE DRWY. CO.#31
424	N/A not a PE signal probaly error msg in events.			
428	MASSACHUSETTS AVE. (MD.396)	SANGAMORE RD.		FIRE HOUSE DRWY. CO.#11
435	N/A not a PE signal probaly error msg in events.			
500	N/A not a PE signal probaly error msg in events.			
558	N/A not a PE signal probaly error msg in events.			
577	N/A not a PE signal probaly error msg in events.			
611	CHESTNUT ST.	EAST DIAMOND AVE.	MCBAIN AVE	Railroad
640	N/A not a PE signal probaly error msg in events.			
657	DEMOCRACY BLVD.			FIREHOUSE CO.#26
668	FREDERICK RD. (MD.355)	OLD HUNDRED RD. (MD.109)		FIREHOUSE CO.#9
681	CONNECTICUT AVE. (MD.185)	DUNLOP ST.		FIREHOUSE CO.#7
686	N/A not a PE signal probaly error msg in events.			
697	DARNESTOWN RD. (MD28)	Potomac Valley Shop. Ctr.		Controlled by FIREHOUSE DRWY. CO.#31
698	N/A not a PE signal probaly error msg in events.			
704	DARNESTOWN RD. (MD.28) &	TSCHIFFLEY SQUARE RD.		Controlled by FIREHOUSE DRWY. CO.#31
732	N/A not a PE signal probaly error msg in events.			
742	N/A not a PE signal probaly error msg in events.			

Appendix C7. Sample of the Emergency Vehicle Preemption Request Data Obtained from Montgomery County, MD.

Date	time	int	preempt	status	date1
4404/24/00	0:05:28	"611,"	ON	44	04/24/00
4504/24/00	0:05:43	"611,"	OFF	45	04/24/00
4404/24/00	0:05:57	"118,"	ON	44	04/24/00
4504/24/00	0:09:22	"118,"	OFF	45	04/24/00
4404/24/00	0:13:27	"318,"	ON	44	04/24/00
4504/24/00	0:14:07	"318,"	OFF	45	04/24/00
4404/24/00	0:16:32	"26,"	ON	44	04/24/00
4404/24/00	0:16:38	"318,"	ON	44	04/24/00
4504/24/00	0:17:12	"318,"	OFF	45	04/24/00
4504/24/00	0:18:09	"26,"	OFF	45	04/24/00
4404/24/00	0:28:49	"8,"	ON	44	04/24/00
4504/24/00	0:29:39	"8,"	OFF	45	04/24/00
4404/24/00	0:29:43	"318,"	ON	44	04/24/00
4504/24/00	0:30:18	"318,"	OFF	45	04/24/00
4404/24/00	0:32:26	"657,"	ON	44	04/24/00
4404/24/00	0:32:34	"129,"	ON	44	04/24/00
4404/24/00	0:32:41	"318,"	ON	44	04/24/00
4404/24/00	0:32:45	"118,"	ON	44	04/24/00
4504/24/00	0:33:09	"118,"	OFF	45	04/24/00
4404/24/00	0:33:15	"118,"	ON	44	04/24/00
4504/24/00	0:33:16	"318,"	OFF	45	04/24/00
4504/24/00	0:33:21	"657,"	OFF	45	04/24/00
4404/24/00	0:34:20	"210,"	ON	44	04/24/00
4504/24/00	0:34:29	"129,"	OFF	45	04/24/00
4504/24/00	0:34:55	"210,"	OFF	45	04/24/00
4404/24/00	0:37:04	"26,"	ON	44	04/24/00
4504/24/00	0:37:06	"118,"	OFF	45	04/24/00
4504/24/00	0:38:39	"26,"	OFF	45	04/24/00
4404/24/00	0:44:39	"8,"	ON	44	04/24/00
4504/24/00	0:45:29	"8,"	OFF	45	04/24/00
4404/24/00	0:47:22	"26,"	ON	44	04/24/00
4504/24/00	0:48:36	"26,"	OFF	45	04/24/00
4404/24/00	0:53:50	"118,"	ON	44	04/24/00
4504/24/00	0:55:22	"118,"	OFF	45	04/24/00
4404/24/00	1:12:20	"318,"	ON	44	04/24/00
4504/24/00	1:12:55	"318,"	OFF	45	04/24/00
4404/24/00	1:19:02	"210,"	ON	44	04/24/00
4504/24/00	1:19:37	"210,"	OFF	45	04/24/00
4404/24/00	1:33:58	"118,"	ON	44	04/24/00
4504/24/00	1:36:20	"118,"	OFF	45	04/24/00
4404/24/00	1:38:29	"26,"	ON	44	04/24/00
4404/24/00	1:40:55	"8,"	ON	44	04/24/00
4504/24/00	1:41:46	"8,"	OFF	45	04/24/00
4504/24/00	1:42:50	"26,"	OFF	45	04/24/00
4404/24/00	1:43:40	"26,"	ON	44	04/24/00
4504/24/00	1:45:13	"26,"	OFF	45	04/24/00

Appendix C8. Significance Tests.

The ANOVA analysis tool is a parametric testing methodology that provides different types of variance analysis. The tool to use depends on the number of factors and the number of samples you have from the populations you want to test. The *ANOVA Two-Factor without Replication* Test performs a two-factor ANOVA that does not include more than one sampling per group, testing the hypothesis that means from two or more samples are equal (drawn from populations with the same mean). This technique expands on tests for two means, such as the t-test *(38)*.

The t-Test analysis tool is a parametric testing methodology and is an appropriate test for small sample sizes assuming that the underlying populations follow a normal distribution with equal variances. The *t-Test: Two-Sample Assuming Equal Variances* analysis tool performs a two-sample student's t-test. This t-test form assumes that the means of both data sets are equal; it is referred to as a homoscedastic t-test. It can be used to determine whether two sample means are equal.

A test statistic for a difference between two population means with equal population variances is given by *(38)*:

$$t^* = \frac{(\overline{X_1} - \overline{X_2}) - (\mu_1 - \mu_2)}{\sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})}},$$

where the term $(\mu_1 - \mu_2)$ is the difference between μ_1 and μ_2 under the null hypothesis. The degrees of freedom of the test statistic are $n_1 + n_2 - 2$, which are the degrees of freedom associated with the pooled estimate of the population variance s_p^2. This pooled variance s_p^2, is based on the sample variance s_1^2 obtained from a sample of size n_1, and a sample variance s_2^2 obtained from a sample of size n_2, and is given by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

C8.1. ANOVA Testing the Sample Variability of Frequency of Emergency Vehicle Preemption Requests among the 25 Intersections.

ANOVA Testing the Sample Variability of the Frequency of EV Requests By Day of Week among the 25 intersections.

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	5	32	6.4	11.3
Row 2	5	115	23	8
Row 3	5	47	9.4	11.3
Row 4	5	4	0.8	3.2
Row 5	5	177	35.4	92.8
Row 6	5	39	7.8	16.7
Row 7	5	80	16	8.5
Row 8	5	89	17.8	15.7
Row 9	5	107	21.4	43.3
Row 10	5	43	8.6	14.3
Row 11	5	43	8.6	14.3
Row 12	5	77	15.4	2.3
Row 13	5	37	7.4	2.8
Row 14	5	35	7	3.5
Row 15	5	179	35.8	39.7
Row 16	5	172	34.4	20.8
Row 17	5	60	12	14.5
Row 18	5	44	8.8	6.2
Row 19	5	24	4.8	33.7
Row 20	5	2	0.4	0.3
Row 21	5	37	7.4	10.8
Row 22	5	2	0.4	0.3
Row 23	5	67	13.4	18.3
Row 24	5	33	6.6	32.3
Row 25	5	26	5.2	16.7
Column 1	25	285	11.4	87.16667
Column 2	25	297	11.88	146.11
Column 3	25	280	11.2	100
Column 4	25	350	14	139.0833
Column 5	25	359	14.36	124.9067

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	12792.27	24	533.0113	33.18083	2.74569E-36	1.63128
Columns	224.272	4	56.068	3.490325	0.01048137	2.466479
Error	1542.128	96	16.06383			
Total	14558.67	124				

Since F> Fcr. for both rows and columns (days of week, intersections),there is evidence to support the notion that there exists a significant difference at the 95% confidence interval in the weekly frequency of EV requests between different days of week and among the 25 intersections.

C8.2. ANOVA Testing the Sample Variability of Frequency of Emergency Vehicle Preemption Requests among the 25 Intersections.

ANOVA Testing the Sample Variability of the Frequency of EV Requests By Hour of Day among the 25 intersections.

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	5	35	7	18.5
Row 2	5	26	5.2	5.7
Row 3	5	12	2.4	2.3
Row 4	5	14	2.8	2.7
Row 5	5	13	2.6	4.8
Row 6	5	21	4.2	5.2
Row 7	5	44	8.8	48.2
Row 8	5	42	8.4	6.3
Row 9	5	92	18.4	23.8
Row 10	5	66	13.2	28.7
Row 11	5	84	16.8	25.7
Row 12	5	94	18.8	30.7
Row 13	5	107	21.4	63.8
Row 14	5	116	23.2	17.7
Row 15	5	102	20.4	114.3
Row 16	5	95	19	41.5
Row 17	5	113	22.6	80.3
Row 18	5	88	17.6	20.8
Row 19	5	80	16	34
Row 20	5	76	15.2	9.7
Row 21	5	67	13.4	8.3
Row 22	5	79	15.8	78.7
Row 23	5	52	10.4	9.3
Row 24	5	48	9.6	16.3
Column 1	24	278	11.58333	40.07971
Column 2	24	299	12.45833	65.30254
Column 3	24	280	11.66667	64.31884
Column 4	24	350	14.58333	83.9058
Column 5	24	359	14.95833	81.51993

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	5168.5	23	224.7174	8.14124	9.09232E-14	1.6472832
Columns	249.7833	4	62.44583	2.262337	0.068379111	2.47068499
Error	2539.417	92	27.60236			
Total	7957.7	119				

Since F> Fcr. for rows (hours of day),there is evidence to support the notion that there exists a significant difference at the 95% confidence interval in the frequency of EV requests between different hours of the day among the 25 intersections.

C8.3 T-tests Testing for Statistical Differences in the Frequency of Emergency Vehicle Preemption Requests By Time of Day.

t-Tests Testing the Sample Variability of the Frequency of EV Requests By Time of Day

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	35.6	63.4
Variance	38.8	96.3
Observations	5	5
Pooled Variance	67.55	
Hypothesized Mean	0	
df	8	
t Stat	-5.348132	
P(T<=t) one-tail	0.000344	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.000687	
t Critical two-tail	2.306006	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	63.4	39.6
Variance	96.3	59.3
Observations	5	5
Pooled Variance	77.8	
Hypothesized Mear	0	
df	8	
t Stat	4.266356699	
P(T<=t) one-tail	0.001368836	
t Critical one-tail	1.85954832	
P(T<=t) two-tail	0.002737673	
t Critical two-tail	2.306005626	

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	35.6	56.2
Variance	38.8	307.7
Observations	5	5
Pooled Variance	173.25	
Hypothesized Mean	0	
df	8	
t Stat	-2.474575	
P(T<=t) one-tail	0.019218	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.038435	
t Critical two-tail	2.306006	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	63.4	56.2
Variance	96.3	307.7
Observations	5	5
Pooled Variance	202	
Hypothesized Mear	0	
df	8	
t Stat	0.800989487	
P(T<=t) one-tail	0.223136148	
t Critical one-tail	1.85954832	
P(T<=t) two-tail	0.446272297	
t Critical two-tail	2.306005626	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	35.6	39.6
Variance	38.8	59.3
Observations	5	5
Pooled Variance	49.05	
Hypothesized Mean	0	
df	8	
t Stat	-0.903047	
P(T<=t) one-tail	0.19644	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.392879	
t Critical two-tail	2.306006	

t-Test: Two-Sample Assuming Equal Variances

	Night	*PM*
Mean	39.6	56.2
Variance	59.3	307.7
Observations	5	5
Pooled Variance	183.5	
Hypothesized Mear	0	
df	8	
t Stat	-1.937581852	
P(T<=t) one-tail	0.044338387	
t Critical one-tail	1.85954832	
P(T<=t) two-tail	0.088676775	
t Critical two-tail	2.306005626	

Since t Stat >t Critical (two tail), we can conclude that the AM and Midday cases; the AM and Midday Cases; and the Midday and Night cases are different at the 95% confidence interval.

C8.4. ANOVA Testing the Sample Variability of Duration of Emergency Vehicle Preemptions among the 25 Intersections.

ANOVA Testing the Sample Variability of the Duration of Preemptions By Day of Week among the 25 intersections.

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	5	395.11	79.022	0.00242
Row 2	5	250.39	50.078	0.00282
Row 3	5	148.59	29.718	0.03447
Row 4	5	39	7.8	304.2
Row 5	5	266.94	53.388	0.17407
Row 6	5	223.52	44.704	28.67508
Row 7	5	590.97	118.194	13.68373
Row 8	5	194.65	38.93	1.6102
Row 9	5	179.01	35.802	0.00332
Row 10	5	18.7	3.74	0.40985
Row 11	5	174.65	34.93	0.0187
Row 12	5	220.04	44.008	3.23672
Row 13	5	261.97	52.394	7.23083
Row 14	5	153.75	30.75	47.22795
Row 15	5	240.43	48.086	7.47548
Row 16	5	165.91	33.182	258.2174
Row 17	5	231.85	46.37	0.10205
Row 18	5	230.58	46.116	0.04748
Row 19	5	388.7	77.74	57.913
Row 20	5	116	23.2	848.7
Row 21	5	275.93	55.186	0.04118
Row 22	5	77	15.4	447.8
Row 23	5	359.68	71.936	0.00343
Row 24	5	398.13	79.626	122.3874
Row 25	5	331	66.2	2.89945
Column 1	25	1139.52	45.5808	717.6006
Column 2	25	1219.33	48.7732	584.2942
Column 3	25	1275.16	51.0064	521.8733
Column 4	25	1147.31	45.8924	756.1535
Column 5	25	1151.18	46.0472	946.0587

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	76572.3	24	3190.512	38.04252	8.74E-39	1.63128
Columns	557.1553	4	139.2888	1.66083	0.165438	2.466479
Error	8051.233	96	83.86701			
Total	85180.68	124				

Since F< Fcr. for columns (days of week),there is no evidence to support the notion that the duration of preemptions is different by day of week.
Since F> Fcr. for rows (intersections),there is evidence to support the notion that the duration of preemptions is different among the 25 intersections.

C8.5 T-tests Testing for Statistical Differences in the Frequency and Duration of Emergency Vehicle Preemption Requests at Signalized Intersections in Fairfax County, VA and in Montgomery County, MD.

Comparison of Frequency and Duration of Preemptions at Signalized Intersections Along Arterials in Fairfax County, VA and in Montgomery County, MD using t-test

t-Test: Two-Sample Assuming Unequal Variances

	Duration MD	***Duration VA***
Mean	47.46	20.25
Variance	638.1024723	15.455
Observations	25	6
Hypothesized Mean Difference	0	
df	28	
t Stat	5.133054857	
P(T<=t) one-tail	9.63834E-06	
t Critical one-tail	1.701130259	
P(T<=t) two-tail	1.92767E-05	
t Critical two-tail	2.048409442	

t-Test: Two-Sample Assuming Unequal Variances

	Frequency MD	***Frequency VA***
Mean	12.568	7.95
Variance	106.6022667	4.363
Observations	25	6
Hypothesized Mean Difference	0	
df	29	
t Stat	2.067040319	
P(T<=t) one-tail	0.023879717	
t Critical one-tail	1.699127097	
P(T<=t) two-tail	0.047759433	
t Critical two-tail	2.045230758	

Since t Stat >t Critical (two tail), we can conclude that there seems to be a difference in the duration of preemptions between the two Counties at the 95% confidence interval. There is a subtle difference between the daily frequencies of preemption requests between the two Counties at the 95% confidence interval.

Note: This analysis tool performs a two-sample student's t-test. This t-test form assumes that the variances of both ranges of data are unequal; it is referred to as a heteroscedastic t-test. It can be used when the groups under study are distinct to determine whether two sample means are equal.

Appendix C9. Analysis and Results-Signalized Railroad Crossings *(39)*.

Table C9.1 shows the number of preemption requests at all the 3 signalized railroad crossings during a day. Figure C9.1 represents the above data graphically. From the standard deviation of number of preemption calls on different days at a particular intersection, at all the intersections, at 95% significance level, there is not enough evidence to conclude that there exists a difference (all the values lies within mean + or – 2* standard deviation) in the number of preemption calls during different days of the week.

Table C9.1. Number of Preemption Requests at Signalized Railroad Crossings

Int	Mon	Tue	Wed	Thu	Fri	Average	Stdev
26	57	48	45	83	88	64.2	20.0
118	58	55	45	58	58	54.8	5.6
611	44	49	41	48	54	47.2	5.0

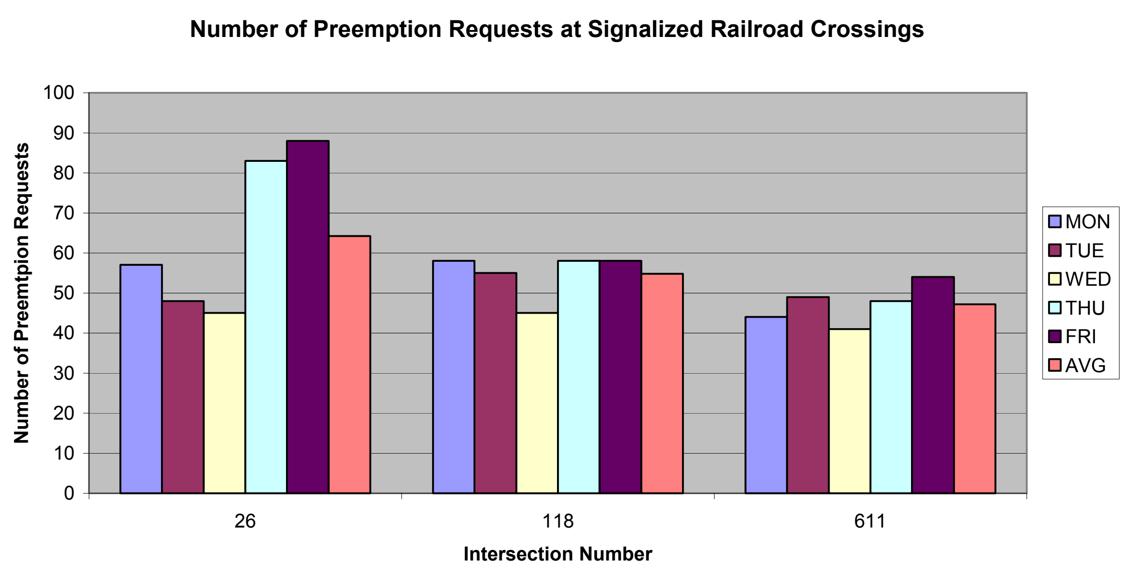


Figure C9.1. Number of Preemption Requests at Signalized Railroad Crossings.

Table C9.2 shows the number of preemption requests at signalized railroad crossings by hour of the day and day of the week. Figure C9.2 represents the above data graphically. From the standard deviation of number of preemption calls on different days in a particular hour, almost during all the hours of the day, at 95% significance level, there is not enough evidence to conclude that there exists a difference (all the values lies within mean + or – 2* standard deviation) in the number of preemption requests during different days of the week. From the graph C9.2, it can be seen that, as a general trend the number of requests decreases till 4 am and then it increases till 8 am, then it decreases till 2 pm. Again the number of preemption requests increases till 5 pm and then it decreases till 10pm. Finally the number requests increases till the end.

Table C9.2. Preemption Requests by Hour of the Day and Day of the Week At Signalized Railroad Crossings

Time Period	Mon	Tue	Wed	Thu	Fri	Average	Stdev
00:00-01:00	8	6	0	8	3	5	3.5
01:00-02:00	3	3	5	3	2	3.2	1.1
02:00-03:00	6	3	2	6	4	4.2	1.8
03:00-04:00	2	3	2	3	0	2	1.2
04:00-05:00	4	2	2	9	2	3.8	3.0
05:00-06:00	6	6	4	7	7	6	1.2
06:00-07:00	14	9	7	10	7	9.4	2.9
07:00-08:00	12	10	8	12	8	10	2.0
08:00-09:00	4	6	6	14	11	8.2	4.1
09:00-10:00	6	4	4	16	6	7.2	5.0
10:00-11:00	7	6	5	8	19	9	5.7
11:00-12:00	5	3	8	1	22	7.8	8.3
12:00-13:00	3	5	2	6	9	5	2.7
13:00-14:00	1	1	5	7	1	3	2.8
14:00-15:00	15	7	8	6	18	10.8	5.4
15:00-16:00	6	12	9	7	5	7.8	2.8
16:00-17:00	9	9	11	13	24	13.2	6.3
17:00-18:00	12	11	15	9	11	11.6	2.2
18:00-19:00	8	8	7	13	17	10.6	4.3
19:00-20:00	14	18	5	9	9	11	5.0
20:00-21:00	8	4	1	2	5	4	2.7
21:00-22:00	0	6	2	0	7	3	3.3
22:00-23:00	0	2	9	10	0	4.2	4.9
23:00-24:00	10	6	4	10	3	6.6	3.3

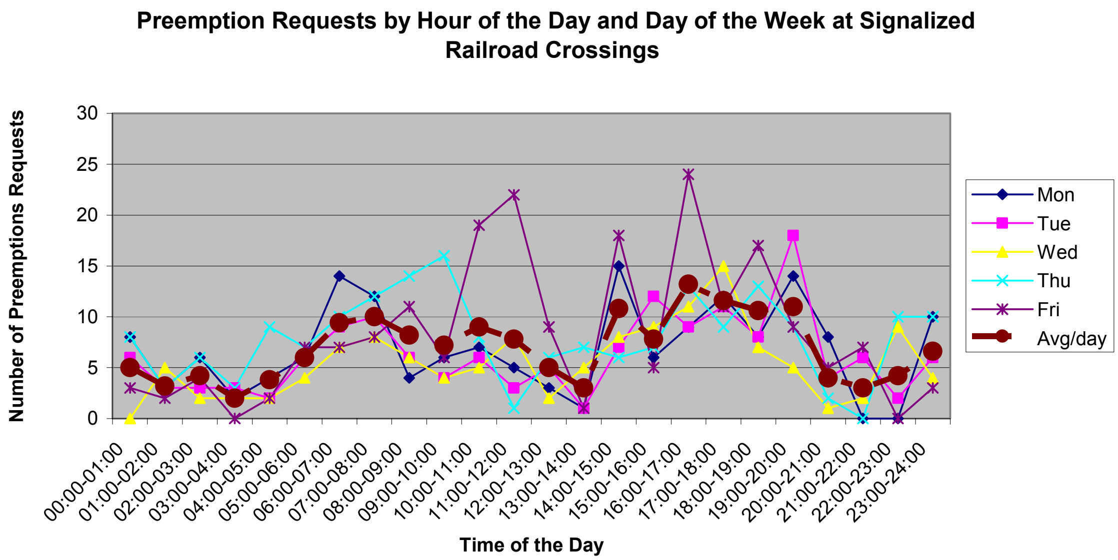


Figure C9.2. Number of Preemption Requests by Hour of the Day and Day of the Week.

Different time periods of day are considered that include four 3-hr periods: AM peak period, Midday, PM peak period and Night. Figure C9.3 shows the number of emergency preemption requests by time of day made during the 5-weekday period under study. The Y-axis represents the number of emergency preemption requests and the X-axis represents the time of day. It can be observed that the frequency of emergency preemption requests is higher during the PM peak period and lower during the AM peak period in most days of week. Thus, the disruption to the other traffic is expected to be more during daytime than during nighttime.

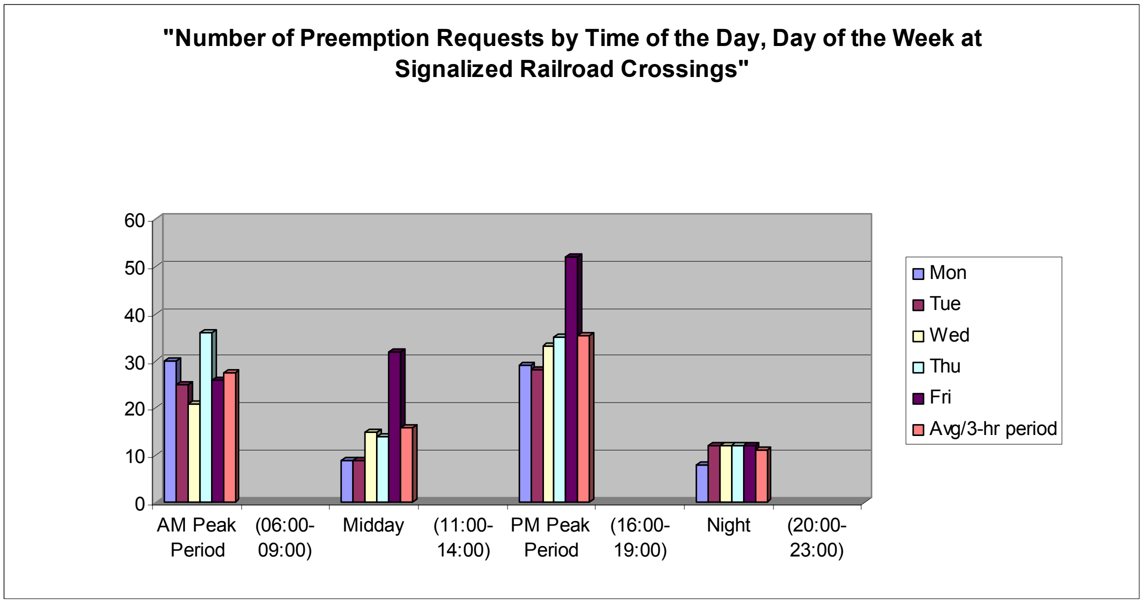


Figure C9.3. Number of Preemption Requests by Time of the Day and Day of the Week.

Table C9.3 shows average duration of preemption time at signalized railroad intersections. Figure C9.4 represents the above data graphically. From the standard deviation of average duration time on different intersections, almost at all the three railroad intersections, at 95% significance level, there is not enough evidence to conclude to there exists a difference (all the values lies within mean + or – 2* standard deviation) in the average duration of preemption calls during different days of the week. The average duration of preemption time at all the intersections is 77.1 seconds (average duration values at all the intersections lie within mean + or – 2* standard deviation).

Table C9.3. Average Duration of Preemptions at Signalized Railroad Crossings.

Int	Mon	Tue	Wed	Thu	Fri	Average	Stdev
26	78.4	78.4	70.8	81.1	44.7	68.8	15.0
118	153.3	157.5	153.3	144.3	129.9	147.3	11.0
611	15.2	15.2	15.2	15.2	15.2	15.2	0.0
					Average	77.1	
					Stdev	66.4	

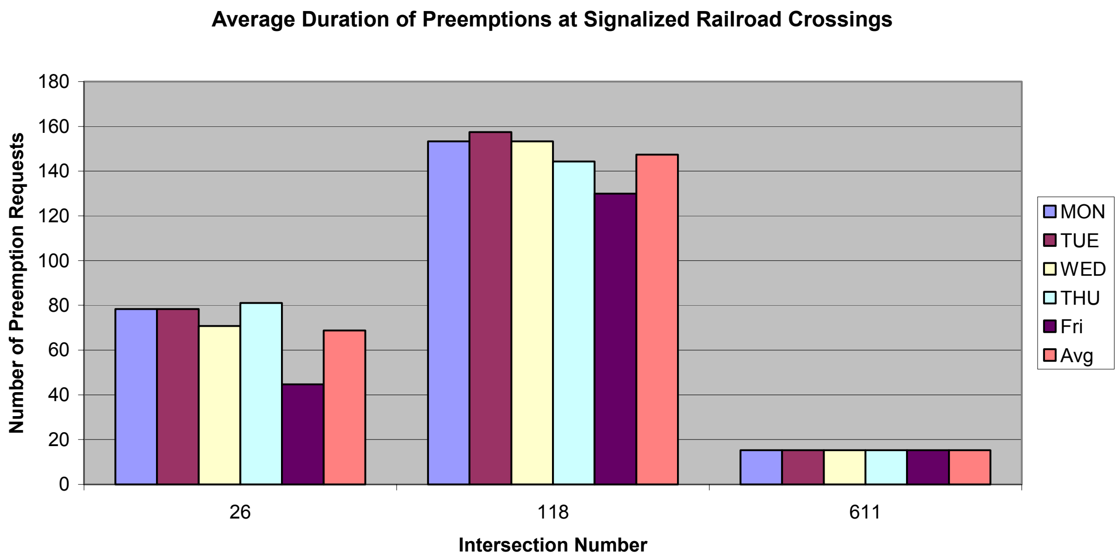
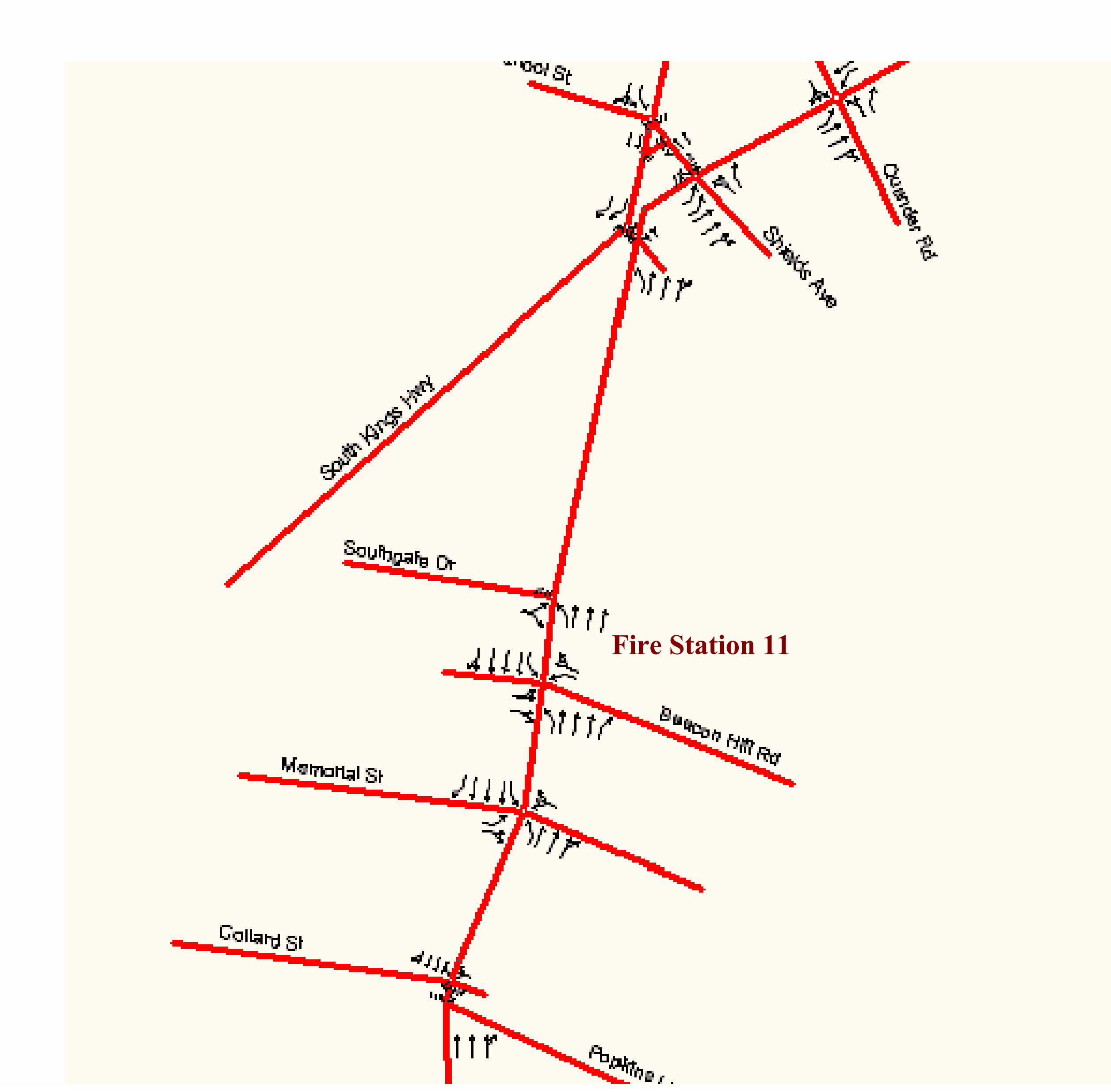


Figure C9.4. Average Duration of Preemptions at Signalized Railroad Crossings.

Appendix D

Analysis of Emergency Preemption & Priority Data From The 3M™ Opticom™ Priority Control System on U.S.1, Fairfax County, VA (04/07/03-04/14/03)

Appendix D1. U.S.1 Study Area Map.



Appendix D2. Sample of the Emergency Vehicle Preemption & Priority Request Data Obtained from the 3M Opticom System.

Chan	Signal #	Log #	Date	Start Time	End Time	Duration	Class	ID	Priority	G. Time	Final G.	Intensity	PRE-EMPT
A	1025	1	4/14/2003	8:26:38	8:27:30	52	0	862	Low	43	2+6	1011	Yes
A	1025	2	4/14/2003	7:59:09	8:00:17	68	7	856	Low	15	2+6	1007	Yes
B	1025	895	4/13/2003	23:28:22	23:28:36	14	6	17	High	7	2+5	837	Yes
B	1025	896	4/13/2003	20:30:13	20:30:28	15	6	17	High	8	2+5	820	Yes
B	1025	897	4/13/2003	20:29:30	20:29:48	18	0	0	High	20	2+5	917	Yes
B	1025	898	4/13/2003	20:29:25	20:29:43	18	6	103	High	15	2+5	924	Yes
B	1025	899	4/13/2003	3:03:14	3:03:23	9	0	0	High	8	2+5	337	Yes
B	1025	900	4/12/2003	22:03:18	22:03:27	9	0	1	High	6	2+5	524	Yes
B	1025	901	4/12/2003	22:03:11	22:03:20	9	6	103	High	5	2	520	Yes
B	1025	902	4/12/2003	13:39:06	13:39:23	17	0	0	High	11	2+5	912	Yes
A	1025	903	4/12/2003	12:25:41	12:25:53	12	7	859	Low	53	2+6	1007	Yes
B	1025	904	4/12/2003	7:56:41	7:56:49	8	7	859	Low	14	2+6	917	Yes
A	1025	905	4/12/2003	6:55:31	6:56:06	35	7	859	Low	14	2+6	1012	Yes
B	1025	906	4/12/2003	3:19:17	3:19:34	17	6	103	High	10	2+5	938	Yes
A	1025	907	4/11/2003	23:17:42	23:17:51	9	7	857	Low	24	2+6	1006	Yes
A	1025	908	4/11/2003	21:26:36	21:26:46	10	7	857	Low	55	2+6	1008	Yes
B	1025	909	4/11/2003	21:05:00	21:05:08	8	7	857	Low	104	2+6	907	Yes
A	1025	910	4/11/2003	19:28:44	19:28:57	13	7	857	Low	23	2+6	918	Yes
B	1025	911	4/11/2003	18:59:58	19:00:06	8	7	857	Low	70	2+6	901	Yes
B	1025	912	4/11/2003	18:34:34	18:34:44	10	0	0	High	3	2+5	541	Yes
A	1025	913	4/11/2003	18:22:12	18:23:17	65	0	864	Low	23	2+6	1014	Yes
A	1025	914	4/11/2003	18:20:56	18:21:05	9	7	859	Low	63	2+6	1002	Yes
B	1025	915	4/11/2003	17:32:44	17:33:00	16	6	17	High	9	2+5	908	Yes
B	1025	916	4/11/2003	17:29:29	17:29:43	14	0	0	High	7	2+5	896	Yes
A	1025	917	4/11/2003	17:24:42	17:26:05	83	7	857	Low	19	2+6	1008	Yes
B	1025	918	4/11/2003	15:26:39	15:26:58	19	6	103	High	12	2+5	898	Yes
B	1025	919	4/11/2003	15:08:33	15:08:53	20	6	17	High	13	2+5	835	Yes
B	1025	920	4/11/2003	15:00:14	15:01:02	48	0	862	Low	12	2+5	906	Yes
B	1025	921	4/11/2003	12:55:33	12:56:01	28	0	862	Low	15	2+5	906	Yes
A	1025	922	4/11/2003	8:59:20	8:59:49	29	0	864	Low	14	2+6	999	Yes
B	1025	923	4/11/2003	8:31:13	8:31:22	9	0	864	Low	84	2+6	842	Yes
A	1025	924	4/11/2003	8:30:08	8:30:20	12	0	862	Low	22	2+6	1006	Yes
A	1025	925	4/11/2003	7:59:37	8:00:04	27	7	856	Low	14	2+6	1010	Yes
B	1025	926	4/11/2003	7:56:47	7:57:03	16	6	103	High	18	2+5	890	Yes
B	1025	927	4/11/2003	7:56:37	7:56:55	18	0	0	High	10	2+5	899	Yes
A	1025	928	4/11/2003	7:29:52	7:30:24	32	0	860	Low	19	2+6	999	Yes
B	1025	929	4/11/2003	7:05:35	7:06:00	25	7	856	Low	17	2+5	903	Yes
B	1025	930	4/11/2003	5:59:18	5:59:32	14	7	857	Low	11	2+5	897	Yes
A	1025	931	4/10/2003	21:23:52	21:24:04	12	7	857	Low	47	2+6	1008	Yes
B	1025	932	4/10/2003	18:56:41	18:56:57	16	0	0	High	9	2+5	712	Yes
B	1025	933	4/10/2003	18:53:30	18:53:43	13	0	1	High	6	2+5	733	Yes
A	1025	934	4/10/2003	18:22:56	18:23:06	10	0	864	Low	22	2+6	1011	Yes
A	1025	935	4/10/2003	17:56:17	17:56:29	12	0	862	Low	41	2+6	1011	Yes
A	1025	936	4/10/2003	17:26:10	17:26:36	26	7	857	Low	90	2+6	1014	Yes
B	1025	937	4/10/2003	16:00:01	16:00:12	11	0	0	High	4	2+5	631	Yes
B	1025	938	4/10/2003	15:58:48	15:59:07	19	0	0	High	12	2+5	713	Yes
B	1025	939	4/10/2003	13:02:09	13:02:18	9	----	----	High	2	2+5	514	Yes
A	1025	940	4/10/2003	8:56:40	8:57:07	27	0	864	Low	17	2+6	1014	Yes
A	1025	941	4/10/2003	8:26:38	8:26:56	18	0	862	Low	14	2+6	1012	Yes
A	1025	942	4/10/2003	7:59:38	7:59:48	10	7	856	Low	16	2+6	1009	Yes
B	1025	943	4/10/2003	7:35:35	7:35:52	17	0	0	High	19	2+5	802	Yes
A	1025	944	4/10/2003	7:30:15	7:30:23	8	0	860	Low	24	2+6	999	Yes
A	1025	945	4/10/2003	6:27:15	6:27:25	10	7	857	Low	47	2+6	1009	Yes
A	1025	946	4/10/2003	5:56:43	5:56:50	7	0	862	Low	17	2+6	1004	Yes
B	1025	947	4/10/2003	5:31:14	5:31:22	8	0	862	Low	102	2+6	903	Yes
B	1025	948	4/10/2003	2:03:47	2:03:59	12	0	0	High	5	2+5	842	Yes
A	1025	949	4/9/2003	21:23:34	21:23:56	22	7	857	Low	19	2+6	1000	Yes
B	1025	950	4/9/2003	21:00:43	21:01:00	17	7	857	Low	2	2	907	Yes
B	1025	951	4/9/2003	20:44:33	20:44:54	21	0	0	High	14	2+5	544	Yes
A	1025	952	4/9/2003	19:25:11	19:25:20	9	7	857	Low	22	2+6	1014	Yes
B	1025	953	4/9/2003	19:23:35	19:23:43	8	0	862	Low	71	2+6	903	Yes
A	1025	954	4/9/2003	18:15:26	18:15:35	9	7	859	Low	4	3	943	Yes
A	1025	955	4/9/2003	17:18:49	17:20:22	93	0	860	Low	19	2+6	999	Yes
B	1025	956	4/9/2003	16:23:58	16:24:06	8	7	857	Low	60	2+6	904	Yes
A	1025	957	4/9/2003	16:21:44	16:23:26	102	7	859	Low	20	2+6	1008	Yes
A	1025	958	4/9/2003	15:16:34	15:17:05	31	0	862	Low	18	2+6	1008	Yes
B	1025	959	4/9/2003	14:57:50	14:58:29	39	0	862	Low	4	2+6	906	Yes
A	1025	960	4/9/2003	14:22:47	14:23:47	60	7	859	Low	14	2+6	1013	Yes
A	1025	961	4/9/2003	13:13:28	13:13:52	24	0	862	Low	19	2+6	1011	Yes
B	1025	962	4/9/2003	11:18:10	11:18:32	22	0	0	High	15	2+5	900	Yes
A	1025	963	4/9/2003	8:27:21	8:27:38	17	0	862	Low	13	2+6	1012	Yes
A	1025	964	4/9/2003	7:59:07	7:59:20	13	7	856	Low	0	5	1011	Yes
A	1025	965	4/9/2003	7:47:57	7:48:54	57	6	17	High	56	1+6	943	Yes
B	1025	966	4/9/2003	7:24:19	7:24:33	14	0	0	High	6	2+5	838	Yes

Appendix D3 Significance Tests.

The ANOVA analysis tool is a parametric testing methodology that provides different types of variance analysis. The tool to use depends on the number of factors and the number of samples you have from the populations you want to test. The *ANOVA Single-Factor* Test performs a simple ANOVA. The *ANOVA Two-Factor without Replication* Test performs a two-factor ANOVA that does not include more than one sampling per group, testing the hypothesis that means from two or more samples are equal (drawn from populations with the same mean). This technique expands on tests for two means, such as the t-test *(38)*.

The t-Test analysis tool is a parametric testing methodology and is an appropriate test for small sample sizes assuming that the underlying populations follow a normal distribution with equal variances. The *t-Test: Two-Sample Assuming Equal Variances* analysis tool performs a two-sample student's t-test. This t-test form assumes that the means of both data sets are equal; it is referred to as a homoscedastic t-test. It can be used to determine whether two sample means are equal.

A test statistic for a difference between two population means with equal population variances is given by *(38)*:

$$t^* = \frac{(\overline{X_1} - \overline{X_2}) - (\mu_1 - \mu_2)}{\sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})}},$$

where the term $(\mu_1 - \mu_2)$ is the difference between μ_1 and μ_2 under the null hypothesis. The degrees of freedom of the test statistic are $n_1 + n_2 - 2$, which are the degrees of freedom associated with the pooled estimate of the population variance s_p^2. This pooled variance s_p^2, is based on the sample variance s_1^2 obtained from a sample of size n_1, and a sample variance s_2^2 obtained from a sample of size n_2, and is given by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

D3.1. ANOVA Testing the Sample Variability of Frequency of Emergency Vehicle Preemption Requests among the six Intersections.

ANOVA Testing the Sample Variability of Frequency of Preemption Requests among the six intersections

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	8	36	4.5	4.857143
Column 2	8	38	4.75	5.071429
Column 3	8	63	7.875	21.55357
Column 4	8	68	8.5	36.28571
Column 5	8	64	8	21.42857
Column 6	8	56	7	14.28571

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	120.1042	5	24.02083	1.392752	0.246579	2.437694491
Within Groups	724.375	42	17.24702			
Total	844.4792	47				

Since F<Fcr. f,there is no evidence to support the notion that the frequency of preemption requests is different among the six intersections.

D3.2. ANOVA Testing the Sample Variability of Frequency of Transit Priority Requests among the six Intersections.

ANOVA Testing the Sample Variability of Frequency of Priority Requests among the six intersections

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	8	71	8.875	78.125
Column 2	8	30	3.75	15.07143
Column 3	8	65	8.125	92.98214
Column 4	8	141	17.625	239.6964
Column 5	8	137	17.125	270.125
Column 6	8	124	15.5	172.8571

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1302.667	5	260.5333	1.799145	0.133906	2.437694
Within Groups	6082	42	144.8095			
Total	7384.667	47				

Since F<Fcr. f,there is no evidence to support the notion that the frequency of priority requests is different among the six intersections.

D3.3. ANOVA Testing the Sample Variability of Duration of Emergency Vehicle Preemptions among the six Intersections.

ANOVA Testing the Sample Variability of Duration of Preemptions among the six intersections

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	36	610	16.94444	62.2254
Column 2	38	828	21.78947	22.60313
Column 3	63	1166	18.50794	252.8024
Column 4	68	1369	20.13235	239.0121
Column 5	64	1727	26.98438	68.14261
Column 6	56	1122	20.03571	18.28961

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3402.3	5	680.46	5.426577	8.30104E-05	2.242288133
Within Groups	40000.67	319	125.394			
Total	43402.97	324				

Since F> Fcr. f,there is evidence to support the notion that the duration of preemptions is different among the six intersections.

D3.4. ANOVA Testing the Sample Variability of Duration of Priority Phase among the six Intersections.

ANOVA Testing the Sample Variability of Duration of Priority Phase among the six intersections

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	71	1811	25.50704	448.7964
Column 2	30	739	24.63333	598.723
Column 3	65	958	14.73846	140.5399
Column 4	141	3880	27.51773	676.2372
Column 5	137	2667	19.46715	389.1037
Column 6	124	2074	16.72581	64.75347

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12892.62	5	2578.524	6.792929	3.6526E-06	2.230052587
Within Groups	213329.3	562	379.5894			
Total	226221.9	567				

Since F> Fcr. f,there is evidence to support the notion that the duration of priority phase is different among the six intersections.

D3.5 T-Tests Testing the Sample Variability of EV Daily Requests Before and After the Deployment of Transit Priority on U.S.1.

t-Tests Testing the Sample Variability of EV Daily Requests Before and After the Deployment of Transit Priority on U.S.1

t-Test: Two-Sample Assuming Equal Varianc **Beacon**

	Before	*After*
Mean	6.603774	8.5
Variance	11.85922	36.28571429
Observations	53	8
Pooled Variance	14.75728	
Hypothesized Me	0	
df	59	
t Stat	-1.301383	
P(T<=t) one-tail	0.099093	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.198186	
t Critical two-tail	2.000997	

t-Test: Two-Sample Assuming Equal Variance **S.Gate**

	Before	*After*
Mean	11.60377	7.875
Variance	19.32075	21.55357143
Observations	53	8
Pooled Variance	19.58567	
Hypothesized Me	0	
df	59	
t Stat	2.221339	
P(T<=t) one-tail	0.015089	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.030178	
t Critical two-tail	2.000997	

t-Test: Two-Sample Assuming Equal Varianc **Popkins**

	Before	*After*
Mean	5.679245	7
Variance	13.56821	12.5
Observations	53	9
Pooled Variance	13.42579	
Hypothesized Me	0	
df	60	
t Stat	-0.999806	
P(T<=t) one-tail	0.16071	
t Critical one-tail	1.670649	
P(T<=t) two-tail	0.32142	
t Critical two-tail	2.000297	

t-Test: Two-Sample Assuming Equal Variance **S.Kings**

	Before	*After*
Mean	8.45283	4.75
Variance	17.32946	5.071428571
Observations	53	8
Pooled Variance	15.87512	
Hypothesized Me	0	
df	59	
t Stat	2.450154	
P(T<=t) one-tail	0.008632	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.017265	
t Critical two-tail	2.000997	

t-Test: Two-Sample Assuming Equal Varianc **Memorial**

	Before	*After*
Mean	6.943396	8
Variance	16.66981	18.75
Observations	53	9
Pooled Variance	16.94717	
Hypothesized Me	0	
df	60	
t Stat	-0.711913	
P(T<=t) one-tail	0.239639	
t Critical one-tail	1.670649	
P(T<=t) two-tail	0.479278	
t Critical two-tail	2.000297	

t-Test: Two-Sample Assuming Equal Variance **N.Kings**

	Before	*After*
Mean	8.415094	4.5
Variance	16.63208	4.857142857
Observations	53	8
Pooled Variance	15.23505	
Hypothesized Me	0	
df	59	
t Stat	2.644468	
P(T<=t) one-tail	0.005234	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.010467	
t Critical two-tail	2.000997	

Since t Stat >t Critical (two tail), we can conclude that the number of EV requests per day at half the intersections are different after the deployment of transit priority on U.S.1

D3.6 T-Tests Testing the Sample Variability of EV Requests Denied Before and After the Deployment of Transit Priority on U.S.1.

t-Tests Testing the Sample Variability of EV Requests Denied Before and After the Deployment of Transit Priority on U.S.1

t-Test: Two-Sample Assuming Equal Variances **Beacon**

	Before	*After*
Mean	0.056604	0.5
Variance	0.054427	0.857143
Observations	53	8
Pooled Variance	0.149664	
Hypothesized Mea	0	
df	59	
t Stat	-3.021698	
P(T<=t) one-tail	0.001857	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.003714	
t Critical two-tail	2.000997	

t-Test: Two-Sample Assuming Equal Variai **Popkins**

	Before	*After*
Mean	0.056604	0
Variance	0.054427	0
Observations	53	8
Pooled Variance	0.04717	
Hypothesized Me	0	
df	59	
t Stat	0.722897	
P(T<=t) one-tail	0.236276	
t Critical one-tail	1.670649	
P(T<=t) two-tail	0.472552	
t Critical two-tail	2.000297	

t-Test: Two-Sample Assuming Equal Variances **Memorial**

	Before	*After*
Mean	0.113208	0.333333
Variance	0.140784	0.5
Observations	53	8
Pooled Variance	0.188679	
Hypothesized Mea	0	
df	59	
t Stat	-1.405634	
P(T<=t) one-tail	0.082495	
t Critical one-tail	1.670649	
P(T<=t) two-tail	0.16499	
t Critical two-tail	2.000297	

t-Test: Two-Sample Assuming Equal Variai **S.Kings**

	Before	*After*
Mean	0.188679	0
Variance	0.386792	0
Observations	53	8
Pooled Variance	0.340902	
Hypothesized Me	0	
df	59	
t Stat	0.851976	
P(T<=t) one-tail	0.198836	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.397672	
t Critical two-tail	2.000997	

t-Test: Two-Sample Assuming Equal Variances **S.Gate**

	Before	*After*
Mean	0.09434	0.625
Variance	0.087083	1.410714
Observations	53	8
Pooled Variance	0.244124	
Hypothesized Mea	0	
df	59	
t Stat	-2.831585	
P(T<=t) one-tail	0.003163	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.006326	
t Critical two-tail	2.000997	

t-Test: Two-Sample Assuming Equal Variai **N.Kings**

	Before	*After*
Mean	0.150943	0
Variance	0.207547	0
Observations	53	8
Pooled Variance	0.182923	
Hypothesized Me	0	
df	59	
t Stat	0.930461	
P(T<=t) one-tail	0.177962	
t Critical one-tail	1.671092	
P(T<=t) two-tail	0.355924	
t Critical two-tail	2.000997	

Since t Stat >t Critical (two tail), we can conclude that the number of EV requests denied are different only at two intersections after the deployment of transit priority on U.S.1.

D3.7 T-Tests Testing the Sample Variability of the Duration of Preemptions Before and After the Deployment of Transit Priority on U.S.1.

t-Tests Testing the Sample Variability of the Duration of Preemptions Before and After the Deployment of Transit Priority on U.S.1

t-Test: Two-Sample Assuming Equal Variances **Popkins**

	Before	*After*
Mean	20.90909091	20.03571
Variance	55.04238329	18.28961
Observatior	297	56
Pooled Vari	49.28340178	
Hypothesiz	0	
df	351	
t Stat	0.853957211	
P(T<=t) one	0.19685556	
t Critical on	1.649207206	
P(T<=t) two	0.393711119	
t Critical tw	1.966745913	

t-Test: Two-Sample Assuming Equal Variar **S.Gate**

	Before	*After*
Mean	15.66338	18.50794
Variance	35.58552	252.8024
Observatior	609	63
Pooled Vari	55.68618	
Hypothesiz	0	
df	670	
t Stat	-2.88028	
P(T<=t) one	0.00205	
t Critical on	1.647131	
P(T<=t) two	0.0041	
t Critical tw	1.963513	

t-Test: Two-Sample Assuming Equal Variances **Memorial**

	Before	*After*
Mean	26.46260388	26.98438
Variance	107.238181	68.14261
Observatior	361	64
Pooled Vari	101.4154362	
Hypothesiz	0	
df	423	
t Stat	-0.38201211	
P(T<=t) one	0.351322112	
t Critical on	1.648463694	
P(T<=t) two	0.702644224	
t Critical tw	1.965586307	

t-Test: Two-Sample Assuming Equal Variar **S.kings**

	Before	*After*
Mean	22.71854	21.78947
Variance	46.23482	22.60313
Observatior	437	38
Pooled Vari	44.38625	
Hypothesiz	0	
df	473	
t Stat	0.824529	
P(T<=t) one	0.205027	
t Critical on	1.648082	
P(T<=t) two	0.410054	
t Critical tw	1.964991	

t-Test: Two-Sample Assuming Equal Variances **Beacon**

	Before	*After*
Mean	18.69075145	20.13235
Variance	96.74756639	239.0121
Observatior	346	68
Pooled Vari	119.8828137	
Hypothesiz	0	
df	412	
t Stat	-0.992565317	
P(T<=t) one	0.160752203	
t Critical on	1.648559191	
P(T<=t) two	0.321504407	
t Critical tw	1.965736374	

t-Test: Two-Sample Assuming Equal Variar **N.Kings**

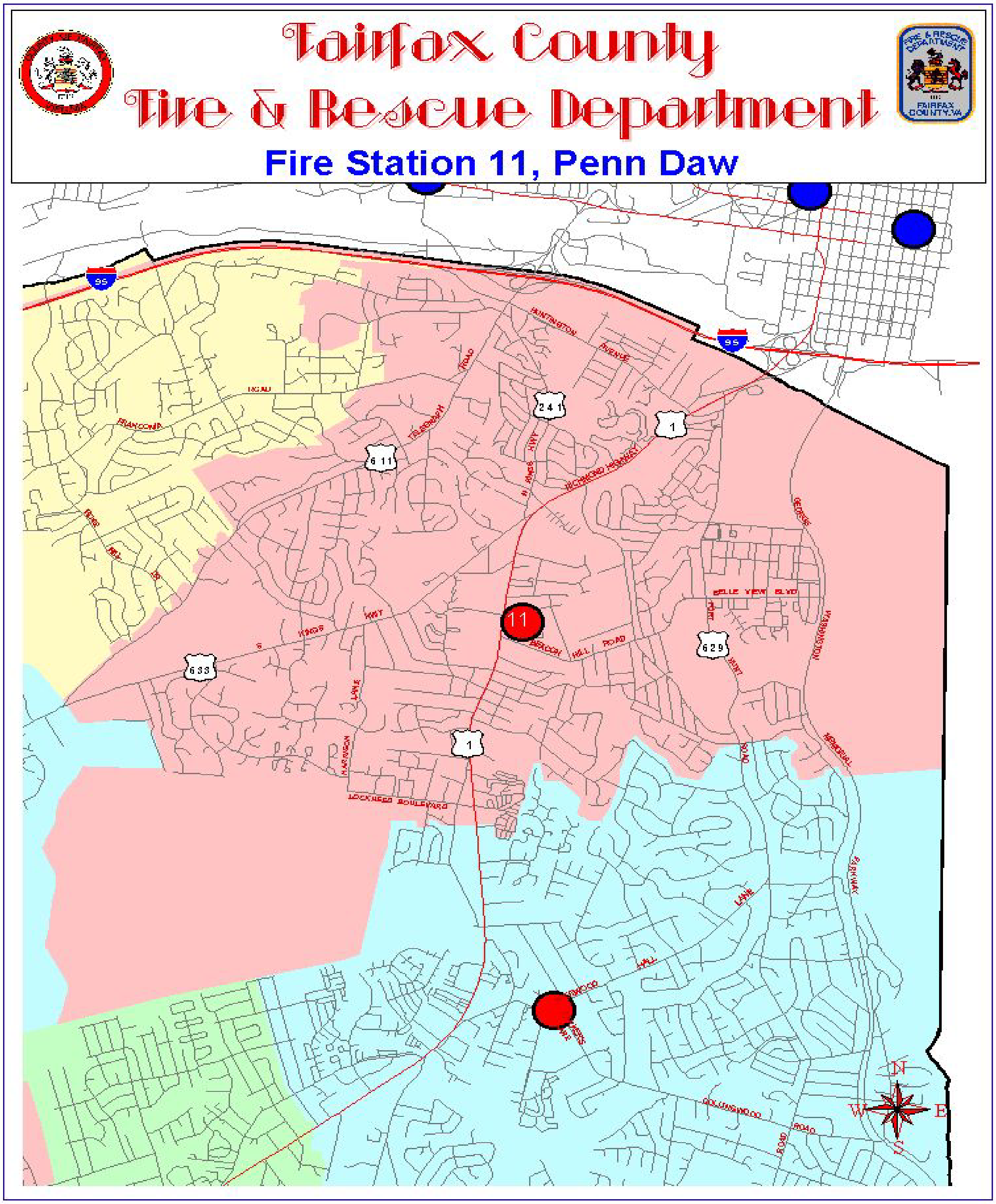
	Before	*After*
Mean	17.08924	16.94444
Variance	47.31082	62.2254
Observatior	437	36
Pooled Vari	48.41913	
Hypothesiz	0	
df	471	
t Stat	0.120011	
P(T<=t) one	0.452263	
t Critical on	1.648095	
P(T<=t) two	0.904525	
t Critical tw	1.965013	

Since t Stat >t Critical (two tail), we can conclude that the duration of EV requests is different only at one intersection after the deployment of transit priority on U.S.1.

Appendix E

Analysis of Emergency Response Log Data From Fire Station 11 on U.S.1, Fairfax County, VA (04/07/03-04/14/03)

Appendix E1. Service Area of Fire Station 11.



Appendix E2. Sample of the Emergency Call Data for Fire Station 11 Obtained from the Fire and Rescue Department.

Obs	EVENT	DATE mmddyyyy	UNIT	DISPTM hhmmss	LOCATION
1	20030970269	4072003	M411	62603	6602 TENTH ST
2	20030970269	4072003	E411	62603	6602 TENTH ST
3	20030970478	4072003	A411	80148	5612 JUSTIS PL
4	20030970985	4072003	A411	123828	3404 GROVETON ST
5	20030971152	4072003	A411	140031	1806 OLD STAGE RD
6	20030971615	4072003	IV11	175422	6300 LACHINE LA
7	20030971630	4072003	M411	180239	2655 ARLINGTON DR
8	20030971630	4072003	R411	180239	2655 ARLINGTON DR
9	20030971954	4072003	M411	214024	7181 LAKE COVE DR
10	20030971975	4072003	A411	215609	5901 MOUNT EAGLE DR
11	20030971985	4072003	R411	220413	BELLE VIEW BV/POTOMAC AV
12	20030971985	4072003	E411	220413	BELLE VIEW BV/POTOMAC AV
13	20030972005	4072003	E411	222403	6800 RICHMOND HY
14	20030972005	4072003	T411	222403	6800 RICHMOND HY
15	20030972005	4072003	R411	222403	6800 RICHMOND HY
16	20030980115	4082003	E411	30311	5840 CAMERON RUN TE
17	20030980115	4082003	T411	30311	5840 CAMERON RUN TE
18	20030980369	4082003	M411	73612	1501 BELLE VIEW BV
19	20030980369	4082003	T411	73612	1501 BELLE VIEW BV
20	20030980409	4082003	IV11	75242	14203 SAINT GERMAIN DR
21	20030980999	4082003	A411	115600	7214 RICHMOND HY
22	20030980999	4082003	T411	115600	7214 RICHMOND HY
23	20030980999	4082003	A411	115600	7214 RICHMOND HY
24	20030980999	4082003	T411	115600	7214 RICHMOND HY
25	20030981045	4082003	M411	121734	LOCKHEED BV/RICHMOND HY
26	20030981045	4082003	T411	121734	LOCKHEED BV/RICHMOND HY
27	20030981258	4082003	R411	134903	4810 CROSS MEADOW PL
28	20030981303	4082003	A411	140800	2017 BELLE VIEW BV
29	20030981403	4082003	E411	144809	SOUTH KINGS HY/TELEGRAPH RD
30	20030981403	4082003	R411	144809	SOUTH KINGS HY/TELEGRAPH RD
31	20030981449	4082003	M411	150601	6708 LENCLAIR ST
32	20030981745	4082003	E411	172017	5842 MOUNT VERNON DR
33	20030981745	4082003	T411	172017	5842 MOUNT VERNON DR
34	20030981745	4082003	A411	172017	5842 MOUNT VERNON DR
35	20030981878	4082003	T411	182709	1202 SOUTH WASHINGTON ST
36	20030982330	4082003	A411	223404	2248 MARY BALDWIN DR
37	20030982428	4082003	E411	234438	6303 RICHMOND HY
38	20030982428	4082003	T411	234438	6303 RICHMOND HY
39	20030990060	4092003	T411	13409	7666 RICHMOND HY
40	20030990164	4092003	A411	51410	3919 SPECT CT
41	20030990210	4092003	E411	61302	6303 RICHMOND HY
42	20030990210	4092003	T411	61302	6303 RICHMOND HY
43	20030990331	4092003	M411	72119	2059 HUNTINGTON AV
44	20030990331	4092003	E411	72119	2059 HUNTINGTON AV
45	20030990600	4092003	T411	93421	3919 SPECT CT
46	20030990786	4092003	E411	111427	6133 BEECH TREE DR
47	20030990829	4092003	E411	114057	6800 RICHMOND HY

Appendix E3. Significance Tests.

The ANOVA analysis tool is a parametric testing methodology that provides different types of variance analysis. The tool to use depends on the number of factors and the number of samples you have from the populations you want to test. The *ANOVA Single-Factor* Test performs a simple ANOVA, testing the hypothesis that means from two or more samples are equal (drawn from populations with the same mean). This technique expands on tests for two means, such as the t-test *(38)*.

The t-Test analysis tool is a parametric testing methodology and is an appropriate test for small sample sizes assuming that the underlying populations follow a normal distribution with equal variances. The *t-Test: Two-Sample Assuming Equal Variances* analysis tool performs a two-sample student's t-test. This t-test form assumes that the means of both data sets are equal; it is referred to as a homoscedastic t-test. It can be used to determine whether two sample means are equal.

A test statistic for a difference between two population means with equal population variances is given by *(38)*:

$$t^* = \frac{(\overline{X_1} - \overline{X_2}) - (\mu_1 - \mu_2)}{\sqrt{s_p^2 (\frac{1}{n_1} + \frac{1}{n_2})}},$$

where the term $(\mu_1 - \mu_2)$ is the difference between μ_1 and μ_2 under the null hypothesis. The degrees of freedom of the test statistic are $n_1 + n_2 - 2$, which are the degrees of freedom associated with the pooled estimate of the population variance s_p^2. This pooled variance s_p^2, is based on the sample variance s_1^2 obtained from a sample of size n_1, and a sample variance s_2^2 obtained from a sample of size n_2, and is given by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

E3.1. ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Hour of Day in Fire Station 11.

ANOVA Testing the Sample Variability of Frequency of Emergency Calls in FS#11 By Hour of Day

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	2	5	2.5	12.5
Row 2	2	5	2.5	4.5
Row 3	2	4	2	0
Row 4	2	6	3	0
Row 5	2	7	3.5	0.5
Row 6	2	10	5	0
Row 7	2	11	5.5	0.5
Row 8	2	19	9.5	12.5
Row 9	2	13	6.5	4.5
Row 10	2	21	10.5	4.5
Row 11	2	16	8	8
Row 12	2	25	12.5	4.5
Row 13	2	18	9	18
Row 14	2	25	12.5	0.5
Row 15	2	26	13	2
Row 16	2	27	13.5	4.5
Row 17	2	24	12	32
Row 18	2	34	17	0
Row 19	2	35	17.5	0.5
Row 20	2	29	14.5	40.5
Row 21	2	26	13	98
Row 22	2	28	14	98
Row 23	2	34	17	50
Row 24	2	27	13.5	180.5

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1159.979	23	50.43388	2.099589	0.038673	1.993239351
Within Groups	576.5	24	24.02083			
Total	1736.479	47				

The difference in the frequency of emergency calls between different hours of day appears to be rather marginal at the 95% confidence interval.

E3.2. T-tests Testing the Sample Variability of Frequency of Emergency Calls By Time of Day in Fire Station 11.

t-Tests Testing the Sample Variability of EV Calls By Time of Day in FS#11

t-Test: Two-Sample Assuming Equal Variances

	AM	*Midday*
Mean	2.75	4
Variance	1.642857	5.714286
Observations	8	8
Pooled Variance	3.678571	
Hypothesized Me	0	
df	14	
t Stat	-1.303468	
P(T<=t) one-tail	0.106722	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.213444	
t Critical two-tail	2.144789	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*Night*
Mean	4	3.125
Variance	5.714286	4.410714
Observations	8	8
Pooled Variance	5.0625	
Hypothesized Me	0	
df	14	
t Stat	0.777778	
P(T<=t) one-tail	0.224822	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.449645	
t Critical two-tail	2.144789	

t-Test: Two-Sample Assuming Equal Variances

	AM	*PM*
Mean	2.75	5.25
Variance	1.642857	6.785714
Observations	8	8
Pooled Variance	4.214286	
Hypothesized Me	0	
df	14	
t Stat	-2.435612	
P(T<=t) one-tail	0.014415	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.02883	
t Critical two-tail	2.144789	

t-Test: Two-Sample Assuming Equal Variances

	AM	*Night*
Mean	2.75	3.125
Variance	1.642857	4.410714
Observations	8	8
Pooled Variance	3.026786	
Hypothesized Me	0	
df	14	
t Stat	-0.431092	
P(T<=t) one-tail	0.336482	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.672965	
t Critical two-tail	2.144789	

t-Test: Two-Sample Assuming Equal Variances

	Midday	*PM*
Mean	4	5.25
Variance	5.714286	6.785714
Observations	8	8
Pooled Variance	6.25	
Hypothesized Me	0	
df	14	
t Stat	-1	
P(T<=t) one-tail	0.167141	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.334282	
t Critical two-tail	2.144789	

t-Test: Two-Sample Assuming Equal Variances

	PM	*Night*
Mean	5.25	3.125
Variance	6.785714	4.410714
Observations	8	8
Pooled Variance	5.598214	
Hypothesized Me	0	
df	14	
t Stat	1.796239	
P(T<=t) one-tail	0.04703	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.094061	
t Critical two-tail	2.144789	

Since t Stat >t Critical (two tail), we can conclude that the AM and PM cases are different at the 95% confidence interval.

E3.3. ANOVA Testing the Sample Variability of Frequency of Emergency Calls By Day of Week in Fire Station 11.

ANOVA Testing the Sample Variability of Frequency of Emergency Calls in FS#11 By Day of Week

Anova: Single Factor

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	7	176.9038	25.27198	0.89564
Column 2	7	181	25.85714	29.14286

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.198463	1	1.198463	0.079795	0.782388	4.747221283
Within Groups	180.231	12	15.01925			
Total	181.4294	13				

Since F< Fcr.,there is no evidence to support the notion that the frequency of emergency calls in FS#11 is different by day of week at the 95% confidence interval.

Appendix F:

Analysis of Emergency Crash Data for U.S.1, Fairfax County, VA (1997-2001)

<u>Appendix F1. Sample of the Emergency Crash Data for U.S.1 Obtained from VDOT.</u>

ACCIDENT_DATE	ACCIDENT_HOUR	DAY_OF_\	DAY_OF_V	INTERSEC	SURFACE_	SURFACE_	LANE_COU	FACILITY_	F	INTERSECT	TRAFFI
6/4/1997	23	3	Wednesday	00001	6	Plant Mix (E	4	0	]	9	03
2/9/1998	14	1	Monday	00001	6	Plant Mix (E	6	1	[	1	03
3/19/1999	17	5	Friday	00001	6	Plant Mix (E	4	0	]	9	08
5/3/1999	23	1	Monday	00001	6	Plant Mix (E	6	1	[	9	06
5/24/1999	8	1	Monday	00001	6	Plant Mix (E	6	1	[	1	03
6/9/1999	19	3	Wednesday	00001	6	Plant Mix (E	6	1	[	4	06
9/27/1999	6	1	Monday	00001	6	Plant Mix (E	4	1	[	9	06
1/21/2000	13	5	Friday	00001	6	Plant Mix (E	6	1	[	1	03
3/11/2000	15	6	Saturday	00001	6	Plant Mix (E	5	0	]	1	03
7/30/2000	3	7	Sunday	00001	8	Portland Ce	4	1	[	9	06
8/22/2000	2	2	Tuesday	00001	6	Plant Mix (E	4	0	]	1	06
10/2/2000	20	1	Monday	00001	6	Plant Mix (E	6	1	[	1	03
11/21/2000	22	4	Thursday	00001	6	Plant Mix (E	4	0	]	9	06
12/20/2000	17	3	Wednesday	00001	6	Plant Mix (E	6	1	[	1	03
12/23/2000	2	6	Saturday	00001	6	Plant Mix (E	6	1	[	1	03
1/8/2001	10	1	Monday	00001	6	Plant Mix (E	6	1	[	1	03
2/22/2001	16	4	Thursday	00001	6	Plant Mix (E	4	0	]	9	06
2/22/2001	16	4	Thursday	00001	6	Plant Mix (E	4	0	]	9	06
4/9/2001	21	1	Monday	00001	6	Plant Mix (E	4	0	]	3	06
5/19/2001	15	6	Saturday	00001	6	Plant Mix (E	5	1	[	3	06
7/9/2001	14	1	Monday	00001	6	Plant Mix (E	6	1	[	1	06
10/3/2001	2	3	Wednesday	00001	6	Plant Mix (E	6	1	[	1	06

ALIGNMEN	ALIGNMEN	WEATHER	WEATHER	SURFACE_	SURFACE_	ROAD_DEI	ROAD_DEI	LIGHTING_	LIGHTING_	COLLISION	COLLISION
1	Straight Le	1	Clear	1	Dry	1	No Defects	5	Darkness -	02	Angle
1	Straight Le	1	Clear	1	Dry	1	No Defects	2	Daylight	02	Angle
1	Straight Le	1	Clear	1	Dry	1	No Defects	2	Daylight	01	Rear End
1	Straight Le	2	Cloudy	1	Dry	1	No Defects	4	Darkness -	04	Sideswipe -
1	Straight Le	5	Raining	2	Wet	1	No Defects	2	Daylight	15	Backed Into
3	Grade Strai	1	Clear	1	Dry	1	No Defects	4	Darkness -	04	Sideswipe -
7	Dip Straigh	2	Cloudy	1	Dry	1	No Defects	5	Darkness -	04	Sideswipe -
4	Grade Curv	1	Clear	1	Dry	1	No Defects	2	Daylight	02	Angle
1	Straight Le	2	Cloudy	1	Dry	1	No Defects	2	Daylight	01	Rear End
1	Straight Le	2	Cloudy	1	Dry	1	No Defects	4	Darkness -	04	Sideswipe -
5	Hillcrest Str	1	Clear	1	Dry	1	No Defects	4	Darkness -	02	Angle
1	Straight Le	1	Clear	1	Dry	1	No Defects	4	Darkness -	02	Angle
1	Straight Le	1	Clear	1	Dry	1	No Defects	4	Darkness -	02	Angle
1	Straight Le	1	Clear	4	Icy	0	Not Stated	4	Darkness -	01	Rear End
1	Straight Le	1	Clear	1	Dry	1	No Defects	4	Darkness -	02	Angle
4	Grade Curv	5	Raining	2	Wet	1	No Defects	2	Daylight	02	Angle
3	Grade Strai	6	Snowing	3	Snowy	1	No Defects	2	Daylight	16	Miscellaneo
3	Grade Strai	6	Snowing	3	Snowy	1	No Defects	2	Daylight	02	Angle
3	Grade Strai	5	Raining	2	Wet	1	No Defects	4	Darkness -	01	Rear End
3	Grade Strai	2	Cloudy	1	Dry	1	No Defects	2	Daylight	01	Rear End
3	Grade Strai	1	Clear	1	Dry	1	No Defects	2	Daylight	01	Rear End
1	Straight Le	1	Clear	1	Dry	1	No Defects	4	Darkness -	01	Rear End

All the variables included in the crash data are presented below:

ACCIDENT_DOCUMENT_NUM	MAJOR_FACTOR_ID	VEHICLE_2_IMPACT_DESC
HTRIS_ROUTE_ID	MAJOR_FACTOR_DESC	VEHICLE_2_DAMAGE_ID
HTRIS_ROUTE_PREFIX	SEVERITY_ID	VEHICLE_2_DAMAGE_DESC
HTRIS_ROUTE_NUMBER	SEVERITY_DESC	DRIVER_2_AGE
HTRIS_ROUTE_SUFFIX	NUM_FATALITIES	DRIVER_2_SEX
HTRIS_NODE	NUM_PEDESTRIAN_FATALITIES	DRIVER_2_ACTION_ID
HTRIS_NODE_OFFSET	NUM_INJURIES	DRIVER_2_ACTION_DESC
HTRIS_NODE_TYPE_ID	NUM_PEDESTRIAN_INJURIES	DRIVER_2_CONDITION_ID
HTRIS_NODE_TYPE_DESC	NUM_VEHICLES	DRIVER_2_CONDITION_DESC
HTRIS_LINK_SEQUENCE	LOCAL_AREA_TYPE_ID	DRIVER_2_DRINK_ID
ROUTE_MILEPOST	LOCAL_AREA_TYPE_DESC	DRIVER_2_DRINK_DESC
JURIS_MILEPOST	LOCALITY_TYPE_ID	DRIVER_2_VISIBILITY_ID
JURIS_NO	LOCALITY_TYPE_DESC	DRIVER_2_VISIBILITY_DESC
JURIS_NAME	SYSTEM	DRIVER_2_EJECTION_ID
CONST_DIST_NO	FUNCTIONAL_CLASS	DRIVER_2_EJECTION_DESC
CONST_DIST_NAME	FEDERAL_AID	PASSENGER_2_EJECTION_ID
MAINTENANCE_JURIS_NO	VEHICLE_1_TYPE_ID	PASSENGER_2_EJECTION_DESC
MAINTENANCE_JURIS_NAME	VEHICLE_1_TYPE_DESC	TRUCK_1_TRACTOR_LENGTH
RESIDENCY	VEHICLE_1_SPEED	TRUCK_1_TRAILER_1_LENGTH
ACCIDENT_DATE	VEHICLE_1_MANEUVER_ID	TRUCK_1_TRAILER_2_LENGTH
ACCIDENT_HOUR	VEHICLE_1_MANEUVER_DESC	TRUCK_1_TRAILER_WIDTH
DAY_OF_WEEK_ID	VEHICLE_1_PLACEMENT	TRUCK_1_AXLE_COUNT
DAY_OF_WEEK_DESC	VEHICLE_1_SKID_ID	TRUCK_2_TRACTOR_LENGTH
INTERSECTING_ROUTE_NUM	VEHICLE_1_SKID_DESC	TRUCK_2_TRAILER_1_LENGTH
SURFACE_TYPE_ID	VEHICLE_1_IMPACT_ID	TRUCK_2_TRAILER_2_LENGTH
SURFACE_TYPE_DESC	VEHICLE_1_IMPACT_DESC	TRUCK_2_TRAILER_WIDTH
LANE_COUNT	VEHICLE_1_DAMAGE_ID	TRUCK_2_AXLE_COUNT
FACILITY_TYPE_ID	VEHICLE_1_DAMAGE_DESC	VEHICLE_1_CONDITION_ID
FACILITY_TYPE_DESC	DRIVER_1_AGE	VEHICLE_1_CONDITION_DESC
INTERSECTION_TYPE_ID	DRIVER_1_SEX	VEHICLE_2_CONDITION_ID
INTERSECTION_TYPE_DESC	DRIVER_1_ACTION_ID	VEHICLE_2_CONDITION_DESC
TRAFFIC_CONTROL_ID	DRIVER_1_ACTION_DESC	PEDESTRIAN_1_ACTION_ID
TRAFFIC_CONTROL_DESC	DRIVER_1_CONDITION_ID	PEDESTRIAN_1_ACTION_DESC
ALIGNMENT_ID	DRIVER_1_CONDITION_DESC	PEDESTRIAN_2_ACTION_ID
ALIGNMENT_DESC	DRIVER_1_DRINK_ID	PEDESTRIAN_2_ACTION_DESC
WEATHER_ID	DRIVER_1_DRINK_DESC	PEDESTRIAN_1_DRINK_ID
WEATHER_DESC	DRIVER_1_VISIBILITY_ID	PEDESTRIAN_1_DRINK_DESC
SURFACE_CONDITION_ID	DRIVER_1_VISIBILITY_DESC	PEDESTRIAN_2_DRINK_ID
SURFACE_CONDITION_DESC	DRIVER_1_EJECTION_ID	PEDESTRIAN_2_DRINK_DESC
ROAD_DEFECT_ID	DRIVER_1_EJECTION_DESC	DAMAGE_AMOUNT
ROAD_DEFECT_DESC	PASSENGER_1_EJECTION_ID	SHAPE_FID
LIGHTING_ID	PASSENGER_1_EJECTION_DESC	
LIGHTING_DESC	VEHICLE_2_TYPE_ID	
COLLISION_TYPE_ID	VEHICLE_2_TYPE_DESC	
COLLISION_TYPE_DESC	VEHICLE_2_SPEED	
VEHICLE_1_FIXED_OBJECT_	VEHICLE_2_MANEUVER_ID	
VEHICLE_1_FIXED_OBJECT_	VEHICLE_2_MANEUVER_DESC	
VEHICLE_2_FIXED_OBJECT_	VEHICLE_2_PLACEMENT	
VEHICLE_2_FIXED_OBJECT_	VEHICLE_2_SKID_ID	
IMPACT_ZONE_ID	VEHICLE_2_SKID_DESC	
IMPACT_ZONE_DESC	VEHICLE_2_IMPACT_ID	

VITA

Konstantina Gkritza was born on November 30, 1977 in Athens, Greece. In 1995, she graduated from Tositsio Arsakio Lyceum of Athens and, upon successfully passed the national examinations she entered the Faculty of Civil Engineering at the National Technical University of Athens. She completed her undergraduate studies in 2001. Then, she started working as a Research Associate at the Department of Transportation Planning and Engineering at the National Technical University of Athens till the Fall 2002 when she started her work towards her Masters Degree in Civil Engineering at the Virginia Polytechnic Institute and State University.

Ms. Gkritza has been recently admitted for further graduate studies at Purdue University in West Lafayette, Indiana.